AQUIND Limited

AQUIND INTERCONNECTOR

Environmental Statement – Volume 1 - Chapter 6 Physical Processes

The Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 - Regulation 5(2)(a)

The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017

Document Ref: 6.1.6

PINS Ref.: EN020022

AQUIND Limited

AQUIND INTERCONNECTOR

Environmental Statement – Volume 1 – Chapter 6 Physical Processes

PINS REF.: EN020022

DOCUMENT: 6.1.6

DATE: 14 NOVEMBER 2019

Units 5 & 10

Stephenson House,

Horsley Business Centre

Horsley,

Northumberland,

NE15 0NY

England, UK

DOCUMENT

Document	6.1.6 Environmental Statement – Volume 1 – Chapter 6 Physical Processes
Revision	001
Document Owner	Natural Power Consultants Ltd.
Prepared By	Partrac Ltd.
Date	23 October 2019
Approved By	Ross Hodson
Date	30 October 2019

CONTENTS

TABLES

PLATES

APPENDICES

6. PHYSICAL PROCESSES

6.1. SCOPE OF THE ASSESSMENT

6.1.1. INTRODUCTION

6.1.1.1. This chapter provides the assessment of environmental impacts on physical processes as a result of the Proposed Development.

6.1.1.2. This chapter outlines information regarding the potential impacts associated with the construction, operation (including repair and maintenance), and decommissioning of the Proposed Development. The potential effects of operation and maintenance (including repair and replacement of Marine Cable) and decommissioning is considered, in the worst case, to be equivalent or potentially lower than those associated with construction and are assessed on this basis. They may potentially be less than those associated with construction depending on for example, the nature of decommissioning activities required, for instance where the Marine Cable is left *in situ*.

6.1.1.3. The physical environment assessment will consider the potential impacts on the shallow geology (unconsolidated and rock), hydrodynamic ('HD') and wave regime, surficial sediments, sediment transport, and geomorphology (bathymetry).

6.1.2. STUDY AREA

6.1.2.1. The Entire Marine Cable Corridor extends from Mean High Water Springs ('MHWS') at Eastney, near Portsmouth on the south coast of the United Kingdom ('UK'), to Pourville located on the Normandy coast of France.

6.1.2.2. For the purposes of this assessment, the study area comprises those elements of the Proposed Development that fall within the Landfall and Marine Cable Corridor within the UK Marine Area (as shown on Figure 3.1 of the Environmental Statement ('ES') Volume 2 (document reference 6.2.3.1). Where impacts arise as a result of the combination of the impacts of the Proposed Development and the impacts of other projects in the UK Marine Area and/or other Member States, these will also be identified and assessed. Further details on the study area are summarised below.

Marine Cable Corridor and Landfall

6.1.2.3. The Marine Cable Corridor encompasses the location of the Landfall and extends from MHWS at Eastney out to the UK/France Exclusive Economic Zone ('EEZ') Boundary Line (see Figure 3.1).

6.1.2.4. For the purposes of this chapter, Landfall is defined as the Horizontal Directional Drilling ('HDD') exit/entry location off the coast. The Marine Cable will make Landfall through the use of HDD methods which will travel underneath the intertidal area at Eastney between an exit/entry point in the marine environment beyond 1 km (between Kilometre Point ('KP') 1 and KP 1.6) and the Transition Joint Bays ('TJBs') located in the car park behind Fraser Range (Figure 3.3 of the ES Volume 2 (document reference 6.2.3.3). It is not determined yet whether the HDD direction will be onshore to marine, marine to onshore, or drilling from both ends.

6.1.2.5. HDD is also proposed to be undertaken at Langstone Harbour to enable the cables to cross underneath Langstone Harbour from Portsea Island to the mainland (see Sheet 2 of Figure 3.9 (see Section 7 on the map) of the ES Volume 2 (document reference 6.2.3.9). It is anticipated that no HDD works will occur within the marine environment of Langstone Harbour as the drilling will be underneath the seabed of the harbour area. The entry and exit points of the drill will be located above the MHWS mark and are therefore not included within this assessment. It has been agreed with the Marine Management Organisation ('MMO') that this is an exempt activity that does not require a Marine Licence, subject to the conditions of Article 35 of Marine Licensing (Exempted Activities) Order 2011 (as amended). The Consultation Report provides further detail on this and other consultations (document reference 5.1).

6.1.2.6. Chapter 3 (Description of the Proposed Development) of the ES Volume 1 (document reference 6.1.3) provides further information on the HDD methodology at Langstone Harbour. Any of the onshore HDD works relating to the Proposed Development are not included in this assessment but are covered in the onshore chapters of the Environmental Statement ('ES').

6.1.2.7. The term 'near field' reflects the boundaries of this assessment that are more local to the location of the Proposed Development (see Plate 6.1). The term 'far field' is used within this chapter and reflects broader scale boundaries implemented within the HD and wave models (i.e. the AQUIND Interconnector Modelling Suite ('AIMS'). The AIMS wave model has been used to support the assessment within the Southern North Sea, Strait of Dover and the Channel. The boundaries of the AIMS wave model domains (outer and nested (inner) grid) are presented in Plate 6.1 and illustrates the extent of the study area used for this chapter. Further details related to the AIMS are presented in Appendix 6.2 (Modelling Technical Report) of the ES of Volume 3 (document reference 6.3.6.2).

6.1.2.8. The adoption of these spatial scales facilitates a robust assessment of the physical processes occurring at, and in the vicinity of the Proposed Development.

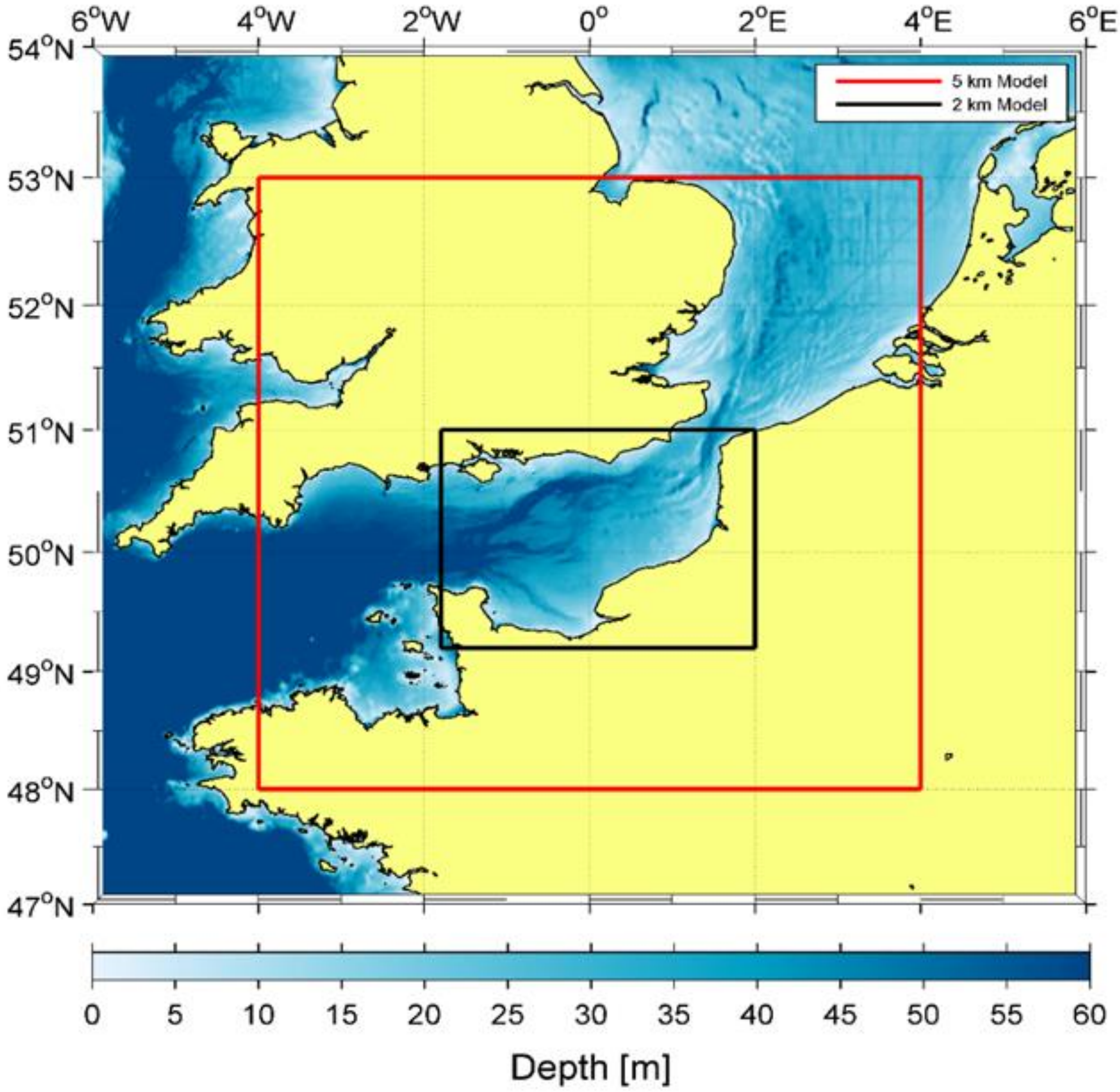


Plate 6.1 – AIMS Model Domains

6.2. LEGISLATION, POLICY AND GUIDANCE

6.2.1.1. This assessment has considered the current legislation, policy and guidance relevant to the physical environment. These are listed below.

6.2.2. LEGISLATION

- The Water Framework Directive ('WFD') (2000/60/EC) European Union water legislation with the overarching objective of all water bodies in Europe attaining good or high ecological status or potential by 2027. The WFD is implemented in England by the Water Environment (Water Framework Directive) (England and Wales) Regulations 2003 and establishes a framework for the prevention of deterioration and protection of surface, lake, groundwater, estuarine (transitional) and coastal water bodies. Objectives include improving the water environment to achieve good/high chemical and ecological status or potential in the context of current uses, maintaining existing good/high status and implementing mitigation to support the water environment at a catchment and water body scale. New activities are required to take into consideration the water body objectives published within the relevant River Basin Management Plan ('RBMP') This overarching legislation and subsequent England and Wales Regulations (see immediately below) are particularly relevant to the coastal and marine physical environment because activities can potentially affect the structure or function of landforms and the hydro-morphological status of a water body.

- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 consolidate, revoke and replace the Water Environment Water Framework Directive) (England Wales) Regulations 2003. The Regulations require the identification of river basin districts. They also make provision for certain protected areas and for the establishment of environmental objectives for each water body and programmes of measures to meet those objectives.
- The Marine and Coastal Access Act 2009 ('MCAA 2009') Act provides the legal mechanism to help ensure clean, healthy, safe, productive and biologically diverse oceans and seas by putting in place a system for improved management and protection of the marine and coastal environment. It established a strategic Marine Planning System which includes production of a Marine Policy Statement ('MPS') and streamlines the marine licensing system. This is relevant because it strives towards elimination or minimisation of effects on coastal and marine processes and geomorphology.
- The Marine Strategy Regulations 2010 transpose Council Directive 2008/56/EC (the Marine Strategy Framework Directive ('MSFD')) into UK law. They provide the competent authorities with the necessary powers to carry out their obligations as required by the Directive. This is relevant to the physical environment because Directive 2008/56/EC requires achievement or maintenance of good environmental status by 2027 (see above).

6.2.3. PLANNING POLICY

National Policy

6.2.3.1. The following presents the relevant national policy:

- Overarching National Policy Statement for Energy (EN-1) (DECC, 2011a):

  Paragraph 5.3.3 that: "*Where the development is subject to EIA [Environmental Impact Assessment] the applicant should ensure that the ES*

[Environmental Statement] clearly sets out any effects on internationally, nationally and locally designated sites of ecological or geological conservation importance, on protected species and on habitats and other species identified as being of principal importance for the conservation of biodiversity".

Section 5.5 requires applications to include an assessment of the effects on coastal processes and geomorphology, accounting for potential effects of climate change. Where a development potentially affects coastal processes then the applicant must demonstrate how adverse effects can be managed or minimised (see paragraph 5.5.7). EN-1 also expects the implications of a proposed project on strategies for managing the coast to be assessed. These strategies include Shoreline Management Plans ('SMP's) and RBMP (see paragraph 5.5.7).

- UK Marine Policy Statement (HM Government, 2011)
  - The UK MPS is the framework for preparing Marine Plans and taking decisions affecting the marine environment (in the absence of an opted marine plan). The MPS aims to contribute to the achievement of sustainable development and ensure that development considers possible impacts on water quality and change to HD processes which may result in coastal change. The South Marine Plan, which covers the spatial extent of the Proposed Development, was adopted in July 2018.
- National Planning Policy Framework ('NPPF') (2019)
  - Section 14: Meeting the challenge of climate change, flooding and coastal change states the requirement to consider UK MPS and marine plans. The framework recommendation is to pursue Integrated Coastal Zone Management across local authority and land/sea boundaries to ensure effective alignment of the terrestrial and marine planning regimes.
  - Section 167 states "plans should reduce risk from coastal change by avoiding inappropriate development in vulnerable areas and not exacerbating the impacts of physical changes to the coast……".

Regional Policy

- The South Inshore and South Offshore Marine Plans introduce a strategic approach to planning within the inshore and offshore waters between Folkestone in Kent and the river Dart in Devon (Department for Environment, Food and Rural Affairs ('DEFRA'), 2018). The plan applies national policies in a local context and includes the following objectives of specific relevance:
  - Objective 7 includes policies to avoid, minimise or mitigate adverse impacts on climate change adaptation measures, and on coastal change;

- Objective 10 includes policies to avoid, minimise or mitigate adverse impacts on marine protected areas;
- Objective 12 includes policies to avoid, minimise or mitigate significant adverse impacts on natural habitat and species.

6.2.3.2. Further detail and consideration on how the proposals for the Proposed Development meet the requirements of these policies is presented within the Planning Statement that accompanies the Application (document reference 5.4)

Local Policy

- The Eastern Solent Coastal Partnership (ESCP; 2012) formed an alliance in 2012 to deliver a combined, efficient and comprehensive coastal management service across the coastlines of four Local Authorities of Fareham Borough Council, Gosport Borough Council, Havant Borough Council and Portsmouth City Council. The innovative initiative was driven forward by a need for coastal management that recognises coastal flooding and erosion risk impacts are not exclusive to Local Authority boundaries.

6.2.4. GUIDANCE

6.2.4.1. This assessment was conducted in line with several key technical guidance documents. These guidance documents are widely used across the UK and represent standard good practice for the assessment for the various consenting regimes. These include:

- Coastal and marine environmental site guide (John *et al*., 2003).
  - The guidance relates to implementing good construction practices and design for coastal and marine sites. This is relevant to this chapter as it contains guiding principles on how to minimise or mitigate adverse impacts on coastal and marine processes and geomorphology.
- The Marine Monitoring Handbook (Davies *et al*., 2001).
  - This is used as guidance by the UK government's statutory nature conservation agencies and their key partners in drawing up monitoring schemes for marine Special Area of Conservation ('SAC's). The Handbook provides guidance on the different options and their relative costs and benefits and describes best practice through a series of procedural guidelines for the common survey/monitoring techniques. It draws on the information gathered from extensive trials of different techniques and their deployment undertaken during the UK Marine SACs project to ensure all advice has a sound practical basis. It includes guidance (for example) on sediment sampling that has relevance to the interpretation of surficial sediment data.

- Offshore Wind Farms: Guidance Note for EIA in Respect to (formerly) Food and Environment Protection Act 1985 ('FEPA') and Coast Protection Act 1949 ('CPA') Requirements (Centre for Environment, Fisheries, and Aquaculture and Science ('Cefas'), 2004).
  - This guidance details EIA / licensing requirements for Offshore Wind Farms ('OWF's) but also provides relevant guidance for other projects undertaking marine works, such as the Proposed Development. The aim of this document is to provide scientific guidance to those involved with the gathering, interpretation and presentation of data within an EIA as part of the consent's application process in England and Wales.
- Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities (Environment Agency ('EA'), 2011).
  - The purpose of this document is to ensure that an economically credible appraisal, taking account of the uncertainties associated with climate change, can be made to support Government investment decisions. In addition, the document provides important information on baseline evolution, which is relevant to this chapter.
- Good practice guidelines for ports and harbours operating within or near UK European marine sites (Associated British Ports ('ABP') Research & Consultancy, 1999).
  - These Guidelines aim to avoid, minimise and address potential environmental impacts arising from ports and harbours, and their operations. This is based on work undertaken by the research and consultancy arm of ABP in 1999. The potential exists for processes in dredge and disposal areas to cause alteration of erosion and sedimentation patterns in adjacent areas, potentially resulting in erosion, or the creation of an intertidal and/or subtidal habitat. There could also be changes in HDs and geomorphology at the dredge and disposal sites. Guidance recommends that the effects of suspended sediments and turbidity are generally short term (<1 week after activity) and near field (<1 km from activity). The guidance recommends ensuring that dredging is undertaken in a manner that limits, as far as practicably possible, the disturbance and dispersion of sediments from the dredger and barges during dredging operations.
- Assessment of the environmental impacts of cables (Oslo and Paris Conventions ('OSPAR'), 2009)
  - Guidance considering the potential environmental impacts resulting from submarine cables suggests that most Construction Stage (cable laying/installation) activities are local and temporary and the primary long-term impact of submarine cables can be the cable itself and any

accompanying protective structures. This guidance relates to OWFs but provides relevant guidance on requirements that must be satisfied when undertaking marine works similar to those that will take place in the Proposed Development.

- Natural England ('NE') Offshore Wind Cabling: ten years' experience and recommendations (Fawcett, 2018)
  - This note documents the experience NE has gained from advising on the environmental impacts of power cable installation over the last ten years, to highlight where issues have arisen with both installation and maintenance that have caused concern from a nature conservation perspective. The note provides some evidence for the current advice NE provide to industry and regulators on offshore wind cabling activities and emphasises that better solutions can be found for both the environment and offshore industries. This guidance relates to OWFs but provides relevant guidance on NE's requirements when undertaking cabling works similar to those that will take place for the Proposed Development.

6.3. SCOPING OPINION AND CONSULTATION

6.3.1. SCOPING OPINION

6.3.1.1. As detailed within Chapter 5 (Consultation) of the ES Volume 1 (document reference 6.1.5), a Scoping Opinion was received by the Applicant from the Planning Inspectorate ('PINS') on 7 December 2018. The Scoping Opinion from PINS in relation to physical processes and how they were addressed is set out in Table 1 in Appendix 6.1 (Physical Processes Consultation Responses) of the ES Volume 3 (document reference 6.3.6.1). This appendix also summarises any consultation relevant to the assessment that was undertaken prior to the publication and consultation on the Preliminary Environmental Information Report ('PEIR'). Key items that were raised included;

- The Inspectorate agrees that air quality assessment in the marine area can be scoped out.
- The study area for the assessment of physical processes needs to be clearly defined.
- Classification of seabed features and bedforms should be considered as receptors.
- The ES should include a description of the marine surveys conducted.
- Model validation and calibration against measured data should be undertaken.
- Identification of embedded mitigation measures should be clearly identified.

- Clarification requested of the assessment methodology and the approach to assessing potential downstream effects on other disciplines (e.g. benthic ecology).

6.3.2. PEIR CONSULTATION

6.3.2.1. Consultation on the PEIR was undertaken between February and April 2019. All of the comments received from the consultation in relation to physical processes are presented in Table 2 in Appendix 6.1 (Physical Processes Consultation Responses) however the key items that were raised included;

- The assessment of dredging activities including the potential effects associated with both dredging and the disposal of material at sea needs to be assessed within the ES.
- Coastal process should be included in the assessment as a receptor.
- Greater detail on the recoverability of bedforms post sandwave clearance should be provided.
- Consideration of cumulative and transboundary effects should be provided within the ES.
- Increased information requested in relation to worst case scenarios.

6.3.3. POST-PEIR CONSULTATION

6.3.3.1. Further consultation with key stakeholders on specific physical processes related data and information has been undertaken. This was to ensure all impacts are assessed. The key items that have been discussed are presented in Table 6.1.

Table 6.1 – Post-PEIR consultation

Consultee	Date (Method of Consultation)	Discussion
NE	13 February 2019 Teleconference	Discussion on the approach to Habitats Regulation Assessment (HRA) and pre-screening of sites for Annex I habitat, marine bird, Annex II migratory fish and marine mammal features.
NE, MMO and Joint Nature Conservation Committee ('JNCC')	7 May 2019 Teleconference	Discussions on the approach to dredge and disposal and the approach to plume dispersion modelling.
NE	27 June 2019 Teleconference	Discussion on the Applicant's responses to the feedback received from NE on the PEIR including comments on physical processes.

Consultee	Date (Method of Consultation)	Discussion
EA	8 July 2019 Email	Agreement and fully support the approach to dredge and disposal proposed.
MMO	18 July 2019 Teleconference	Discussion on the Applicant's responses to the feedback received from MMO on the PEIR including comments on physical processes.
JNCC	24 July 2019 Email	Consultation feedback received on the draft Deemed Marine Licence ('dML')
NE	25 July 2019 Teleconference	Review and discussions on the draft dML.
EA	31 July 2019 Email	Review and feedback on the draft dML.
MMO	1 August 2019 Teleconference	Review and discussions on the draft dML.
JNCC	13 August 2019 Email	Review and agreement on the Applicant's responses to JNCC feedback on the PEIR.
EA	20 August 2019 Email	Review and agreement on the \p's responses to Environment Agency feedback on the PEIR.
PINS	23 August 2019 Email	Review and feedback on draft HRA Report.
MMO	19 September and 02 October 2019 Email	MMO are content with approach to cumulative assessment and requested one new coastal project to be added to long list.
NE	20 September 2019 Email and Teleconference (30 September 2019)	Review and feedback on the draft HRA Report
EA	26 September 2019 Email	Review and feedback on the WFD assessment and HRA report.
JNCC	28 September 2019 Email	Review and feedback on the draft HRA Report. Further feedback provided on 11 October 2019 in response to query for clarification.
NE	08 October 2019 Email	Review and feedback on the Marine Conservation Zone ('MCZ') assessment

Consultee	Date (Method of Consultation)	Discussion
JNCC	09 October 2019 Email	Review and feedback on the MCZ assessment
NE	09 October 2019 Email	NE are content with the plume dispersion modelling approach taken for disposal activities and the resultant outputs with respect to predicted sedimentation and Suspended Sediment Concentrations ('SSC') levels, spatial extent and duration.
MMO	11 October 2019 Email	MMO provided feedback that the rationale for the additional 10% non-burial protection contingency during operation looks satisfactory however further clarity to be provided post submission.
MMO/Cefas	22 October 2019	Review and feedback on the disposal site characterisation report.

6.3.3.2. Agreed minutes notes for the teleconferences held and briefing notes issued to record responses to PEIR review are presented as appendices within the Consultation Report (document reference 5.1).

6.3.3.3. Consultation on the standalone HRA Report (document reference 6.8.1) was undertaken with statutory and non-statutory consultees including NE, EA, JNCC and States of Alderney. Comments received from these consultations on the HRA specifically are provided in Appendix 4 of the HRA Report (document reference 6.2.8.4).

6.3.3.4. Consultation on Appendix 7.1 (Marine WFD assessment) of the ES Volume 3 (document reference 6.3.7.1) and Appendix 8.5 (Marine Conservation Zone Assessment) of the ES Volume 3 (document reference 6.3.8.5) is further detailed in Chapter 7 (Marine Water and Sediment Quality) of the ES Volume 1 (document reference 6.1.7) and Chapter 8 (Intertidal and Benthic Habitats) of the ES Volume 1 (document reference 6.1.8), respectively.

6.3.4. ELEMENTS SCOPED OUT OF THE ASSESSMENT

6.3.4.1. Due to the nature of the Proposed Development and receiving environment, and on the basis that the main source of atmospheric emissions would be exhaust emissions from vessels which is unlikely to result in significant increase in emissions PINS agreed within the Scoping Opinion to scope out the air quality assessment within the marine environment (ID 4.1.1).

6.3.5. IMPACTS SCOPED INTO THE ASSESSMENT

6.3.5.1. Following consultation, the following impacts were scoped into the assessment of physical processes for construction, operation (including repair and maintenance) and decommissioning where relevant. These included:

- Physical disturbance to seabed geology and morphology through alteration of bedform features and impacts on local flow patterns;
- Impacts to local sediment regimes through impacts on local flow patterns and local increases in SSC; and
- Impacts upon coastal and marine processes and the sediment transport regime.

6.3.5.2. Chapter 7 (Marine Water and Sediment Quality) presents the assessment of potential impacts on water and sediment quality resulting from the Proposed Development. This includes an assessment of potential effects from increased suspended sediments, resuspension of contaminated sediments (Appendix 7.3 Contaminated Sediments Report of the ES Volume 3, document reference 6.3.7.3) and a Marine WFD Assessment (Appendix 7.1 (Marine WFD Assessment)). An MCZ assessment is presented in Appendix 8.5 (Marine Conservation Zone Assessment) and an HRA Report accompanies the Application (document reference 6.8.1).

6.4. ASSESSMENT METHODOLOGY

6.4.1.1. The physical environment, for the purposes of this assessment, is referred to as the shallow geology (unconsolidated and rock), HD and wave regime, surficial sediments, sediment transport, and geomorphology (bathymetry). This chapter encompasses the following:

- Baseline conditions along the Marine Cable Corridor from available information;
- Identification of the potential effects of the Proposed Development on the physical environment (with embedded mitigation) during the development construction, decommissioning and operational (including repair and maintenance) stages; and
- Identification of additional mitigation (if/where necessary), and the subsequent residual effects, their magnitude and significance.

6.4.1.2. The assessment methodology follows that presented within Chapter 4 (EIA Methodology) of the ES Volume 1 (document reference 6.1.4), and is in accordance with the guidance detailed by CEFAS (2004) which states that it is necessary to assess the magnitude, and significance of change, caused directly to the following receptors:

- Sediments (e.g. composition, particle size);

- HDs (e.g. waves, tidal flows);
- Sedimentary environment (e.g. sediment re-suspension, transport pathways, patterns and rates and sediment deposition);
- Sedimentary structures (e.g. channels, banks, large scale bedforms); and
- Suspended sediment concentrations ('SSC').
- Coastal processes.

6.4.1.3. Consideration of the above issues was made with respect to the near-field and far-field (these spatial scales are defined in Section 6.1.2 and Plate 6.1).

6.4.1.4. Each of these receptors are considered to be of **low** value as the baseline physical environment is either abundant (i.e. the sediments within the channel, Atlantic Ocean and North Sea), constant (e.g. astronomically driven tidal flows) and/or everchanging (i.e. is in a constant state of flux). It is often impractical to provide full details of installation activities and the full specification of equipment as such detail is dependent on procurement of engineering options. Thus, the assessment of potential impacts on the physical environment has been based on a realistic worst-case scenario. The worst-case parameters that were assessed are presented in Table 6.15 in Section 6.6.3.

6.4.1.5. The magnitude of impact has been considered with regards to the level at which the receptors will be impacted, using the duration of the impact, timing, scale, size and frequency to determine the magnitude of the impact to each receptor.

6.4.2. SIGNIFICANCE CRITERIA

6.4.2.1. In determining the significance of a potential effect, the magnitude of impact arising from the Proposed Development is correlated with the sensitivity of the environmental attribute or process under consideration.

6.4.2.2. As described within Chapter 4 (EIA methodology), sensitivity is a means to measure how affected receptors/processes and/or the receiving environment is to change. The sensitivity is assigned at the receptor/process level. This may be defined in terms of quality, value, rarity or importance, and be classed as negligible, low, medium, or high.

6.4.2.3. The overall significance has been assessed using the matrix shown in Table 6.2. Effects deemed to be significant for the purpose of assessment are those which are described as 'major' and 'moderate/major'. In addition, 'moderate' effects can also be deemed as significant. Whether they do so shall be determined by a qualitative analysis of the specific impact to the environment and is based on professional judgement. If/where this is the case, the basis for any judgement has been outlined.

Table 6.2 – Significance of effects matrix

		Sensitivity of Receptor			
		High	**Medium**	**Low**	**Negligible**
Magnitude of Impact	**High**	Major	Major to Moderate	Moderate	Negligible
	Medium	Major to Moderate	Moderate	Minor to Moderate	Negligible
	Low	Moderate	Minor to Moderate	Minor	Negligible
	Negligible	Negligible	Negligible	Negligible	Negligible

6.4.3. ASSUMPTIONS AND LIMITATIONS

6.4.3.1. The baseline understanding, and the assessment of potential impacts during the construction and operational stages, relies on numerical modelling. Though these models have been extensively calibrated/validated against measured data, these historic data have been sourced from publicly available sources and thus the model has not been calibrated/validated against recently collected measured datasets obtained from specific locations along the Marine Cable Corridor. Furthermore, numerical models are only ever an approximation of reality (particularly where numerical modelling approaches are utilised to investigate sediment transport processes). Therefore, the outputs and results provided by these models must be considered, and interpreted, in light of these limitations.

