



Morven Hawthorn Pit Grid Connection Project

Preliminary Environmental Information Report

Volume 2, Annex 1.1: Physical Processes Technical
Report

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Glossary

Term	Meaning
Bathymetry	The measurement of water depth in oceans, seas and lakes.
Benthic	Living organisms that live on or within the sediments at the bottom of aquatic environments.
Chlorophyll-a	Chlorophyll-a is the green substance used by plants to photosynthesise (creating sugars from basic chemical building blocks, using sunlight).
Highly Protected Marine Area (HMPA)	Areas of the sea (including the shoreline) that allow the protection and full recovery of marine ecosystems. HPMAs protect all species and habitats and associated ecosystem processes within the site boundary, including the seabed and water column.
Hindcast	Reanalysis of historical weather and oceanographic data using numerical models to simulate past conditions
Intertidal area	The area between Mean High Water Springs (MHWS) and Mean Low Water Springs (MLWS).
Landfall	The area in which the offshore export cables make landfall (come onshore) and the transitional area between the offshore cabling and the onshore cabling. This term applies to the entire landfall area between the trenchless technique exit pits and the transition joint bay inclusive of all construction works.
Lowest Astronomical Tide (LAT)	The lowest tide level that can be expected to occur under average meteorological conditions and under any combination of astronomical conditions.
Marine Conservation Zone (MCZ)	An area designated under the Marine and Coastal Access Act 2009 for the purpose of conserving marine flora, fauna, habitats, or features of geological or geomorphological interest.
Marine Directorate Licensing Operations Team (MD-LOT)	The part of the Scottish Government's Marine Directorate responsible for assessing and administering applications for marine licences for Scottish waters and Section 36 consent (offshore) in Scotland.
Marine Management Organisation (MMO)	The MMO, as a UK government body, is responsible for licensing, regulating and overseeing activities in the marine environment for English waters. For a DCO and deemed marine licence, the MMO acts as a statutory consultee, advising on marine planning, environmental impacts, habitats and compliance with marine licensing regulations.
MHPGC Project Scoping Opinions	Separate scoping opinions received from PINS (on behalf of the Secretary of State) and MD-LOT (on behalf of the Scottish Ministers) in response to the MHPGC Project Scoping Report. The MHPGC Project Scoping Opinions contain the range of issues that PINS, and MD-LOT in consultation with statutory stakeholders, have identified

Term	Meaning
	should be considered within the Environmental Impact Assessment (EIA) process.
MHPGC Project Scoping Report	A Scoping Report for the MHPGC Project, scoping the likely significant effects of the project on the environment, was submitted and accepted by Planning Inspectorate (PINS) and submitted to the Scottish Ministers, via the Marine Directorate – Licencing Operations Team (MD-LOT) in February 2025.
MHPGC Project Preliminary Environmental Information Report (PEIR)	A report that provides preliminary environmental information in accordance with the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017. This is information that enables consultees to understand the likely significant environmental effects of a project and which helps to inform consultation responses.
Morven Hawthorn Pit Grid Connection Project (hereafter MHPGC Project)	The MHPGC Project is comprised of the offshore export cables in Scottish and English waters from the Morven North or the Morven South offshore substation platform(s) (OSP), landfall, onshore export cables, the onshore land substation (LSS) and AC connection cables. Also referred to in this report as the MHPGC Project, for ease of reading.
Marine Protected Area (MPA)	Areas within the United Kingdom's seas designated for the protection of marine life and habitats against damage caused by human activities.
Morphology	Term used to describe channel form and its process of change in shape and direction over time
Morven North Offshore Wind Array Project and Morven South Offshore Wind Array Project	Morven North and Morven South comprises the Morven North Offshore Wind Array Project and Morven South Offshore Wind Array Project, collectively.
Offshore Export Cable Corridor	The proposed offshore area in which the offshore export cables will be laid, from either the Morven North offshore substation platform or Morven South offshore substation platform to the transition joint bay at landfall.
Offshore Export Cables	HVDC cables which bring electricity from either the Morven North or Morven South OSP to the TJB at landfall.
Planning Inspectorate (PINS)	The PINS is an executive agency of the UK Government responsible for administering and examining DCO applications for NSIPs in England. PINS manages the application process, oversees consultation and examination, and makes a recommendation to the relevant Secretary of State on whether consent should be granted.
Physical Processes	The collective term for the following: hydrodynamics (water levels and currents); winds and waves; stratification and frontal systems; geology and seabed sediments (including sediment transport); seabed geomorphology; and coastal geomorphology.

Term	Meaning
Sites of Special Scientific Interest (SSSI)	Designated areas which feature rare flora or fauna or are host to important features (physiological or geological) which are of scientific interest, designated under the Wildlife and Countryside Act 1981 (as amended).
Special Areas of Conservation (SAC)	A site designation specified in the Habitats Directive (Council Directive 92/43/EEC) and protected in the UK under the Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Marine Habitats and Species Regulations 2017 in England. Each site is designated for one or more of the habitats and species listed in the Directive. The Directive requires that a management plan be prepared and implemented for each SAC to ensure the Favourable Conservation Status of the habitats or species for which it was designated.
Special Protection Area (SPA)	Locations within the UK designated to conserve rare, vulnerable, and migratory bird species of European importance, as classified by the Conservation (Natural Habitats, &c.) Regulations 1994 (in Scotland), the Conservation of Habitats and Species Regulations 2017 (in England) and Conservation of Offshore Marine Habitats and Species Regulations 2017 (in Scotland and England).
Spring tidal excursion	The distance suspended sediment is transported prior to being carried back on the returning tide.
The Study Area	For each environmental topic, the baseline environment will be characterised, and the likely significant effect will be described within a topic-specific Study Area. Specific Study Areas are defined for each topic and are based on the maximum spatial extent across which likely significant effects of the MHPGC Project may be experienced by the relevant receptors (i.e. Zone of Influence).
Tidal cycle	One high tide plus a successive low tide.
Tidal ellipse	The illustration of the variance of tidal currents in horizontal space.

Acronyms

Acronym	Definition
ABPmer	ABP Marine Environmental Research Limited
BGS	British Geological Survey
CD	Chart Datum
Cefas	Centre for Environment, Fisheries and Aquaculture Science
DTM	Digital Terrain Model

Acronym	Definition
DWR	Directional Wave Rider
EIA	Environmental Impact Assessment
EMODnet	European Marine Observation and Data Network
GIS	Geographical Information System
HPMA	Highly Protected Marine Area
HW	High water
JNCC	Joint Nature Conservation Committee
KP	Kilometre Point
LAT	Lowest Astronomical Tide
LW	Low water
MBES	Multibeam Echo Sounder
MCZ	Marine Conservation Zone
MHPGC	Morven Hawthorn Pit Grid Connection
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
MPA	Marine Protected Area
MSL	Mean Sea Level
NGI	Norwegian Geotechnical Institute
ODN	Ordnance Datum Newlyn
OSP	Offshore Substation Platform
PDE	Project Design Envelope
PSA	Particle Size Analysis
PEIR	Preliminary Environmental Information Report
RCP	Representative Concentration Pathway
SAC	Special Area of Conservation
SMP	Sectoral Marine Plan
SPA	Special Protection Area
SPM	Suspended Particulate Matter
SSSI	Site of Special Scientific Interest
UK	United Kingdom
UKCP18	United Kingdom Climate Projections 2018
UKHO	United Kingdom Hydrographic Office
UTM	Universal Transverse Mercator
Hs	Significant Wave Height

Units

Unit	Meaning
km	Kilometre
m	Metre
m ³	Cubic Metre
m CD	metres Chart Datum
m MSL	metres Mean Sea Level
mg/l	Milligram per litre
mm	Millimetre
mODN	Metre Ordnance Datum Newlyn
m/s	Metre per second
nm	Nautical mile
°	Degree
%	Percent
µm	Micrometre

Executive Summary

This Technical Report provides a high-level overview of the existing physical environment within the Physical Processes Study Area for the Morven Hawthorn Pit Grid Connection Project (hereafter 'the MHPGC Project'), prior to the installation of any transmission infrastructure. The baseline characterisation covers bathymetry, water levels, currents, waves, seabed sediments and coastal/seabed geomorphology, forming the foundation for assessing the likely significant effects on physical processes.

