Offshore Wind Power Limited

West of Orkney Windfarm Offshore EIA Report

Volume 1, Chapter 8 - Marine Physical and Coastal Processes

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West of Orkney Windfarm

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CONTENTS

8 MARINE PHYSICAL AND COASTAL PROCESSES

Chapter summary

This chapter of the Offshore Environmental Impact Assessment (EIA) Report assesses the potential effects from the offshore Project on marine physical and coastal processes receptors. This includes direct, indirect, whole project assessment, cumulative, inter-related and transboundary effects. A project specific numerical model 'the West of Orkney model' was used to inform the assessment, alongside data from an extensive seabed survey campaign.

The marine physical and coastal processes topic covers a range of receptors and characterises a number of pathways which can have consequences for other receptors. Receptors include the seabed, the coast in the vicinity of the Project landfall location, and designated sites, amongst others. Additionally the assessment considers sediment transport and water column stratification.

Within the offshore Project area, bedrock geology comprises soft red sandstone. Seabed sediments are mostly sandy and quite coarse, with gravel also being prevalent in places. There are two bank features within the Option Agreement Area (OAA) (Stormy Bank and Whiten Head Bank) which do not appear to be actively migrating. In addition, the seabed within the offshore Project area is covered in sandwaves, depressions and megaripples. Boulders occur throughout the offshore Project area, including extensive areas classed as boulder fields. The coastline adjacent to the offshore Project area is characterised by hard and mixed substrate which is considered to be erosion resistant.

With respect to the metocean conditions within the offshore Project area, flow speeds are relatively low so the sediment transport potential across the offshore Project area is also low. Waves within the offshore Project area originate predominantly from the north/northwest and swell waves make up a considerable part of the local wave climate. There is evidence of some thermal stratification in the offshore Project area, this is limited in scale and only evident from late spring until autumn. Changes in salinity correspond to the variation in temperature. The following impacts were identified as requiring assessment:

- Pre-construction, construction and decommissioning:
  - Change to seabed levels, sediment properties and suspended sediment concentrations;
  - Impact on interest features within the designated sites due to export cable construction;
  - Change to landfall morphology;
- Operation and maintenance:
  - Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors;
  - Introduction of scour;
  - Changes to water column structure with impact to stratification;
  - Re-exposure of buried cables at landfall and changes to coastal processes and landfall morphology from remedial protection measures.

The assessment has taken account of embedded mitigation measures for the assessment of potential effects. No significant impacts to any marine physical and coastal processes receptors are predicted, either for the offshore Project alone, or cumulatively with other developments. Therefore, no secondary mitigation or monitoring requirements are proposed. There are also no inter-related effects or transboundary effects associated with the Project. There is no overlap between the effects associated with the onshore Project and the impacts on marine physical and coastal processes receptors as assessed for the offshore Project.

Marine Licence applications ahead of construction may be required for seabed preparation e.g. dredging and subsequent disposal and boulder clearance. Requirements will be confirmed post-in consultation with MD-LOT.

8.1 Introduction

This chapter of the Offshore Environmental Impact Assessment (EIA) Report presents the marine physical and coastal processes receptors of relevance to the offshore Project and assesses the potential impacts from the pre-construction, construction, operation and maintenance and decommissioning of the offshore Project on these receptors. Where required, mitigation is proposed, and the residual impacts and their significance are assessed. Potential cumulative and transboundary impacts are also considered.

Table 8-1 below provides a list of all the supporting studies which relate to and should be read in conjunction with the marine physical and coastal processes impact assessment. All supporting studies are appended to this Offshore EIA Report and issued on the accompanying Universal Serial Bus (USB).

Table 8-1 Supporting studies

DETAILS OF STUDY	LOCATIONS OF SUPPORTING STUDY
Marine Physical and Coastal Processes Supporting Study (including technical appendices and modelling results)	Offshore EIA report, Supporting Study (SS) 3: Marine physical and coastal processes supporting study
Benthic Environmental Baseline Report	Offshore EIA report, Supporting Study (SS) 5: Benthic environmental baseline report
Intertidal Survey Habitat Assessment	Offshore EIA report, Supporting Study (SS) 6: Intertidal survey habitat assessment

The impact assessment presented within this chapter informs information presented within other impact assessments within this Offshore EIA Report. Reference to this chapter is provided in the relevant Offshore EIA Report chapters, where information pertaining to the marine physical and coastal processes is used to inform the respective topic specific assessments. This interaction between the impacts assessed within different topic assessment chapters on a receptor is defined as an 'inter-relationship'. The chapters and impacts related to the assessment of potential effects on marine physical and coastal processes are provided in Table 8-2.

Table 8-2 Marine physical and coastal processes inter-relationships

CHAPTER	IMPACT	DESCRIPTION
Water and sediment quality (chapter 9, Offshore EIA Report)	Change to seabed levels, sediment properties and suspended sediment concentrations	Sediments disturbed during construction can cause areas of localised contamination contained within sediment to be released into the wider environment, in addition to increases in suspended sediment concentration. This has consequences on water and sediment quality. The development and spread of a sediment plume in addition to potential increases in suspended sediment concentrations and associated deposition during construction are assessed in section 8.6.1.1 of this chapter.
	Changes to water column structure with impact to stratification	The presence of structures in the water column can have consequences for mixing. This therefore affects thermal and salinity stratification and can have an impact on water quality. Assessment of changes to water column structure are considered in section 8.6.2.3 of this chapter.
	Re-exposure of buried cables at landfall and changes to coastal processes and landfall morphology from remedial protection measures	The effect of cable protection measures on coastal processes and landfall morphology can cause disturbance of contaminants with consequences to both water and sediment quality. Assessment of re-exposure of buried cables at landfall and changes to coastal processes and landfall morphology from remedial protection measures is considered in section 8.6.2.4 of this chapter.
Benthic intertidal and subtidal ecology (chapter 10, Offshore EIA Report)	Change to seabed levels, sediment properties and suspended sediment concentrations	Sediment disturbed during construction will be deposited throughout the offshore Project area. A small proportion of finer sediments will enter into suspension and will also ultimately be deposited. This deposition can have implications for benthic species through the potential for smothering etc. Increased suspended sediment concentrations and associated deposition during construction are assessed in section 8.6.1.1 of this chapter.
	Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors	Changes to physical processes (beyond increased suspended sediment concentrations and deposition) may affect certain benthic species, for example those which are reliant on specific hydrodynamic conditions. Operational changes to flows, waves, sediment transport and the consequences on morphology and coastal receptors are assessed in section 8.6.2.1 of this chapter.
Fish and shellfish ecology (chapter 11, Offshore EIA Report)	Change to seabed levels, sediment properties and suspended sediment concentrations	Changes to seabed levels, sediment properties and suspended sediment concentrations can result in habitat disturbance or loss for fish and shellfish species directly, or for their prey. Changes to seabed levels, sediment properties and suspended sediment concentrations, both offshore and at the Crosskirk

CHAPTER	IMPACT	DESCRIPTION
		landfall (in proximity to the Forss water river mouth), are considered in section 8.6.1.1 of this chapter. The impact of suspended sediment on fish and shellfish ecology was scoped out of the assessment (see chapter 11: Fish and shellfish ecology). Effects on fish and shellfish receptors could also indirectly affect higher trophic levels such as marine mammals (chapter 12: Marine mammals and megafauna) and birds (chapter 13: Offshore and intertidal ornithology).
Shipping and navigation (chapter 15, Offshore EIA Report)	Change to seabed levels, sediment properties and suspended sediment concentrations	Changes to seabed levels can result in changes to under keel clearance with direct consequences to shipping and navigation receptors. Changes to seabed levels, sediment properties and suspended sediment concentrations are considered in section 8.6.1.1 of this chapter.
Marine archaeology and cultural heritage (chapter 16, Offshore EIA Report)	Change to seabed levels, sediment properties and suspended sediment concentrations	Sediment disturbed during construction will be deposited throughout the offshore Project area. This deposition can have implications for marine archaeology and cultural heritage receptors. Additionally, installation activities and footprints associated with installed infrastructure could potentially cause damage to, as yet undiscovered, features of archaeological significance. Change to seabed levels, sediment properties and suspended sediment concentrations is assessed in section 8.6.1.1 of this chapter.
	Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors	Changes to marine processes can result in increased erosion of features which may protect marine archaeology and cultural heritage. Additionally, this could lead to the discovery of previously unidentified features of archaeological significance etc. Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors is assessed in section 8.6.2.1 of this chapter.
	Introduction of scour	The introduction of scour can result in the potential exposure of marine archaeology and cultural heritage features. Such exposure could enhance degradation of these features but could also lead to the discovery of previously unidentified features of archaeological significance. Introduction of scour is addressed in section 8.6.2.2 of this chapter.
Other sea users (chapter 18, Offshore EIA Report)	Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors	Changes to wave regime can have consequences on recreational sea users (e.g. surfers). Additionally, changes along the coast can affect land users. Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors are assessed in section 8.6.2.1.
	Re-exposure of buried cables at landfall and changes to coastal	Re-exposure of cables can become a hazard in areas which other sea users may utilise. More generally, changes along the

CHAPTER	IMPACT	DESCRIPTION
	processes and landfall morphology from remedial protection measures	coast can affect land users. Re-exposure of buried cables at landfall and changes to coastal processes and landfall morphology from remedial protection measures are assessed in section 8.6.2.4.
Seascape, landscape and visual (chapter 20, Offshore EIA Report)	Change to coastal landfall morphology	Changes to coastal landfall morphology during construction can result in visual changes to the coast with consequences to seascape, landscape and visual receptors. Change to coastal landfall morphology is considered in section 8.6.1.3.

The following specialists have contributed to the assessment:

- Xodus Group Limited (Xodus)– marine physical and coastal processes baseline description, impact assessment, Offshore EIA Report chapter write up, and supporting technical study; and
- Ports and Coastal Solutions (PCS) – modelling of baseline and construction and operational effects and accompanying modelling calibration and results reports.

There are additional Marine Licences that may be required for certain activities that have been assessed in this chapter:

- Dredging and subsequent disposal, could entail a separate Marine Licence application to Marine Directorate - Licensing Operations Team (MD-LOT). The exact need for dredging and disposal will not be confirmed post-consent during detailed design. If dredging is required, sediment samples would be collected, analysed as required in support of the Marine Licence application; and
- Boulder clearance may also be subject to a separate Marine Licence application. Again, the requirements will be confirmed post-consent during detailed design, following this there will be consultation with MD-LOT to confirm any licensing requirements.

8.2 Legislation, policy and guidance

Over and above the legislation presented in chapter 3: Planning policy and legislative context, the following legislation, policy and guidance are relevant to the assessment of impacts from the offshore Project on marine physical and coastal processes:

- Legislation:
  - There are no specific legislative controls relevant to the scope of the marine physical and coastal processes impact assessment.
- Policy:
  - Scotland's National Marine Plan (NMP). General Policy 8 (Scottish Government, 2015). This policy deals with coastal process and flooding, whereby developments and activities in the marine environment should be resilient to coastal change and flooding, and not have unacceptable adverse impact on coastal processes or

contribute to coastal flooding. An important consideration is the potential for coastal erosion and associated flooding;

  - Pilot Pentland Firth and Orkney Water Marine Spatial Plan. General Policy 5B (Scottish Government, 2016). This policy again considers coastal process and flooding and is the implementation of Scotland's NMP for the Pentland Firth and Orkney Water marine region;
  - Orkney Islands Regional Marine Plan (OIRMP) (Consultation Draft). General Policy 7 (Orkney Islands Council (OIC), 2023). General Policy 7 of the OIRMP relates to coastal development and coastal change and necessitates the consideration of coastal processes and developments in the marine environment should not adversely significantly affect coastal processes.
- Guidance[1]:
  - Advice to Inform Development of Guidance on Marine, Coastal and Estuarine Physical Processes Numerical Modelling Assessments. Report No 208 (NRW, 2017). Presents a review and outline of best practice in developing, evaluating and implementing numerical modelling for developments / assessments within the marine environment;
  - Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to Inform EIA of Major Development Projects. Report No 243 (NRW, 2018). Sets out best practice for baseline data needed to inform marine and coastal processes impact assessments and the appropriate acquisition and interpretation of relevant survey data;
  - Guidance Note. Marine Physical Processes Guidance to inform Environmental Impact Assessment (EIA). GN041 (NRW, 2020). The guidance summarises the key methods and approaches presented in the NRW (2017) and NRW (2018) guidance documents required in order to inform impact assessment for marine and coastal processes;
  - Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment: Best Practice Guidance (COWRIE, 2009)[2]. Provides best practice guidance on the development, calibration, validation and implementation of numerical modelling for offshore wind developments; and
  - Advice on key sensitivities of habitats and Marine Protected Areas in English Waters to offshore wind farm cabling within Proposed Round 4 leasing areas (Natural England and JNCC, 2019). This summarises the Statutory Nature Conservation Bodies (SNCB) advice on habitat sensitivities within Marine Protected Areas (MPA) particularly relating to cabling activities from Round 4 leasing areas.

8.3 Scoping and consultation

Stakeholder consultation has been ongoing throughout the EIA and has played an important part in ensuring the scope of the baseline characterisation and impact assessment are appropriate with respect to the offshore Project and the requirements of the regulators and their advisors.

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[1] *Please note, some of this guidance applies to other jurisdictions (England and Wales), however has been included here because it provides relevant industry standards and best practice which are applicable to the offshore Project.*

[2] *Despite the age of this guidance, it is continually applied in the impact assessment for a range of Offshore Wind Farm (OWF) developments across the UK and is a recognised industry best practice.*

The Scoping Report (OWPL, 2022a) was submitted to Scottish Ministers (via Marine Scotland Licencing and Operations Team (MS-LOT)[3]) and The Highland Council (THC) on 1st March 2022[4]. MS-LOT circulated the Scoping Report to consultees relevant to the offshore Project, and a Scoping Opinion was received from MS-LOT on 29th June 2022. Relevant comments from the Scoping Opinion specific to marine physical and coastal processes are provided in Table 8-4 below, which provides a response on how these comments have been addressed within the Offshore EIA Report.

Further consultation has been undertaken throughout the pre-application stage (see Table 8-3). The list below summarises the consultation activities carried out relevant to marine physical and coastal processes:

Table 8-3 Consultation activities for marine physical and coastal processes

CONSULTEE AND TYPE OF CONSULTATION	DATE	SUMMARY
Consultation Meeting		
NatureScot, OIC and THC	29th June 2022	Provided a summary of the surveys being completed of relevance to the marine and coastal physical processes, water and sediment quality, benthic and intertidal ecology and fish and shellfish ecology topics. Also provided some initial responses to questions presented in the Scoping Opinion (MS-LOT, 2022) and requests for further clarification where the request was not clear in the Scoping Opinion.
Numerical Modelling Method Statement	August 2022	A Method Statement was produced detailing the approach to hydrodynamic, wave and sediment transport modelling of baseline and post-construction conditions, supported by site-specific data. This document was provided in response to Scoping Opinion comments and was sent to Marine Scotland[5] and NatureScot for consultation to ensure agreement of the approach with relevant consultees. NatureScot in turn consulted with the JNCC with respect to the North-West Orkney Nature Conservation Marine Protected Area (NCMPA). Response was received from NatureScot.
NatureScot, OIC and THC	4th October 2022	Discussion on the Methods Statement and process for identification of designated sites for inclusion in the assessment. Consultees also emphasised the need for the EIA should provide full justification on why

[3] *MS-LOT have since been renamed Marine Directorate Licensing Operations Team (MD-LOT).*

[4] *The Scoping Report was also submitted to the Orkney Islands Council (OIC), as the scoping exercise included consideration of power export to the Flotta Hydrogen Hub, however, this scope is not covered in the Offshore EIA Report and will be subject to separate Marine Licence and onshore planning applications.*

CONSULTEE AND TYPE OF CONSULTATION	DATE	SUMMARY
		the modelling approach (specifically regarding wave directionality in the model).
NatureScot	26th October 2022	Update was provided on the status of the metocean, geophysical and benthic surveys and discuss on the approach to the numerical modelling and analytical approaches used to inform the marine physical and coastal processes topic. In line with information presented in the Method Statement (OWPL, 2022b), information was presented on the hydrodynamic and wave numerical modelling for construction and operation impacts and the analytical approaches to evaluating sediment transport, deposition, blockage effects, coastline change and water column mixing. The definition of the study area was presented, along with the justification for scoping out the North-West Orkney NCMPA from the marine physical and coastal processes topic. Confirmation was provided that no baroclinic modelling was to be completed for water column properties. Following the consultation meeting, confirmation was received from NatureScot for the North-West Orkney Nature Conservation Marine Protected Area (NCMPA) to be scoped out from the marine physical and coastal processes topic. Confirmation was also received of the presented analytical approach for assessing sediment transport.
Marine Scotland Science	16th November 2022	MS-LOT quarterly update and consultation comments, received by email. MS-LOT had no further comment and deferred to NatureScot for matters relating to the marine physical and coastal processes topic.

Table 8-4 Comments from the Scoping Opinion consultation responses specific to marine physical and coastal processes

CONSULTEE	COMMENT	RESPONSE
Scottish Ministers (via MS-LOT)	The Scottish Ministers are broadly content with the proposed study area outlined in section 2.1.2 of the Scoping Report. For the avoidance of doubt, potential impacts out with the study area, in particular to the Marine Geomorphology of the Scottish Shelf Seabed feature of the North-West Orkney Nature Conservation ("NC") MPA, should be considered in line with the NatureScot representation and MSS advice. In regard to the baseline information detailed in Table 2-1 of the Scoping Report, the Scottish Ministers highlight the representation from NatureScot and advise that the 'Dynamic Coast' project data source should be updated to the 'Dynamic Coast 2' mapping project. Additionally, in relation to data sources, the Scottish Ministers recommend that the advice provided by MSS is fully considered.	The study area has been defined on the basis of the maximum tidal excursion. Receptors within the study area are addressed directly, inclusive of relevant designated interest features within designated sites should they overlap with the study area. The North-West Orkney NCMPA does not overlap with the study area (i.e. based on a 10 km and 15 km buffer around the OAA and offshore Export Cable Corridor (ECC) respectively, section 8.4.1) and therefore the North-West Orkney NCMPA has not been included within the impact assessment presented herein. This approach was accepted by NatureScot during consultation on the 26th June 2022. Furthermore, it is noted that the potential for stratification and fronts is not listed as a designated interest feature within the North-West Orkney NCMPA, and neither is the potential for fronts or stratification a supporting mechanism for the designated interest features within the NCMPA. There is therefore not considered to be any pathway between the offshore Project and impacts on the North-West Orkney NCMPA warranting inclusion in the impact assessment. Information from the updated Dynamic Coast 2 study has been incorporated into the data sources. Advice provided by Marine Scotland Science (MSS) have been considered throughout. Responses have been provided to the specific points where relevant.
Scottish Ministers (via MS-LOT)	The Scottish Ministers broadly agree with the potential impacts scoped in for further assessment in the EIA Report as contained within Table 2-5 of the Scoping Report. However, in line with the NatureScot representation the Scottish Ministers advise that changes to coastal processes, resulting from measures to secure re-exposed cables at landfall, must also be scoped into the EIA Report. In line with advice provided by MSS, the Scottish Ministers advise that the potential changes to water column structure must also be scoped into the EIA Report. The Scottish	Re-exposure of buried cables at and changes to coastal processes and landfall morphology from remedial protection measures has now been scoped in for assessment (section 8.6.2.4). Per consultee advice, changes to water column structure with impact to stratification have been considered in the assessment (section 8.6.2.3).

CONSULTEE	COMMENT	RESPONSE
	Ministers advise that the Developer must fully address the MSS advice in this regard.	
Scottish Ministers (via MS-LOT)	For the impact pathways scoped in to the EIA Report, the Scottish Ministers advise that the full range of mitigation techniques and published guidance is considered and discussed in the EIA Report. The Scottish Ministers highlight the NatureScot representation and advise that in addition to the designated sites listed in table 2-2, impacts from the Proposed Development on the geological designated features of the Non-marine Devonian in Red Point Coast Special Site of Scientific Interest ("SSSI") and of the Moine in Strathy Coast SSSI, must be assessed in the EIA Report.	Embedded project mitigation measures relevant to marine physical process properties and receptors are detailed within section 8.5.4 (chapter 8: Marine physical and coastal processes, Offshore EIA Report). At the same time best practice guidance has been considered. Impacts on geological features within designated sites which overlap with the study area (including the Non-marine Devonian feature in Red Point Coast SSSI and the Moine feature in Strathy Coast SSSI) are considered in section 8.6.1.2.
Scottish Ministers (via MS-LOT)	In regards to the proposed assessment approach, the Scottish Ministers advise that sufficient evidence must be provided to justify the simplified approach. The MSS advice in this regard must be addressed in full by the Developer in the EIA Report.	Hydrodynamic, wave and sediment transport modelling of baseline and post-construction conditions, supported by site-specific data has been produced as detailed in SS3: Marine physical and coastal processes supporting study.. A Method Statement was prepared providing detail on the proposed assessment approach, with particular focus on the modelling approach (OWPL, 2022b). The assessment approach was established and informed through consultation with NatureScot (including advice from JNCC) who approved the proposed approach in a consultation meeting held in 4th October 2022 (Table 8-3) and through a confirmation email received on 26th October 2022 (Table 8-3). Marine Scotland Science were also informed of the modelling approach, with no further comment on the approach received in email communication on 16th November 2022.
Scottish Ministers (via MS-LOT)	In section 2.1.6 of the Scoping Report the Developer has listed the onwards impacts to other EIA topics. The Scottish Ministers draw the attention of the Developer to the representation from OIC and advise that the impacts of historic environment assets, and landscape and seascape, should be included and scoped into the EIA Report in addition to the impacts summarised in Table 2-5 of the Scoping Report.	As provided in response to OIC, it is agreed that physical processes can be pathways to onward impacts to archaeology and historic environment assets and to a certain degree landscape and seascape. Relevant information on potential changes to the physical environment as a result of the development, has been shared with other topic receptors and assessed in their respective impact assessments. Project inter-relationships are detailed in section 8.1.

CONSULTEE	COMMENT	RESPONSE
Scottish Ministers (via MS-LOT)	In section 2.1.9.1 of the Scoping Report the Developer details the approach and the tools that will be used to assess the nature and magnitude of any impacts to physical and coastal process from the Proposed Development. The Scottish Ministers highlight the representation from OIC regarding the need to assess cable landfall, cable laying, cable protection and transition joints bay work within the EIA Report. Additionally, the Scottish Ministers highlight the advice from NatureScot in relation to consultation prior to undertaking the proposed hydrodynamic modelling. The Scottish Ministers advise that the Developer must fully address the points raised by NatureScot, OIC and MSS within the EIA Report.	An additional impact has been added for assessment within the Offshore EIA Report as described in Table 8-10, which is as follows "Re-exposure of buried cables at and changes to coastal processes and landfall morphology from remedial protection measures". NatureScot has been consulted on the numerical modelling method statement (agreed on the 26th October 2022). It should be noted that as the transition joint bay works will be located above Mean High Water Springs (MHWS), they have not been considered within this Offshore EIA Report. They have been considered within the Onshore EIA Report, a summary of which can be found within chapter 21: Onshore EIA summary. Due to the fact export of power to the Flotta Hydrogen Hub isn't part of the current application, it has not been necessary to assess the potential impacts and associated processes (sediment transport, erosion, accretion, blockage, sediment character, and so on) of landfall works on the Orkney coastline. However, the impacts and associated processes have been considered for the two landfall location options presented in the EIA.
Scottish Ministers (via MS-LOT)	With regards to cumulative assessment, the Scottish Ministers advise that the Developer consider the impacts from other types of construction, aquaculture and port and harbour construction within the EIA Report in line with the NatureScot representation and MSS advice.	A project long list and zone of influence has been used to identify the range of ongoing and new potential developments to assess for cumulative effects on marine physical processes properties (waves, tides, sediment transport and so on). The developments which are considered likely to interact with the proposed Project are considered cumulatively in section 8.7.
Scottish Ministers (via MS-LOT)	If there is any potential for cable protection to be used, this must be assessed in the EIA Report including details on materials, quantities and location. In addition, any seabed levelling or removal of substance or objects from on or under the seabed, required for installation of both the inter-array cables and export cables, will require consideration in the EIA Report and may require a Marine Licence. Should seabed preparation involve dredging, the EIA Report must identify the quantities of dredged material and identify the likely location for deposit. The	The options for and potential lengths of cable requiring protection of cable are described in chapter 5: Project description, in the Offshore EIA. Specific locations of cable protection installation are not known at the current time. Seabed preparation activities, including dredging have been assessed in the EIA, but not included in the Project Marine Licence application as the specific deposit

CONSULTEE	COMMENT	RESPONSE
	Developer may also be required to submit pre-dredge sample analysis, this should include supporting characterisation of the new or existing deposit sites. The Scoping Report at section 2.1.4.1.1 identifies that boulders are likely to be present at the site of the Proposed Development. The EIA Report must provide the anticipated estimate of boulders to be cleared (including how much uncertainty may be associated with the figures presented). Clear narrative must be provided within the EIA Report to show how this has been estimated.	location is still to be confirmed, i.e. already licenced site, or Project specific location. Boulder clearance is expected to be required ahead of construction. An estimation of the areas of boulders to be removed are provided in Table 10-15 (chapter 9: Marine physical and coastal processes, Offshore EIA Report) and the potential impacts associated with this clearance has been assessed in Section 10.6.1. Final boulder clearance requirements (e.g. in terms of number of boulders), will be defined during detailed design following which there will be consultation with MD-LOT to confirm any licencing requirements
MSS	MSS agree with NS comments and have the following responses to the questions listed in the Scoping Report. In particular, we have some recommendations regarding the proposed assessment approach.	Noted, and responses have been provided to each respective comment.
MSS	The study areas should be extended to include the whole of North-West Orkney NCMPA, to account for possible changes to stratification.	The study area is defined on the basis of the mean spring tidal excursion distance, which is considered to be appropriate to capture effects that extend beyond the offshore development. This includes effects associated with pathways for tidal advection of sediment plumes from seabed disturbance activities and the extent of wakes and water column mixing due to flows and waves passing individual foundations and the wider array. The proposed study area is described in Section 8.4.1 and it is noted that the extents do not overlap with the North-West Orkney Nature Conservation Marine Protected Area (NCMPA) (Figure 8-6). Therefore, the NCMPA has not been included within the study area or impact assessment presented herein. This approach was accepted by NatureScot during consultation on 26th June 2022 (Table 8-3). Furthermore, as discussed in section 8.6.2.3, the assessment of impact regarding changes to the water column defined the predicted magnitude of impact to be low. Overall, given the scale of the offshore Project in the context of processes such as stratification, no significant impact was determined.

CONSULTEE	COMMENT	RESPONSE
MSS	2.1 Physical and Coastal Processes: There are a number of West Orkney Windfarm personal communications, 2021, regarding residual circulation, sediment transport, and non-tidal current speeds in the study area. We recommend that more rigorous references are provided. 2.1.4.1.6 Frontal Zones: The DECC (2016) reference is not listed in the reference list. MSS assume it is the DECC data source listed in the "Hydrodynamics and Waves" section on page 58.	Noted. The information in 2.1 Physical and Coastal Processes (of the Scoping report) regarding residual circulation, sediment transport, and non-tidal current speeds in the study area originated from bid documentation. These references have now been updated, are largely relates to OWPL (2023) West of Orkney Windfarm EIA Metocean Design Basis, which has been referenced throughout. This is correct, the DECC (2016) reference is to the UK Offshore Energy Strategic Environmental Assessment 3 (OESEA3) section on the water environment.
MSS	We advise consideration of the following data sets: • Scottish Shelf Waters Reanalysis Service: https://tinyurl.com/SSW-Reanalysis ; • Cefas WaveNet data: https://wavenet.cefas.co.uk/	These datasets have been incorporated into the study as listed in the data sources (section 8.4.2) to inform modelling and characterisation of the baseline environment in section 8.4.4.
MSS	The North-West Orkney NCMPA appears to be an omission, and should be considered, with respect to potential changes to extent and timing of seasonal stratification.	The potential for and timing of stratification within the OAA has been explored based on site-specific surveys and using information from three-dimensional (3D) baroclinic models, such as the Atlantic – European North West Shelf – Ocean Physics Reanalysis, available from Copernicus Marine. It should also be noted that the potential for stratification and fronts is not listed as a designated interest feature within the North-West Orkney NCMPA. However, as discussed above, the North-West Orkney NCMPA was scoped out, with the assessment approach agreed in consultation with NatureScot during consultation on 26th June 2022 (Table 8-3), with no further comment from Marine Scotland Science received in email communication on 16th November 2022.
MSS	The proposed approach to sediment modelling is pragmatic, although sufficient evidence should be provided to justify this simplified approach.	Hydrodynamic, wave and sediment transport modelling of baseline and post-construction conditions, supported by the site-specific data has been undertaken to support this assessment, the approach and results of the modelling are provided in SS3: Marine physical and coastal processes supporting study.

CONSULTEE	COMMENT	RESPONSE
		Agreement of the modelling approach presented in the method statement was provided in email communication received on 26th October (Table 8-3). Prior to completion of the assessment, a Method Statement was produced and the approach to modelling was finalised through consultation with NatureScot (who sought advice from the JNCC).
MSS	Very few details of the numerical modelling approach have been provided and we recommend that a detailed method statement is provided prior to modelling work being undertaken, including details of sediment modelling. This should include modelling methodology, such as boundary forcing data sources, model resolution, whether the model is 2D or 3D and how wind farm structures will be represented.	The Method Statement (OWPL, 2022b) set out the proposed hydrodynamic, wave and sediment transport modelling of baseline and post-construction conditions. This was provided for consultation and responses from consultees including agreement of the proposed approach was obtained from NatureScot through email communication on 26th October 2022 (Table 8-3), with no further comment from MS-LOT received in email communication on 16th November 2023 (Table 8-3).
MSS	An additional impact that should be investigated is the potential for changes to water column structure including timing and extent of seasonal stratification. Whether the windfarm is likely to change the extent and timing of stratification should be scoped into the EIA. A (floating) windfarm could change water column mixing, as structures can generate turbulent wakes, and/or by altering the near sea surface wind speeds (Christiansen *et al.* 2022, Durrell *et al.* 2022). The applicant should provide details of the baseline water column conditions, including the extent and timing of stratification. Qualitatively considering how the windfarm could alter these processes may be a pragmatic/proportional approach as long as sufficient evidence is provided, e.g. good baseline description, using data from 3D hydrodynamics models, and citing research evidence. If there are uncertainties as to how the wind farm may change stratification, then 3D hydrodynamic modelling may be required. Changes to mixing have the potential to impact other receptors, such as productivity as well as higher trophic levels, and this should also be qualitatively considered in the EIA. Impact on NCMPAs where fronts are a designated feature should be considered. When considering	Floating foundations are no longer under consideration for the current application. An additional impact has been added for assessment within the EIA as described in Table 8-10, which is as follows "Changes to water column structure with impact to stratification". In completing the assessment for this impact, no 3D hydrodynamic modelling has been undertaken. This approach was agreed through consultation with NatureScot on the 26th October 2022 (Table 8-3). Instead the potential for and timing of stratification within the OAA has been explored based on site-specific surveys and using information from 3D baroclinic models, such as the Atlantic – European North West Shelf – Ocean Physics Reanalysis, available from Copernicus Marine. The assessment of potential impacts linked to increased mixing due to OWF foundation structures, has been completed qualitatively on the basis of the acquired site-specific temperature and salinity in addition to available secondary information from completed OWF developments elsewhere, such as that discussed for the DanTsyk OWF in Schultze *et al.* (2020).

CONSULTEE	COMMENT	RESPONSE
	potential cumulative impacts, regional tidal stream developments (e.g. in the Pentland Firth) should also be considered.	Please refer to the previous responses with respect to the NCMPA and fronts as designated features.
MSS	Do you agree with the suggested embedded mitigation measures and is this mitigation appropriate? Yes	Noted, see Section 8.5.4
MSS	Do you agree with scoping out transboundary impacts? Yes	Noted, see Section 8.10
NatureScot	We are content with the study areas proposed including the consideration of 'both near field and far field effects', which should include potential impacts on receptors outwith the study area, in particular the Marine Geomorphology of the Scottish Shelf Seabed feature of the North-West Orkney NCMPA.	The study area has been defined on the basis of the maximum tidal excursion (see section 8.4.1). Receptors within the study area are directly addressed, inclusive of relevant designated interest features within designated sites should they overlap with the study area. Notably, the study area does not overlap with the NCMPA, so there is not considered to be a pathway for impacts (please see above responses regarding inclusion of the NCMPA). This approach has been agreed through consultation with NatureScot.
NatureScot	We agree that the relevant data sources have been included in Table 2-1 (Section 2.1.3) apart from the inclusion of the 2017 initial outputs of the Dynamic Coast project. We recommend that the data source should be changed to the 2021 'Dynamic Coast 2' mapping project, which supersedes that from 2017 to take account of future sea-level rise.	The updated Dynamic Coast 2 study has been used to as a data source to inform the EIA (see section 8.4.2).
NatureScot	Table 2-2, Section 2.1.4.1.9, lists the relevant designated sites that may be impacted. The following geological notified features of designated sites that could potentially be impacted and therefore should be added to those	Impacts on geological features within designated sites which overlap with the study area (including the Non-marine Devonian feature in Red Point Coast SSSI and the Moine feature in Strathy Coast SSSI) are considered in section 8.6.1.2.1.

CONSULTEE	COMMENT	RESPONSE
	considered 'relevant' include Non-marine Devonian in Red Point Coast SSSI and Moine in Strathy Coast SSSI.	
NatureScot	We are broadly content with the impacts that are scoped in. However, we recommend the following additional impact should also be scoped in for assessment: Change to coastal processes and landforms resulting from measures to address any re-exposure by coastal change of a buried cable landfall.	An additional operational impact is proposed, which is as follows "Re-exposure of buried cables at and changes to coastal processes and landfall morphology from remedial protection measures". This impact is assessed in section 8.6.2.4.
NatureScot	Due to accelerating sea-level rise, some landfall locations could experience coastal retreat over decades, manifested as periodic beach lowering and erosion of the coastal edge during clusters of storms. If this resulted in re-exposure of buried cable(s), then work to secure the cable(s) such as re-burial or installation of hard protection, could affect coastal processes and landforms. Robust planning for this eventuality would help adapt the overall project to one of the key effects of climate change.	The baseline characterisation at the landfall locations identified the coastline to mainly comprise of rock and to be stable (i.e. not eroding). Based on the geological substrates at the coast, it is considered that the same properties are expected to continue as part of the future baseline. As the landfall methodology is to include HDD, with a minimum HDD exit depth of 10 m Lowest Astronomical Tide (LAT), the potential for re-ex-exposure of cables is considered to be limited. Nonetheless, an additional operational impact is proposed, which is as follows "re-exposure of buried cables at and changes to coastal processes and landfall morphology from remedial protection measures", to account for any potential influence of protection measures. This impact is assessed in section 8.6.2.4. The coastline where the offshore ECC landfall will occur consists of erosion resistant rock. To date, the coastline is considered to be stable and there is no evidence of erosion. Further detail is provided in chapter 8: Marine physical and coastal processes.
NatureScot	We are generally content with the assessment methods described in Section 2.1.9. However, at present there isn't any detail on the proposed hydrodynamic modelling. We recommend the methods for modelling (and analysis of sediment transport), including how results would be presented, should be the subject of	A method statement, which set out the proposed hydrodynamic, wave and sediment transport modelling of baseline and post-construction conditions was submitted to Marine Scotland and consulted on by NatureScot (OWPL, 2022b). This approach was accepted by NatureScot in email communication received on 26th October 2022 (Table 8-3).

CONSULTEE	COMMENT	RESPONSE
	technical consultation to relevant consultees including NatureScot, prior to the modelling being undertaken.	The approach was accepted by NatureScot in email communication received on 26th October 2022.
NatureScot	Where impact pathways have been identified and are scoped in, we advise that the full range of mitigation techniques and published guidance is considered and discussed in the EIA Report.	Embedded project mitigation measures relevant to marine physical process properties and receptors are detailed within section 8.5.4. At the same time best practice guidance has been considered.
NatureScot	We advise that there are unlikely to be any transboundary impacts.	Noted, see section 8.10. Due to the localised nature of impacts on physical and coastal processes, transboundary effects for marine physical and coastal processes receptors have not been considered further.
OIC	It is stated that 'As pathways, physical and coastal processes have the potential to lead to changes with onward impacts to receptors associated with other EIA topics, including but not limited to: • Water and sediment quality; • Commercial fisheries; • Benthic ecology; • Shipping and navigation; • Fish and shellfish ecology; and • Other sea users. This should include archaeology and historic environment assets, and landscape and seascape. Also include these topics in Table 2-5 EIA Scoping Assessment for Physical Processes.	Inter-relationships between marine physical and coastal processes have been described in Table 8-2, inclusive of marine archaeology and cultural heritage and seascape, landscape and visual.
OIC	Cable landfall, laying, protection and transition joints bay works should be assessed to addressed significant effects on coastal processes. Significant adverse effects on coastal infrastructure, culture/historic assets, coastal/marine habitats, species and geomorphological features, including due to, but not limited to,	Due to the fact export of power to the Flotta Hydrogen Hub isn't part of the current application, it has not been necessary to assess the potential impacts and associated processes (sediment transport, erosion, accretion, blockage, sediment character, and so on) of landfall works on the Orkney coastline.

CONSULTEE	COMMENT	RESPONSE
	erosion, sediment transport, accretion, scouring and/or coastal flooding, should be avoided, minimised and/or appropriately mitigated. The proposed development should not increase risks from coastal erosion, flooding and/or wider coastal change.	
SEPA	We recommend Dynamic Coast 2 data set is added to the list for the Orkney Landfalls but there do not appear to be any potential landfalls that would be in/influenced/in the vicinity to future projected erosion scenarios in the Caithness landfall areas.	The updated Dynamic Coast 2 study has been used as a data source to inform the EIA.

8.4 Baseline characterisation

This section outlines the baseline for marine physical and coastal processes within the marine physical and coastal processes offshore study area. The baseline characterisation provides a description of physical features in the marine environment which may be influenced by offshore Project activities. These features include the local seabed, adjacent coastline, and properties of the water column (particularly waves, tides and turbidity). This description helps to establish the reference condition against which the potential physical effects of the development are assessed.

In addition, the baseline represents the marine physical and coastal processes conditions that are expected to prevail without any development taking place and with consideration of a duration equivalent to that of the offshore Project. Given that the offshore Project timescale spans several decades (e.g. up to four years for construction, with some pre-construction activity in the year ahead of construction, and an anticipated 30 years for operation), baseline variability over this period is also a consideration, including the likely effects of climate change.

The baseline characterisation has been informed by a combination of desk-based studies and site-specific surveys (which are summarised in section 8.4.3). As part of the process undertaken for the EIA, numerical modelling of potential impacts associated with the Project was conducted. Where relevant, the model outputs have been used to inform the baseline. A number of publicly available data sets and published scientific literature have also been utilised throughout the baseline. The publicly available data sources and site-specific survey information which have contributed to the characterisation of the baseline are presented in full in sections 8.4.2 and 8.4.3 respectively.

8.4.1 Study area

The marine physical and coastal processes study area ("study area") has been established using a 10 km buffer around the Option Agreement Area (OAA) and a 15 km buffer around the offshore ECC; this is shown in Figure 8-1. This is based on the mean spring tidal excursion distance from the UK Atlas of Marine Renewable Energy Resources meso-scale model (ABPmer, 2008). Different buffer distances are applied between the OAA and offshore ECC to account for the variation in excursion distance between the two Project elements. The proximity of the export cable to faster and stronger flows through the Pentland Firth between the Scottish mainland and Orkney Islands accounts for the larger excursion distance for the offshore ECC. The landward boundary of the study area is MHWS.

Water depths within the OAA range from 41 mLAT and 100 mLAT. Two morphological bedforms, namely Whiten Head Bank and Stormy Bank occur within the OAA and coincide with the locations of the shallowest depths within the OAA (Ocean Infinity, 2023a). Within the offshore ECC, the water has a maximum depth of 110 mLAT which gets shallower until landfall is achieved (Ocean Infinity, 2023b,c).

The applied buffer (10 km and 15 km for the OAA and offshore ECC, respectively) is considered to be appropriate on the basis of regional flow characteristics, to capture effects that extend beyond the offshore Project. This includes effects associated with pathways for tidal advection, net drift and dispersion of sediment plumes from seabed disturbance activities and the extent of wakes and water column mixing due to flows and waves passing individual foundations and the wider array. The applied study area has been agreed with the Regulator (i.e. MD-LOT) and consultees (i.e. NatureScot and Marine Scotland Science) through the consultation process (section 8.3). The proposed marine physical and coastal processes study area is to enable the impact assessment; a wider region has been applied for the numerical modelling as described in SS3: Marine physical and coastal processes supporting study.

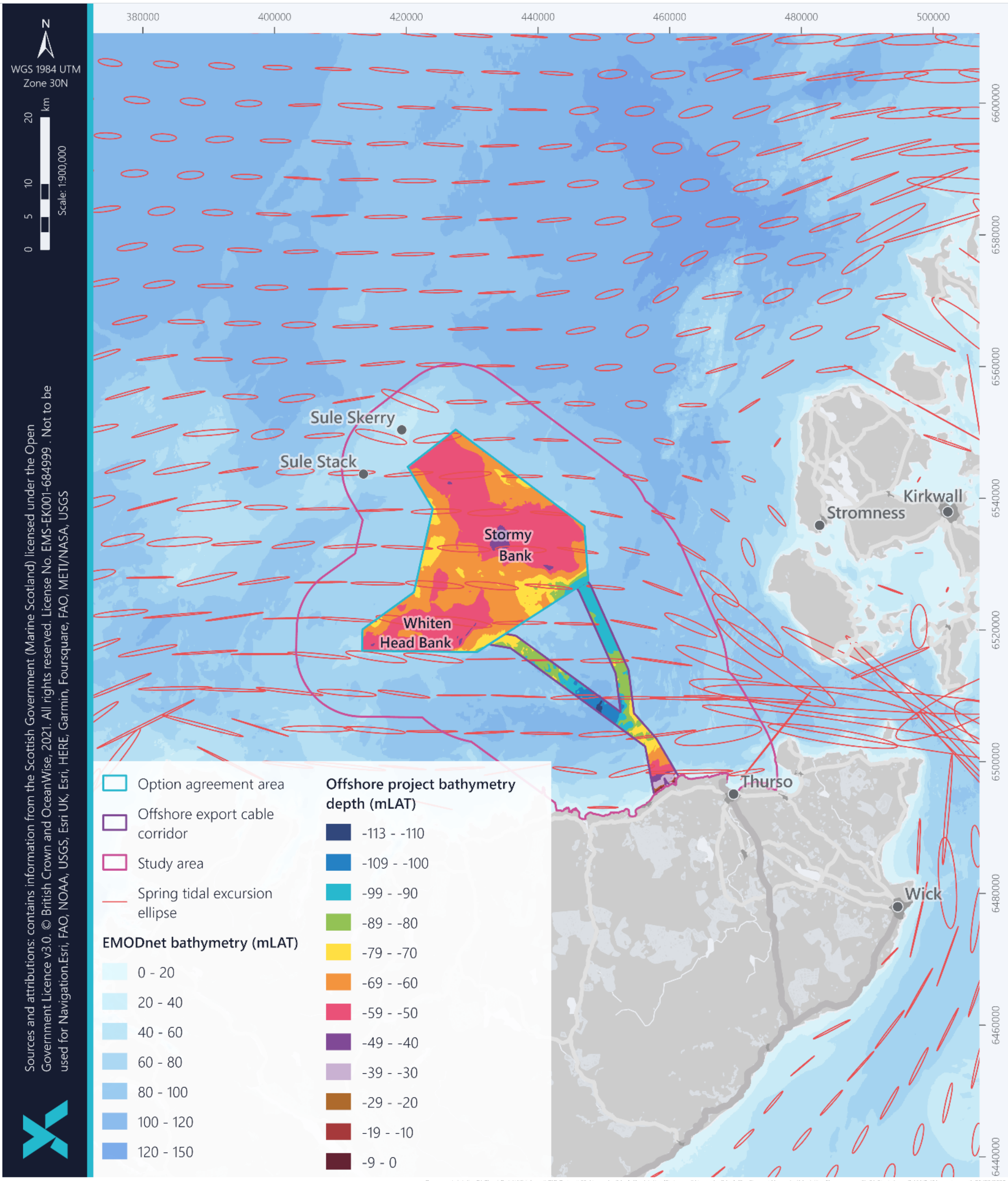

Figure 8-1 Marine physical and coastal process study area[6]

[6] *It is standard practice is present the EMODnet bathymetry data as positive numbers, while the Project specific bathymetry is provided as minus number. Regardless of the values sign both are presenting the water depth.*

8.4.2 Data sources

In addition to the site-specific surveys and hindcast data acquired for the offshore Project described in section 8.4.3, a number of published data sources have been used to inform this topic as summarised in Table 8-5.