6.4.3.2. Assessment has also been undertaken based on the information provided within Chapter 3 (Description of the Proposed Development) and using the worst-case parameters presented in Appendix 3.2 (Marine Worst-Case Design Parameters) of the ES Volume 3 (document reference 6.3.3.2). How these parameters are relevant for worst case scenarios for physical processes is presented in Section 6.6.3.

6.5. BASELINE ENVIRONMENT

6.5.1.1. This section presents the baseline environment assessed based on information gathered from the sources shown in Table 6.3. In addition, a coupled HD and wave model was also developed to support the assessment (i.e. the AIMS model). The development of the AIMS (including a description of model setup, validation and calibration) is presented in Appendix 6.2 (Modelling Technical Report). Finally, the key sediment grain size statistics from two surveys of the Marine Cable Corridor are presented in Appendix 6.3 (Grain Size Statistics) of the ES Volume 3 (document reference 6.3.6.3). Appendix 6.5 (Disposal Site Characterisation Report) of the ES Volume 3 (document reference 6.3.6.5) presents further information relating to characterisation of the proposed disposal site.

6.5.2. DATA SOURCES

6.5.2.1. To develop a comprehensive understanding of the baseline scenario a wide variety of sources were consulted including site specific geophysical, geotechnical and benthic data sets, supported through inclusion of regional and site-specific information/data available from public sources and the published scientific literature. The Channel is, historically, a comparatively well-studied and well understood marine environment, supported here by project specific geophysical, geotechnical and environmental surveys. The current analysis benefits from the construction of a similar project (the National Grid/Réseau de Transport d'Électricité Interconnexion France Angleterre 2, known as IFA2) subsea electricity link to the west of the Proposed Development. Consequently, a large amount of background data exists regarding the physical environment in the region of the Proposed Development. Table 6.3 lists studies that are particularly relevant and form the focus of the desk-based assessment.

Table 6.3 – Data Sources

Data/Information	Source	Data Use
AQUIND commissioned surveys (geophysical, geotechnical and benthic ecology)	MMT, 2017/2018 Natural Power, 2017	Determination of baseline conditions
Bathymetric data	EMODnet	HD model setup
Nearshore bathymetric data	Global Self-consistent, Hierarchical, High-resolution Geography ('GSHHG') Database	HD model setup
Atmospheric Data	Climate Forecast System Reanalysis ('CFSR')	HD model setup
Atmospheric Data	National Centres for Environmental Prediction ('NCEP')	HD model setup
Ocean tides	Oregon State University TPXO 7.2 Atlantic Ocean model	HD model setup
Meteorological forecasting	European Centre for Medium-Range Weather Forecasts ('ECMWF')	Data provided boundary conditions for the SWAN model

Data/Information	Source	Data Use
Water Levels (Portsmouth harbour)	National Tidal Sea Level Facility ('NTSLF')	HD model validation/calibration Determination of baseline conditions
Measured wave and tide data (Sandown Pier wave radar and wave buoys positioned at Hayling Island and Bracklesham)	Channel Coastal Observatory ('CCO')	HD model validation/calibration Determination of baseline conditions
Surface and sub-surface sedimentology and geology	British Geological Survey ('BGS')	Determination of baseline conditions
Metocean and sedimentological data/information	IFA-2 Routeing and Siting Feasibility Desktop Study IFA-2 Marine Cable Route Desktop Study France – England Connection, Channel	Determination of baseline conditions
Various academic studies	Hamblin *et al.*, 1992; Tappin *et al.*, 2007; James *et al.*, 2007; James *et al.*, 2010; Paphitis *et al.*, 2010	Determination of baseline conditions

6.5.2.2. In addition to site-specific datasets and publicly available information/data, a numerical modelling approach has been adopted to enable a thorough and complete consideration of the relevant baseline physical processes occurring along the Entire Marine Cable Corridor within UK waters. An appreciation of the wider distribution and geospatial variation of tidal flow, water levels and the wave regime across the Proposed Development is available through development of a site-specific coupled HD and wave model developed using the MIKE21 2D modelling and SWAN numerical modelling software packages[1] (AIMS, 2018).

6.5.2.3. The AIMS has been validated extensively and to acceptable industry standards, utilising water level, wave and tidal flow data from several locations and various providers (including the CCO, the UK Meteorological Office ('UKMO'), the British

[1] The MIKE21 2D modelling package, a comprehensive modelling system for two-dimensional water modelling developed at the Danish Hydraulic Institute (DHI). SWAN is a third-generation wave model, developed at Delft University of Technology, which computes random, short-crested wind-generated waves in coastal regions and inland waters.

Oceanographic Data Centre and an installation at Newhaven Port). Model validation / calibration is described in Appendix 6.2 (Modelling Technical Report).

6.5.2.4. Hindcast data (between 1998 – 2017) was extracted from the HD and SWAN models at five points along the Marine Cable Corridor. These model inspection points are broadly logarithmically spaced with increased data resolution at the UK Landfall at Eastney. Time-series of AIMS model data (over the twenty-year period) was extracted for the following parameters:

- Significant wave height (H_s, m);
- Mean wave direction (M_{dir}, degrees from);
- Mean zero- crossing wave period (T_z, s);
- Current velocity (depth-averaged) (C_s, m s^{-1}); and
- Current direction (depth-averaged) (C_d, degrees towards).

6.5.2.5. Specific analyses of these data for the purposes of determining baseline conditions is presented in Appendix 6.2 (Modelling Technical Report).

6.5.2.6. Table 6.4 details the locations of the model inspection points along the Marine Cable Corridor. These locations of model inspection points are also illustrated in Figure 12 in Appendix 6.2 (Modelling Technical Report).

Table 6.4 – The location of the model inspection points along the Marine Cable Corridor

Model Point	Nearest KP	Latitude	Longitude
1	1.60	50° 46.348'N	1° 1.986'W
2	5.30	50° 44.840'N	1° 0.185'W
3	15.25	50° 41.695'N	0° 53.474'W
4	40.90	50° 36.512'N	0° 34.079'W
5	67.00	50° 28.787'N	0° 15.986'W

6.5.2.7. The data retrieved from the model has been analysed to support the interpretation of baseline processes occurring in the vicinity of the Proposed Development. Additional data and analyses are presented in Appendix 6.2 (Modelling Technical Report).

6.5.2.8. Further numerical modelling utilising the particle tracking module of MIKE 21 Flow Model has been conducted to assess the dispersion of sediment plumes generated during dredge disposal activities.

6.5.2.9. The set-up and parameterisation of the particle tracking model is reported in Appendix 6.2 (Modelling Technical Report).

6.5.2.10. The following paragraphs describe the physical environment baseline conditions along the Marine Cable Corridor (and Landfall) location (inshore; MHWS – UK 12 nautical miles (‘nmi’)), and in the wider area (offshore; UK 12 nmi to UK/France EEZ Boundary Line), with respect to bathymetry, physical oceanographic regime, solid geology, sub surface and surficial sediments (not including contamination), sediment transport (incl. tidal flows and waves) and coastal geomorphology.

6.5.3. BATHYMETRY

6.5.3.1. The Marine Cable Corridor runs through the Eastern Channel, which extends from a north-south line between the Isle of Wight and Cherbourg east to the Dover Strait. The seabed in this area comprises a very low angled planation surface with maximum depths of 60-70 m in the Central Channel, rising gently to the east to a depth of > 40 m and to north to the UK and south to the French coastlines.

6.5.3.2. Several different bathymetric datasets have been used in this study. Information on the wide-area bathymetry of the Channel is available from sources used in the development of the AIMS, namely data from the EMODnet, a standardised database of bathymetric and coastline data for north-west Europe. The AIMS also integrated, where appropriate, bathymetric raster charts from Oceanwise. Plate 6.2 and Plate 6.3. present the bathymetry from this dataset of the Channel, and of the Landfall at Eastney, respectively.

6.5.3.3. Several major bathymetric features characterise this area including St. Catherine’s Deep, a 60 m deep linear channel located just south of the Isle of Wight and the Northern Palaeovalley which is an open channel system which runs across the seabed along much of the fringe of southern England. Both features are shown by the darker blue areas illustrated within Plate 6.2 and Plate 6.3.

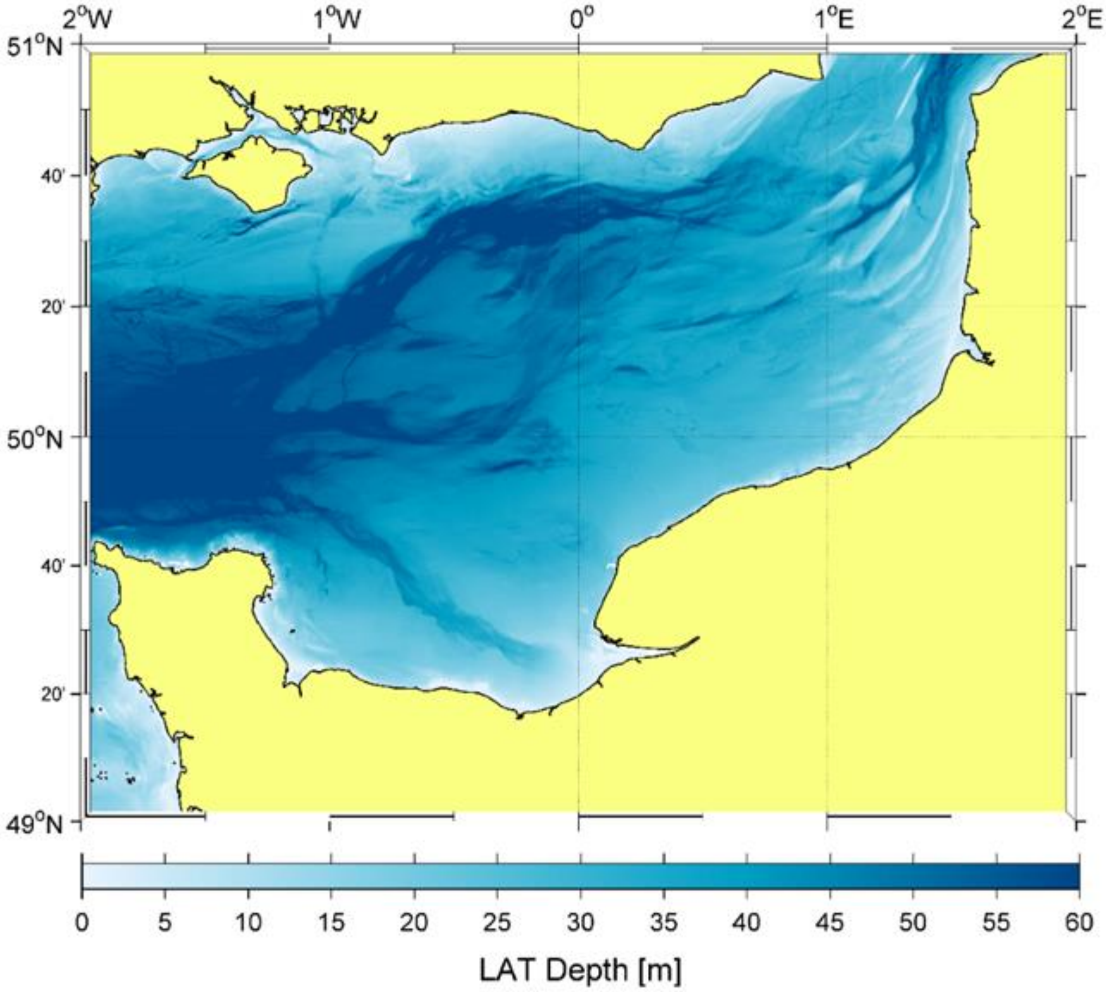


Plate 6.2 – Bathymetry of the wider Channel. Source: AIMS (2018)

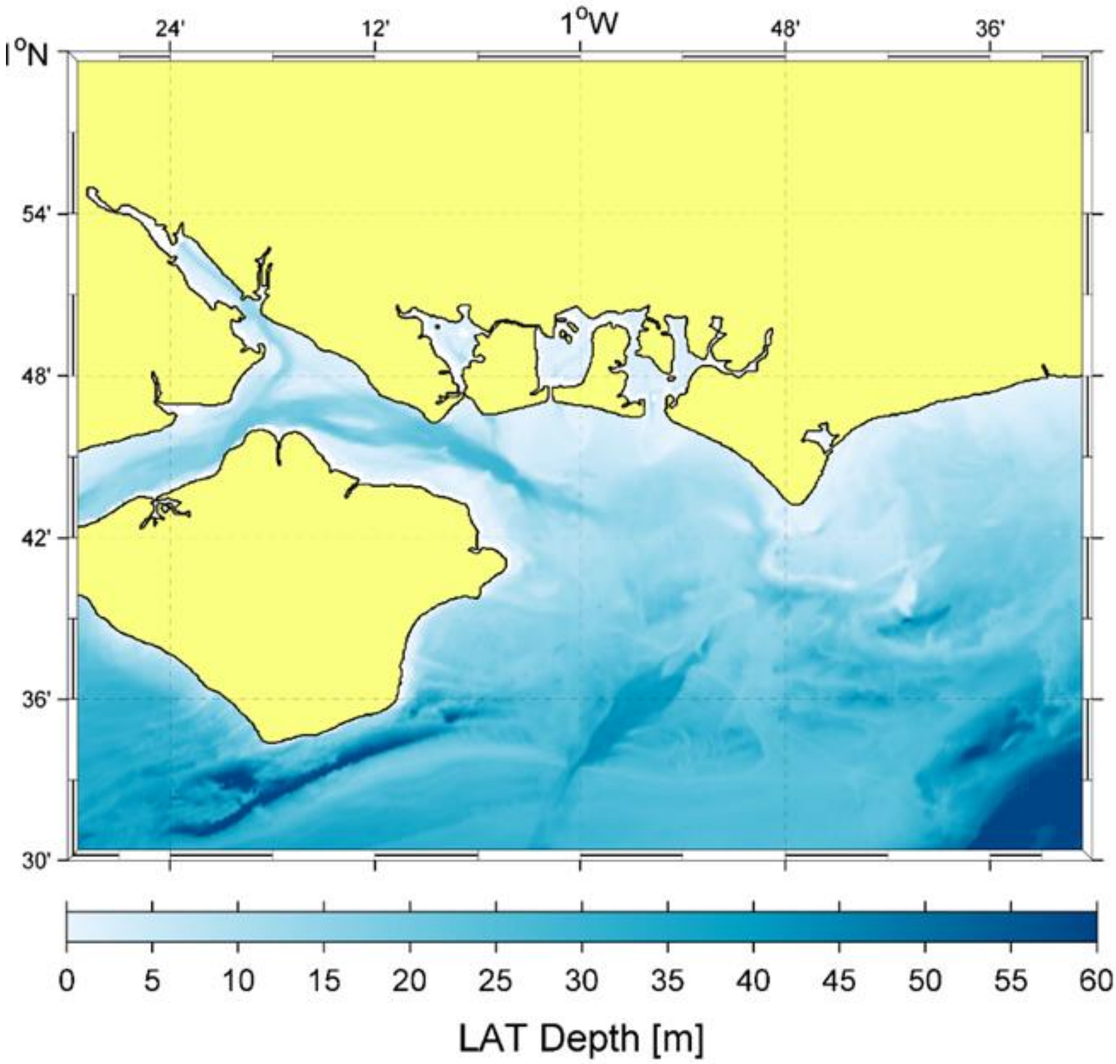
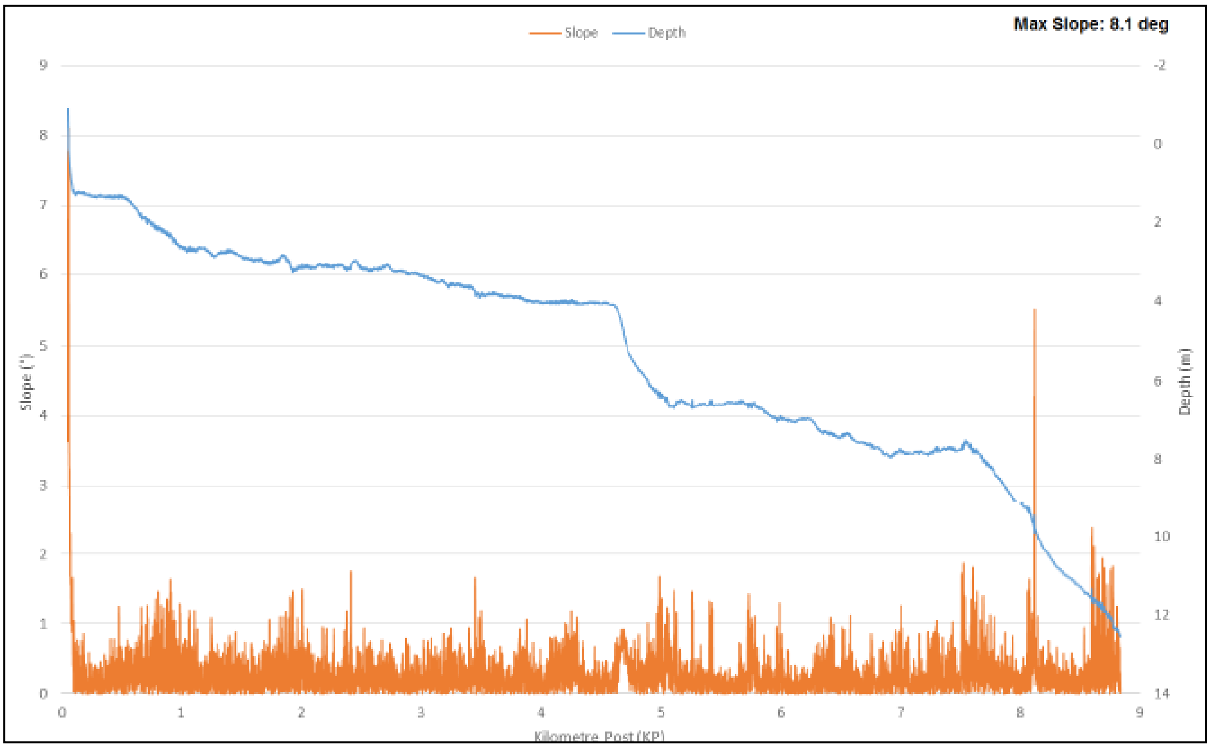
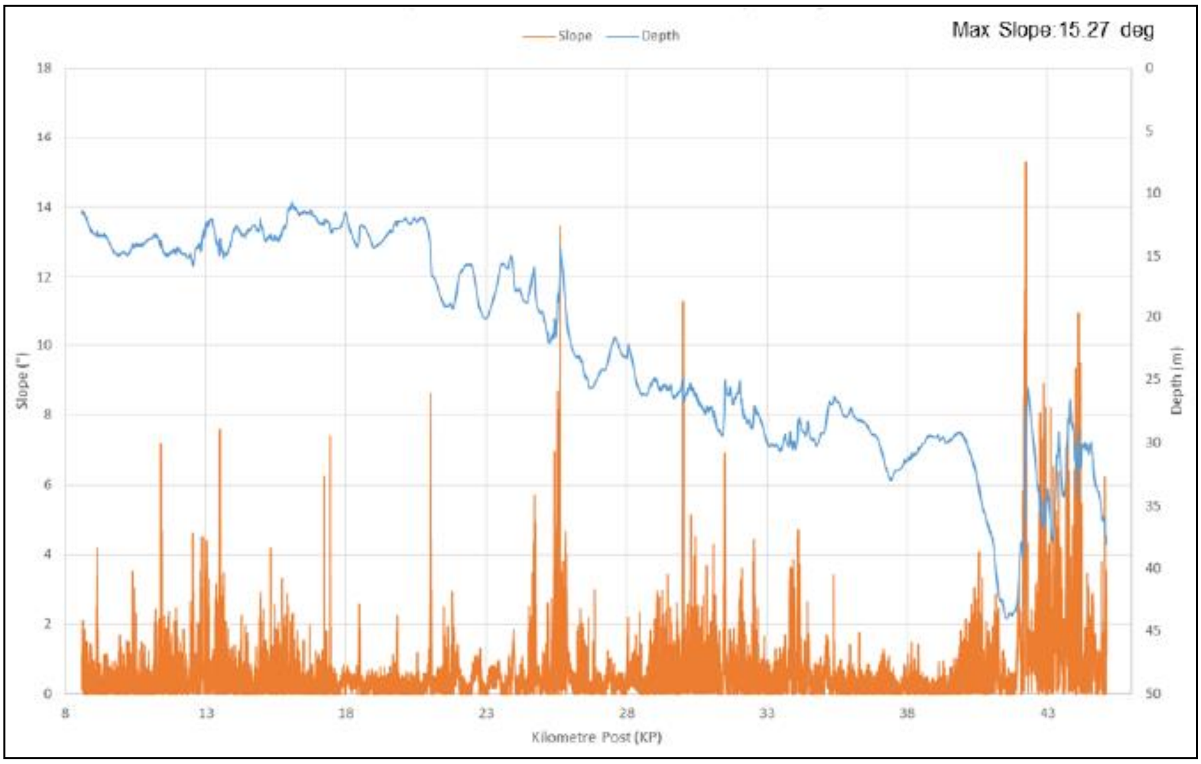


Plate 6.3 – Bathymetry of the region of Eastney. Source: AIMS (2018)

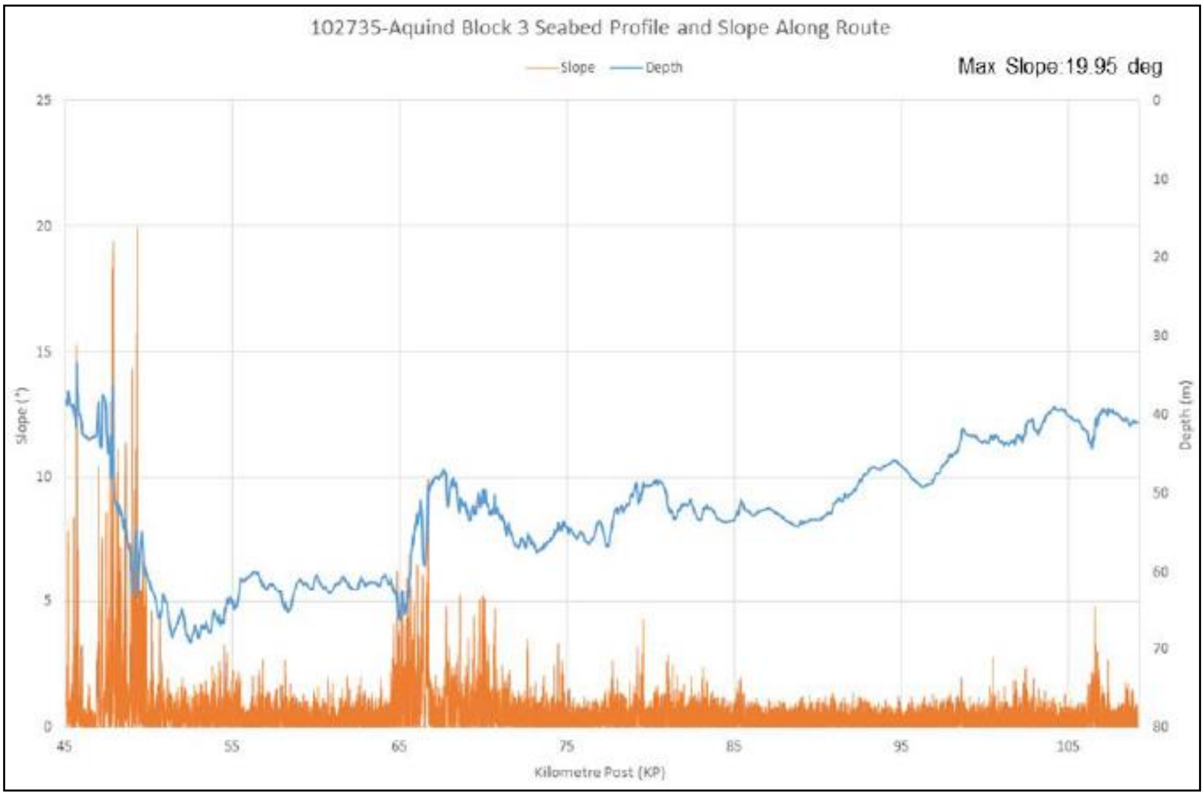
6.5.3.4. A full bathymetric survey of the Entire Marine Cable Corridor was also carried out as part of the overall geophysical survey for the Proposed Development. High-resolution bathymetric data was collected in the nearshore using a Kongsberg EM2040 Multibeam echo sounder, and offshore using a Kongsberg EM710 Multibeam echo sounder, with data recorded using Kongsberg SIS software. The bathymetry profile for Blocks 1, 2 and 3 (which comprise the seabed in UK waters) is presented in Plate 6.4.



Block 1: KP 0 to KP 8.600



Block 2: KP 8.600 to KP 45.116



Block 3: KP 45.116 to KP 109.107

Plate 6.4 – A longitudinal profile showing the distribution of water depths along the Marine Cable Corridor in UK waters. Depth is in metres (positive below VORF Lowest Astronomical Tide ('LAT') benchmark) and slope is in degrees (being the absolute value for visualisation). Source: MMT (2018/2019)

6.5.3.5. Water depths (in UK Waters) along the Marine Cable Corridor from Eastney to the UK/France EEZ Boundary Line range between the shallower waters of the Solent (*c.* 0-18 m) to water depths of *c.* 60 – 70 m. The deeper parts occur in the Northern Palaeovalley and briefly in the mid channel at the UK/France EEZ Boundary Line.

6.5.3.6. Throughout much of the Marine Cable Corridor depths range from 30 m to 65 m. Although the morphology of the seabed in the Channel has not been directly influenced by glacial processes, the events of the Pleistocene (multiple Ice Ages) have had an important effect. The variations in sea level during episodes of glaciation were responsible for periods of deposition and erosion. A gently dipping marine planation surface sloping south is observed everywhere along the southern English coast but does not extend farther offshore than about 20 km as it is incised by numerous channels in the seabed (palaeochannels) that were formed when sea levels were lower, allowing fluvial processes to incise the seabed, and accumulations of sand and gravel in the form of ridges and banks. Marine processes subsequently altered the channels and partially or fully filled them with marine sediment.

6.5.3.7. For the purposes of presenting a coherent description of the variation of bathymetry, the Marine Cable Corridor has been sub-divided into two segments (an Inshore Marine Cable Corridor from MHWS to the UK 12 nmi territorial limit [approximately 22.2 km, though equivalent to approximately KP 45 due to routeing]), and an Offshore Marine Cable Corridor from the UK 12 nmi territorial limit to the UK/France EEZ Boundary Line (approximately KP 109).

Inshore Marine Cable Corridor (MHWS – UK 12 nmi territorial limit)

6.5.3.8. The seabed is a southerly dipping marine planation surface and exhibits an initial moderate gradient close to the beach to *c.* 3 m below LAT; thereafter the profile is slightly concave, generally rather featureless and gently sloping to *c.* 15 m LAT at KP 10.0. From this point to approximately KP 22.2 the overall profile flattens but is characterised by a series of irregularly located rock outcrops, incisions and depressions (generally 2-3 m deep).

6.5.3.9. The only notable bathymetric feature of the nearshore region is a prominent gradient change across a bathymetric step with associated ripples at KP 21.0 (maximum slope reaches 7.0°) (see Plate 6.5) where water depths change from *c.* 12 m LAT to more than 19 m LAT. Seaward from KP 22.2 the Marine Cable Corridor gently slopes (<5^0) from *c.* 20 m to *c.* 50 m, crossing a secondary depression (locally depths increase by 12-14 m and slope increases to 15^0) centred on KP 40.0. The route then crosses the major bathymetric feature within the Channel (the east-west aligned Northern Palaeovalley which crosses the inshore and offshore boundaries of the Marine Cable Corridor between approximately KP 40.0 and KP 50.0), seen most clearly in plan view in the EMODnet Digital Terrain Model ('DTM') (see Plate 6.2), and where the maximum depths (and wall slopes) of the route are found (68 m LAT at KP44.0). The Northern Palaeovalley is a broad, semi-infilled valley feature incised into the bedrock by antecedent processes at lower sea level stands (Hamblin *et al*., 1992).