The Physical Processes Study Area (shown in **Figure 2.1**) is located within a semi-diurnal tidal regime. Spring tidal range increasing from approximately 2.5 metres (m) at the northern end of the MHPGC Project PEIR Red Line Boundary to around 4.3m at the landfall which is at Blast Beach, just south of Seaham. Tidal currents are generally weak, with peak current speed on a mean spring tide typically less than 0.6m/s. Waves predominantly come from the north and northeast, with a typical significant wave height of 1m to 2m, increasing to 4.1m near landfall to 7m offshore for a 1:1 year storm event, and 6.4m and 10.1m respectively for a 1:50 year event.

Seabed composition varies across the Physical Processes Study Area, with nearshore sediments comprise silty sands interspersed with gravelly deposits, boulder fields, and exposed bedrock, while offshore sediments transition from muddy sands to Holocene sands overlying Pleistocene deposits. Surficial Holocene layers are typically thin (<2m). Water depths range from approximately 107m Lowest Astronomical Tide (LAT) offshore to 0m LAT at the landfall, with generally gentle gradients (<1°) except for locally steep slopes (~50°) near coastal boulder fields.

Net sediment transport is predominantly northward, driven by tidal currents, with observed bedform migration of up to 4m per year in places. Wave-induced sediment mobility is limited offshore but may occur nearshore (in shallower areas) during storm events. The coastline between Sunderland and Hartlepool is largely undefended, with cliffs, beaches and dunes; the landfall south of Seaham comprises dolostone cliffs, reclaimed ground and gravelly beach sands, which are all currently stable.

Future baseline evolution will reflect natural variability, climate change, and coastal management. By 2075, relative sea level rise of approximately 0.6m (Representative Concentration Pathway (RCP) 8.5) is projected, potentially increasing wave energy at the coast and reducing the extent of intertidal habitats. United Kingdom Climate Projections (UKCP18) projections indicate that changes in extreme coastal water levels will be dominated by mean sea level (MSL) rise, with minimal additional influence from storminess.

1 Introduction

1.1 Overview

- 1.1.1.1 This report presents a baseline description of Physical Processes for the Morven Hawthorn Pit Grid Connection Project (hereafter 'the MHPGC Project'). It forms **Volume 2, Annex 1.1: Physical Processes Technical Report, of the Preliminary Environmental Information Report (PEIR)** prepared for the MHPGC Project and supports **Volume 2, Chapter 1: Physical Processes, of the PEIR**.
- 1.1.1.2 Specifically, the report details the metocean, sediment transport, seabed morphology, and coastal/ seabed geomorphology baseline description derived from a combination of site-specific survey data, readily available data and numerical modelling. The MHPGC Project will connect the offshore substation platforms (OSP of either Morven North Offshore Wind Array Project or Morven South Offshore Wind Array Project (referred to hereafter as 'Morven North or Morven South') to the National Grid Hawthorn Pit Substation. The proposed offshore export cables have a maximum length of up to 326.00km extending from Morven North or Morven South OSP to Mean High Water Springs (MHWS)'.
- 1.1.1.3 The report presented is informed by the following technical chapters:
- **Volume 1, Chapter 2: Project Description, of the PEIR;**
- 1.1.1.4 The report also draws on information contained within the following annexes:
- **Volume 2, Annex 1.2: Model Design, Validation and Results, of the PEIR.**

1.2 Approach

- 1.2.1.1 The physical processes considered for the MHPGC Project fall under the following categories:
- Metocean regimes: (water levels, currents, winds, waves and future change);
 - Sediments, morphology, sediment transport and seabed morphology; and
 - Coastlines, beaches and nearshore processes.
- 1.2.1.2 The natural variability of the above is explored in the absence of any of the proposed infrastructure for the development. Consequently, this provides the 'baseline' conditions within the Physical Processes Study Area upon which potential impacts from the MHPGC Project can be assessed.
- 1.2.1.3 Baseline understanding has been developed in accordance with industry best practice, with attention given to:
- The identification of the processes maintaining the system, the reasons for any past changes, and sensitivity of the system to changes in the controlling processes;
 - The identification and quantification of the relative importance of high-energy, low frequency ('episodic' events), versus low-energy, high frequency processes;
 - The identification of the processes controlling temporal and spatial morphological change (e.g., longevity and stability of bedforms; cliff recession; loss of beach volume; or bank and channel migration; intertidal accretion/erosion), which may require a review of bathymetric and topographic data;
 - The identification of sediment sources, pathways and sinks, and quantification of transport fluxes;
 - The identification of the inherited geological, geophysical and geotechnical properties of the sediments at the site, and the depth of any sediment strata;
 - The interaction of waves and tides and the subsequent quantification of the extent to which seabed sediment is mobilised; and the assessment of the scales and magnitudes of processes controlling sediment transport rates and pathways.

2 Physical Processes Study Area

2.1 Overview

2.1.1.1 The Physical Processes Study Area is located off the northeast coast of England and southeast coast of Scotland and extends from offshore areas up to MHWS. It represents the area across which baseline data collation and characterisation has been undertaken for the purposes of informing the physical processes assessment (**Figure 2.1**). A 'Zone of Influence' has also been defined based on a spring tidal excursion: this is the area within which the MHPGC Project may cause direct or indirect changes to hydrodynamics, sediments, morphology, or the water column. It has been defined on the basis of:

- The distance away from the MHPGC Project which suspended sediment plumes may be advected (and interact with potentially sensitive receptors). This has been defined by a spring tidal excursion ellipse buffer around the MHPGC Project PEIR Red Line Boundary, see **Volume 2, Annex 1.2: Model Design, Validation and Results, of the PEIR**;
- The distance up/down drift from the landfall, that littoral processes could theoretically be affected by infrastructure associated with the MHPGC Project.