Table 8-5 Data sources used to inform the marine physical and coastal processes assessment

	DATA	SOURCE	YEAR
General	Marine Scotland Data Portal	https://marine.gov.scot/data/marine-scotland-data-portal	2023
	Marine Scotland NMPI maps	https://marinescotland.atkinsgeospatial.com/nmpi/	2023
	Offshore Wind Energy in Scottish Waters Regional Locational Guidance	https://www.gov.scot/publications/sectoral-marine-plan-regional-locational-guidance/documents/	2020
	Coasts and seas of the United Kingdom, Region 3 North-east Scotland: Cape Wrath to St. Cyrus	https://data.jncc.gov.uk/data/6473ed35-d1cb-428e-ad69-eb81d6c52045/pubs-csuk-region-03.pdf	1996
	NatureScot SiteLink (information on designated sites)	https://sitelink.nature.scot/home	Variable
Sediments, geology and geomorphology	British Geological Survey (BGS) Offshore GeoIndex Map	https://mapapps2.bgs.ac.uk/geoindex_offshore/home.html	2020
	Institute of Geosciences borehole records	https://mapapps2.bgs.ac.uk/geoindex_offshore/home.html	Variable
Bathymetry	United Kingdom Hydrographic Office (UKHO) bathymetry from the INSPIRE data portal	https://www.gov.uk/guidance/inspire-portal-and-medin-bathymetry-data-archive-centre	Variable
	EMODnet Bathymetry	https://www.emodnet-bathymetry.eu/	2022
	Marine Scotland bathymetry: Farr Point, West and North Orkney and Pentland Firth	http://marine.gov.scot/information	Variable
Waves, flows and water levels	British Oceanographic Data Centre (BODC) current metre series for a number of sites between 1971 and 2021	https://www.bodc.ac.uk/data/bodc_database/currents/search/	2021

	National Tidal and Sea Level Facility (NTSLF)- Observational Water Level Records	https://www.ntslf.org/	2022
	WaveNet wave buoy data	https://wavenet.cefas.co.uk/map	2022
	Costa Head metocean, Acoustic Dopper Current Profiler (ADCP) data and report	The Crown Estate Marine Data Exchange	2013
	The Scottish Shelf Model. Part 2: Pentland Firth and Orkney Waters (PFOW) Sub-Domain	https://marine.gov.scot/information/pentland-firth-and-orkney-waters-model#:~:text=The%20Pentland%20Firth%20and%20Orkney%20Waters%20(PFOW)%20is%20an%20important,total%20Scottish%20tidal%20stream%20resource	2016
	Scottish Shelf Waters Reanalysis Service	https://tinyurl.com/SSW-Reanalysis	2020
	Pentland Firth and Orkney Waters Climatology 1.02	https://data.marine.gov.scot/dataset/pentland-firth-and-orkney-waters-climatology-102 O'Hara and Campbell	2021
	UKHO Admiralty TotalTide	Software	2022
	SEASTATES Metocean Data and Statistics Interactive Map	https://www.seastates.net/explore-data/	1979 - 2022
	UK Climate Projections (UKCP) 18	https://www.metoffice.gov.uk/research/approach/collaboration/ukcp	2022
Stratification and frontal systems	Atlantic – European North West Shelf – Ocean Physics Analysis and Forecast	https://resources.marine.copernicus.eu/product-detail/NORTHWESTSHELF_ANALYSIS_FORECAST_PHY_004_013/INFORMATION (https://doi.org/10.48670/moi-00054)	2021
	Atlantic – European North West Shelf – Ocean Physics Reanalysis	https://resources.marine.copernicus.eu/product-detail/NWSHELF_MULTIYEAR_PHY_004_009/INFORMATION (https://doi.org/10.48670/moi-00059)	2019
	Pentland Firth and Orkney Waters Climatology 1.02	https://data.marine.gov.scot/dataset/pentland-firth-and-orkney-waters-climatology-102 O'Hara and Campbell	2021
	BODC Conductivity Temperature Depth (CTD) Records for a number of sites between 1971 and 2021	https://www.bodc.ac.uk/data/bodc_database/ctd/search/	2019

	Frequent locations of oceanic fronts as an indicator of pelagic diversity: Application to marine protected areas and renewables.	Miller and Christodoulou	2014
	Emergence of Large-Scale Hydrodynamic Structures Due to Atmospheric Offshore Wind Farm Wakes	Christiansen *et al.*	2022
	Increased mixing and turbulence in the wake of offshore wind farm foundations	Schultze *et al.*	2020
	Anthropogenic Mixing in Seasonally Stratified Shelf Seas by Offshore Wind Farm Infrastructure	Dorrell *et al.*	2022
	Potential Impacts of Offshore Wind Farms on North Sea Stratification	Carpenter *et al.*	2016
	Unstructured grid modelling of offshore wind farm impacts on seasonally stratified shelf seas	Cazenave *et al.*	2016
Coastal morphology	Dynamic Coast 2	https://www.dynamiccoast.com/	2020
	Coastal Cells in Scotland: Cell 4 – Duncansby Head to Cape Wrath	https://www.dynamiccoast.com/files/Ramsay_Brampton_Cell_04.pdf	2000
	Dynamic Coast 1 – Dynamic Coast – National Coastal Change Assessment: Cell 4 – Duncansby Head to Cape Wrath	https://www.dynamiccoast.com/files/reports/NCCA%20-%20Cell%204%20-%20Duncansby%20Head%20to%20Cape%20Wrath.pdf	2017

8.4.3 Project site-specific surveys and studies

8.4.3.1 Geophysical surveys

Details of the completed site-specific surveys are provided in SS3: Marine physical and coastal processes supporting study, with a summary provided here as relevant.

8.4.3.1.1 Offshore

Ocean Infinity were contracted by OWPL to conduct a geophysical survey across the offshore Project area between April and September in 2022, in order to characterise the seabed conditions and geological substrate. The geophysical data acquired during the survey consisted of:

- Multibeam Echo Sounder (MBES) bathymetry and backscatter;
- Side-scan sonar (SSS) both low frequency (LF) 300 kilohertz (kHz) and 600 kHz at 75 m range;
- Magnetometer;
- Sub-Bottom Profiler (SBP) to approximately 10 m below seabed; and
- Ultra High Resolution Seismic (UHRS) to approximately 100 m below seabed.

The findings of the survey have been detailed in three reports, which have been used to establish the detailed baseline conditions (section 8.4.4) and inputs for modelling parameters (see SS3: Marine physical and coastal processes supporting study):

- Offshore Geophysical Site Investigation West of Orkney Windfarm: Volume 1 – OAA Results Report (Ocean Infinity, 2023a);
- Offshore Geophysical Site Investigation West of Orkney Windfarm: Volume 2a – Export Cable Corridor (ECC) Results Report (Whiten Head Bank to Crosskirk) (Ocean Infinity, 2023b); and
- Offshore Geophysical Site Investigation West of Orkney Windfarm: Volume 2b – ECC Results Report (Stormy Bank to Crosskirk) (Ocean Infinity, 2023c).

8.4.3.1.2 Nearshore

OWPL contracted Spectrum Geosurvey Limited ("Spectrum") between August and October 2022 to complete a marine geophysical survey across the nearshore area of the offshore ECC and proposed landfalls. The survey was completed to a similar specification as that described for the offshore (section 8.4.3.1.1) and included the acquisition of MBES, SSS, magnetometer and SBP data. Also associated with this survey is the completion of an intertidal survey (section 8.4.3.3.3). The results of the nearshore marine geophysical survey are detailed in Volume 1 – West of Orkney Windfarm Nearshore Geophysical Survey Results and Charts Report (Spectrum, 2023).

8.4.3.2 Reconnaissance geotechnical investigations

Reconnaissance geotechnical investigations have been undertaken which comprise seabed sampling using a high power vibrocorer and in-situ seabed testing using Cone Penetration Tests (CPT). A total of 50 locations were sampled through vibrocorer or CPT across the OAA (for areas where export cables could be installed) and offshore ECC. Results of the geotechnical testing are reported in Offshore Geotechnical Site Investigation, Volume I – Shallow Geotechnical Report (Ocean Infinity, 2023d).

8.4.3.3 Environmental survey

Details of the completed site-specific surveys are provided in SS3: Marine physical and coastal processes supporting study, with a summary provided here as relevant. An environmental baseline survey was completed by Ocean Infinity between August and September of 2022 within the OAA and along the offshore ECC. Additionally, a nearshore environmental survey was carried out in October 2022 by Spectrum Geosurvey Limited and Ocean Ecology Limited (section 8.4.3.3.3).

The offshore benthic and environmental survey data acquisition included sediment sampling and imagery, with continuous video, water sampling and CTD profiling to establish a baseline for the habitats and faunal communities within the survey area. The findings from both environmental surveys are fully detailed within SS5: Benthic environmental baseline report.

8.4.3.3.1 Seabed sediments

Environmental sampling was completed for seabed sediments as detailed below. The sampled locations used to inform the environmental baseline characterisation and analyses for marine physical and coastal processes are illustrated in Figure 8-2.

Offshore

For the environmental baseline survey conducted in the OAA and offshore ECC, grab sampling was planned at a total of 82 locations with 73 successfully sampled. At each site, one sample was acquired for taxonomic and biomass analyses, one sample for Particle Size Analysis (PSA), and one sample for sediment chemistry and contaminants analysis. For PSA, a total of 67 samples were obtained, 34 across the OAA, 18 from the western offshore ECC and 15 from the eastern offshore ECC (Figure 8-2). For PSA sampling, the primary grab sampler utilised was the Dual Van Veen (DVV; 2 x 0.1 m^2) and the secondary grab sampler, e.g. in areas of coarse sediment, was the Hamon Grab (HG; 0.1 m^2).

Nearshore

During the nearshore environmental survey, grab sampling was planned at four locations for taxonomic and biomass analyses, PSA, and sediment chemistry and contaminant analyses. Three out of the four locations were successfully sampled. The primary grab sampler utilised for PSA and sediment chemistry and contaminants grab sampling during the nearshore survey was a Shipek grab (0.05 m^2).

8.4.3.3.2 Water column properties

Sampling for water column properties was completed at 25 locations across the OAA and offshore ECC. The sampled locations used to inform the environmental baseline characterisation and analyses for marine physical and coastal processes are illustrated in Figure 8-3, with the sampling approach described below.

Offshore

Water sampling for Total Suspended Solids (TSS) as an indication of Suspended Sediment Concentration (SSC), together with CTD profiling, was completed at a total of 20 sampling locations across the OAA and offshore ECC. At four of these locations, water sampling was carried out during spring tides and then again during neap tides as indicated in Figure 8-3. Water samples were collected at three depths (bottom, middle and top).

Water sampling for TSS was performed using 5 L Niskin bottles attached to a Rosette sampler, with a CTD and external turbidity sensor also fitted to the Rosette sampler, which collected information on depth, conductivity, dissolved oxygen, turbidity, pH, and temperature through the water column. The water sampling was undertaken prior to the deployment of the Drop Down Video (DDV) or grab sampler, so that seabed sediment had not been disturbed. Full details of the water sampling methodology are provided in the Benthic Environmental Baseline Report (SS5: Benthic environmental baseline report).

Nearshore

For the nearshore surveys, water samples were collected at all five planned water sampling locations, with samples obtained at three depths. Similar to the offshore surveys, water sampling was performed using a five L Niskin bottle on a rosette sample, with turbidity and CTD sensors attached, and the same data acquired as for the offshore (section 8.4.3.3.3). Full details of the water sampling methodology are provided in SS5: Benthic environmental baseline report.

8.4.3.3.3 Intertidal

Intertidal surveys, extending between the Mean Low Water Springs (MLWS) and MHWS, were completed by Ocean Ecology Limited at the Dounreay and Crosskirk landfall locations between 24th and 26th October 2022 (SS6: Intertidal survey habitat assessment). The surveys comprised collecting high resolution Unmanned Aerial Vehicle (UAV) imagery at low water across the length of the landfall options within the offshore ECC and a Phase I walk over survey to characterise the intertidal habitats and substrates. The acquired UAV imagery were stitched together to generate ortho-mosaic and Digital Terrain Model (DTM) outputs for the intertidal survey areas (SS6: Intertidal survey habitat assessment). For the purpose of marine physical and coastal processes, the UAV imagery was used to inform shoreline extents, while outputs of the Phase I walkover survey were used to inform the characteristics of the intertidal substrate.

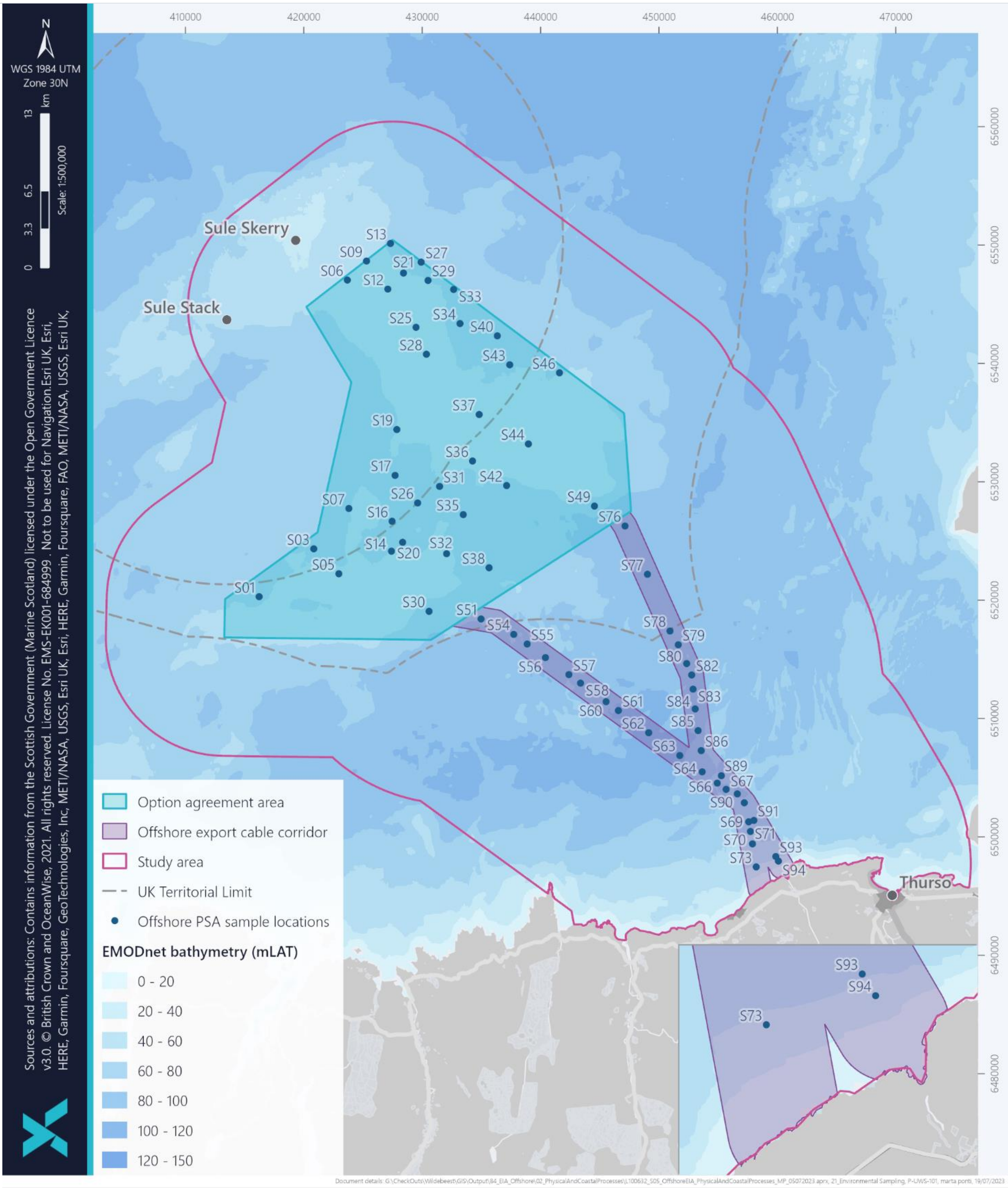

Figure 8-2 Seabed environmental sampling locations

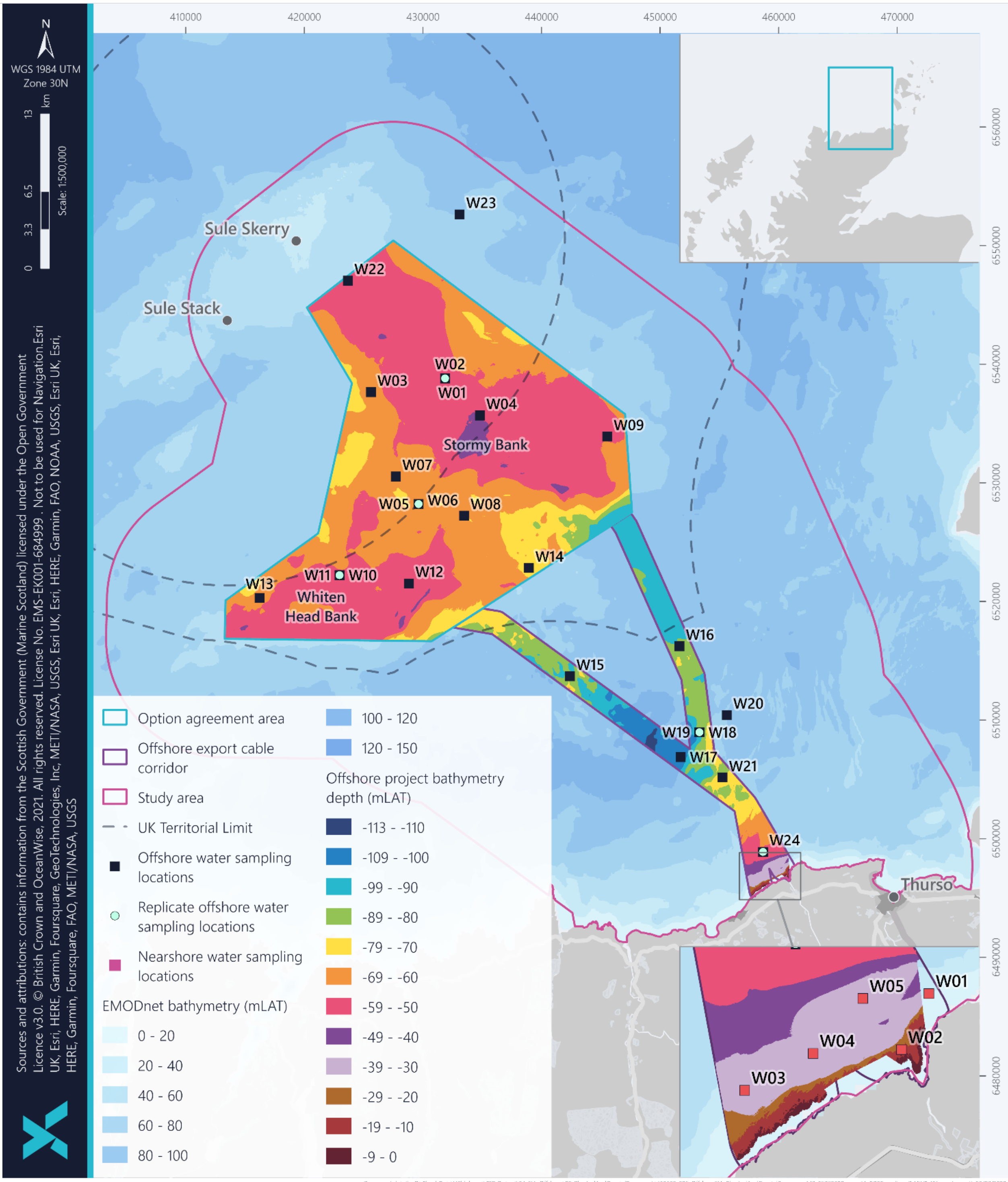

Figure 8-3 Water sampling locations used to inform the marine physical and coastal processes assessment[7]

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[7] *It is standard practice is present the EMODnet bathymetry data as positive numbers, while the Project specific bathymetry is provided as minus number. Regardless of the values sign both are presenting the water depth.*

8.4.3.4 Metocean hindcast data

To inform the bid application for the N1 Plan Option area, OWPL commissioned metocean operational and extreme statistics analyses based on hindcast timeseries from three locations within the OAA. The hindcast datasets included the following:

- Hydrodynamic hindcast dataset comprising 39-year (1979 – 2018) water levels, depth averaged current speeds and directions at 20-minute intervals. Hindcast acquired from the MetOceanWorks European model and is illustrated as Current Point 1 in Figure 8-4;
- Hydrodynamics climatology: 1-year (2010) 15-minute interval hindcast timeseries, comprising water level relative to MSL, current speed and direction, from one location derived from the TPXO global model and illustrated as Current Point 2 in Figure 8-4;
- Hydrodynamics residuals: 10-year (2008 – 2018) daily residuals of current speed and direction from four depth layers through the water column, from two locations (separate to the hydrodynamics climatology data) derived from the Hybrid Coordinate Ocean Model (HYCOM) model and illustrated as Hycom 28W and Hycom 32W in Figure 8-4; and
- Waves: 37-year wave hindcast timeseries (1979 – 2015), comprising hourly waves height, peak period and direction from the MetOceanWorks European model and illustrated as Wave Hindcast in Figure 8-4.

All the above metocean hindcast datasets were used to inform the preparation of the West of Orkney numerical model described further in section 8.4.3.5 and SS3: Marine physical and coastal processes supporting study. This study in turn has provided the basis for this assessment, from helping to characterise the environmental baseline environment and providing validation for the developed numerical model to enabling interpretation of the completed modelling and analyses results.

In addition to the metocean hindcast datasets introduced above, hydrodynamic climatology dataset was also acquired from Marine Scotland's Pentland Firth and Orkney Waters (PFOW) model as introduced in Table 8-5. The PFOW model was created by Marine Scotland in recognition of the region's importance for marine renewable energy. The PFOW model is an implementation of the Finite Volume Community Ocean Model (FVCOM) and has a domain covering the northern Isles of Orkney and Shetland and Moray Firth. The main output from the model to date is a one year long climatology representing typical present day conditions (1990-2014).

The locations of the applied metocean hindcast datasets described above and additional data acquired from secondary sources (including output locations from the PFOW climatology (O'Hara and Campbell, 2021)) are illustrated in Figure 8-4, with the modelling process described in section 8.4.3.5.

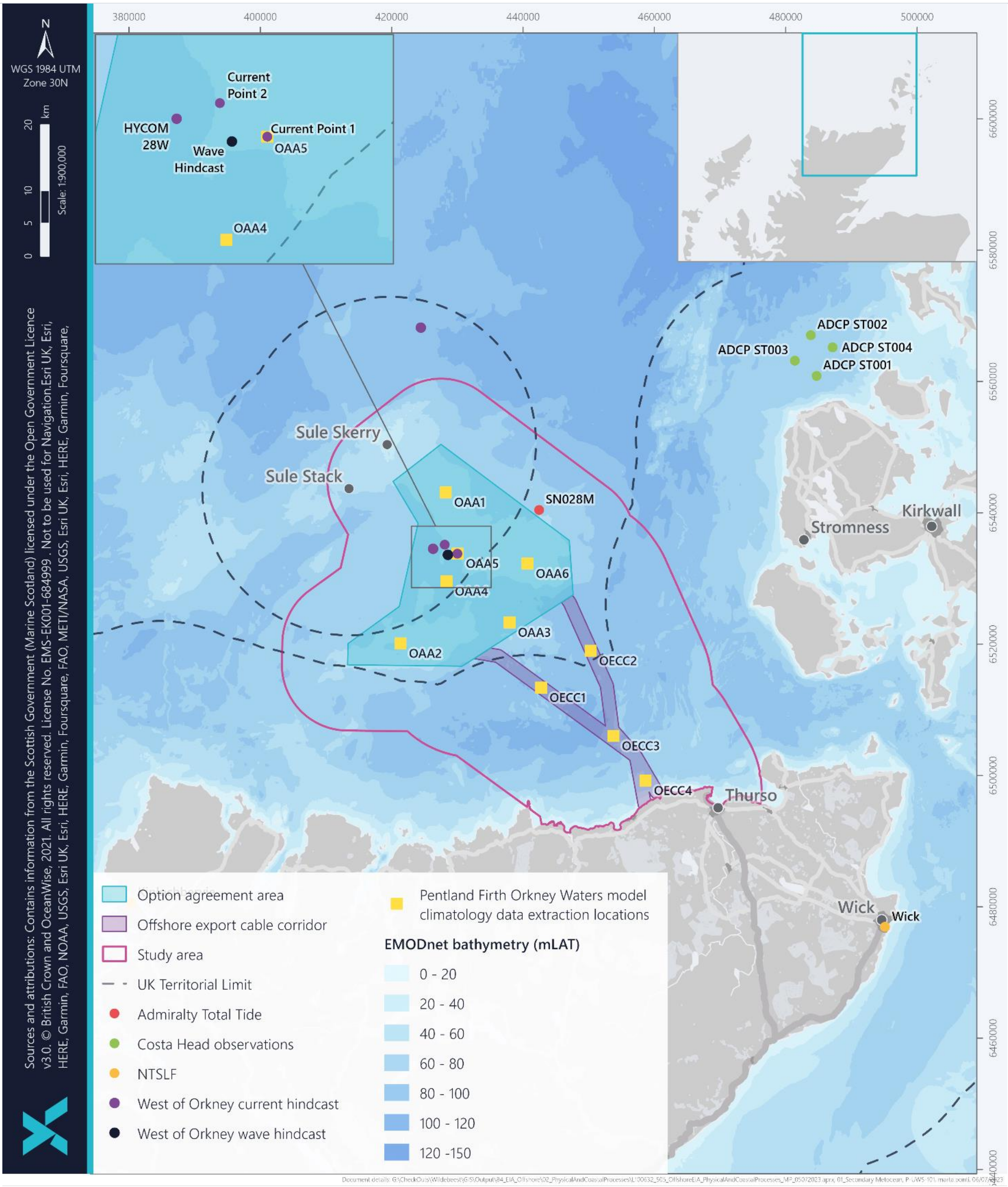
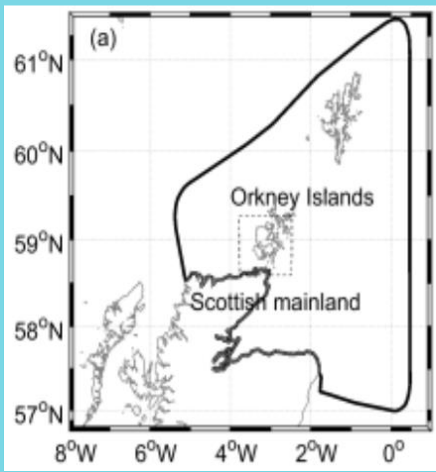


Figure 8-4 Metocean data locations and sources used to inform the marine physical and coastal processes assessment. Data sources include those introduced in Table 8-5 and section 8.4.3.4

Two key models are referenced in the text which were integral to supplementing the baseline environmental characterisation (section 8.4.4). A brief summary is provided here for clarity to aid distinction between the two.

The **West of Orkney model** was created in support of the offshore Project. In addition to informing the baseline, the West of Orkney model generated results of potential Project impacts at construction and operational stages, so is referenced throughout sections 8.6.1 and 8.6.2 respectively.

The **Pentland Firth Orkney Waters (PFOW) model** was created by Marine Scotland in recognition of the region's importance for marine renewable energy (the model boundary is shown opposite). A number of model runs, variations, and outputs have been produced. The main model output is the PFOW climatology, which is used to inform the baseline conditions across a number of receptors, as well as calibrate and validate the West of Orkney model.



Coverage of the PFOW model developed by Marine Scotland (2016)

In addition to the above, a number of publicly available **hindcast models** also provided source data for the West of Orkney model. These are fully detailed above in section 8.4.3.4.

8.4.3.5 Modelling completed for the offshore Project

Numerical modelling was conducted in support of the Marine Physical and Coastal Processes Technical Report and subsequently this chapter. The following were the primary requirements of the model (referred to as the 'West of Orkney model'):

- Develop hydrodynamic and spectral wave models covering both the marine physical and coastal process study area and the Orkney Islands[8];
- Characterise the existing baseline conditions at the offshore Project area based on the numerical modelling results and other available information (section 8.4.4);
- Apply the developed models to assess the effects of installation (for structures and cables) on marine physical processes (relevant to the impact assessment associated with the construction stage of the Project in section 8.6.1); and
- Apply the developed models to assess the potential operational effects of two windfarm layouts comprising 125 Wind Turbine Generators (WTGs) and Offshore Substation Platforms (OSPs) on marine physical and coastal

[8] *Physical processes dynamics within the Orkney Islands are complex and have far reaching influence. In order to capture this intricacy, the Orkney Islands were included within the West of Orkney model domain.*

processes (relevant to the impact assessment associated with the operation and maintenance stage of the Project in section 8.6.2). For the purposes of the EIA "worst case" WTG layouts were developed as required to inform the receptor specific assessments, as presented in section 8.5.5. For the purposes of the marine physical and coastal processes, two layouts were developed, as follows:

- One which represented the potential for the worst case blockage of dominant waves approaching from the west and flows; and
- A second which represents the worst case impact to northwest approaching waves, with structures occurring at shallower depths on the Whiten Head Bank and Stormy Bank, also resulting in blockage effects.

The West of Orkney model provided a number of outputs, including baseline conditions which are presented in section 8.4.4, and modelled results of potential Project impacts at construction and operational stages (discussed in sections 8.6.1 and 8.6.2 respectively). Model calibration and validation, and modelling of baseline and operational impacts, were completed for a spring-neap tidal cycle, with results extracted for a 15-day representative period. For construction impacts, modelling was completed over a 16-day continuous period, again indicative of a representative spring-neap cycle, with the impacts of varying construction activities investigated. For modelling of operational flow impacts, again a spring-neap cycle of varying flows was modelled, with a representation of WTG and OSP infrastructure included to investigate for potential changes to flows. To support the assessment of operational wave impacts, these were modelled as instantaneous events over a short time frame, again with a representation of WTG and OSP infrastructure included, to investigate potential changes to waves. Further detail on the applied modelling approach and results are provided in SS3: Marine physical and coastal processes supporting study and the appendices therein.

To help inform the baseline characterisation and assessment, a number of model points (shown in Figure 8-5) were used to extract various environmental parameters, such as flow speeds, which contributed to the baseline understanding and impact assessment of the offshore Project. Note, the points in Figure 8-5 are distinct from those in Figure 8-4. The extraction points in Figure 8-4 originate from the PFOW model and provide information on the hydrodynamic (water levels and flows) and water column properties (temperature and salinity). The locations of the West of Orkney model extraction points shown in Figure 8-5 were chosen specifically to investigate the baseline hydrodynamic and wave characteristics across the offshore Project area, in addition to the construction and operation impacts on associated with the offshore Project. In particular the West of Orkney model extraction points were spatially distributed across varying water depths and seabed sediment and morphological properties, in order to capture information from the more detailed and higher resolution West of Orkney model. Information on the assumptions and parameters that underpin the completed modelling are included in sections 8.6.1 and 8.6.2 as relevant, with further detail provided in SS3: Marine physical and coastal processes supporting study and appendices therein.

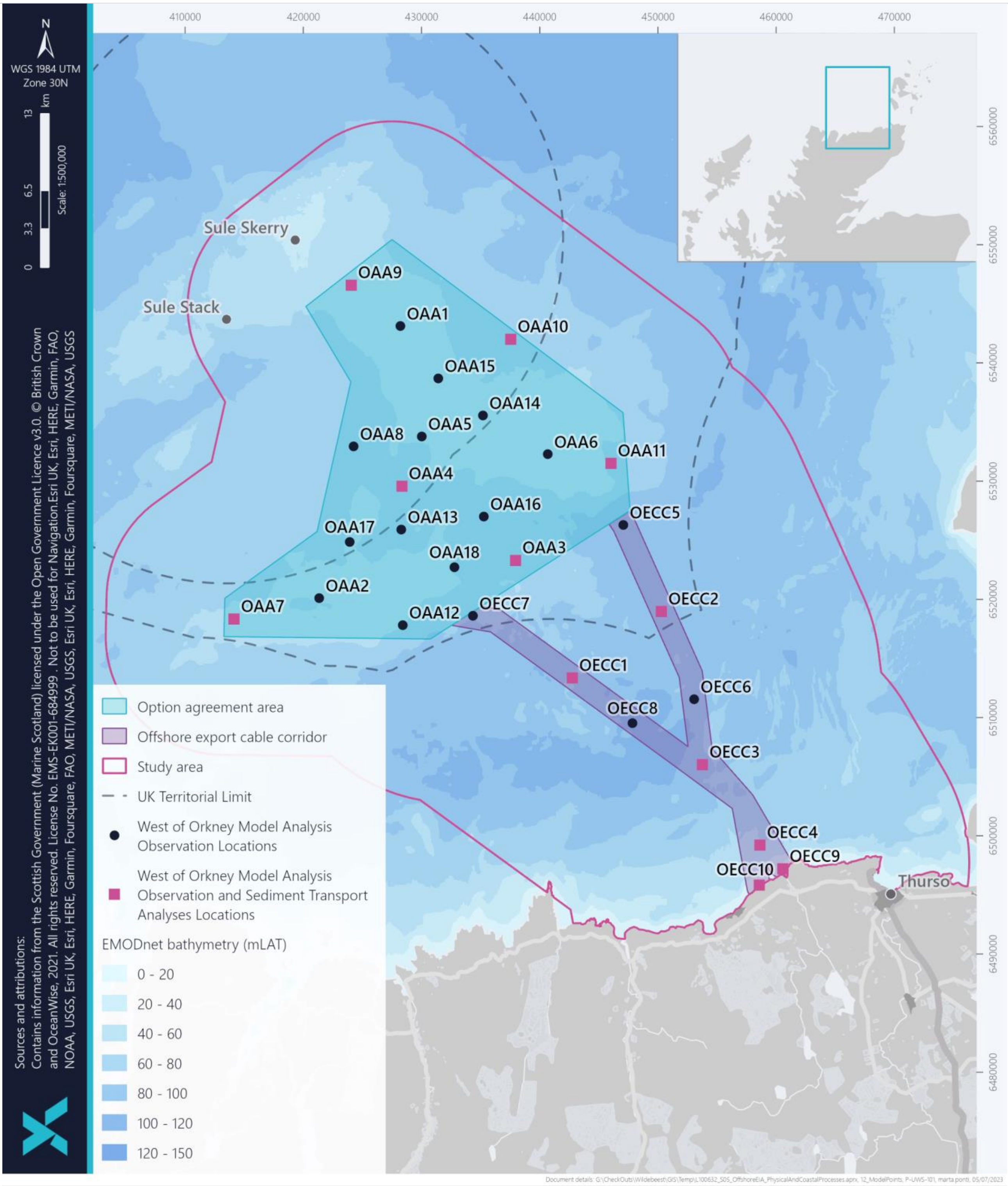


Figure 8-5 Model observation locations

8.4.4 Existing baseline

A review of literature and available data sources augmented by consultation and Project site-specific surveys has been undertaken to describe the current baseline environment for marine physical and coastal processes. Further detail on the environmental baseline is included within SS3: Marine physical and coastal processes supporting study and summarised here as relevant in order to inform the impact assessment.

8.4.4.1 Designated sites

A number of designated sites are located entirely or partly within the marine physical and coastal processes study area (including Special Area of Conservation (SACs), SSSIs and Geological Conservation Review (GCR) sites (JNCC, 2019)), which are designated for features of interest to marine physical and coastal processes. These sites are shown in Figure 8-6. For a site to be considered within the assessment, it must be designated for a feature which has possible connectivity to the potential impacts. Some features, such as maritime cliffs, though terrestrial, are dependent on conditions which are inherently linked to marine physical processes. The sites which are within the marine physical and coastal processes study area and which may be affected by the offshore Project are listed in Table 8-6.

As agreed in comments received on 22nd September 2022 in consultation minutes , the North-West Orkney NCMPA is excluded from further assessment as it does not overlap the study area. This approach has been agreed with consultees (including NatureScot and Marine Scotland Science) (see Table 8-4).

Table 8-6 Designated sites and associated interest features that intersect the study area

SITE NAME AND ID	DESCRIPTION OF SITE	INTEREST FEATURE	DISTANCE TO PROJECT AREA
Red Point Coast SSSI	Red Point Coast SSSI is a 6 km stretch of coast between Sandside Bay in Caithness and Melvich Bay in Sutherland. The site is located to the west of Sandside Bay and is nationally important for geology, coastal vegetation and colonies of breeding seabirds (NatureScot, 2009a; 2009b; 2009c). The coastline along this site is not considered to be erodible (Dynamic Coast, 2021), with the maritime cliff interest feature mostly affected by terrestrial factors.	Quaternary of Scotland Non-marine Devonian Maritime cliff	4.6 km
Sandside Bay SSSI	Sandside Bay SSSI lies just north of Reay, on the north coast of Caithness. The site is located to the west of the offshore ECC and covers the entire area of Sandside Bay. The site is comprised of two parts; the main part of the site includes the foreshore, dunes, dune slacks and the banks of the Burn of Isauld (NatureScot, 2008d; 2008e). The second part of the site, known locally as the Sahara, is an area of herb-rich grassland within Reay Golf Course.	Sand dunes	3.7 km
Ushat Head SSSI	Ushat Head SSSI is a low exposed headland, on the north coast of Caithness, adjacent to the Crosskirk landfall. It is of particular botanical importance for its maritime heath, which is a northern,	Maritime cliff	Adjacent to the offshore

SITE NAME AND ID	DESCRIPTION OF SITE	INTEREST FEATURE	DISTANCE TO PROJECT AREA
	species rich type of heathland that is found only in Caithness, Sutherland and Orkney. There is a good representation of species-rich maritime heath communities in a mosaic with maritime grassland (NatureScot, 2008c). The vegetation within this site is known to have developed in relation to sea spray occurring.		ECC (at the landfall)
Dunnet Head SSSI	Located on the north coast of Caithness east of the offshore ECC landfall. The site is designated for the nationally important coastal vegetation and breeding seabirds (NatureScot, 2010b). Maritime cliff vegetation grows in a narrow strip along the cliff tops and on some of the cliff ledges. Species-rich maritime heath grows in a mosaic with maritime grassland on the cliff tops. The cliff ledges support a range of plant species which thrive close to the sea. Negative pressures on this site are in relation to livestock grazing activities.	Maritime cliff	10.5 km
Pennylands SSSI	Pennylands SSSI is located on the foreshore between Thurso and Scrabster on the north coast of Caithness. The site has been notified due to the exposure of a sequence of layers of sedimentary rocks which contain both fossil fish and evidence of the geography and environment in which the fish lived. These rocks were deposited around 380 million years ago during the Middle Devonian geological era (NatureScot, 2008a). The site and interest feature are considered to be in a favourable maintained condition and are not believed to be exposed to any negative pressures.	Non-marine Devonian	7 km
Holborn Head SSSI	Holborn Head SSSI lies east of the offshore ECC. The site covers 4.5 km of coast west of the lighthouse at Scrabster. The site is designated for its nationally important Middle Devonian fossil fish and coastal vegetation, with terrestrial factors influencing its condition (NatureScot, 2009d).	Maritime cliff	4 km
Strathy Coast SSSI	Strathy Coast SSSI covers a section of the north Sutherland coast centred around Strathy Point, west of the offshore ECC landfall. It comprises north, east and west facing cliffs, interrupted by beach systems at Armadale, Strathy and Melvich. The site is notified for the nationally important maritime cliff, sand dune, machair and salt marsh habitats found along the coast and for the assemblage of rare plants. It is also notified for the Moine rocks around Portskerra (NatureScot, 2010a). Pressures on the sites and some interest features are noted as being terrestrial.	Maritime cliff Saltmarsh Sand dunes Moine Machair	11.8 km
Strathy Point SAC	Strathy Point SAC is a terrestrial designated site along the headland of Strath Point. The SAC is an important example of northern, hard acidic rock cliffs, subject to extreme wind and wave exposure, which contribute the diverse vegetation	Vegetated sea cliffs	16.4 km

SITE NAME AND ID	DESCRIPTION OF SITE	INTEREST FEATURE	DISTANCE TO PROJECT AREA
	communities (NatureScot, 2019). As a result, the vegetated sea cliffs are considered to be one of the best representative areas of vegetated sea cliffs of the Atlantic and Baltic coasts in the UK. The vegetated sea cliff interest feature is considered to be in favourable maintained condition, with the primary negative pressures being from over grazing and a lack of proactive management (NatureScot, 2019).		
Red Point GCR	The site provides the best example of Middle Devonian lake-margin deposits associated with an unconformity in Scotland (JNCC, 2019). In this area, the Orcadian Basin lake lapped against the metamorphic basement. Features formed at this lake-margin include unusual (possibly algal) limestones draping the sides of the exhumed hill of metamorphic rock, and small beach-ridges of angular gravel derived from the basement. The vertical extent of the limestones indicates the large fluctuations there must have been in lake-level within short periods of time. The rapid transition from the basement hill to the flat-bedded flagstones, typical of the main lake, is of importance and this is a facies unique to the Orcadian Basin (JNCC, 2019).	Non-marine Devonian	6.8 km
Drumhollistan GCR	Geological sedimentary units demonstrating key Quaternary of Scotland deposits, particularly the Quaternary stratigraphy of Caithness and comprising two till units (of varying origin) separated by a layer of sand and gravel. The sediment provide evidence for the pattern of ice movements in Caithness and the interaction between two separate ice masses of local and external origin. The age(s) of the tills is uncertain, and the site has important research potential (JNCC, 2019).	Quaternary of Scotland	8.2 km
Sgeir Ruadh Portskerra GCR	Exposures of the quartzose Moine gneisses, amphibolite and several generations of granite. It is the northernmost part of the Strath Halladale migmatite-granite complex, with examples of unconformable contact with the overlying Old Red Sandstone breccias and sandstones. At least three different ages of granites can be recognised within this site with a clear exposition of relationships within the Strath Halladale migmatite-granite complex. The fine development of the Old Red Sandstone overlying the unconformity is itself of first rate importance. The deposits demonstrated in this GCR are rarely seen inland due to very poor exposure in critical areas. The greatest significance attaches to the red granitic sheets, which are believed to be part of the Strath Halladale granite dated at 649±30 Ma. This is crucially important as it represents the proof of the late Precambrian and Caledonian (sl) granites cutting the earlier (mid-Proterozoic) migmatite complex which is developed throughout east Sutherland (JNCC, 2019).	Moine	11.6 km

SITE NAME AND ID	DESCRIPTION OF SITE	INTEREST FEATURE	DISTANCE TO PROJECT AREA
Holborn Head Quarry GCR	Large quarry with evidence of middle Devonian, Givetian, lacustrine sediments from the Ham-Scarfskerry Subgroup of the Upper Caithness Flagstone Group. The deposit contains large evidence of fossil fish and is the best site to collect Osteolepis panderi which makes up the largest percentage of the fauna here. The deposit is largely unexposed just beneath the quarry floor (JNCC, 2019).	Silurian – Devonian Chordata	4.4 km
Pennyland GCR	Occurs along the coast as a section of Old Red Sandstone (Upper Givetian) sediments and contains several fish beds. The sequence of sediment in this GCR demonstrates the transition from the mainly lacustrine Mey Subgroup of the Upper Caithness Flagstone Group to the predominantly fluvial John o'Groats Sandstones, which is usually faulted out in Caithness. It is also the richest remaining occurrence and well preserved of the Millerosteus minor geological sub-group (JNCC, 2019). Fossil fauna assemblages that occur here can be compared with species from the Baltic.	Silurian – Devonian Chordata	7.1 km
Pennyland to Castlehill (Thurso-Scrabster) GCR	A well-exposed section through the topmost part of the Middle Devonian Caithness Flagstones and the transition to the predominantly fluvial John o'Groats Sandstone. The section shows a variety of interbedded, mainly shallow-lake sediments with a few fish beds, and several sand bodies (possibly of both fluvial and aeolian origin). This example of a sand-rich flagstone sequence from a more marginal part of the basin contrasts with sections at Wick and Stromness. It occurs in a critical, often poorly-exposed, part of the Middle Old Red Sandstone succession, with the potential to extend knowledge of the Orcadian Basin environments and palaeogeography (JNCC, 2019).	Non-marine Devonian	7.1 km

Of the range of designated sites with maritime or vegetated sea cliffs interest features that intersect the applied marine physical and coastal processes study area as detailed in Table 8-6, only the Ushat Head SSSI directly borders the offshore Project area. For the other designated sites comprising the Red Point Coast SSSI (NatureScot, 2009a), Dunnet Head SSSI (NatureScot, 2010b), Holborn Head SSSI (NatureScot, 2009d), Strathy Coast SSSI (NatureScot, 2010a) and Strathy Point SAC (NatureScot, 2019), the sites are either considered to be in a favourable condition or the pressures are from terrestrial factors such as grazing. For these designated sites that do not directly overlap the offshore Project area, but intersect the applied study area, there is not considered to be a pathway for impacts to the interest features within the designated sites, due to their terrestrial control. Therefore, the SSSIs' and one SAC are not taken forward for assessment. The only designated sites with the maritime or vegetated sea cliffs interest feature taken forward for assessment is the Ushat Head SSSI, due to its proximity with the offshore Project area.