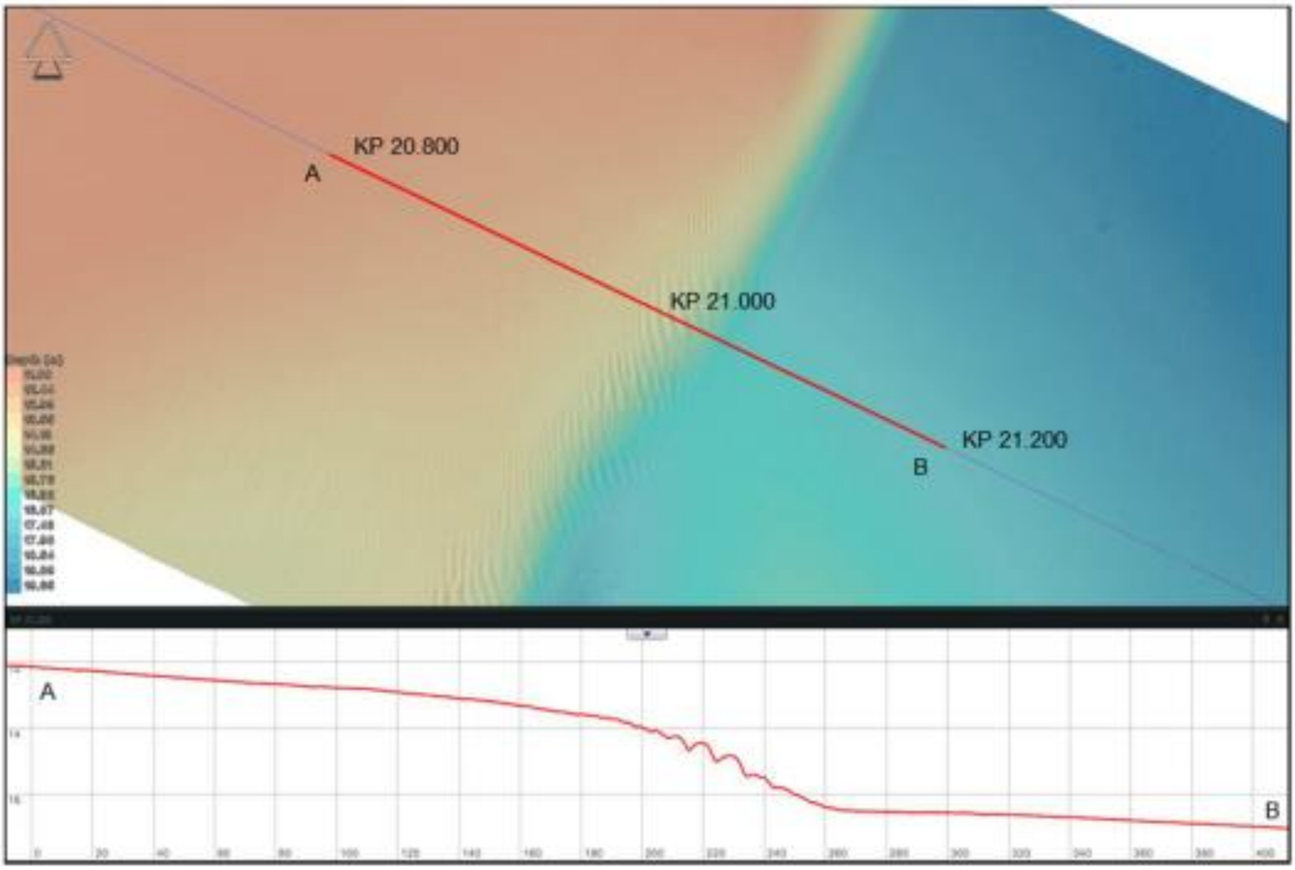


Plate 6.5 – Prominent gradient change at KP 21.0, close to the 12 nmi inshore-offshore corridor boundary, 7.01° with associated large ripples. The profile goes between A and B as shown in the image. Source: MMT (2018)

Offshore Marine Cable Corridor (UK 12 nmi territorial limit to UK/France EEZ Boundary Line)

6.5.3.10. The seafloor of the Channel can be considered a peneplain which begins at a depositional basin at the Western Approaches and continues in an upstream direction into the drainage basins of the rivers Somme and Seine, through the Strait of Dover and into the southern North Sea (Wright, 2004). The marine planation surface comprising the majority of the seafloor of the Channel is broadly incised to 50 m lower than surrounding UK and French coasts (Reynaud *et al*., 2003). The EMODnet DTM shows water depths range from *c.* 40 m – 68 m along the offshore corridor (see Plate 6.2). The Marine Cable Corridor gradually shallows as it crosses two secondary bathymetric depressions (*c.* 8 – 10 km wide where locally, depths increase by 5-10 m) between KP 70.0 – 91.0. From this point to the EEZ Boundary Line (KP 109.0), the bed profile shoals gradually to *c.* 40 m LAT with predominantly low slopes (< 5^0).

6.5.4. PHYSICAL OCEANOGRAPHIC REGIME

6.5.4.1. The physical oceanographic regime is defined herein as the behaviour of bulk water movements driven by the action of tides and non-tidal influences such as river flows and meteorological conditions (winds, atmospheric events and storm surges), and includes wave processes formed by the shearing action of wind on the water surface.

6.5.4.2. The Channel is a shallow epicontinental sea, linking the Atlantic Ocean and the North Sea. The water body is about 560 km (350 mi) long and varies in width from 240 km (150 mi) at its widest point to 33.3 km (20.7 mi) at its narrowest point in the Strait of Dover. It covers an area of some 75,000 km^2 (29,000 square miles) and can be considered as an excellent example of a tidally dominated shallow marine system, influenced by waves that originate mainly from the WSW and which only affect the shallow water areas during storms. The semidiurnal lunar tide is the most important tidal constituent. The tidal wave takes approximately 6.5 hours to travel the distance from Land's End in Cornwall to the Dover Strait.

Water Elevations

6.5.4.3. Tidal variation of water levels is driven by the passage of a tidal wave propagating broadly north-eastward (during flood tide) up the Channel and entering the southern North Sea. The Channel effectively acts as a funnel that amplifies the tidal range from less than a metre (as observed at sea) to > 6 metres (as observed in the Channel Islands, the west coast of the Cotentin Peninsula and the north coast of Brittany). The time difference of about six hours between high water at the eastern and western limits of the Channel is indicative of the tidal range being amplified further by resonance.

6.5.4.4. At a regional level, the standard reference station for tides in the area is Portsmouth, which is the nearest 'standard port' to Eastney. At this location (50°48'07.9"N 1°06'40.3"W) the UK National Tide Gauge Network (owned and operated by the Environment Agency) records tidal elevation which are relative to Admiralty Chart Datum. Table 6.5 summarises water elevation statistics for the Portsmouth gauge and each model inspection point (AIMS, 2018). The coastal location may be classified as mesotidal with a mean Spring tidal range of 3.99 m. For reference, water level data derived from the AIMS is presented in the form of time series in Figure 13 to Figure 17 in Appendix 6.2 (Modelling Technical Report).

Table 6.5 – Water elevation statistics at the Portsmouth tide gauge. Source: NTSLF (2018)

Tidal Levels	Portsmouth tide gauge (height [m] relative to Chart Datum)	Model inspection point (approximate Mean Height [m] relative to water surface)				
		1	2	3	4	5
Highest Astronomical Tide (HAT)	5.13	5.60	5.65	5.68	6.41	7.11
LAT	0.14	0	0	0	0	0
MHWS	4.72	4.60	4.67	4.69	5.40	6.05
Mean High Water Neaps (MHNS)	3.87	4.01	4.07	4.07	4.65	5.17
Mean Low Water Neaps (MLWN)	1.90	1.53	1.57	1.53	1.62	1.75
Mean Low Water Springs (MLWS)	0.73	0.79	0.83	0.81	0.83	0.87
Highest for year (2018)	4.99	5.26	5.32	5.34	6.17	6.80
Lowest for year (2018)	0.30	0.27	0.31	0.29	0.28	0.29
Mean Spring Range (MSR)	3.99	3.81	3.83	3.87	4.58	5.17
Mean Neap Range (MNR)	1.97	2.48	2.50	2.53	3.03	3.43

Tidal Flows

6.5.4.5. The central and eastern Channel is a semi-enclosed coastal sea. Detailed information on the spatial variation of currents within the main body of the Channel is available from the HD modelling (AIMS, 2018). The temporal variation of tidal flow velocities in the Channel during a flooding and ebbing Spring tide are presented in Figure 18 to Figure 31 in Appendix 6.2 (Modelling Technical Report). These plots reveal that within the main body of the Channel, a well-defined zone of relatively high tidal current velocities (>1.45 ms^{-1}) forms during the mid-tide, which extends from the Cotentin Peninsula across to the Isle of Wight. Tidal current velocities reduce to the east, and west, away from this zone; however, it is evident these higher flow velocities straddle the offshore Marine Cable Corridor during the mid and later stages of the flooding tides, and increased velocities (> 1 ms^{-1}) are observed to develop during the early ebb tide south off Selsey Bill (which is likely a result of the formation of recirculating gyres), and where tidal waters drain out of the entrances to Portsmouth, Langstone and Chichester inlets (harbours) on ebb tides.

6.5.4.6. A Eulerian view of the current velocities is presented in abstracted time-series of magnitude and direction derived from the data from model inspection points 1 – 5 from the AIMS model (Figure 32 to Figure 36 in Appendix 6.2 (Modelling Technical Report)). The Spring to Neap transition is clear with lower current magnitudes observed during the Neap tide and higher current magnitudes observed during Spring tides. The curves also show a near monotonic increase in mean, and peak, flow magnitudes with distance offshore, with offshore sites (model inspection points 4 and 5) centred on, or exceeding, 1 ms^{-1}, and the nearshore sites (i.e. model inspection points 1 and 2) being < approximately 0.6 ms^{-1}. Statistical data on current magnitudes is presented in Table 6.6.

Table 6.6 – Statistics related to modelled currents from the AIMS model, inspection points 1-5.

Model Inspection Point	Minimum velocity observed (ms^{-1})	Mean velocity observed (ms^{-1})	Maximum velocity observed (ms^{-1})	Associated standard deviation (ms^{-1})
1	0.00	0.25	0.73	0.11
2	0.00	0.24	0.52	0.08
3	0.00	0.37	0.79	0.15
4	0.00	0.47	1.07	0.21
5	0.00	0.53	1.45	0.28

6.5.4.7. In Appendix 6.2 (Modelling Technical Report), Figure 37 to Figure 41 display current direction vs magnitude at each of the model points in the form of current roses which provides for a visually simple appreciation of the predominant tidal axis and reveals significant variation in the directionality of flows between the Inshore Marine Cable Corridor (within 22.2 km of the coast) and locations further offshore. Inshore, the current directions through the tide are significantly more variable, as a result of proximity to the entrance to the tidal inlets of Portsmouth and Langstone Harbour (model inspection point 1), and bathymetric and coastal physiographic factors (model inspection points 2 and 3). With distance offshore, the tidal flows become increasingly rectilinear in form with a principal tidal axis-oriented ENE to WSW (i.e. the flood currents flow eastward, and the ebb currents flow westward), with a significant E – W component.

<u>**Tidal Asymmetry and Excursion Distances**</u>

6.5.4.8. The data from AIMS indicate that offshore (i.e. within the main body of the channel, model inspection points 4 and 5) there is an observable tidal asymmetry in favour of the flood tides; the flood tidal phase is always stronger in magnitude on both Spring and Neap tidal cycles, and shorter in duration, than corresponding ebb currents (illustrated in Plate 6.6 for model inspection point 5, and Table 2, Table 3 and Table 4 in Appendix 6.2 (Modelling Technical Report)). The difference in magnitude of the current velocities varies with tide range and is greater farther offshore where currents are naturally stronger.

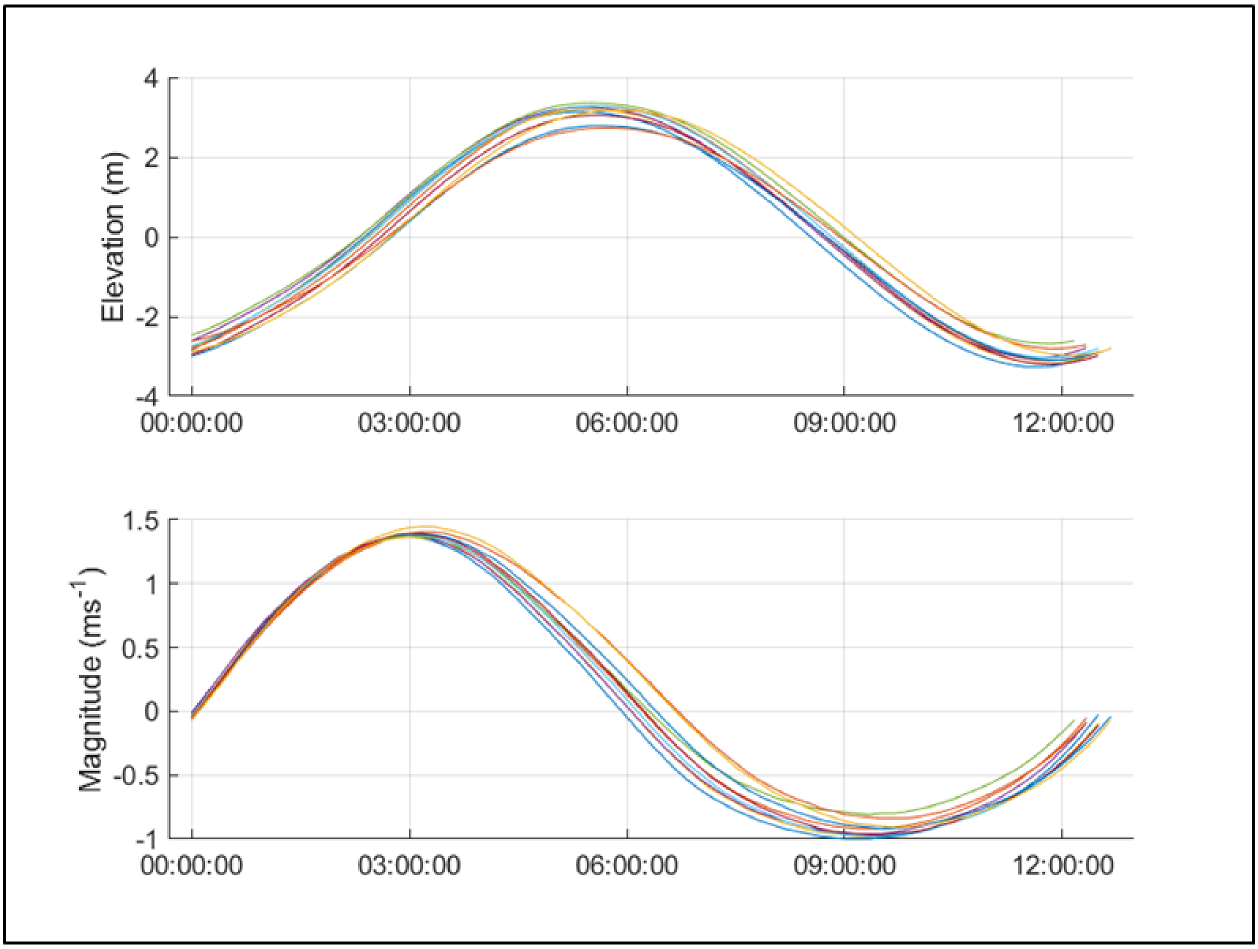


Plate 6.6 – Illustration of tidal asymmetry at model point 5 during a Spring tide. This analysis reveals a shorter (by up to 40 mins), and stronger (by approximately 37-70%) flood phase

6.5.4.9. At model inspection point 3 the relationship between magnitude and direction is less pronounced (for Neap tides), sometimes contradictory and on occasion reversed. For example, on Spring tides, flood currents are weaker than corresponding ebb currents. Farther inshore at model inspection point 1 and 2 the relationship is less clear, as the tides are notably non-rectilinear in form, varying through a wide range of directions throughout the tidal cycle. Due to this, the foregoing magnitude-duration analysis cannot readily be applied for the inshore locations. A general appreciation of the difference in the nature of the tidal currents is afforded by comparison of the rose plots for model inspection points 2 and 5 (see Figure 38 and Figure 41 in Appendix 6.2 (Modelling Technical Report), respectively).

6.5.4.10. The tidal excursion distance is a function of the tidal curve (asymmetry) and represents the net horizontal distance a water particle moves during a half-tidal cycle (i.e. the distance over which a water particle travels during the flooding and ebbing tide; Savenije, 1989). Knowledge of these distances is central to several areas. It provides an understanding of the maximum distances resuspended sediments could be transported away from their source (e.g. during scour and release around structures), or the maximum distances suspended sediment may be transported within a given time interval. The tidal excursion concept, when applied to the inshore sites (model inspection points 1, 2 and 3) is relatively meaningless since the tidal circulations are complex, and the net excursion may not be significant. For the offshore region (model inspection points 4 and 5), where tides are stronger and display a clear rectilinear relationship, a parcel of water can undergo significant horizontal translation. Illustrative tidal excursion diagrams for model inspection point 5 during Neap and Spring conditions are presented in Plate 6.7 and Plate 6.8, respectively. These show significant differences between the Spring and Neap tides; the Spring tides, which provide for the greatest horizontal translation, can extend for some 20 – 25 km along the tidal axis during a half Spring tide (during the flood or ebb cycle).

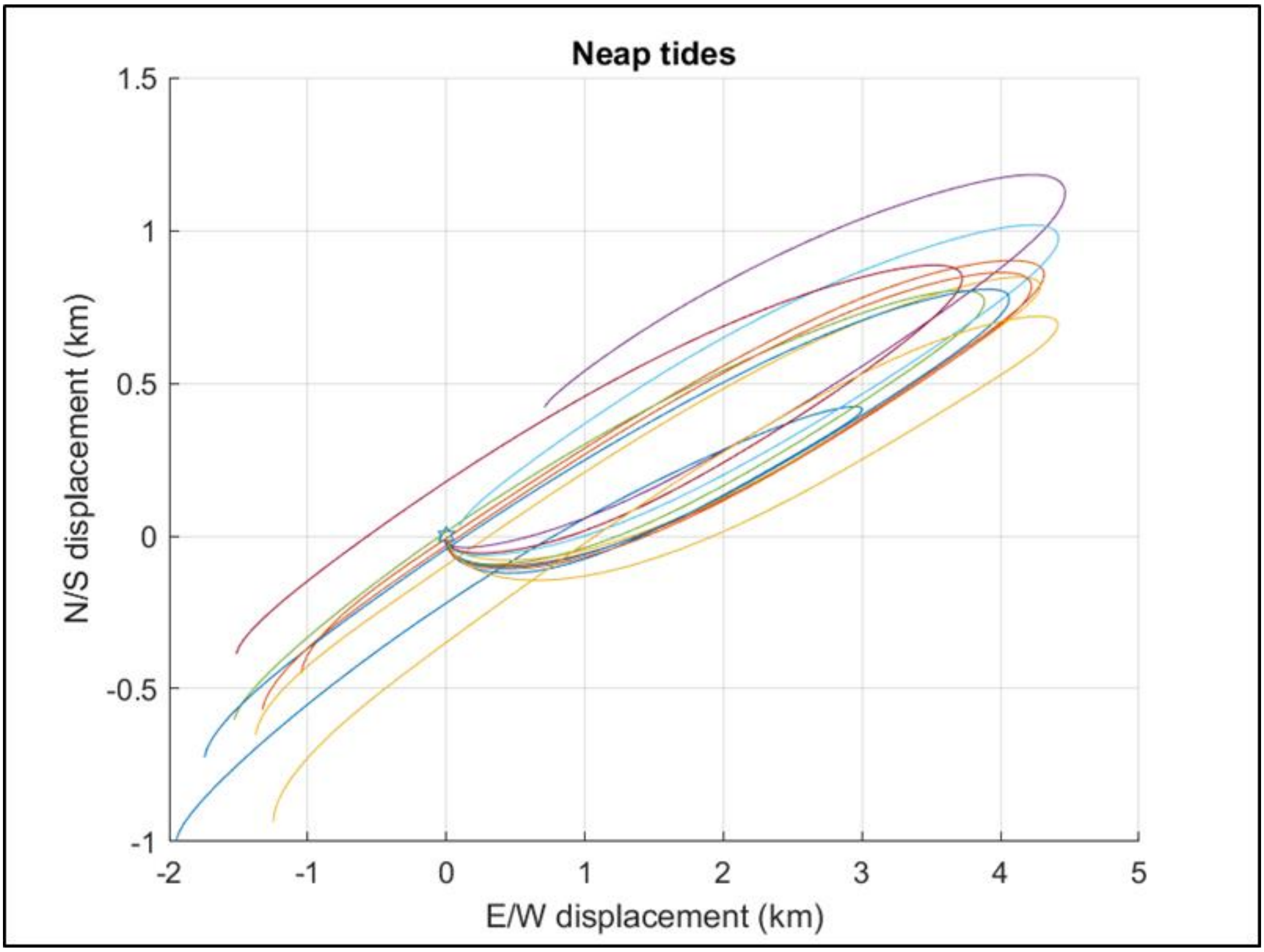


Plate 6.7 – Illustrative tidal excursion (progressive vector) plot for model point 5 during Neap tidal conditions

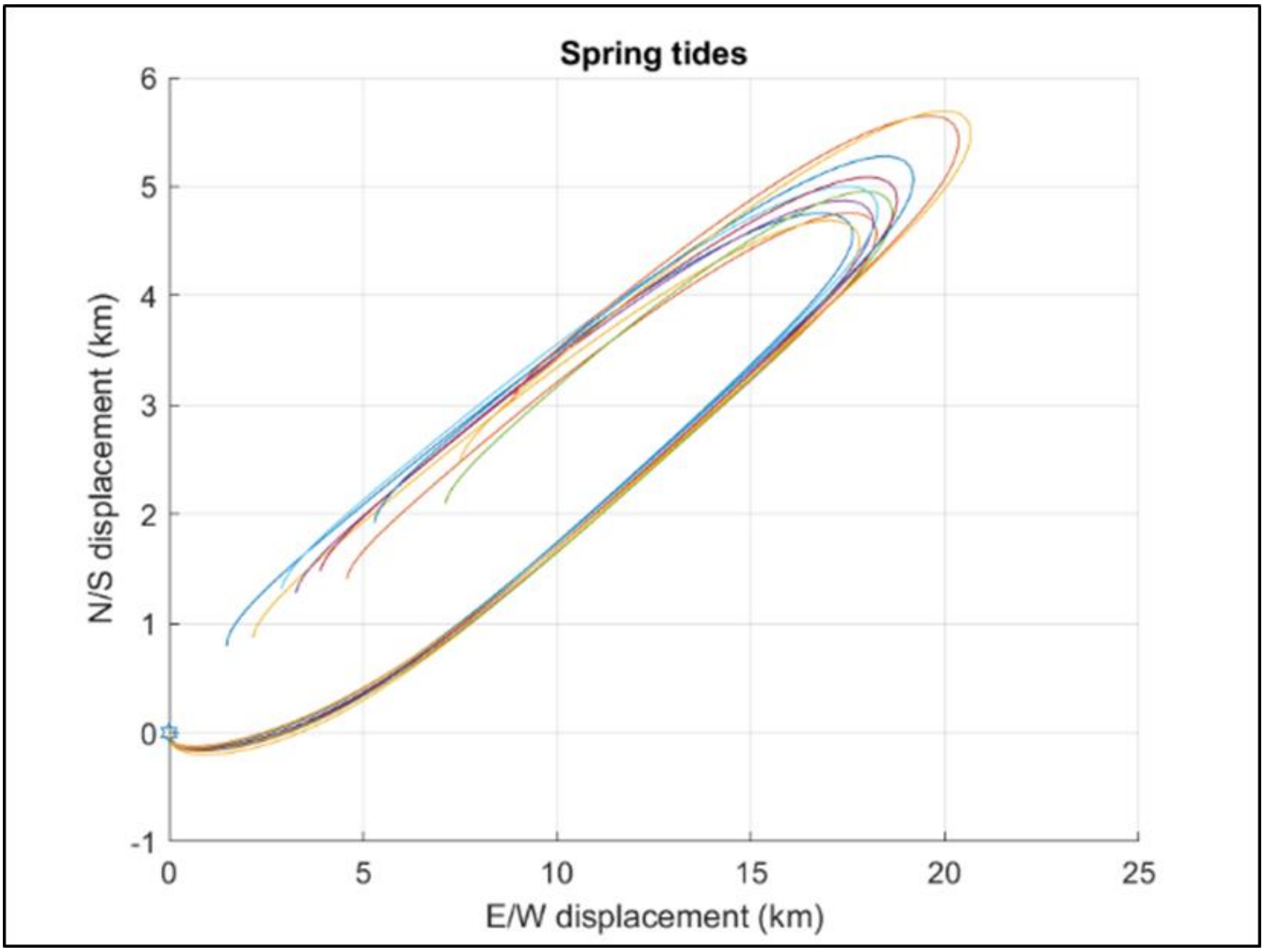


Plate 6.8 – Illustrative tidal excursion (progressive vector) plot for model point 5 during Spring tidal conditions

Non-Tidal Currents

6.5.4.11. Superimposed on the regular tidal behaviour, various random non-tidal effects may be present. Many of these non-tidal effects originate from meteorological influences. Persistent winds can generate wind-driven currents, elevate water levels and develop sea states that lead to wind-wave generation. Storm surges occur in the Channel during severe events. Due to the land masses of the United Kingdom and Western Europe the area experiences a funnelling effect and as a result, coastal areas in the East Channel experience greater levels of surge than areas located to the west. A skew surge is the difference between the maximum observed sea level and the maximum predicted tide regardless of their timing during the tidal cycle – thus there is one skew surge value per tidal cycle. Table 6.7 lists the top ten highest skew surges during the period 1991 - 2012 (NTSLF, 2018). These data indicate relatively significant excess water levels, with nearly a metre of water added onto the predicted tide during the most significant events.

Table 6.7 – The ten highest skew surges recorded for the Portsmouth tide gauge from 1991 – 2012. Data Source: NTSLF (2018).

Date	Time	Difference (m) between the maximum observed sea level and the maximum predicted tide
2002/11/14	08:00	0.824
1998/01/04	15:00	0.812
1995/01/19	13:00	0.794
2001/01/02	03:30	0.774
2008/03/01	18:00	0.766
1994/12/07	02:00	0.763
2007/03/06	00:30	0.760
1993/02/21	11:30	0.747
2008/03/01	13:00	0.709
2002/02/22	19:00	0.687

*** At Portsmouth, between the years 2008 to 2026 the predicted HAT is 5.13 m; during the same time period the predicted mean high water during the Spring tidal cycle is 4.72 m.**

6.5.4.12. Storm surges are usually accompanied by increases in flow velocities, and therefore the potential exists for enhanced sediment transport, although there is limited data which separates velocities due to the surge component alone. Modelling completed by Flather (1986) suggests that, based on a 50-year storm surge event in the Channel, the current velocity could be increased by up to $0.6ms^{-1}$ in the vicinity of the Proposed Development.

Wave Regime

6.5.4.13. Waves result from the transfer of wind energy to create sea states and the propagation of such energy across the water surface by wave motion. The amount of wind energy transfer, and thus wind-wave development, is a function of the available fetch distance across which the wind blows, wind speed, wind duration and the original sea state. The longer the fetch distance, the greater potential there is for the wind to interact with the water surface and generate waves. Since wind generated waves originate from meteorological forcing, the wave regime is highly episodic and exhibits strong seasonal variation.

6.5.4.14. The Channel is situated at the downwind end of one of the windiest seas of the world, resulting in severe wave conditions and high average values of wave energy (Hamblin *et al*., 1992). These conditions have significant consequences for local sediment transport, especially in shallower regions where wave effects become more pronounced. Information on the synoptic, wide area wave climate in the region of the Proposed Development is available via the data from the AIMS coupled wave and HD model.

6.5.4.15. For each model inspection point, for a 12-month record (from the year 1998), wave roses are presented showing the significant wave height (H_{m0}) vs direction (Figure 42 to Figure 46 in Appendix 6.2 (Modelling Technical Report)), and the zero up-crossing wave period (T_z) vs direction (Figure 47 to Figure 51 in Appendix 6.2 (Modelling Technical Report)). The predicted significant wave heights (H_{m0}) is also presented in the form of time series (Figure 52 to Figure 56 in Appendix 6.2 (Modelling Technical Report)). Finally, a more accurate assessment of the frequency – magnitude of the wave climate along the Proposed Development is accessible via Figure 57 to Figure 61 in Appendix 6.2 (Modelling Technical Report) which present joint probability distributions with respect to significant wave height (H_{m0}) and wave approach (compass quadrants), and significant wave height and wave period (T_z) for each model inspection point.

6.5.4.16. The following points summarise the key features of the modelled wave regime along the Proposed Development:

- The frequency and magnitude data show a relatively dynamic wave regime along the Marine Cable Corridor.
- The data reveals there is a greater frequency of storms during winter months (i.e. winter storms generate frequent higher energy episodes).
- At model inspection point 5 (the farthest offshore) higher energy episodes are observed (e.g. where maximum wave heights of > 7 m are observed). However, generally waves are observed of <2 m in the summer months, increasing to <4 m in the winter months.
- The most common wave period is between 2 and 4 seconds (‘s’), indicative of local (wind generated) sea; higher period events (to maxima of 15 s inshore and 9 s offshore) do occur, though more infrequently at inshore locations.
- At model inspection point 5 the wave direction spectrum shows a greater incidence of waves from the WSW (principally as waves approaching the Marine Cable Corridor are unaffected by the coastline).

6.5.4.17. The key statistics with regard to the wave climate and the most frequently observed wave conditions during the modelled period are detailed in Table 6.8 and Table 6.9.