2.1.1.2 The Physical Processes Study Area and Zone of Influence is shown on **Figure 2.1**.

2.2 Designated sites

2.2.1.1 The Physical Processes Study Area contains several nationally and internationally designated sites.

2.2.1.2 Designated sites within the Physical Processes Study Area located in Scottish waters are as follows, with distances from the MHPGC PEIR Red Line Boundary provided:

- Firth of Forth Banks Complex Marine Protected Area (MPA) (33km away);

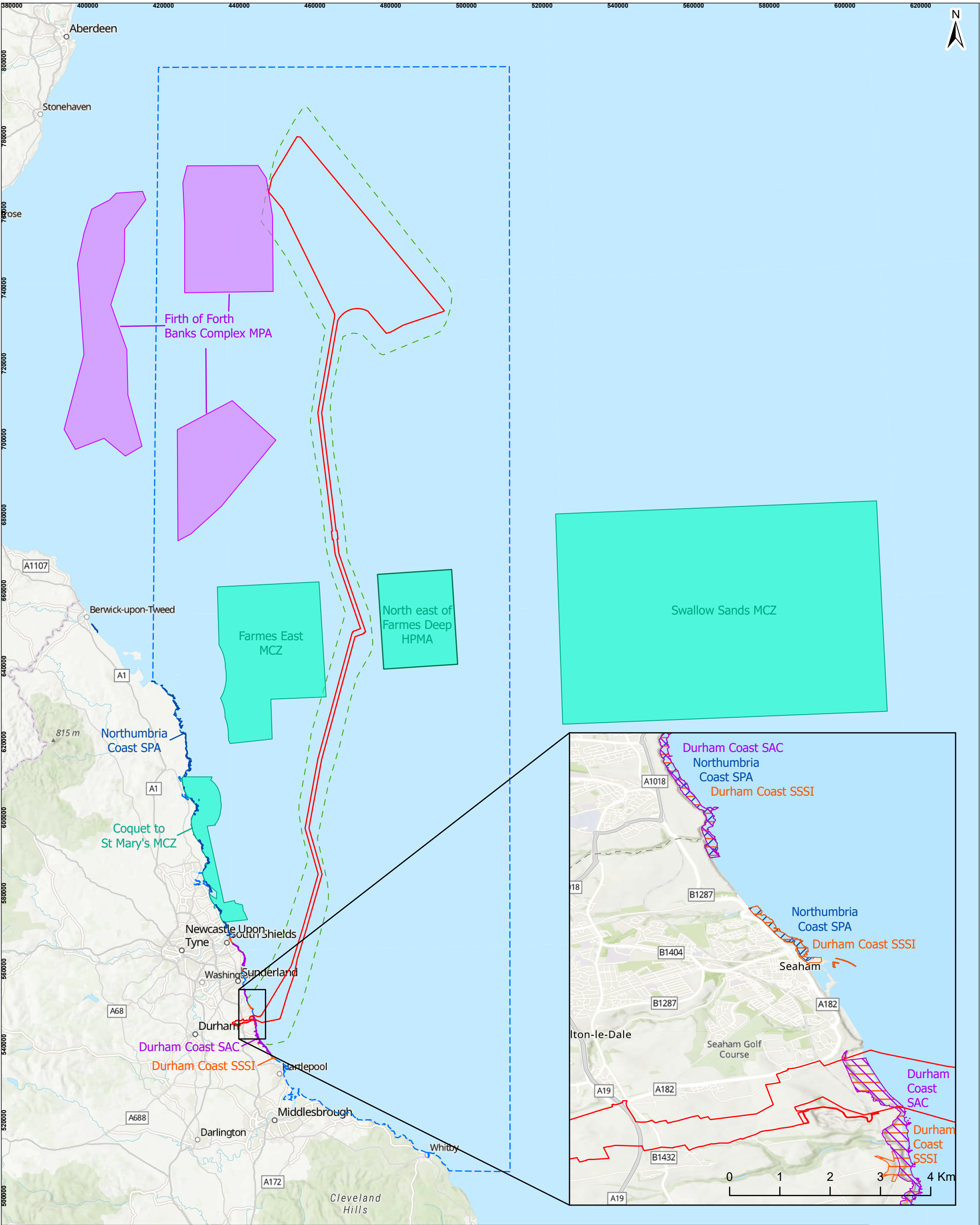
2.2.1.3 Designated sites within the Physical Processes Study Area located in English waters are as follows, with distances from the MHPGC PEIR Red Line Boundary provided:

- Farnes East Marine Conservation Zone (MCZ) (offshore) (2km away);
- North East of Farnes Deep Highly Protected Marine Area (HPMA) (offshore) and MCZ (4km away);
- Swallow Sands MCZ (offshore) (51km away);
- Durham Coast Special Area of Conservation (SAC) (nearshore) (overlap with the MHPGC PEIR Red Line Boundary);
- Durham Coast Site of Scientific Special Interest (SSSI) (nearshore) (overlap with the MHPGC PEIR Red Line Boundary);
- Northumbrian Coast Special Protection Area (SPA) (nearshore) (2km away);
- Croquet to St. Mary's MCZ (nearshore) (15km away).

2.2.1.4 With the exception of the Durham Coast SAC and SSSI at the landfall, there are no other designated sites seaward of MHWS, that overlap with the MHPGC PEIR Red Line Boundary, see **Figure 2.1**. Several Priority Marine Feature (PMF) habitat types (offshore subtidal sands and gravels) are located within the MHPGC PEIR Red Line Boundary, but not within a designated site.

2.2.1.5 The sites are designated for the habitats and species they contain, and in some instances for the presence of geological and geomorphological features. This is the case with the Durham Coast of SAC, which has been designated for vegetated sea cliffs on Magnesium Limestone, the only example within the United Kingdom (UK) (JNCC, 2025). This is also the case with the Firth of Forth Banks Complex MPA, which is located approximately 20km to the west of the north-western extent of the MHPGC Project PEIR Red Line Boundary and contains moraines considered to be representative of the Wee Bankie Key Geodiversity Area (JNCC, 2014).

-
- 2.2.1.6 At all designated sites, changes to the physical characteristics of these sites have the potential to impact the habitats they support and, therefore, consideration is given to them in the physical processes assessment (**Volume 2, Chapter 1: Physical Processes, of the PEIR**).





Project Name:
MORVEN HAWTORN PIT GRID CONNECTION PROJECT

Drawing Title:
FIGURE 2.1: PHYSICAL PROCESSES STUDY AREA

Drawing Number:
MHPGC-ABP-PP-0001

Data Sources:
© Natural England copyright. Contains Ordnance Survey data. © Crown copyright and database right 2024 © NatureScot 2024. OGL V3

Geodetic Information:
World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS
World Hillshade: Esri, CGAR, N Brown, NOAA, USGS
World Hillshade: Esri, Intermap, NASA, NGA, USGS
World Topographic Map: Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

VER	DATE	DETAILS	BY	CHECK
00	04/12/25	Initial Issue	HMN	HKG
01	09/07/26	Update Issue	ALN	DOL
-	-	-	-	-
-	-	-	-	-

Service Layer Credits:
Datum: OSGB 1936
Projection: British National Grid

0 5 10 15 20 25 30 35 40 km

Scale@A3:1:900,000

LEGEND









3 Methodology

3.1.1.1 This technical report has used a combination of site-specific surveys undertaken for the MHPGC Project and publicly available data to inform the baseline. These various data sources are outlined in **Table 3.1** and **Table 3.2**, with locations of key data, as well as the spatial extent of bathymetry data used to inform the analysis, shown in **Figure 3.1**.