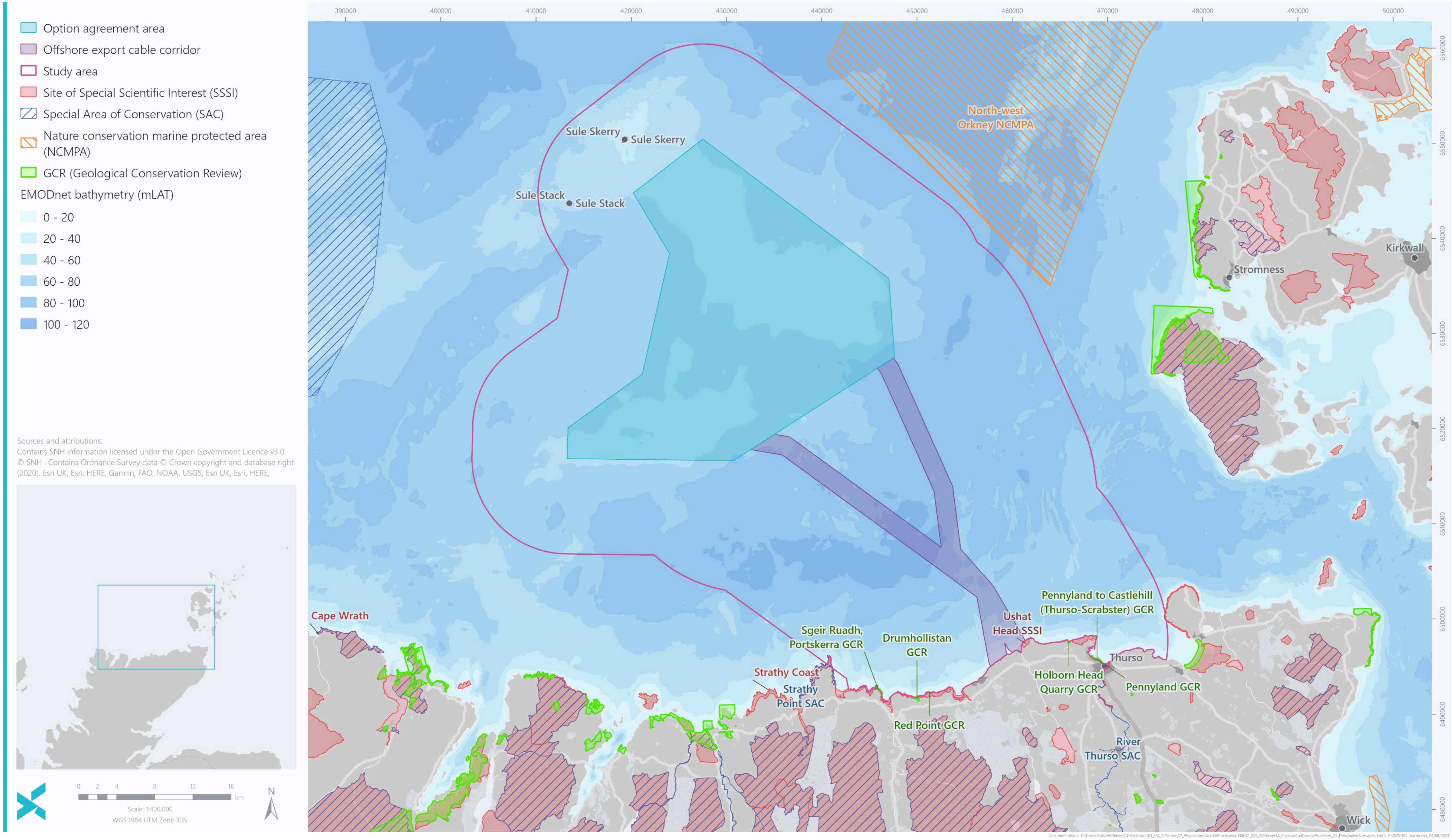


Figure 8-6 Designated sites near the offshore Project area

8.4.4.2 Seabed bathymetry

Bathymetry across the offshore Project area is shown in Figure 8-7. Water depths within the OAA range between approximately 45 mLAT and 99 mLAT, with shallower depths recorded over the Whiten Head Bank and Stormy Bank that occur within the OAA. The depth variation in relation to the banks ranges from 45 to 100 mLAT. The bank features are separated from one another by a deeper area in the centre of the OAA (which reaches varying depths of 60-70 mLAT; Ocean Infinity, 2023a). Within the offshore ECC, the water depth ranges from 44 mLAT to approximately 110 mLAT (Ocean Infinity, 2023b,c). The bathymetry along the offshore ECC is much more variable, but generally deeper than within the OAA. At the offshore end of the offshore ECC, both the eastern and western offshore ECC options begin in deep water which continues to deepen. Along the final section to the coast, the water depth within offshore ECC gradually becomes shallower reaching a depth of approximately 60 mLAT at 2 km from the coast. Inshore of this point, the ascent to shore is relatively rapid with slope gradients of up to 11°.

8.4.4.3 Seabed morphology

8.4.4.3.1 Overview

As introduced in section 8.4.4.2, there are two large bedform features within the OAA which represent banks and are illustrated in Figure 8-7. Whiten Head Bank is located in the south of the OAA, close to the southeastern boundary where the western offshore ECC begins (Figure 8-7). Stormy Bank is located north of centre in the OAA (Figure 8-7) According to site-specific survey outputs, Stormy Bank is aligned northwest to southeast roughly parallel with the northern border of the OAA. Whiten Head Bank is oriented southwest to northeast and is narrower in shape, featuring a sharp crest along the leading eastern edge of the bank, with marginally steeper slopes than the surrounding seabed, of up to 3°.

With regards to smaller seabed features, sandwave bedforms are apparent along the edges of Stormy Bank, in areas of greater water depth. Bedform fields (considered to comprise sand and gravels) are found in the slightly deeper water which separates the two named bank features. The bedforms occur on a scale of up to approximately 1 km in length. The bedforms are orientated almost due north-south. These features align with the residual flow direction which suggests they are tidally controlled. Further bedforms are also present along the leading edge of the Whiten Head Bank, to the east of the steep crest described above. Rippled scour depressions are also characteristic of the whole OAA, including both Whiten Head Bank and Stormy Bank (Ocean Infinity, 2023a). The area of deeper water between the two banks is additionally densely filled with megaripple features. Anecdotal information from local fishermen (obtained during discussions in the Project's Fisheries Working Group) suggests that sediment overlying bank features in the north of Scotland can be highly variable and dynamic, which may apply to the seabed across Stormy Bank and Whiten Head Bank.

Bedform features comprising sandwaves, megaripples and depressions are all found at points within the offshore ECC. The megaripples often appear to be superimposed on the sandwaves oriented perpendicular to the larger sandwaves. As introduced in section 8.4.4.5, there is a feature close to the Crosskirk landfall defined by deeper superficial sediments. The feature appears to be a bank formation, or similar, approximately 3.5 km in length as illustrated in Figure 8-8. The crest of the feature (i.e. the greatest sediment depth) is oriented southwest to northeast, parallel with the coast (Spectrum, 2023). At the landfall, a strip of exposed bedrock is apparent which is bordered by loose rock. Steep escarpments and areas of tessellated pavement are visible along the coastal bedrock. Areas of boulders are associated with this exposed coastal bedrock.

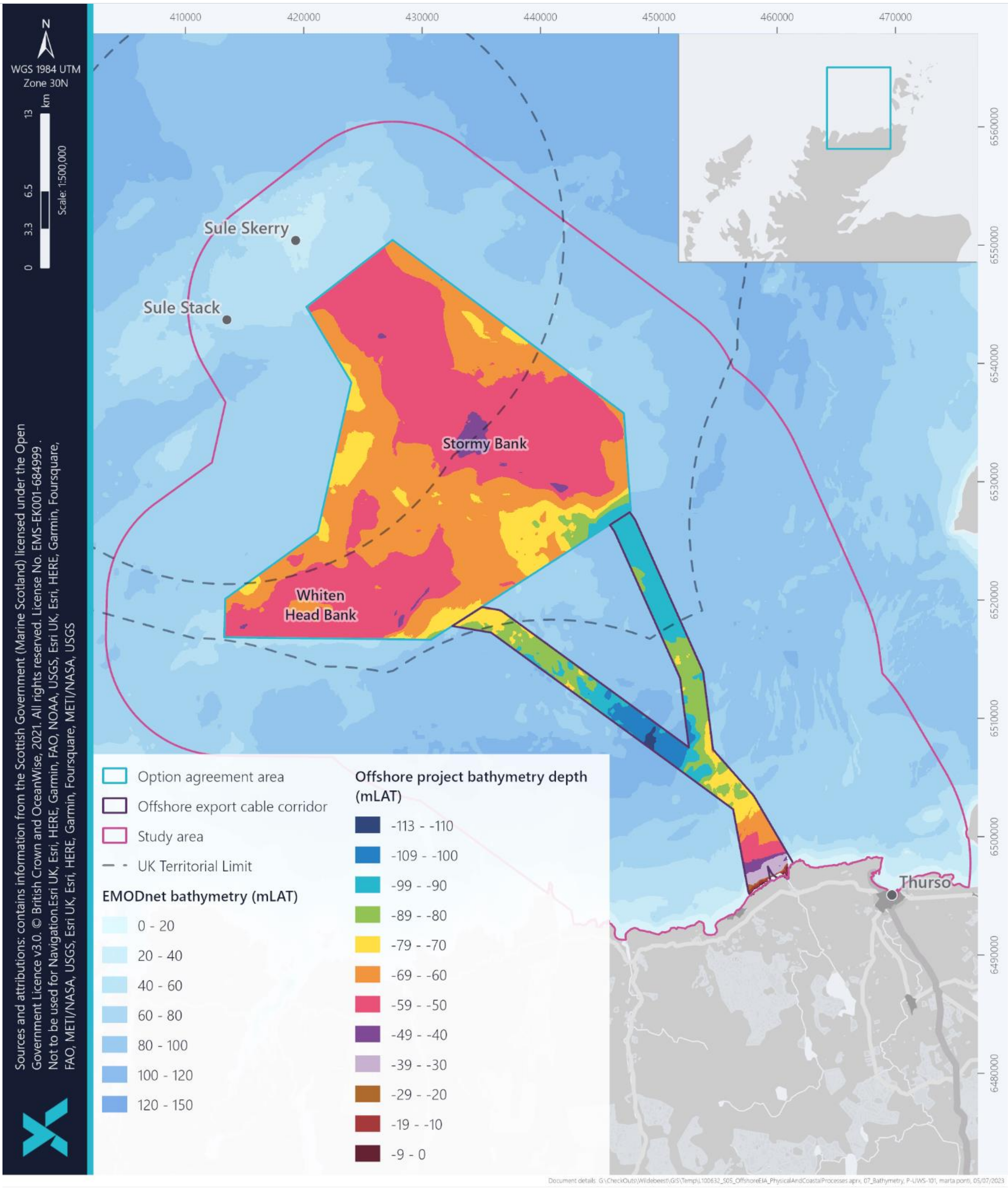


Figure 8-7 Bathymetry across the offshore Project area as informed by site specific geophysical surveys (Ocean Infinity, 2023a; 2023b; 2023c)[9]

[9] *It is standard practice to present the EMODnet bathymetry data as positive numbers, while the Project specific bathymetry is provided as minus number. Regardless of the values sign both are presenting the water depth.*

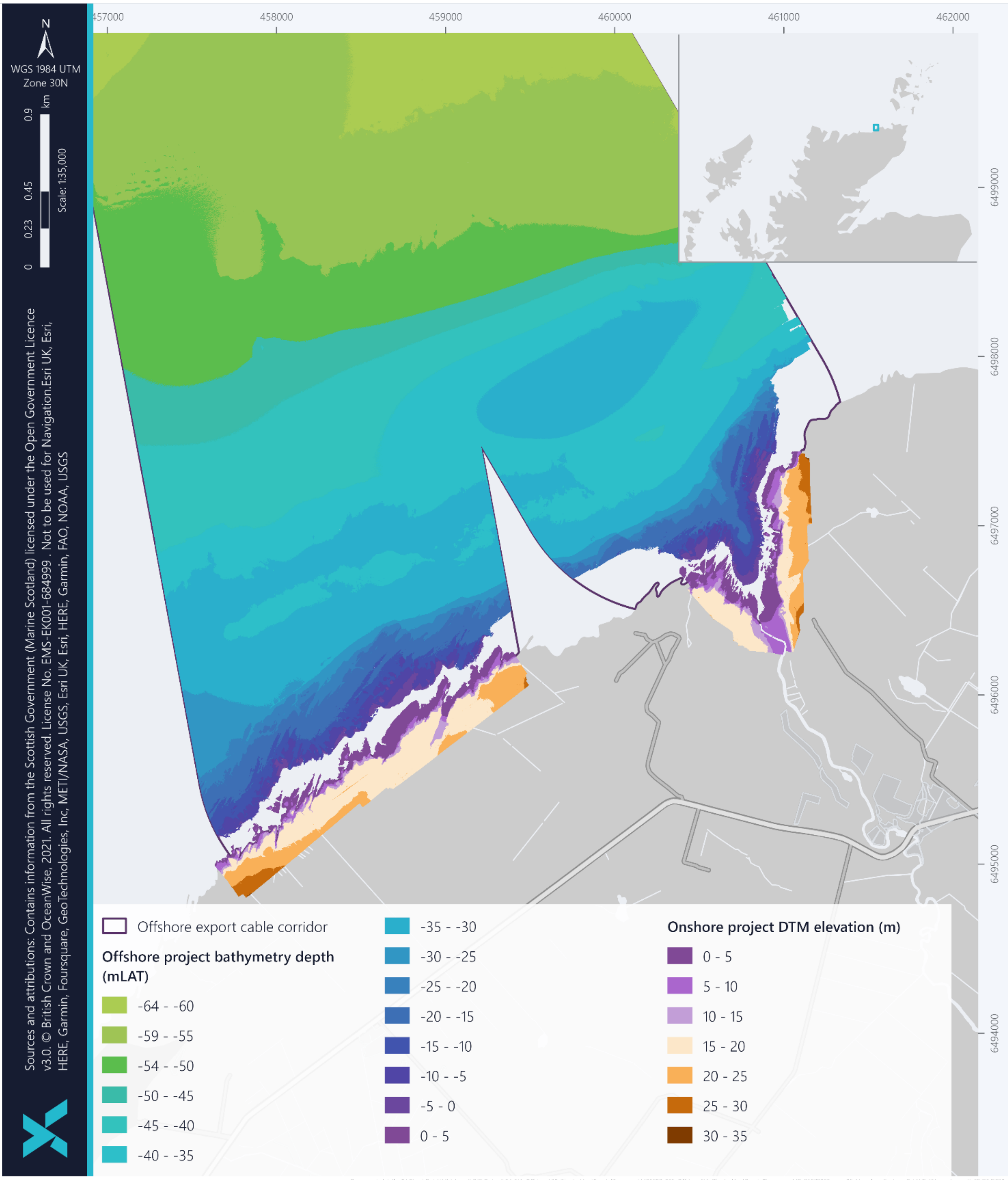


Figure 8-8 Nearshore morphological features at the landfall options represented in the seabed bathymetry[10]

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[10] *Blank spaces are due to water depths restricting vessel access.*

8.4.4.3.2 Bedform migration

Analysis of bedform mobility and migration was conducted within the OAA and offshore ECC. This involved comparing multiple bathymetry data sets (namely recent site-specific bathymetry and EMODnet publicly available data) through time to determine areas of change. Any such areas of change indicate whether bedform migration associated with the larger Stormy Bank and Whiten Head Bank has occurred. While the granularity of the available data sets was variable, overall, the results of the analyses demonstrated that there has been relatively little change in the bank features over time. This was concluded based on the EMODnet and site-specific bathymetries being well aligned. Crucially, the analyses determined that there was no change associated with either of the larger bank features between the broadscale EMODnet bathymetry (EMODnet, 2020) and the site-specific surveys in 2022, thereby suggesting that the bank features within the OAA are stable.

The same analysis was conducted within the offshore ECC, where the finding similarly demonstrated that the EMODnet and site-specific data were well aligned. Consequently, there is also unlikely to be active movement of bedforms within the offshore ECC and offshore Project area as a whole.

Further detail regarding the methods of analysis and visual representations of the outcomes discussed above are presented in SS3: Marine physical and coastal processes supporting study.

8.4.4.4 Bedrock geology

The bedrock across the Project and study area primarily comprises Permian-Triassic undifferentiated sandstone, siltstone and mudstone with evaporites occurring over most of the OAA and offshore ECC. Closer to the coast, Devonian mudstone and siltstone occur on approach to landfall (BGS, 1981; 1989).

Bedrock depths are informed by BGS borehole records. Two historical BGS borehole core records are located west of the OAA (BH72/28 and BH73/31), within approximately 3 km of the OAA boundary (see Figure 8-9). These reported the depth of Quaternary sediments to be between approximately 28 m and 36 m before transitioning to bedrock. Vibrocore and CPT samples from within the offshore ECC, acquired during site-specific geotechnical surveys, indicate bedrock occurring at varying depths, from surface exposures to depths well below the potential cable burial depth (i.e. at depths of greater than 6 m below the seabed) (Ocean Infinity, 2023d) and in some instances, over 100 m below the seabed (Ocean Infinity, 2023a; 2023b) as illustrated in Figure 8-9. BGS information described the bedrock as soft, friable, well sorted dark red sandstone. At greater depths, the sandstone was interbedded with occasional mudstone films. The consistency of the sand making up the red sandstone was described as subangular rounded with occasional coarser grains (Institute of Geological Sciences, 1972a). Closer to the offshore ECC, a further BGS borehole (BH72/27) noted that the depth of overlying sediment was approximately 18 m before bedrock was recorded, in line with observations from the site-specific geotechnical surveys (Ocean Infinity, 2023d). The BGS again described the bedrock as red, soft, friable sandstone with occasional hard bands, the substrate was noted as being so soft that it was difficult to recover and collapsed to fine sand upon retrieval (Institute of Geological Sciences, 1972b). With respect to observations from the site-specific geotechnical survey, bedrock within the offshore ECC, bedrock is mostly described as a very dense granular sandstone in the acquired vibrocore samples (Ocean Infinity, 2023d).

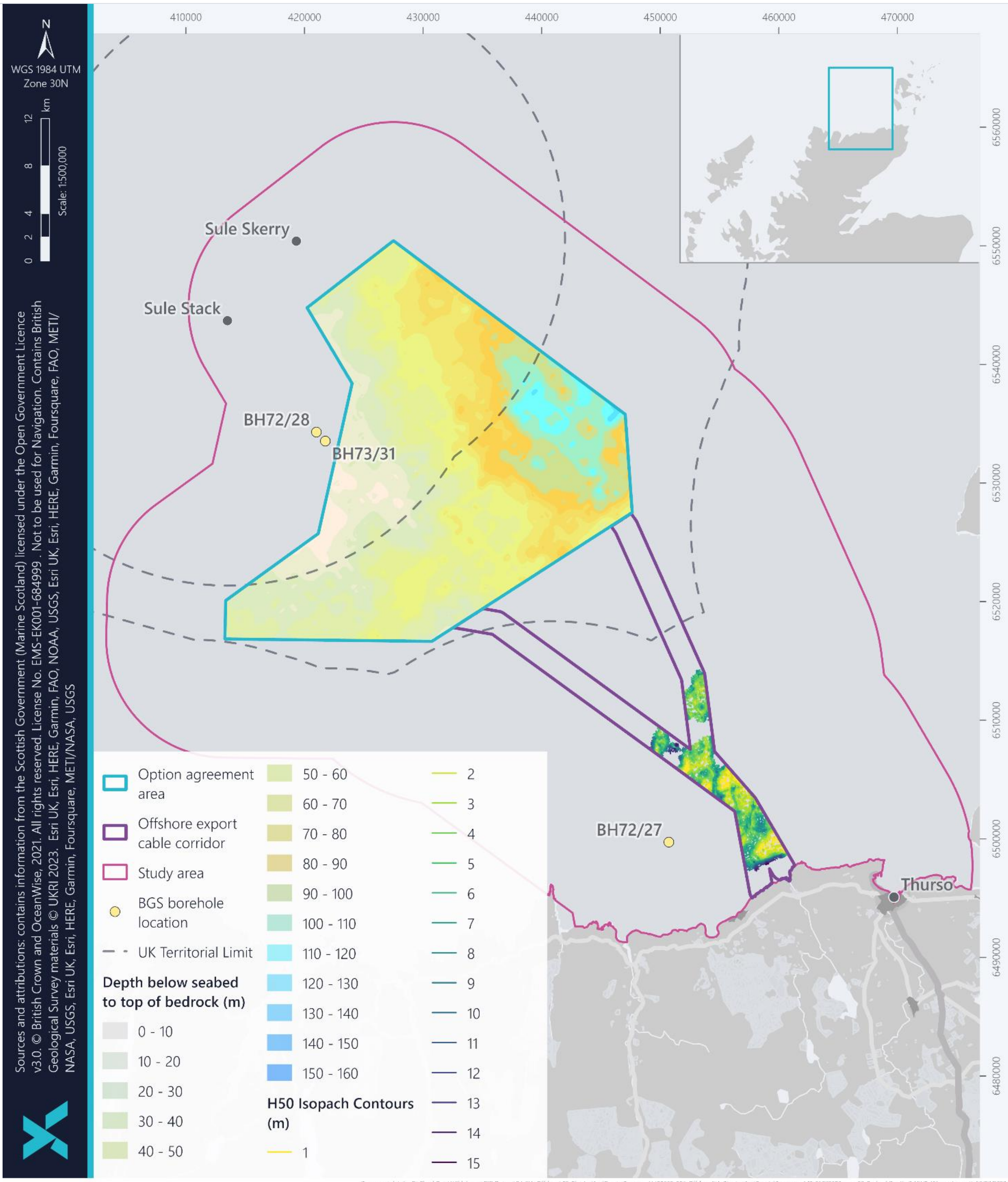

Figure 8-9 Depth of bedrock below surface sediments across the offshore Project area (Ocean Infinity, 2023a; 2023b), with BGS borehole locations[11]

[11]*Horizon (H50) represents the top of bedrock. The contours of the depth to H50 (i.e. to top of bedrock) have been provided for the offshore ECC where raster data was unavailable.*

8.4.4.5 Quaternary geology and seabed sediments

8.4.4.5.1 Overview

The Quaternary deposits across the northwest Scottish continental shelf are varied and considered to be predominantly undifferentiated, with diamict[12] occurring further offshore (BGS, 2022). There is little recent sediment input to the continental shelf in this area. Consequently, the modern seabed environment represents the rework by currents of the topography and sediments which originated during former glacial periods (DECC, 2016a). Therefore, the seabed across the study area is dominated by a succession of Quaternary sandy deposits overlying glacial till. This is also the case for the substrates within the offshore ECC, as indicated by the site-specific geotechnical investigations (Ocean Infinity, 2023d).

The depth of Quaternary sediment within the offshore Project area is highly variable. BGS data indicate that across the OAA, bedrock occurs between 5 m and over 50 m below the surficial seabed sediments (comprising both Quaternary and Holocene units) (BGS, 2022). Across the offshore ECC, bedrock occurs as exposures to similar depths as described for the OAA (BGS, 2022). Site-specific geophysical (Ocean Infinity, 2023a) and geotechnical (Ocean Infinity, 2023d) results are largely in alignment with the BGS data; the proximity of bedrock to the surface of the seabed ranges from 0 m (where overlying sediments were absent and the bedrock was exposed) to 133.7 m below the seabed (Ocean Infinity, 2023a; 2023d).

Site-specific geophysical data determined that there were a number of Holocene (i.e. upper part of Quaternary) deposit units within the OAA which varied in thickness across the site. The uppermost deposit later ranged from 0 m (where absent) to a maximum thickness of 11.4 m. Areas of increased deposit thicknesses are generally associated with the larger bedform features within the offshore Project area, for example the Stormy Bank and Whiten Head Bank features. Other geomorphological features, such as megaripples and depressions, are associated with this uppermost layer of sediments. Within the offshore ECC, directly offshore from the Crosskirk landfall, the site-specific survey data identified an area of thick sediment deposit. This deposit is up to 13 m thick at the most (Spectrum, 2023) and may be indicative of a morphological bedform. Geomorphological features, including the larger banks and smaller seabed features, are addressed in section 8.4.4.3.

Surficial seabed sediment is mostly of a sandy nature with the following typologies being present, as indicated by BGS seabed sediment (BGS, 2022) and site-specific environmental surveys (Ocean Infinity, 2023a; 2023b; 2023c):

- Gravelly sand;
- Slightly gravelly sand;
- Sand; and
- Sandy gravel.

The PSA results from the site-specific environmental survey (section 8.4.3.2) confirmed the seabed sediment across the offshore Project area mainly comprises a coarse sediment fraction, with marginally more fine sediment occurring within the offshore ECC, although mean grain sizes were highly variable (SS5: Benthic environmental baseline report).

[12] *Diamict is a term used to describe unsorted to poorly sorted sediment which can contain particles covering a range of sizes.*

The following sections describe the surficial sediments in the offshore Project area according to sediments, which comprise the mobile fraction of the seabed (section 8.4.4.5.2), and larger cobble and boulder clasts (section 8.4.4.5.3).

8.4.4.5.2 Mobile sediment fraction particle size distribution

The findings of the PSA show that, throughout the OAA, sediments are mostly gravelly sand, slightly gravelly sand and gravelly muddy sand. BGS (2022) data suggested that the proportion of samples which were classed as sand increased along the offshore ECC with proximity to the coast. This is consistent with the findings of the PSA (SS5: Benthic environmental baseline report), as described below.

From the 70 samples obtained and analysed across the offshore Project area, sediments were recorded as ranging from fine sand with a mean size of 0.12 mm (at sample S62 midway along the offshore ECC), to medium gravel with a mean size of 11.12 mm (at sample S36 in the middle of the OAA). The overall mean sediment size within the offshore Project was 1.50 mm, classed as very coarse sand (SS5: Benthic environmental baseline report). Within the OAA specifically, the mean sediment size was 2.21 mm. Sediments along the offshore ECC were generally finer, with an average size of 0.80 mm.

Within individual samples, the sediment composition and proportion of sediments of different sizes (i.e. sediment fractions) varied considerably, as detailed further in SS3: Marine physical and coastal processes supporting study. For example, within the OAA, medium sand (0.25-0.50 mm) was present in 100% of samples, with a maximum content of medium sand of 69.0% within each sample. Very coarse gravel (32-64 mm) was present in only 9.1% of samples within the OAA and the contribution of this sediment in any individual sample was up to 43.1%. Additionally, within the offshore ECC fine silts (0.002-0.008 mm) were found in 90.9% of samples, but only ever represented 1% of any given sample. An overview of the PSA results, and the contribution of sediment fractions within samples, is shown in Figure 8-10, superimposed on the backscatter data. On the whole, this indicates that sediments across the whole offshore Project area were generally classed as poorly to moderately sorted, with only a few stations moderately well sorted (SS5: Benthic environmental baseline report). The variation in the samples across the offshore Project area was important in defining the model parameters; the presence of fine versus coarser sediments across the offshore Project area forms the basis for understanding the mobility of sediments in the offshore Project area (section 8.4.4.9), and for assessing the potential effects of the offshore Project on the transport and sedimentation regimes.

8.4.4.5.3 Cobble and boulder clasts

Boulders (classed as anything > 0.5 m) occur throughout the OAA and ECC. Areas where there is a significant concentration of boulders have been termed boulder fields. In addition to the presence of boulder fields there are individual boulders in lower densities across the OAA and offshore ECC. Boulder fields of high boulder density (>20 boulders per 50 x 50 m area) cover extensive areas of the OAA (see Figure 8-11). Some smaller areas of medium boulder density (10-20 boulders per 50 x 50 m area) were also found in the northeast of the OAA. Survey evidence indicated the boulder fields were often found adjacent to till outcrops surrounded by mobile sediments likely composed of sand (Ocean Infinity, 2023a). Within the offshore ECC, site-specific surveys identified the presence of boulders along much of the offshore ECC (Ocean Infinity, 2023b; 2023c; Spectrum, 2023, see Figure 8-11). Most boulders were less than 1 m in size; however, some were as large as 3.5 m (Spectrum, 2023). Further discussion on the distribution of boulders across the offshore Project area is included in SS3: Marine physical and coastal processes supporting study.

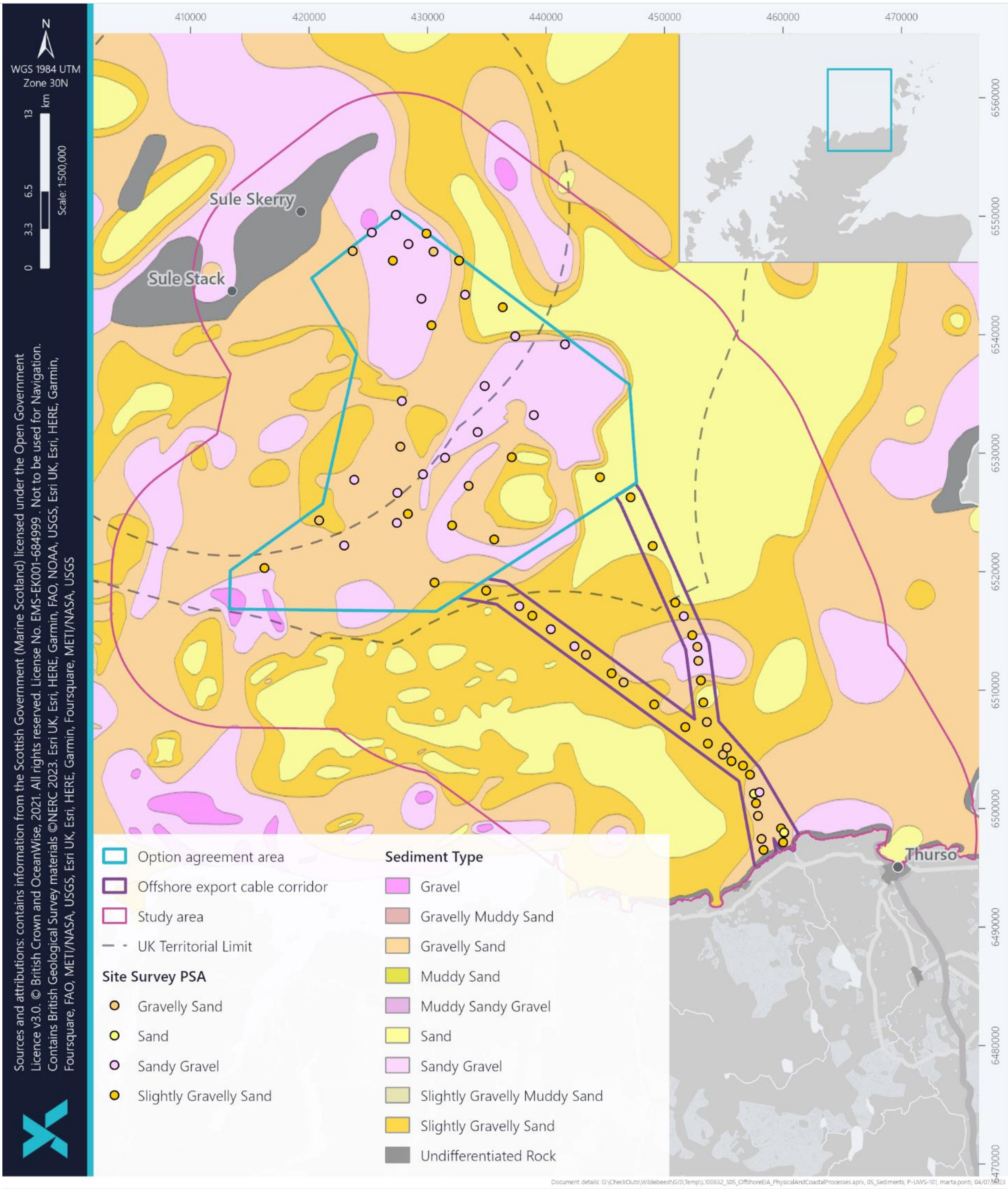

Figure 8-10 Overview of BGS sediment data (BGS, 2022) overlain with site-specific survey PSA results as points (SS5: Benthic environmental baseline report)

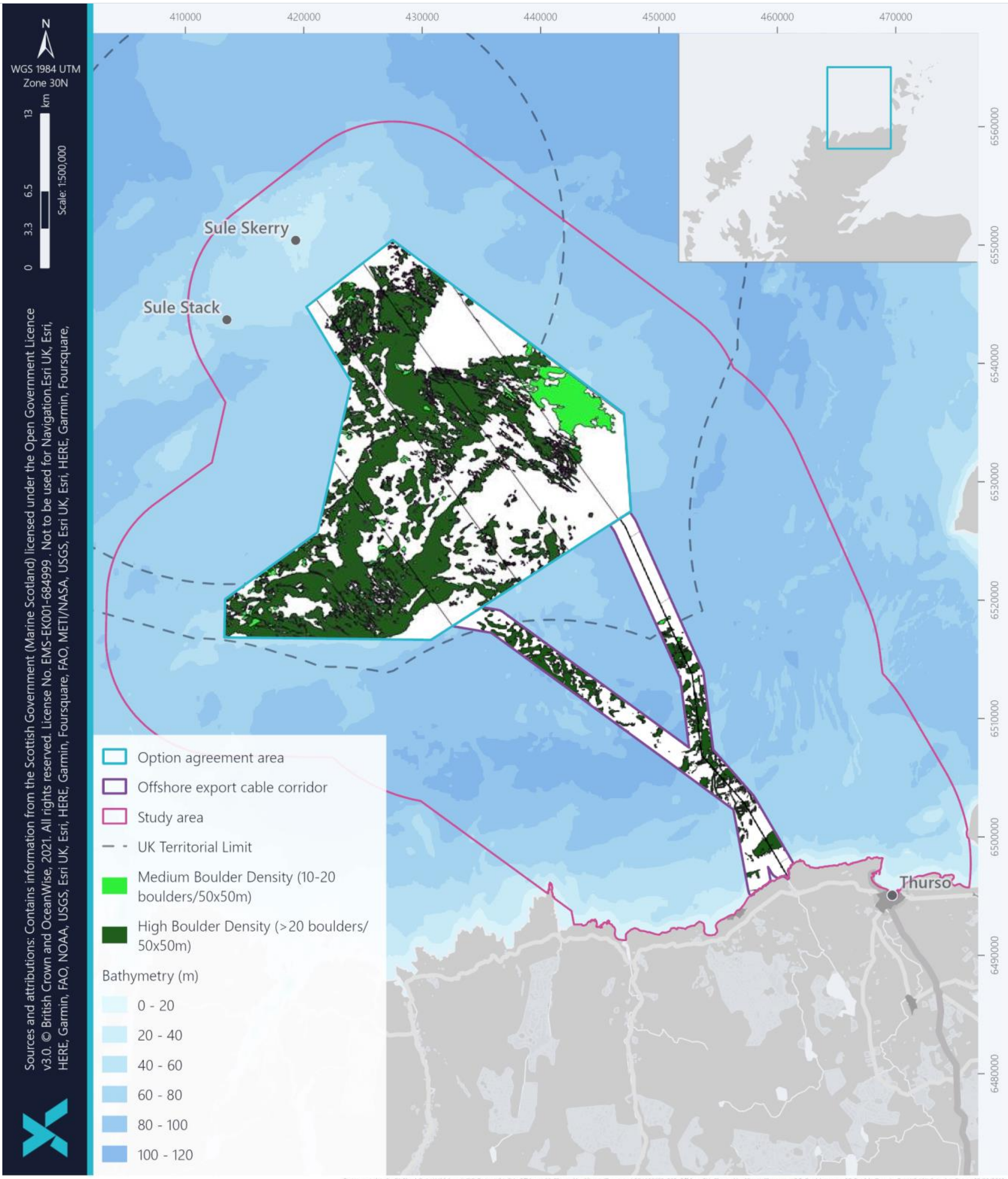

Figure 8-11 Boulder field coverage across the offshore Project area

8.4.4.6 Water levels

8.4.4.6.1 Overview

Available modelled spatial information on water levels across the northwest Scottish continental shelf and the Pentland Firth suggests a north to south variation in tidal range, with a larger range in water level occurring to the south. The offshore Project area is located in a meso-tidal setting, with a mean spring tidal range of 3.01-3.50 m further offshore, increasing to 3.51-4.0 m within the offshore ECC along the coastline of mainland Scotland. Tidal levels considered to be representative of the offshore Project area are shown in Table 8-7, which is also supported by modelled baseline conditions presented in SS3: Marine physical and coastal processes supporting study. Observational data from the NTSLF sites at Wick and Kinlochbervie (British Oceanographic Data Centre, 2022; Figure 8-4) broadly aligns with the statistics in Table 8-7, from the available current hindcast 1 time series introduced in section 8.4.3.4.

Table 8-7 Tidal levels for the offshore Project area (OWPL, 2023), based on data from current hindcast location 1 (Figure 8-4). Water levels are provided with respect to LAT

TIDAL LEVEL		CURRENT HINDCAST 1 (m)
Highest Astronomical Tide	HAT	4.82
Mean High Water Springs	MHWS	4.15
Mean High Water	MHW	3.69
Mean High Water Neaps	MHWN	3.23
Mean Sea Level	MSL	2.47
Mean Low Water Neaps	MLWN	1.71
Mean Low Water	MLW	1.25
Mean Low Water Springs	MLWS	0.79
Lowest Astronomical Tide	LAT	0

8.4.4.6.2 Storm surges and extremes

Across the offshore Project area and wider northwest Scottish continental shelf, non-tidal influences on water levels (i.e. surges) are typically on the order of ±0.5 m on the tidal level, but can occasionally increase during storm events to around ±1.6 m.

Data on surges at Kinlochbervie has been recorded since 1991, and at Wick since 1990, up to 2021 for both sites. Typically, surges at both locations did not exceed 1 m, with lower surge levels occurring at Wick compared with Kinlochbervie. Monthly extreme surges are up to ±1.1 m and ±1.7 m at Wick and Kinlochbervie respectively, with both having larger positive surges(British Oceanographic Data Centre, 2022). Surges at Kinlochbervie are considerably higher than those at Wick, which is to be expected due to the influence of waves from the North Atlantic reaching Kinlochbervie. Surges in January 2020 and November 1998 were consistent between locations, suggesting those were particularly severe storm events.

8.4.4.7 Tidal and residual flows / currents

8.4.4.7.1 Overview

Strong tidal flows are present around the north of mainland Scotland and within the channels of the Orkney Islands (OIC, 2020). The Pentland Firth channel, which separates the Orkney Islands from the Scottish mainland and connects the Atlantic Ocean with the North Sea, in particular is characterised by strong tidal currents with widespread and highly energetic tidal races, eddies, overfalls and areas of general turbulence.

Depth averaged peak flow speeds within the offshore Project area on a spring tide range from 0.5 m/s to 1.0 m/s (ABPmer, 2008). Equivalent depth averaged peak neap flows are typically around 50% less than those on springs, regularly being <0.5 m/s. Flows extracted from the West of Orkney model (as introduced in section 8.4.3.5) for peak flood conditions on a spring and neap tide are shown for comparison in Figure 8-12. Within the OAA, modelled current data (i.e. from the West of Orkney model) was extracted at a number of locations to inform the baseline environment and assess for potential Project impacts. Within the OAA, modelled peak spring ebb and flood depth averaged flow speeds were 0.74 m/s, with flood tides towards the east, turning towards the south-east and approaching the Pentland Firth as illustrated in Figure 8-12. Ebb tides are largely towards the west on exiting the Pentland Firth (Figure 8-12). The West of Orkney modelled flow speeds generally agree with that determined from current hindcast 2, whereby peak spring surface current speeds were 0.76 m/s were calculated at the datapoint (Figure 8-4) (OWPL, 2023).

Tides across the offshore Project area are also asymmetric, with slightly more energetic tidal flows associated with the flood, and marginally less energetic tidal flows associated with the ebb (Marine Scotland, 2016). This results in a marginal flood residual. However, over a spring-neap cycle, the West of Orkney model produced for the offshore Project determined that residual flow speeds are very low, at less than 0.05 m/s across the majority of the Project area, with no dominant residual flow direction (Figure 8-12). Across the wider marine physical and coastal processes study area, spring-neap cycle residual tidal flow speeds are also at or below 0.05 m/s, with only a small region reaching up to 0.1 m/s along the eastern margin of the study area adjacent to the Pentland Firth. The low spring-neap cycle tidal residual across the majority of the Project area strongly indicates a low sediment transport potential. The sediment transport regime in the offshore Project area with respect to the flow condition is described in section 8.4.4.9, while further characterisation of the modelled flows are included in SS3: Marine physical and coastal processes supporting study.

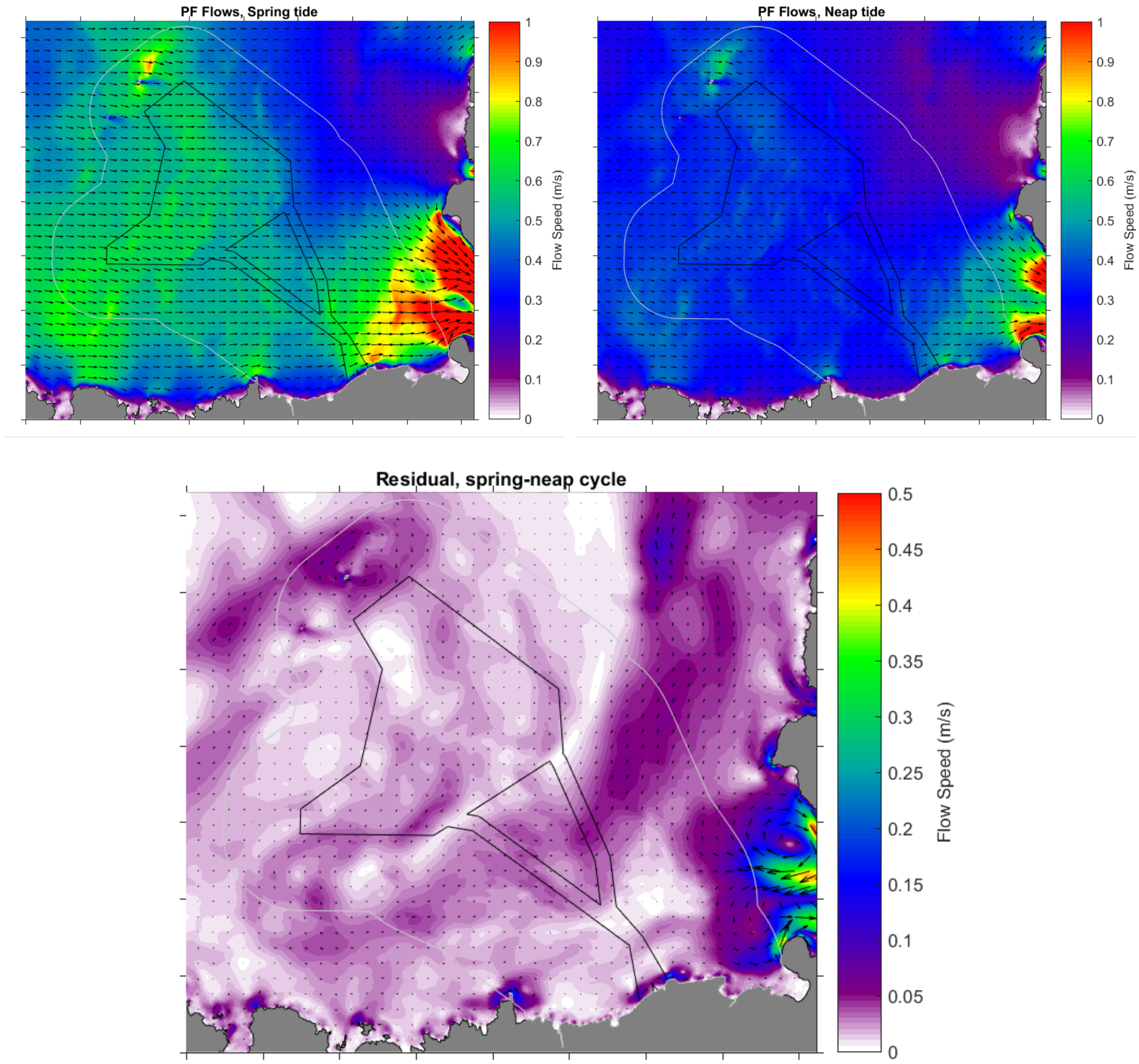

Figure 8-12 Peak flood flow speeds on a spring (top left) and neap (top right) tide and residual flows (bottom) from the West of Orkney model. Colours illustrate the flow speed and the vectors illustrate the flow speed and direction

8.4.4.7.2 Extremes

Data from the Marine Renewables Atlas (ABPmer, 2008) indicates that the depth averaged tidal stream exceeds 2 m/s less than 11% of the time for the area of the offshore Project where coverage is available. This is lower than to the east in the Pentland Firth where this figure rises to over 50% annual exceedance of 2 m/s. Across the Project area, extreme non-tidal current speeds with respect to surge events are around 1.5 m/s at the surface and 0.8 m/s at the seabed based on a 5-year return period event. For a 100-year return period event, speeds of up to 2.2 m/s are predicted to occur at the surface and 1.2 m/s near the seabed (OWPL, 2023).

8.4.4.8 Waves

8.4.4.8.1 Overview

There is large natural variability to Scotland's wave climate with seasonal variation as a result of large scale weather conditions such as autumnal and winter storms (DECC, 2016b). Wave types within the study area vary from short steep waves which are created locally to waves with longer swell which originate from further afield in the Atlantic Ocean. Comparatively, the east coast of Shetland, Orkney Islands and the Scottish mainland are more sheltered and less frequently exposed to large, powerful waves originating in the Atlantic. However, large wave heights can still occur as a result of North Sea storms and swells (DECC, 2016b).

Figure 8-13 illustrates the wave conditions within the offshore Project area informed by hindcast data spanning 1979 to 2015 at wave hindcast 1 (Figure 8-4) (OWPL, 2023). These data indicate that the significant waves originate predominantly from the west and northwest (Figure 8-13), which is expected given that the dominant wind direction increases the fetch in this area.

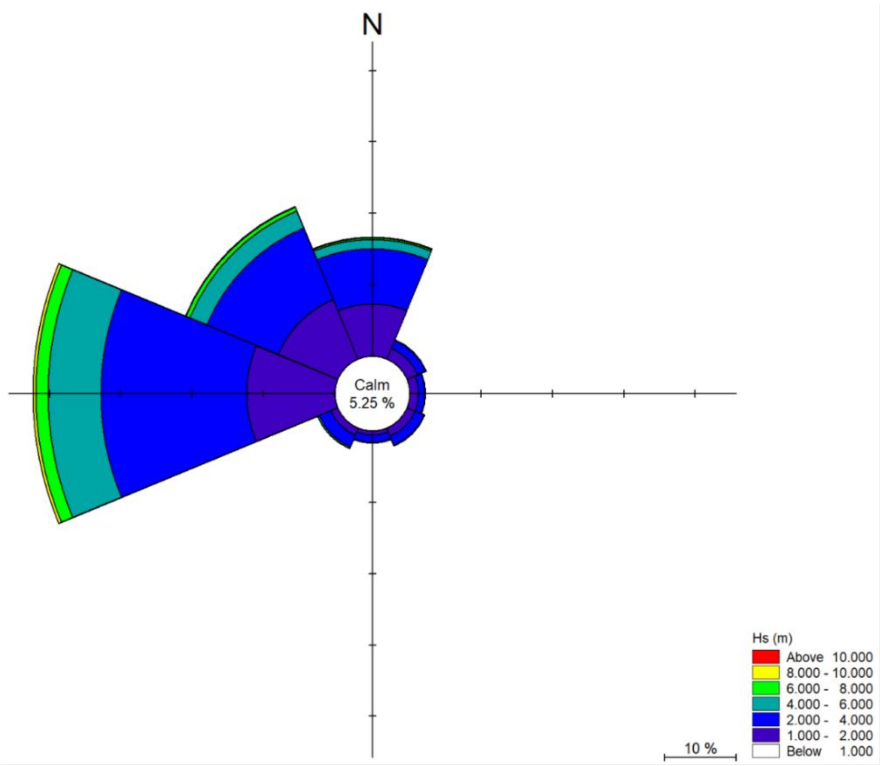

Figure 8-13 Wave rose for the offshore Project area using time series hindcast data from Wave Hindcast 1 (section 8.4.3.4) from the entire 37-year hindcast

Wave hindcast data indicates that waves with a significant height of 1-1.5 m and corresponding peak periods of 9-10 s are most frequent in the offshore Project area; these waves occur 4.43% of the time. Waves with peak periods longer than 10 s are also likely to occur regularly in the OAA as analysed and presented within SS3: Marine physical and coastal processes supporting study. Waves with long peak periods (typically >10 s) tend to be indicative of swell-dominated climatologies, which are likely to have originated in the Atlantic, or beyond.