Table 6.8 – Key statistics associated with the wave regime, specifically related with wave height

Model Point	Smallest wave observed (m)	Mean wave height observed (m)	Median wave height observed (m)	Largest wave observed (m)	Standard Deviation	Components most frequently observed		Frequency observed (%)	Components most frequently observed		Frequency observed (%)
						$H_{m}{}^{0}$ (m)	Dir		$H_{m}{}^{0}$ (m)	T_z (s)	
1	0.01	0.39	0.31	2.5	0.32	0 -> 0.5	S	21.97	0 -> 0.5	2 -> 4	58.82
2	0.01	0.57	0.45	3.88	0.42	0 -> 0.5	SSW	14.53	0 -> 0.5	2 -> 4	47.01
3	0.03	0.82	0.66	5.23	0.56	0.5 -> 1	SW	13.54	0.5 -> 1	2 -> 4	36.26
4	0.06	1.13	0.92	6.64	0.74	0.5 -> 1	WSW	11.55	0.5 -> 1	2 -> 4	31.87
5	0.06	1.23	1.01	7.29	0.8	0.5 -> 1	WSW	16.75	0.5 -> 1	2 -> 4	31.24

Table 6.9 – Key statistics associated with the wave regime, specifically related to wave period

Model Point	Smallest wave period observed (s)	Mean wave period observed (s)	Median wave period observed (s)	Highest wave period observed (s)	Standard deviation	Component most frequently observed	
						T_z (s)	H_m^0 (m)
1	1.39	3.19	2.98	14.83	1.11	2 -> 4	0 -> 0.5
2	1.4	3.2	3.01	14.24	0.97	2 -> 4	0 -> 0.5
3	1.46	3.61	3.44	11.64	0.89	2 -> 4	0.5 -> 1
4	1.67	4.08	3.93	9.64	0.94	2 -> 4	0.5 -> 1
5	1.66	4.07	3.9	8.77	0.92	2 -> 4	0.5 -> 1

Wave Modification

6.5.4.18. In deep water, waves will move across the sea surface without major modification but as they move into shallower water the orbital motion of the wave through the water column eventually reaches the seabed whereupon frictional drag changes the shape of the wave. Refraction, shoaling (wave steepening) and eventually wave breaking will occur as the waves move progressively into shallower water and towards the shore. Several important modifications occur as waves begin to interact with the seabed. These include:

- Shoaling and refraction (depth and current);
- Energy loss due to breaking;
- Energy loss due to bottom friction; and,
- Momentum and mass transport effects.

6.5.4.19. There is evidence for these processes occurring along the Marine Cable Corridor, and waves affected in this way are normally termed shallow water waves. Model inspection points 1 – 5 broadly comprise a shore-normal gradient, which is particularly useful for assessing wave modification. Plate 6.9 and Plate 6.10 present scatter plots showing the relationship between data retrieved model point 1 and model point 5 with regard to direction of wave approach and significant wave height, respectively.

6.5.4.20. Inspection of the hindcast time series data reveal the impact of seabed bathymetry and coastline topography on the significant wave height and show how waves approaching the coastline from various directions are modified (dissipated). Offshore waves will reduce in height somewhere in the order of 40 – 60 % by the time they reach inshore areas. The greatest reduction in significant wave height is observed when waves approach the coastline from the South and West quadrants. In addition, the hindcast data indicates that the direction of wave approach could change by up to 180°, however typically direction shifts of *c.* 60° from offshore model inspection point 5 to inshore areas (nearshore inspection point 1) are observed. These transformation effects would be slightly more pronounced in lower (H_{m0} of < 2 m) wave conditions.

6.5.4.21. Wave modification can be summarised by the following:

- At model inspection site 1 and 2 the modal wave direction spectrum shifts and is centred on S and SSW, respectively. This is due to the orientation of the coastline and wave refraction (of waves principally arising from W and WSW) in which the angle of the wave crests to the shoreline is modified by the shallowing water, and the wave crests become increasingly parallel to the shoreline.

- At model inspection points further inshore (i.e. model point 1), the data reflects the process of wave shoaling. Observed significant wave heights are lower due to the frictional dissipation of wave energy at the seabed and a slowing of the waves as they enter shallow water.

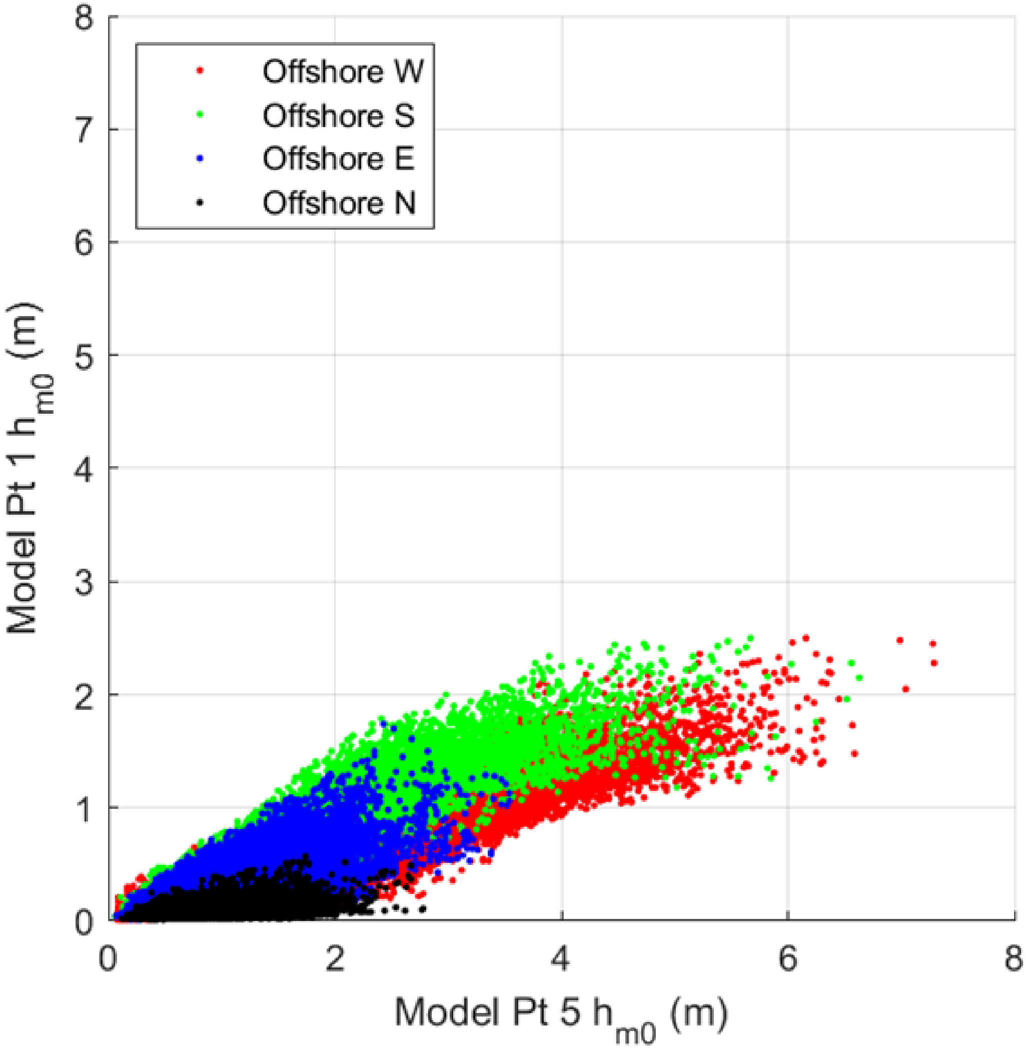


Plate 6.9 – Modification of significant wave height (*H_{m0}*) from model point 5 to model point 1 for all offshore waves from the hindcast dataset

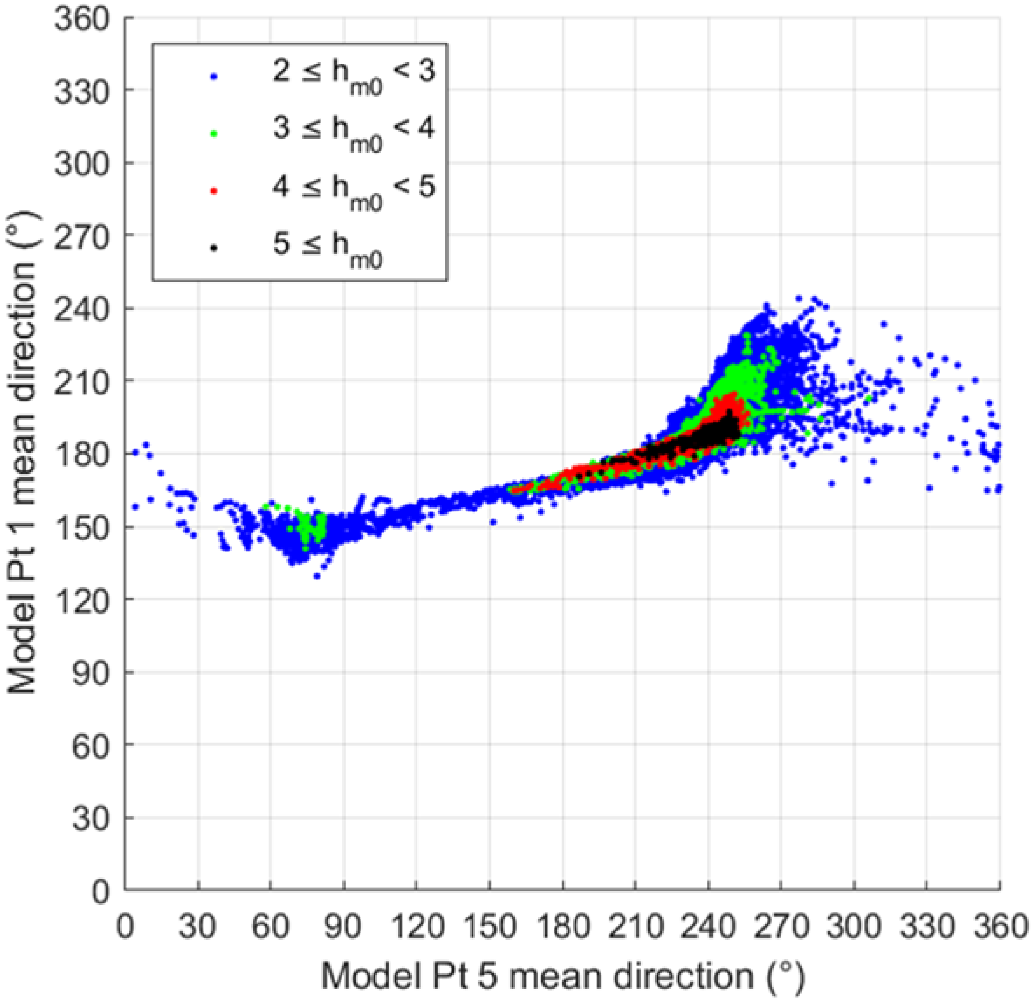


Plate 6.10 – Modification of wave approach from model point 5 to model point 1 for offshore waves from the directional sectors north, east, south and west

6.5.5. SOLID GEOLOGY

6.5.5.1. The geology of the Channel region is complex with geological formations deposited in a range of environments from the Middle Jurassic and Lower to Upper Cretaceous overlain by discontinuous packages of Quaternary to recent sediments. In addition, the area has been subject to major faulting and folding throughout its history, as a result of multiple phases of tectonic extension and compression. The present-day channel configuration is thought to have been created between 450,000 before present (bp) and 180,000 bp by glacial lake outburst flood. Hamblin *et al*., (1992) provide an overview of the geological formations of the Channel (Plate 6.11) and provides a summary of the geological history and associated lithostratigraphy.

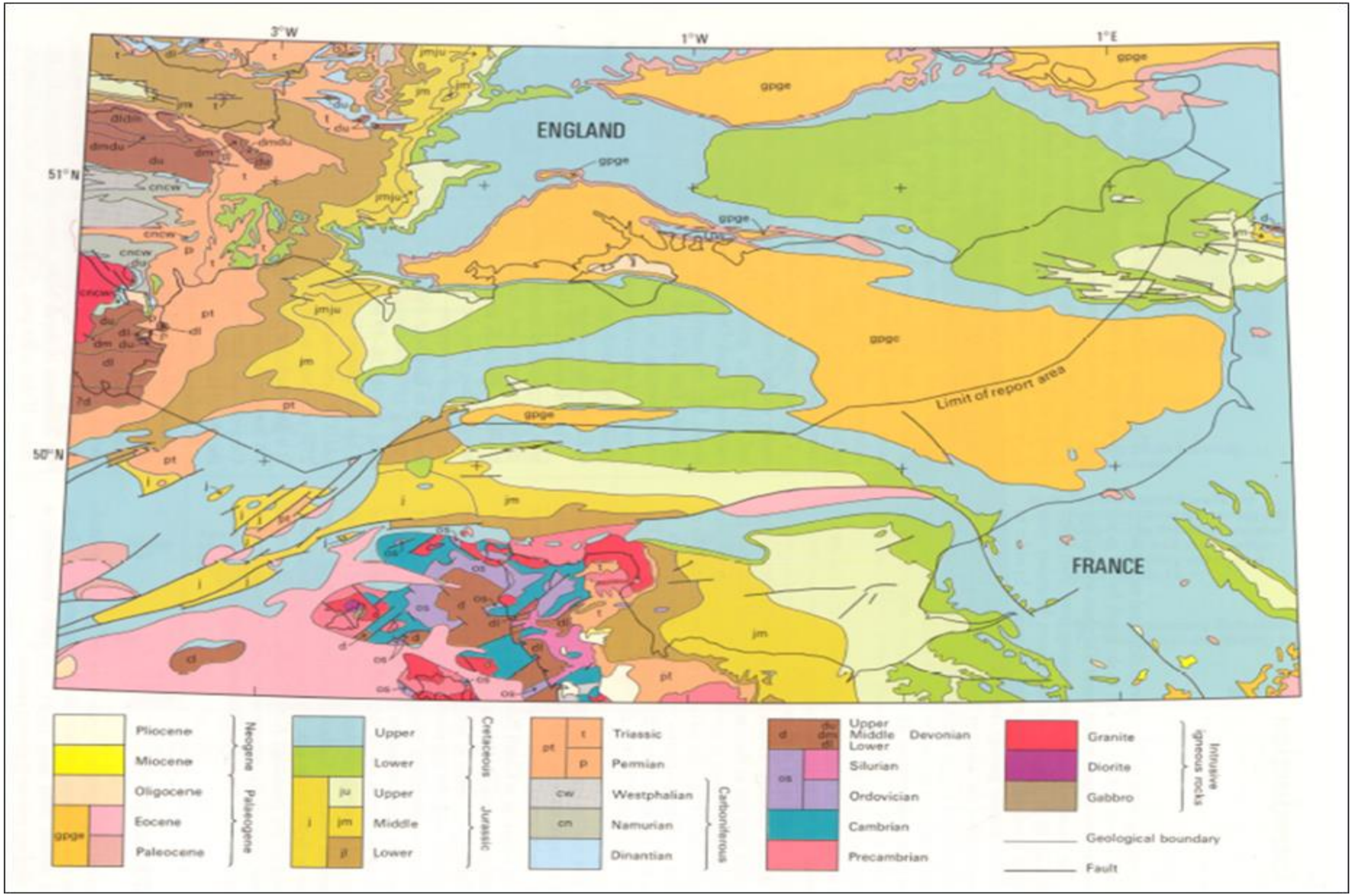


Plate 6.11 – Geological map of the Channel: Source: Hamblin *et al.*, 1992)

6.5.5.2. The geological and structural evolution of the broader Channel was also summarised by Smith and Curry (1975) who described the Channel into three distinct provinces, being the Eastern province, the Central province and the Western province. The Marine Cable Corridor crosses the Eastern and Central provinces.

6.5.5.3. The Central province is underlain by geology ranging in age from Permian to Eocene that outcrop at the seafloor. Within this province there are three major structural features, two possibly linked to the Ouessant-Alderney fault zone and the third forming the Isle of Wight-Purbeck monocline. The south-easterly alignment adopted by the monocline forms the Bembridge-St.Valery-en-Caux line, dividing the Central and Eastern provinces.

6.5.5.4. The Eastern province is dominated by a relatively undisturbed open syncline (referred to as the Hampshire-Dieppe Basin) of tertiary strata flanked to the north east by the continuation of the weald Artois anticlinorium of south eastern England across into the Boulonnais area of northern France. The natural morphological limit of the eastern province is the marked shallowing and narrowing of the Strait of Dover (Pas de Calais). The Hampshire–Dieppe basin dominates much of the seabed geology of the eastern Channel (Plate 6.11), which is the area through which the Marine Cable Corridor passes. The basin is a broad, gently dipping structure trending in a WNW – ESE direction and composed of mainly lower cretaceous (Lower Greensand, Gault and Upper Greensand), Upper Cretaceous (Chalk) and tertiary strata. The boundary between the youngest tertiary sediments of the Oligocene and those of Quaternary age represents a major hiatus in the geological record of the Channel (Wright, 2004), with Miocene and Pliocene deposits largely unknown (Hamblin *et al*., 1992). Broadly, the Quaternary deposits have only been preserved in the form of palaeovalley infills and seabed lag sediments.

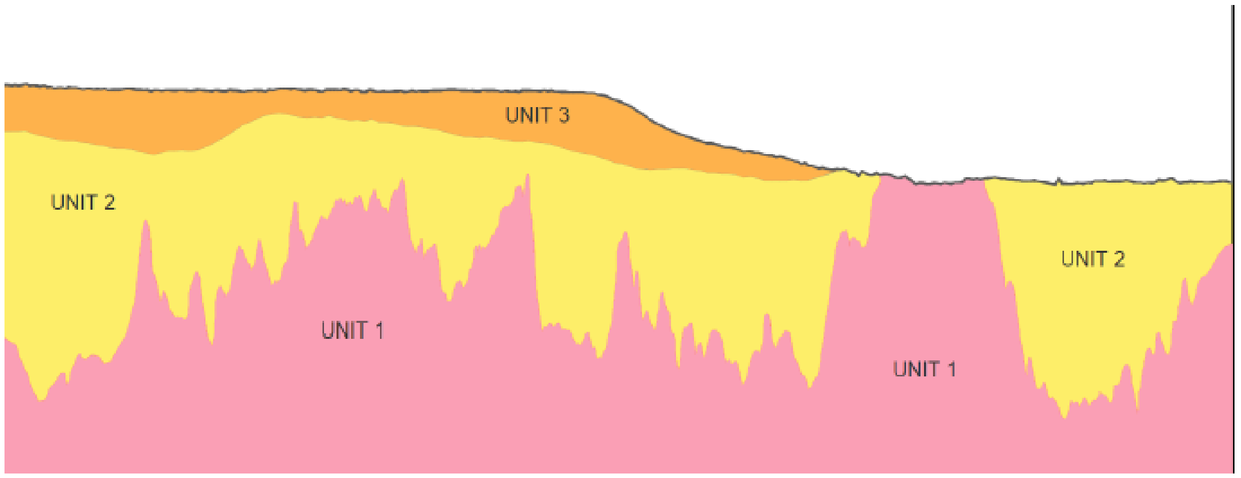
6.5.6. SUB-SURFACE AND SURFACE SEDIMENTOLOGY

6.5.6.1. Reynaud *et al*., (2003) conducted a review of the present-day surficial sediments of the Channel focusing in particular on the sandy accumulations (tidal sandbank systems and bedforms). Through the synthesis of the available data, and in an analogous approach to Smith and Curry (1975) they divided the channel into three major sectors being; the Eastern Channel, the Central (and Western central) Channel, and the Western Approaches, based upon the sediment nature and distribution on the sea-floor and the large-scale depositional architecture of the sediments (Wright, 2004). The Central (and Western central) Channel is characterised by a paucity of seabed surface sediment (Reynaud *et al*., 2003) which, where present comprises a thin veneer generally less than 20 - 50 cm thick.

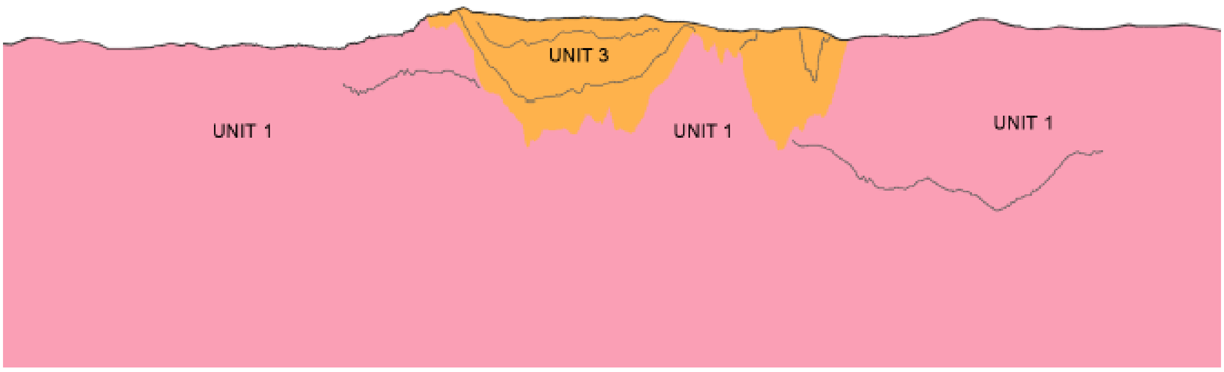
6.5.6.2. Hamblin (1989) noted that in the areas of the Eastern Channel where sandbanks and ridges are absent, the seafloor erosion surface has a discontinuous veneer cover of lag deposits interspersed with exposures of bedrock. Investigations into the nature of the lag deposits show they are typically gravels, sandy gravels and gravely sands. The sand fraction contains high (40 – 100%) shell-derived carbonate content whereas the gravel fraction has a conversely low content of biogenic carbonate (0 – 40%) (Wright, 2004). The lithic content of the gravels is dominated by flints of two types: fresh, blackhearted, that was derived locally and brown, worn flint with a long history of rederivation via tertiary deposits (Hamblin, 1989). Significant other contributions to the lithic content of the gravel fraction are made up of chalk, limestone, sandstone, ironstone, mudstone and chert but notably only locally, and in areas where they make up the underlying solid geology – excepting a very small proportion of the gravel which is exotic to the area (Hamblin, 1989).

6.5.6.3. During 2017 and 2018, geophysical surveys and geotechnical investigations were undertaken to assess sub-seabed characteristics along the Marine Cable Corridor within UK waters. Data collected during the geophysical survey (MMT, 2017/2018) of the Marine Cable Corridor has been used to derive a semi-quantitative map of the surficial sediment cover. This information is presented as three maps shown in Plate 6.12. The shallow geology generally comprises three units, being:

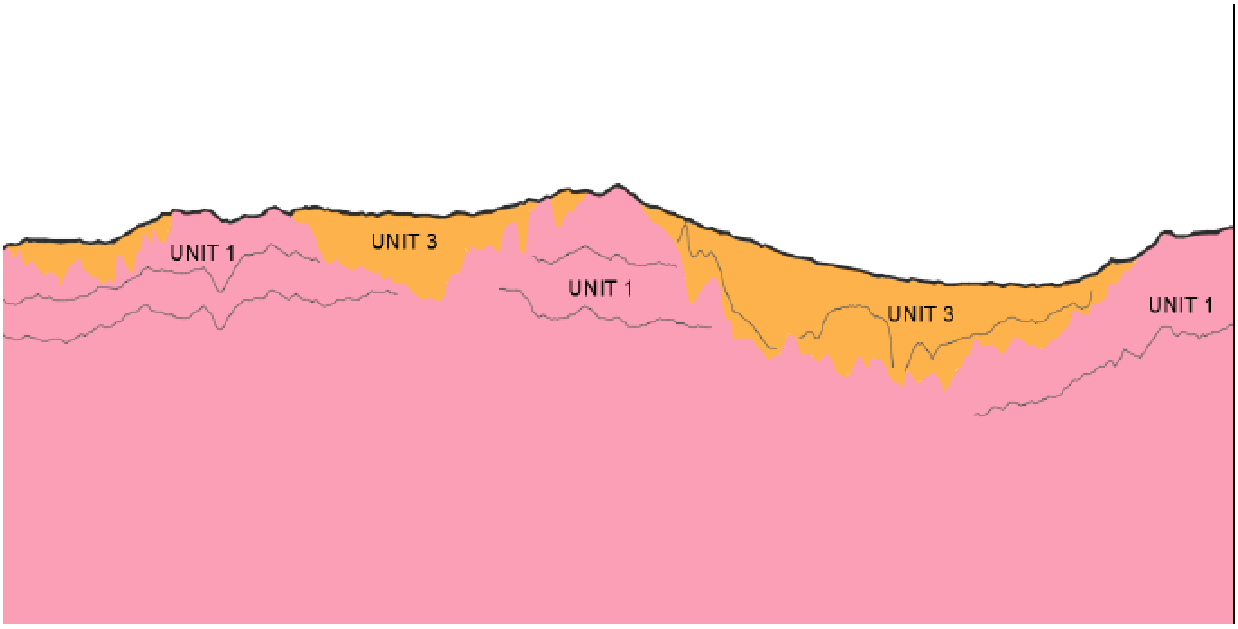
- Unit 1 – comprises HARDGROUND.
- Unit 2 – interpreted as comprising finer fractions, SILT and SAND. Unit 2 is likely to often be channel infill sediments and the thickness varies from a thin veneer up to 8m.
- Unit 3 – the uppermost layer interpreted to consist of SAND or SAND and GRAVEL. When present, Unit 3 is between 0.5 and 2.0 m thick.



Block 1: KP 0 to KP 8.600



Block 2: 8.600 to KP 45.116



Block 3: KP 45.116 to KP 109.107

Plate 6.12 – General stratigraphy along the Marine Cable Corridor in UK waters. The image shows the general layer sequence in the block. Grey lines represent internal reflectors.

6.5.6.4. During the ground investigation (MMT, 2017/2018), in total 101 sediment cores were collected at 88 locations and 114 Piezocone Penetrometer Tests were conducted at 86 locations. Summary grain size statistics for all samples analysed for their particle size distribution are presented in Appendix 6.3 (Grain Size Statistics). The 'down core' vertical sequence of sediments, and their varying geological and hydraulic properties is considered critical data for the prediction of scour potential for any proposed structures constructed on, or into, the seabed.

6.5.6.5. The grain size statistics reveal a dominantly sandy/gravelly seabed with *c*. 50% of the samples analysed comprising > 50% sand and *c*. 30% of the samples analysed comprised of > 50% gravel.

6.5.6.6. Along the Marine Cable Corridor, the total fines content within the samples analysed is typically low (i.e. samples comprising < 10% fines), however in generally isolated pockets (i.e. between KP 9 - 13 and KP 42 - 47) along the route the fines content is increased. Indeed, in total 30% of samples analysed comprise > 10% total fines content. Interestingly, 80% of samples analysed which had a total fines content of > 10 % were located subsurface which is in agreeance with the general description of the subsurface and surface sedimentology described in section 6.5.6.1 and section 6.5.6.2. As a general trend, greater fines content was observed within samples located closer to the shore, which is a result of the high flow velocities observed offshore. Where areas of fine material are observed at the surface these are hypothesised to be outcropping areas of clay geology which are broadly resistant to erosion from tidal flows.

6.5.6.7. During the benthic ecology survey campaign, samples of the seabed surface sediment were also collected along the length of the Marine Cable Corridor using a seabed sediment grab sampler. Such a device collects a small, shallow sample of the surficial deposits. In total, 21 discrete seabed sediment samples were collected, providing a quantitative dataset on the specific grain sizes that constitute the seabed sediments along the Marine Cable Corridor. These data broadly corroborate the data collected from the boreholes along the Marine Cable Corridor and are also presented in Appendix 6.3 (Grain Size Statistics).

6.5.6.8. The surficial seabed sediments in the area are predominantly very fine GRAVEL or coarse SAND. Typically, the silt and clay component is < 5% (in 13 samples) and this is commonly observed in samples collected further offshore. However, 9 samples show > 5% silt and clay content, including 3 samples which show > 10% silt and clay content and one sample showing > 60%, with a noticeable increase in fines along the Marine Cable Corridor between KP 5.0 and KP 15.0. The grain size distributions are generally very poorly sorted (i.e. a wide variety of grain sizes are found).

6.5.7. SEDIMENT TRANSPORT REGIME

6.5.7.1. Seabed sediments are susceptible to resuspension by tidal currents and waves. Resuspension occurs when the frictional drag (the ‘bed stress’; τ_0) exerted by currents and waves, separately (e.g. during summer months when waves are negligible) and in combination (e.g. during winter storms), exceeds the submerged weight of particles, which act to retain particles on the bed; the stress at which sediment motion is first produced is called the 'critical bed stress', denoted τ_{0crit}. When $\tau_0 > \tau_{0crit}$. sediments are mobilised, and for many coastal environments this is evident by an increase in the concentration of sediments in suspension. The term [τ_0 - τ_{0crit}.] is defined as the 'excess bed stress', and lower values derived from this coefficient may be regarded as indicative of relatively low rates of sediment transport, likely evidenced by near bed sediment concentrations being only slightly above background, whereas larger values of excess stress can be considered to drive greater rates of sediment transport which would be indicated by significant elevations of suspended sediments.