3.2 Desktop study

3.2.1.1 Information on physical processes within the Physical Processes Study Area was collected through a detailed desktop review of existing studies; datasets used to inform the analysis are summarised in **Table 3.1**.

Table 3.1: Summary of key desktop datasets and reports for the physical processes baseline characterisation

Title	Source	Date	Summary	Coverage of the Physical Processes Study Area
ABP Marine Environmental Research Ltd (ABPmer) SEASTATES	ABPmer (2025)	1979-2022	Modelled hindcast wave and hydrodynamic data from across the Physical Processes Study Area.	Full coverage
British Geological Survey (BGS) offshore geindex	BGS (2025)	Data accessed: 2025	Seabed sediment maps (based on Folk classification) and borehole records from point locations within the Physical Processes Study Area.	Partial coverage
European Marine Observation and Data Network (EMODnet) Data Layers	EMODnet (2025)	Data accessed: 2025	Gridded Digital Terrain Model (DTM) of the bathymetry of the European Shelf.	Full coverage
MPA Geodiversity Mapping	(Brooks <i>et al.</i> 2011)	2011	Mapping of geological and geomorphological features within Scottish MPAs, based on publicly available seabed surveys and research.	Partial coverage
Marine Renewables Atlas	ABPmer, Met Office and POL (2008)	2008	Modelled hindcast wave and hydrodynamic data from across the Physical Processes Study Area.	Full coverage
Suspended Particulate Matter (SPM) mapping	Cefas (2016)	2016	Monthly and seasonal SPM maps for the Physical Processes Study Area.	Full coverage
UK Hydrographic Office (UKHO) Total Tide Data	UKHO (2025)	2025	Tidal water levels from point locations within the Physical Processes Study Area.	Partial coverage
Metocean Reports	Metoceanworks (2024a to f)	2024	Metocean reports detailing the representative metocean conditions for the MHPGC Project location.	Partial coverage (three points within the MHPGC Project PEIR Red Line Boundary)

Title	Source	Date	Summary	Coverage of the Physical Processes Study Area
Key publications including Pitman <i>et al.</i> (2024) and Royal Haskoning (2014)	[various]	[various]	Public and grey literature considering coastal morphology and behaviour at sensitive coastal locations within the Physical Processes Study Area	Full to Partial coverage

3.3 Site-specific surveys

3.3.1.1 A summary of the surveys undertaken to inform the physical processes baseline is outlined in **Table 3.2** below.

Table 3.2: Summary of site-specific surveys undertaken for the physical processes baseline characterisation

Survey Type	Scope of survey	Coverage of the Physical Processes Study Area
Offshore export cable corridor geophysical and environmental survey (XOCEAN Ltd., 2023) Year of survey: 2023	Multibeam Echosounder (MBES) and sub bottom profiler on three route and four landfall options	Partial coverage
Offshore export cable corridor geophysical and environmental survey (XOCEAN Ltd., 2025) Year of survey: 2024	MBES and sub bottom profiler within MHPGC Project PEIR Red Line Boundary	Nearly full coverage, Morven North and Morven South extent of the MHPGC Project PEIR Red Line Boundary, small section offshore from landfall missing.
Benthic sample survey (Gardline Ltd., 2023) Year of survey: 2023	128 grab samples (with accompanying Particle Size Analysis (PSA))	Nearly full coverage of MHPGC Project PEIR Red Line Boundary
Benthic sample survey (Gardline Ltd., 2024a) Year of Survey: 2024	42 grab samples (with accompanying PSA analysis)	Partial coverage
Geotechnical survey (Gardline Ltd., 2024b) Year of Survey: 2023	54 vibrocore samples at 44 locations 204 Cone Penetration Tests at 182 locations	Partial coverage
Floating Lidar (EOLOS, 2025) Deployed: October 2022 Recovered: 2024	Floating lidar deployments measuring metocean parameters	Partial coverage
Wave buoy (Partrac, 2024) Deployed: October 2022 Recovered: May 2024	Two direction wave rider wave buoy devices deployed in Morven North and Morven South, measuring wave parameters	Partial coverage

4 Baseline characterisation

4.1 Metocean regime

4.1.1 Water levels

- 4.1.1.1 The Physical Processes Study Area is located within a semi-diurnal tidal environment with tidal range increasing from north-east to south-west. Tidal statistics for five points along (or near) to the MHPGC Project PEIR Red Line Boundary are provided in **Table 4.1**, this data originates from a 40+ year hindcast model (MetOceanWorks, 2024). Morven South-East (SE) is the only point located in Scottish waters, Export Cable Corridor (ECC) 1,2,4 and 5 are all points within English waters (**Figure 3.1**). The points were chosen to illustrate the degree of spatial variability in water levels within the MHPGC Project PEIR Red Line Boundary.

Table 4.1: Summary tidal statistics along the MHPGC Project PEIR Red Line Boundary

	Morven SE (Scottish waters)	ECC5 (English waters)	ECC4 (English waters)	ECC2 (English waters)	ECC1 (English waters)
Highest Astronomical Tide (m Mean Sea Level (MSL))	1.67	2.14	2.46	2.70	2.73
Mean High Water Spring Tide (mMSL)	1.24	1.64	1.92	2.11	2.14
Mean High Water Neap Tide (mMSL)	0.63	0.83	0.97	1.06	1.08
Mean Low Water Neap Tide (mMSL)	-0.63	-0.83	-0.97	-1.06	-1.08
Mean Low Water Spring Tide (mMSL)	-1.24	-1.64	-1.92	-2.11	-2.14
Lowest Astronomical Tide (mMSL)	-1.87	-2.48	-2.86	-3.00	-3.00
Mean Spring Range (metre (m))	2.48	3.28	3.84	4.22	4.28

ECC3 and ECC6 not included as the data extraction locations are not within the MHPGC Project PEIR Red Line Boundary

Scottish waters

- 4.1.1.2 The furthest northern extent of the MHPGC Project PEIR Red Line Boundary, in Scottish waters, has a spring tidal range of ~2.5m.

English waters

- 4.1.1.3 The spring tidal range increases as the cable runs southward, into English waters and to landfall. Near the central point of the MHPGC Project PEIR Red Line Boundary (ECC 5), in English waters, the spring tidal range is ~3.3m. At the landfall the spring tidal range further increases to ~4.3m. Summary tidal statistics for Sunderland, in English waters (to the north of landfall) are shown in **Table 4.2**.

Table 4.2: Summary tidal statistics for Sunderland (54°55'N 1°22'W)

	Sunderland (m Chart Datum (CD))	Sunderland (m Ordnance Datum (ODN))
Highest Astronomical Tide	5.8	3.08
Mean High Water Spring Tide	5.3	2.58
Mean High Water Neap Tide	4.2	1.48
Mean Tide Level	3.14	0.42
Mean Low Water Neap Tide	2.0	-0.72
Mean Low Water Spring Tide	0.9	-1.82
Lowest Astronomical Tide	0.0	-2.72
Mean Spring Range	4.4	
CD to ODN	-2.72	

Data source: UKHO (2025)

- 4.1.1.4 Extreme water levels within the Physical Processes Study Area typically result from storm surge propagation in the North Sea and are generally well understood, having been extensively studied. In brief, a storm surge is produced when high winds build up a body of water, further exacerbated by the effects of atmospheric pressure (Prichard, 2013). The 50-year return period surge level (tide + surge) at the landfall is predicted to be 3.83mODN (Environment Agency, 2019). The impact of a surge will depend critically on the associated state of the tide, with the biggest risk of flooding and erosion occurring if the surge peak coincides with high water (HW) on a spring tide.