The omni-directional mean significant wave height (with the omni-directional statistic considered to be an average across all directional sectors) across the offshore Project area is 2.63 m with a corresponding peak period of 11 s (OWPL, 2023). The most frequently occurring wave parameters is taken to be 1.5 m significant height and 9.5 seconds peak period, which is consistent with the overall mean significant wave height determined for the offshore Project. The wave parameters are important as these are used in defining the local sediment transport regime presented in section 8.4.4.9. Based on the available wave hindcast information for the offshore Project from Wave Hindcast 1 (Figure 8-4), statistics associated operational percentiles and extremes statistics were calculated for the Project as summarised in Table 8-8 for the most frequent wave approach directions (OWPL, 2023). As introduced in section 8.4.3.5 and discussed in detail in SS3: Marine physical and coastal processes supporting study, the wave statistics from the Wave Hindcast 1 were also used to determine the appropriate wave conditions at the West of Orkney model boundaries to then model the wave transformation and propagation across the offshore Project area. The return period statistics represent extreme conditions, which are considered further in section 8.4.4.8.2.

Table 8-8 Wave parameters (significant wave height (Hs), wave peak period (Tp), and wind speed) at Wave Hindcast 1, from the dominant approach directions modelled for baseline characterisation and to investigate operational impacts

STATISTIC	WEST (270°)			NORTHWEST (315°)			NORTH (0° / 360°)		
	Hs (m)	Tp (s)	WIND SPEED (m/s)	Hs (m)	Tp (s)	WIND SPEED (m/s)	Hs (m)	Tp (s)	WIND SPEED (m/s)
50th Percentile[13]	2.62	11.0	9.3	2.22	10.6	7.1	2.06	10.4	7.2
90th Percentile[14]	5.06	13.0	16.0	4.34	12.5	13.3	3.88	12.1	12.8
1 in 1 Return Period	10.2	15.7	24.8	9.2	15.3	23.1	8.2	14.8	21.2
1 in 5 Return Period	12.0	16.4	27.5	10.8	15.9	25.8	9.6	15.4	23.8
1 in 10 Return Period	12.6	16.7	28.3	11.4	16.2	26.6	10.1	15.7	24.7
1 in 50 Return Period	13.6	17.0	29.4	12.3	16.5	27.8	10.9	16.0	25.9
1 in 100 Return Period	14.0	17.2	29.8	12.6	16.7	28.3	11.2	16.2	26.4

[13] *The 50th percentile waves are defined as those which 50% of waves will exceed in significant wave height and peak period. Conversely, the remaining 50% will be smaller than the 50th percentile wave.*

[14] *The 90th percentile waves are defined as those which 10% of waves will exceed in significant wave height and peak period. Conversely, the remaining 90% will be smaller than the 90th percentile wave.*

At the landfalls, nearshore (mean) significant wave heights are typically around 1.6 m, with waves largely approaching from the north, but also the northwest and west approach sectors. Observational data from a Cefas WaveNet buoy located offshore at Dounreay (approximately 1.5 km to the west of the offshore ECC) suggests that the waves are slightly smaller although have a similar period; the most frequent waves are associated with a significant height ranging between 0.5 and 1 m and peak period between 9 and 10 seconds (Cefas, 2022).

8.4.4.8.2 Extremes

Extreme wave conditions for the OAA show that largest waves come from the west, associated with the largest fetch and swell waves from the Atlantic. Based on the wave hindcast timeseries, extreme wave properties were calculated for a number of return period events (OWPL, 2023). As presented in Table 8-8, based on calculated wave statistics from Wave Hindcast 1, wave properties associated with the 1 in 1-year storm event (i.e. 1 in 1 return period) from the dominant westerly approach sector (i.e. 270°) indicates a significant wave height of 10.2 m with a corresponding peak wave period of 15.7 s. During a 1 in 100-year storm event (i.e. 1 in 100 return period), the significant wave height reaches 14 m with a corresponding peak period of 17.2 s.

8.4.4.9 Sediment transport

8.4.4.9.1 Overview

The interaction of the seabed with wave and tidal processes determines how often unconsolidated surficial sediments become mobilised and the way they are transported (i.e. bed load transport and/or suspended load transport).

The Pentland Firth has been identified as a bedload parting zone[15] with transport directed into the North Sea in the eastern section and into the north Atlantic in the western section. While the current speeds within the Pentland Firth are particularly high, there are areas of lower sediment mobility associated with headlands, islands and areas of weaker current in and amongst the Orkney Islands. Within the Pentland Firth, Fairley *et al*., (2015) found that the rate of bed level change on a spring tide was almost 1 m/day. On a neap tide, this was considerably lower at <0.1 m/day.

8.4.4.9.2 Coarse sediments

Based on the sampled sediment across the Project area, as described in section 8.4.4.5, the mean sediment size within the OAA is around 2.21 mm (i.e. very fine gravel) and around 0.80 mm (i.e. coarse sand) within the offshore ECC and nearshore. Coarser sediments (i.e. sands and gravels) typically move as bedload transport in response to waves and tides. Using outputs from the West of Orkney model, a time series of flow speeds and water levels were extracted for a 15-day period between 16/01/2013 and 31/01/2013, across a spring-neap tidal cycle, to characterise the baseline environment. The data was extracted for the 28 model extraction locations across the offshore Project area (shown in Figure 8-5). Of these locations, ten were chosen for sediment transport analysis, covering a range of sediment types and water depths within the OAA and offshore ECC (Figure 8-5). The wave parameters described in section 8.4.4.8.1 also fed into the analysis.

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[15] *Bedload parting zone in the marine environment defines a location in which there is a divergence in bedload sediment transport pathways, with transport occurring in opposing directions on either side of the bedload parting.*

The influence of the defined metocean properties was then assessed in relation to the sediments known to occur at those ten locations. Currents and waves were investigated in isolation to determine if they could generate sediment transport. A combined wave and current scenario was also investigated. The output of this analysis was in the format of the percentage of time over the 15-day period where sediments were mobile at each analysis location. Full analyses results of the sediment transport potential at the analysed ten locations, based on the modelled timeseries of baseline flows from the West of Orkney model and the most frequent and mean wave conditions and for all sediment sizes characteristic of the offshore Project area, are presented in SS3: Marine physical and coastal processes supporting study, with a summary of the key results presented here.

The output of the analysis indicates that sediment transport mobility is relatively consistent across the offshore Project area. Currents are typically the principal driving force behind sediment transport. This is reflected in the sediment transport results; currents acting in isolation were able to generate sediment mobility of fine, medium and coarse sand at most locations within the OAA. However, at some locations the influence of waves is evident, particularly under the larger wave parameters (i.e. a significant wave height of 2.6 m and peak period of 11 s, indicative of the 50th percentile wave). Based on the modelled 50th percentile wave condition, sediments of medium sand or finer were, on occasion, mobile under waves alone even at the depths that occur across the offshore Project area. This is due to the ability of large waves to interact with the seabed and mobilise material based on the depths that occur within the offshore Project area. However, sediments which are disturbed by swell are only moved in an orbit associated with each swell wave. Ultimately, sediments are picked up by the oscillation of the wave and deposited in the same location. Therefore, the high percentages of mobility associated with waves are not necessarily representative of transport over a distance, but a localised disturbance event.

Under the smaller wave parameters, fine sands (0.175 mm) are mobile at most of the sample locations 20-40% of the time. This mobility generally corresponds to spring tides and peak neaps. At the analysis locations associated with Stormy Bank, mobility of fine and medium grained sand was seen under the smaller wave conditions, albeit at lower levels than elsewhere within the OAA (SS3: Marine physical and coastal processes supporting study).

Sediment transport within the offshore ECC differs from that seen within the OAA. The range in sediment mobility also varies considerably throughout the offshore ECC, increasing towards the coast. Under the smaller wave conditions, fine sands within the offshore ECC are mobile more than 30% of the time, except at one location (i.e. ECC2) midway along the offshore ECC at a water depth of 98 mLAT, which exhibits lower mobility of fine sediments (under a combined currents and wave scenario). Common to both the OAA and offshore ECC is greater sediment transport potential attributed with larger wave conditions.

8.4.4.9.3 Fine sediments

In addition to the transport of sediments through bedload processes, when finer sediments (i.e. silts and muds) are mobilised they are typically carried in suspension, contributing to higher Suspended Sediment Concentration (SSC) and increasing the turbidity of the water column until they are able to settle out and deposit.

Long-term (1998 to 2015) monthly average concentrations of sea surface Suspended Particulate Matter (SPM) collected and deduced from satellite data by Cefas (2016) is applied here as a proxy for SSC. Within the OAA, concentrations can be considered low, in the region of 0.5 to 1.0 mg/l. Along the offshore ECC, the concentration of suspended sediment are even lower at between 0.08 to 0.6 mg/l (Cefas, 2016). Occasional areas of higher SSC along the coastline suggest that there are areas which are exposed to more active metocean conditions, or receive input from rivers, estuaries or coastal erosion.

Water sampling was conducted as part of the site-specific environmental sampling as described in section 8.4.3.2 (SS5: Benthic environmental baseline report). Twenty-nine TSS[16] water samples were taken from 25 locations across the offshore Project area. Seventeen samples were acquired within the OAA (including replicates), and 12 across the offshore ECC (comprising seven within the offshore areas ECC, 17 samples within the OAA and five within the nearshore) (Figure 8-3). The water samples were obtained across spring and neap conditions, with the replicates at the four locations (in the OAA and offshore ECC only) acquired at both spring and neap tidal states. As introduced in section 8.4.3.2, three samples were taken at each sample location; one at the surface; one mid-way through the water column; and one at the bottom, close to the seabed.

Overall, TSS ranged from <5 mg/l to 35 mg/l across the offshore Project area. Most samples showed a TSS of <5 mg/l. This is in line with the general understanding of the region and assumed to be approximately representative of background levels. On the whole, higher concentrations of TSS were more common along the offshore ECC, although not in the nearshore survey area. This is expected given the greater prevalence of finer sediments in deeper parts of the offshore ECC, as described in section 8.4.4.5. Of the samples taken, concentrations appear to be highest at the mid-point in the water column as presented in the supporting Marine Physical and Coastal Processes Technical Report (SS3). The measured TSS across the OAA and offshore ECC would seem to suggest that concentrations are higher on a neap tide; however, this is not entirely conclusive as this pattern was not strongly reflected in the replicate samples, with only two of the four neap samples demonstrating higher concentration and the remaining two being at background levels. Further results are presented in the Marine Physical and Coastal Processes Technical Report (SS3).

In addition to TSS samples, turbidity measurements were also taken at the 24 sample locations (Figure 8-3) (turbidity measurements were not acquired for one nearshore location). These measurements show the turbidity throughout the water column, with measurements presented in Nephelometric Turbidity Units (NTU). NTU measurements across the offshore Project area ranged from negative to positive 4. The negative values are attributed to the low SSC that occurs across the offshore Project area, so the actual SSC is less than the instrumentation thresholds. NTU correlates positively with TSS. Overall, the NTU is low in line with the low TSS concentrations. This suggests that the water within the offshore Project area is clear (SS3: Marine physical and coastal processes supporting study).

8.4.4.10 Stratification and fronts

Thermal stratification is the development of relatively stable, warmer and colder layers within a body of water. Typically, thermally stratified waters also show stratification in terms of salinity. Where a well-mixed and stratified water body meet, they can develop a distinct density feature known as a front. Fronts can also be associated with higher concentrations of nutrients leading to higher rates of primary productivity. Consequently, these areas are often very important to animals such as marine mammals.

Fronts are one of five large-scale features included on the list of Marine Protected Area (MPA) search features. SNH (now NatureScot) (2014) applied front detection and aggregation techniques to high resolution satellite ocean colour data to describe frequently occurring fronts near to the Scottish coast. The key frontal zones were selected through

[16] *Please note, TSS and SSC are used interchangeably to refer to concentrations of suspended sediment in the water column.*

detailed analysis of the seasonal chlorophyll and thermal front distributions. The offshore Project area does not coincide with any area of strong frontal activity, such as those identified in SNH (2014).

Miller and Christodoulou (2014) investigated the average seasonal occurrence of fronts based on ten years of satellite data (1998 to 2008). The occurrence of fronts varies within the marine physical and coastal processes study area. At the coast, within the offshore ECC, fronts occurred in summer up to seven times over the ten-year period. The occurrences within the OAA were much higher, at between 15 and 30 times. The most easterly parts of the study area, closer to the Pentland Firth, the frequency of occurrence was up to 60 times, so the potential for fronts are more prevalent in this region.

Outputs of the PFOW climatology (O'Hara and Campbell, 2021) at a number of locations (Figure 8-4) were used to inform seasonal variation and stratification in salinity and temperature across the offshore Project area. Over the course of the year the overall range in temperatures within the OAA remains relatively consistent, with a low of approximately 7°C and 15°C encompassing the whole water column. Between mid-May and mid-August, thermal stratification is apparent within the OAA further offshore, as near surface waters are up to 2°C higher than waters mid way through the water column (Marine Scotland, 2016).

Based on information from the PFOW climatology (introduced in Table 8-5), temperature stratification coincides with a seasonal increase in salinity within the OAA. While salinity is marginally higher in the spring months, stratification occurs between May and August. Within the offshore Project area, areas of increased salinity stratification align with the greatest extent of thermal stratification (Marine Scotland, 2016). Data from the PFOW climatology was provided in parts per thousand (ppt), which is exactly the same as practical salinity units (psu) used in the rest of this report. Information from the PFOW climatology indicates a salinity level of between 34.6 and 35.4 psu for the OAA. Within the offshore ECC, salinity is slightly lower, ranging from approximately 33.7 to 34.5 psu. There is overall much less evidence of stratification within the offshore ECC, with the exception of a few months (in summer) which see marginal differences in salinity throughout the water column. However, these peaks are very temporary in duration and represent a difference of <0.1 psu between the surface and near-bottom.

As part of site-specific survey (section 8.4.3.3.2), CTD casts were taken at the same time as the water sampling to investigate the salinity and water temperature throughout the water column. At nearly all locations across the OAA and offshore ECC, there is some evidence of thermal and salinity stratification, with the maximum range in temperature being 1.2°C (temperature ranging from 13.3°C to 14.5°C) and for salinity being approximately 0.5 psu (salinity ranging from 34.55 psu to 35.00 psu). There was, however, little to no stratification observed across the nearshore samples, with samples acquired in the autumn (i.e. in October, section 8.4.3.3.3).

For the temperature and salinity stratification observed across the OAA and offshore ECC, the identified stratification is considered to be strong in the summer months and occurs within the upper 30 m of water, showing that surface waters are warmer and less saline, which is the case in the PFOW climatology and the site-specific samples. Generally, stratification (mainly salinity, but also observed for temperature) appears to be more pronounced in the offshore ECC. The freshwater inflow from the coast could be contributing to the higher degree of stratification observed across the offshore ECC, with the OAA being a more mixed environment, with less pronounced stratification. The measured CTD observations showed more prominent stratification in the offshore ECC than the PFOW climatology suggested (O'Hara and Campbell, 2021). This could be due to the PFOW climatology resolution, and its assumptions.

With respect to the nearshore and absence of any stratification, sampling in the nearshore was completed in October (SS5: Benthic environmental baseline report), where available information for the wider PFOW climatology (O'Hara and Campbell, 2021) indicates the absence of stratification in offshore waters. The season is therefore likely to be the main reason why no stratification was observed, given the water depths present at the nearshore sampling locations. Although, there is also the possibility that the shallower water depths and also the proximity to the coast contribute to the absence of any stratification, as observed during the nearshore surveys (SS5: Benthic environmental baseline report).

As for TSS, the water samples enabled comparison between neap and spring conditions. Overall, for both salinity and temperature, stratification was more apparent on a neap tide. This suggests that stratification also varies marginally between spring and neap conditions, likely to be in relation to the volume of water and flow speed associated with the different tidal states.

8.4.4.11 Coastal morphology

Close to the coast, the offshore ECC splits to the potential landfall locations. One to the east of the offshore ECC at Crosskirk and one to the west at Greeny Geo as shown in Figure 8-14. The coastline within the offshore ECC is oriented southwest to northeast which faces the prevailing wave direction (section 8.4.4.8). At the landfall, a strip of exposed bedrock is apparent which is bordered by loose rock. Steep escarpments and areas of tessellated pavement[17] are visible along the coastal bedrock. In the west of the landfall location, there is an area of rough ground, which has been interpreted as till (Spectrum, 2023). Within the final 1 km before landfall, the seabed slopes upward rapidly. Prior to this point, the incline is relatively gentle. Roughly 1 km from shore, the depth at the landfall is approximately 60 mLAT before reducing sharply. As described in section 8.4.4.3, there is a feature close to the Crosskirk landfall defined by deeper superficial sediments. The feature appears to be a bank formation, or similar, approximately 3.5 km in length close to the Crosskirk landfall.

The coastline where the offshore ECC achieves landfall is characterised by hard and mixed substrate, with cliffs along much of the coast (Hurst *et al.*, 2021) based on the updated Dynamic Coast project (Dynamic Coast, 2021). The coastline at the offshore ECC landfall is considered not erodible according to NatureScot's Dynamic Coast mapping tool (Dynamic Coast, 2021). The EMODnet CoastType is classed as "Erosion-resistant rock and/or cliff, without loose eroded material in the fronting sea" (EMODnet, 2021). Analysis of the coastline according to Google Earth imagery between 2004 and 2021 indicates there has been no change to the coastline since the early 2000s. Furthermore, completed nearshore and intertidal surveys identified the presence of exposed resistant bedrock, with acquired ortho-imagery also demonstrating the presence of rock platform (Spectrum, 2023). The site-specific observations at the landfalls are in agreement with the wider understanding of this coastline (Dynamic Coast, 2021).

[17] *Tessellated pavement is described as a relatively flat rock surface which has been divided into rough rectangular blocks or polygon shapes by fractures or joints within the rock.*

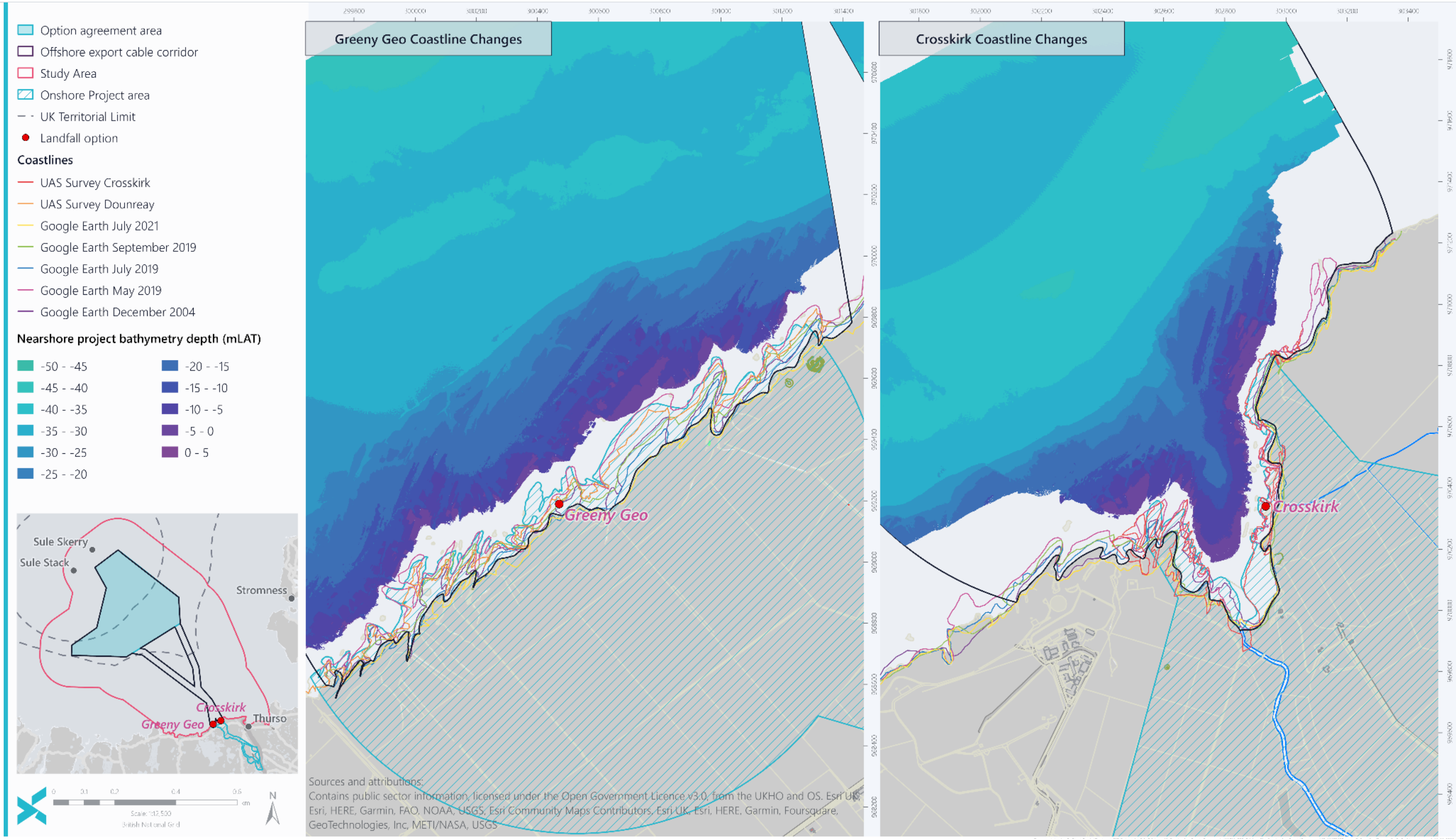

Figure 8-14 Coastal change at the offshore ECC landfall

8.4.5 Future baseline

Aspects of the marine physical and coastal processes baseline are likely to change over time, largely due to climate change. However, the degree of change is uncertain. Certain features of the physical environment, such as the bedrock geology and subsurface sediments, will remain unchanged over time. These features have been consistent within the offshore Project area for millennia and will continue to be so into the future. In contrast, metocean regimes within the area are likely to be influenced over time by the changing climate. This may have consequences for other dependant physical features and properties such as fronts, sediment transport etc.

8.4.5.1 Seabed bathymetry and morphology

There is not anticipated to be any change to the seabed bathymetry in the long term. The absence of change in large bedforms and the consistency in seabed depths over time thus far (sections 8.4.4.2 and 8.4.4.3) supports this conclusion. Bathymetry here pertains to seabed topography. In terms of the relationship the seabed has to water levels, this is discussed in the following section 8.4.5.2.

8.4.5.2 Water levels

With regards to changes in water level, the UK Climate Projections (UKCP) provide details of climate change projections for mean sea level at sites around the UK coastline. The projections extend to 2100 for various scenarios (Representative Concentration Pathways, RCP). Under RCP8.5 (the high emissions scenario), climate change is expected to contribute a 1–2 mm increase in the sea level rise per year in the UK. Under the high-emissions scenario, by 2100 the sea level at the offshore ECC landfall location will have risen by approximately 1 m, based on the 95th percentile estimate.

Over the last approximately thousand years, the average relative sea-level rise around the Orkney Islands has been around 0.2 mm per annum. This is still the case even with the variable isostatic recovery of the Scottish land masses after the effects of glaciation due to the thawing of the Scottish Ice Sheet (Dawson *et al.*, 2013). This isostatic adjustment will continue in tandem with the predicted rise in sea level attributed to changes in the climate described above. Sea level changes associated with isostatic adjustment are slow and part of an ongoing process which will continue beyond the lifetime of the Project. However, what is more likely to occur is the rise in relative sea level in line with UKCP projections, albeit at relatively low levels at the coastal landfall, resulting in a landward advance of high water, the effect of which is considered in relation to the coastal morphology in section 8.4.5.7.

8.4.5.3 Waves

Due to naturally high inter-annual variability in the wave climate and low confidence in future climate change projections, there is presently no clear consensus on future wave climates affecting the north coast of Scotland (Wolf *et al.*, 2020; Bircheno *et al.*, 2023), although it is expected that natural variability will continue to contribute to the trends observed in the frequency and intensity of waves and storms within the North Atlantic. The most recent Marine Climate Change Impacts report card suggests that there is likely to be an overall reduction in mean significant wave height in the north of the UK (compared to an increase in the south; Bircheno *et al.*, 2023). Any change attributable to ongoing climate change will occur on timescales beyond the operational life of the Project.

8.4.5.4 Tidal flows

There is not expected to be any change to tidal flows in the future. The tidal properties within the offshore Project area are associated with much larger regional scale tidal movement. Tidal flows are additionally independent of wind and wave conditions.

8.4.5.5 Sediment transport

Given that there are not expected to be any changes to the regional scale tidal properties, and only natural variation to the wave climate in response to climate change is likely to occur, there is not anticipated to be any variation to the sediment transport characteristics in the future (beyond existing natural variability), especially within the Project lifespan.

8.4.5.6 Stratification and fronts

While there is no evidence to support the presence of fronts in the offshore Project area, site-specific data (as described in section 8.4.4.10) supports the presence of seasonal stratification within the area, both in terms of temperature and salinity. While the degree of this stratification appears to be quite limited, any changes to the frequency of occurrence or properties of fronts and stratification will be dictated by mesoscale processes and regional changes to the water column, which would also be influenced by climate change. This would be dependent on the conditions described in previous sections.

8.4.5.7 Coastal morphology

As described in section 8.4.4.11, the coastline where the offshore ECC landfall will occur consists of erosion resistant rock. To date, the coastline is considered to be stable and there is no evidence of erosion. Although the wider coastline between Duncansby Head and Cape Wrath has experienced relative variability between the 1970s and 2017 (Fitton *et al*., 2017), with the predictions of relative sea level rise (in section 8.4.5.2) and the landward movement of high water associated with relative sea level rise, there is the potential that this would result in coastal erosion. This erosion would likely be constrained to locations which have a softer and more erodible frontage (Horsburgh *et al*., 2020). Consequently, this is less likely to apply to the landfall location given the nature of the geology there. Furthermore, the timescale of this change would be beyond the operational life of the Project.

8.4.6 Summary and key issues

Table 8-9 Summary and key issues for marine physical and coastal processes

	OFFSHORE PROJECT AREA
SUMMARY AND KEY ISSUES	• A number of designated sites overlap with the marine physical and coastal processes study area. • Bedrock geology is likely consistent across the whole offshore Project area and constitutes soft red sandstone dated to the Permian-Triassic. • Surface sediments are mostly sandy and quite coarse, with gravel also making a considerable component in places. Boulders are also a common feature across the offshore Project area, with extensive areas characterised as having medium to high boulder density. • Water depths within the OAA range between approximately 41 mLAT and 90 mLAT with shallower regions of less than 60 m located on the two banks (Whiten Head Bank and Stormy Bank). Within the offshore ECC, the water depth is more variable but generally deeper, ranging from 44 mLAT to approximately 110 mLAT in offshore areas, noting that as the offshore ECC reaches landfall the water depth reduces to 0mLAT. • The two banks within the OAA are stable and there is no evidence of active migration. In addition to the two larger bank features, the seabed within the offshore Project area regularly features bedforms including sandwaves, depressions and megaripples. • Peak flow speeds within the offshore Project area on a spring tide range from 0.5 m/s to 1.0 m/s. Equivalent peak neap flows are typically around 50% less than those on springs, regularly being <0.5 m/s. There is no dominant residual flow direction within the offshore Project area. • Residual flow speeds are relatively slow at less than 0.1 m/s, so the sediment transport potential across the offshore Project area is low. • Waves within the offshore Project area originate predominantly from the north/northwest. The majority of waves in the offshore Project area have a significant height of 1-1.5 m and corresponding peak period of 9-10 s. Swell waves, which originate further afield, feature considerably as part of the local wave climate. • There is evidence of some thermal stratification in the offshore Project area, this is limited in scale and only evident from late spring until autumn. Changes in salinity correspond to the variation in temperature. • The coastline where the offshore ECC landfalls will occur is characterised by hard and mixed substrate which is considered to be erosion resistant. There is also the presence of a sedimentary feature in the nearshore of the Crosskirk landfall, which is parallel with the coastline, which ranges in depths of around 25 mLAT at its shallowest to over 40 mLAT at its base.

8.4.7 Data limitations and uncertainties

Complementary evidence has been collated from various sources to support the development of the baseline characterisation. Whilst good overall understanding is achieved, there remain some data limitations across the offshore Project in the quantification of measured flows and waves, which places reliance on existing models to provide these details. Validated models, such as that of the PFOW climatology (O'Hara and Campbell, 2021) and the Project specific West of Orkney model, have been used within this Offshore EIA Report and are an accepted basis for describing the marine environment and are appropriate to support a robust impact assessment.

ScotMER

The scope of the marine physical and coastal processes assessment undertaken for the West of Orkney Windfarm offshore wind project directly addresses and will provide useful data to inform some of the key research themes identified by the ScotMER physical processes receptor group, including:

- Modelling development and validation; seabed and sediment impacts; cumulative impacts – A Project specific model has been developed to inform seabed and sediment impacts and far field cumulative effects. Full details of the model, including input data is provided in the Marine Physical and Coastal Processes Technical Report; and
- Ecology and mixing – Project specific survey data was collected to inform stratification in the Project area and potential changes to water column structures from the presence of the Project. This in turn informed potential ecosystem level effects.

8.5 Impact assessment methodology

8.5.1 Impacts requiring assessment

The impacts identified as requiring consideration for marine physical and coastal processes are listed in Table 8-10. Information on the nature of impact (i.e. direct or indirect) is also described.

Table 8-10 Impacts requiring assessment for marine physical and coastal processes

POTENTIAL IMPACT	NATURE OF IMPACT
Construction (including pre-construction) and decommissioning*	
Change to seabed levels, sediment properties and suspended sediment concentrations	Direct / indirect
Impact on interest features within the designated sites due to export cable construction	Direct
Change to coastal landfall morphology	Direct
Operation and maintenance	
Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors	Direct / indirect
Introduction of scour	Direct
Changes to water column structure with impact to stratification	Direct

POTENTIAL IMPACT	NATURE OF IMPACT
Re-exposure of buried cables and changes to coastal processes and landfall morphology from remedial protection measures	Direct
*In the absence of detailed information regarding decommissioning works, and unless otherwise stated, the impacts during the decommissioning of the offshore Project considered analogous with, or likely less than, those of the construction stage. Where this is not the case, decommissioning impacts have been listed separately and have been assessed in section 8.6.3.	

8.5.2 Impacts scoped out of the assessment

Table 8-11 Impacts scoped out for marine physical and coastal processes

POTENTIAL IMPACT	JUSTIFICATION
Construction (including pre-construction) and decommissioning	
n/a	
Operation and maintenance	
Seabed abrasion associated with Project infrastructure (e.g. anchor chains if a floating structure is progressed)	This impact has been scoped out as floating structures are no longer part of the current application. The Project will involve installation of fixed foundation WTGs.

8.5.3 Assessment methodology

An assessment of potential impacts is provided separately for the construction (including pre-construction), operation and maintenance and decommissioning stages.

The assessment for marine physical and coastal processes is undertaken following the principles set out in chapter 7: EIA methodology. The sensitivity of the receptor is combined with the magnitude to determine the impact significance. Topic-specific sensitivity and magnitude criteria are assigned based on professional judgement, as described in Table 8-12 and Table 8-13 respectively.

Table 8-12 Sensitivity criteria

SENSITIVITY OF RECEPTOR	DEFINITION
High	Receptor is of very high importance and is protected under national and international legislation. Receptor with no or very low capacity to accommodate a particular effect with no or low ability to recover or adapt.
Medium	Receptor is of high importance and is protected under national and international legislation. Receptor with low capacity to accommodate a particular effect without significantly altering character. Receptor has moderate ability to recover or adapt.
Low	Receptor is of moderate importance, but with no associated designation. The receptor is considered tolerant to change without significant detriment to its character; some limited or minor change may occur. Receptor has some tolerance to accommodate a particular effect and a high ability to recover or adapt.
Negligible	Receptor of very low importance, with no associated designations. Receptor is generally tolerant and can accommodate a particular effect without the need to recover or adapt and without effect on its fundamental character.

Table 8-13 Magnitude criteria

MAGNITUDE CRITERIA	DEFINITION
High	Impact occurs over a large spatial extent resulting in widespread, long term or permanent changes in baseline conditions or affecting a large proportion of the receptor. The impact is very likely to occur and /or will occur at a high frequency or intensity.
Medium	Impact occurs over a local to medium extent, with short to medium term change to baseline conditions or affecting a moderate proportion of the receptor. The impact is likely to occur and/ or will occur at a moderate frequency or intensity.
Low	Impact is localised and temporary or short term, leading to detectable change in baseline conditions or noticeable effect on small proportion of the receptor. The impact is unlikely to occur or may occur but at low frequency or intensity.
Negligible	Impact is highly localised and short term with full rapid recovery expected to result in very slight or imperceptible changes to baseline conditions or the receptor. The impact is very unlikely to occur and if it does will occur at very low frequency or intensity.

The consequence and significance of effect is then determined using the matrix provided in chapter 7: EIA methodology.

8.5.4 Embedded mitigation

As described in chapter 7: EIA methodology, certain measures have been adopted as part of the Project development process in order to reduce the potential for impacts to the environment, as presented in Table 8-14. These have been accounted for in the assessment presented below. The requirement for additional mitigation measures (secondary mitigation) will be dependent on the significance of the effects on marine physical and coastal processes receptors.

Table 8-14 Embedded mitigation measures relevant to marine physical and coastal processes

MITIGATION MEASURE	TYPE	DESCRIPTION	HOW MITIGATION WILL BE SECURED
Site selection	Primary	The offshore Project, including the OAA and offshore ECC, avoids any overlap with designated sites with seabed features (e.g. the North West Orkney NCMPA).	Already secured through the OAA and offshore ECC boundaries.
Scour protection	Primary	The use of scour protection around the foundations of WTGs and OSPs will minimise scour effects around infrastructure. However, scour protection will only be implemented where required and will be minimised as far as is practicable. This will be informed by a scour assessment, undertaken post-consent.	Final scour requirements will be informed by the scour assessment and detailed within the Construction Method Statement (CMS), required under Section 36 Consent and/or Marine Licence conditions.
Cable protection	Primary	Suitable implementation and monitoring of cable protection (via burial or external protection). Cables will be buried as the first choice of protection. External cable protection will be used where adequate burial cannot be achieved and this will be minimised as far as is practicable. This will be informed by a Cable Burial Risk Assessment (CBRA) undertaken post consent following results of the geotechnical survey.	Final cable design will be informed by the CBRA and detailed within the Cable Plan (CaP), required under Section 36 Consent and/or Marine Licence conditions.
Landfall installation methodology	Primary	Landfall installation methodology (Horizontal Directional Drilling, HDD) will avoid direct impacts to the intertidal area.	Landfall installation methodology will be detailed within the CMS, required under Section 36 Consent and/or Marine Licence conditions.
Pre-construction cable route surveys	Primary	Pre-construction cable route survey to confirm the state of the seabed and that no significant changes have occurred from previous surveys, confirm the presence of morphological features and the requirement for micro-siting around	Requirement for pre-construction cable route survey will be secured under Section 36 Consent and/or Marine Licence conditions. Final cable design will be detailed within the CaP,

MITIGATION MEASURE	TYPE	DESCRIPTION	HOW MITIGATION WILL BE SECURED
		these or completion of seabed preparation works. The final offshore Project layout will be presented within the Development Specification and Layout Plan (DSLP) and CaP.	required under Section 36 Consent and/or Marine Licence conditions.
Decommissioning Programme	Tertiary	The development of, and adherence to, a Decommissioning Programme, approved by Scottish Ministers prior to construction and updated throughout the Project lifespan.	The production and approval of a Decommissioning Programme will be required under Section 105 of the Energy Act 2004 (as amended).

8.5.5 Worst case scenario

As detailed in chapter 7: EIA methodology, this assessment considers the worst case scenario for the offshore Project parameters which are predicted to result in the greatest environmental impact, known as the 'worst case scenario'. The worst case scenario represents, for any given receptor and potential impact, the design option (or combination of options) that would result in the greatest potential for change.

Given that the worst case scenario is based on the design option (or combination of options) that represents the greatest potential for change, the development of any alternative options within the design parameters will give rise to no worse effects than those assessed in this impact assessment. Table 8-15 presents the worst case scenario for potential impacts on marine physical and coastal processes during construction, operation and maintenance, and decommissioning.

As detailed in SS3: Marine physical and coastal processes supporting study, the pathways for effect on marine physical processes are primarily through seabed disturbance, loss or alteration of seabed and blockage. Due to the nature of marine physical and coastal processes and the range of potential Project design options for construction (including pre-construction), operation and decommissioning, it is the case that there are different impact pathways necessitating varying worst case scenarios. Therefore, section 8.5.5.1 to section 8.5.5.2 summarises the Project design relevant to inform the different impacts, with respect to the Project stage and impact pathways. Table 8-15 provides direction to the relevant section and justification for the applied Project design worst case. The applied worst case Project design also directly informed SS3: Marine physical and coastal processes supporting study and the completed numerical modelling. However, it should be noted that the modelling of potential impacts and analysis of blockage effects were completed with respect to more conservative parameters relating to the Project's design. The numerical model was developed early in the EIA, during, and informed by the EIA, there were some changes to the Project Design Envelope, including a reduction in the monopile diameter. Therefore, the underlying assumptions for certain parameters used to inform the modelling for bedform clearance are larger than that represented in the final Project design for the EIA. Where there are differences, these are explained within the relevant impact assessment. On the basis that the assessment do not identify any significant impacts as described in section 8.6, it is considered that a smaller envelope will result in even smaller impacts than presented.

Table 8-15 Worst case scenario specific to marine physical and coastal processes receptor impact assessment

POTENTIAL IMPACT	WORST CASE SCENARIO	JUSTIFICATION
Construction (including pre-construction)		
Changes to seabed levels, sediment properties and suspended sediment concentrations	The following activities may cause changes to seabed levels, sediment properties and suspended sediment concentrations: • Seabed preparation, including boulder clearance and bedform clearance (by Trailing Suction Hopper Dredger (TSHD) or Controlled Flow Excavator (CFE)); • WTG and OSP foundation installation (drilling); and • Cable installation by CFE. Parameters associated with the worst case based on the different impact pathways (listed above) are outlined in Table 8-16 to Table 8-19. CFE and dredging by TSHD[18] have been accounted for as potential worst case activities in the assessment, based on the different disturbance mechanisms. Should TSHD be used, excavated material may be disposed of in designated/licensed disposal sites or within the offshore Project area[19].	This covers the largest spatial area of impact associated with seabed clearance activities, WTG, OSP, and cable installation activities (including scour and remedial cable protection measures). The areas of impact associated with each activity are presented separately although in reality these footprints will overlap considerably. Maximum volumes of sediment to be cleared and volumes of rock protection are also provided. The maximum dimensions of WTG and OSP foundations are also given, including maximum drilling parameters.

[18] *Dredging by TSHD includes disposal, which would entail a separate Marine Licence application to MD-LOT. The exact need for dredging and disposal will not be confirmed until a further stage of the Project. If dredging is required, OWPL understand that sediment samples must be collect, analysed and provided to MD-LOT in support of the Marine Licence application.*

[19] *Please note, this disposal location has not yet been selected as part of the Project Design Envelope. For the purposes of this assessment and for ease of quantification of impacts, a nominal indicative disposal area has been chosen for some context.*

POTENTIAL IMPACT	WORST CASE SCENARIO	JUSTIFICATION
	For the drilling of WTG foundations, consideration is given to the drilling of a single WTG and also two WTGs being drilling concurrently. In addition, while these activities are all considered alone, an in-combination scenario is also considered in the assessment. There are three proposed foundation types for the 125 WTGs: • Monopiles; • Piled jackets; and • Suction bucket jackets. Key parameters for each foundation option are shown in Table 8-17. These parameters include quantification of scour protection measures associated with each foundation type. There are two proposed foundation types for the five OSPs; • Piled jackets; and • Suction bucket jackets. The key parameters of the two assessed foundation types are summarised in Table 8-18, inclusive of scour protection. The Project intends to install all cables by trenching and burial. The worst case scenario assumes that installation of cables will be done by use of CFE. Parameters associated with cable installation are shown in Table 8-19. This includes external protection measures (assumed for assessment purposes to be rock).	
Impacts on designated features within designated sites due to export cable construction	The worst case scenario parameters relating to this impact are the same as outlined above. A number of the designated sites lie within the study area (section 8.4.4.1). These lie primarily along the coast of the Scottish mainland, therefore are closest to the offshore ECC. It is important to clarify that, while the offshore ECC is immediately adjacent to one site (Ushat Head SSSI), no activity associated with the Project will occur directly within site	The worst case scenario parameters relating to this impact are the same as outlined above.

POTENTIAL IMPACT	WORST CASE SCENARIO	JUSTIFICATION
	boundaries. Consequently, there will be no direct loss of features as a result of cable lay or placement of rock protection.	
Changes to coastal landfall morphology	Two potential landfalls are being considered, one at Crosskirk and the other at Greeny Geo, with Horizontal Directional Drilling (HDD) being proposed. The location of the offshore exit point is expected to occur between 10 and 40 mLAT. Aspects of cable installation, as described above (and presented in Table 8-19) are also relevant to this impact. However, the worst case parameters with regards to activity at the landfall specifically are as follows: • Maximum of six exit pits (five plus one spare) each of an area of 300 m^2 (totalling 1,800 m^2), at a water depth of approximately 10 - 40 m below Lowest Astronomical Tide (LAT) (approximately at a minimum of 100 m offshore from 0 mLAT); • Typical HDD exit pits would be 10 m wide x 30 m long x up to 5 m deep; • The pits are assumed to be orientated perpendicular to the coast (so the 30 m length will extend offshore); • Each pit will have a volume of up to 1,500 m^3; • An anticipated 9,000 m^3 of material will be removed as a result of the six pits; • Approximately 1,630 m^3 of cuttings (including bulking) will be removed from each of the six HDD bores at the onshore end of the HDD bore; • The cuttings will be transported by lorry to suitable disposal location onshore; and • Material excavated during HDD will be extracted back on land with little to no release at sea. The exception is only at punch-out at the HDD exit, where a small volume of drilling fluid may be released. The drilling fluid will comprise bentonite, which is an inert substance considered to Pose Little or No Risk to the Environment (PLONOR).	Aspects of cable installation relating to this impact are covered by the impacts above. Additional parameters here are provided in relation to the HDD exit pits (including the maximum number, dimension, volume etc.).
Operation and maintenance		

POTENTIAL IMPACT	WORST CASE SCENARIO	JUSTIFICATION
Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors	An arrangement of WTGs was organised into two Layouts (1 and 2), shown in Figure 8-15. Layout 1 was orientated in relation to the dominant wave and flow direction, with the minimum spacing and the potential for blockages and the coalescence of these effects within the OAA. Layout 2 represents an orientation in relation to the northwest wave approach direction, with structures occurring at shallower depths on the Whiten Head Bank and Stormy Bank features, which again presents the potential for blockage effects. Note, these two layouts were devised for the purposes of use in the marine physical processes assessment for input to the West of Orkney model[20]. With regards to assessing blockage effects associated with the installed infrastructure, WTG spacing is described in Table 8-17. Blockage effects may also arise as a result of the presence of rock berms, as a cable protection measure, with the rock berm potentially influencing localised flows and associated sediment transport. The footprint of rock protection is given in Table 8-19, while further description of the cable protection measures being considered are described in Table 8-20.	This covers the two WTG OAA layout options developed to inform the marine physical and coastal processes impact assessment. These layouts were developed to assess for the worst case potential blockages to west and northwest waves. In addition the potential blockage to sediment transport are also evaluated in relation to the presence of protection measures on the seabed.
Introduction of scour	The predicted area of scour associated with the Project installations is stated in section, Table 8-17 and Table 8-18. Scour parameters in association with WTG and OSP foundations are detailed in Table 8-21. For assessment of the worst case scenario, protection is assumed to constitute rock placement.	Maximum parameters in relation to scour are provided here, covering the maximum spatial extent of scour and rock protection measures against scour formation. This is given for both WTGs and OSPs.
Changes to water column structure with impact to stratification	The worst case scenario parameters relating to this impact are the same as outlined above, and Table 8-17, Table 8-18 and Figure 8-15.	The worst case scenario parameters relating to this impact are the same as outlined for construction impacts above.

[20] *The final design and layout parameters will be secured within a Development Specification and Layout Plan (DSLP).*

POTENTIAL IMPACT	WORST CASE SCENARIO	JUSTIFICATION
Re-exposure of buried cables at landfall and changes to coastal processes and landfall morphology from remedial protection measures	The worst case scenario parameters relating to this impact are the same as outlined above.	The worst case scenario parameters relating to this impact are the same as outlined for construction impacts.
Decommissioning		
In the absence of detailed information regarding decommissioning works, the implications for marine physical and coastal processes are considered analogous to or likely less than those of the construction stage. Therefore, the worst case parameters defined for the construction (including pre-construction) stage also apply to decommissioning. The decommissioning approach is set out in chapter 5: Project description.		

8.5.5.1 Construction

The information presented in this section corresponds to the worst case scenarios for the construction impacts outlined in Table 8-15.

The parameters associated with the anticipated seabed preparation (boulder and bedform clearance) for all offshore infrastructure is summarised in Table 8-16.