6.5.7.2. Sediments finer than ~0.2 mm are prone to being mobilised directly into suspension, those > 2 mm are usually transported as bedload and transport in this manner leads to the formation of bedforms, and the intermediate sizes (and for mixed size sediments) the transport mode is commonly a combination of the two.

6.5.7.3. Whereas tides exert a time varying bed stress on sediments associated with daily tidal and longer-term Spring – Neap variability, the superposition of waves on tides, namely during winter-time periods, results in enhancement of the bed shear-stress acting on the seabed and surficial sediments. The boundary layers at the bed associated with waves and the current interact non-linearly, and this has the effect of enhancing both the mean and oscillatory bed shear-stresses. Thus, the bed shear-stress acting on the bed due to the combination of waves and current is enhanced beyond the value which would result from a linear addition of the bed shear-stress due to waves, and the bed shear-stress due to current. When waves occur concurrently with peak tidal currents, the consequent bed stress is a powerful driver of sediment transport.

6.5.7.4. The primary questions that arise in relation to understanding the baseline sediment transport regime for the Proposed Development include:

- Are the tidal currents along the Marine Cable Corridor sufficient to generate sediment transport?
- If so, what is the percentage of time that flow conditions exist which are sufficiently powerful to generate transport?
- If so, what are the rates of suspension and bedload transport?
- Are there asymmetries in transport which create a net transport direction?
- Are there differences in expected transport rates across the site in relation to differing sediment types?
- Is the wave climate sufficient to generate sediment transport?
- If so, what are the critical height-periods which do so, and thus is transport enhanced seasonally?

- What is the percentage of time that wave conditions exist which are sufficiently powerful to mobilise sediment?
- How variable is sediment transport expected to be along the Marine Cable Corridor?;
- How do wave and tide currents combine to generate sediment transport, and how important is this?

6.5.7.5. Broadly, the seabed sediment across the area can be divided into two categories;

1. a coarse lag deposit that is not mobile under tidal flow which occurs over the majority of the area (Dickson and Lee, 1973); and,
2. a suite of finer grained sediment, including major sandbanks, which are mobile under the forcing of tidal flows, which overlay the lag deposit.

6.5.7.6. The lag deposit covers extensive areas of the seabed and was formed by the winnowing away of fine-grained material to leave a relatively coarse residual sediment. The deposits maximum grain size reflects local tidal velocities at the time of formation but the sand:gravel ratio has been modified through winnowing by currents since formation. Gravels and sandy gravels result from winnowing by high-velocity currents, whereas gravelly sands occur where winnowing has been less intense due to current velocities being lower (Hamblin *et al*., 1992). Further evidence of the stability of the gravel fraction is provided by examination of the larger gravel fraction which shows that these larger fractions (i.e. pebbles and cobble sized material) have been bored and encrusted with serpulids, bryazoa and barnacles, and thus have likely been stable and *in situ* since the last marine transgression (Stride, 1990).

6.5.7.7. The Eastern Channel is characterised by dominant flood tidal currents, whereas the Western Channel is ebb dominated. Such tidal asymmetry can drive a residual (i.e. net) sediment transport in the flood (i.e. easterly) direction for both bedload and suspended load sediments in the offshore zone, particularly during Spring tides which are of greater magnitude. In other words, there is a net drift of (suspended) sediments in the easterly direction on a general basis and over the medium to long term. The worst-case scenario (i.e. when residual transport will be at a maximum), will be when the storm events from the southwest stir up the fine bottom sediments as strong Spring tidal currents transport these sediments in suspension eastwards.

6.5.7.8. The central zone is considered to be a bedload parting zone (Johnson *et al*., 1982). Broadly, in the Channel, tidal residual suspended load transport is characterised by a central divergence in the form of a ‘Y’ shape ending with two branches on both sides of the Isle of Wight (Guillou *et al*., 2010). The region between the two northern branches is characterised by complex sediment transport pathways with two prominent gyres, which act to trap suspended sediments (Menesguen and Gohin, 2006). Plate 6.13 shows the broad sediment transport regime across the Central and Eastern Channel on a map.

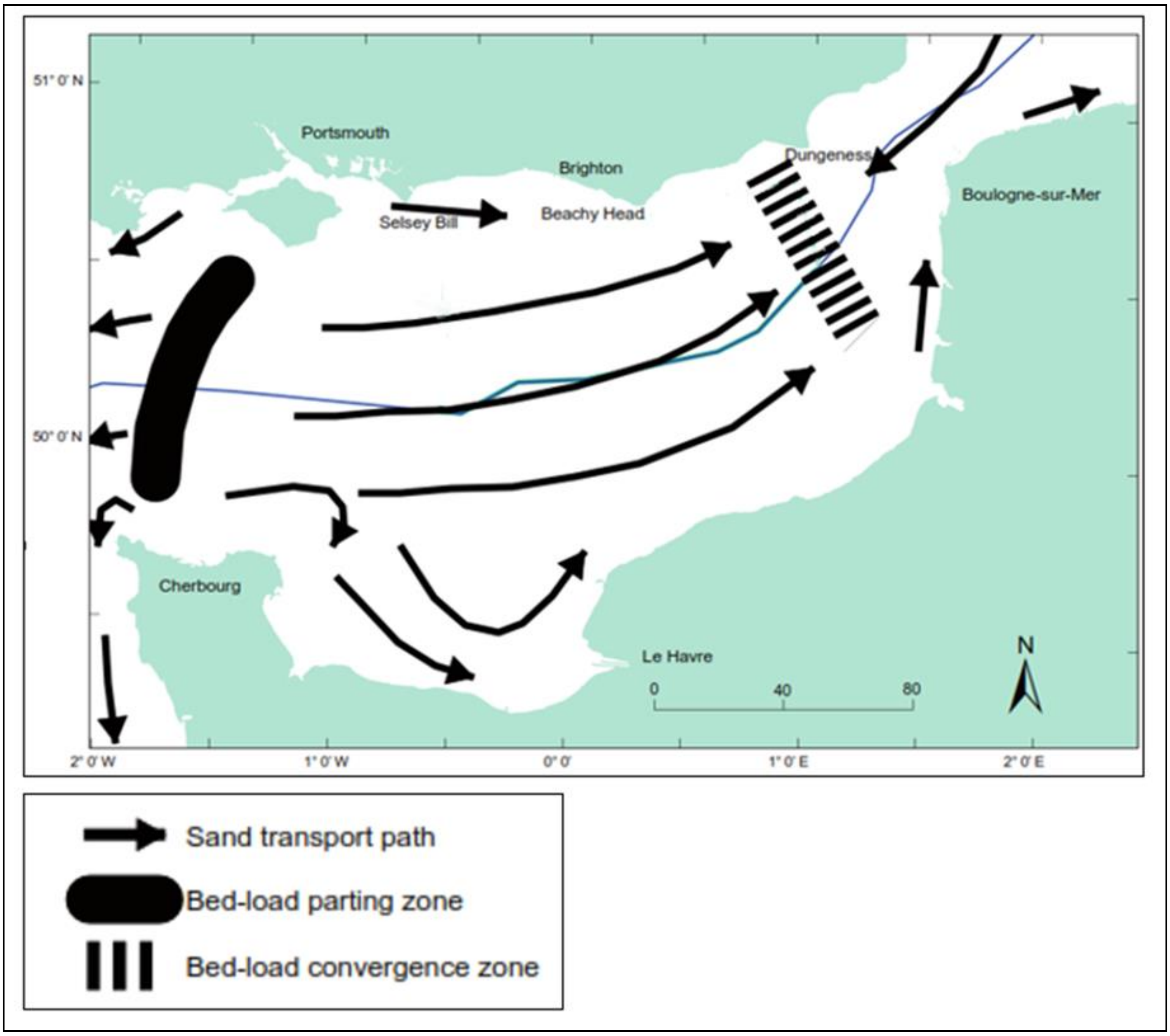


Plate 6.13 – Broad sediment transport directions within the Channel. Sediment transport direction is noted, as is a bedload parting zone and a bedload convergence zone. Image reproduced from James *et al.* (2007)

Morphological Evidence for Sediment Transport

6.5.7.9. Raised sediment features on the seabed are called bedforms. The presence of bedforms on the seabed, as described in Table 6.10, can provide indications as to the prevalence of sediment transport and also provide clues as to the predominant transport direction[s]. Bedforms produced by waves are generally symmetrical, whereas those formed by tidal flow are asymmetrical. The type of bedform which develops (i.e. ripples, megaripples or sandwaves) are a function of the flow velocity, sediment grain size (i.e. bed roughness) and water depth. Typically, small scale ripples form at relatively slow current speeds and where sediment is finer than *c*. 0.6 mm. As flow velocity increases, or where sediments are coarser grained, megaripples form and then sandwaves develop where the sediment supply is sufficient.

6.5.7.10. Sediment transport and bedform development are controlled by shear stress acting on the seabed at any given point in space and time. Shear stress is a function of tidal flow velocity, water depth and bottom roughness, and, on occasion turbulence associated with the orbital velocity of waves. The net effect of the bedload parting zone (which runs from the Isle of Wight to the Cotentin Peninsula and is associated with a zone of high bed shear stress) is the entrainment of material of size *c.* medium sand. In addition, to the east of the area there is a zone of bedload convergence (associated with a zone of low bed shear stress) into which tidal currents transport material from both sides. This leads to the accumulation of tidal sand ridges, with sandwaves evident on their surface. Moving south west towards the zone of bedload parting sparse bedform developments are observed which reflects the steady rise in tidal flow velocity magnitude. The presence of this morphology itself indicates a dynamic and non-cohesive seabed, limited mud and gravel fractions, and a generally higher current velocity regime (Stride, 1982; Amos and King, 1984) across the study area, but particularly in offshore regions.

Table 6.10 – Criteria for classification of bedforms. Source: MMT (2018)

Sidescan Sonar Image	Seabed Feature	Criteria / Dimensions
	Ripples	Length <5 m Height 0.01-0.1 m
	Large ripples	Wave length 5-15 m Height 0.1-1 m

Sidescan Sonar Image	Seabed Feature	Criteria / Dimensions
	Sandwaves	Wave length >50 m Height 3-5 m

6.5.7.11. From the geophysical survey, several bedform features have been observed along the Proposed Development. Large ripples are present between approximately KP 3.8 and KP 50.5, including one nearshore location in the East Solent where small, irregular, hummocky and individual sandwaves and narrow trains of sandwaves have been described in the literature (Hamblin *et al*., 1992). Large ripples occupy 3.9 km (3.6% of the Marine Cable Corridor) across eight locations, and sandwaves occupy 4.0 km (3.7% of the Marine Cable Corridor) across nine locations. In total, sandwaves are observed between approximately KP 31.5 and KP 54.8.

6.5.7.12. Figure 3.6 (Sheets 1-4) of the ES Volume 2 (document reference 6.2.3.6) within Chapter 3 (Description of the Proposed Development) present further detailed information on the locations and extents of these seabed features (sandwaves and ripples) along the Marine Cable Corridor.

Suspended Sediment

6.5.7.13. Suspended sediment is an important component of a sediment regime and requires consideration, especially within a highly dynamic system such as the Channel. Sediment in suspension is generally derived from:

- Resuspension of bed sediments at the site induced by waves and/or tidal currents;
- Fluvial inputs in the vicinity of the site; and,
- Regions external to the site (e.g. advection of turbid waters).

6.5.7.14. Mineralogical and tracer studies conducted by McManus *et al*. (1991) endorse the view that most offshore sediments do not arise from riverine inputs but are found to be derived from the offshore region itself (e.g. seabed redistribution; post erosion of Quaternary sediments). Thus, it is considered that the fines observed within samples collected during the benthic (Natural Power, 2017/2018) and geotechnical (MMT 2018/2019) sampling campaigns (data presented in Appendix 6.3 (Grain Size Statistics)) are most likely to have arisen from *in situ* seabed erosion.

6.5.7.15. Several studies have examined the flux of suspended sediment (and associated contaminants) in the Channel, confirming the highest levels of Suspended

Particulate Material (SPM) are generally observed on the UK coast (Lafite *et al*, 2000; Velegrakis, *et al.,* 1997 and Statham *et al*., 1999). Measured data sets reveal significant temporal variability within coastal waters with SPM concentrations observed to range from 4.2 to 74.5 mg l^{-1}(Lafite *et al*., 2000). Comparatively in offshore waters SPM concentrations show less variation ranging from 0.9 to 6.0 mg l^{-1}.

6.5.7.16. Data derived from satellite imagery provide a useful dataset to assess large scale spatiotemporal trends in near surface SSC over the north western European Shelf. Satellite images (i.e. reflectances) derived from Moderate Resolution Imaging Spectroradiometer ('MODIS') [National Aeronautics and Space Administration, NASA]), and MERIS (Medium Resolution Imaging Spectrometer [European Space Agency, ('ESA')) are processed using the semi-analytical algorithm developed by Gohin (2011), and are regularly used to assess near-surface SSC in the Channel (e.g. Guillou *et al*. 2015 and 2017; Menesguen and Gohin, 2006; Souza *et al*., 2007; Sykes and Barcelia, 2012).

6.5.7.17. Typical near surface SSC in UK Territorial Waters along, or near, the Proposed Development ranges from 2 mg l^{-1} – 25 mg l^{-1}. Turbidity significantly increases at the coastline and during periods of enhanced forcing (i.e. during storms). Although bottom waters are more turbid than surface waters, Velegrakis *et al* (1997) hypothesise that this phenomenon was not likely to be due to erosion, entrainment and resuspension of *in situ* sediments, rather it is more likely to be controlled by advective mechanisms, describing the Channel in later research as being characterised as an area of fine-grained sediment 'bypass' (Velegrakis *et al*, 1999). This interpretation is corroborated by a) the general absence of fine-grained sediment deposits and, b) correlation between the potential resuspension time of fine particles and seabed sediment distribution (Velgrakis, *et al* 1999). The limited resuspension signal within the Channel is thought to be a function of the limited availability of fine-grained material within bottom sediments and bed armouring processes (Velegrakis *et al* 1997).

6.5.7.18. Local resuspension is clearly observed characterised by significant seasonal, and tidal, variation increasing during the winter months (i.e. during the time where the frequency and magnitude of storms is enhanced) and during the spring tidal cycle. A particularly turbid area surrounds the Isle of Wight, which is a function of local resuspension and complex recirculation's, with yearly averaged near-surface SSC values around 10 – 15 mg l^{-1}. In this area, significant variation in surface SSC also exists during the Spring-Neap cycle with SSC increasing from 5 mg l^{-1} during Neap tides to > 15 mg l^{-1} during the Spring tidal cycle.

6.5.7.19. During winter storms, near surface SSC increases by up to 20 mg l^{-1} (Guillou *et al*. 2015). Broadly, in the Channel, tidal residual suspended load transports are characterised by a central divergence in the form of a 'Y' shape ending with two branches on both sides of the Isle of Wight (Guillou *et al*. 2010). The region between the two northern branches is characterised by complex sediment transport pathways with two prominent gyres, which act to trap suspended sediments (Menesguen and Gohin, 2006). Plate 6.14 presents satellite observations of near surface SSC in the Channel.

6.5.7.20. The data reported in the literature are summarised as follows:

- In the nearshore region natural variation in SSC/SPM ranges from approximately <5 to 75 mg l^{-1} in coastal areas, with annual averages of between 5 – 15 mg l^{-1} observed within surface waters.
- Comparatively, offshore, natural variation is significantly reduced ranging from <1 to 6 mg l^{-1}.
- SSC/SPM is enhanced during periods of higher energy. For example, during spring tides near surface SSCs have been observed to increase by up to 10 mg l^{-1} and during storm events by up to 20 mg l^{-1}.

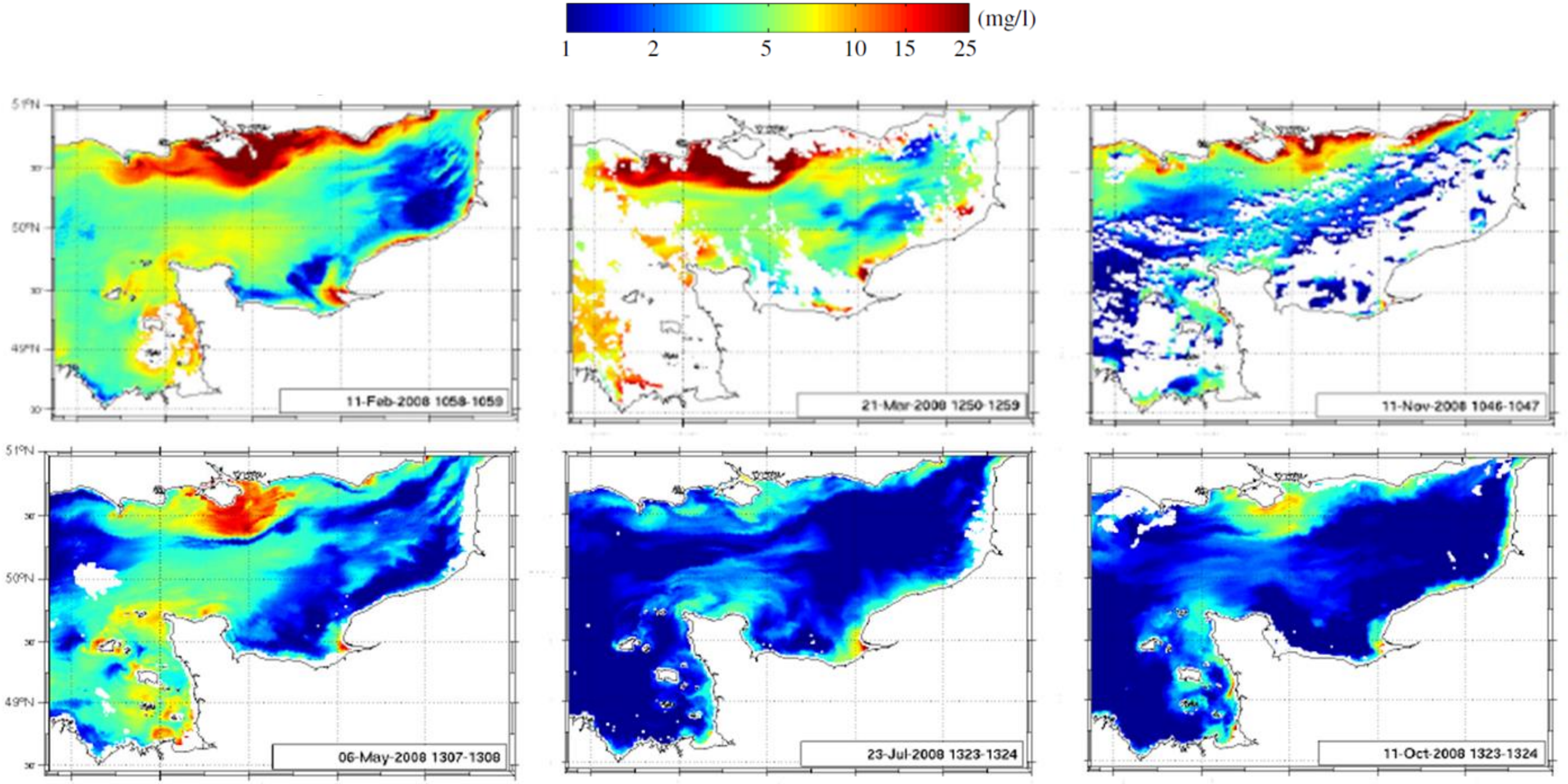


Plate 6.14 – Near-surface SSC observed (i.e. derived from satellite imagery) for moderate waves conditions and spring (top left), mean (top centre) and neap (top right) tides. Near surface SSC observed for stormy wave conditions and spring (bottom left), mean (bottom centre) and neap (bottom right) tides. Images reproduced from Guillou *et al.*, 2015

Sediment Mobility Under Tidal Flows

6.5.7.21. An approach using the stress/excess bed stress concept has been adopted here. An indication of the sediment fraction likely to be suspended at each model inspection point by the bed stresses, together with an assessment of the percentage of time the critical stress is exceeded (i.e. the expected mobility duration), is afforded through development of 'exceedance' plots. Plots have been constructed reflecting the admixed mud / sand / gravel nature of the seabed sediments, being for the sediment fractions: coarse sand and gravel; medium sand; coarse silt and fine sand; and clay and silt. These plots are presented in Figure 62 to Figure 65 in Appendix 6.2 (Modelling Technical Report). The data is summarised in Table 6.11.

Table 6.11 – Summary of critical stress % exceedance for various bottom sediment size fractions/drag coefficients. Following the method of Soulsby (1997), based upon the entire available flow velocity records, and using a C_{100} value of 0.0024

Sediment Fraction	Median grain size (mm)	$\tau_{ocrit.}$ (Nm^{-2})	Exceedance (%)									
			Model Point 1		Model Point 2		Model Point 3		Model Point 4		Model Point 5	
			C_D	C_{100}	C_D	C_{100}	C_D	C_{100}	C_D	C_{100}	C_D	C_{100}
Coarse sand and gravel	32.250	28.440	0	0	0	0	0	0	0	0	0	0
Medium Sand	0.312	0.206	21	21	14	13	53	50	64	59	66	61
Coarse silt and fine sand	0.087	0.136	42	42	34	32	66	64	74	70	74	70
Clay and silt	0.025	0.074	71	71	74	72	81	80	85	82	82	0

6.5.7.22. The foregoing analysis shows that coarse sand and gravel size material at each of the model inspection points is stable under the tidal flow (HD) regime. Conversely, sand material (and thus all other finer material) is subject to resuspension at all model point locations, but there is a marked difference in both the maximum grain sizes suspended and the relative frequency of suspension[2]; Figures 62 to 65 in

[2] This analysis assumes that where sands are brought into suspension then finer constituents (silts, clays), found in some samples, and varying in proportion from minor to dominant, are also brought into suspension. However, conversely, as the analysis is based on a median grain size, where a size fraction is determined to be stable under the prevailing current regime, the potential exists that finer fractions within the denoted size fraction (e.g. the coarse sand in the 'coarse sand and gravel' fraction) may be mobilised.

Appendix 2 (Modelling Technical Report) show frequent tidal mobilisation of the finer fractions through to the medium sand. The overall pattern reflects a highly dynamic transport regime. Greater mobilisation occurs in the region of higher current velocities located offshore where transport rates and frequencies would be expected to be higher. It is noteworthy that, sediments are more frequently mobilised at model point 1 compared to model point 2 due to the greater tidal forcing in the area which is a function of water depth and the interaction with the shoreline and the tidal inlet at Langstone.

6.5.7.23. The observations suggest that sediment entrainment/transport due to tides alone is significant which is corroborated by the relatively strong re-suspension signal observed in nearshore areas (where finer sediments, most susceptible to re-suspension reside), and the extensive bedform features (which are themselves indicative of an active bedload transport regime) observed along the Marine Cable Corridor.

Sediment Mobility Under Combined Forcing (Waves and Tidal Flows)

6.5.7.24. The foregoing analysis of tide-only forced sediment transport indicates that bed sediments (excepting the coarsest sand and gravel fraction) in the nearshore and offshore region, are mobilised on tidal timeframes and due to the significant excess stress component, the transport can be considered, significant. This situation exists only during periods when there are no or small waves (e.g. during summer months).

6.5.7.25. In shallow continental shelf environments waves, created by the wind blowing across the ocean surface, can also give rise to sediment entrainment and transport if the energy associated with the wave is able to penetrate to the seabed. Some consideration of the potential for waves to mobilise the seabed sediments is thus necessary. Note, since the sea is nearly always in motion due to tides (except during brief periods of high/low tide standstill [slack water] when currents are close to zero), this consideration is strictly one of waves and currents in combination, rather than just solely waves.

6.5.7.26. From consideration of the characteristics at each of the model inspection points it is possible to determine whether the waves will ‘feel’ the seabed at each location. Waves produce an oscillatory velocity in the water column which is a function of wave properties (namely, height and period) and which decreases in amplitude (magnitude) with depth. Whether the seabed ‘feels’ this flow therefore depends on the ratio of the water depth to wave height, and period. Wave energy will penetrate to the seabed where:

$$H < 10\ H_{m0}$$

6.5.7.27. Where H is the water depth and H_{m0} is significant wave height (Soulsby, 1997). In the ensuing analyses this criterion has been used to determine the limiting significant wave height above which wave energy is expected to penetrate to the seafloor at each of the model inspection points (Table 6.12).

Table 6.12 – The limiting significant wave height required for waves to feel the seabed at the locations of monitoring stations. The percentage of time waves which exceed these limiting thresholds are observed are detailed.

Model Point	Water depth (m) (mean sea level)	H_{m0} where waves 'feel' the seafloor based upon Soulsby criterion (m)	Exceedance (%)
1	4.73	0.47	28.75
2	8.34	0.83	19.48
3	15.63	1.56	10.22
4	37.60	3.76	0.80
5	51.80	5.18	0.14

6.5.7.28. In terms of sand transport, there remains an offshore region of higher flow which drives a significant sand transport, but which does not appear to be significantly enhanced by wave action, due to the rarity of waves large enough to feel the seabed in deeper water. Superposition of waves at inshore areas along the Marine Cable Corridor exposes the seabed to higher stress. Larger excess stresses, due to amplification by a substantially greater wave event, would be expected to elevate resuspension rates, once again.

6.5.7.29. Due to the generally high nearshore tidal flow velocities sediments resuspended by wave action would potentially be transported significant distances, particularly when large events coincide with a spring tide. Though, the redistribution of sediments locally in the nearshore area may be limited by the recirculating gyres located around the Isle of Wight which may act to retain sediments locally. At these inshore locations there may be some local morphological adjustment at the bed due to especially high bed stresses, during high energy events.

6.5.8. COASTAL GEOMORPHOLOGY

6.5.8.1. The past, present and future forms of the North Solent shoreline are shaped by anthropogenic constraints; the antecedent geology; natural forces; and coastal vegetation. The area is characterised by a generally flat, low lying coastal plain extending inland to the toe of the South Downs Chalk escarpment upon which transgressive gravel barrier beaches and three major tidal inlets have developed, as sea levels have risen. These harbours (Portsmouth, Langstone and Chichester) are characterised by mudflat and saltmarsh habitats.

6.5.8.2. Each harbour acts as a sink for fine sediments, with coarser sands and gravels being preferentially flushed seaward, forming large ebb tidal deltas (with corresponding smaller flood tidal deltas, shoreward). Each of the harbours behave broadly as self-contained units, with limited interaction (in terms of sediment transport/delivery) with the open coast of the East Solent.

6.5.8.3. Eastney and nearshore areas surrounding Eastney have been considered within the North Solent SMP (New Forest District Council (2010)). Of relevance to this assessment is Appendix C of the Plan, entitled 'Baseline Process Understanding' which contains useful information regarding the regional and local sediment regime.

6.5.8.4. The physical processes operating at the shoreline are a function of the geology and geomorphology of the coastline, shoreline orientation, tidal regime and exposure to wave action. Whereas hard areas such as cliffs and headlands are considered highly resistant to marine erosion, unconsolidated material along the coastline, deposited during the glacial period and subsequent deglaciation, has since been moved and sorted by waves and tidal currents.

6.5.8.5. In the East Solent area natural sediment sources include:

- Relict nearshore deposits of post-glacial sand and gravel;
- Eroded material from the low soft cliffs located along the shoreline at Selsey Bill, East Wittering and from Lee on the Solent to beyond Solent Breezes;
- Eroded material from exposed nearshore outcrops of bed rock;
- Ebb tidal deltas located at the entrance channel to each of the harbours; and
- Fine sediment eroded from areas of saltmarsh within the harbours.

6.5.8.6. The coastline has been dramatically altered through time via the installation of coastal protection and flood defence works, land reclamation and dredging (aggregate and maintenance) (New Forest District Council, 2010)). Overall, these activities have depleted the sediment budget meaning beach nourishment, and sediment recycling provide a major source of sediment to the coast and as such effective sediment management is noted as being key to broader coastal management now, and in the future.

6.5.8.7. Along areas of open coast, littoral drift is dominated by breaking wave and swash zone processes (i.e. uprush, backwash, saltation and advection). The dominant drift direction varies along the coast, relative to the shoreline orientation and dominant wave approach. A point of divergence exists near to Eastoke point, Eastney point and Southsea where the littoral drift is directed eastward (see Plate 6.15).

6.5.8.8. The beach at Eastney is a shingle gravel dominated beach which has seen significant accretion through time due to consistent sediment input from the Langstone ebb tidal delta, and this general pattern of accretion is predicted to continue.