4.1.2 Currents

- 4.1.2.1 A map of surface current speeds (and directions) on a representative mean spring tide are shown in **Figure 4.1**, based on modelled output from the modified, project-specific ABPmer Northwest European Shelf Hydrodynamic Model (ABPmer, 2017), with increased resolution across the Physical Processes Study Area (see **Volume 2, Annex 1.2: Model Design, Validation and Results, of the PEIR**).
- 4.1.2.2 **Figure 4.2** shows timeseries comparison plots of the modelled tidal current speed and direction with depth-averaged ADCP data for E41 FLiDAR buoy (EOLOS, 2025) over a mean spring-neap tidal cycle. A spring-neap cycle repeats approximately every 14.7 days and therefore this time period is sufficiently representative of the range of tidal conditions experienced in this location across a typical tidal cycle. The model shows good agreement with the measured data, satisfactorily replicating both the general current speed and direction in the vicinity of the FLiDAR deployment.
- 4.1.2.3 Within the Physical Processes Study Area, tidal currents are relatively weak. Depth-averaged mean spring peak current speeds, predicted in the absence of any meteorological influences, are typically less than 0.6 metre per second (m/s). Slack periods during spring tides maintain flows of around 0.2m/s. During neap tides, peak currents reach approximately 0.3m/s to 0.4m/s, with slack water phases showing very low flow (<0.1m/s).

- 4.1.2.4 Current speed is relatively uniform in space across the MHPGC Project PEIR Red Line Boundary, with Scottish and English regions of the MHPGC Project PEIR Red Line Boundary showing similar current speed values. Throughout the Physical Processes Study Area, flow direction is generally northward during the ebb tide and southward during the flood tide.

Scottish waters

- 4.1.2.5 During peak flows coinciding with (close to) low water (LW), current direction is approximately northwards in Scottish waters. During peak flows coinciding with (close to) HW, flow directions are reversed.
- 4.1.2.6 During slack water periods flow directions in Scottish waters diverge and converge as the tide exits and enters the Firth of Forth.

English waters

- 4.1.2.7 During peak flows coinciding with (close to) LW, current direction is approximately north northwesterly in English waters. During peak flows coinciding with (close to) HW, flow directions are reversed. Closer to the coast, the current direction aligns more with the coastline, which is oriented northwest to southeast and exhibits a greater degree of rectilinearity.

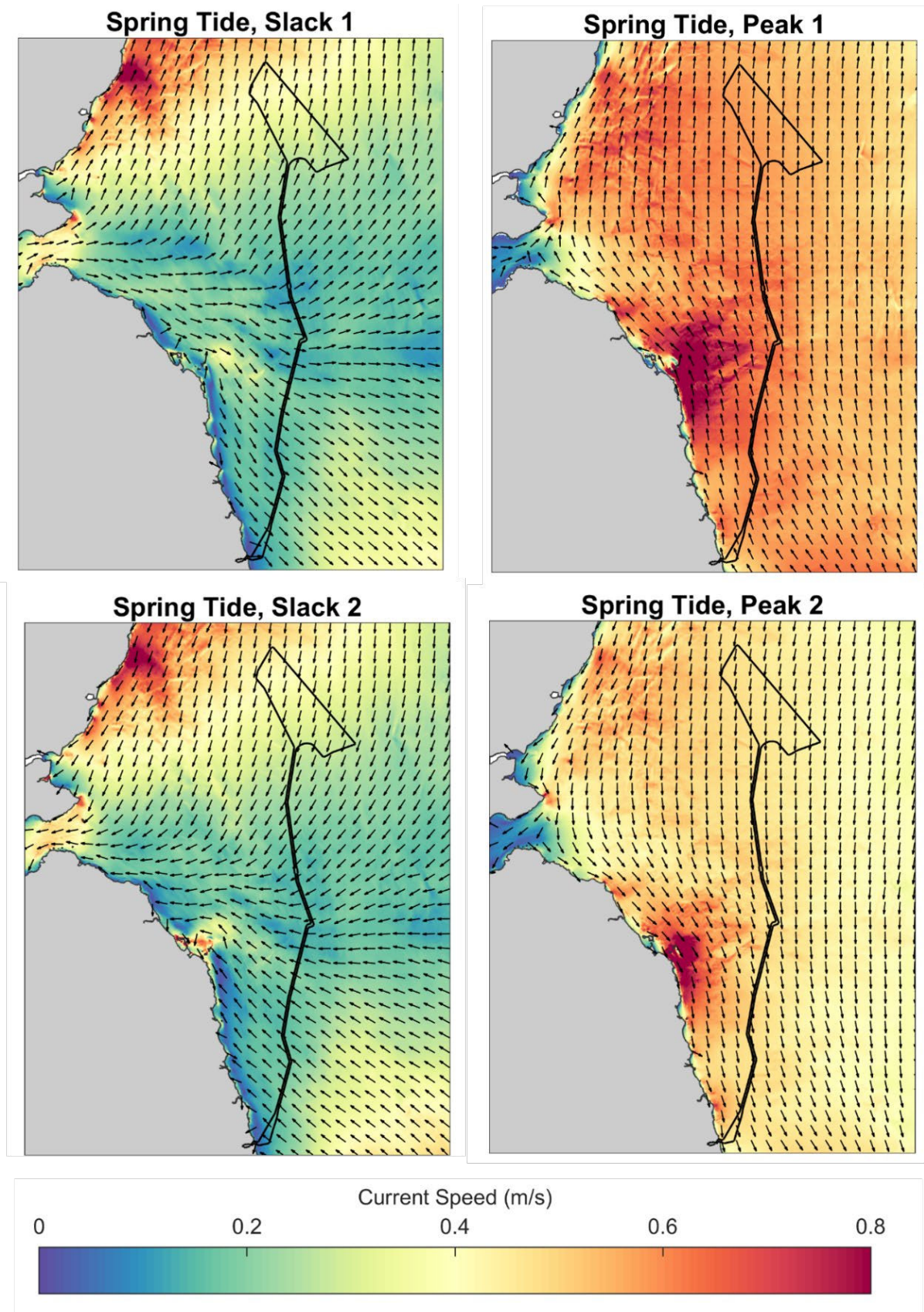


Figure 4.1: Baseline tidal current speed and direction during a representative spring tidal condition