Table 8-16 Seabed clearance construction parameters

PARAMETER	WTG & OSP FOUNDATIONS	EXPORT CABLES	INTER-ARRAY CABLES	INTERCONNECTOR CABLES
Maximum boulder clearance footprint across all areas (m^2)	30,442,900			
Maximum bedform clearance and levelling width (m)	N/A	1,000	150	150
Maximum bedform clearance and levelling length (km)	N/A	19.2	33.8	19.5
Maximum bedform clearance and levelling footprint (m^2)	39	19,200,000	3,375,000	2,925,000
Maximum bedform clearance and levelling volume (m^3)	250,000	495,000	382,360	382,360

Key parameters for each WTG foundation option are shown in Table 8-17. The key parameters of the two OSP foundation types are summarised in Table 8-18. These parameters include quantification of scour protection measures associated with each foundation type.

Table 8-17 WTG foundation construction specifications

PARAMETER	LARGEST MONOPILE	LARGEST PILED JACKET	LARGEST SUCTION BUCKET JACKET
Minimum WTG spacing (m)[21]	1,320	1,200	1,200
Maximum foundation length (m)	18[22]	20	20
Maximum foundation breadth (m)	18	20	20
Maximum seabed footprint per WTG foundation (m^2) excluding scour protection	255	170	2,100
Maximum number of piles per WTG	1	4	n/a
Maximum pile/suction bucket diameter (m)	18	4	13
Maximum pile penetration depth (m)	40	53	N/A
Maximum drilling depth (m)	40	53	N/A
Maximum suction bucket penetration depth (m)	N/A	N/A	30
Maximum drill volume per WTG (m^3)	11,000	2,660	N/A
Maximum drill volume OWF (m^3)	1,375,000	332,500	N/A
Maximum scour protection area per WTG (excluding pile area) (m^2)	~8,000	~9,500	~9,500
Maximum total footprint per WTG (including scour protection) (m^2)	~8,255	~11,200	~11,600

Table 8-18 OSP foundation construction specifications

PARAMETER	LARGE PILED JACKET	LARGE SUCTION BUCKET JACKET
Number of legs per foundation	8	8
Number of piles per leg	2	N/A
Seabed foot per foundation (m^2)	3,700	4,120
Jacket leg diameter (m)	4	4
Pile diameter (m)	4	N/A
Pile penetration depth (m)	40	N/A
Suction bucket diameter (m)	N/A	8
Suction bucket penetration depth (m)	N/A	14
Drilling depth (m)	40	N/A
Scour protection area per foundation (excluding pile area) (m^2)	16,500	17,300
Total footprint per foundation (including scour protection) (m^2)	20,200	21,420

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[21] *A smaller WTG spacing of 944 m is relevant to the smallest foundation size, however it is noted that with this smaller spacing the ratio between the spacing and foundation diameter is larger than that for the larger diameter, so the spacing for the largest foundation size is still considered to be the worst case.*

[22] *Following development of the numerical model, during and informed by the EIA certain design parameters in the PDE were amended, including reduction of monopile diameter from 18 m to 14 m. As 18 m was larger than the revised parameter (and therefore represented a worst case assessment), it was not necessary to update the numerical model for a smaller monopile diameter.*

The worst case scenario assumes that installation of cables will be done by use of CFE. Parameters associated with cable installation are shown in Table 8-19.

Table 8-19 Cable installation specifications

PARAMETER	EXPORT CABLE	INTER-ARRAY	INTERCONNECTOR CABLES
Maximum number of cables	5	140	6
Maximum total length of cables (km)	320	500	150
Maximum corridor width (m)	1,000	150	150
Target burial depth (m)	3	3	3
Maximum trench width (m)	5	5	5
Maximum total area of seabed disturbance (km^2)	16	25	8
Maximum total length of expected cable burial (km)	224	400	51
Maximum total length of expected cable protection (km)	93.5	100	99
Maximum rock berm width (at base) (m)		20	
Maximum rock berm height (m)		3	
Maximum cable protection berm footprint (m^2)	1,870,000	2,000,000	1,980,000
Maximum number of crossings	5	10	
Maximum crossing berm footprint (m^2)	62,500	62,500	

8.5.5.2 Operation and maintenance

The information presented in this section corresponds to the worst case scenarios for the operation and maintenance impacts outlined in Table 8-15. The arrangement of WTGs in Layouts 1 and 2 are shown in Figure 8-15.

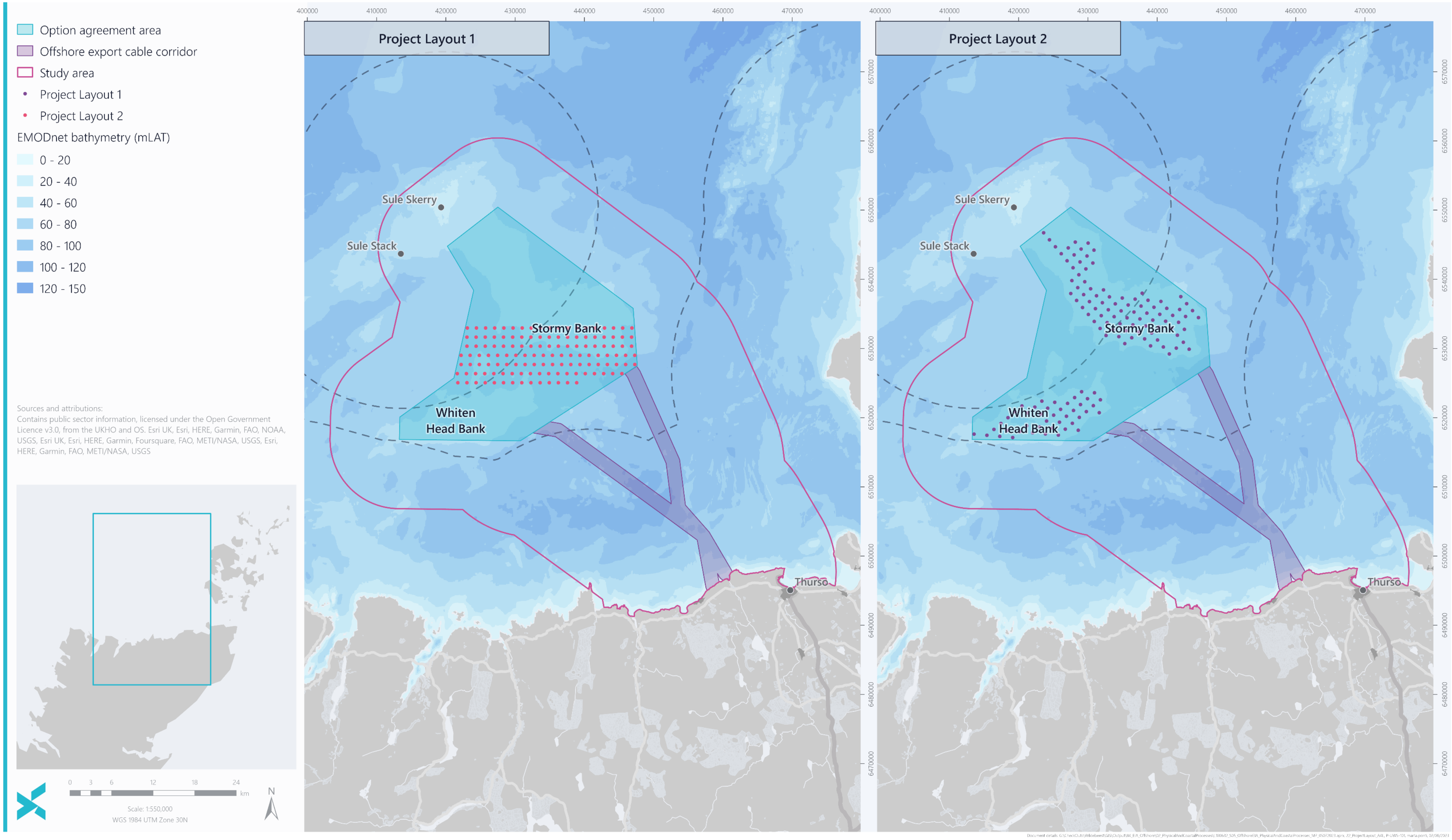

Figure 8-15 Worst case foundation layouts for marine physical and coastal processes impact assessment

Cable protection measures are described in Table 8-20.

Table 8-20 Cable rock protection parameters

PARAMETER	EXPORT CABLE	INTER-ARRAY	INTERCONNECTOR CABLES
Maximum total length of expected cable protection (km)	93.5	100	99
Maximum cable protection berm height (m)	3	3	3
Maximum cable protection berm width (m)	20	20	20
Maximum cable protection berm footprint (m^2)	1,870,000	2,000,000	1,980,000
Maximum number of crossings	5		10
Maximum crossing berm height (m)	4		4
Maximum crossing berm width (m)	25		25
Maximum crossing berm length (m)	500		500
Maximum crossing berm footprint (m^2)	62,500		62,500

Worst case scour parameters (i.e. scour properties and protection footprints) in association with WTG and OSPs foundations are detailed in Table 8-21.

Table 8-21 WTG foundation scour and associated protection measures

PARAMETER	LARGEST MONOPILE WTG	LARGEST PILED JACKET WTG	LARGEST SUCTION BUCKET JACKET WTG	LARGE TOPSIDE SUCTION BUCKET JACKET OSP
Maximum scour protection material per foundation (m^3)	~19,000	~23,500	~23,000	~39,200
Maximum scour protection height (m)	up to ~2.5	up to ~2.5	up to ~2.5	Up to ~2.5

PARAMETER	LARGEST MONOPILE WTG	LARGEST PILED JACKET WTG	LARGEST SUCTION BUCKET JACKET WTG	LARGE TOPSIDE SUCTION BUCKET JACKET OSP
Maximum scour protection area per WTG / OSP (excluding pile area) (m^2)	~8,000	~9,500	~9,500	~17,300
Maximum total footprint per WTG / OSP (including scour protection) (m^2)	~8,255	~11,200	~11,600	~21,420
Maximum extent of scour protection from edge of pile (m)	~41	~20	~20	~26
Maximum scour protection volume for OWF (m^3)	~2,380,000	~2,900,000	~2,860,000	~216,000

8.6 Assessment of potential effects

Modelling and analytical methods were used to assess for the potential effects associated with the offshore Project and the different stages of development. Detail on the modelling approach and analytical methods are presented in SS3: Marine physical and coastal processes supporting study (and appendices there in), with a summary presented within this Offshore EIA Report as relevant. In particular, section 8.4.3.5 provides a high-level introduction to the completed modelling, including the extracted outputs and results that have aided the assessment of potential effects.

8.6.1 Potential effects during construction (including pre-construction)

8.6.1.1 Change to seabed levels, sediment properties and suspended sediment concentrations

A number of different aspects of the proposed construction (including pre-construction) activities will have an effect on seabed levels, sediment properties and SSC, which are considered to be different disturbance pathways. To ensure all these aspects are comprehensively captured, each is considered in turn. Each of the following subsections presents the outcomes of the different analyses undertaken to assess for the varying disturbance pathways, with a consideration of the overall impact assessment in section 8.6.1.1.4. Detailed analyses on the disturbance pathways relating to this impact have been completed and presented within SS3: Marine physical and coastal processes supporting study, with a summary of the key results presented here.

8.6.1.1.1 Changes to seabed levels

Changes to seabed levels will arise through the clearance (for WTG, OSPs and cables) or trenching activity as described in the Project design in Table 8-16 to Table 8-19 (section 8.5.5.1), in addition to the deposition of sediment which has been disturbed during construction activities as presented in section 8.5.5.1. The potential deposition thickness and extent are evaluated together, where the deposition extent is compared against the offshore Project areas, including that of the indicative Dredge Material Placement Area (DMPA), OAA, offshore ECC and the total offshore Project area. For simplicity, only the proportion of the indicative DMPA and offshore Project area that would be covered by varying deposition thicknesses are presented in 8.6.1.1.1, based on disposal potentially occurring within a defined location or more widely across the offshore Project area. Consideration of the changes to seabed levels also evaluates the introduction of subsea infrastructure including foundations, cables and remedial protection, the proposed clearance and trenching depth, in addition to the sedimentation (extent and deposition thickness) that would occur associated with the different construction activities.

Seabed preparation

Removal of boulders is a discrete activity which will not result in overall changes to seabed levels. Consequently, this activity is not considered further in the context of changes to seabed levels. Boulder clearance will be considered in section 8.6.1.1.2 and 8.6.1.1.3 in relation to changes to sediment properties and SSC, respectively.

Bedform clearance to be undertaken during seabed preparation through use of TSHD or by CFE (8.6.1.1.1), up to a depth of 3.5 m where bedforms are present, resulting in the deposition of displaced sediments, within licensed disposal sites[23]. While the implications of this activity on SSC are considered in section 8.6.1.1.3, only the change in seabed levels associated with the construction activity and deposition are considered herein. It should be noted that based on the seabed characteristics across the offshore Project area, a dredge and disposal approach may be more applicable for clearance operations, with the use of CFE only in isolated discrete areas. However for completeness, the seabed level changes based on the entire Project clearance volumes are applied to each clearance method to understand the potential impacts from each method. It is not the case that the assessed impacts from each method are cumulative.

Bedform clearance by dredging

The volumes to be cleared as part of Project activities are set out in Table 8-16, with a clearance depth of up to 3.5 m where bedforms area present. Of the total volumes to be cleared and disposed, a large proportion (on average 99.75%) would fall directly to the seabed in the immediate vicinity of the disposal event during the active phase of deposition, leaving only a small proportion (i.e. approximately 0.25% on average) to form a plume as assessed in section 8.6.1.1.3. Table 8-22 summarises the sediment volumes considered as direct deposition as part of the active deposition phase.

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[23] As stated in footnote 9, in section 8.5.5.1, should dredging be applied, disposal will be necessary, which would entail a separate Marine Licence application to MD-LOT, when the requirement is confirmed.

Table 8-22 Volumes of sediment which will fall directly to the seabed through active transport

PARAMETER	OAA (M^3)	OFFSHORE ECC (M^3)	TOTAL PROJECT (M^3)
Maximum total sediment clearance volume	1,014,720	495,000	1,509,720
Maximum sediment volume assumed for direct deposition	1,013,502	492,426	1,505,928

The resulting deposition thickness of the clearance activity would be a cumulative total of the deposition associated with the disposal events (Table 8-23), where sedimentation extent and deposition thickness are inversely linked and that from the sediment plume (Figure 8-16). Table 8-23 presents a number of outcomes based on different theoretical sediment deposition scenarios. Deposition from the TSHD vessel can be uniform or form a cone. The depositional scenarios assume deposition as a cone, which would be based on the maximum angle of repose of the sediment and the total volume, of which there is a finite amount and for which there could be up to 150 TSHD disposal events for the offshore Project area. The alternative assumed depositional scenario is material is uniformly spread to a given thickness over the available area. In reality, deposition will be somewhere between the two. While Table 8-23 presents the extremes at either end of the range of possible deposition outcomes, results presented in SS3: Marine physical and coastal processes supporting study considers further scenarios. Ultimately, the actual deposition thickness and area of coverage will fall somewhere within the range presented in Table 8-23.

The formation of a single depositional cone for all 150 disposal release events is highly unrealistic, but it is the starting basis to inform increasing radii of depositional mounds. By increasing the cone radius beyond that of the steepest cone, the thickness of sediment decreases. It is assumed that multiple contiguous disposal mounds could be applied within the DMPA, equating to the cone scenarios, with a minimum of four radii used (so four depositional mounds). For illustration, the deposition thickness between four and five radii is presented in Table 8-23, which presents a scenario in which an area of 0.9 km^2 or 1.4 km^2 will be covered in sediment up to 5.2 m or 3.3 m thick respectively. The other end of the theoretical scale is represented by the scenario that the TSHD will be able to deposit the material at a constant thickness (i.e. uniformly). Under a minimum possible theoretical thickness of sediment deposition of 0.1 m an area of 15.1 km^2 would covered, with a deposition thickness of up to 2 m and area of 0.8 km^2 would be covered (Table 8-23). Overall, the reality is that the actual sedimentation extent and depositional thickness would be between that represented in Table 8-23. In addition to further considering the full range of possible deposition outcomes, SS3: Marine physical and coastal processes supporting study also breaks this discussion down in terms of the extent of deposition associated with OAA and offshore ECC activities alone.

Table 8-23 Range of estimated dredge and disposal sedimentation extent and deposition thickness, associated with the Project[24]

DEPOSITION ASSUMPTION		DEPOSITION THICKNESS (m)	SEDIMENTATION AREA (km^2)	PERCENTAGE DISPOSAL AREA	PERCENTAGE TOTAL OFFSHORE PROJECT AREA
Cone[25]	4 x radius	5.2	0.9	4.0%	0.1%
	5 x radius	3.3	1.4	6.2%	0.2%
Uniform	2	2	0.8	3.4%	0.1%
	0.1	0.1	15.1	68.5%	1.9%

In addition to the potential sedimentation extent and thickness presented in Table 8-23, the completed numerical modelling assessed the potential sedimentation associated with approximately 0.25% sediment bulk within the plume, the results of which are illustrated in Figure 8-16. The modelled deposition thickness associated with the small proportion of sediment within the plume (as a result of disposal) is generally less than 2 mm and primarily occurs within the indicative DMPA[26]. Elsewhere across the OAA and offshore ECC, associated with where drag-head disturbance and overflow occurred, sedimentation thickness was <0.1 mm. The modelled results indicate that sedimentation from any plume would be indiscernible from the surrounding seabed due to the minimal deposition thickness of up to 2 mm across the plume extent (Figure 8-16). Therefore, the cumulative sediment deposition would mainly occur in relation to the processes resulting in thickness suggested in Table 8-23, with respect to the disposal events within the DMPA.

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[24] It should be noted that any deposition thickness would be in line with available guidance, such as the Maritime and Coastguard Agency (MCA) guidance on changes to seabed depths.

[25] The cone depositional scenario applied at four and five times the radius, can be considered to analogous to four or five deposition locations, without accounting for the dispersal by flows.

[26] Please note, the location of the DMPA has yet to be agreed. Consequently, the deposition illustrated within the DMPA is purely indicative for modelling purposes.

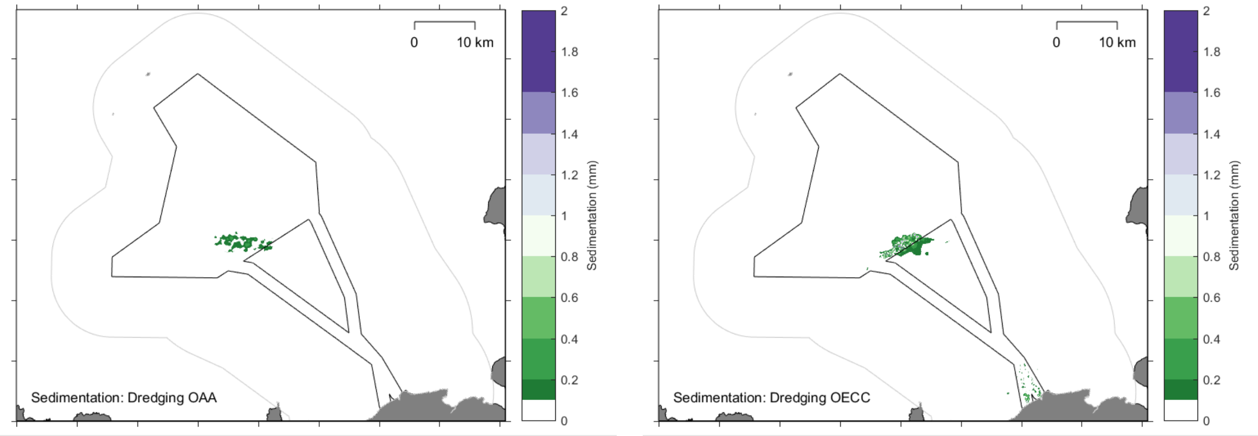

Figure 8-16 Modelled sedimentation associated with dredge and disposal clearance across the OAA (left) and offshore ECC (right)

Bedform clearance by CFE

The pathway for changes to seabed levels as a result of this activity are as a result of the clearance up to a depth of 3.5 m and the associated deposition of disturbed sediment. The method for determining the sediment deposition in the wake of clearance by CFE is based on the disturbance occurring at or near the seabed, which is transient and continuous as the CFE moves. This is in contrast to dredging mentioned above. As CFE occurs at the seabed, local flows have been taken into account; a range from 0.25 m/s to 1 m/s is considered based on the environmental description provided in section 8.4.4.7, while the range in sediments across the offshore Project area is also considered. A disturbance width of 10 m is assumed for the CFE, with potential CFE ejection heights of 5 m, 10 m and 15 m above the seabed. Deposition from CFE only assumes a uniform layer of disposal. For illustrative purposes, only the 10 m ejection height results are shown in Table 8-24. However, the full suite of analysed scenarios are available in SS3: Marine physical and coastal processes supporting study. The deposition thickness associated with clearance by CFE, would be in relation to the sediment that falls directly to the seabed during the active deposition phase, as illustrated in Table 8-24 and that from the plume (Figure 8-17) based on the small proportion of fine sediment contained within it. As clearance could occur anywhere within the offshore Project area, so would the associated deposition, rather than in a specific location as assumed for clearance by dredging.

In Table 8-24, the deposition thicknesses and extents vary according to flow speeds and sediment size. This does not take into consideration the reality that the sediments within the offshore Project area will be mixed. The deposition thickness ranges from 4.1 m to 0.04 m., with coarser sediments and slower flow speeds resulting in thicker deposits, although these deposits cover a smaller area. The corresponding area of deposits ranges from 0.4 km^2 to 24.9 km^2. Under the 10 m ejection height assumption, a maximum of 3.2% of the offshore Project area could be covered in sediments displaced during CFE bedform clearance activities if the sediments were composed entirely of sands, deposited to a thickness of 0.04 m (Table 8-24). As detailed further in SS3: Marine physical and coastal processes supporting study, a range of ejection heights are considered, with the resulting deposition thickness and extent discussed therein, with the results presented in Table 8-24 considered to be a representative illustration of the actual outcome of Project construction.

With respect to the modelled sedimentation from the plume, Figure 8-17 illustrates the modelled results for CFE clearance across the OAA and offshore ECC, where thickness of up to 0.6 mm could occur away from the immediate disturbance site, reducing to <0.2 mm towards the plume extent. Overall, the extent of deposition associated with the plume is minimal and also the deposition from the plume remains within the study area boundary. Overall, sedimentation as a result of the plume would be largely indiscernible from the surrounding seabed, with the sediment deposition mainly occurring in relation to the sedimentation in proximity to the CFE clearance (based on the active deposition phase), resulting in thickness suggested in Table 8-24.

Table 8-24 CFE clearance estimated sedimentation extent and deposition thickness, associated with the total offshore Project clearance volumes [16]

CURRENT SPEED (M/S)	CFE HEIGHT ABOVE SEABED (M)	FINE GRAVEL			COARSE SAND			MEDIUM SAND			FINE SAND		
		DEPOSITION THICKNESS (M)	AREA (KM²)	PERCENTAGE OFFSHORE PROJECT AREA	DEPOSITION THICKNESS (M)	AREA (KM²)	PERCENTAGE OFFSHORE PROJECT AREA	DEPOSITION THICKNESS (M)	AREA (KM²)	PERCENTAGE OFFSHORE PROJECT AREA	DEPOSITION THICKNESS (M)	AREA (KM²)	PERCENTAGE OFFSHORE PROJECT AREA
0.25	10	4.1	0.4	0.05%	2.0	0.8	0.10%	0.7	1.9	0.24%	0.14	6.2	0.80%
0.5	10	2.0	0.7	0.10%	1.0	1.5	0.20%	0.4	3.7	0.48%	0.07	12.5	1.59%
0.75	10	1.4	1.1	0.14%	0.7	2.3	0.30%	0.2	5.6	0.71%	0.05	18.7	2.39%
1	10	1.0	1.5	0.19%	0.5	3.1	0.39%	0.2	7.4	0.95%	0.04	24.9	3.19%

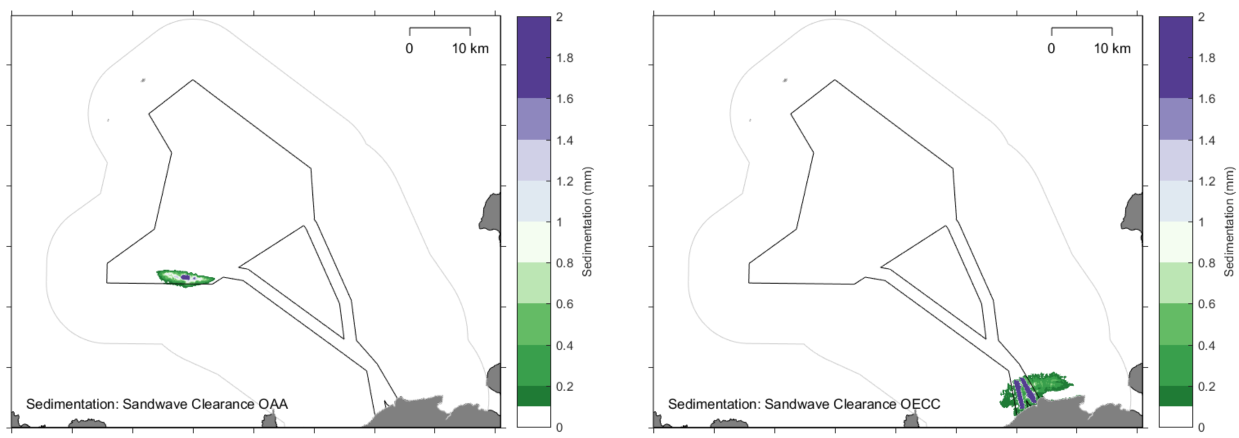

Figure 8-17 Modelled sedimentation associated with CFE clearance across the OAA (left) and offshore ECC (right)

WTG and OSP foundation installation

Change in seabed levels associated with the WTG and OSP installation relates to clearance up to a depth of 3.5 m where bedforms are present, in addition to the deposition of disturbed sediment (from clearance) and drilled material. The primary factor influencing the change in seabed levels associated with this activity is the deposition of the drilled volume, so this is therefore assessed in further detail below. The area of deposition and its thickness varies depending on the foundation type. The thickness and area of the deposits associated with the various foundations are shown in Table 8-25. A monopile WTG has the largest sedimentation extent per WTG, as the volume to be drilled per monopile foundation is much larger, even compared with the total volume associated with the 16 drilled piles required for an OSP (i.e. based on eight jacket legs, with two drilled piles per leg). As before, the thickness of the deposit is inversely correlated with the sedimentation area, so the deposition thickness is largest with the smallest sedimentation extent.

Drilling is a static activity and, although the activity itself occurs at the seabed, release of sediment may occur at the seabed or at the sea surface. The analyses of deposition thickness and extent, is the same as that applied for dredging activity, where material deposition is more with respect to the volume of material released from the sea surface (this assumption is also used in the modelling in 8.6.1.1.3). Table 8-25 therefore shows the results of the deposition analysis for WTG and OSP foundations, including the area of deposition as a proportion of the OAA, based on the Project design WTG and OSP drill volumes (Table 8-21).

Based on the theoretical deposition scenarios (as a cone or uniformly deposited) for a WTG monopile, the deposition thickness per WTG varies between 0.25 m and 4.0 m. The deposition thickness for all 125 WTGs equates to a sedimentation percentage cover of 0.84% and 0.16% of the OAA respectively (Table 8-25). Deposition thickness and sedimentation extents associated with OSPs were larger than that estimated for WTG jackets, but still less than estimated for WTG monopolies. The sum of the sedimentation extents associated with the WTG monopiles and OSPs, still results in less than 1% of the OAA being covered with 0.25 m sediment.

As the drilling would be ongoing for a number of hours across multiple flood and ebb tidal cycles, the pattern of sedimentation and deposition would alter with the varying flow conditions. Therefore, the actual deposition thickness and sedimentation extent and coverage would likely be within the assessed ranges represented in Table 8-25.

Table 8-25 Deposition thickness and sedimentation area associated with WTG and OSP foundation installation

DEPOSITION ASSUMPTION	DEPOSITION ASSUMPTION	DEPOSITION THICKNESS (m)	SEABED DEPOSITION AREA FOR ALL WTGS/OSPS (km²)	PERCENTAGE OF COVERAGE WITHIN OAA
WTG monopile[27]				
Cone[28]	2 x radius	4.0	1.3	0.16%
	3 x radius	1.8	2.32	0.4%
Uniform	1 m	1	1.4	0.2%
	0.25 m	0.3	5.5	0.8%
WTG jacket (with four piles)				
Cone[28]	2 x radius	1.5	0.6	0.09%
	3 x radius	0.7	1.4	0.2%
Uniform	1 m	1	0.3	0.05%
	0.25 m	0.3	1.2	0.2%
OSP jacket (with 16 piles)				
Cone[28]	2 x radius	1.5	0.09	0.01%
	3 x radius	0.7	0.2	0.03%
Uniform	1 m	1	0.1	0.01%
	0.25 m	0.3	0.2	0.03%

[27] Monopile foundations have only one pile, hence the deposition area and thickness are the same per pile as for per WTG under this foundation option.

[28] The cone depositional scenario applied for drilling accounts for the potential dispersion associated with flows due to the continuous nature of the activity. Therefore, the settling velocity and sedimentation distance for gravel sized sediment across the range of depths that WTG foundations could be installed at within the OAA, is used to infer the potential minimum depositional radius. The sedimentation distance for gravels (based on an average flow speed of 0.5 m/s) is similar to the twice and three times the radius of the steepest depositional cone.

The modelling assessed the potential sedimentation associated with sediments which were taken up into the plume (approximately 0.25% of the sediment bulk). The results of this sedimentation within the OAA associated with installation of WTG foundations (one at a time or two simultaneously) are shown in Figure 8-18. Thickness of up to 1.2 mm could occur close to the location of the drilling activity, reducing to <0.2 mm at the furthest extent of the plume. With the deposition of sediment, the material would in turn form part of the sediment transport regime across the region. Therefore, sedimentation mainly occurs in relation to the processes resulting in thickness suggested in Table 8-25. When two WTG foundations are drilled at the same time, the extent of sedimentation thickness up to 1.2 mm is larger; however, the overall scale of sedimentation is negligible in the context of the natural environment.

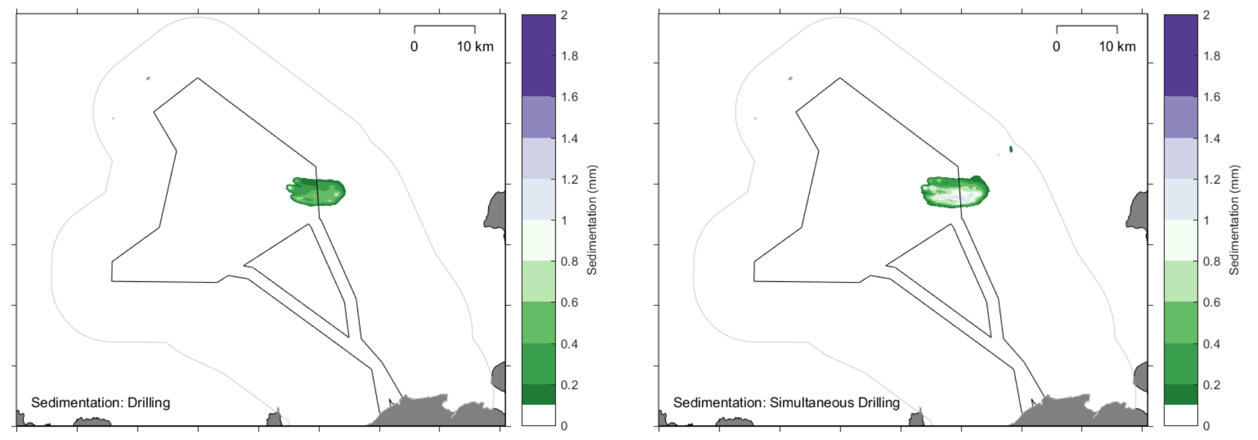

Figure 8-18 Modelled sedimentation associated with drilling one WTG monopile (left) and two WTG monopiles simultaneously (right)

Cable installation

The proposed trench properties (depth and width) associated with this activity are summarised in Table 8-19, where the trench target depth of 3 m is an indication of the potential change in seabed level, in addition to the deposition of displaced sediment from the trench described in more detail below. While CFE can be used for bedform clearance (discussed above in 8.6.1.1.1 -Seabed preparation), it also represents the worst case method of cable trenching during installation. Compared to clearance, which is a slower process involving flattening of seabed features, trenching will occur quickly with a transit rate of 150 m/hr for export and interconnector cables, and 200 m/hr for inter-array cables. The sediment being displaced by CFE will largely remain within the trench and therefore the majority of the cables will be buried with the seabed being naturally reinstated.

Due to the more targeted nature of trenching, the CFE ejection height has been assumed to be either 1 m, 5 m or 10 m above the seabed. The deposition analysis takes into account a range of flow speeds (0.25 m/s, 0.5 m/s, 0.75 m/s and 1 m/s), in addition to the range of sediments known to occur in the offshore Project area. The results of the deposition analysis for CFE cable trenching are shown in Table 8-26. Only results based on the 5 m ejection height are shown here for illustrative purposes. The full scope of deposition analysis results are discussed in SS3: Marine physical and coastal processes supporting study.

With increasing ejection height, the dispersion distance increases. This is as expected, the greater the ejection height, the further sediment will be dispersed and, in the case of finer sediments these will be subject to water flows further afield. Under an ejection height of 10 m and flow speeds of 1 m/s, fine sand can travel up to 1 km from the location of the activity. At this distance, the thickness of deposition is very thin at 0.02 m. Generally, the thickness of fine sand deposits are always <1 m. For larger sediments, like fine gravel, the range in deposition thickness ranges from <1 m to 17.4 m (under the 1 m ejection height). In reality, resulting seabed deposition will be somewhere between the extreme ends of the range presented in SS3: Marine physical and coastal processes supporting study, and somewhat in line with the results in Table 8-26. This is due to the range and properties of seabed sediments that occur across the offshore Project area, the varying flow speeds during installation activities and the trenching method applied. Overall, under any of the analysed conditions, deposition occurs within 1 km of the activity. Deposition will ultimately not be uniform and also will be temporary given the CFE process will continue and, in doing so, will re-disturb any deposits.

The sedimentation associated with the plume (discussed in 8.6.1.1.3 - Cable installation) generated by cable installation is shown in Figure 8-19, according to cable lay within the OAA and offshore ECC. Within the OAA, the sedimentation thickness is very low at <0.6 mm within the track of activity, meaning there is little sedimentation associated with the plume, with the majority of the impact occurring in relation to processes resulting in thickness suggested in Table 8-26. Furthermore, the sedimentation is highly localised within the area of immediate disturbance; sedimentation does not occur in areas beyond the direct CFE path. Comparatively, in the offshore ECC, sedimentation results in a marginally thicker layer. Thickness of up to 0.8 mm could occur close to the location of the drilling activity, reducing to <0.2 mm at the furthest extent of the plume. The plume extent associated with this activity within the offshore ECC is greater than within the OAA (8.6.1.1.3 - Cable installation), therefore the extent of sedimentation is similarly greater. However, sedimentation occurs almost exclusively within the offshore Project area boundary. Areas beyond this are only subject to sedimentation up to 0.2 mm in thickness. Overall, the sedimentation which may result due to cable installation will be indiscernible from the existing surrounding seabed conditions.

Table 8-26 Deposition thickness associated with cable installation by CFE

CURRENT SPEED (M/S)	EJECTION HEIGHT ABOVE SEABED(m)	FINE GRAVEL		COARSE SAND		MEDIUM SAND		FINE SAND	
		DOWNSTREAM DISPERSION DISTANCE (m)	DEPOSITION THICKNESS (m)	DOWNSTREAM DISPERSION DISTANCE (m)	DEPOSITION THICKNESS (m)	DOWNSTREAM DISPERSION DISTANCE (m)	DEPOSITION THICKNESS (m)	DOWNSTREAM DISPERSION DISTANCE (m)	DEPOSITION THICKNESS (m)
0.25	5	4.3	3.5	8.9	1.7	25	0.6	125	0.1
0.5	5	8.6	1.7	17.9	0.8	50	0.3	250	0.1
0.75	5	12.9	1.2	26.8	0.6	75	0.2	375	0.04
1	5	17.2	0.9	35.7	0.4	100	0.2	500	0.03

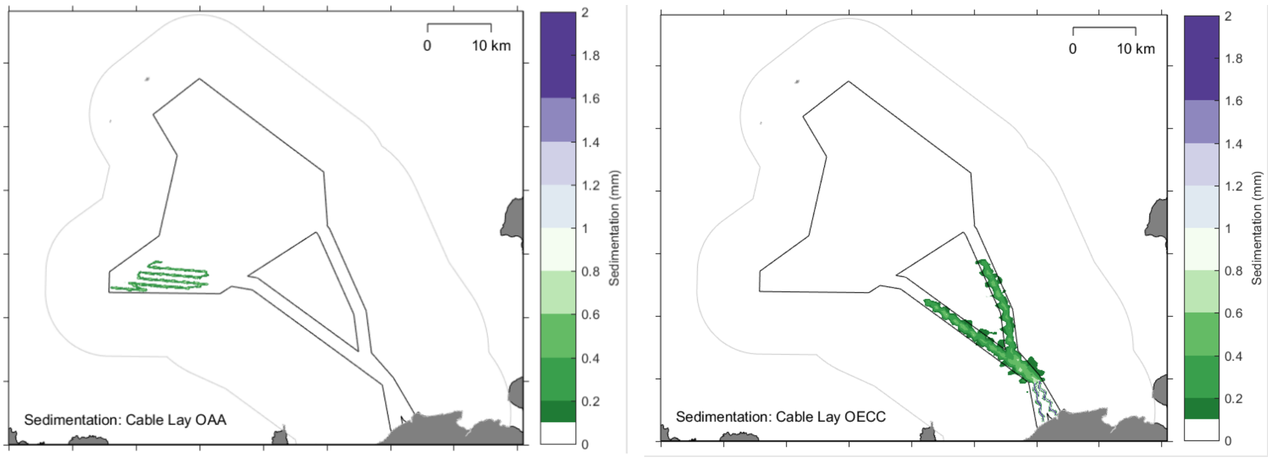

Figure 8-19 Modelled sedimentation associated with cable installation by CFE within the OAA (left) and offshore ECC (right)

8.6.1.1.2 Changes to sediment properties

Changes to sediment properties may arise during construction (including pre-construction) due to the Project activities outlined in section 8.5.5. Boulder clearance has the potential to change the local characterisation of the seabed. The geophysical surveys of the offshore Project area identified boulders throughout the OAA and offshore ECC. In places, these boulders (defined as >0.5 m) were considered to occur at a high density and often were associated with outcrops of underlying geological units (8.4.4.5.3 and described further in SS3: Marine physical and coastal processes supporting study. While the intention is to avoid boulders wherever possible through micro-siting, this may not be feasible in areas where a large number of boulders are present (i.e. in the higher density boulder field areas), therefore boulder clearance in discrete areas will take place across the OAA and offshore ECC to ensure their presence does not impede cable lay and foundation installation.

Where boulders need to be cleared prior to cable installation, clearance will be achieved through use of a boulder clearance (SCAR) plough and/or grabs. For all cables, a corridor of up to 30 m per cable circuit could be cleared (15 m each side of the proposed cable route) to ensure there is sufficient width for micro-routing, navigational contingencies/snaking and for the operation of the cable burial tools. SCAR plough width can be up to 15 m so two passes will be required. Boulders will likely only be moved a short distance to ensure technical and safety risks are eliminated. Boulders will also be likely to be required to be moved ahead of foundation installation (WTGS and OSPs) for both the foundations themselves and installation vessels. A predicted total boulder clearance area of 30.4 km^2 is estimated (approximately 4% of the total offshore Project area), noting that the extent of clearance activities will be dependent on the presence of boulders.

The movement of boulders inherently changes the characterisation of the immediate area. However, the Project has committed not to remove boulders from the offshore Project area. Given the ubiquitous presence of boulders, any which would be cleared during seabed preparations would likely be placed in environments with similar properties, i.e. also having a medium to high density boulders. As stated previously, boulders are only likely to be moved a short distance. Given the relative prevalence of boulders throughout the offshore Project area, and the fact that they will only be moved a short distance, it is highly unlikely that a significant number of boulders will be placed within an area of sandy seabed, which would result in a potential change to the seabed sediment properties.

While boulder clearance will have a relatively limited impact on the characteristics of the seabed, other project activities may have a greater effect. The deposition of sediments (as detailed in section 8.6.1.1.1 above) will inevitably result in some mixing of sediment types. While the majority of proposed activities largely affect surficial sediments, drilling (for WTG installation) will interact with the subsurface geology, releasing up to a total volume of 1,375,000 m^3 of drill cuttings for all WTG associated with the largest monopile option (Table 8-17). This can all result in localised changes to sediment.

The OAA seabed sediment is variably characterised by gravelly sand, slightly gravelly sand, gravelly muddy sand and some small discrete patches of sand. Within the offshore ECC, sediments are similar with the exception of an increased proportion of sands (section 8.4.4.5). This is evidenced in Figure 8-10 which shows the distribution of the differing sediment fractions. Section 8.6.1.1.1 outlined the potential for changes in seabed levels; overall, deposition is generally limited in scale. However, particularly with reference to finer sediments which are dispersed more widely as part of a plume, this will result in changes to sediment properties.

It is important to note that the analysis results in section 8.6.1.1.1 do not account for the variation in seabed sediments across the offshore Project area; instead, the results are quantified according to sediment type on the assumption that only one sediment type characterises the area. Consequently, the results are not entirely representative of the reality of deposition likely to occur, but they frame the extremes at either end of what is possible.

Deposition associated with most construction activities occurs within a few kilometres of the activity and the thickness of the deposit is generally less than 10 m. Some activities generate thicker deposits, but these are typically associated with the more extreme conditions outlined in section 8.6.1.1.1, with the exception of dredging during seabed preparation. In the case of seabed clearance activities, there is unlikely to be a change to sediment properties. Compared to surficial sediments, geology is consistently soft, friable sandstone bedrock across the offshore Project area (section 8.4.4.4). While the activities above are largely concerned with the surficial sediments, drilling the WTG foundations to a maximum depth of 53 m (see section 8.5.5.1, Table 8-17) will result in contact with the sandstone bedrock. The drilled sandstone could completely disaggregate and be deposited as the sand present within the surficial sediment or alternatively as large clasts. Either way, the introduction of bedrock across the OAA during foundation drilling is unlikely to change the seabed sediment type across the whole OAA, but more locally to the deposition sites described further in section 8.6.1.1.3- WTG and OSP foundation installation. While this constitutes a change in the sediment properties, there are outcrops of bedrock throughout the offshore Project area, especially within the OAA where drilling will occur. Furthermore, while drilling will bring up different substrate, the sandstone is universal across the whole offshore Project area. Consequently, the sediments which characterise the area may already originate from the bedrock. Therefore, drilling will not cause a discernible change in sediment properties. Consequently, the distribution of a variety of sediments throughout a diverse sediment regime will not be noticeable beyond naturally varying conditions. Overall, sedimentation thickness within a few kilometres of the activity (i.e. attributed to plumes) has already dropped to ≤0.4 mm. This constitutes the finest sediment fraction which will become readily incorporated into the surrounding seabed and consequently will become part of the sediment transport regime. This process will redistribute sediments throughout the offshore Project area and beyond regardless of deposition induced by Project activities.

The footprint of infrastructure to be installed as part of the offshore Project also results in a change in substrate, from the naturally occurring sediments to a hard substrate. The footprints associated with the offshore Project are presented below.

With respect to the worst case scenarios associated with changes to sediment properties during construction (as described in section 8.5.5.1), the total maximum Project footprint (inclusive of scour protection) associated with all WTG and OSP foundations is shown in Table 8-27. The largest footprints (inclusive of WTG/OSP infrastructure and scour protection) are associated with the largest suction bucket jacket WTG and OSP options at 1.25 km^2 and 0.11 km^2 respectively, resulting in a worst case total area of 1.36 km^2. This comes to a total of approximately 0.2% of the OAA. Overall, a very small area of seabed will be covered by the installation of Project structures and within the wider regional seabed context, this is a very small proportion.

Table 8-27 demonstrates that a large proportion of the described Project footprint relates to the scour protection for the jacket structures, with a total footprint area of 1.27 km^2 for scour protection footprint. The introduction of scour protection will mean the placement of hard substrate likely introducing a different type of rock. In addition to the scour protection associated with WTG and OSP foundations, a proportion of the cables across the offshore Project will need protecting, in areas where adequate burial may not have been achieved or where crossings occur. Table 8-28 illustrates the cable/crossing protection footprint expected across the OAA and offshore ECC with respect to the Project elements, where up to a total of 5.98 km^2 could require protection meaning the potential introduction of rock.

The potential maximum total area of rock within the OAA (from scour and cable protection) would be 5.5 km^2 (Table 8-27 and Table 8-28). In the context of the OAA (which occupies an area of approximately 657 km^2), the area of rock will cover 0.8% of the OAA. The total area of rock within the offshore ECC is 1.9 km^2 (Table 8-27 and Table 8-28). The total offshore ECC area is approximately 125 km^2, therefore, could occupy up to 1.6% of the offshore ECC. Overall, proportionately, the area of rock within the offshore Project area as a whole is minimal and these predicted areas are expected to reduce further. There are areas of bedrock exposed within the offshore Project area, so hard substrate is not entirely out of place. However, the type of rock used for scour and cable protection measures is currently unknown and will be determined post-consent.