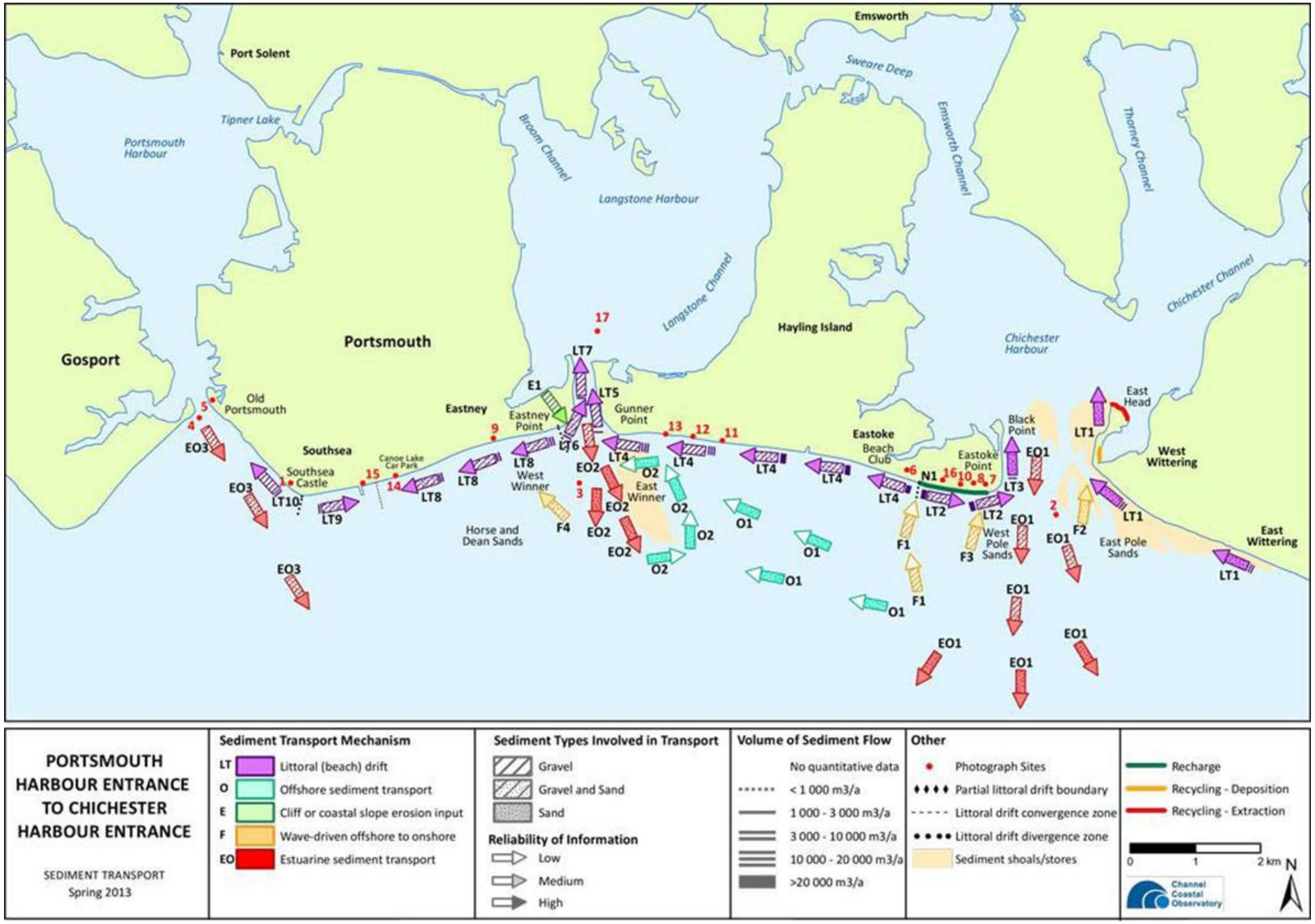


Plate 6.15 – Sediment transport between Portsmouth Harbour and Chichester Harbour entrances (New Forest District Council, 2017)

6.5.9. FUTURE BASELINE

6.5.9.1. Unusually energetic and infrequent metocean events (e.g. storms) give rise to extreme values of significant wave heights and wave periods. It is widely expected that climate change will result in global effects which are anticipated to be manifested at regional scales by increased storminess and rising mean sea level (Lowe *et al*., 2009).

6.5.9.2. A hypothesised increase in the frequency and magnitude of storm events will increase the potential for resuspension of sediment along the Marine Cable Corridor due to the increased likelihood of wave conditions that are sufficient to penetrate to the seabed. A review of storminess over the North Atlantic and north-western Europe by Feser *et al.* (2015) presented a field of evidence showing significant changes in storminess have occurred in the North Atlantic over the last century. Longer term studies reveal relative storminess increased in the late 20th Century (e.g. Alexandersson *et al.,* 2000). Although a decline in storminess was noticed in the early 2000s (e.g. Matulla *et al.,* 2007), the general observations of an increase in storminess in the North Atlantic is corroborated by similar studies into the long-term wave climate of the North Sea (e.g. Beniston *et al*., 2007).

6.5.9.3. In addition to an increase in storminess within the Channel, it is anticipated that mean sea level is likely to rise during the lifetime of the Proposed Development. This change is widely accepted to include contributions from global eustatic (water volume) changes in mean sea level and regionally varying vertical (isostatic) adjustments of the land. Information on the rate and magnitude of anticipated relative sea level change during the 21st Century is available from the United Kingdom Climate Projections (UKCP18, 2018).

6.5.9.4. Summary predictions of 21st Century changes in relative sea level at Eastney are presented in Plate 6.16. These predictions indicate that by 2100, in the worst-case scenario (RCP 8.5) relative sea level at Eastney is predicted to be *c.* 0.78 m above 2007 levels. As shown in the plot, the majority of predicted sea level rise occurs during the second half of this century when the rate of change is predicted to be greatest. It should be noted however that such an increase in mean water level is significantly smaller than the tidal and non-tidal (e.g. barometric pressure) water level variations presently encountered at the site. It is also noteworthy, that it is considered that predicted sea level rise as a result of future climate change, is unlikely to affect the marine HDD location based on present-day bathymetry and water depths.

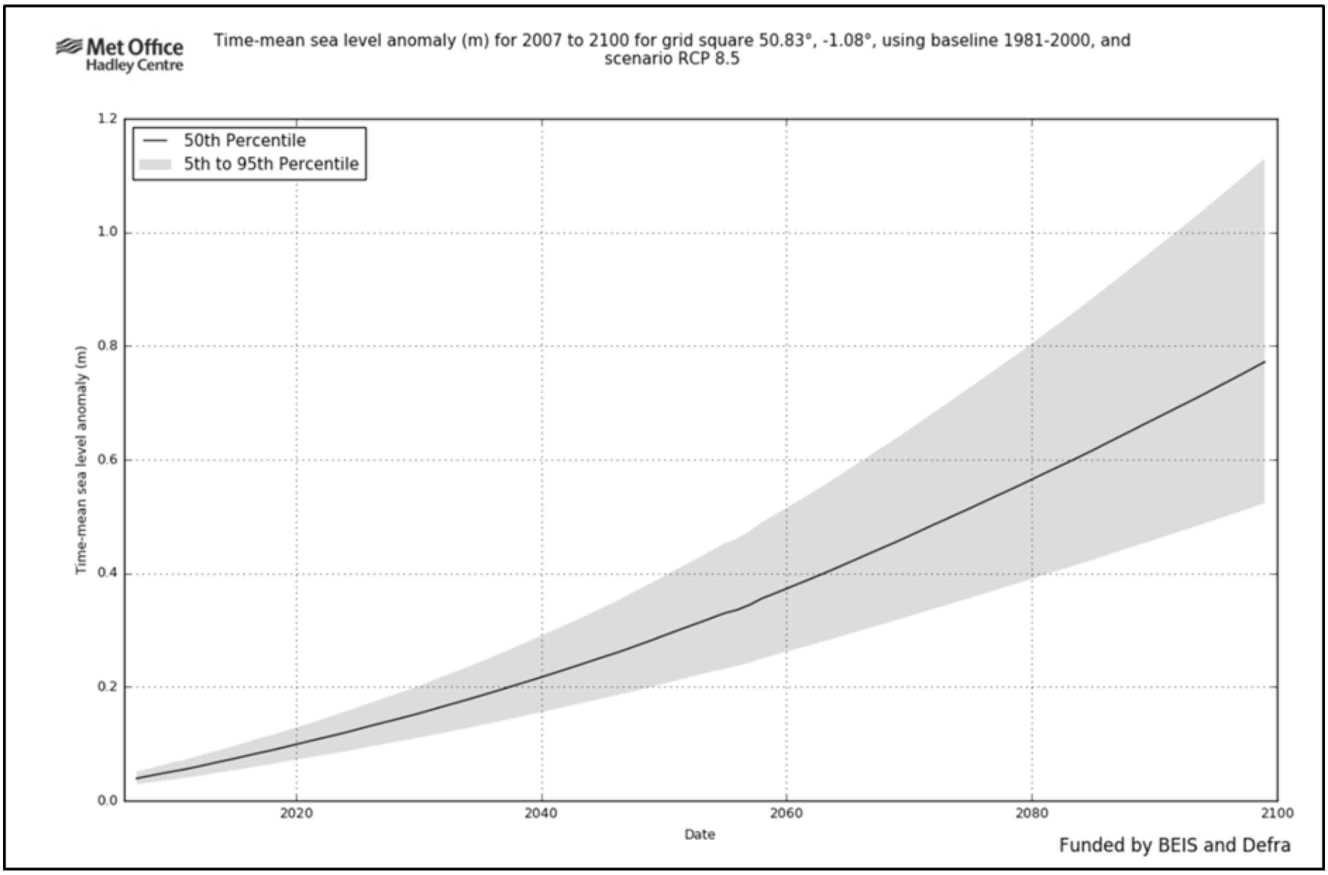


Plate 6.16 – Predicted mean sea level rise for 2007 - 2100 based on the worst-case emissions scenario (RCP 8.5). Data Source: UK Climate Projections 2018

6.6. IMPACT ASSESSMENT

6.6.1.1. The following describes the potential impacts of the Proposed Development upon the coastal and marine physical environment, which includes, for the purposes of this assessment, coastal and marine processes, geology and geomorphology. A worst-case scenario has been assumed where uncertainties remain, but confidence in the assessment is broadly high owing to the quantity of literature available from similar projects and their effects on the physical environment.

6.6.1.2. In accordance with Cefas guidance (2004), the following potential impacts from construction, operation (including repair and maintenance) and decommissioning of the Proposed Development have been identified for assessment;

- Physical disturbance to seabed geology and morphology through alteration of bedform features and impacts on local flow patterns;
- Impacts to local sediment regimes through impacts on local flow patterns and local increases in SSC; and
- Impacts upon coastal and marine processes and the sediment transport regime.

6.6.1.3. Based on the design envelope of the Proposed Development, these impacts broadly fall under the following subheadings which have been used for the impact assessment below:

- Increase in SSC
- Morphological change and alteration of bedforms
- Obstruction to flow, scour around structures and impact on nearfield flow.

6.6.1.4. The options for decommissioning will likely include consideration of leaving the Marine Cable *in situ*, removal of the entire Marine Cable or removal of sections of the Marine Cable. As such, the corresponding potential impacts resulting from decommissioning are considered to be equivalent to or lesser in nature than those considered for construction activities. A similar set of options i.e. leave *in situ,* partial or full removal, would also be considered for associated infrastructure placed on the seabed (e.g. non-burial cable protection).

6.6.1.5. The assessment of the potential impacts associated with the operational stage, including repair / replacement of cables and maintenance, was performed based upon guidelines and recommendations described in key industry guidance.

6.6.1.6. The Proposed Development has been designed so that insofar as is possible regular maintenance of the Marine Cables is not required during its operational lifetime. During operation, it is assumed that an indicative worst-case failure rate of the Marine Cables would require one repair every 10-12 years.

6.6.1.7. Should repair works be required, it is anticipated that the relevant section of the Marine Cable will be recovered using methods like those employed during installation. Should repair / replacement and maintenance works be required, it is anticipated that the works would be of shorter duration and smaller in extent than the construction stage.

6.6.2. EMBEDDED MITIGATION

6.6.2.1. Table 6.13 provides a description of the good practice and embedded mitigation measures that have been adopted and included within the design of the Proposed Development on the physical environment during construction and decommissioning.

Table 6.13 – Embedded mitigation

	Aspect of environment affected	Embedded Mitigation
Route Design	Seabed Morphology Seabed Sediments and Geology	The route has been planned to avoid hard substrate as far as possible to ensure that the cable can be buried. The route has also been planned to minimise the requirement for pre-sweeping of mobile sediments in the form of bedforms (sand

	Aspect of environment affected	Embedded Mitigation
		waves and large ripples). This process comprises ongoing route development – comprising the initial desk-based assessment and route planning, route surveys and further engineering considerations.
Cable Design	Seabed Morphology Seabed Sediments and Geology	The bundled cable design means that only two trenches will be required for burial along the entire route (except for a very short stretch seaward of the HDD entry / exit).
Cable Burial	Tidal Currents Seabed Morphology Seabed Sediments and Geology	Pre-sweeping operations will be designed to trench only where necessary through the seabed features, thereby minimising sediment disturbance and potential resuspension. Any pre-swept trench will be kept to a minimum possible length, width and depth, such that cable burial can proceed effectively and result in a stable burial depth. Installation of the cable to a stable burial depth will minimise the requirement for any external cable protection and future disturbance.
Disposal operations	Seabed sediments and seabed morphology	Disposal of dredged material within the Marine Cable Corridor will only occur seaward of KP 21 of the Marine Cable Corridor. The proposed marine disposal site is located between KP 21 and KP 109. Also see Appendix 6.5 (Disposal Site Characterisation Report).
Cable Protection	Tidal Currents Seabed Morphology Seabed Sediments	The use of cable protection measures will be minimised. It is the intention that the cable will be buried wherever possible along the route. Where protection is required (i.e. at cable crossings), its profile will be minimised to reduce effects on seabed currents.
Effect of construction equipment on physical environment	Tidal Currents Seabed Morphology Seabed Sediments	During construction all necessary equipment will remain on site for the minimum practical period of time to ensure any influence on the physical environment is of short duration and localised to the operation to be carried out.

6.6.2.2. Table 6.14 provides a description of the embedded mitigation of the Proposed Development on the physical environment during operation (including repair and maintenance).

Table 6.14 – Embedded mitigation for the operational stage

	Aspect of environment effected	Embedded Mitigation
Cable Protection	Tidal Currents Seabed Morphology Seabed Sediments	The use of cable protection measures will be minimised. It is the intention that the cable will be buried wherever possible along the route. Where protection is required, its profile will be minimised to reduce effects on seabed currents.
Cable Maintenance and Repair	Seabed Morphology Seabed Sediments	The Proposed Development has been designed so that routine/regular maintenance to the Marine Cable is not required during its operational lifetime (40 years).

6.6.3. WORST CASE DESIGN ENVELOPE

6.6.3.1. Table 6.15 describes the current worst-case design parameters relevant to the physical environment and the impacts assessed for the Proposed Development during the construction (and decommissioning) and operational stages.

6.6.3.2. Due to potential downstream effects on other receptors (i.e. marine water and sediment quality, benthic ecology, fish and shellfish, marine mammals and marine ornithology) the potential impacts of other activities have also been considered as part of the assessment and these are described in Section 6.6.4.

Table 6.15 – Worst case design parameters

Potential Impact	Activities	Worst case parameters used in this assessment
Construction (& Decommissioning) Stage		
Increase in SSC (In the nearshore (KP 0 – 21) cable installation and HDD pit excavation is assessed as the worst case, see paragraphs 6.6.4.9 to 6.6.4.17. Further offshore (KP 21 – 109) dredge disposal activities are assessed as the worst case, see paragraph 6.6.4.18 to 6.6.4.24)	Pre-sweeping and other dredging requirements	Sediment clearance may be required for the following: • Clearance of sandwaves and large ripples using a Trailing Suction Hopper Dredger ('TSHD') or Mass Flow Excavation ('MFE') for the purposes of cable burial; • At HDD entry/exit points in the nearshore using MFE and/or backhoe dredger; and, • At Cable Joint location on the seabed using a TSHD or MFE (although the number (and type) of joints required are not known at this stage). **(KP0 - 21) HDD Entry/Exit Pit Excavation between KP 1 and 1.6:** If required, entry / exit pits may be necessary to position the drill casing and protect the HDD end cap whilst minimising impacts on navigation depth. These will be location specific, but as worst case assumes a single pit (rather than 4 discrete pits) approximately 60 m x 15 m and 3 m. Maximum volume of HDD dredging/excavation is predicted to be **2,700 m^3**. At these nearshore locations a backhoe dredge and/or MFE will be used to perform the dredging. A barge would be used to transport the material from these locations to the disposal area. **(KP21 - 109) Sandwave (and large ripple) clearance** is required along an estimated 4.2 km of the Marine Cable Corridor beyond KP 30 (see Figure 3.5 of

Potential Impact	Activities	Worst case parameters used in this assessment
		the ES Volume 2, document reference 6.2.3.5). The area of disturbance includes a dredging corridor width of 80 m and batter slopes at the edge of the excavation of up to approximately a further 40 m on each side (a total of up to 160 m wide). Total area of dredging footprint = Approx. 0.67 km^2 Maximum volume of sandwave and large ripple clearance = **1,751,000 m^3**. The estimated maximum volume of seabed sediment (that includes the above scenarios) to be cleared is *c.***1,754,000 m^3**.
	Cable installation activities	For cable burial the worst-case scenario includes the burial of up to two pairs Marine Cables using the jet trenching method (justification provided in Table 6.16 and paragraph 6.6.4.11) with parameters taken from Appendix 3.2 (Marine Worst-Case Scenarios) as below: Jet Trenching – up to 20 km of Marine Cable Corridor • Width of jet trench assumed to be configured to 0.35 m between jet swords, 0.5m overall • Width of tracks = 0.8 m x 2 • Area of surface disturbance = *c.* 84,000 m^2 • Volume of trench disturbed = 2 (pairs of cables) x 0.5 m (overall jet sword width) x target depth of lowering = *c.* 85,000 m^3
	Dredge disposal operations	Maximum deposit of approx. 1,754,000 m^3 (includes sand wave clearance and HDD pit excavation) of cleared sediment in the disposal area (KP 21 – 109) within the Marine Cable Corridor (see Appendix 6.5 (Disposal Site Characterisation Report)) via surface release from barge hatches.

Potential Impact	Activities	Worst case parameters used in this assessment
Morphological Change and Alteration of Bedforms (Pre-sweeping and other dredging requirements are assessed as the worst case, see paragraph 6.6.4.29 to 6.6.4.33)	Pre-sweeping and other dredging requirements	**As described above**
	Dredge disposal operations	**As described above**
Obstruction to Flow, Scour Around Structures, Impact on Near Field Flow (Installation of non – burial cable protection is assessed as the worst case, see paragraph 6.6.4.35 to 6.6.4.38)	Installation of non-burial cable protection	Non-burial protection for construction along *c.* 11 km (10%) of the Marine Cable Route using rock placement: Rock Placement: Width of protection = 15 m Height of protection = 1.5 m Footprint = 330,000 m^2 (0.33 km^2) An allowance has also been added to include an additional 10% (11 km or 0.33 km^2) non-burial contingency, if further non-burial protection is required during maintenance and repair activities during the first 15 years of operation. Both the remedial non burial protection and contingency have been considered as part of the worst case. **Indicative maximum footprint non burial protection and contingency = *c.*0.7 km^2**

Potential Impact	Activities	Worst case parameters used in this assessment
		This maximum footprint also includes protection used at HDD exit pits (900 m^2) and for the Atlantic cable crossing design (37,800 m^2).
Operational Stage (including repair and maintenance)		
Obstruction to flow, scour around structures and impact on near field flow (Installation of non-burial protection on the seabed is assessed as the worst case, see paragraph 6.6.5.1)	Installation of non-burial cable protection	Non-burial protection and infrastructure installed on the seabed. The specific details of each element are provided in the construction section of this table. Infrastructure includes: • Rock/mattressing; and • Rock berms. Note as mentioned previously; allowance has also been added to include an additional 10% (11 km) non-burial contingency, to cover where burial depths are not met during construction and/or if further non- burial protection is required during repair activities during operation. **Indicative maximum footprint is *c.*0.7 km^2.**
Increase in SSC	Maintenance and Repair	The Proposed Development has been designed so that maintenance of the Marine Cables is not required during its operational lifetime. During operation, it is assumed that an indicative worst-case failure rate of the Marine Cables would require one repair every 10-12 years. Reburial of cables and placement of cable protection may be required but it is predicted that the replacement of sections of cable would constitute the worst case. It is assumed that an indicative worst-case failure rate of the Marine Cables would require: • A length of cable up to 3 x water depth to be recovered from the seabed (e.g. in the worst-case, at the maximum water depth of approximately 70 m, this

Potential Impact	Activities	Worst case parameters used in this assessment
		could amount to approx. 1,100 m of cable to typically be recovered and re-laid for each repair of a cable pair); • The actual jointing operation may take up to 5 – 6 days, and the handling of the joint and deployment to the seabed could take 1 – 2 days. Depending on the extent of cable damage, cable repair operations typically have duration of several weeks to months. It is therefore considered that should any repair works be required; the works would be of shorter duration and smaller in extent than the construction stage.

6.6.4. CONSTRUCTION (AND DECOMMISSIONING)

Increase in SSC

6.6.4.1. The potential exists for SSC to be enhanced due to construction activities; these activities include:

- Pre lay grapnel run;
- Pre-sweeping and other dredging requirements;
- Cable installation activities including tool trials;
- Dredge disposal operations; and,
- Placement/installation of cable protection.

Pre-Lay Grapnel Run (PLGR)

6.6.4.2. To snag, recover and remove any seabed obstructions a PLGR will be conducted; a grapnel hook will be towed by a vessel along the centreline of each cable route (the cables will be buried in pairs in two trenches). The grapnel run will be undertaken where conditions permit along the entire length of the Marine Cable Corridor. Along each of the two lines it is anticipated that the grapnel will affect an area of the seabed no greater than 1 m wide with a typical maximum penetration depth of *c.* 1 m. Along the cable route, where surficial sediments are dominantly comprised of coarser sediments (i.e. coarse sands and gravels) it is considered unlikely that SSCs would be enhanced significantly beyond natural (background) levels during the PLGR with sediments suspended settling to the bed almost immediately. These coarser sediments would also deposit within close vicinity (i.e. tens of m) of the Marine Cable Route within the Marine Cable Corridor. Where surficial sediments are dominantly comprised of finer sediments comprising silt and clays (e.g. between KP 5.0 and KP 15.0 and KP 42.0 and KP 47.0, which are isolated pockets likely to be associated with outcropping consolidated clay geology), the pre lay grapnel run is likely to suspend material which would then be locally redistributed by the prevailing tidal flows. The spatial extent of the dispersion of fine sediments would depend on the timing of operations; suspended sediments would be distributed across a greater spatial extent (i.e. potentially hundreds of m) during periods of higher flow velocity (i.e. spring tides). However, as the quantity of fine sediments present within surficial sediments (depth below seabed < 1 m) along the Marine Cable Corridor is generally low (i.e. observed within < 10% of samples collected), it is anticipated that the effects and subsequent impacts upon seabed sediments and physical processes associated with the PLGR are considered to be of **low** magnitude. In addition, they will also have a localised spatial extent relative to the Marine Cable Corridor and will be temporary in nature with mobilised sediments rapidly being reincorporated into the local sediment transport regime. The potential effect on seabed sediments and physical processes resulting from the pre lay grapnel run is considered to be of **minor** significance.

Pre-sweeping and Other Dredging Requirements

6.6.4.3. Several areas of mobile bedforms (sandwaves and megaripples) have been identified along the Marine Cable Corridor. Migration of mobile bedforms following installation of the cable may cause the cable to become exposed or develop free spans (Whitehouse *et al*., 2000). To minimise effects on the cable from migration of bedforms and/or to allow the cable installation equipment to work effectively, a technique referred to as 'pre-sweeping' will be employed to remove material to a reference seabed level prior to cable installation, principally to ensure the cable is able to be buried to the required depth. At present, two options are being considered for bedform clearance; 1) MFE, or; 2) dredging by TSHD. In the locations along the Marine Cable Corridor where this operation is necessary the extent of the excavated or dredged area will vary depending on the shape and size of the features to be crossed. Where dredging is required, a TSHD dredger is considered the worst-case scenario for conducting pre-sweeping operations. When dredging is undertaken using a TSHD, sediment can be released into the water column by a wide range of mechanisms (see Plate 6.17). These include:

- Overflow from the hopper;
- Disturbance of the seabed by the draghead; and,
- Scour of the bed caused by vessel propellers.

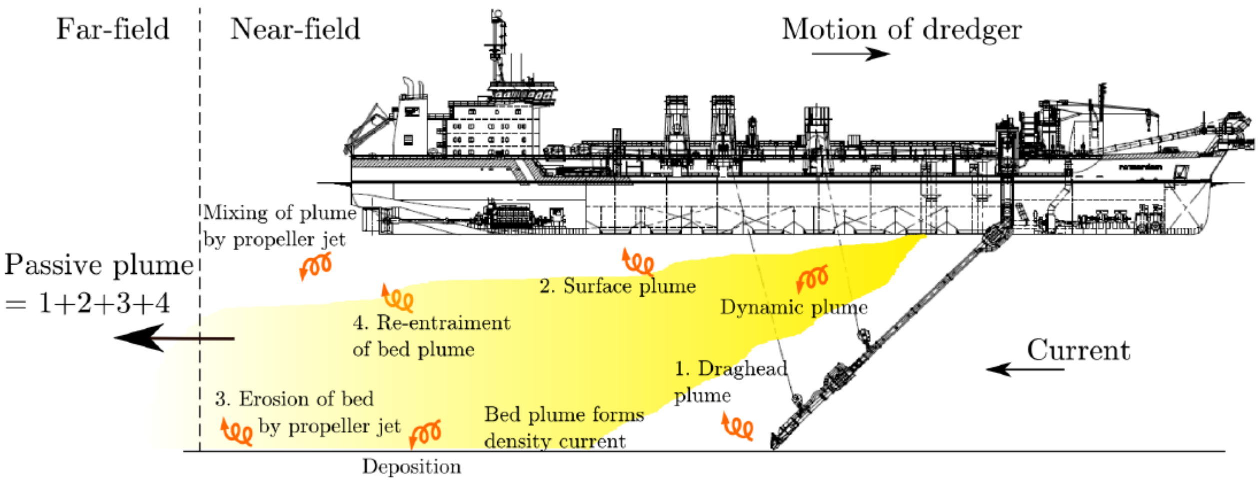


Plate 6.17 – Mechanisms for release of sediment from TSHD dredging. Reproduced from Becker *et al* (2015).

6.6.4.4. The release mechanisms influence the near and far field impact of the plume created. Sediment released close to the seabed will settle quickly, reducing the impact to the environment. Comparatively, sediment released at the surface will be dispersed across a greater spatial extent. Each mechanism will also be associated with a different rate of release and may or may not occur sequentially at each dredge location.

6.6.4.5. The release of material from within the vessel (i.e. via discharge of the overflow) comprises a sediment–water mixture; finer sediment, which has not settled out in the vessel may be discharged along with the excess water. These sediments, as they are released at the surface, have the potential to be dispersed in the direction of the prevailing flow over significant distances (e.g. tens of km), being deposited and re-mobilised variously through the tidal cycle. The dispersion of these sediments would be greater where release occurred during the periods of higher flow velocity (i.e. during the spring tidal phase). However, as these large scale bedform features (sandwaves and megaripples) are inherently dominated by coarse (sand and gravel sized) sediments, once these materials are dredged into the vessel, it is highly likely that material will rapidly settle with limited fine sediment available for release via overflow.

6.6.4.6. A further potential input into the passive plume created during the activity of dredging is disturbance/agitation of the seabed at the draghead. Again, as the features to be swept are dominated by coarse sediments, the volume of material which is likely to be suspended due to disturbance/agitation at the bed is considered to be low; further, materials which are suspended are also likely to be rapidly deposited locally and thus remain within the local morphology. These sediments would be reworked and reincorporated within the sediment transport regime by local seabed processes. Due to the nature of the sediments to be dredged during pre-sweeping, it is anticipated that the effects associated with dredge operations and subsequent impacts upon seabed sediments and physical processes are considered to be of **low** magnitude, as the effects have a localised spatial extent relative to the Marine Cable Corridor and are temporary in nature. The potential effect on seabed sediments and physical processes resulting from dredging operations is considered to be of **minor** significance.

6.6.4.7. In addition, as part of cable installation operations MFE and / or backhoe dredger maybe used for excavation of depressions (i.e. pits in the seabed) at the marine exit/entry point for the HDD Landfall (located between KP 1.00 - 1.60) for the four HDD ducts. To dredge the HDD pits (which are located at inshore shallow water sites) a backhoe dredger is likely (although a MFE may potentially be used) to be used in combination with a barge to transport the material to an area suitable for disposal i.e. the proposed marine disposal site between KP 21 and KP 109. When dredging using a backhoe dredger, and transporting material using a barge, potential sediment release mechanisms include:

- Impact of the grab on the bed;
- Spillage from the grab during hoisting;
- Material washed from the outer surface of the grab during hoisting;
- Leakage during slewing to the barge;
- Washing of residual adhering material during lowering; and,
- Splashing and leakage from transport barge.