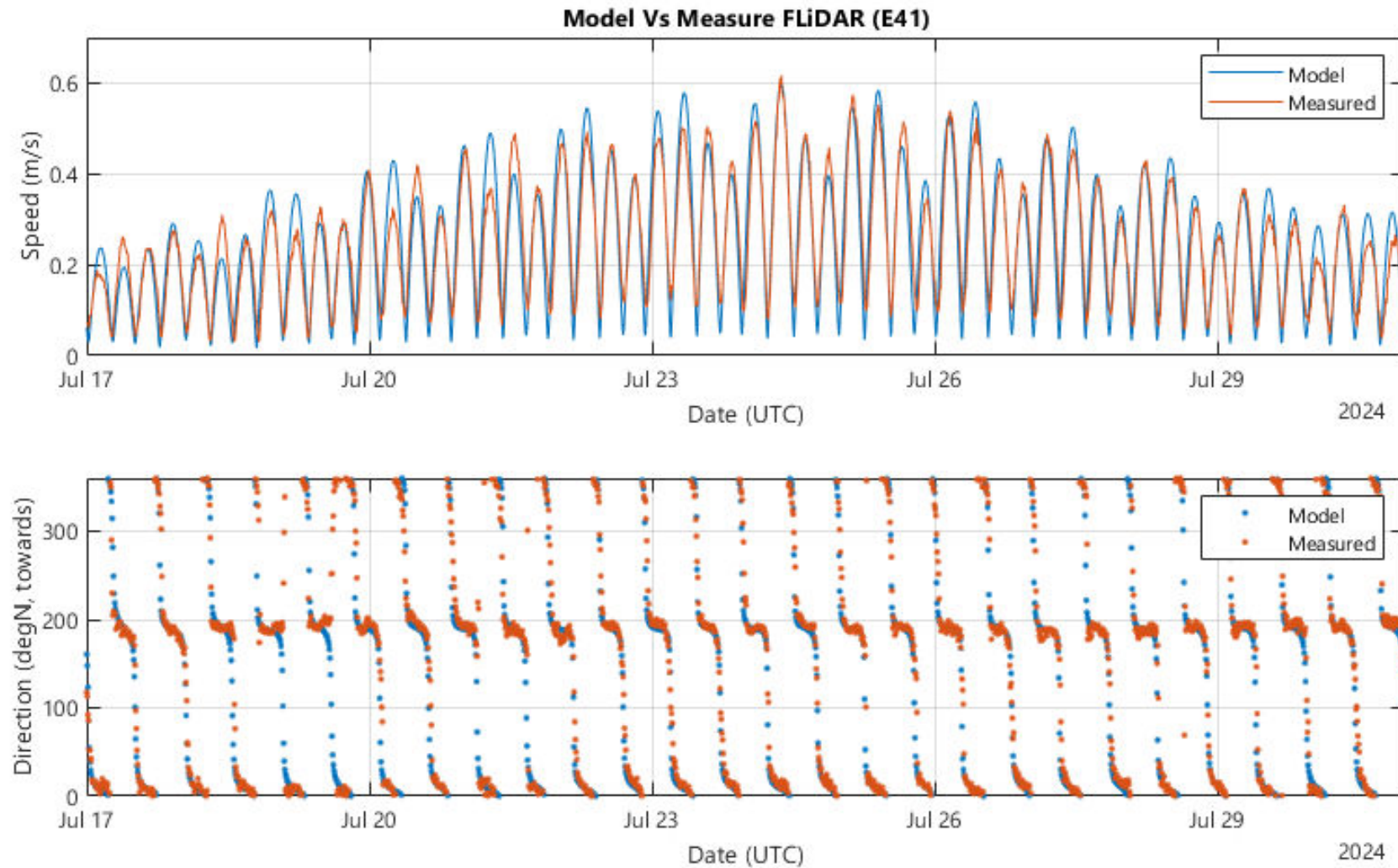


Figure 4.2: Comparison of modelled current speed and direction and the measured FLiDAR E41 data

4.1.3 Winds

- 4.1.3.1 An understanding of the wind climate is important for physical processes, as it plays a key role in shaping the prevailing wave regime and non-tidal water levels and currents. The relationship between wave generation and meteorological forcing means that the wind and wave regimes are similarly episodic and exhibit both seasonal and inter-annual variation in proportion with the frequency and magnitude of changes in wind strength and direction.
- 4.1.3.2 A long-term hindcast record of wind data within the Physical Processes Study Area is available from the ABPmer SEASTATES NW European Shelf Wave Hindcast Model (ABPmer, 2025a).
- 4.1.3.3 From this dataset, four wind roses were generated. One was for a location in Scottish waters, Morven South - which is broadly representative of the whole array, and three for locations in English waters: ECC2, ECC4, and ECC5 (see **Figure 4.3** to **Figure 4.6**; locations shown in **Figure 3.1**).
- 4.1.3.4 The wind roses indicate that wind directions show relatively little variation between the four sites, and between Scottish, English offshore and English nearshore waters. For all locations plotted, the predominant wind direction is from the southwest and west, accounting for around 40% of the modelled timesteps. This aligns with the prevailing wind direction experienced across the UK.

Scottish waters

- 4.1.3.5 Wind speeds are typically higher further offshore, and within the MHPGC Project PEIR Red Line Boundary in Scottish waters. The occurrence of wind speeds in the maximum bin (>16m/s) is greatest for the data extraction location in Morven South, compared to points closer to shore in the MHPGC Project PEIR Red Line Boundary in English waters.

English waters

- 4.1.3.6 Wind speeds typically decrease towards the landfall. The occurrence of windspeeds less than 8m/s are far more common at ECC2, nearer the coast in English waters, than for the further offshore site in English waters, ECC5.

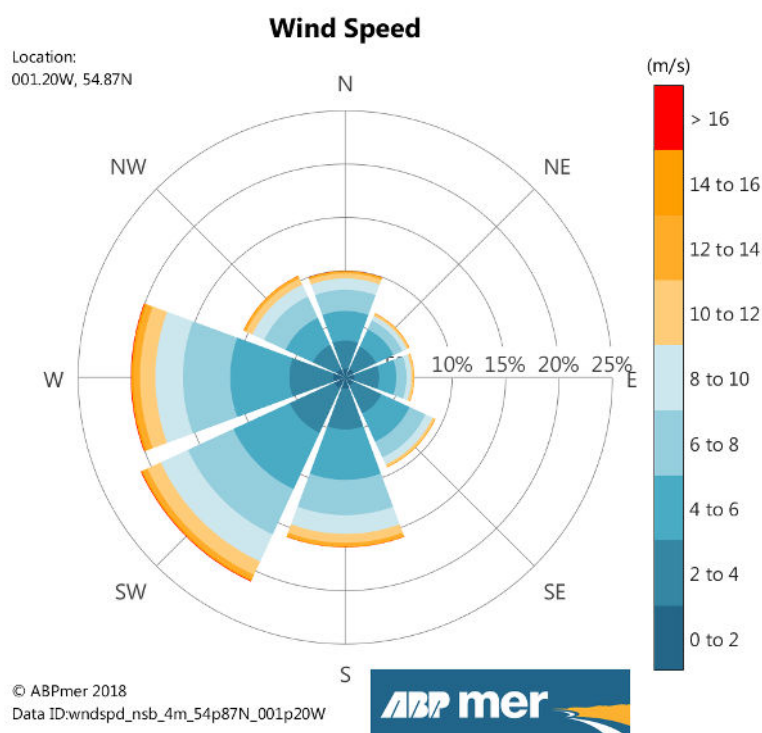


Figure 4.3: Rose plot of wind speed and direction for ECC2, over the period of 1979 to 2023 (directions indicate 'coming from')