Table 8-27 Total Project footprint associated with WTG and OSP options

PARAMETER	LARGEST MONOPILE	LARGEST PILED JACKET	LARGEST SUCTION BUCKET JACKET	OSP LARGE PILED JACKET	OSP LARGE SUCTION BUCKET JACKET
Total scour protection footprint (excluding pile area) (km^2)	1.00	1.19	1.19	0.08	0.09
Total seabed footprint (inclusive of scour protection) (km^2)	1.03	1.20	1.25	0.10	0.11

Table 8-28 Total protection footprint associated with cables and crossings

PARAMETER	OFFSHORE ECC	INTER-ARRAY	INTERCONNECTOR CABLES	OFFSHORE ECC CROSSINGS	INTER-ARRAY CROSSINGS
Total protection footprint (km^2)	1.87	2.0	1.98	0.06	0.06

8.6.1.1.3 Changes to suspended sediment concentrations

There are multiple mechanisms by which seabed disturbance during construction (including pre-construction) may lead to an increase in SSC as introduced in section 8.5.5.1. The West of Orkney model assessed the potential disturbance and resulting plume extents associated with all construction activities (with the exception of boulder clearance activities). Detailed results of the suspended sediment plume propagation, direction, duration and concentration are presented for each of the sediment disturbance mechanisms in SS3: Marine physical and coastal processes supporting study, with a summary of the key results presented here. Based on the sediment properties within the offshore Project area, only a very small percentage of the sediment bulk will form a plume (approximately 0.25% on average across the offshore Project); therefore, the model outputs only refer to a very small proportion of sediments, which primarily consists of the finer sediment fraction. The majority of sediments (i.e. the remaining 99.75%) will fall directly to the seabed within a relatively short distance from the disturbance site or disposal event, as assessed in section 8.6.1.1.1. This means that, although SSC may increase locally by several orders of magnitude, the effect will be very short-lived (of the order of minutes) as sediment is immediately deposited on the seabed. Therefore, increases in SSC associated with the active deposition phase are not directly modelled or quantified, but are considered to be several orders of magnitude greater (i.e. over thousands of mg/l), than the background levels of <5 mg/l characteristic to the study area. However, these high concentrations would only be within tens of metres of the disturbance. The high SSC would also only be short-lived, of the order of minutes, and reduce very quickly with increasing distance from the disturbance site as the sediment quickly settles to the seabed. Therefore, SSC associated with the active deposition are not assessed further, but instead the SSC likely to occur associated with the sediment plume are considered in more detail with respect to the magnitude, extent and duration.

Seabed preparation

As described in section 8.6.1.1.2 above, boulder clearance in discrete areas will take place across the OAA and offshore ECC to ensure cable lay and WTG and OSP installation can occur safely and effectively. While the boulder clearance activity has been assessed in the context of changes to the local sediment properties, the act of removing the boulders from a 30 m corridor is a very low level of mechanical disturbance of short-term duration. The act of boulder removal could lead to a slight increase in bed roughness in the immediate locality of the activity; however, this is not sufficient to generate a plume of any description. The expectation would be that any disturbed sediment would immediately fall to the seabed. Consequently, boulder clearance is not considered further within the context of changes to SSC.

Conversely, bedform clearance (through either TSHD or CFE) as a seabed preparation activity does generate a sediment plume. These activities were considered in the modelled scenarios, with the full outputs provided in SS3: Marine physical and coastal processes supporting study and summarised below.

Bedform clearance by dredging

With respect to the potential disturbance associated with bedform clearance by dredging, Figure 8-20 illustrates the SSC extent that could occur over the course of the 16-day modelling period, associated with bedform clearance by TSHD. While the dredging activity disturbance pathway will be near the seabed, disposal within the indicative DMPA will occur from a release of sediments at the sea surface. Plumes are generated from disposal event and as a result of the dredging itself (i.e. from the drag-head and overflow) as illustrated in Figure 8-20, where the dredging throughout the OAA leaves a distinct 'path' compared to the larger area which aligns with the indicative DMPA and represents the location of disposal.

Based on the completed modelling and clearance volumes as set out by the Project design, the whole OAA can be dredged within the applied 16-day model period, so the TSHD process is relatively rapid compared to other activities (such as CFE, discussed in section 8.6.1.1.3 - Seabed preparation). However, it should be noted that dredging may not be completed in one instant, but staged across the seabed preparation programme of up to 18-months. Due to the coarse nature of the seabed, with low fine sediment fraction, increases in SSC from the dredge and disposal activity are short-lived, with the SSC levels generally remaining below 1 mg/l for large parts of the OAA for the majority of the model period. As stated in section 8.4.4.9.3, most locations throughout the OAA recorded SSC of <5 mg/l. Therefore, the plumes associated with TSHD generally fall within what can be considered as background SSC levels. The maximum modelled SSC associated with the plume in relation to the dredge and disposal clearance at any given moment during the activity is 190 mg/l, which primarily relates to disposal events (Figure 8-20). However, this maximum is so limited spatially and temporally that, as seen in Figure 8-20, SSC largely is <5 mg/l across most of the plume extent. Plume extents for the dredging within the offshore ECC differ from those observed further offshore. This is largely due to the differing environmental conditions in the offshore ECC. As stated previously, there is a greater proportion of fine sediments within the offshore ECC. This results in the potential for a greater proportion of sediments to enter into suspension and contribute to the presence of a plume. In addition, as stated in section 8.4.4.7, flow speeds are higher within the offshore ECC, which is key to determining the extent of the plume. The modelled maximum SSC across the model domain at any given time was up to 800 mg/l, based on the disposal of sediment dredged from the offshore ECC within the DMPA.

As expected, the plume travels further on a flood tide (to the east) to a maximum distance of approximately 8 km. On an ebb tide the extent is approximately halved. While there is a difference in plume extent over the course of an individual tidal cycle, there is little difference in the plume extent between spring and neap tides. The maximum plume extent is observed closer to the coast, where flow speeds are marginally faster compared with locations further offshore.

While the TSHD process is relatively quick, the dispersal of the sediment plume also occurs rapidly. The 99th percentile result (in Figure 8-20) is indicative of locations that have experienced SSC levels for over 3.2 hours across the 16-day model period. For both the OAA and offshore ECC, this covers a very small area within the OAA (corresponding to the DMPA specifically). This suggests that the plume disperses rapidly as little evidence of the plume remains after 3.2 hours. Furthermore, the plume that remains in excess of 3.2 hours is associated with the DMPA, not the wider OAA or along the offshore ECC. Overall, the plume has dissipated within the course of a tidal cycle.

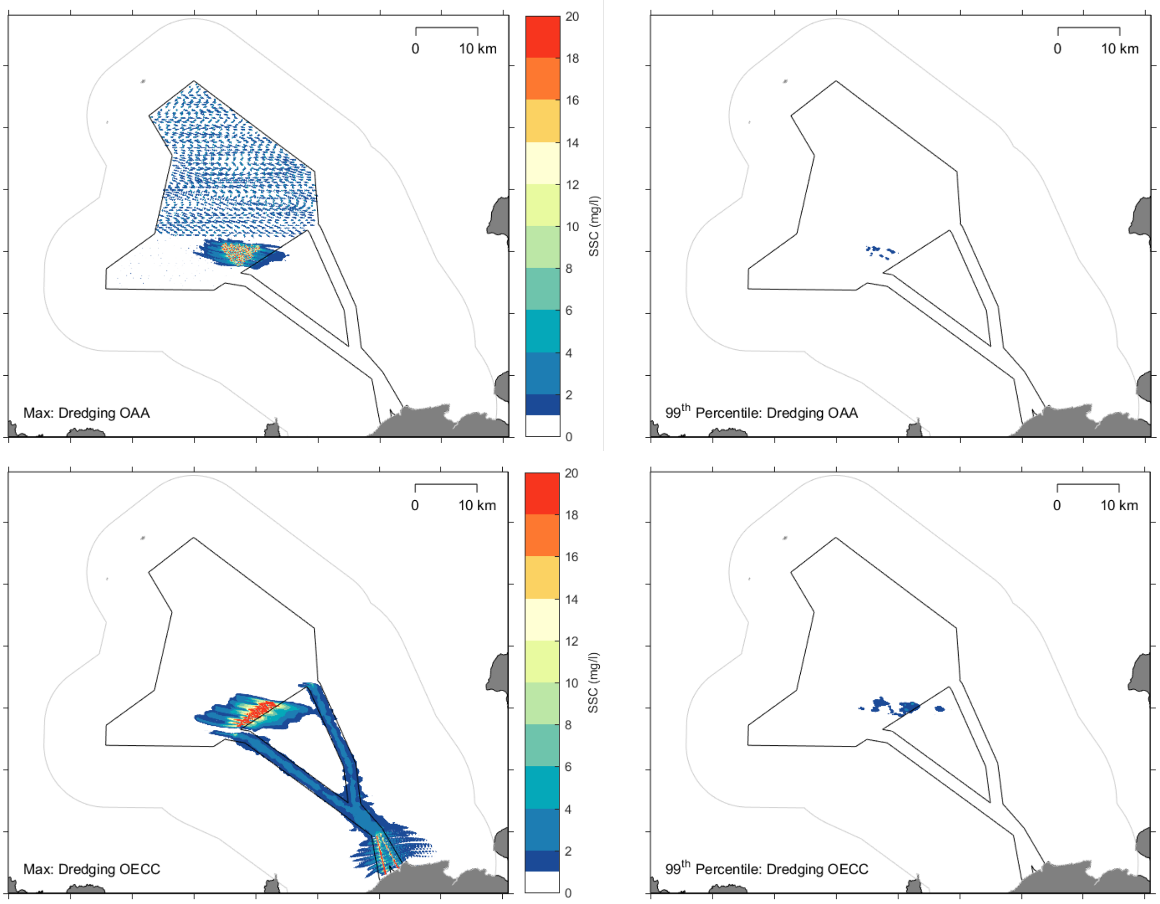

Figure 8-20 Model results for TSHD for the OAA (top) and offshore ECC (bottom) showing the maximum plume extent across the 16-day model period (left) and the 99th percentile result (right)

Bedform clearance by CFE

Model results for bedform clearance by CFE are illustrated in Figure 8-21. The southern part of the OAA experiences slightly faster flow residuals, hence the model focussed on CFE occurring in this area. Modelled results for this construction activity within the OAA are illustrated in Figure 8-21 for the maximum along with the 99th percentile result. The maximum plume extents are approximately 5 km to the east and 4 km to the west, associated with the flood and ebb respectively (Figure 8-21), while the maximum SSC during the clearance process is around 48 mg/l.

The slow clearance rate associated with CFE transit during clearance (i.e. at 25 m/hr) means concentrations may be elevated above background levels for longer periods. This is demonstrated by the 99th percentile where larger areas are at concentrations of 4 mg/l and above for over to 3.7 hours. By the 95th percentile (representative of approximately 18.6 hours), concentrations are already generally less than 2 mg/l, with the exception of a small area being between 2 and 6 mg/l.

As the sediments along the offshore ECC have a marginally higher fines content, this results in higher concentrations of SSC. Within the OAA, the applied percentage of fines within sediments was approximately 0.6%, compared with the percentage of fines within offshore ECC sediments at 2.6%. Additionally, faster flows along the offshore ECC means marginally larger plume extents. The model results of the maximum, 99th and 95th plume SSC and extents are presented in Figure 8-21. At the CFE disturbance site within the offshore ECC, instantaneous maximum SSC on the order of 1,200 mg/l is modelled to occur, which is much higher than is predicted for the same activity within the OAA.

Maximum plume extents within the offshore ECC are approximately 7 km to the east and 5 km to the west associated with the flood and ebb respectively. Again, the orientation of the plume is broadly parallel to the coast, but with the slow transit of the CFE during clearance, the plume has a broader north-south axis, with increased SSC reaching the coast. The plume is directed towards the coast as the tide transitions from flood to ebb. The slow clearance rate associated with CFE transit means sediment concentrations tend to build up. This is demonstrated by the 99th percentile where larger areas are at concentrations of 2 mg/l and above for over 3.7 hours (Figure 8-21). However, by the 95th percentile (i.e. approximately 18.6 hours) concentrations are generally less than 2 mg/l and at background levels characteristic to the offshore Project area (Figure 8-21).

Overall, the SSC reduces to less than 10 mg/l within 1 km of the release. SSC returns to background levels of less than 5 mg/l at distances of 2 to 3 km. Upon completion of the bedform clearance works, plume effects are not expected to last for more than a few tidal cycles and within the illustrated maximum extents across the whole offshore Project and study area.

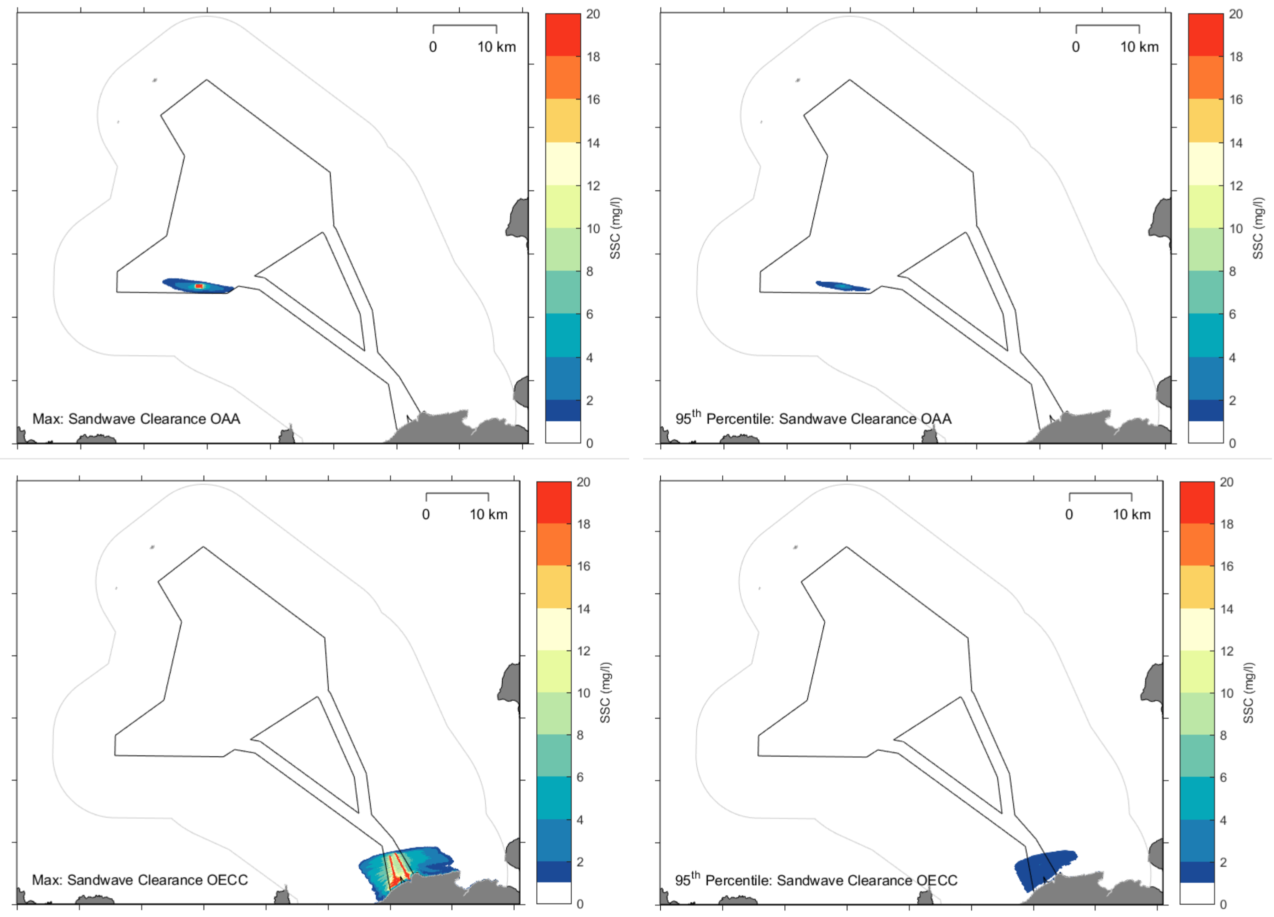

Figure 8-21 Model results for CFE clearance for the OAA (top) and offshore ECC (bottom) showing the maximum plume extent across the 16-day model period (left) and the 99th percentile result (right)

WTG and OSP foundation installation

Drilling of the seabed for the installation of WTG monopiles has the potential to result in the complete breakup of the underlying bedrock and could result in the release of disaggregated sediment at the surface. Considering the friable nature of the bedrock underlying the offshore Project area (section 8.4.4.4), this is expected to occur. Although drilling occurs at the seabed, release of sediments can occur at the seabed or at the surface. With regards to capturing the worst case scenario, the modelling has assumed that the plumes will form as a result of a release at the surface. This results in a plume which has a greater extent than an equivalent plume at the seabed.

The worst case disturbance impact was assessed to occur in relation to drilling of the largest monopile foundation (section 8.5.5.1). The drilling could either be undertaken at one WTG foundation at a time or two foundations at a time, so the modelling has assessed both options. The applied modelling approach is continuous over the 16-day period, so with drilling one monopile taking approximately 135-hours, and an assumed 9-hour stand down as the drilling vessel relocates, this results in approximately 2.5 WTGs being drilled within the model period, as reflected in the modelled results.

The modelled maximum spatial extent and magnitude of the sediment plume associated with drilling of a single WTG is shown in Figure 8-22. This represents the extent of the plume while drilling WTGs sequentially over a 16-day period. The WTG locations were modelled along the westernmost edge of the OAA, with results demonstrating a plume extending beyond the OAA but remaining well within the study area. The spatial extent of the plume reaches a maximum extent of approximately 5 km east and west, on the flood and ebb tide respectively. The SSC within much of the plume is ≤6 mg/l. This is consistent with background conditions for the OAA (see section 8.4.4.9.3) and as assessed for other construction activities within the OAA (8.6.1.1.3 - Seabed preparation). The maximum SSC at the drilling location is 48 mg/l, with the SSC occurring in the immediate vicinity of the drill site, before quickly reducing.

From the percentiles presented in Figure 8-22, it is inferred that between 3.7 (i.e. represented by the 99th percentile) and 18.6 hours (represented by the 95th percentile) post-drilling, the plume extent is already significantly reduced. 72-hours after the fact (the 80th percentile result), the area has all but returned to background levels and beyond this point (Figure 8-22), and after 186-hours (7.5 days) the plume has completely dispersed. Further results presented in SS3: Marine physical and coastal processes supporting study demonstrate the decay in SSC across the model domain on cessation of a drilling event.

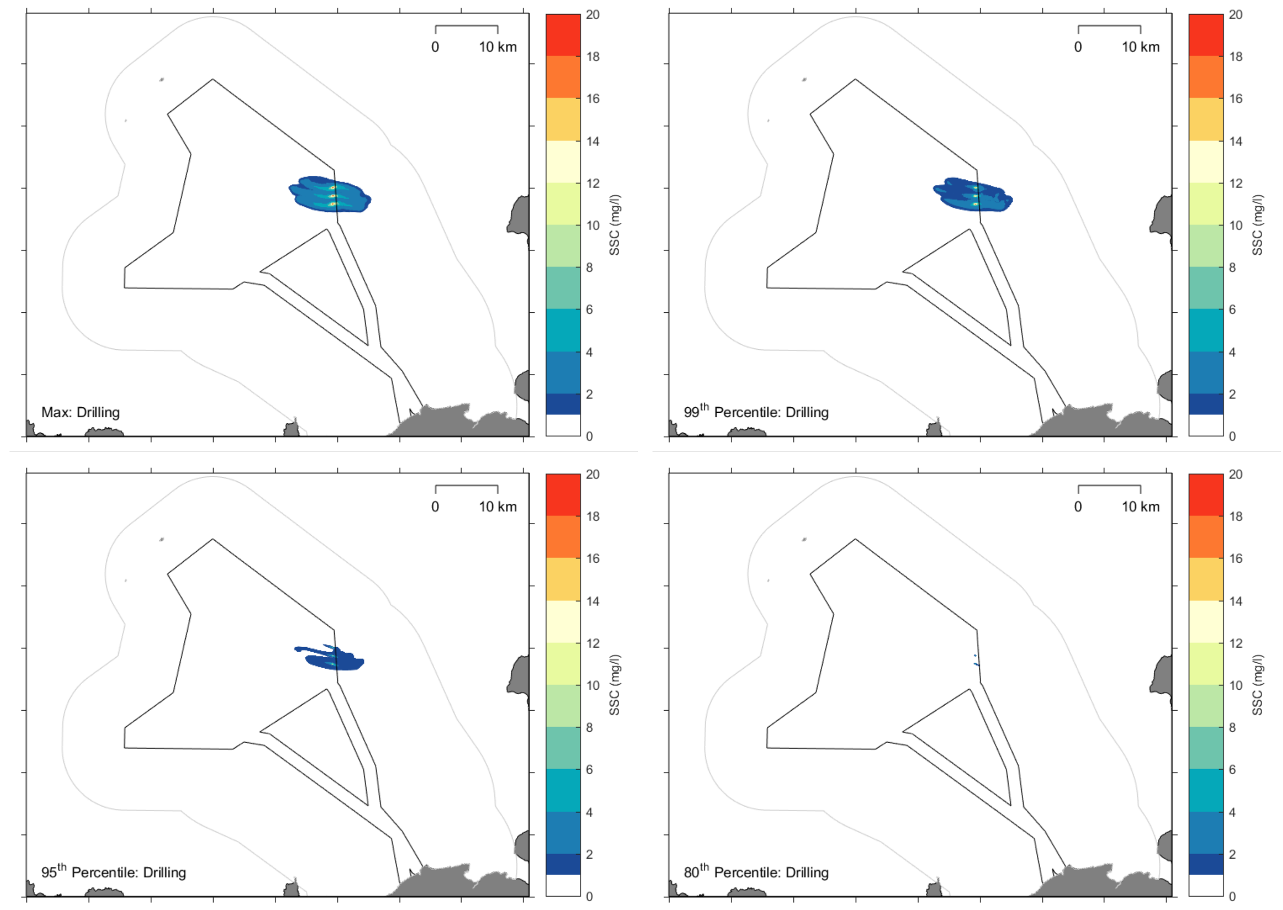

Figure 8-22 Drilling of a single WTG over the 16-day model period, showing the maximum plume extent (top left), and then the decrease in plume extent over time (remaining panels)

As described above, two and a half WTGs could be drilled within a 16-day model period, which means over the same 16-day period a total of four WTGs could be fully installed with another two part-way completed, based on two WTGs being installed concurrently. This is represented in the model results in Figure 8-23. When drilling two WTGs at a time, SSC is higher; the instantaneous maximum SSC is 76 mg/l, which is less than double what can be expected for one WTG alone. This maximum SSC is due to the plumes from each WTG coalescing and resulting in a combined increase.

Initially, the extent of the plume is relatively similar in Figure 8-23 when compared against Figure 8-22 above. However, the SSC within the plume is higher. Drilling two WTGs at once results in much of the plume having an SSC of 6 mg/l (Figure 8-23), which is marginally higher than under the single WTG scenario. The 95th percentile result in Figure 8-23 shows that after approximately 18.6-hours the plume, while smaller in extent, is still very much present. However, it is important to note that the SSC within the plume is <10 mg/l. Comparatively, under the single drilling scenario, after the same amount of time the plume was beginning to disperse before eventually having almost completely dissipated after 72-hours (the 80th percentile result). In Figure 8-23, after 72-hours the plume is still present, albeit at SSC levels consistent with the background conditions. Ultimately, only once the drilling activity is complete does the SSC fall back to 0 mg/l.

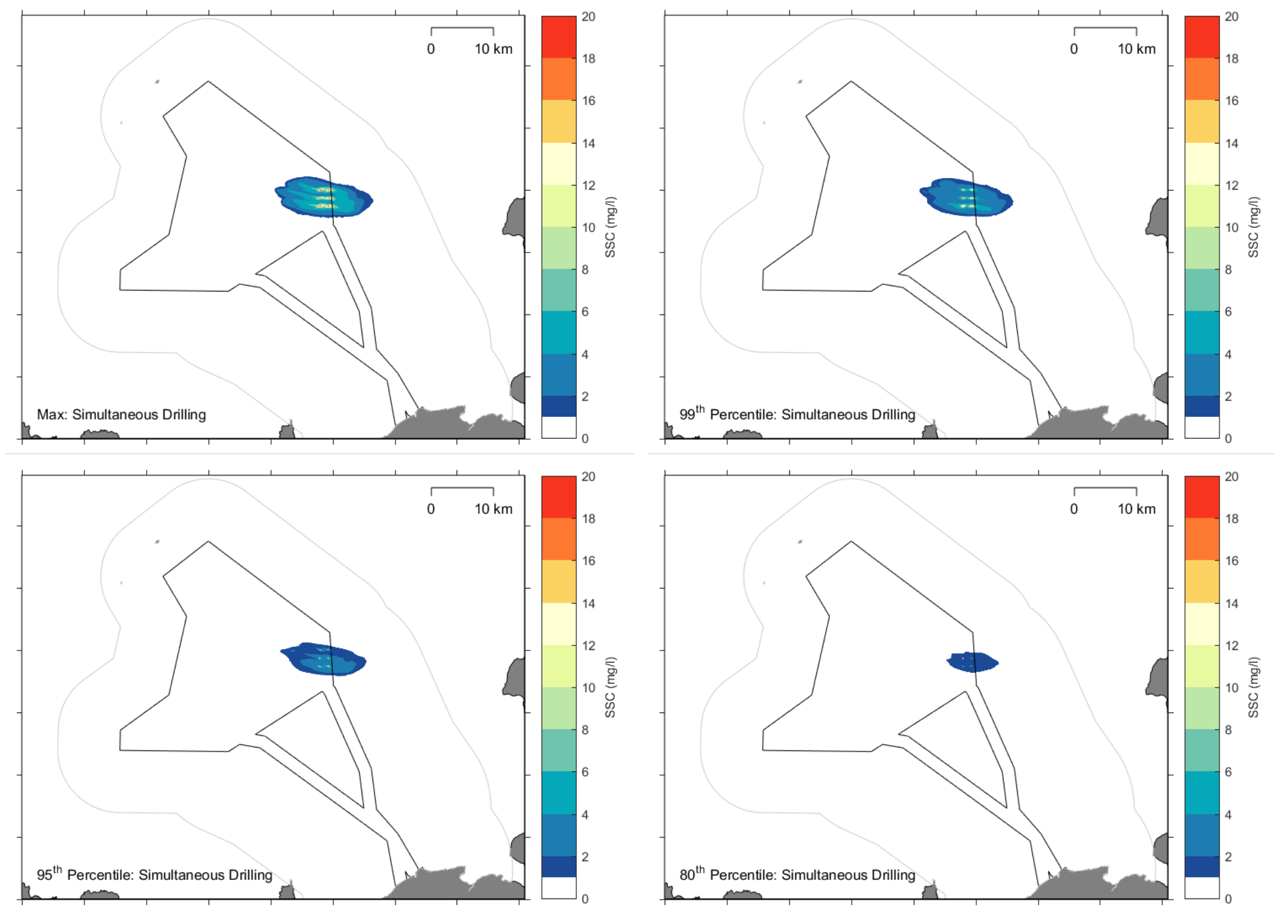

Figure 8-23 Drilling of two WTGs concurrently over the 16-day model period, showing the maximum plume extent (top left), and then the decrease in plume extent over time (remaining panels)

Cable installation

Model results for cable installation by CFE within the OAA are illustrated in Figure 8-24. The plume generated by the CFE for cable installation is approximately 2 km in extent on a flood or ebb tide. Most of the time there is no real visible plume extent, the area of increase SSC is highly localised to the immediate location of the CFE taking place. The speed of CFE for cable installation is faster than for bedform clearance (discussed in section 8.6.1.1.3 - Seabed preparation), at around 125 m/hr. The faster speed of CFE during cable installation means that the plume diluted and dispersed quicker associated with the ebb and flood flow speeds, instead of building up as during bedform clearance. Consequently, the maximum SSC associated with cable installation (at 20 mg/l) is also much lower than for bedform clearance. The duration of the plume presence is also very short-lived. By the 99th percentile (i.e. after 3.7 hours) evidence of the plume has almost disappeared. In addition, the spatial extent of the plume is very limited; the plume is barely detected within 300 m of the site of activity.

As for other activities within the offshore ECC, the higher finer sediment component within the offshore ECC contributes to the comparatively larger plume extents as finer sediments are more susceptible to being lifted into suspension. CFE cable installation within the offshore ECC reaches an instantaneous maximum of 550 mg/l. This is considerably higher than for CFE activity within the OAA. This difference is replicated in the results for bedform clearance by CFE (in section 8.6.1.1.3 - Seabed preparation). While there is little difference in plume extent under flow and ebb tide conditions, closer to the coast, the plume extends on a flood/ebb tide and remains a single plume formation from the source. Comparatively, further offshore within the offshore ECC, the plume disperses more quickly upon formation. The results of the 99th percentile demonstrate that the locations and extent of maximum SSC along the installation track are isolated to small pockets with SSC of above 2 mg/l, but still less than 4 mg/l (Figure 8-24). Within tens of metres of the activity occurring, SSC levels are so low that they are indiscernible against background concentrations. While the plume extent might reach beyond this, levels of SSC are so low. Consequently, the drop from the maximum instantaneous release of 550 mg/l to background levels occurs within tens of metres of the activity.

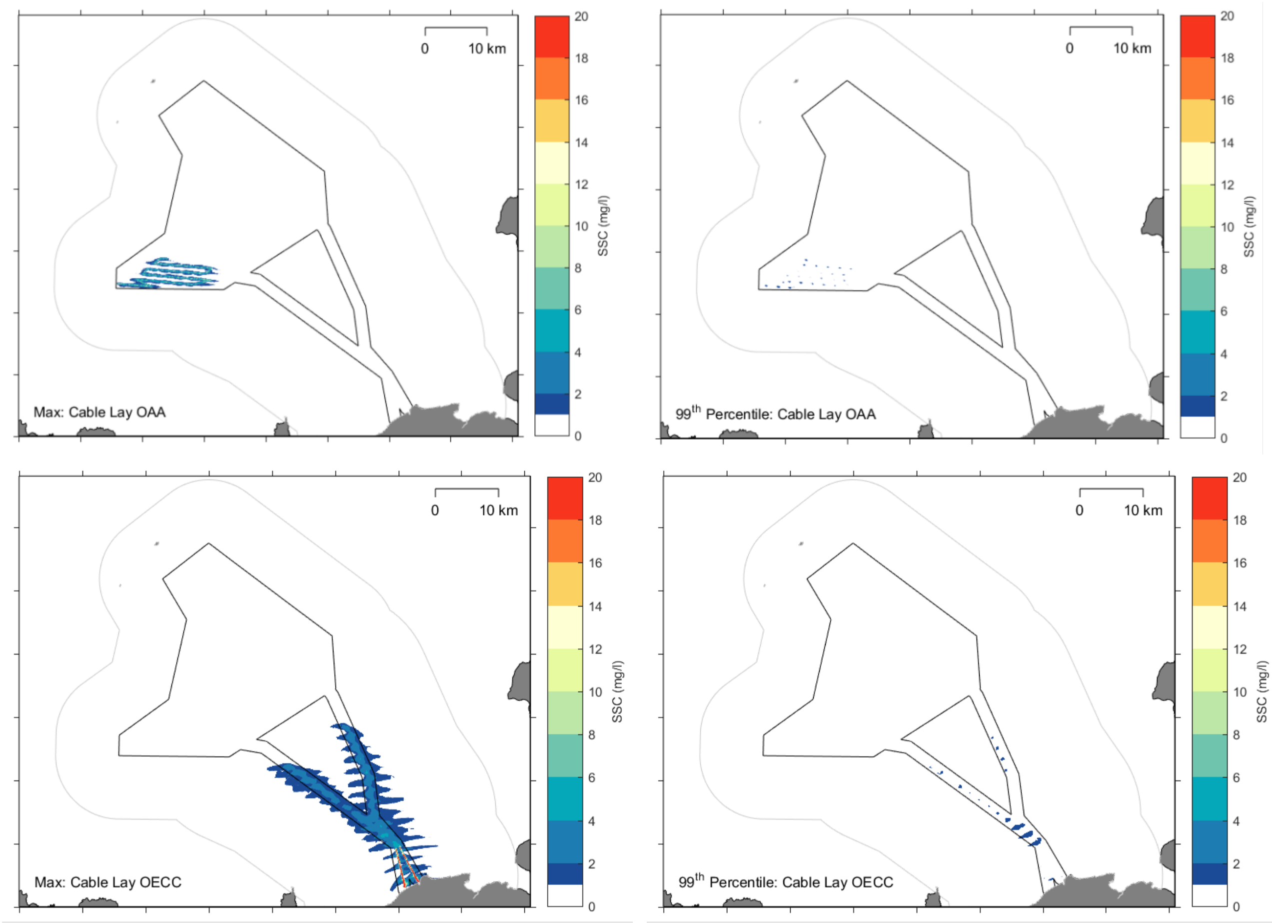

Figure 8-24 Model results for cable installation using CFE for the OAA (top) and offshore ECC (bottom) showing the maximum plume extent across the 16-day model period (left) and the 99th percentile result (right)

In-combination construction (including pre-construction) activities

There is a possibility that some of the construction (including pre-construction) activities will overlap in duration. The activities which have the greatest potential to result in an in-combination effect are those which occur within the OAA, namely WTG foundation drilling of two WTGs concurrently, with bedform clearance by CFE and cable burial by CFE (with a separation based on the WTG spacing). The basis for the model assumed that these activities would be, at a minimum, occurring at a spacing consistent with the proposed WTG spacing (1,320 m); therefore, at the closest point, the activities will be 1,320 m apart (based on the largest monopile foundation, where smaller foundations, including jackets, could have a spacing of 944 m). These three activities were modelled together based on the underlying assumptions of the activity in isolation and generated the results, as shown in Figure 8-25.

With all three activities occurring concurrently, the maximum instantaneous SSC was approximately 58 mg/l. This is relatively consistent with the SSC generated by these activities alone (covered in previous sections). The highest SSC generated by activities within the OAA is attributed to bedform clearance by CFE. This had a maximum instantaneous SSC of approximately 48 mg/l which will provide the largest contribution to the in-combination SSC. As by the modelling results illustrated in Figure 8-25, the maximum plume extent for the in-combination assessment spatially covers the combined area for all three in-combination activities, with a maximum extent of up to approximately 7 km east and west (depending on the tide). The cumulative influence of the SSC is most apparent as the tide changes and the plume direction switches; this results in some overlap between the plumes generated by the different activities as the plume extent exceeds the minimum spacing of the activities.

While the spatial extent of the in-combination plume may appear greater than for each of the individual activities, the majority of the plume is <5 mg/l. On the whole, SSC is never above 3 mg/l, even within a kilometre of the activity. The plume also appears to have almost completely dispersed by the 80th percentile (i.e. after approximately 74-hours).

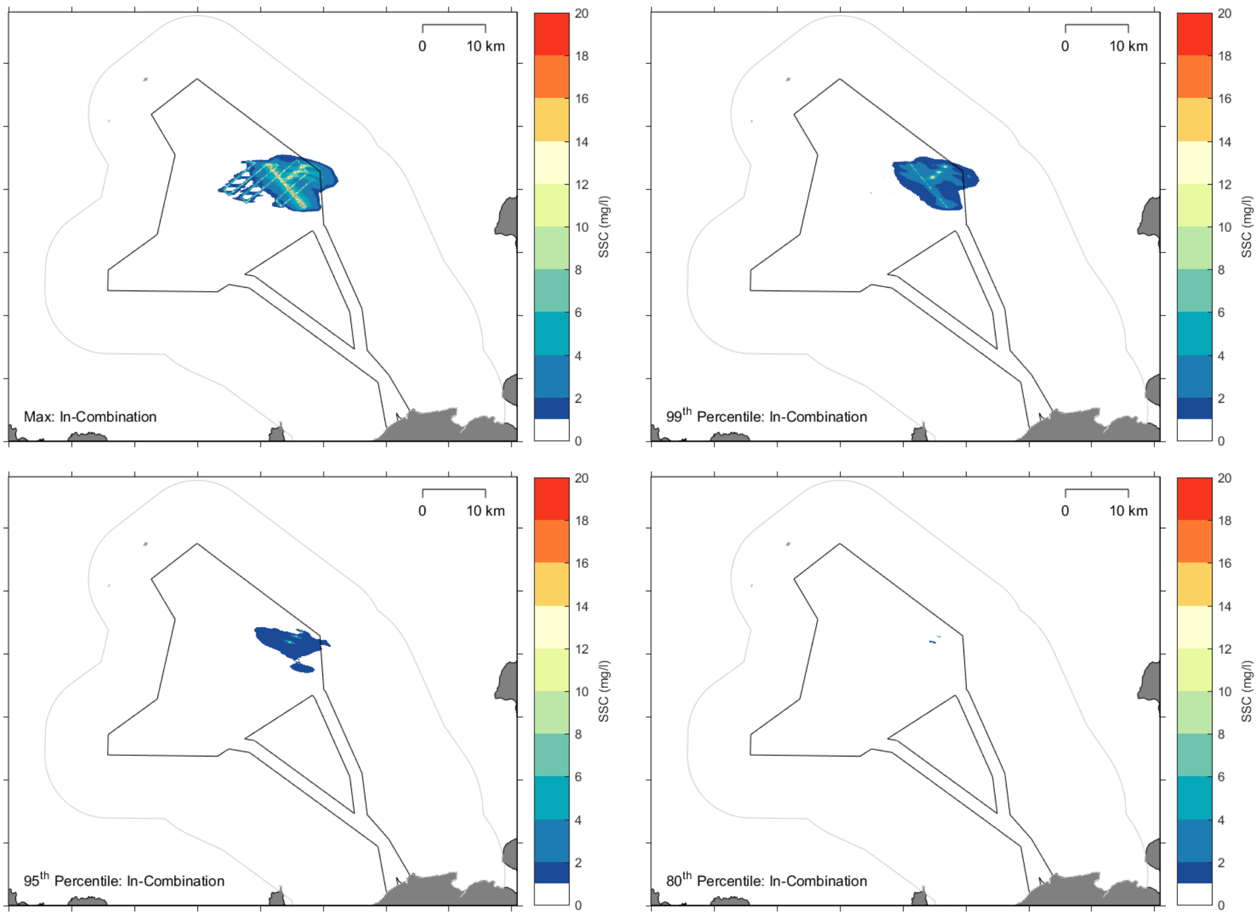

Figure 8-25 Model results for the in-combination assessment within the OAA showing the maximum plume SSC and extent (top left), and then the decrease in plume extent over time (remaining panels)

8.6.1.1.4 Impact assessment

Section 8.6.1.1.1 summarises the changes to seabed levels, as a function of the pre-construction / construction activity and the associated sedimentation / deposition. With respect to the Project activity, the main changes in seabed levels would be in relation to the clearance depth, because it is assumed that for trenching the seabed will mostly be backfilled. In terms of changes to seabed levels with respect to sedimentation, this would occur in relation to all Project pre-construction / construction activities (i.e. clearance, trenching and drilling). Therefore, the completed analyses accounts for the sediment that will be deposited directly at the seabed, or released at the sea surface (TSHD), and the small proportion of sediment which will form a plume and be deposited further afield.

Overall, deposition in relation to the plumes generated by construction (including pre-construction) activities is very limited in extent and thickness (i.e. in the region of millimetres). Based on the fact that only a small proportion of sediments will enter into suspension in the first place, this is expected. Consequently, the contribution of sediment deposition from the plume is minimal. Sediments deposited as a result of a plume, though more far reaching, will be rapidly incorporated into the local sediment transport regime. Instead, the primary mechanism for changes to seabed levels is through the deposition of the larger sediment fraction in the immediate vicinity of the activity or, in the case of TSHD, from the sea surface.

Deposition thickness per the activities described throughout section 8.6.1.1.1 is typically in the range of metres. The spread of deposition can extend to kilometres, but this only corresponds to a thin layer of deposit, as the relationship between extent and thickness are inversely correlated. On the whole, deposition associated with construction activity will affect a very small proportion of the offshore Project area. The theoretical deposition values presented throughout section 8.6.1.1.1, are indicative of the potential range in change to seabed level. Once deposited, the material would form part of the sediment transport regime, with the seabed potentially returning to original levels in locations with relatively thin deposition.

Generally, the thickest areas of deposition are located closest to the area of activity (with the exception of disposal associated with TSHD which is concentrated at the location of disposal). Comparatively, bedform features throughout the offshore Project area are large in scale; bedforms occur on a scale of up to approximately 1 km in length (section 8.4.4.3).

Based on the assessment presented in section 8.6.1.1.2, introduction of new or relocation of existing sediment substrate will not result in a change to the sediment properties or characteristics across the offshore Project. As described for the seabed sediment (section 8.4.4.5), the offshore Project area is diverse with a range of varying seabed sediment and clast sizes. Therefore, the Project related effects would largely be in keeping with the varied nature of the seabed environment.

Section 8.6.1.1.3 described the effect on SSC associated with sediments which have entered into suspension as a result of the Project activities. Prior to deposition, as described above, a small proportion of sediment will be suspended in the water column. The offshore Project area as a whole is characterised by clear waters with a low SSC. While construction activity does elevate SSC, the plumes associated with this remain within the study area. Generally, plumes extend up to a maximum of approximately 8 km (associated with clearance dredging activity) on a flood tide. On the whole, plumes do not travel as far on the ebb tide. While the instantaneous maximum SSC is high within the immediate vicinity of the activity, this rapidly decreases, often within a matter of tens of metres. The majority of the plume constitutes SSC of <5 mg/l which is generally consistent with background concentrations. Furthermore, for most activities, the plume is shown to dissipate within a tidal cycle. When assessing the effect of activities occurring simultaneously (in combination, section 8.6.1.1.3- In-combination construction (including pre-construction) activities), the plume takes longer to disperse (up to 74 hours). However, even before this point, this SSC has fallen to <5 mg/l. Overall, the proposed construction activities will not result in a material change in SSC. The change will be largely localised to the area of the activity and will be short-term and, in the wake of activity, the plume will not last beyond 3 days.

Based on the completed analyses, the disturbance pathways leading the changes to seabed levels, sediment properties and SSC are varied as presented above. In terms of the receiving environment within the OAA, the sensitivity of the seabed and water column to such impacts is considered to have a negligible sensitivity. This is because there are no designated features within the OAA or study area, furthermore, the seabed environment across the OAA is already varied in terms of the sediment properties. Based on the assessed impacts and pathways, construction activities are considered to have a low magnitude, mainly due to depositional context associated with the construction activities. Within the offshore ECC, the presence of the coast and proximity to coastal designated sites (although there is no direct overlap with the offshore Project), means a low sensitivity is considered to apply to the receiving environment, while a low magnitude is also applicable in relation to the depositional context. Therefore, at an overall Project scale, a worst case low sensitivity and low magnitude is considered to apply.

Evaluation of significance

The receiving environment across the offshore Project is at worst considered to have a low sensitivity (based on the low sensitivity associated with the offshore ECC and its proximity to the coast), with a low magnitude of impact associated with construction activities due to the extent of potential changes. This results in a negligible consequence and the construction activities are considered to be not significant in EIA terms.

Location	Sensitivity	Magnitude of impact	Consequence
OAA	Negligible	Low	Negligible
Offshore ECC	Low	Low	Negligible

Impact significance – NOT SIGNIFICANT

8.6.1.2 Impact on interest features within the designated sites due to export cable construction

A number of designated sites intersect the marine physical and coastal processes study area. These sites are listed in section 8.4.4.1. For assessment purposes, these designated sites have been grouped according to their designated features, such that similar features are considered together. The subsequent sections follow this layout:

- Geological features including GCRs (section 8.6.1.2.1): Red Point Coast SSSI, Pennylands SSSI and Strathy Coast SSSI, Drumhollistan GCR, Holborn Head Quarry GCR, Pennyland GCR, Red Point GCR, Pennyland to Castlehill (Thurso-Scrabster) GCR and Sgeir Ruadh, Portskerra GCR;
- Maritime and vegetated cliff features (section 8.6.1.2.2): Ushat Head SSSI; and
- Other coastal habitat features (including sand dunes, saltmarsh, and machair; section 8.6.1.2.3): Sandside Bay SSSI and Strathy Coast SSSI.

8.6.1.2.1 Geological features

The designated features of Red Point Coast SSSI, Pennylands SSSI and Strathy Coast SSSI include geological features. In addition, there are a number of GCRs (Drumhollistan GCR, Holborn Head Quarry GCR, Pennyland GCR, Red Point GCR, Pennyland to Castlehill (Thurso-Scrabster) GCR and Sgeir Ruadh, Portskerra GCR), which only overlap the applied study area and do not intersect the offshore Project at all. As there are no direct works to be completed with any GCR, the potential impacts to geological features within the GCRs are therefore assessed all together.

Red Point Coast SSSI is designated for Quaternary of Scotland and non-marine Devonian features. The site constitutes a 6 km section of coastline along the north coast of Scotland. The site is located 4.6 km west of the offshore ECC landfall and entirely within the marine physical and coastal processes study area. The Quaternary geology designation is given for the exposed Quaternary sediments which represent layers of till from the last glacial period. These deposits provide evidence for the pattern of ice movements in Caithness and the interaction between two separate ice masses of local and external origin approximately 22,000 years ago. The geology at Red Point also represents the best known example of Devonian lake-margin deposits associated with an ancient lake which is key to understanding the palaeogeography of the area (NatureScot, 2009a, 2009b). The two geological features are considered to be in favourable maintained conditions and are not considered to be exposed to any negative pressures. However, geological features are gradually being lost due to natural erosional processes (NatureScot, 2009a). Operations within the boundary of the SSSI requiring permission from NatureScot are exclusively terrestrial in nature (NatureScot, 2009c). Consequently, the proposed Project works, occurring in the marine environment are unlikely to affect the integrity of the SSSI features.

The marine physical and coastal processes study area was defined by the tidal excursion extent (section 8.4.1), therefore there is some possibility for connectivity between the site and the proposed construction activities. Although, being located west of the offshore ECC, the influence of Project activities will only reach the site on an ebb tide, if at all. With regards to plume extents and sediment deposition, these factors are not likely to affect the geological features of the site. Furthermore, any activities at the landfall (as assessed in section 8.6.1.3) have no connectivity with the geological designated features. Moreover, at a distance of 4.6 km, changes in local wave, flow and sediment transport regimes are not likely to be discernible in the context of natural variation, therefore will not contribute to the erosional processes which occur in timescales beyond the lifespan of the Project. Therefore, there is not considered to be a pathway for impacts to this designated site and interest features.