6.6.4.8. The rate of release and the volume of material released during the process of dredging HDD pits is more likely to significantly enhance local SSC, potentially with sediment plumes arising from dredge activities of a similar magnitude to plumes created during cable installation activities. During dredging of these areas, the potential exists for sediment to be released within the water column and at the surface and thus the potential for dispersion of fine sediment over a greater spatial extent is increased. The effects are transient and short lived with plumes rapidly dispersing and continuous fallout at the bottom boundary layer of the plume. The concentration of the plume is considered likely to be of a similar magnitude to that created during a high energy storm event (but without the forcing associated with that event) and thus is considered tolerable within the environment. Due to this, the nearshore location and the presence of fines in the surficial and subsurface sediments in the area, the effects and subsequent impacts upon seabed sediments and physical processes with respect to sediment plume creation during dredging of HDD pits are considered to be of **medium** magnitude and of **minor to moderate** significance.

Cable Installation Activities

6.6.4.9. Several cable installation methods are proposed; cable burial can be achieved by ploughing, jet or mechanical trenching and it is likely that a combination of these techniques will be employed during cable installation operations, principally to account for different water depths and seabed conditions along the Marine Cable Corridor.

6.6.4.10. The Business Enterprise and Regulatory Reform (BERR, 2008) undertook a review of cabling techniques and environmental impacts for the OWF industry. Table 6.16 and Table 6.17 quantify the level of seabed disturbance that results from the various cable burial methods and operations. The results of the exercise produced a ranking from 1 to 10, with 1 indicating a low level of disturbance and 10 a high level of disturbance. BERR's assessment simplifies a complex process but is considered to provide a reasonable indication of the level of disturbance that is likely to occur when cable burial operations take place across a range of seabed substrates.

Table 6.16 – Level of seabed sediment disturbance arising from use of trenching types for cable installation across different ground conditions. Table reproduced from BERR (2008)

Type	Ground Conditions					
	Sand	Silts	Gravels	Clay	Unstructured Rock – Matrix Material	Weak Rock (Chalk)
Conventional Narrow Blade	1	1	1	1	N/A	N/A
Advanced with Jetting	2	3	2	2	2	N/A
Deep Burial	1	1	1	1	1	N/A
Rock Ripping	1	1	1	1	1	4
Vibrating	1	2	1	1	2	6
Level of disturbance 1 = Low, 10 = High, N/A = Not applicable						

Table 6.17 - Level of seabed sediment disturbance arising from use of other cable installation/burial tools across different ground conditions. Table reproduced from BERR (2008)

Tool		Ground Conditions						
		Sand	Silts	Gravels	Clay	Unstructured Rock	Chalk	Structured Rock
Jetting	Fluidisation	2	2	N/A	N/A	N/A	N/A	N/A
Jetting	Erosion	3	4	3	3	N/A	N/A	N/A
Dredging		4	6	4		N/A	N/A	N/A
Rock Wheel		3	4	3	3	3	8	4
Mechanical Chain Excavators		3	4	3	3	3	N/A	N/A
Level of disturbance 1 = Low, 10 = High, N/A = Not applicable								

6.6.4.11. A consequence of cable installation will be the disturbance and liberation of fine sediment (where present within the surficial sediments) into suspension within the water column just above the seabed. It is considered that jetting typically results in greater sediment suspension (see Table 6.16), introducing the potential for distribution of greater volumes of material over a larger spatial area than other cable laying techniques which may be employed during construction. This method involves fluidising the material to form a narrow trench into which the cable is laid. The jetting process results in a large proportion of the fluidised sediment from the trench being liberated into suspension in the water column above the bed and dispersed due to the forcing associated with local tidal flows. The subsurface and surficial geological and geomorphological seabed characteristics determine the sediment type disturbed during cable burial operations. Where the Tertiary geology is overlain by superficial deposits, these deposits are predominantly comprised of sands and gravels in the offshore region, with some finer material (silt and clay) mixed in locally in generally isolated pockets along some of the inshore areas of the Marine Cable Corridor. The unconsolidated nature of these deposits/sediments lends itself to the possibility of jetting to install the cable to the required depth (see Table 6.16, BERR [2008]). Thus, the effects of jetting can be assessed as the worst–case scenario for cable installation operations.

6.6.4.12. Assessment of this worst-case scenario is achieved using results of numerical modelling analyses performed for similar operations proximal to the Proposed Development (e.g. Navitus Bay OWF, the (constructed) Rampion OWF and the IFA2 (UK France Interconnector cable). Table 6.18 summarises the findings of studies designed to assess the dispersion of sediments released to the water column during trenching and cable burial activities. Of particular relevance to this commission is the Navitus Bay OWF project and the IFA2 project due to their location in the eastern Channel (i.e. the magnitude and direction of the currents and settling characteristics of the suspended material determine the extent over which it will be dispersed and deposited and these will be highly similar between projects). As such, it is concluded that this information provides reasonable context for the assessment of impacts that has been made for the Proposed Development.

Table 6.18 – Summary of the findings of studies conducted to assess dispersion of sediment plumes during cable installation activities. Table reproduced from National Grid (2016).

Project	Sediment Type	Maximum deposition distance	Duration to return to background levels
Nemo	Coarse	100 m (SSCs up to 10 mg l^{-1} above background) 700 m (SSCs < 1 mg l^{-1} above background)	-
Norway - UK	Fine	5.6 km (silt)	-
	Coarse	60 m (up to and including fine sand)	-
Navitus Bay	Fine	4 km (SSCs up to 20 mg l^{-1} above background)	Few hours
	Coarse	Pebble gravel (15 mm, up to 6m) Medium sand (0.5 mm, up to 43 m) Fine sand (0.15 mm, up to 167 m) Seabed level changes > 5cm depth not expected > 30 m from cable route.	Tens of minutes
Nysted OWF (referenced in Rampion OWF ES)	Coarse	200 m (average SSC 15 mg l^{-1})	-
IFA 2 (concluded worst case)	Fine	4 km	Few hours to days
	Coarse	700 m	Minutes

6.6.4.13. Within the ES for the IFA2 interconnector cable (National Grid, 2016) located within the Eastern Channel (at some areas in very close proximity to the Proposed Development), sediment dispersion modelling information from the proposed Navitus Bay OWF (Navitus Bay Development Ltd, 2014) were utilised to inform how sediments suspended into the water column during cable installation operations might be transported away from trenching operations. This modelling indicated that:

- Gravel sized material (15 mm diameter) once suspended was deposited within *c.* 2-20 s and would travel on the order of *c.* 1-6 m from the trench;
- Medium sand sized material (0.5 mm diameter) would remain suspended within the water column for *c.* 14-143 s travelling some *c.* 4 – 43 m from the trench; and

- In the nearshore section of the cable route (considered a dynamic environment with sediment transport affected by tides, currents and waves in an area of natural sediment redistribution processes), where greater quantities of silt and clay persisted, fine material was predicted to be transported up to 4 km away from the cable trench.

6.6.4.14. In addition, ABPmer (2012) in their numerical modelling assessment of the effects of export cable installation on suspended sediment dispersion, transport and deposition for the (now constructed) Rampion OWF EIA (to the east of the Proposed Development) predicted the following:

- Peak depth averaged SSCs rose when the installation of the cable was conducted in very shallow (~ 5m above Chart Datum [CD]) water depths near to shore. In these locations' maximum concentrations of *c.* 200 mg l^{-1} were predicted by the modelling although these concentrations were typically very localised (i.e. < 2 km) from the cable trench;
- Elevated depth averaged SSCs were typically less than 100 mg l^{-1} in deeper waters.
- After 90 hours (following completion of trenching activities), the plume had dispersed as a result of advection and diffusion with residual concentrations of 5 to 10 mg l^{-1} observed at *c.* 5 km to the east of the cable trench.
- Any released sand sized material was predicted to quickly deposit, persisting in the water column for < 1 hr. Once this material is settled upon the seabed, it would quickly be incorporated into the natural mobile bed regime
- Bed level changes of up to 1.5 mm (i.e. depositional thicknesses) are observed in close proximity (< 200 m) to trenching, and 0.5 - 1 mm up to a distance of approximately 3 km from trenching activities.

6.6.4.15. These analyses predict the magnitude (i.e. the size, concentration and spatial extent) of sediment plumes generated during cable installation activities will be greatest in shallower inshore areas of the cable route where the fines content within sediments increases. Where fine sediments persist and are released in these areas, sediments will be dispersed in the direction of the prevailing flow (i.e. broadly eastward on a flooding tide and broadly westward on an ebbing tide, maximum distances travelled prior to depositing estimated to be up to 6 – 10 km in these areas). In the deeper offshore region, coarser sediments are more prevalent, and thus plume generation will be limited, with sand and gravel sized sediments anticipated to deposit close to the Marine Cable Corridor (maximum distance travelled prior to depositing estimated to be 500 – 1000 m). Further, within studies where ground conditions are highly similar to those of the Proposed Development, during cable installation activities, peak increases in SSCs above background are predicted to be within the natural variation of SSCs, being approximately 20 mg l^{-1} (National Grid, 2016).

6.6.4.16. Based on the foregoing analyses the predicted transport of sediment plumes, and subsequent deposition, created during cable installation (and/or dredging of HDD ducts) activities in the nearshore region can be summarised as follows:

- The finest sediments will potentially be transported up to 6-10 km in the nearshore area, however it is highly likely that SSCs at these distances will be low (< 5 mg l^{-1}) and therefore not discernible above natural variation, which ranges from approximately <5 to 75 mg l^{-1} in coastal areas, with annual averages of between 5 – 15 mg l^{-1} observed within surface waters.
- It is predicted that peak SSCs of up to 200 mg l^{-1} may be observed locally (i.e. within 2 km of the cable trench / HDD pit) and these concentrations could potentially persist for several hours following completion of construction activities. Sediment plumes are also likely to be transported up to 5 km away from the trench / pit at which point concentrations of 5 to 10 mg/l are predicted; SSC is expected to return to background levels within a few days following completion of these activities.
- Deposition is not predicted to be significant; any coarse material mobilised will deposit rapidly (i.e. within several hundred metres of the cable trench). Finer sediment will be dispersed across a greater spatial extent, transiently depositing throughout the tidal cycle. However, due to the volumes of sediment likely to be liberated into the water column and significant dispersion of fine sediment, it is considered that deposition will be negligible with sediments quickly resuspended and redistributed under the forcing of tidal flows.

6.6.4.17. It is anticipated therefore that the impacts upon seabed sediments and physical processes with respect to cable installation activities are considered to be of **medium** magnitude. However, as the effects have a localised spatial extent relative to the Marine Cable Corridor, and broadly fall within the natural variation (i.e. SSC are similar to those predicted to be observed during storm conditions) and are temporary in nature (timescale similar to the duration of installation, i.e. a matter of weeks/months), the potential effect on seabed sediments and physical processes is considered to be of **minor to moderate** significance.

Dredge Disposal Operations

6.6.4.18. Sediment arising from dredging for the purposes of pre-sweeping i.e. sandwave and large ripple clearance, and/or installation of HDD exit pits and cable joints will be disposed of within the Marine Cable Corridor beyond KP 21 (see Appendix 6.5 (Disposal Site Characterisation Report)), ideally in proximity to the dredging works, in an analogous fashion to the methodology employed during the installation of the BritNed interconnector cable (Royal Haskoning, 2005).

6.6.4.19. Numerical (plume dispersion) modelling has been employed (utilising the AIMS HD model as the HD input) to investigate potential effects associated with the disposal of the dredge material on near and far field SSCs and changes in seabed level due to deposition (see Appendix 6.3 (Grain Size Statistics)). These simulations were conducted to assist with design iteration and to help minimise potential environmental impacts of disposal of dredge material during dredging activities. A realistic worst-case scenario model run encompassing disposal of the worst-case material volumes (*c.* 1,754,000 m^3) was conducted. How the dredge volumes were determined is presented in Section 4.2.2 of Appendix 16.2 (Modelling Technical Report).

6.6.4.20. Suspended sediment plumes created during dredge disposal operations are predicted to enhance SSC in the near (i.e. to the point of release) and far field (i.e. up to 20 – 25 km from the point of release), transiently. The maximum observed values at **any** time during the model run are presented in Plate 6.18 highlighting the predicted worst-case plume footprint resulting from disposal events at 14 locations along the Marine Cable Corridor between KP 21 and KP 80 as these areas were considered most likely for disposal activities to occur based on the current locations of bedforms. This footprint extends up to *c.*20–25 km relative to the Marine Cable Corridor, along the dominant tidal axis both in the ebb and flood direction. The spatial extent of this footprint is mainly due to the presence of fine material at the extremities of the plume. Closer to the point of release, the plume also comprises sand sized sediments, but these are likely to be deposited rapidly, and locally to the point of release (i.e. within 1000 m). The model setup, validation and calibration and some additional outputs are presented in Appendix 6.2 (Modelling Technical Report). This report also describes the approach for disposal operations and the constraints exercise that informed this approach. The approach to disposal operations and the approach to plume dispersion modelling were consulted upon with NE, JNCC, EA and the MMO. A Disposal Site Characterisation Report is also presented in Appendix 6.5 (Disposal Site Characterisation Report).

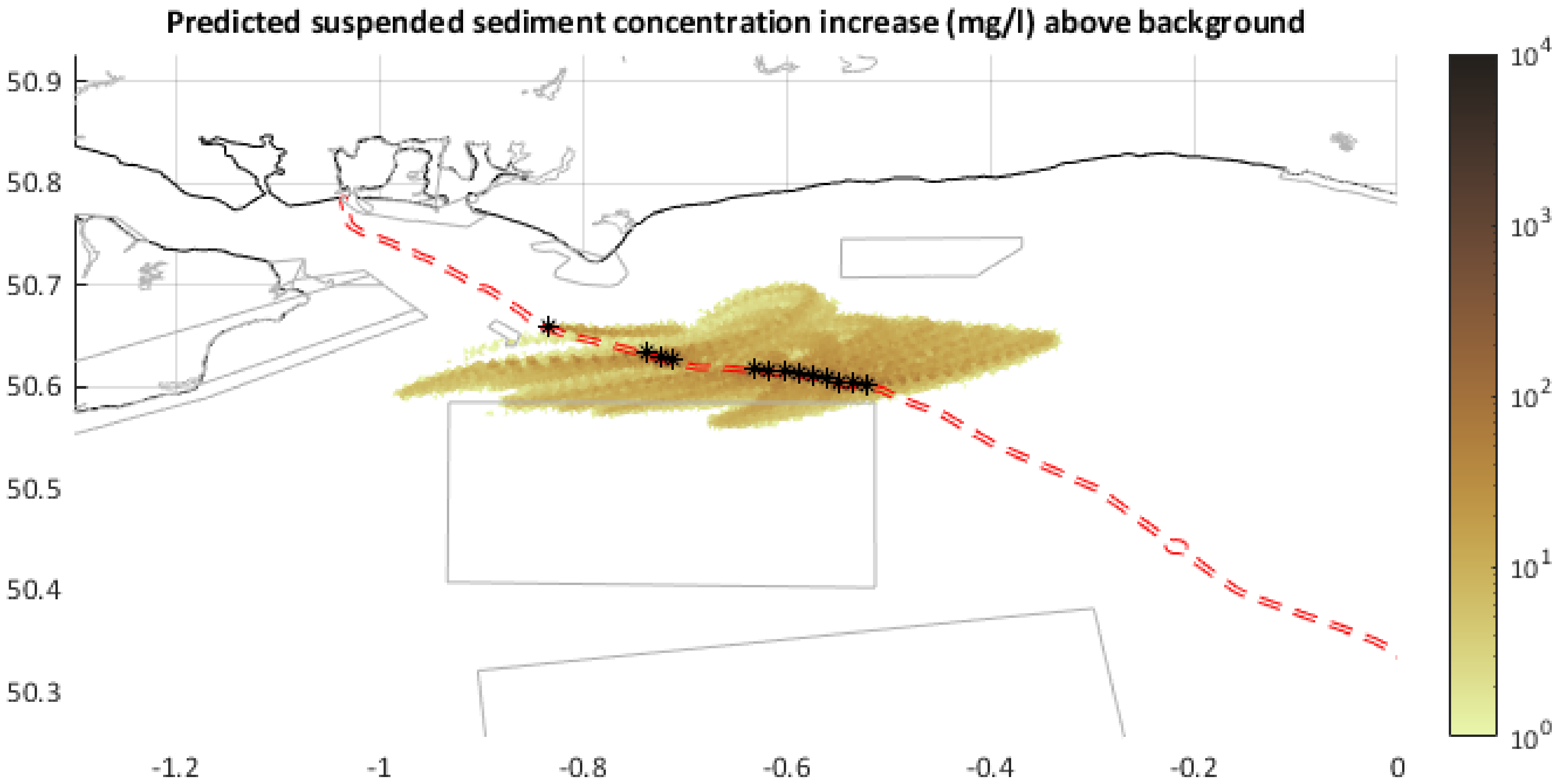


Plate 6.18 – Maximum values of predicted suspended sediment concentration increase above background in UK Waters during the model run. ***Note; this plot does not show the actual plume at any one time but rather the peak values attained at each location over the course of the simulation. The black stars depict disposal locations along the Marine Cable Corridor.***

6.6.4.21. Based on the analyses outlined above, the predicted transport of sediment plumes and subsequent deposition during dredge disposal activities in the offshore region beyond KP 21 can be summarised as follows:

- Peak SSC of 1000 mg l^{-1} predicted to occur within 1 km from the release point but coarser sediment expected to deposit quickly (almost immediately) with significant reductions of SSC within hours of disposal at each location.
- Beyond 1 km from release, the passive plume which is transported beyond this is likely to generate SSC in the region of approximately 20 mg l^{-1}, transported in the direction of the prevailing flow out to a worst case distance of up to 25 km. SSC is predicted to reduce to background levels (<1 – 6 mg l^{-1}) within the timeframe of a few days following the completion of dredge disposal activities; and
- Sediment deposition from disposal activities will be local to the point of release (i.e. within 1000 m), with deposits of coarser sediments potentially observed to depths of between 10 mm and 1.5 m, with greatest deposition observed across an area of a few hundred metres, elongated in the direction of the prevailing flow at the time of release, relative to the release site. Finer sediments will be redistributed and any deposition outside the locality of the release point (i.e. >1000 m) will be transient and negligible, with any settled material being quickly redistributed under the forcing of tidal flows.

6.6.4.22. Based on the results of the model simulation, considered and interpreted in light of the foregoing analysis presented in this chapter, it is anticipated that the effects upon seabed sediments and physical processes with respect to the disposal of dredge material along the within the proposed marine disposal site are predicted to be of **medium** magnitude, principally due to the transient high values of SSC in the nearfield immediately following disposal. However, as the effects have a relatively localised spatial extent relative to the Marine Cable Corridor and are temporary in nature (timescales similar to the duration of disposal activities, i.e. intermittent effects observed over a matter of weeks/months) with the sediments to be disposed of locally to the area of dredging, thus remaining within the local sediment budget. The potential effect on seabed sediments and physical processes is considered to be of **minor to moderate** significance.

6.6.4.23. The potential exists for deposits placed within the Marine Cable Corridor following the pre-sweeping operations to be used as backfill for sections of the cable route. This process requires re-dredging of the deposit on the bed and emplacement in the desired location along the cable route. As it is anticipated that some time will have lapsed between the original dredge operations and trench infill operations, the following would be likely to have occurred during this time period:

- Partial redistribution of sediments via bedload transport processes; and,

- Winnowing of any fine sediments present within the surficial (or mobile layer) of the deposit.

6.6.4.24. The result of these processes would be the formation of a predominantly coarser deposit on the seabed, which would subsequently be suitable for re-use. Any impact associated with these operations would be contained within the bounds of the Marine Cable Corridor, on the basis of their hydraulic properties which would promote rapid settling to the bed. As such, the effects associated with re-dredging and emplacement of material on the seabed is considered to be of **negligible** magnitude, and thus of **negligible** significance.

Installation of Cable Protection

6.6.4.25. Following cable lay, the installation of cable protection where required along the Marine Cable Corridor during the construction stage, is likely to disturb surficial sediments, potentially liberating fine sediment present within the surficial sediments to the water column. In comparison to cable installation activities, which are considered more vigorous, impacts relating to emplacement of protection infrastructure upon seabed sediments with respect to SSC are considered to be of **low** magnitude, have a localised spatial extent (limited to the Marine Cable Corridor) and only a short duration (timescale similar to the duration of installation, i.e. a matter of months, but potentially intermittent). The potential impact upon seabed sediments and physical processes is therefore considered to be of **minor** significance.

6.6.4.26. As discussed earlier, the liberation and release of fine sediment in nearshore areas due to pre-sweeping, dredging, and cable installation activities has the potential to increase the suspended sediment load within coastal areas within the Solent. This is due to both activities occurring in the nearshore and a prevailing circulatory gyre which persists to the south of the Isle of Wight which could act to transport, and, trap suspended sediment within the coastal area.

6.6.4.27. Based on the foregoing analysis it is anticipated that under the prevailing HD conditions, fine material would be readily re-mobilised and redistributed, especially in the shallow nearshore area where waves regularly stir the seabed. Where these sediments are transported towards the coast (rather than in the alongshore or offshore direction) they may be delivered to the harbours in the local area which generally act as sinks for suspended sediments. However, due to the dynamic nature of the nearshore and coastal environment and the likely significant dispersal of suspended sediments in the offshore region the levels of suspended sediment are not anticipated to be greater than levels observed during higher energy storm events. Thus, the potential effect on coastal processes is considered to be of **minor to moderate** significance.

Morphological Change and Alteration of Bedforms

6.6.4.28. The potential exists for impacts to occur which affect the local morphology and bedform features during Construction Stage activities, these activities include:

- Pre-sweeping and other dredging requirements; and
- Dredge disposal operations.

Pre-sweeping and Other Dredging Requirements

6.6.4.29. Pre-sweeping of these sedimentary bedform features will alter the geometry. This has the potential to impact morphodynamic processes and flow patterns locally. However, the potential effects to tidal flow patterns are considered to be of low magnitude, have a localised spatial extent (limited to the Marine Cable Corridor) and only a short duration occurring only until the seabed has reached a new natural state of dynamic equilibrium (timescale anticipated to be similar to the duration of installation, i.e. discontinuously over a matter of months).

6.6.4.30. Studies to examine how bedform features are altered, and the length of time pre-swept trenches continue to persist post sweeping, were undertaken for the environmental assessment of the NEMO Link Interconnector installed in the southern North Sea between the UK and Belgium (HR Wallingford, 2013). The studies, revealed that the features and local processes would not suffer any permanent alteration and that the trench would infill within a matter of weeks, leading to the reformation of the bedform features. However, more recent evidence from a monitoring campaign targeting bedform recoverability at Race Bank OWF, critiqued by RPS (2018) as part of their submission for the Hornsea 3 OWF, indicated recovery to a new natural equilibrium state occurred over the medium to long term (in the order of months to years). RPS (2018) note the following recovery mechanisms exist:

- Infilling of the dredge area with the affected sandwaves remaining *in situ*; and,
- Recovery associated with the migration of the sandwaves.

6.6.4.31. The recovery potential of levelled sandwaves is controlled by the following factors:

- The dimensions of the dredged area (relative to the overall sandwave height) and the alignment of the dredged channel relative to the crest axis; and,
- The magnitude of sediment mobility at the dredge location.

6.6.4.32. At present, it is not possible to predict the location or geometry of the dredge area or the location or magnitude of sandwaves which will be pre-swept for the Proposed Development during future dredging activities as bedforms are mobile. However, the foregoing analysis of sediment mobility at locations along the Marine Cable Corridor show a highly dynamic sediment transport regime (see Section 6.5.7) and as such, infilling of the dredge areas and/or migration of sandwaves into these areas is predicted to occur over the short to medium term (assuming sufficient sediment supply exists). As such, it is anticipated that the impacts upon bedform features, seabed sediments and local morphodynamics as a result of pre-sweeping will be of **medium** magnitude, principally as timescales for full recovery of these features are difficult to predict and could extend beyond the period of installation. However, as these impacts are limited to local morphology and features within the Marine Cable Corridor and it is likely that although the seabed will not return to its exact baseline state, it is likely only a short duration until the mobile seabed will have reached a new natural state of equilibrium (timescale anticipated to be similar to the duration of installation, i.e. a matter of months). Thus, the impacts are considered to be temporary and the potential effects on bedform features, seabed sediments and local morphology is considered to be of **minor to moderate** significance.

Disposal Operations

6.6.4.33. Due to the coarse nature of the sediment which comprise these bedform features, disposal operations will likely induce a build-up of sediment on the seabed local to the sediment release point (i.e. within the disposal area). While this deposited sediment is predicted to remain in place in the short term, bedload transport processes will act to disperse it over time, assisting the regeneration of bedforms and a return to a state of dynamic equilibrium and baseline seabed processes. Furthermore, the potential exists for these coarse deposits to be used to infill dredged areas. Thus, the impacts of dredge disposal in terms of morphological change and alteration to bedforms are considered to be temporary and of **minor** significance.

6.6.4.34. The impact of morphological change and alteration of bedforms on coastal processes is **negligible** as all potential impacts are local to seabed features and the Marine Cable Corridor.

Obstruction to Flow, Scour Around Structures, Impact on Near Field Flow

6.6.4.35. The potential exists for effects upon the seabed and sediment transport regime, including scouring of the seabed and tidal flows due to activities which may occur during the Construction Stage, these include:

- Installation of cable protection variously along the cable route;
- Installation of two pre-lay rock berms and installation of two post lay rock berms (for Atlantic Crossing);
- Dredging shallow pits on the seabed as part of HDD works (HDD pit excavation);
- Temporary use of jack up vessel and grounding cable lay vessels; and,
- Temporary placement of moorings on the seabed.

Installation of Cable Protection

6.6.4.36. Locations have been identified where non-burial protection is likely to be required. These include:

- In-service cable crossings;
- Boulder or gravel fields where seabed clearance has not been possible;
- Areas of mobile sediment which are underlain by material in which minimum depth of lowering could not be achieved;
- Where burial installation activities have been unsuccessful (i.e. cable was surface laid or minimum depth of lowering could not be reached, or where the trenching system has had to be recovered, either to a change in burial technique, for repairs or due to poor weather);
- At a cable repair / joint location; and,
- At the transition between the Landfall HDD exit/entry location and the buried cable.

6.6.4.37. There is a variety of methods available for the protection of Marine Cables, such as rock placement and concrete or frond mattressing. These methods are occasionally employed in combination (e.g. concrete mattresses installed with frond mattresses). All methods employed have the potential to interrupt seabed processes on a very local scale during construction. Protection infrastructure will raise the seabed level by up to 1.5 m (in the worst-case scenario) creating a discontinuous linear feature on the seabed, positioned on occasion in a shore normal direction and on occasion in a shore parallel direction. The installation of protection influences the local flow field creating areas of flow acceleration, de-acceleration and turbulence. The scale of the turbulent features corresponds to the size and geometry of the structure. As such, where concrete or frond mattressing are used which are low profile (0.3 m vertical height, which means the vertical change is likely to be within the scale of natural variability of the local seabed topography along the Marine Cable Corridor), it is anticipated the flow field surrounding these structures will come into equilibrium with the local HD conditions relatively quickly and will be highly localised (turbulent flows present in the flow field only for a few metres downstream of the structure), and as such of **low** magnitude, and therefore of **minor** significance.

6.6.4.38. However, it is considered that the placement of rock, due to the geometry of the features, will create a greater magnitude of disturbance in the flow field. However, again, it is likely the flow field surrounding these structures will come into equilibrium with the local HD conditions relatively quickly and will be highly localised (turbulent flows present in the flow field only for tens of metres downstream of the structure). Thus, is also considered to be of **low** magnitude, and therefore of **minor** significance.

6.6.4.39. Immediately post-construction, due to localised effects on the flow field, there is potential for scouring to develop around the edge of the installed protection. The extent of scour (i.e. the scour potential) is dependent upon the HD conditions experienced during the construction stage (i.e. the potential for scour will be enhanced during spring tidal phase during which time greater flow velocity magnitudes are observed). Scour effects on the seabed will generally scale with the cable protection used and thus, scouring will be enhanced where rock is placed on the seabed. Where concrete or frond mattressing is used, the protection is often tapered from the centre point to the seabed; therefore, at most a shallow depression in the seabed at the edge of the protection (edge scour) may arise through time. Due to the highly dynamic sediment transport regime in the Channel, it is anticipated that this will come into equilibrium with the local HD conditions relatively quickly and will be highly localised, of short duration (until the point where equilibrium is reached) and **low** magnitude, and therefore of **minor** significance. However, where rock protection is emplaced on the seabed the potential exists for greater scouring (especially where they are placed perpendicular to the flow) and thus due to the potential impact on surrounding bedform features the effect is of medium magnitude and of **minor to moderate** significance.

6.6.4.40. In addition to the installation of cable protection variously along the cable route, it is anticipated that two rock berm structures will be installed on the seabed pre and post cable lay as part of the Atlantic Cable Crossing protection. The pre-lay berms will be up to 30 m wide extending 100 m in length, post lay it is proposed each berm will be extended to extend 600 m in length. At present the location, orientation (relative to the direction of flow) and specific engineering design of these berms is yet to be finalised. The presence of the berms in the near-bed boundary layer flow regime creates a complex local flow disturbance acting on the seabed, including:

- Acceleration of the flow over the berm crests, and an accompanying up/downstream reduction in near-bed pressure;
- Flow separation up and downstream of the berms and the formation of vortices;
- A local increase in turbulent intensity;
- Amplification of local bed stress, including on the edges of the berm structure;
- Secondary flow patterns (helical flow); and
- Localised disruption to flow direction.