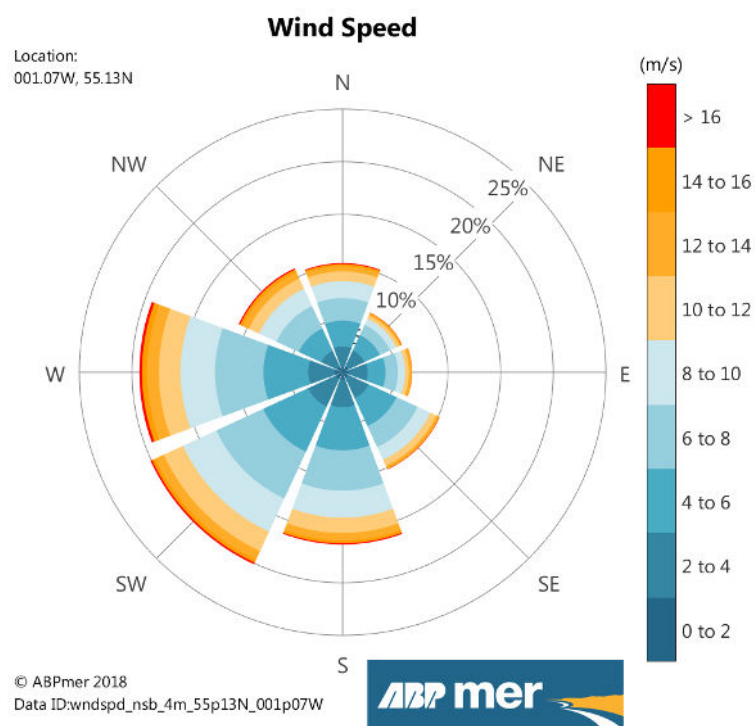


Figure 4.4: Rose plot of wind speed and direction for ECC4, over the period of 1979 to 2023 (directions indicate 'coming from')

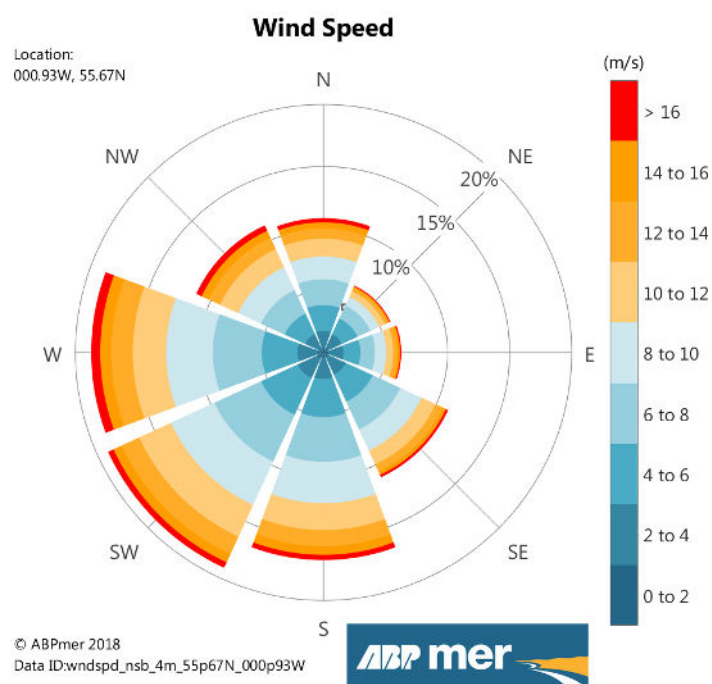


Figure 4.5: Rose plot of wind speed and direction for ECC5, over the period 1979 to 2023 (directions indicate 'coming from')

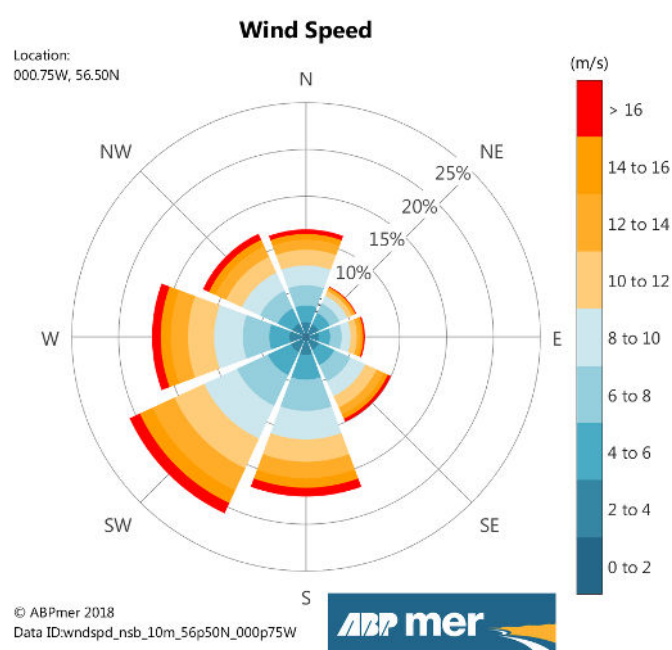


Figure 4.6: Rose plot of wind speed and direction for Morven South, over the period 1979 to 2023 (directions indicate 'coming from')

4.1.4 Waves

- 4.1.4.1 The wave climate is the result of the transfer of wind energy to the sea, creating sea states and the propagation of that energy across the water surface by wave motion. The amount of wind energy transfer and wind-wave development is a function of the available fetch distance across which the wind blows, wind speed, wind duration and the original state of the sea. The longer the fetch distance, the greater the potential for the wind to interact with the water surface and generate waves. In shallower water, water depth is an additional limiting factor on the size of the waves.
- 4.1.4.2 The wave regime is dominated by locally generated wind waves across the wider North Sea region. The Physical Processes Study Area is exposed to longer wave fetches from the north to northeast. Smaller wave conditions generated by local winds predominantly come from the southeasterly directions.
- 4.1.4.3 Based on a 40+ year hindcast dataset (Metoceanworks, 2024a-f), the mean significant wave height and extreme values are shown in **Table 4.3**.

Table 4.3: Mean significant wave height and extreme return periods along the MHPGC Project PEIR Red Line Boundary

	Morven SE (Scottish waters)	ECC6 (English waters)	ECC5 (English waters)	ECC4 (English waters)	ECC3 (English waters)	ECC2 (English waters)	ECC1 (English waters)
Mean Hs (m)	1.9	1.7	1.6	1.4	1.5	1.2	0.9
1 in 1 year Hs (m)	7.0	6.4	6.3	5.8	5.9	4.7	4.1
1 in 10-year Hs (m)	8.8	8.1	8.1	7.6	7.6	6.2	5.5
1 in 50-year Hs (m)	10.1	9.3	9.4	8.8	8.7	7.3	6.4

Scottish waters

- 4.1.4.4 Mean and extreme significant wave height values are greatest for the extraction location in Scottish waters (Morven SE). Mean significant wave height is 1.9m and the 1 in 10-year return period significant wave height is 8.8m.
- 4.1.4.5 Mean wave direction is generally northward (345° to 15°) for further offshore sites, including Morven SE in Scottish waters.
- 4.1.4.6 Mean peak wave period ranges from 4 seconds to 10 seconds at these locations.
- 4.1.4.7 **Figure 4.7** and **Figure 4.8** show wave roses generated from the measured data recorded by the Directional Wave Rider (DWR) wave buoys deployed in the section of the MHPGC Project PEIR Red Line Boundary that overlaps with Morven North and Morven South (Partrac, 2024). Both deployment locations are in Scottish waters.
- 4.1.4.8 Although the measured datasets cover a much shorter period than the hindcast wave data used to produce the wave statistics in **Table 4.3**, and wave roses in **Figure 4.9**, **Figure 4.10**, and **Figure 4.11**, the general pattern of wave direction aligns well between the modelled and measured data, with the prevailing mean wave direction coming from the north in Scottish waters. Larger measured waves are associated with winter months, when storms are more frequent and winds are higher, and smaller measured waves occur more frequently for longer periods in summer months.