The Pennylands SSSI is located 7 km east of the offshore ECC landfall within Thurso Bay. The site is designated for non-marine Devonian geological features. This relates to the stratigraphy of the cliff face and foreshore rock outcrops. The section shows a sequence of shallow lake sediments with numerous thin beds containing fossil fish. This particular geological sequence is well represented at Pennylands when it is often poorly exposed elsewhere (NatureScot, 2008a). This feature is considered to be in a favourable maintained condition and is not believed to be exposed to any negative pressures. However, natural erosion in the area has been noted to periodically reveal new rock surfaces. This has the potential to expose new fossils and rock formations and does not currently threaten the interest of the site. The coastline in Thurso Bay is considered to be erodible (unlike at the Project offshore ECC landfall; Dynamic Coast, 2021). However, monitoring of the geological features in 2006 found the extent, composition and visibility of the rock layers and fossil beds had been maintained since the baseline survey in 1995 (NatureScot, 2008b). At 7 km from the offshore ECC boundary, changes to the wave regime as a result of landfall activities will not influence or enhance erosion within the Pennylands SSSI. Changes in sea level are also noted as being a factor which may detract from the integrity of the site; a rise in sea level would reduce accessibility of the geological layers (NatureScot, 2008b). Construction activities associated with the Project will not affect sea levels. Consequently, there is no pathway for impacts to the site.

Moine geology is a designated feature within the Strathy Coast SSSI. This site is located 11.8 km from the offshore ECC. Monitoring of the Moine geology took place in 2002. There had been no significant change in the area, composition or visibility of the geological since the previous survey in 1993. There has been some 'rock work' in Portskerra harbour, which required removal of some of the outcrop, but new rock exposures of the same importance were created at the same time. The proposed Project activity would not equate in scale to the works described at Portskerra harbour (NatureScot, 2010a). These works were not considered to affect the status of the feature; therefore, Project construction is unlikely to. Factors likely to affect the site integrity are terrestrial in nature, relating largely to tourism. Therefore, Project activities have little to no connectivity with the geological feature of the site.

The evaluated GCRs include the Drumhollistan GCR, Holborn Head Quarry GCR, Pennyland GCR, Red Point GCR, Pennyland to Castlehill (Thurso-Scrabster) GCR and Sgeir Ruadh, Portskerra GCR, which are illustrated in Table 8-6. Information from the GCR database extract (JNCC, 2019), and as summarised in Table 8-6, demonstrate the interest features within the GCRs range between exposures or presence of unique and rich representations of Scotland's geological heritage, from the Pre-Cambrian to more recent glacial and post-glacial deposits. Within the sediment represented by the GCR interest features, is also evidence of rich faunal assemblages representative of varying water environments from fluvial to lacustrine and marine. Overall, the GCRs represent a rich source of information of the geological heritage of Scotland, with value to enhance understanding into the future. It is important to note that no GCRs overlap the offshore Project, and the GCRs only occur within the study area, so there will be no direct works to impact the sites and interest features.

By their nature as designated sites of interest, the sites are considered to have medium sensitivity. Due to the nature of the proposed Project activities, and the distance from the offshore ECC to the coastal SSSIs, there is little opportunity for connectivity between the sites and Project construction. Furthermore, the geological features of the site are not known to be under negative pressures and are more so influenced by terrestrial activity. Therefore, a negligible magnitude of impact is considered to be applicable.

Evaluation of significance

Owing to the geological features being worthy of designation for their unique contribution to geological understanding at both a local and regional scale, the sensitivity of the sites to change is considered medium.

However, the magnitude of impact is considered negligible as there is little to no opportunity for connectivity between the geological features and the Project construction activities. Therefore, overall consequence of the Project on these sites designated for geological features is negligible. The impact is considered to be not significant in EIA terms.

Sensitivity	Magnitude of impact	Consequence
Medium	Negligible	Negligible

Impact significance – NOT SIGNIFICANT

8.6.1.2.2 Maritime and vegetated sea cliffs

As introduced in section 8.4.4.1, although a number of designated sites intersect the study area, only the Ushat Head SSSI directly borders the offshore Project area and is therefore the only designated site taken forward for assessment for the maritime and vegetated sea cliff interest feature. Ushat Head SSSI borders the offshore ECC at the Crosskirk landfall. The SSSI extends from the high water mark inland for approximately 500 m. The offshore Project boundary ends at MHWS. The primary reason for designation relates to the site vegetation which is a mixture of coastal grassland and maritime heath grading into wet heath; the abundance of Scottish primrose is particularly notable. Extensive areas of bare ground were noted near the cliff tops. These are likely to have arisen from natural causes, primarily exposure to wind and spray. During severe storms areas of turf immediately at the cliff top can be completely removed. In the short term this reduces the numbers of Scottish primrose but is considered to be beneficial to the species in the medium to longer term as Scottish primrose recolonises the open ground. This is a natural process and characteristic of this habitat (NatureScot, 2008c). While there is potential for some change to the local wave regime as a result of landfall activities (section 8.6.1.3), particularly given the proximity of the SSSI to the proposed construction activities, this will not necessarily affect spray. In section 8.6.1.3 the change to the waves as a result of the excavated HDD exit pits is compared to storm conditions which are understood to occur in the offshore Project area on an annual basis. Therefore, any impacts associated with the Project construction activities will at worst, not negatively affect the vegetation and at best, will promote the natural colonisation of the habitat. Finally, since 1983 the condition of the site has been maintained and, at present, the maritime cliff feature is not exposed to any negative pressures (NatureScot, 2008c). Consequently, no impacts are predicted on the site features.

By virtue of being a feature which is found in designated sites, the sensitivity of the maritime cliff as a receptor is considered to be medium. Amongst all the sites discussed above, the primary pressures to maritime and vegetated sea cliffs are terrestrial in nature. However, these habitats are inherently dependent on marine processes for their maintenance, namely through conditions relating to their exposure (i.e. salt spray). Consequently, they would be affected by changes to local metocean conditions. However, as covered in section 8.6.1.3, while HDD exit pits at the landfall may cause localised wave shoaling closer to the coast, this will be on a scale comparable to that of local storms. Such storm conditions are often described as integral to the maritime and vegetated sea cliff features. Therefore, the magnitude of impact on these features is considered negligible.

Evaluation of significance

Owing to the importance of maritime and vegetated sea cliffs as a feature worth designation, the sensitivity of the sites to change is considered medium. However, the pressures to these features are terrestrial. The magnitude of impact is considered negligible as the features are largely characterised by exposed conditions. The Project construction activities will not affect these conditions beyond the extent of natural variation (inclusive of storm conditions). The overall, consequence of the Project on these sites designated for maritime and vegetated sea cliff features is **negligible**. The impact is considered to be **not significant** in EIA terms.

Sensitivity	Magnitude of impact	Consequence
Medium	Negligible	Negligible

Impact significance – NOT SIGNIFICANT

8.6.1.2.3 Other coastal habitat features

The **Sandside Bay SSSI** is designated for sand dunes as physical features and also for the vegetation communities they support. The site is 3.7 km southwest of the offshore ECC landfall at Greeny Geo. While the most influential pressures on the site are terrestrial, coastal erosion is noted as being a factor which does affect the sand dunes. Part of the SSSI has been subject to erosion from the burns that flow through the site, particularly when flooding occurs at high tide. However, this erosion is largely attributed to onshore water courses (NatureScot, 2008d). The coastline within Sandside Bay is considered to be erodible (Dynamic Coasts, 2021). Any erection of sea defences or coastal protection works require consent prior to commencement within the SSSI (NatureScot, 2008e) suggesting that activities along the coastline may directly influence the sand dunes.

Deposition associated with the construction activities, as discussed throughout section 8.6.1.1.1, could result in deposition of material along the coast or within the SSSI. However, the deposition would be in relation to the fine sediment plume with only millimetres of deposition that would largely be indiscernible from the background and natural variation. Furthermore, changes at the landfall due to HDD exit pit excavation are unlikely to enhance the wave regime such that, at 3.7 km away erosion within the SSSI is increased. Overall, Project construction will have little connectivity with the sand dune feature of the Sandside Bay SSSI which is mostly influenced by terrestrial factors. **Therefore, there is not considered to be a pathway for impacts to this designated site and interest features.**

In addition to the geological and maritime cliff features, the **Strathy Coast SSSI** is designated for saltmarsh, sand dunes and machair habitat. Machair grasslands are relatively rare habitats. The machair is considered to be in favourable condition. The sand dunes are designated specifically with regards to the presence of the vegetation they support. Monitoring of the habitat found that there was little strand vegetation between the edge of the dunes and MHWS. Consequently, the area most likely to be influenced by physical processes does not necessarily contribute to the designation. With regards to the saltmarsh designated feature, the marsh has developed in the sheltered intertidal area behind the beach where silty and gravely muds have accumulated. There has been no evidence of changes in vegetation composition or zonation over time therefore the feature is in favourable condition. All these habitats are mostly sensitive to terrestrial influences (NatureScot, 2010a).

Reclamation of land from sea, estuary or marsh, is an activity which requires consent from NatureScot prior to taking place within the Strathy Coast SSSI (NatureScot, 2010c), although this is not specifically with reference to the dune, marsh or machair features. Changes to the coastline, including inadvertent land reclamation, would require a significant change to the local sediment transport regime. Though the site is located 11.8 km from the offshore ECC, i.e. within a tidal excursion of the landfall activities, sediment transport is extremely unlikely to be affected by the possible changes to wave shoaling at the coast in relation to HDD activities (section 8.6.1.3), much less on a scale that would be required to change the coastline within the SSSI. Furthermore, sediment deposition associated with plumes during construction will not extend as far as the site (the maximum plume extent within the offshore ECC is 7 km associated with CFE bedform clearance; see section 8.6.1.1.3 - Seabed preparation). Consequently, there is little connectivity between these habitat features of the Strathy Coast SSSI and the Project activities.

These features, being designated, are considered to be of medium sensitivity. These habitats are mostly influenced by terrestrial activities, however marine processes are integral to maintaining sand dunes in particular. As the designated sites with these interest features occur within the study area, direct deposition associated with the construction works is not expected. Instead, any deposition will be in relation to the plume and be minimal, and not affect any of the sites mentioned above. Furthermore, these activities will be temporary in nature and extremely unlikely to enhance local erosional processes, where they are known to be occurring. Therefore, the magnitude of impact on these features is considered negligible.

Evaluation of significance

The sensitivity of the sites to change is considered medium because of their inherent importance through being designated.

The magnitude of impact is considered negligible as the features are largely affected by terrestrial pressures. Furthermore, Project landfall activities and plumes generated during construction will not occur on a scale such that local processes, such as erosion, are enhanced.

The overall, consequence of the Project on these sites designated for sand dunes, saltmarsh and machair features is negligible. The impact is considered to be not significant in EIA terms.

Sensitivity	Magnitude of impact	Consequence
Medium	Negligible	Negligible

Impact significance - NOT SIGNIFICANT

8.6.1.3 Change to coastal landfall morphology

This section focuses on the landfall location and construction activity associated with the HDD at the coast, which includes the dredging of exit pits and associated formation of sediment berms. Detailed analyses on the potential changes relating to this impact have been completed and presented within SS3: Marine physical and coastal processes supporting study, with a summary of the key results presented here.

As described in section 8.4.4.11, the coastline at the offshore ECC landfalls at Crosskirk and Greeny Geo are characterised by hard and mixed substrates which are erosion resistant. Additionally, the coastline appears to be stable through time which indicates that erosion is not occurring in the area.

As stated in section 8.4.3.3.3, HDD is to be employed with a minimum HDD exit depth of 10 mLAT, approximately 188 m offshore (from 0 mLAT) at the Greeny Geo landfall and 100 m offshore at the Crosskirk landfall. However, a more realistic exit depth is likely to be between a minimum depth of 20 mLAT (at a distance of 340 m and 230 m offshore from 0 mLAT at the Greeny Geo and Crosskirk landfalls respectively) and maximum depth of 40 mLAT. Up to six HDD exit pits measuring up to 10 m wide x 30 m long x up to 5 m deep may be required at one or between both landfalls. The excavation of these pits will have a maximum volume of 1,500 m^3 per pit and total of up to 9,000 m^3. It is assumed the pits will be orientated offshore, with the 30 m length extending from the approximately HDD exit in the cross-shore direction. The excavated material could be disposed of or temporarily stored beside the exit pits as side-cast sediment berms, which could be back-filled on completion of cable installation of left to infill following natural processes. It is assumed that the height of the temporary side-cast sediment berm, would be the same or less than that applied to protection (i.e. a berm height of up to 3 m) and associated with this height is a minimum berm width of 20 m (assuming a 'U' shaped berm). Depending on ground conditions, it is possible that a single pit for all five cables may be considered, leading to a minimum 60 m wide pit, extending 30 m offshore. There is the potential for both temporary trenches and berms in the nearshore at the shallowest HDD exit of 10 mLAT (although the deeper depth of 20 mLAT is considered more realistic). Therefore, the worst case is assessed on the basis that the trenches (for each pit separately and grouped into one single pit) and sediment berms are left to infill naturally, with both occurring at the 10 mLAT depth. The coarse nature of the seabed at the landfalls means it would primarily require wave activity to backfill.

Due to the long period waves that are characteristic to the offshore Project area (peak period at around 9.5 seconds and calculated wavelength of approximately 61 m), depths of around 70 m are when the waves transition from deep water to transitional breaking waves that feel the bottom. For even longer period waves, with peak period of around 11 seconds, the majority of the OAA and offshore ECC can be considered to be within a transitional breaking wave regime, as the water depths are less than half the wavelength (wavelength calculated as approximately 190 m) associated with the 11 second peak period waves. On approach to the coast and landfall at 10 mLAT, waves with a peak period of 11 seconds and above would begin to shoal, including steepen and breaking, with the peak period 9.5 second waves breaking at shallower water depths. For the shorter period waves, with a peak period of around 6 seconds recorded at the Dounreay WaveNet buoy, these would begin to shoal and break at even shallow depths still of around 3 m water depths. With the excavation of a single 60 m wide but 30 m long pit, there is the potential for localised interference with the longer period waves, where the deeper water depth created by the pit would mean wave shoaling and breaking occurs closer inshore at a shallower water depth. The change to nearshore waves could potentially be akin to conditions expected during a storm, the likes of which would occur annually. While a departure from general conditions, the presence of the pit would not alter waves beyond that which already occurs at the landfalls. The influence of such an excavation on waves could extend parallel to the coast in the region of ten to hundreds of metres from the location of the pit. The relative resistance of the coastal bedrock to erosion would suggest that, irrespective of that wave energy being brought closer to the coast through delayed shoaling, there would be no promotion of erosional processes at the landfall. In the instance the excavation pits are installed as individual 10 m wide pits, there is less potential for interference, as the narrower profile of the pits with respect to the wave approach which would mean the wave is less likely to feel the narrower deeper area within the pit.

The introduction of the single exit pit (i.e. 60 m wide and 30 m long) could be similar to that of offshore orientated rip channels in the seabed. Waves propagating to the coast occur at a much larger, regional, mesoscale, so the effect from the presence of the single 60 m wide excavation pit would not ultimately disrupt the entire wave from progressing, but instead locally delay the shoaling process and likely introduce concentration of offshore flows through the pit. Natural examples of such rip channels can already be seen at the Crosskirk landfall. Therefore, such a feature as created by the excavations would not be entirely out of place there.

With the side-casting of the excavated material creating a sediment berm of up to 3 m high and 20 m wide based on each excavation pit at the minimum HDD exit depth of 10 mLAT, the presence of the berm could again theoretically interact with wave shoaling and breaking of the longer period waves. However, as it is assumed the berm would be orientated perpendicular to the coast, it would be perpendicular with the wave approach direction and therefore not disrupt but locally increase wave shoaling along the length of the berm. It could be that with the presence of the single 60 m wide excavation pit and associated sediment berms, there could be a localised region of mixed sea state, with areas of delayed shoaling and breaking adjacent to locations of increased shoaling. This effect or area of mixed sea states would likely extend tens of metres from the locations of the exit pits and sediment berms towards the coast and in the offshore direction. Based on the potential mixed sea state the exit pit(s) and associated sediment berms could introduce, further investigation could be completed post-consent to determine the requirement for backfilling the exit pits.

The potential for blockage to flows and sediment transport as a result of the sediment berm is the same as the operational impact of potential changes to sediment transport due to the presence of remedial material, assessed in section 8.6.2.4. This assessment concluded that the presence of rock berms as cable protection measures would not affect flows. Consequently, no impact on sediment transport is anticipated (please see section 8.6.2.4 for the full assessment). While impacts on sediment transport associated with the presence of the sediment berm are unlikely to be notable, the presence of the pits may affect the local wave regime and may act to enhance localised flow speeds. Consequently, this may have implications on sediment transport processes beyond the presence of the berm. The bedform feature identified in the nearshore offshore ECC (section 8.4.4.3) is on the scale of kilometres, therefore is unlikely to be affected by the comparatively small scale localised changes to the sediment transport regime. However, smaller features close to the coast (e.g. megaripples) are more susceptible to the consequences of landfall activity. Based on the non-erodible coastline, the presence of seabed features akin to the proposed exit pits and proximity to coastal designated sites (although there is no direct overlap with the offshore Project), the coastline is considered to have a low sensitivity.

As assessed in section 8.6.2.4, based on the potential for rock berms at 10 mLAT, identified that there was no change to flows downstream. Therefore, there was not considered to be any changes to sediment transport associated with flows, but as has been demonstrated for the landfall locations, transport due to flows in isolation is limited at the landfalls, with the main transport occurring in relation to waves.

The PDE states that the excavation pit could be back filled mechanically or left to do so naturally. In the instance that it was left to backfill naturally, the coarse nature of the seabed at the landfalls (comprising of medium and coarse sand, section 8.4.4.5.2) means it would primarily require wave activity to back fill. Based on the estimated sediment transport potential calculated at the landfall locations, waves with a significant wave height of 1.5 m and 9.5 second peak period could move the seabed material present, with little contribution from flows. Although, these particular waves are only observed to occur around 7.5% of the time in the approximately 3.5-year wave observation record from the Dounreay WaveNet buoy, waves of over 0.5 m significant height associated with a peak period of 9 seconds and over, occurred over 60% of the time. Based on frequency of the wave events, it is estimated that the pits could naturally backfill, but this would occur over a period of months to over a year or more, depending on the occurrence and frequency of the larger and longer period waves. Should finer sediment be present, it is likely that this could be winnowed away during intermittent periods of stronger current flows, leaving a coarser sediment fraction, which is not uncharacteristic to the seabed at the landfall. Bearing in mind the duration of time over which the excavated pits could remain exposed, and the infrequency of the waves required to infill the pits, the magnitude of the impact is considered to be medium.

Evaluation of significance

Due to the erosion resistant nature of the coast and the presence of seabed features akin to the proposed excavation pits and proximity to coastal designated sites (although there is no direct overlap with the offshore Project), coastal landfall morphology is considered to have a low sensitivity. The scale of the excavated HDD pits and associated sediment berm may cause changes to the wave regime in the locality of the cable landfall, resulting in a confused sea state, which could extend tens of metres towards the coast and in the offshore direction. This may have consequences on the local sediment transport regime and therefore morphological features in the vicinity. However, there is likely to be less influences on flows. Given the duration of time over which the excavated HDD exit pits may remain exposed, and the potential for changes to local metocean conditions over that period, the magnitude of impact is considered medium.

As a result of construction activities, the consequence of the impact on the coastal landfall is minor. Overall, the impact is not significant in EIA terms.

Sensitivity	Magnitude of impact	Consequence
Low	Medium	Minor

Impact significance – NOT SIGNIFICANT

8.6.2 Potential effects during operation and maintenance

8.6.2.1 Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors

Detailed analyses on the potential changes relating to this impact have been completed and presented within SS3: Marine physical and coastal processes supporting study, with a summary of the key results presented here as relevant to this impact assessment.

8.6.2.1.1 Changes to flows

The presence of structures in the water column results in a potential blockage to flows. The presence of a WTG through the water column will cause a divergence in flow around the structure, with turbulence occurring in the wake of each individual WTG, the length of which would vary in relation to the flow properties and blockage width through the water column. The assumption was applied that the worst case blockage would be from solid structures through the water column, which in this case relates to monopile foundations. For jacket foundations, although these have larger overall diameters (section 8.5.5.2), these are not solid structures, but instead include smaller diameter legs with braces in between, which do not ultimately obstruct the flow over a large area. The blockage density effects were compared between the different monopile foundation sizes and separation, in all cases, the number of WTGs was consistently assumed to be 125. Blockage density for jackets were not quantitatively assessed as it was considered to be less than that for monopiles, due to the smaller piles and the opportunity for flow to continue through the legs and braces. To account for OSP foundations, these were treated as a further five monopiles, recognising that although these structures are larger, they are jackets so result in a less blockage effects. To determine the blockage density a representative blockage width was calculated, which is based on the average width through the water column. The completed analyses considered the mean and maximum density (with the reality most likely to be between the values), along with the ratio between the foundation diameter and separation distance, with results presented in Table 8-29.

The calculated blockage density for the assessed monopile foundation sizes ranges from 1.9 to 10.7 m/km^2 (Table 8-29). Given the monopile diameter and the minimum spacing, the flow separation associated with each individual structure is expected to reconverge downstream of the foundation. The turbulence immediately adjacent to the foundation will dissipate quickly over a distance of several hundred metres. The minimum spacing of (or over) 87 times the foundation diameter (Table 8-29) means the turbulence associated with each WTG would not coalesce with that from the next adjacent structure. Consequently, it is not anticipated that there will be any blockage density effects and, as stated in section 8.5.5, the worst case monopile diameter has been revised down.

However, it should be noted that the modelling of potential impacts and analysis of blockage effects were completed with respect to more conservative parameters relating to the Project's design. Since completion of these elements, the Project design has been revised down. Therefore, the underlying assumptions used to inform the modelling for bedform clearance and installation of cables are larger than that represented in the Project design below. Where there are differences, these are explained within the relevant impact assessment. On the basis that the achieved results do not identify any significant impacts as described in section 8.6, it is considered that a smaller envelope will result in even smaller impacts than presented.

Table 8-29 Blockage density for monopile foundation sizes and spacing, based on 125 WTGs and five OSPs (based on monopiles as a proxy)

MONOPILE DIAMETER (m)	BLOCKAGE WIDTH (m)	MINIMUM WTG SPACING (m)	RATIO BLOCKAGE WIDTH TO SPACING	BLOCKAGE DENSITY (m/km^2)	
				MEAN	MAXIMUM
18	15.25	1,320	87	3.0	8.8
11	9.5	1,000	105	1.9	9.5
11	9.5	944	99	1.9	10.7

In addition to this empirical analysis, the model also provided outputs of anticipated change to flows during the operation and maintenance stage of the Project. Overall, the model outputs demonstrate that there are no changes in water level within the offshore Project at any stage of the tide. Although flow separation may occur locally with respect to each WTG, overall, that the divergence of flows around each WTG individually is not sufficient to generate an overall change to current speeds. The post-construction residual flows in the OAA are shown in Figure 8-26. The absolute difference in flow speeds is limited to ±0.01 m/s. While the results indicate that the location of possible change may be different between the two proposed layouts, the scale of change is such that it would be indistinguishable from the natural variation expected of the area. Furthermore, the resolution of the model is limited below a certain point suggesting that these levels of change may be even less than shown in Figure 8-26.

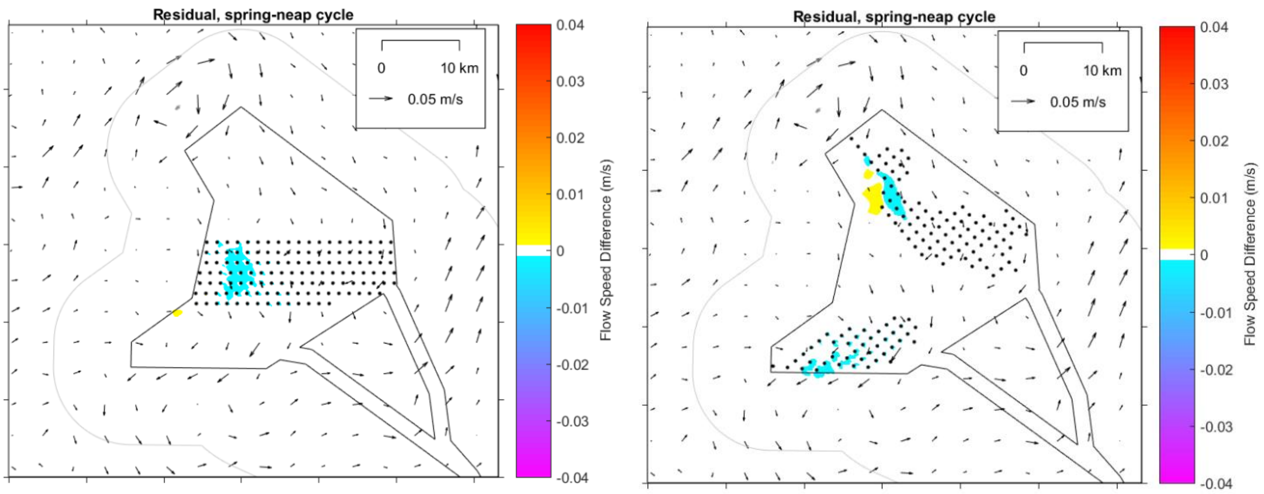

Figure 8-26 Post-construction residual flows within the offshore Project area for Layout 1 (left) and Layout 2 (right). Colours illustrate the post-construction flow speed difference, while the vectors illustrate the baseline residual flow speed and direction

Baseline flows were compared against post-construction flows at a number of locations throughout the offshore Project area as presented in SS3: Marine physical and coastal processes supporting study. This comparison of the absolute change in flow properties demonstrated changes of less than 0.01 m/s, with some model extraction locations demonstrating no change at all. Therefore, it is considered that the minimum spacing between WTGs (as discussed above) allows for sufficient space for currents to recover in the wake of each structure prior to encountering the next WTG, per the understanding that wakes would dissipate over a distance of hundreds of metres in the lee of the structure. Consequently, there is not considered to be any overall impact on flows post-construction.

8.6.2.1.2 Changes to waves

In the offshore Project area waves originate predominantly from the north, northwest and west. A number of wave parameters, originating from these directions were compared between the baseline and post-construction as presented in SS3: Marine physical and coastal processes supporting study. The wave parameters which were used to define the West of Orkney model boundary conditions are shown in Table 8-8, while the modelled boundary conditions for the different percentile and return period waves from the three directional sectors are set out in Appendix A.3.5 of SS3: Marine physical and coastal processes supporting study.

During the operation and maintenance stage, for all wave approach directions, there is a marginal increase in wave height upstream of the OAA (with respect to the wave approach direction), with the reverse occurring downstream. Although multiple wave return periods were modelled, the largest change is seen for the smaller waves, with the smallest wave parameters modelled belonging to a 50th percentile wave. For illustrative purposes, the model outputs for the 50th percentile and extreme 1 in 100-year wave (originating from the west, as this is the dominant approach direction) are shown according to the two different WTG layouts in Figure 8-27 and Figure 8-28 respectively. The absolute change in significant wave height is shown alongside the relative percentage change height and the absolute change in peak period, noting that for the period, the extent of change was minimal such that it was not visible in the model outputs. The full model outputs for all wave directions and sizes are shown in SS3: Marine physical and coastal processes supporting study.

The outputs of the model indicate that the spatial extent of absolute change in significant wave height reaches beyond the marine physical and coastal processes study area (Figure 8-27). Waves associated 50th percentile conditions could experience small absolute changes in significant wave height of up to ±0.04 m beyond the offshore Project area, however these changes do not extend much beyond the applied study area of 10 km buffer around the OAA, where absolute changes in significant wave height are less than ±0.02 m (Figure 8-27). These are conditions that can be considered to occur a lot of the time over an annual period. Proportionately, an absolute change of ±0.04 m in significant wave height is larger with respect to a smaller wave. Modelled results demonstrate that the larger waves that occur across the northwest Scottish continental shelf are less affected by the presence of the Project. These waves are so large that they pass through the WTG array largely unimpeded, with relative changes largely being undetectable, as demonstrated in Figure 8-28. Whereas changes associated with the more infrequent storm conditions or extreme events, will be undetectable within the offshore Project area and study area, as demonstrated in Figure 8-28. These findings apply to both the WTG layout options assessed.

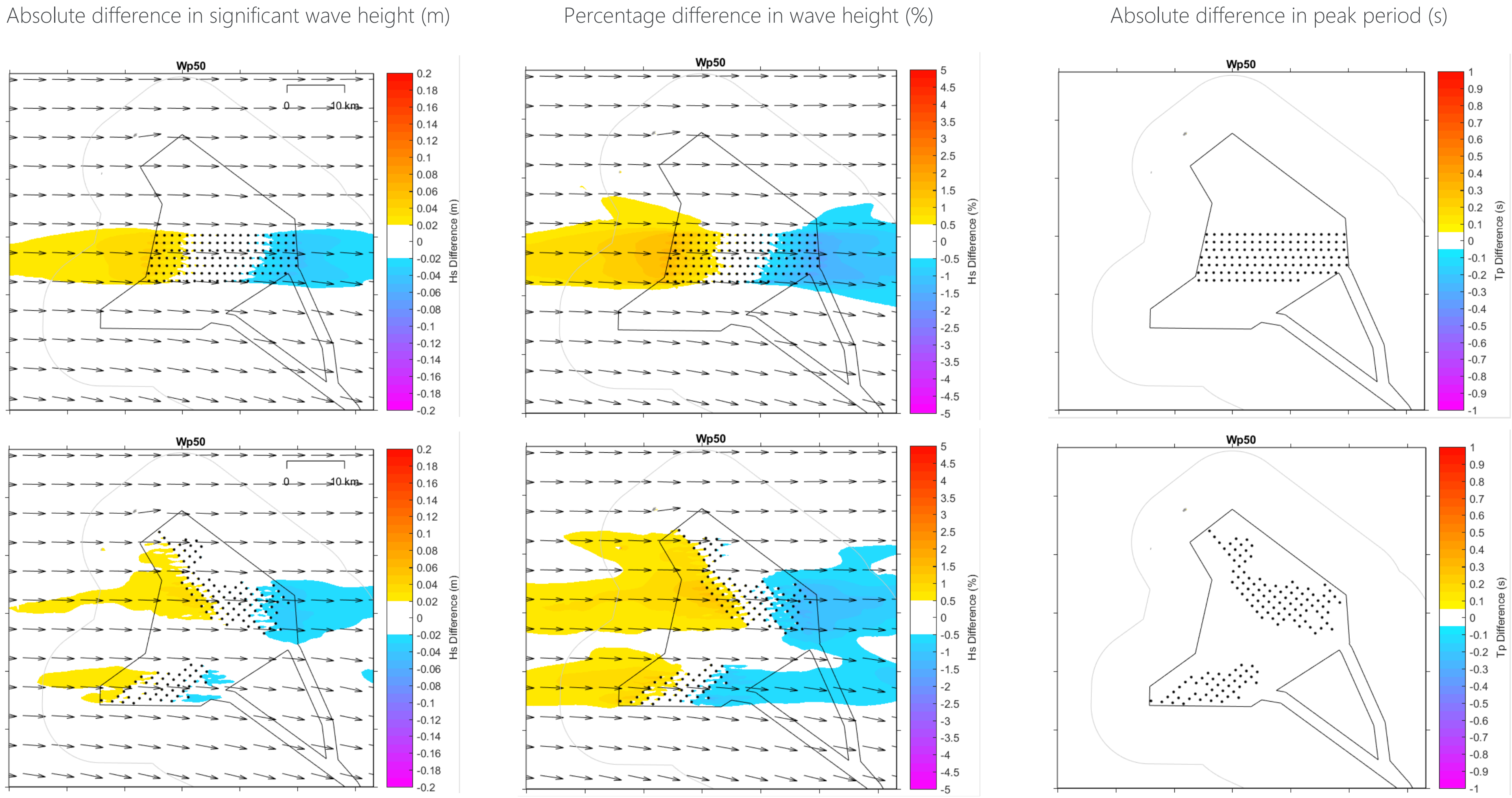

Figure 8-27 Post-construction potential change in the 50th percentile wave originating from the west for Layout 1 (top) and Layout 2 (bottom). Colours illustrate the post-construction difference, while the vectors illustrate the wave approach direction only

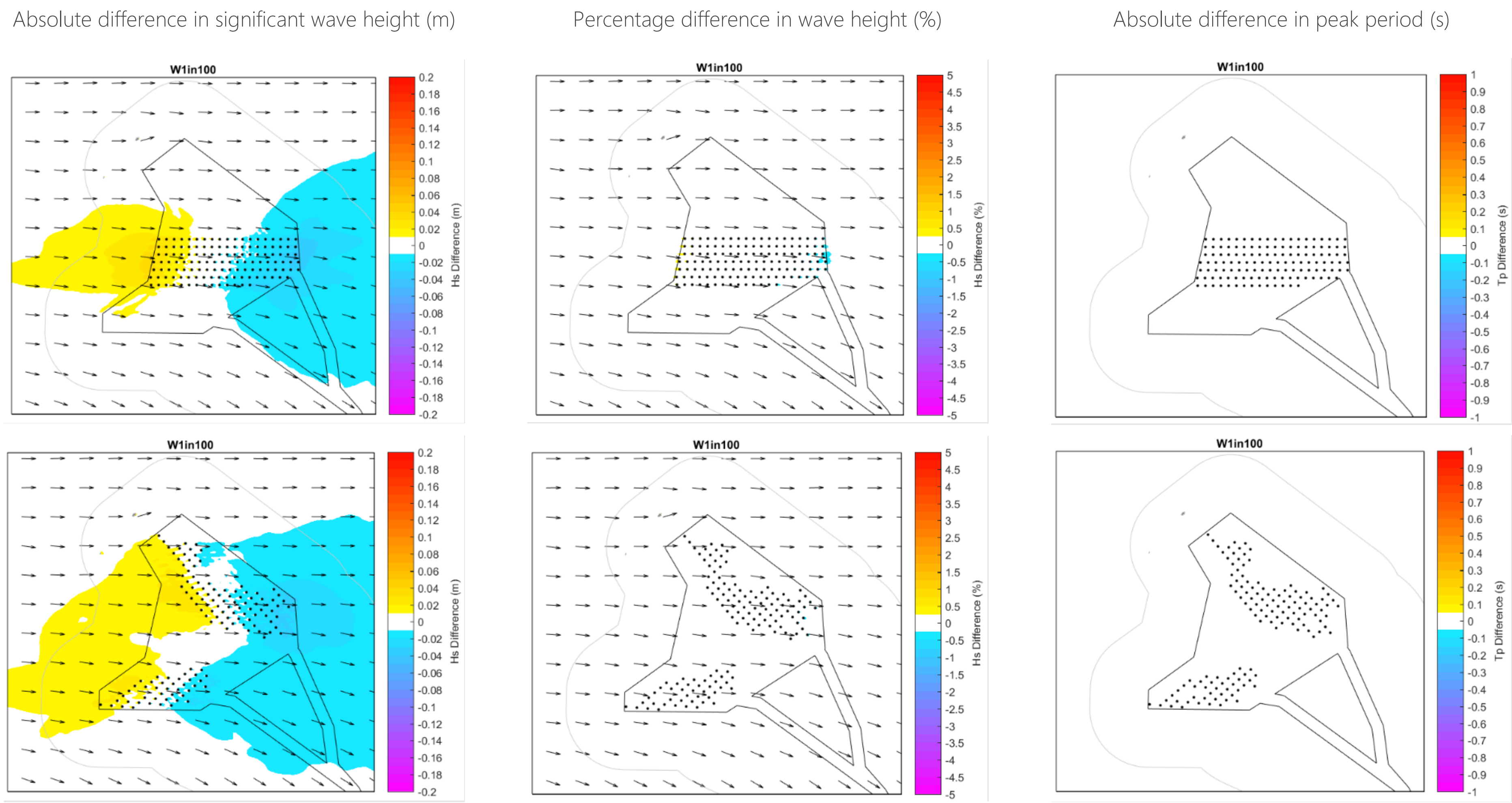

Figure 8-28 Post-construction potential change in the 1 in 100-year wave originating from the west for Layout 1 (top) and Layout 2 (bottom). Colours illustrate the post-construction difference, while the vectors illustrate the wave approach direction only

8.6.2.1.3 Changes to sediment transport

Sediment transport is dependent on tidal flow and wave properties. These factors drive the potential for sediment mobility. Based on the results described in sections 8.6.2.1.1 and 8.6.2.1.2, there was no apparent change to the local tidal and wave regimes. Consequently, there is predicted to be no change in sediment transport as a result of the Project.

Post-construction flows at the 28 model extraction locations (Figure 8-5) were extracted and compared against the baseline understanding of sediment transport as presented in SS3: Marine physical and coastal processes supporting study. Given the very marginal change in flows and wave parameters, the extent of change was very small. At only two analysis locations was there any change in sediment transport potential from baseline levels (SS3: Marine physical and coastal processes supporting study). At these locations the mobility of fine sands post-construction changed by a maximum of ±1% compared to baseline sediment transport potential. This equates to approximately a 40-minute period within a spring-neap tidal cycle (i.e. based on the 15-day assessment period, in line with the timeframe used for the baseline characterisation, section 8.4.4.9), during which sediment transport of fine sands was different from the baseline transport potential. Consequently, this change in sediment transport is not likely to manifest in any noticeable change to the seabed.

8.6.2.1.4 Impact assessment

Impacts as a result of changes to tides, waves and sediment transport regimes, mainly reflect on morphology and coastal receptors. Overall, the influence of the WTGs on the local tidal regime and wave parameters is minimal. This is reflected in the lack of change in sediment transport post-construction. As outlined in section 8.4.4.3.2, morphological analysis of the bedforms within the OAA and offshore ECC (including Stormy Bank and Whiten Head Bank within the OAA) indicates that these features are stable under present metocean conditions and the local sediment transport regime. Furthermore, the large bedform features are entirely formed and maintained by these regional processes. In general, the seabed and present bedforms within the OAA are considered to be of negligible sensitivity to changes in local environmental conditions. Based on the findings outlined above, including the model outputs, the magnitude of predicted change to the tidal, wave and sediment transport regime is negligible. Consequently, there is no opportunity for any impact to the morphology features within the offshore Project area.

With regards to the coast, as described in section 8.4.4.11, the coastline is classed as "Erosion-resistant rock and/or cliff, without loose eroded material in the fronting sea" (EMODnet, 2021). Additionally, there is no evidence of change through time based on imagery of the coastline. Based on this evidence, under present conditions, there is no erosion occurring. Furthermore, the nature of the substrate does not lend itself to erosion in the future (see section 8.4.5.7). Therefore, the sensitivity of the landfall to changes in the tidal, wave and sediment transport regime is negligible.

Considering the minimal extent of change in metocean conditions will be imperceptible within the spectrum of natural variation, and that there is no change predicted in the sediment transport regime, the magnitude of impact on the landfall is negligible.

Evaluation of significance

The bedforms within the offshore Project area are currently considered to be stable, while the coast is erosion-resistant. However, at worst, the receiving environment across the offshore Project is at worst considered to have a low sensitivity (based on the low sensitivity associated with the offshore ECC and its proximity to the coast) to changes in tidal, wave and sediment transport regimes.

Based on the evidence provided above, there is no predicted change to the tidal, wave or sediment transport regime as a result of the Project presence. Therefore, the magnitude of impact is negligible.

As a result, the consequence of the predicted level of change on the tidal, wave and sediment transport regimes is negligible. Overall, the impact is not significant in EIA terms.

Location	Sensitivity	Magnitude of impact	Consequence
OAA	Negligible	Negligible	Negligible
Offshore ECC	Low	Negligible	Negligible
Impact significance – NOT SIGNIFICANT			

8.6.2.2 Introduction of scour

The term scour refers here to the development of pits or depressions in the seabed around the base of WTG or OSP foundations. Scour is the result of localised erosion due to the three-dimensional interaction between the foundation and flows. No equivalent assessment has been completed for the offshore ECC as the cable is intended to be buried. Therefore, scour formation within the offshore ECC is not considered further.

The extent and depth of scouring is mainly related to the scale and shape of the structure (in this case the foundations), geological properties of the surface and sub-surface seabed sediments, and metocean properties (tidal range, water depth, wave-tide climate). These factors are largely summarised throughout section 8.4.4. A comprehensive explanation of scour formation and environmental conditions in the offshore Project area are available in SS3: Marine physical and coastal processes supporting study.

Scour, once formed, can continue to develop until it reaches a point of equilibrium. However, the presence of scour can be of concern from an engineering and structural stability perspective. With regards to the environment, the presence of scour causes concerns as the seabed will be modified from its natural state, and the act of scouring results in sediment resuspension. The assessment considers the three possible WTG foundation types (monopile, piled jacket and suction bucket jacket) and the two possible OSP foundation types (piled jacket and suction bucket jacket). A full assessment of scour formation is presented in SS3: Marine physical and coastal processes supporting study. The key outcomes of the assessment, and those which are instrumental to the assessment of impact, are as follows:

- With regards to the WTG foundations, the monopile foundation generates the greatest scour depth and extent, at approximately 41 m across and approximately 21 m deep. This is approximately twice the size of the scour pits generated under the other two foundation options.
- For OSP foundations, the worst scour is estimated for the suction bucket jacket at approximately 26 m across and approximately 13 m deep. However, this is significantly less than for the WTG monopile.
- Across the offshore Project area, sediment transport for finer sediments (as far as coarse sand) occurs variably over the course of a tidal cycle. Fine sands are mostly mobile 30% of the time, typically on spring tides. Larger sediments are mobile less frequently (section 8.4.4.9). Given the sediment transport mobility characteristic of the offshore Project area, rates of backfilling of the scour will be relatively slow. Consequently, once these scour holes are generated, they will remain largely unchanged. Storm events may assist in promoting backfilling however such events are generally rare and short in duration.
- The offshore Project area is flood dominant with more energetic currents travelling from west to east (section 8.4.4.7). The implication of this being that scour will be slightly asymmetric around the foundations, although it is not expected to be pronounced.
- In order to mitigate against scour, protection material (most likely rock) will be placed around the foundations. Scour protection is expected to be placed in a circular form surrounding the entirety of the foundation at the seabed. Excluding the foundation area, an estimated 8,000 m^2 of scour protection is anticipated for monopile WTGs. Approximately 9,500 m^2 of protection is required per individual WTG piled jacket and suction bucket jacket foundation (Table 8-17). Using the maximum scour protection extent per WTG (9,500 m^2), this results in a total area of protection of 1,187,500 m^2 across all WTGs within the OAA.
- An estimated 16,500 m^2 and 17,300 m^2 of protection are required per OSP piled jacket and suction bucket foundations respectively (Table 8-18). Assuming the maximum extent of scour protection (17,300 m^2), this equates to 86,500 m^2 of protection for all OSPs.

The seabed across the OAA is considered to be of negligible sensitivity as described in relation to previous impacts to changes in local environmental conditions While the presence of structures on the seabed will inevitably result in the formation of scour, scour protection has been integrated into the engineering and design of the Project to mitigate against this (section 8.5.4), which would be installed at construction. Based on the assumed presence of protection measures, it is anticipated that no scour will form at the base of the foundations. The OAA covers an area of approximately 657 km^2, and the area of proposed protection equates to approximately 0.19% of the OAA as a whole. Consequently, the magnitude of impact is considered to be negligible.

Evaluation of significance

The seabed is considered to have a negligible sensitivity. Considering mitigation measures embedded within Project design and given the placement of rock protection at construction thereby negating the development of scour, the magnitude of impact is negligible. Therefore, the overall consequence of introduction of scour is negligible and the impact is considered not significant in EIA terms.

Sensitivity	Magnitude of impact	Consequence
Negligible	Negligible	Negligible
Impact significance – NOT SIGNIFICANT		

8.6.2.3 Changes to water column structure with impact to stratification

A number of studies have investigated the potential for impacts of offshore windfarms developments on regional fronts and stratifications either in isolation or cumulatively, based on site observations following construction (Schultze *et al.*, 2020; Floeter *et al.*, 2017), modelling results (Carpenter *et al.*, 2016; Cazenave *et al.*, 2016) and a conceptual assessment (Dorrell *et al.*, 2022). A brief synthesis of these studies is provided here, while SS3: Marine physical and coastal processes supporting study, presents a comprehensive discussion on the findings of these reports. The significance of changes to stratification can have consequences on the presence of fronts. There are no fronts within the offshore Project area (section 8.4.4.10); however, patterns in stratification influence the availability of nutrients and therefore the distribution and growth rates of marine flora and fauna. While stratification is important in the regulation of the marine environment, the feature occurs on a large scale and so is likely to be beyond the influence of a windfarm. As described in section 8.4.4.10, the stratification observed within the offshore Project area is considered to be strong when present, based on the large variance recorded and the consistency across the surveyed extent during all tidal states, across the July – August survey period. However, as represented within the PFOW climatology (O'Hara and Campbell, 2021) and suggested by site observations, the stratification is seasonal and limited throughout the year within the offshore Project area.

Schultze *et al.* (2020) investigated the possible impact of a monopile on the mixing of a stratified water column and presented observations on monitoring of the thermal water structure in the lee wake of a foundation (6 m diameter monopile in a water depth of 24 m) of the DanTsyk offshore wind farm off the west coast of Denmark (in the German Bight of the North Sea). The study ultimately found that although there was increased mixing, this was localised to within a few hundred metres of the structure. At the offshore windfarm scale, there was no clear influence of increased mixing due to the monopile foundations. This was especially the case in locations and periods of strong stratification variance. Overall, the study concluded that although single WTGs could increase turbulence and mixing, this would occur locally and would be low in scale. While salinity was not specifically assessed, the findings of Schultze *et al.* (2020) are likely to be applicable to salinity too. Carpenter *et al.*, (2016) also investigated the potential for large scale changes in stratification in tidal shelf seas (i.e. the German Bight region of the North Sea) attributed to the cumulative presence of offshore windfarms. The study concluded that stratification is broken down very gradually by interaction with a windfarm, with the process potentially occurring over a timescale in the order of 100 to 500 days. However, these timescales suggested are likely to be highly conservative. Therefore, the overall conclusion was that no large-scale changes to stratification within the North Sea are expected based on proposed levels of development (current at time of that publication). Though the level of offshore windfarm development has increased substantially since the conclusions of Carpenter *et al.* (2016) were established, the proposed Project is located outside of the North Sea and in deeper waters.