6.6.4.41. These flow disturbances have the potential to result in extensive scouring in the vicinity of the structure, particularly where berms are positioned perpendicular to the direction of flow. Scour potential, as previously discussed, is a function of the seabed and sub-surface characteristics, HD regime and the geometry (and extent) of the structure. It is anticipated that scour potential will be rigorously assessed during the design of these features. Thus, primarily due to the scale of morphological change which could occur due to scouring in the vicinity of these features (which has the potential to exceed natural variation in morphological change) the magnitude of impact is considered to be of **medium** magnitude and thus of **minor to moderate** significance.

Dredging Shallow Pits on the Seabed as Part of HDD Works

6.6.4.42. During construction of the HDD pit/s, each depression/s will be filled with temporary protection (e.g. grout bags), reducing the depth of each depression. After cable pull, the grout bags will be replaced with rock. Thus, it is anticipated that there will not be any significant impact at the regional scale on HDs and boundary layer flow structure related to the creation of depressions in the seabed. There may be some localised and small-scale decreases in near bed flow velocities due to seabed roughness and slightly elevated turbulence intensities as a result of the presence of the shallow depression, but this is likely to be of **negligible** magnitude, highly localised and only short duration (timescale similar to the duration of installation, i.e. a matter of months) and therefore is predicted to be of **negligible** significance.

6.6.4.43. The potential impacts on seabed morphology, the sediment transport and HD regime described in the foregoing analysis is predicted to have limited impact on local coastal processes. On occasion, during the period of construction the potential exists for the liberation and release of fine sediment in nearshore areas due to changes in the local flow field around structures placed on the seabed and / or depressions created in the seabed. This has the potential to increase the suspended sediment load within coastal areas within the Solent. However, as these impacts are temporary in nature and generally highly localised, the volume of material released is considered to negligible in the context of the nearshore region.

6.6.4.44. Due to the dynamic nature of the nearshore and coastal environment in the area and generally low levels of suspended sediment anticipated to be released in the nearshore the potential effect on coastal processes is therefore considered to be of **minor** significance. Onshore HDD construction works at Eastney will be confined to above MHWS and thus, works are beyond the scope of this assessment. Similarly, no HDD work is anticipated to occur within the marine environment of Langstone Harbour as the drilling will occur beneath the harbour. The entry/exit points of the drill will also be located above MHWS. As such no effect on marine and coastal physical processes are anticipated from this work. Overall, the effects of the HDD Landfall activities upon coastal processes and morphology are therefore considered to be localised, of **negligible** magnitude and temporary, and as such are considered to be of **negligible** significance.

Temporary use of Jack up Vessel and Grounding of Vessels

6.6.4.45. It is anticipated that a jack-up vessel (and other associated vessels and equipment) may be utilised for various operations during the construction stage at the Landfall where HDD works are to be undertaken off the coast at Eastney (e.g. HDD operations, duct installation and for the subsequent cable pull). Construction stage related impacts are predicted to be of a temporary nature with construction vessels on-site for a period of months. As a worst case, two vessels (up to 120 m Length Overall ('LOA') and up to 33 m beam width) may also be grounded at any one time (at low tides) between KP 1.0 and KP 4.7, for a period up to a maximum of 4 weeks. Previous assessment of scour due to seabed erosion and sediment mobility caused by the flow around the hull of large vessels during grounding operations has been undertaken by Partrac Ltd. (unpublished) using a Computational Fluid Dynamics ('CFD') modelling approach which considers the flow behaviour around the vessel's hull and the associated seabed shear stresses for selected grounding scenarios. The model simulations indicated that a vessel's presence will impact the HD flow and flow velocity around and beneath the vessel creating areas of reduced flow, stagnation points and acceleration. The CFD analysis indicates a high scour potential particularly during the spring tidal phase, and in the short period before actual grounding. Similarly, legs of jack-up vessels, where these are utilised, will cause a temporary localised obstruction to flow but only for a short duration. For the use of towed, jack-up barges or specialised jack-up vessels (that can move under their own means), four (or more) legs will be placed onto the bed to stabilise the vessel. These legs can penetrate the seabed to some depth. During construction, scour can arise around the legs of the vessel, due to the acceleration of tidal flow around the fixed leg structures. Scour potential is a function of the surficial sediment characteristics, tidal forcing, structure size and the duration the structure (in this instance the legs of the jack up vessels) are fixed to the seabed. It is anticipated that these vessels will be moved promptly once operations at a single location are completed, and as such, these impacts are anticipated to be short term. Thus, the total volumes of sediment released due to scour are expected to be limited. However due to the high scour potential and potential for downstream bed level change (particularly where vessels are grounded) is considered to be of **medium** magnitude and thus of **minor to moderate** significance.

Temporary Emplacement of Moorings on the Seabed

6.6.4.46. Similar short-term impacts to those observed where jack up vessels are installed on the seabed may be expected where construction vessels are anchored on site. However, anchoring is considered less intrusive and for a shorter duration the use of a jack up vessel during construction. It is anticipated these vessels will be moved promptly once operations at a single location are completed and as such, these impacts are anticipated to be short term and highly localised. Therefore, due to the temporary, highly localised nature of the impacts on the flow field and sediment transport regime they are considered to be of **low** magnitude, and thus of **minor** significance.

6.6.5. OPERATION (INCLUDING REPAIR AND MAINTENANCE)

Obstruction to Flow, Scour Around Structures, Impact on Near Field Flow

Non-Burial Protection

6.6.5.1. The design of the Marine Cable Route and installation method is to be optimised in order to increase cable burial and thus minimise the requirement for external cable protection. As described in paragraph 6.6.4.37, all methods of cable protection will interrupt seabed processes on a very local scale. The near-field impacts on HD flow from the presence of non-burial cable protection structures will potentially create areas of flow reduction, stagnation and acceleration. Near bed flows are also likely to be impacted by an increase in bed roughness associated with the presence of cable protection measures (e.g. rock berms or rock protection). This may cause the formation of wakes and eddies that will exist in the flow downstream of features. Given the anticipated scale (spatially and geometrically) of the cable protection, the near-field impact on HD flows (and any associated impacts on resuspension of adjacent sediments due to the presence of eddies and turbulence in the local flow field) are therefore likely to be of **low** magnitude and highly localised, and thus effects of only **minor** significance on the physical marine and coastal environment are predicted.

Increase in SSC

Repair

6.6.5.2. Cable maintenance may include the need to rebury exposed cables, cable repairs and replacements. As cable repair/replacement is likely to require cable de-burial, recovery to the surface, repair and reburial, it is broadly expected to represent the worst-case scenario. Where cable repair/replacement is required it is likely that near bed SSCs may be elevated compared to baseline levels as cable sections would be exposed and recovered to the surface. During these operations, it is possible that surficial sediments may be disturbed temporarily, and fine sediment released during this time. It is anticipated that this release will be limited, short term, highly localised and highly dependent on local seabed and HD conditions at the time of repair. Though during the removal of the Marine Cable, the total volume of sediment displaced is likely to be low, the potential exists for a shallow trench to form on the seabed immediately following removal of the section of the cable to be repaired. The formation of this trench is considered to be within the scale of natural variability of the local seabed topography. Further, due to the highly dynamic nature of the sediment transport regime it is considered any impact is likely to be temporary, short lived and of thus of **minor** significance.

6.6.5.3. Following repair, the Marine Cable will be re-buried using similar methods utilised during construction. As such, it is anticipated that the effects and subsequent impacts upon seabed sediments are as described in the relevant paragraphs of Section 6.6.4, though it is likely that the volume of fine sediment available for potential release will be slightly reduced compared to volumes at the time of the original burial activities. With respect to SSC and seabed morphology, impacts are considered to be of **low** magnitude, have a localised spatial extent (limited to the Marine Cable Corridor) and only a short duration (timescale similar to the duration of installation, i.e. a matter of weeks/months). The potential effect on the physical marine and coastal environment is therefore considered to be of **minor** significance.

6.6.5.4. As the potential effects on the physical environment during operation are considered to be **minor**, no additional impacts to coastal processes are predicted as a result of the Proposed Development.

6.7. CUMULATIVE EFFECTS ASSESSMENT

6.7.1. INTER-PROJECT EFFECTS

6.7.1.1. Cumulative impacts on the physical environment may arise from the interaction of impacts from the Proposed Development during construction, operation or decommissioning and impacts from other planned or consented projects in the wider vicinity of the Proposed Development.

6.7.1.2. It has generally been considered that the potential for cumulative effects will be greatest during the Construction Stage of the Proposed Development. Decommissioning is assumed to have similar (or lesser) impacts than construction. In the event that cables need to be repaired or maintained, the activities required to undertake the works are considered similar to the effects that may arise during construction but are predicted to lower in magnitude (due to considerably reduced scale of the works) and duration.

6.7.1.3. A list of projects within the wider region that have the potential to give rise to a cumulative impact on the physical environment have been considered (see Appendix 6.4 (Physical Processes Cumulative Assessment Matrix) of the ES Volume 3 (document reference 6.3.6.4)). This included major projects (OWFs, interconnector cables, oil and gas), aggregate dredging projects, dredging and disposal projects, and coastal projects. This long list was agreed with the MMO (see Table 6.1). The locations of projects within this list in relation to the Proposed Development are shown in Figures 29.1 to 29.5 of the ES Volume 2 (document references 6.2.29.1, 6.2.29.2, 6.2.29.3, 6.2.29.4 and 6.2.29.5). As detailed within Chapter 29 (Cumulative Effects) of the ES Volume 1 (document reference 6.1.29), this assessment is to be undertaken with regards to PINS Advice Note Seventeen – Cumulative Effects Assessment (PIN, 2019). The list of projects presented in Appendix 6.4 (Physical Processes Cumulative Assessment Matrix) has been refined for the physical environment as follows:

- First, a spatial assessment was conducted. Any project identified in the long list of cumulative projects falling within the Zone of Influence ('ZOI') for the physical environment (25 km from the Marine Cable Corridor, based upon the spatial extent of the suspended sediment plumes from construction activities) was screened in for further consideration;

- A temporal, scale and nature-based assessment was conducted for those projects where a potential spatial overlap was identified; and
- Taking the above into account, any projects considered likely to affect the physical environment, and/or likely to result in significant effects due to their scale and nature were identified.

6.7.1.4. Those projects carried through to Stage 3 and 4 assessment where the potential exists for a significant cumulative impact are identified below:

- AQUIND Interconnector (France); and
- IFA2.

6.7.1.5. Potential cumulative effects on physical processes due to these projects may include:

- Increase in SSC;
- Morphological change and alteration of bedforms; and
- Obstruction to flow, scour around structures, impact on nearfield flow.

6.7.1.6. Cumulative effects are of principal concern where construction activities overlap due to the predicted greater magnitude, duration and extent of impacts (when compared to the operational and maintenance phase). With regards the IFA2, based on currently available information, the Construction Stage for IFA2 is expected to be completed by 2020 and therefore it is anticipated that there is no possibility of construction activities overlapping with the Proposed Development. Therefore, only operational effects from IFA2 are predicted. Table 6.19 presents the assessment of cumulative effects for these two projects as well as the Proposed Development.

6.7.1.7. Further, as no transboundary effects are anticipated, no cumulative effects during construction, operation and decommissioning of the AQUIND Interconnector (France) are predicted. This is discussed further in Section 6.7.3 below.

Table 6.19 – Summary of cumulative assessment

ID	Tier	Project Name and Reference	Assessment of cumulative effect	Proposed mitigation	Residual cumulative effect
1	2	AQUIND Interconnector (France)	**Increased SSC** Construction Similar activities are required during the construction of the French Aquind project as are required the Proposed Project. If construction activities in UK and French waters coincide potential cumulative effects from the liberation of sediments into suspension from multiple activities occurring coincidently could potentially result in enhanced SSC across the area. Dredge disposal activities which are considered to result in the greatest magnitude and extent of increased SSC, should they occur at the same time, are of significant distances apart (i.e. greater than 50 km) that they are not predicted to act cumulatively. Thus, as the impacts are considered to be localised, temporary and relatively short duration, the cumulative effects related to enhanced SSC are considered to be of **low** magnitude and thus of **minor** significance.	None	**Not Significant**

ID	Tier	Project Name and Reference	Assessment of cumulative effect	Proposed mitigation	Residual cumulative effect
			<u>Operation</u> There is potential that there could be temporal overlap of operational activities between the two projects including for cable repair/replacement. However, again such activities will result in SSC increases which are of **low** magnitude, small extent and short duration (days to weeks), and therefore it is predicted that any cumulative effects are of **minor** significance.		
7	1	IFA2	**Increased SSC** The possibility exists that construction activities for the Proposed Development may overlap with maintenance activities of the IFA2 interconnector only. If these activities coincided, potential cumulative effects could include the liberation of sediments into suspension from multiple activities occurring coincidently, enhancing SSC across the area. It was concluded within the ES for IFA2 that suspended fine sediments would only remain in suspension over the period of a few hours to days. If coincident activities were conducted which were likely to liberate fine sediments at the same time, in the same	None	**Not Significant**

ID	Tier	Project Name and Reference	Assessment of cumulative effect	Proposed mitigation	Residual cumulative effect
			spatial region, enhanced levels of SSC would be observed. However, the sediment plumes generated would be transient and as most impacts are considered to be localised, temporary and of short duration, the cumulative effects related to enhanced SSC are considered to be of **low** magnitude and thus of **minor** significance. However, were activities both located in the nearshore region, where there is a greater presence of fine sediments in the surficial sediment along the cable route the effects of cumulative enhanced SSC would be considered to be of **medium** magnitude and thus of **minor to moderate** significance		
1	2	AQUIND Interconnector (France)	**Effects on the HD regime and morphological change/obstruction of flows** Other potential cumulative effects on the HD regime and morphological change could potentially occur due to the cumulative effect of cable protection (and other structures on the seabed) on the local flow field. However as predicted impacts are local to the structures on the seabed, potential cumulative effects are considered to be **negligible** magnitude and thus of **negligible** significance.	None	**Not Significant**
7	1	IFA2			

6.7.2. INTRA-PROJECT EFFECTS

6.7.2.1. As detailed in Chapter 4 (EIA Methodology), Chapter 29 (Cumulative Effects) presents consideration of potential intra-project effects with physical receptors and processes.

6.7.3. TRANSBOUNDARY EFFECTS

6.7.3.1. The possibility for transboundary effects exists as the Marine Cable Corridor extends from Eastney to the UK/France EEZ Boundary Line. However, transboundary effects are predicted to be **not significant**.

6.7.3.2. Where structures (i.e. cable protection measures) are located on the seabed close (i.e. within 500 m) to the EEZ Boundary Line potential transboundary effects could potentially occur however this would be of low magnitude and thus of **minor** significance.

6.7.3.3. Where suspended sediment plumes are generated by activities near the EEZ Boundary Line, sediment plumes would be transported in the direction of the prevailing flow. In areas further offshore, this is typically observed along an east – west axis, and therefore there is limited potential for plumes to be transported into French waters. Regardless, given the relatively low magnitude, short duration and transient nature of the potential impacts, any effects are predicted to be of **minor** significance.

6.8. PROPOSED MITIGATION

6.8.1.1. No potentially significant effects are predicted for the physical environment as a result of the construction, decommissioning and operation, repair or maintenance of the Proposed Development (based upon those impacts and receptors assessed within this chapter). Therefore, no additional mitigation is proposed.

6.9. RESIDUAL EFFECTS

6.9.1.1. Table 6.20 summarises the effects of all impacts assessed.

Table 6.20 –Summary of Effects for Physical Processes

Impacts	Receptor	Sensitivity of Receptor	Magnitude and nature of Impact	Significance of effect	Mitigation	Significance of Residual Effect
Construction (and Decommissioning)						
Increase in SSC	The seabed and associated sediments, coastal processes	Low	Medium/Low Localised to the Temporary	Minor to moderate / Minor	None	Not significant
Morphological Change and Alteration of Bedforms	Bedform features, tidal flows, coastal processes	Low	Medium / negligible Localised Temporary	Minor to moderate / Negligible	None	Not significant
Obstruction to Flow, Scour Around Structures, Impact on Near Field Flow	Tidal flows, coastal processes	Low	Medium / Low / Negligible Localised Temporary	Minor to Moderate / Minor / Negligible	None	Not significant
Operation (incl. Repair and Maintenance)						
Obstruction to flow, scour around structures and increase in SSC	Tidal flow, the seabed and associated sediments, coastal processes	Low	Low Localised	Minor	None	Not significant

REFERENCES

ABP Research & Consultancy (1999) Good practice guidelines for ports and harbours operating within or near UK European marine sites. English Nature, UK Marine SACs Project. pp 120.. Available from: http://www.ukmarinesac.org.uk/pdfs/guidelines.pdf [Accessed: 29 October 2019].

ABPmer (2012) Rampion Offshore Wind Farm Environmental Statement section 6 – Physical Environment, Appendix 6.4: Coastal Processes Assessment.

Alexandersson, H., Tuomenvirta, H., Schmith, T., Iden, K (2000). Trends of storms in NW Europe derived from an updated pressure data set. Climate Research 14: 71-73.

Amos, C.L. and King, E.L. (1984) Sandwaves and sand ridges of the Canadian Eastern Seaboard -- a comparison to global occurrences. In: B.D. Bornhold and A. Guilcher (Editors), Sedimentation on High-Latitude Continental Shelves. Mar: Geol., 57: 167-- 208.

Becker, J. H., Van Eekelen, E. M. M., Wiechen, J. J. J., De Lange, W., Damsma, T., Smolders, T., Van Koningsveld, M. (2015). Estimating source terms for far field dredge plume modelling. Journal of Environmental Management. 1; 149:282.

Beniston, M., Stephenson, D. B., Christensen, O. B., Ferro, C. A. T., Frei, C., Goyette, S., Halsnaes, K., Holt, T., Jylha, K., Koffi, B., Palutikof, J., Scholl, R., Semmler, T., Woth, K. (2007). Future extreme events in European climate: An exploration of regional climate model projections. Climate Change. 81: 71-95.

Centre for Environment, Fisheries and Aquaculture Science (Cefas) (2004) Offshore Wind Farms: Guidance Note for EIA in Respect to FEPA and CPA Requirements. Available from: https://www.cefas.co.uk/publications/files/windfarm-guidance.pdf [Accessed: 29 October 2019]

Chartered Institute of Ecology and Environmental Management (CIEEM) (2018). Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater and Coastal.

Davies, J., Baxter, J., Bradley, M., Connor, D., Khan, J., Murray, E., Sanderson, W., Turnbull, C. and Vincent, M. (2001) *Marine Monitoring Handbook*, 405 pp, ISBN 1 85716 550

Delavenne, J (2012) Conservation of marine habitats under multiple human uses: Methods, objectives and constraints to optimize a Marine Protected Areas network in the Eastern English Channel. Unpublished PhD Thesis. Muséum National d'Histoire Naturelle.

Department for Business Enterprise and Regulatory Reform (BERR) (2008).

Department for Environment, Food and Rural Affairs (DEFRA) (2018). South Inshore and South Offshore Marine Plan https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/726867/South_Marine_Plan_2018.pdf [Accessed: 29 October 2019]

Department of Energy and Climate Change (2011a) Overarching National Policy Statement for Energy (EN-1). [Online].. Available from:https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47854/1938-overarching-nps-for-energy-en1.pdf [Accessed: 29 October 2019].

Department of Energy and Climate Change (2011b) National Policy Statement for Renewable Energy (EN-3). Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47856/1940-nps-renewable-energy-en3.pdf [Accessed: 29 October 2019].

Dickson, R. and Lee, A. (1971) Gravel extraction effects on seabed topography. Offshore Services. **6**, 32-39 & 56-61.

Environment Agency (2011) Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/297379/geho0711btzu-e-e.pdf. [Accessed: 29 October 2019].

Fawcett, A. (2018). Natural England: Offshore windfarm cabling: ten years' experience and recommendations. *1*. 1 (1), 1.

Feser, F., Barcikowska, M., Krueger, O., Schenk, F., Weisse, R., Xia, L. (2014). Storminess over the North Atlantic and northwestern Europe - A review. *Quarterly Journal of the Royal Meteorological Society*. 141 (1), 350-382.

Flather, R.A. (1986) Estimates of Extreme Conditions of Tide and Surge using a Numerical Model of the North-West European Continental Shelf. *Estuarine, Coastal and Shelf Science*. **24**, 69-93.

Gohin, F. (2011). Annual cycle of chlorophyll-a, non-algal suspended particulate matter and turbidity observed from space and in-situ in coastal waters. *Ocean Science*. **7**, 705 – 732.

Guillou, N. and Chapalain, G. (2010). Modelling impact of northerly wind-generated waves on sediments resuspensions in the Dover Strait and adjacent waters. *Continental Shelf Research*, **30**, 806 – 819.

Guillou, N., Rivier, A., Gohin, F. and Chapalain, G. (2015). Modeling Near-Surface Suspended Sediment Concentration in the English Channel. *Journal of Marine Science and Engineering*. **2**, 193 - 215.

Guillou, N., Rivier, A., Chapalain., G. and Gohin, F. (2017). The impact of tides and waves on near-surface suspended sediment concentrations in the English Channel. *Oceanologia*. **59**, 28 - 36.

Hamblin, R.J.O. (1989) *Dungeness – Boulogne, Sheet 50°N 00°: Sea Bed Sediments and Quaternary Geology*. 1:250000 Offshore Map Series, Keyworth, British Geological Survey.

Hamblin, R.J.O., Crosby, A., Balson, P.S., Jones, S.M., Chadwick, R.A., Penn, I.E. and Arthur, M.J. (1992) *United Kingdom offshore regional report: the geology of the English Channel*. HMSO for the British Geological Survey, London.

HM Government (2011). UK Marine Policy Statement. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69322/pb3654-marine-policy-statement-110316.pdf. [Accessed: 29 October 2019].

HM Government (2016). Water Framework Directive assessment: estuarine and coastal waters. [Online]. Available from: https://www.gov.uk/guidance/water-framework-directive-assessment-estuarine-and-coastal-waters. [Accessed: 29 October 2019].

HR Wallingford (2013) Project Nemo - UK to Belgium Interconnector, Tidal Flow Modelling. Technical Note DDR4633-01, In: Nemo Link, Environmental Statement Volume II: Technical Appendices: Appendix 7. Pp 30-165.

James, J.W.C., Pearce, B., Coggan, R.A., Arnott, S.H.L., Clark, R., Plim, J.F., Pinnion, J., Barrio Frójan, C., Gardiner, J.P., Morando, A., Baggaley, P.A., Scott, G, and Bigourdan, N. (2010) The South Coast Regional Environmental Characterisation. British Geological Survey Open Report OR/09/51. 249 pp.

James J.W.C., Pearce B., Coggan R.A., Leivers M., Clark R.W.E., Plim J.F., Hill J.M., Arnott S.H.L., Bateson L., De-Bugh Thomas A. and Baggaley P.A. (2007) British Geological Survey Open report OR/11/01. . The MALSF synthesis study in the central and eastern English Channel. (249 pp.)

John, S., Meakins, N., Basford, K., Craven, H. and Charles, P. (eds.) (2003). Coastal and marine environmental site guide (second edition) (C744). London: CIRIA.

Lafite, R., Shimwell, S., Grochowski, N., Dupont, J., Nash, L., Saloman, J., Cabioch, L., Collins, M., Gao, S. (2000). Suspended particulate matter fluxes through the straits of Dover, English Channel: observations and modelling. *Oceanologica Acta*. 23 (6), 687-700.

Lowe, J.A., Howard, T., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., *et al*. (2009) UK Climate Projections science report: Marine and coastal projections. Available from: http://ukclimateprojections.metoffice.gov.uk/22538 [Accessed: 29 October 2019].

Matulla, C., Schoner, W., Alexandersson, H., von Storch, H., Wang, X. (2007). European storminess: Late nineteenth century to present. Climate Dynamics. 31: 125-130.

Menesguen, A. and Gohin, F. (2006). Observation and Modelling of natural retention structures in the English Channel. *Journal of Marine Systems*, **63**, 244 – 256.

Mcmanus, J. F., Bond, G. C. and Broecker, W. S. (1991). The North Atlantic Heinrich events. Eos (Transactions of the American Geophysical Union), 72(44), 271.

Ministry of Housing, Communities and Local Government (2019). National Planning Policy Framework. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/810197/NPPF_Feb_2019_revised.pdf [Accessed: 29 October 2019]

MMT (2018/2019). Aquind interconnector Geotechnical Survey. Field report and appendices. Report no: 102735-AQU-MMT-SUR-REP-FRGTECNE.

National Grid (2016) IFA2 UK Offshore Development Environmental Statement. Document Reference: IF2-ENV-STM-0024

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

New Forest District Council (2010), North Solent Shoreline Management Plan

New Forest District Council (2017). 2012 Update of Carter, D., Bray, M., & Hooke, J., 2004 SCOPAC Sediment Transport Study, www.scopac.org.uk/sts.

OSPAR Commission (2009). Assessment of the environmental impacts of cables, Biodiversity Series.

Paphitis, D., Velegrakis, A., Collins, M.B. (2000) Residual circulation and associated sediment transport in the eastern approaches to the Solent. In: Colllins, M.B., Ansell, K., (eds) Solent Science: A Review. Proceedings in Marine Science Series. Elsevier, Amsterdam. 107-110

PINS (2019) Advice Note Seventeen: Cumulative Effects Assessment. Available online from: https://infrastructure.planninginspectorate.gov.uk/legislation-and-advice/advice-notes/ [Accessed 02/01/2019]

Reynaud, J.-Y, Tessier, B., Auffret, J.-P., Berné, S., De Batist, M., Marsset, T. and Walker, P. (2003) The offshore Quaternary sediment bodies of the English Channel and its Western Approaches. *Journal of Quaternary Science*. **18**(3-4), 361-371.

Royal Haskoning (2005). EIS, SEA and Habitat Assessment for BritNed Interconnector, Summary. Document ref: 9M3538.B1/R031/PCWV/Nijm.

RPS. (2018). Hornsea Project Three Offshore Wind Farm Appendix 11 to Deadline I Submission - Sandwave Clearance Clarification Note. Available: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010080/EN010080-001133-DI_HOW03_Appendix%2011.pdf. [Accessed 29/10/2019].

RSK Environmental Ltd. (2012) Rampion Offshore Wind Farm. ES Section 6 - Physical Environment. Available from https://www.rampionoffshore.com/environmental-statement/ (Accessed: 29 October 2019].

Savenije, H.H.G (1989) Salt intrusion model for high-water slack, low-water slack, and mean tide on spread sheet. *Journal of Hydrology*. **107**(1), 9-18.

Smith, A.J. and Curry, D. (1975) The structure and geological evolution of the English Channel. *Philosophical Transactions of the Royal Society of London*. **A279**, 3-20.

Soulsby, R. (1997) *Dynamics of Marine Sands*. HR walingford. Wallingford,

Souza, A.J., Holt, J.T., Proctor, R. (2007). Modelling SPM on the NW European Shelf Seas. In: Balson, P, Collins, M (Eds.), Coastal and Shelf Sediment Transport. Geological Society London, 147 – 158.

Statham, P. J., Leclercq, V., Hart, V., Batte, M., Auger, Y., Wartel, M., Cheftel, J. (1999). Dissolved and particulate trace metal fluxes through the central English Channel, and the influence of coastal gyres. *Continental Shelf Research* . 19 (1), 2019-2040.

Stride, A.H. (1990) Growth and burial of the English Channel unconformity. *Proceedings of the Geologists' Association*. **101**(4), 335-340.

Stride, A. H. (1982) (ed). *Offshore Tidal Sands: Processes and Deposits*. xvi, 222 pp. Chapman & Hall.

Sykes, P.A., Barcelia, R.M., (2012). Assessment and development of a sediment model within an operational system. *Journal of Geophysical Research*, 117.

Tappin, D.R.; Mason, T.; Rocks, K.F.. 2007 DTI Strategic Environmental Assessment Area 8 : superficial seabed processes and hydrocarbon prospectivity. British Geological Survey, 91pp. (CR/07/075N) (Unpublished).

Velegrakis, A. F., Gao, S., Lafite, R., Dupont, J. P., Huault, M. F., Nash, L. A., Collins, M. B. (1997). Resuspension and advection processes affecting suspended particulate matter concentrations in the central English Channel. *Journal of Sea Research*. 38 (1), 17-34.

Velegrakis, A. F., Michel, D., Collins, M. B., Lafite, R., Oikonomou, E. K., Dupont, J. P., Huault, M. F., Lecouturier, M., Salomon, J. C., Bishop, C. (1999). Sources, sinks and resuspension of suspended particulate matter in the eastern English Channel. *Continental Shelf Research* . 19 (1), 1933-1957.

Weiss, R., Stawarz, M. (2005). Long term changes and potential future developments of the north sea wave climate. GKSS Research Centre Institute for Coastal Research Geesthacht Germany.

Wright, M.R. (2004) Later Quaternary palaeovalley systems of the eastern English Channel. Unpubished PhD Thesis, Durham University