Modelled results from Cazenave *et al.* (2016) indicated that the introduction of WTG structures across an OWF influenced mixing within the model domain. Horizontally, foundation structures were modelled to reduce flow velocities at several times the foundation diameter, in some cases up to 250 times the foundation diameter, and even larger when considering the full array of WTG foundations within the OWF. Vertically, the foundations increased mixing of the water column due to flow up and down each monopile. In areas where stratification occurs, the increased vertical mixing resulted in a decrease in stratification between 5 and 15%, the horizontal extent of which was larger than the sum of the monopile footprints. However, the limitations of the model were discussed, which suggested the applied model scale and parameterisation was not entirely appropriate to fully distinguish the mixing processes at the array and wider regional scales (Cazenave *et al.*, 2016).

Available information would all confirm the likely influence on vertical water column and potential stratification mixing in the immediate vicinity of the monopile foundations within the OAA. However, the spatial length scales of this influence are considered to be in line with the baseline stratification modelled in the PFOW climatology (section 8.4.4.10). Site-specific data confirmed the presence of stratification within the months of July and August, with the PFOW climatology indicating seasonal stratification between the months of May and August, equating to approximately four months of the year. The outputs from the PFOW climatology would suggest strong stratification when present due to the large variance with the maximum temperature and salinity variance observed during site-specific surveys supporting this assertion (section 8.4.4.10). When stratification is present, it is possible that foundations may cause some minor decrease in the strength of water column stratification across the OAA, in the immediate vicinity and wake of the foundations, due to increased mixing. The mixing length scales are considered to be in the order of hundreds of metres and several times the foundation diameter. However, the mixing length scale is still considered to be less than the applied separation at approximately 73 times the foundation diameter (monopiles in this case). Field observations from Schultze *et al*. (2020) would support this understanding as during periods of strong stratification, mixing length scales were less than 10 times the foundation diameter. It is therefore also considered unlikely that water which is stratified entering the OAA will become fully mixed on moving through the offshore Project, particularly the OAA. The stratification of the north coast of Scotland is understood to be strong as it is driven by mesoscale properties. Therefore, the water column and stratification is considered to have a low sensitivity. The regional scale patterns of stratification interpreted to exist in this part of the northwest Scottish continental shelf will be unaffected and will continue to be subject to natural processes and variability. Given the regional context and scale of stratification patterns compared to the relatively localise potential impact associated with the OAA, the magnitude of impact is considered to be low.

Evaluation of significance

Stratification occurs at a regional scale. Therefore, it is considered to be of low sensitivity to change. Additionally, there are no fronts present in the offshore Project area.

Based on the assessment of scientific evidence, the influence of structures in the marine environment is only likely to affect stratification in a highly localised manner i.e. within the immediate wake of a structure. Therefore, the magnitude of impact is low.

Overall, the consequence of the Project presence on stratification is considered to be negligible and therefore the impact is not significant in EIA terms.

Sensitivity	Magnitude of impact	Consequence
Low	Low	Negligible
Impact significance–- NOT SIGNIFICANT		

8.6.2.4 Re-exposure of buried cables and changes to coastal processes and landfall morphology from remedial protection measures

The use of HDD at the landfall will result in cable exit points between 10 mLAT and 40 mLAT. Therefore, the minimum water depth along the offshore ECC at which a rock berm or remedial protection can be placed is 10 mLAT, which is between 100 m and 200 m offshore (from 0 mLAT). As described in section 8.5.5, protection may be used at the HDD exit location, with a berm height and width of up to 3 m and 20 m respectively. Remedial protection measures at the HDD exit along the offshore ECC close to landfall have the potential to limit sediment transport as a result of the blockage effect they present within the water column. The presence of a rock berm (the assumed method of external cable protection for the assessment) can affect downstream flows, thereby impeding sediment transport processes. As water depth is a key factor in determining the influence of a rock berm on sediment transport, this is only relevant in the shallower coastal waters within the offshore ECC. In deeper water, as present within the OAA, and along parts of the offshore ECC, the presence of the protection would be indiscernible.

Table 8-30 shows the predicted change in spring and neap currents at the shallowest point in the offshore ECC. Based on baseline conditions within the ECC and the dimensions of the rock berm (described in section 8.5.5), at the shallowest point along the offshore ECC, there is no observable change to downstream water levels, resulting in no changes to flow speeds under spring or neap conditions (Table 8-30). This is similar in the case at depths greater than 10 mLAT. As defined with respect to potential construction impacts to coastal morphology, the coastal receptor is considered to have a low sensitivity.

To note, the shallowest point within the OAA is 41 mLAT. At this depth, the presence of the rock berm will not generate a change in flows (Table 8-30). With respect to the potential for near-bed blockage of flow and sediment transport, the presence of protection on the seabed will not result in any demonstrable change to flows. Therefore, changes to sediment transport are unlikely. Consequently, as sediment transport processes are expected to remain unchanged by the presence of remedial protection measures, changes to landfall morphology are not anticipated. Long-term, if impacts on sediment transport are not likely to occur, there would be limited opportunity for re-exposure of cables in the nearshore. Additionally, as assessed throughout section 8.6.2.1, the presence of the Project will not have an impact on tidal or wave properties beyond the scope of natural variation. Therefore, there is limited opportunity for re-exposure of cables because of changes to local marine processes. Hence the magnitude of impact is considered to be low.

Table 8-30 Blockage due to rock placement

LOCATION	ANALYSED WATER DEPTHS (mLAT)	FLOW (m/s)[1]	SPEED	SPRING[2]		NEAP[2]	
		SPRING	NEAP	DOWNSTREAM FLOW SPEED (m/s)	PERCENTAGE CHANGE (%)	DOWNSTREAM FLOW SPEED (m/s)	PERCENTAGE CHANGE (%)
Offshore ECC	10	0.72	0.26	0.72	No Change	0.26	No Change
OAA	41	0.74	0.56	0.74	No Change	0.56	No Change

[1]: Flow speed across the informed by the baseline characterisation (section 8.4.4.7); and

[2]: Assessed changes to flow speeds as a result of the 3 m high rock protection.

During construction, as discussed in section 8.6.1.3, up to six HDD exit pits may be excavated. The effect of these pits and their influence on local wave shoaling has been assessed already in section 8.6.1.3. Associated with these pits will be up to six berms of excavated material. Based on the understanding that remedial protection will not affect flows and sediment transport processes, this is equally applicable to the sediment berms.

Evaluation of significance

Overall, the presence of remedial protection within the offshore ECC close to the landfall is not expected to affect sediment transport processes. Therefore, the sensitivity of landfall morphology and coastal processes to operation effects is considered to be low.

The degree of change to flows at a water depth of 10 mLAT is very small therefore is low in magnitude. The overall consequence to re-exposure of cables, changes to coastal processes and landfall morphology as a result of cable protection measures is **negligible**. Therefore, the impact is **not significant** in EIA terms.

Sensitivity	Magnitude of impact	Consequence
Low	Low	Negligible

Impact significance - NOT SIGNIFICANT

8.6.3 Potential effects during decommissioning

In the absence of detailed information regarding decommissioning works, the impacts during the decommissioning of the offshore Project are considered analogous with, or likely less than, those of the construction stage.

The worst case scenario for decommissioning will be a clear seabed, where substructures and foundations that extend below the seabed will be cut approximately 1 m below the seabed to allow removal of the substructure, although, scour protection may be left *in situ*, due to the habitat it provides. The same applies for the worst case scenario of the offshore export cables, inter-array cables and the interconnector cables; a clear seabed where some materials may be left *in situ*. The cable ends will be buried at an acceptable depth below the seabed and exposed sections of the cable will most likely be cut and removed or subjected to rock placement.

A Decommissioning Programme will be developed and approved pre-construction to address the principal decommissioning measures for the offshore Project, this will be written in accordance with applicable guidance and will detail the management, environmental management and schedule for decommissioning. Prior to the commencement of any decommissioning works, the Decommissioning Programme will be reviewed and revised as required in accordance with the industry practice at that time. The decommissioning activities are expected to take a similar duration as the construction programme.

Given the nature of the decommissioning activities, which will largely be a reversal of the installation process, the impacts during decommissioning are expected to be similar to or less than those assessed for the construction stage. Therefore, the magnitude of impacts assigned to marine physical and coastal processes receptors during the construction stage are also applicable to the decommissioning stage. It is also assumed that the receptor sensitivities will not materially change over the lifetime of the offshore Project. Therefore, the decommissioning effects are not expected to exceed those assessed for construction.

8.6.4 Summary of potential effects

A summary of the outcomes of the assessment of potential effects from the pre-construction, construction, operation and maintenance and decommissioning of the Project is provided in Table 8-31. No significant effects on marine physical and coastal processes were identified. Therefore, mitigation measures in addition to the embedded mitigation measures listed in section 8.5.4 are not considered necessary.

Table 8-31 Summary of potential effects

POTENTIAL EFFECT	RECEPTOR	SENSITIVITY OF RECEPTOR	MAGNITUDE OF IMPACT	CONSEQUENCE (SIGNIFICANCE OF EFFECT)	SECONDARY MITIGATION REQUIREMENTS	RESIDUAL CONSEQUENCE (SIGNIFICANT OF EFFECT)
Construction and decommissioning						
Change to seabed levels, sediment properties and suspended sediment concentrations	OAA	Negligible	Low	Negligible (not significant)	None required above embedded mitigation measures	Negligible (not significant)
	Offshore ECC	Low	Low	Negligible (not significant)	None required above embedded mitigation measures	Negligible (not significant)
Impact on interest features within the designated sites due to export cable construction	Geological features	Medium	Negligible	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)
	Maritime and vegetated sea cliffs	Medium	Negligible	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)

POTENTIAL EFFECT	RECEPTOR	SENSITIVITY OF RECEPTOR	MAGNITUDE OF IMPACT	CONSEQUENCE (SIGNIFICANCE OF EFFECT)	SECONDARY MITIGATION REQUIREMENTS	RESIDUAL CONSEQUENCE (SIGNIFICANT OF EFFECT)
	Other coastal habitat features	Medium	Negligible	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)
Change to coastal landfall morphology	Coastal morphology	Low	Medium	Minor (not significant)	None required above embedded mitigation measures.	Minor (not significant)
Operation and maintenance						
Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors	OAA	Negligible	Negligible	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)
	Offshore ECC	Low	Negligible	Minor (not significant)	None required above embedded mitigation measures.	Minor (not significant)
Introduction of scour	Seabed	Negligible	Negligible	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)

POTENTIAL EFFECT	RECEPTOR	SENSITIVITY OF RECEPTOR	MAGNITUDE OF IMPACT	CONSEQUENCE (SIGNIFICANCE OF EFFECT)	SECONDARY MITIGATION REQUIREMENTS	RESIDUAL CONSEQUENCE (SIGNIFICANT OF EFFECT)
Changes to water column structure with impact to stratification	Water column stratification	Low	Low	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)
Re-exposure of buried cables and changes to coastal processes and landfall morphology from remedial protection measures	Coastal morphology	Low	Low	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)

8.7 Assessment of cumulative effects

8.7.1 Introduction

Potential impacts from the offshore Project have the potential to interact with those from other projects (developments), plans and activities, resulting in a cumulative effect on marine physical and coastal processes receptors. The approach to the cumulative effects assessment is described in chapter 7: EIA methodology, and further detail is provided below.

The list of relevant developments for inclusion within the cumulative effects assessment is outlined in Table 8-32. This has been informed by a screening exercise, undertaken to identify relevant developments for consideration within the cumulative effects assessments for each EIA topic, based on defined Zones of Influence (ZoI).

ZoIs with respect to impacts offshore have been defined by a 20 km buffer around the OAA. The ZoI around the offshore ECC is 30 km. This accounts for the relative higher sensitivity of coastal receptors compared against the offshore environment. These ZoIs are double the study area extent in order to capture any potential buffer of impacts from other surrounding developments.

Table 8-32 List of developments considered for the marine physical and coastal processes cumulative impact assessment

LOCATION	DEVELOPMENT TYPE	DEVELOPMENT NAME	DISTANCE TO OAA (KM)	DISTANCE TO OFFSHORE ECC (KM)	STATUS	CONFIDENCE
West of Orkney	Offshore Wind Farm	West of Orkney Windfarm – transmission connection to the Flotta Hydrogen Hub	0	0	Pre-application	Low
Pentland Firth (Caithness to Mainland Orkney)	Power transmission cable	Scottish Hydro Electric Transmission Limited (SHET-L) Caithness to Orkney High Voltage Alternating Current (HVAC) Link	22	0	Consented	Medium
Muckle Bay, Caithness to Rackwick Bay, Orkney	Power distribution cable	Pentland Firth East (3) Cable Replacement	26	11	Under construction	Medium

LOCATION	DEVELOPMENT TYPE	DEVELOPMENT NAME	DISTANCE TO OAA (KM)	DISTANCE TO OFFSHORE ECC (KM)	STATUS	CONFIDENCE
Pentland Firth	Offshore Wind Farm	Pentland Floating Offshore Wind Farm (PFOWF)[29]	20	2	Consented	Medium

The following impacts have been taken forward for cumulative assessment:

- Construction and decommissioning;
  - Change to seabed levels, sediment properties and suspended sediment concentrations;
  - Impact on designated features within the designated sites due to export cable construction;
  - Change to coastal landfall morphology;
- Operation and maintenance;
  - Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors;
  - Introduction of scour;
  - Changes to water column structure with impact to stratification; and
  - Re-exposure of buried cables at landfall and changes to coastal processes and landfall morphology from remedial protection measures.

8.7.2 Cumulative construction effects

8.7.2.1 Change to seabed levels, sediment properties and suspended sediment concentrations

The West of Orkney Windfarm – transmission connection to the Flotta Hydrogen Hub, PFOWF, SHET-L Caithness to Orkney HVAC Link and Pentland Firth East (3) Cable Replacement developments all have the potential to affect seabed levels, sediment properties and suspended sediment concentrations. Therefore, they are considered here in the context of cumulative impacts.

Due to the early stage of the development, very little information exists on the West of Orkney Windfarm – transmission connection to the Flotta Hydrogen Hub. However, an overlap with the construction of the offshore Project cannot be ruled out. It is expected that the level of impacts associated with the cable would be equivalent to

[29] *Pentland Floating Offshore Wind Farm (PFOWF) will incorporate the currently consented Pentland Floating Offshore Wind Demonstrator turbine, and hence PFOWF only has been considered. The PFOWF Section 36 Consent and Marine Licence was granted for 10 years. However, the cumulative effects assessment has been based on the Project Design Envelope, as specified within the EIA, and therefore, an operational life of up to 30 years for the PFOWF has been considered. Since consent was granted in June 2023, PFOWF have submitted a Screening Report to MD-LOT with the intention to request a variation to the Section 36 Consent. This variation will incorporate refinements to the Project Design Envelope and to extend the operational life to 25 years.*

other similar developments (detailed further below). Overall, it is expected that the scale of disturbance would be highly localised and changes to seabed levels, sediment properties and suspended sediment concentrations would be transient and minimal.

The PFOWF EIA concluded that the majority of the disturbed sediment during trenching would be deposited within the 500 m of the disturbance (Pentland Floating Offshore Wind Farm, 2022). Only a small proportion would enter into suspension (discussed below). The SHET-L Caithness to Orkney HVAC Link development suggests that sediments disturbed by trenching activities are likely to re-settle within the immediate vicinity of the trench, less than 10 m either side, for sand or coarser sediments (Xodus, 2019). The Pentland Firth East (3) Cable Replacement similarly expects sediment resettlement to occur within the immediate vicinity of the installation trenching activities (Intertek, 2022a). The scale of deposition associated with Project construction activities is somewhat greater (section 8.6.1.1.1). However, this is considered to be minimal overall in the context of the whole offshore Project area. In combination with these three other developments, the scale of deposition and change to seabed levels is unlikely to be noticeable in the context of the wider environment.

SSC was assessed in the PFOWF EIA. Only the silt fraction (less than 5% of the sediment fraction) was assumed to contribute to the formation of a plume. The maximum sediment plume extent was estimated to be 3.3 km on a flood tide, with a duration of 4.7-hours. On an ebb tide, the plume is expected to have an extent of around 2.4 km and a duration of less than 4 hours. The PFOWF EIA suggested that a similar plume development could occur with the SHET-L Caithness to Orkney HVAC Link development. In both cases the plume would disperse with the tidal and wave currents in the nearshore area within a few hours and certainly within a tidal cycle (Pentland Floating Offshore Wind Farm, 2022). These extents and timescales are relatively consistent with what is discussed in section 8.6.1.1 for the Project alone, albeit slightly reduced. Most importantly, the timelines associated with these two other developments appear to indicate that construction activities will conclude in 2027. Therefore, the opportunity for overlap in sediment plumes associated with all these activities is highly unlikely.

The Pentland Firth East (3) Cable Replacement concluded that, given the generally turbulent conditions within Pentland Firth and the surrounding waters, particulates are expected to rapidly disperse through the water column. Therefore, any plumes generated during installation will be highly transient (Intertek, 2022a). The highest concentrations of suspended sediments will be limited to within 300 m of the cable installation jetting activity. Gravel and coarser sand deposits are likely to instead be deposited within 20 m of the trench (Intertek, 2022a). Not only is this activity highly localised in scale, but the Pentland Firth East also (3) Cable Replacement is projected to conclude in August 2023. Therefore, as with the developments discussed above, there is no opportunity for overlap between plumes generated by the offshore Project and Pentland Firth East (3) Cable Replacement.

The PFOWF assumes up to 12.5 km in total of their export cable will require external protection, resulting in a footprint of 0.09 km^2. Within the corresponding PFOWF array area, approximately 0.16 km^2 of the development area will be occupied by the placement of hard substrate. As the development is floating and small in scale, the impact on the seabed is comparatively limited. The PFOWF cumulative assessment, identified a region of overlap between the windfarm and the SHET-L Caithness to Orkney HVAC Link development of approximately a 500 m section off the coast (depending on final HDD exit locations). Therefore, the area of overlap is very small and the requirement for cable protection measures within that area from both developments is unlikely. The PFOWF EIA concluded there was no cumulative impact. These two developments reach landfall approximately 2 km southwest from the Project Greeny Geo offshore ECC landfall location, therefore will not overlap directly with the offshore Project area at this point.

The SHET-L Caithness to Orkney HVAC Link development will cross the Project offshore ECC further offshore thereby necessitating the use of rock protection at the crossing (as it assumed that the SHET-L Caithness to Orkney HVAC Link development will be installed first). While the Project offshore ECC will not cross the Pentland Firth East (3) Cable Replacement development directly, external protection/stabilisation (in the form of rock placement, concrete mattresses or grout bags) will be required for the development where burial cannot be achieved. However, the quantity of protection is minimal (Intertek, 2022a, 2022b). As described in section 8.4.4.5, the offshore Project area is mostly covered in mixed sediments which are generally coarser in nature. The overall scale of seabed lost due to rock placement is minimal in the context of the wider region. With regards to other construction impacts, these will be temporary in nature and so the seabed is expected to recover from this temporary disturbance rapidly.

Overall, the scale of the other three developments is small in comparison to the Project. Therefore, the impacts associated with the other developments are not likely to add considerably to the impact of the Project alone. Therefore, the cumulative impact remains consistent with the assessment for the Project alone, as in section 8.6.1.1. The sensitivity of the seabed to changes in seabed levels, sediment properties and suspended sediment conditions is considered low. The magnitude of impact associated with the Project activities in combination with the other developments remains low. Overall, the consequence is negligible and so, the impact is not significant.

8.7.2.2 Impact on interest features within the designated sites due to export cable construction

The assessment completed in relation to the offshore Project in section 8.6.1.2, indicated that there is little to no pathway for impacts to designated sites and interest features, relating to geological (section 8.6.1.2.1) and other coastal habitat features (section 8.6.1.2.3). No Project activities are being completed directly within the designated sites to impact interest features, or the designated sites are at distances where sedimentation occurring with respect to construction works will not alter the characteristic or integrity of the interest features. On the basis that there are no pathways or connectivity for impacts to the designated sites associated with the offshore Project, there is therefore no potential for cumulative effects in relation to the offshore Project and other nearby projects.

The only site for which there is considered to be the potential for connectivity with the offshore Project is the Ushat Head SSSI, which overlaps the offshore Project area (section 8.6.1.2.2). Therefore, the potential for cumulative impacts is completed only in relation to this designated site and the associated maritime and vegetated sea cliff interest feature. Due to the intervening distance between the designated site and cumulative projects, only the SHET-L Caithness to Orkney HVAC Link cable is considered to be relevant. Documentation prepared in support of the SHET-L Caithness to Orkney HVAC Link cable discounted consideration of sites designated for terrestrial features, including those of a geological/geomorphological nature. Due to the intention to use HDD at the development landfall, and the HDD borehole exit being approximately 1 km offshore, there was thought to be no pathway for effect with these SSSIs (Xodus, 2019). Furthermore, disturbance associated with installation of the SHET-L Caithness to Orkney HVAC Link cable is would be short-lived and transient, with the aim of keeping the majority of the sediment within the cable trench, with only a very localised plume. Consequently, there is not expected to be any impact on the Ushat Head SSSI as a result of development activities affecting marine physical and coastal processes.

Based on the above, there is no opportunity for the Project to interact cumulatively with the above developments as their timelines are not always aligned and often pathways for impact were ruled out. Consequently, the assessment outcome remains as for the Project alone:

- Geological features;
  - The sensitivity of these features is considered medium. The magnitude of impact remains negligible and so the overall consequence is negligible. There is no significant impact on geological designated features with regards to cumulative assessment;
- Maritime and vegetated sea cliffs;
  - The sensitivity of these features is considered medium. The magnitude of impact remains negligible and so the overall consequence is negligible. There is no significant impact on maritime and vegetated sea cliffs with regards to cumulative assessment;
- Other coastal habitat features;
  - The sensitivity of these features is considered medium. The magnitude of impact remains negligible and so the overall consequence is negligible. There is no significant impact on other coastal habitat features with regards to cumulative assessment.

8.7.2.3 Change to coastal landfall morphology

Of the developments listed in Table 8-32, only the PFOWF, West of Orkney Windfarm – transmission connection to the Flotta Hydrogen Hub and SHET-L Caithness to Orkney HVAC Link are likely to coincide with the Project in a way that may result in cumulative impacts. The transmission connection to the Flotta Hydrogen Hub intersects the offshore ECC offshore, and reaches landfall on Hoy, Orkney. Therefore, there is no opportunity for cumulative impacts on coastal receptors associated with this development. The Pentland Firth East (3) Cable Replacement will landfall at Thurso Bay, which is located within the study area.

While the scale of the PFOWF, at a maximum of up to 10 WTGs, is much smaller than the Project, the development export cable interacts with the Project offshore ECC and the development reaches landfall along the same stretch of coastline as the offshore ECC. The SHET-L Caithness to Orkney HVAC Link cable also achieves landfall along the same section of coastline as the offshore ECC.

The PFOWF will also utilise HDD at the export cable landfall. The exit pit will be between 400 and 700 m offshore in water depths of approximately 20 mLAT, but the actual disturbance from this will be very limited and localised to the exit point, such that impacts on landfall were scoped out of consideration from the PFOWF EIA (Pentland Floating Offshore Wind Farm, 2022). HDD could take place in 2024, so this may occur in advance of the Project landfall activities. Consequently, there is little opportunity for overlap between the PFOWF and the Project with respect to cumulative impacts which may affect the landfall.

The SHET-L Caithness to Orkney HVAC Link cable will utilise HDD at the landfall which will exit approximately 900 m to 1,050 m offshore. The duct will be approximately 5 m x 5 m (Xodus, 2019). This suggests that the duct is not comparable in scale to the exit pits proposed at the Project landfall. Consequently, there is no opportunity for the development landfall to act cumulatively with the proposed Project. Additionally, the timelines for the development and the Project could overlap, as according to best available information, the SHET-L Caithness to Orkney HVAC Link cable works will conclude in 2027, which could coincide with the initial construction programme for the Project. However, given the scale of the development, any residual impacts along the coastline associated with the development landfall are likely to have recovered by the time the proposed Project construction commences.

As discussed in section 8.6.1.3, the creation of HDD exit pits at the offshore ECC landfall may alter localised wave shoaling. The PFOWF and SHET-L Caithness to Orkney HVAC Link are assumed to achieve landfall approximately 2 km south of the Project offshore ECC landfall at Greeny Geo. The distance from these developments to the Project landfall means that any localised wave shoaling associated with the exit pits at the Project landfall will not be exacerbated.

The Pentland Firth East (3) Cable Replacement landfall is located close to Thurso at the furthest eastern extent of the marine physical and coastal processes study area. The landfall will involve excavation works from MLWS to a transition joint pit. The cable will be pulled through into the pre-excavated trench (Intertek, 2022b). Considering the Pentland Firth East (3) Cable Replacement works are expected to be completed in August 2023, and the intention is to reinstate the landfall locations to their original condition (Intertek, 2022b), it is likely that the landfall will have recovered prior to the commencement of the offshore Project activities. Consequently, no cumulative impacts are expected with respect to landfall morphology as a result of the Pentland Firth East (3) Cable Replacement.

Considering the above in relation to other developments within the marine physical and coastal processes ZoI, there is no likely cumulative impact on coastal landfall morphology. Therefore, the impact assessment remains as it is in section 8.6.1.3 for the Project alone: the sensitivity of the receptor is low, the magnitude of impact is medium which has a minor consequence. The overall impact is not significant in EIA terms.

8.7.3 Cumulative operation and maintenance effects

8.7.3.1 Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors

As described for the Project assessment (section 8.6.2.1), the scale of change to the tidal, wave and sediment transport regimes is considered negligible as a result of the presence of the Project.

Additionally, the three cable developments listed in Table 8-32 involve exclusively subsea construction and installation activities. Therefore, the scale of these developments would not be sufficient to affect tidal, wave and sediment transport regimes in a way such that there will be consequences on morphology and coast receptors. Therefore, only the PFOWF has the potential to act cumulatively with the offshore Project.

The scale of the PFOWF, at a maximum of up to 10 WTGs, is much smaller than the offshore Project. The spacing of the floating turbines in the PFOWF is set to a minimum of 800 m. Wakes from the floating structures within the PFOWF are expected to dissipate over a distance of several hundred metres, so will not interact with the offshore Project. With regards to the wave regime, fixed structures on the seabed associated with the floating turbines are considered to be too deep to interfere with waves. Ultimately, the relatively small scale of the development is such that effects on waves are expected to be minimal and localised to each floating structure. As a result, there is not anticipated to be any measurable change to either flows or wave energy transmission reaching the coast. Overall, this was assessed not to have an impact on sediment transport (Pentland Floating Offshore Wind Farm, 2022). It is reasonable to expect that changes to tidal, wave and sediment transport regimes associated with the PFOWF are considerably less than associated with the Project. Therefore, from a cumulative perspective, there is no greater impact on morphology and coastal receptors than for the Project alone.

The sensitivity of these receptors is considered negligible. The magnitude of impact is also negligible. Therefore, the consequence is also negligible and overall, there is no significant impact in EIA terms with respect to the cumulative assessment.

8.7.3.2 Introduction of scour

The potential for group scour only relates to the jacket foundation options for the WTGs and OSPs, where the legs act locally and cumulatively in the generation of scour. However, based on the minimum spacing between individual foundations (section 8.5.5, Table 8-17), scour is not expected to coalesce between foundations. Furthermore, scour protection measures have been considered in the Project design to ensure scour does not form. Scour formation is not likely along any of the cables or within the offshore ECC so is limited to the context of the foundations in the OAA. The developments listed in Table 8-32 are located at variable distances from the OAA, with the PFOWF being closest at 20 km away. The PFOWF is also the only development with comparable impacts on the seabed, such as scour. Given the scale of potential scour, the measure taken to ensure it does not form, and the distance of other developments from the Project, there is no possibility for overlap of scour between the Project and any other developments in the area. Therefore, the sensitivity of the seabed to scour is negligible, the impact remains negligible in terms of magnitude, and the overall consequence is negligible. Overall, the impact is not significant in EIA terms.

8.7.3.3 Changes to water column structure with impact to stratification

Several authors, whose works are referenced in section 8.6.2.2, stress the importance of cumulative effects from multiple large offshore wind developments (which together cover hundreds of kilometres), on mesoscale processes such as stratification. In the context of the offshore Project, the West of Orkney offshore windfarm off the northwest coast of Scotland on the northwest Scottish continental shelf is the only development at present occurring at such a large scale. Although there is potential for more developments to arise in the future as a result of the offshore wind plan option areas (Marine Scotland, 2022). The proposed PFOWF, closer to the coast, is a lot smaller, so it is not considered to be at the same scale to generate the cumulative effects described by authors. As stated in section 8.6.2.2, the influence of structures on stratification is limited to within hundreds of metres of the structure. At present, there is not considered to be the potential for the cumulative disruption to stratification that are described for other areas across the North Sea. Therefore, the cumulative assessment on impacts on stratification remains consistent as for the Project alone. The receptor is of a low sensitivity, the impact remains at a low magnitude, and the consequence on stratification is negligible. Therefore, cumulative effects are not significant in EIA terms.

8.7.3.4 Re-exposure of buried cables and changes to coastal processes and landfall morphology from remedial protection measures

Remedial protection measures have the potential to affect flows close to the seabed. This in turn affects sediment transport processes. However, the assessment for the offshore Project alone (in section 8.6.2.4) determined that, even at water depths of 10 mLAT, there would be no change to flows. Consequently, there is no knock-on effect anticipated which would affect landfall morphology over the life of the Project. Of the developments in Table 8-32, the PFOWF and SHET-L Caithness to Orkney HVAC Link require consideration in the context of cumulative impacts at the Project landfall. This is because these two developments achieve their own landfall along the same stretch of coastline as the Project offshore ECC. The Pentland Firth East (3) Cable Replacement will landfall at Thurso Bay which, while located within the study area, at 14 km from the Crosskirk landfall is sufficiently far enough away that any impacts associated with cable re-exposure will not act cumulatively with the offshore Project.

All of these developments have some requirement for cable protection measures. The PFOWF HDD exit point will be in approximately 20 mLAT. Therefore, associated rock protection will not occur in water depths less than this (Pentland Floating Offshore Wind Farm, 2022). The SHET-L Caithness to Orkney HVAC Link HDD exit duct will be located approximately 900 m to 1,050 m offshore (Xodus, 2019). While no equivalent depth is provided for this distance, it is likely to be in water depths below even 20 mLAT. Consequently, rock placement will be in water depths greater than this.

Considering the Project alone is not predicted to affect processes close to the coast, the added influence of rock placed in association with the other developments described above is highly unlikely to change the impact assessment outcome. Overall, the sensitivity of the landfall morphology and coastal processes to operational effects is considered low. The magnitude of impact also remains low. Therefore, the overall consequence is considered to be negligible. The impact is not significant in terms of cumulative impacts.

8.7.4 Cumulative decommissioning effects

There is limited information on the decommissioning of the offshore Project and that of other developments. However, the cumulative effects are expected to be less than or equal to the construction stage. Furthermore, decommissioning of multiple other developments would not be expected to occur at the same time as the decommissioning stage of the offshore Project.

A Decommissioning Programme will be developed pre-construction to address the principal decommissioning measures for the offshore Project and will be written in accordance with applicable guidance. The Decommissioning Programme will detail the environmental management, and schedule for decommissioning and will be reviewed and updated throughout the lifetime of the offshore Project to account for changing best practices.

8.7.5 Summary of cumulative effects

A summary of the outcomes of the assessment of cumulative effects for the pre-construction, construction, operation and maintenance and decommissioning stages of the offshore Project is provided in Table 8-33.

Table 8-33 Summary of assessment of cumulative effects

POTENTIAL EFFECT	RECEPTOR	SENSITIVITY OF RECEPTOR	MAGNITUDE OF IMPACT	CONSEQUENCE (SIGNIFICANCE OF EFFECT)	SECONDARY MITIGATION REQUIREMENTS	RESIDUAL CONSEQUENCE (SIGNIFICANT OF EFFECT)
Construction and decommissioning						
Change to seabed levels, sediment properties and suspended sediment concentrations	Seabed levels, sediment properties and suspended sediment concentrations	Low	Low	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)
Impact on interest features within the designated sites due to export cable construction	Geological features	Medium	Negligible	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)
	Maritime and vegetated sea cliffs	Medium	Negligible	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)
	Other coastal habitat features	Medium	Negligible	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)

POTENTIAL EFFECT	RECEPTOR	SENSITIVITY OF RECEPTOR	MAGNITUDE OF IMPACT	CONSEQUENCE (SIGNIFICANCE OF EFFECT)	SECONDARY MITIGATION REQUIREMENTS	RESIDUAL CONSEQUENCE (SIGNIFICANT OF EFFECT)
Change to coastal landfall morphology	Coastal landfall morphology	Low	Medium	Minor (not significant)	None required above embedded mitigation measures.	Minor (not significant)
Operation and maintenance						
Change to the tidal, wave and sediment transport regimes resulting in impacts on morphology and coast receptors	Morphology and coast receptors	Negligible	Negligible	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)
Introduction of scour	Seabed	Negligible	Negligible	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)
Changes to water column structure with impact to stratification	Stratification	Low	Low	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)

POTENTIAL EFFECT	RECEPTOR	SENSITIVITY OF RECEPTOR	MAGNITUDE OF IMPACT	CONSEQUENCE (SIGNIFICANCE OF EFFECT)	SECONDARY MITIGATION REQUIREMENTS	RESIDUAL CONSEQUENCE (SIGNIFICANT OF EFFECT)
Re-exposure of buried cables and changes to coastal processes and landfall morphology from remedial protection measures	Coastal processes and landfall morphology	Low	Low	Negligible (not significant)	None required above embedded mitigation measures.	Negligible (not significant)

8.8 Inter-related effects

Inter-related effects are the potential effects of multiple impacts affecting one receptor or a group of receptors. Inter-related effects include interactions between the impacts of the different stages of the offshore Project (i.e. interaction of impacts across pre- construction, construction, operation and maintenance and decommissioning), as well as the interaction between impacts on a receptor within an offshore Project stage. The potential inter-related effects for marine physical and coastal processes receptors are described below.

8.8.1 Inter-related effects between offshore Project stages

All offshore Project stages have the potential to impacts various marine physical and coastal process receptors. However, impacts assessed for the construction stage of the Project are unique to that period in the Project lifecycle. The activities discussed throughout section 8.6.1 are all temporary in nature and limited temporally to the window in which construction will occur. The exceptions to this are changes to the seabed associated with installation of structures and rock protection measures. Therefore, the expectation is that, once construction has been completed, there will be no lasting impact associated with construction. For instance, sediment plumes generated during construction are shown to dissipate relatively rapidly, and certainly will have done so by the time Project operation is achieved.

The exception to this is the potential for HDD excavated pits assuming natural backfill, to remain in situ for a period of months to over a year or more, depending on the occurrence and frequency of the larger and longer period waves. Consequently, this aspect of construction may continue into the operation and maintenance stage of the Project. However, there is no predicted significant change to the landfall as a result of either construction or operation therefore there will be no combined effect between these two stages.

There is no expected inter-related impact between construction and decommissioning given the period of time between these stages (i.e. the lifespan of the Project).

8.8.2 Inter-related effects within an offshore Project stage

Inter-related effects (e.g. multiple aspects which may affect the same receptor) have been considered through the impacts in section 8.6. For instance, change to seabed levels, sediment properties and suspended sediment concentrations are all addressed in section 8.6.1.1 and ultimately these aspects all affect various features of the seabed. Therefore, the combined effect has already been considered.

8.9 Whole Project assessment

The onshore Project is summarised in chapter 5: Project description and a summary of the effects of the onshore Project is provided in chapter 21: Onshore EIA summary. These onshore aspects of the Project have been considered in relation to the impacts assessed in section 8.5.5.1. The findings are presented below.

The onshore Project will undertake HDD operations above MHWS, with an HDD exit point offshore. The impacts from the HDD exit point on marine physical and coastal processes have been assessed in full in section 8.6.1.3. It is not anticipated that there will be any additional impacts from the onshore Project on these receptors as all other activities from the onshore Project are fully terrestrial.

8.10 Transboundary effects

Transboundary effects arise when impacts from a development within one European Economic Area (EEA) state's territory affects the environment of another EEA state(s).

There is no potential for transboundary impacts upon marine physical and coastal processes receptors due to pre-construction, construction, operation and maintenance and decommissioning of the offshore Project. The potential impacts, including those informed by project specific numerical modelling, are localised and are not expected to affect other EEA states. Furthermore, a number of the marine processes discussed throughout this chapter occur on a scale beyond that of any individual Exclusive Economic Zone (EEZ). The scale of change, as documented throughout the chapter, is not sufficient to affect processes on an international level.

Therefore, transboundary effects for marine physical and coastal processes receptors do not need to be considered further.

8.11 Summary of mitigation and monitoring

No secondary mitigation, over and above the embedded mitigation measures proposed in section 8.5.4, is either required or proposed in relation to the potential effects of the offshore Project on marine physical and coastal processes as no adverse significant impacts are predicted. No monitoring is proposed for marine physical and coastal processes.

8.12 References

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8.13 Abbreviations

ACRONYM	DEFINITION
ADCP	Acoustic Doppler Current Profiler
BGS	British Geological Survey
BODC	British Oceanographic Data Centre
CBRA	Cable Burial Risk Assessment
CFE	Controlled Flow Excavator
CMS	Construction Method Statement
CPT	Cone Penetration Tests
CTD	Conductivity Temperature Depth
DDV	Drop Down Video
DMPA	Dredge Material Placement Area
DSLP	Development Specification and Layout Plan
DTM	Digital Terrain Model
DVV	Dual Van Veen
ECC	Export Cable Corridor
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
FVCOM	Finite Volume Community Ocean Model
GCR	Geological Conservation Review

ACRONYM	DEFINITION
HDD	Horizontal Directional Drilling
HG	Hamon Grab
HVAC	High Voltage Alternating Current
HYCOM	Hybrid Coordinate Ocean Model
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
MBES	Multibeam Echo Sounder
MD-LOT	Marine Directorate - Licensing Operations Team
MHW	Mean High Water
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLW	Mean Low Water
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MS-LOT	Marine Scotland - Licensing Operations Team
MSS	Marine Scotland Science
NCMPA	Nature Conservation Marine Protected Area
NMP	National Marine Plan
NMPI	National Marine Plan Interactive

ACRONYM	DEFINITION
NS	NatureScot
NTSLF	National Tidal and Sea Level Facility
NTU	Nephelometric Turbidity Units
OAA	Option Agreement Area
OIC	Orkney Islands Council
OIRMP	Orkney Islands Regional Marine Plan
OSP	Offshore Substation Platform
OWF	Offshore Windfarm
OWPL	Offshore Wind Power Limited
PCS	Ports and Coastal Solutions
PDE	Project Design Envelope
PFOWF	Pentland Floating Offshore Wind Farm
PLONOR	Pose Little or No Risk to the Environment
PSA	Particle Size Analysis
RCP	Representative Concentration Pathways
SAC	Special Area of Conservation
SBP	Sub-Bottom Profiler
SEPA	Scottish Environment Protection Agency
SHET-L	Scottish Hydro Electric Transmission Limited

ACRONYM	DEFINITION
SNCB	Statutory Nature Conservation Bodies
SNH	Scottish Natural Heritage
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentration
SSE	Scottish and Southern Electricity Networks
SSSI	Special Site of Scientific Interest
THC	The Highland Council
TSHD	Trailing Suction Hopper Dredger
TSS	Total Suspended Solids
UAV	Unmanned Aerial Vehicle
UHRS	Ultra High Resolution Seismic
UK	United Kingdom
UKCP	United Kingdom Climate Predictions
UKHO	United Kingdom Hydrographic Office
USB	Universal Serial Bus
WTG	Wind Turbine Generator

8.14 Glossary

TERM	DEFINITION
Bathymetry	A measurement of the depth at various locations within the offshore environment indicating the bedform features present such as shallow banks and steep slopes.
Bedload parting zone	Bedload parting zone in the marine environment defines a location in which there is a divergence in bedload sediment transport pathways, with transport occurring in opposing directions on either side of the bedload parting
Clasts	Fragments of smaller grains of mineral or rock (e.g., siltstone, sandstone, mudstone), or a fragment of boulders and cobbles.
Climate Change	A global change in the climate resulting in long-term changes to sea level with increasing sea level.
Coast	Where the ocean waves meet the land.
Coastal Processes	Natural processes that occur as waves intersect with the coastline, e.g., sediment transportation and deposition, and erosion. These processes can be altered due to offshore Project activities, such as with increased suspended sediment concentration, or modified flows and wave energy affecting mixing.
Controlled Flow Excavator	A Controlled Flow Excavator is a tool that is capable of dredging the seabed to clear material and will be used for sandwave clearance within the OAA and offshore ECC to prepare the seabed prior to installation of infrastructure.
Diamict	A term used to describe unsorted to poorly sorted sediment which can contain particles covering a range of sizes.
Extreme Waves	Waves that are of a significant height. The largest waves that can be expected to be formed in a region based on extreme conditions (i.e., storm conditions).
Friable	Term used to describe rock that has a tendency to be broken up easily.
Geology – Bedrock	The composition of the bedrock as it was formed over time (e.g., rock, sandstone) which can be dated to geological eras (e.g., Palaeozoic) and geological periods (e.g., Permian, Triassic)
Geology – Quaternary	A geological period within the Cenozoic era spanning to present day in which the seabed sediment and deposits can be dated back to.
Glacial Till	Sediment that has been transported and deposited from glaciers.
Highest Astronomical Tide	The highest tidal levels which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions. The highest astronomical tide does not necessarily

TERM	DEFINITION
	represent the highest levels which may occur as it represents average meteorological conditions, and storm surges may result in higher tidal levels.
Hydrodynamic	Hydrodynamics is concerned with the forces acting on or exerted by fluids.
Interbedding	Geological term used to describe when particular layers of rock lie between or alternate between layers comprised of different types of rock.
Lowest Astronomical Tide	The lowest tidal levels which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions. The lowest astronomical tide does not necessarily represent the lowest levels which may occur as it represents average meteorological conditions, and storm surges may result in lower tidal levels.
Mean High Water Spring	The average throughout the year of the heights of two successive high waters during a 24-hour period in each month, when the tidal range is greatest (spring tides).
Mean Low Water Spring	The average throughout the year of the heights of two successive low waters during a 24-hour period in each month during spring tides.
Mean Sea Level	The average height of the sea surface for all tidal stages.
Metocean	Metocean conditions refer to the combined wind, wave and climate (etc.) conditions as found on a certain location.
Morphology – Bedforms	A bedform is a geological feature that develops as a result of bed material being moved by flows, for example sandwaves.
Nearshore	The location of the survey sampling referring to the region located closest to the coast towards landfall within the offshore ECC.
Numerical Modelling	Use of software to model the complex physics of hydrodynamic, wave and sediment transport processes.
Outcropping	Refers to bedrock geology being exposed at the surface.
Return Period	Statistical representation of the number of years when an event on average is expected to be exceeded.
Salinity	The quality or degree of being saline i.e., the quantity of salt within a sample.
Scour	A type of mark (e.g., a depression or pattern) observed within the sediment that can be associated with currents, or the movement of glaciers and boulders across the seabed.
Seabed Sediment	The composition of the sediment that is present on the seabed which can be categorised based on the fraction of the sediment that is coarse (gravel) or fine (sand).

TERM	DEFINITION
Sediment Transport	The movement of sediment by the forces of currents and waves. Sediment transport potential refers to the amount of sediment that could be expected to move under a given combination of waves and currents and is not supply limited.
Sediment Transport Pathway	A sediment transport pathway indicates that there is a local direction or trend with regards to sediment transport .
Stratification	The separation of water in layers.
Surge	Difference in water level (positive or negative) as result of meteorological forcing from what is recorded or modelled to occur.
Suspended sediment	Sediment transported by a fluid that it is fine enough for turbulent eddies to outweigh settling of the particles.
Suspended Sediment Concentration	Mass of sediment in suspension per unit volume of water.
Tessellated pavement	A relatively flat rock surface which has been divided into rough rectangular blocks or polygon shapes by fractures or joints within the rock.
Tidal asymmetry	This is caused by differences in the duration and magnitude of flood and ebb tides.
Tidal excursion	The extent to which suspended sediment, resulting from seabed disturbance from the offshore Project activities, may be carried through physical processes (e.g., spring tides).
Tide – Ebb Tide	The receding tide, occurring between the time when the tide is highest to lowest.
Tide – Flood Tide	The incoming or rising tide, occurring between the time when the tide is lowest to highest.
Tide – Neap Tide	A tide just after the first or third quarters of the moon when there is least difference between high and low water:
Tide – Spring Tide	A tide just after a new or full moon, when there is the greatest difference between high and low water.
Tidal regime	The tidal regime in an area is based on the daily movement of the tide locally.
Tidal residual	The difference between the total current and the linearly predicted tidal current for a given tidal state (i.e. flood / ebb or spring / neap).
Total Suspended Solids	A way of measuring suspended sediment concentrations through water sampling.

TERM	DEFINITION
Trailer Suction Hopper Dredger	Trailer Suction Hopper Dredger (TSHD) is a proposed method for dredging. TSHD operates by pumping water at a high pressure into the seabed and then suctioning sediment up into a hopper onboard the vessel.
Turbidity	Water turbidity is a physical measure within water and is in respect of how clear or cloudy water is.
Wave – Significant Wave Height	The average height of the top third highest waves.
Wave – Wave Period	The period of a wave is the duration of time (in seconds) between wave peaks. Longer periods are typically associated with swell waves.
Wave – Swell Wave	Are waves are generated in a different region and tend to travel a considerable distance before breaking. Swell waves typically have longer periods and wavelengths and carry more energy.
Wave – Wind Wave	Locally generated waves, which remain within the same fetch.
Wave – Deep Water Wave	Where the wavelength is less than twice the water depth. Typically referring to waves occurring in oceans and seas, where water depths are greater than twice the wave wavelength.
Wave – Transitional Wave	This is where waves a transforming from deep water wave to a breaking / shoaling wave, so the wave properties (height, period and wavelength) are such that the wave is beginning to feel the bottom, although not enough to increase friction and steepening as occurs during breaking.
Wave – Transformation	The change in the wave properties as it moves between different states as it typically begins to progress into shallower water with respect to the wavelength, height and period.
Wave – Shoaling and Breaking	Where the wave feels the seabed, leading to steepening. A number of conditions lead to shoaling / breaking, which mainly relate to the ratio between the wave height, wavelength and water depth. Typically for breaking waves, the wave height is greater than three quarters of the water depth.