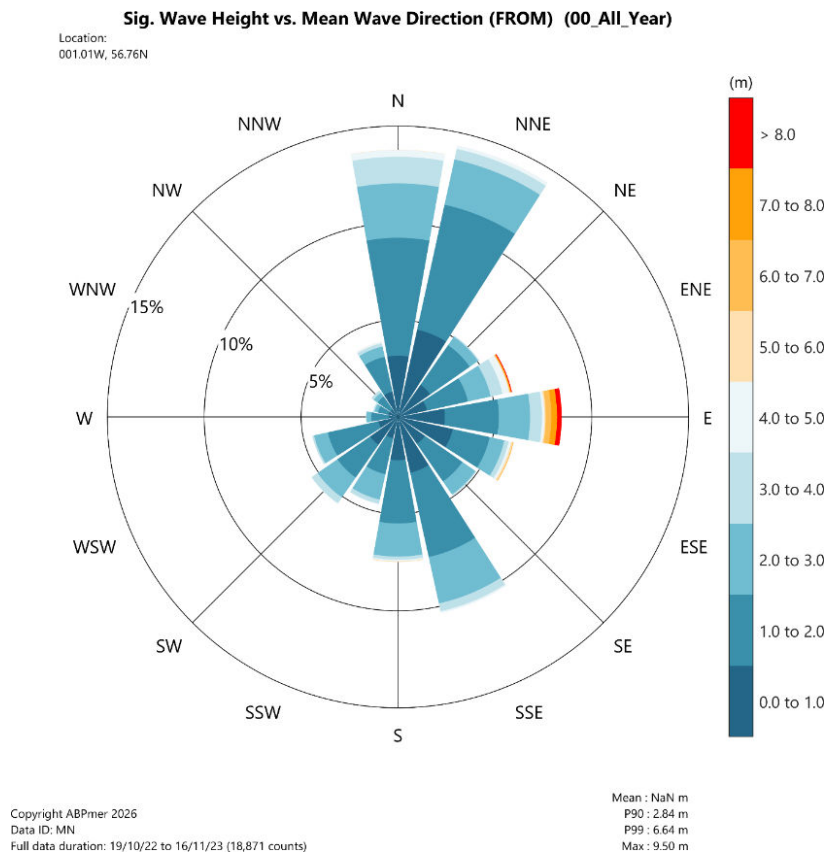


Figure 4.7: Rose plot of measured significant wave height and direction at Morven North over the period Oct 2022 to May 2024 (directions indicate 'coming from'). Source: ABPmer (2017)

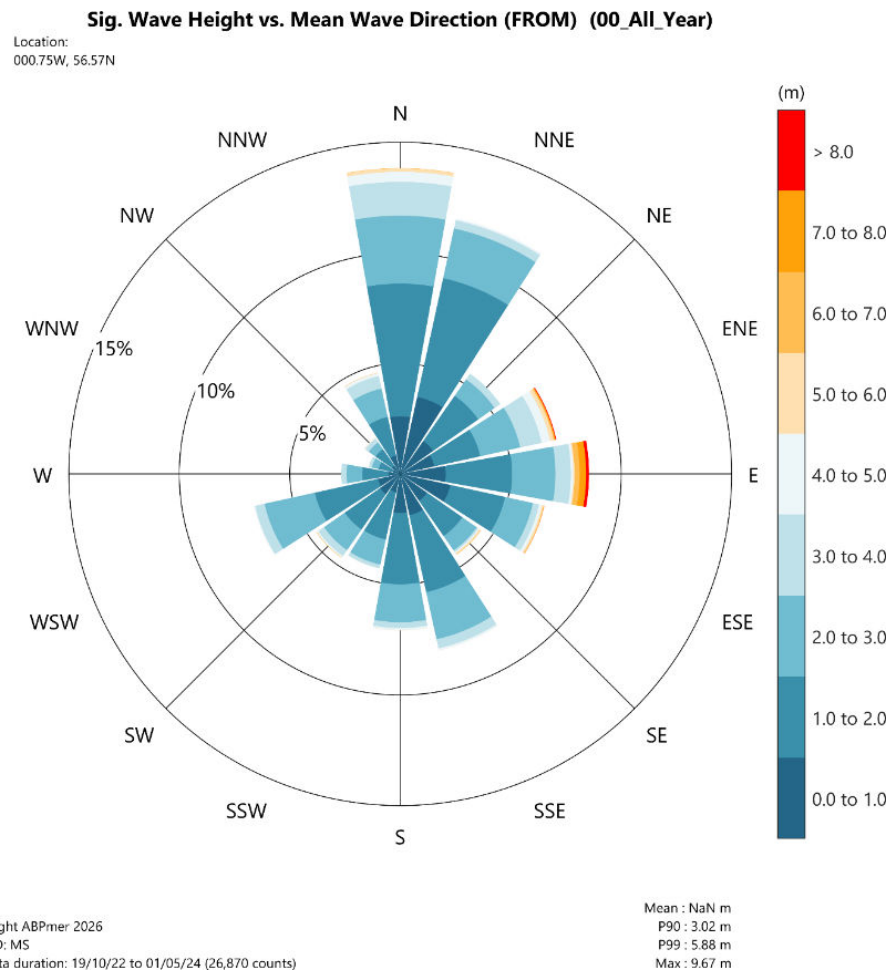


Figure 4.8: Rose plot of measured significant wave height and direction at Morven North over the period Oct 2022 to May 2024 (directions indicate 'coming from'). Source: ABPmer (2017)

English waters

- 4.1.4.9 Mean and extreme significant wave height values reduce towards the Landfall, with generally lower values in English waters compared to further northwards and offshore Scottish waters. For the closest point to the landfall in English waters, the mean significant wave height is 0.9m and the 1 in 10-year return period significant wave height is 5.5m.
- 4.1.4.10 Mean wave direction is from 15° to 45° at ECC1 and ECC2 closer to the landfall, with a slight northward rotation to 345° to 15° for further offshore sites, ECC3, ECC4, ECC5, ECC6.
- 4.1.4.11 Mean peak wave period ranged from 4 seconds to 10 seconds at these locations.
- 4.1.4.12 **Figure 4.9 to Figure 4.11** shows rose plots of the significant wave heights at three of the Metocean points (ECC2, ECC4 and ECC5) taken from Metoceanworks (2024b, d, e). At ECC2, the largest waves come from the northeast sector, which has the longest fetch into the North Sea. At ECC4 and ECC5, mean wave direction is from the north and northeast between 15% to 20% of the time, reflecting swell waves generated from the northern North Sea.

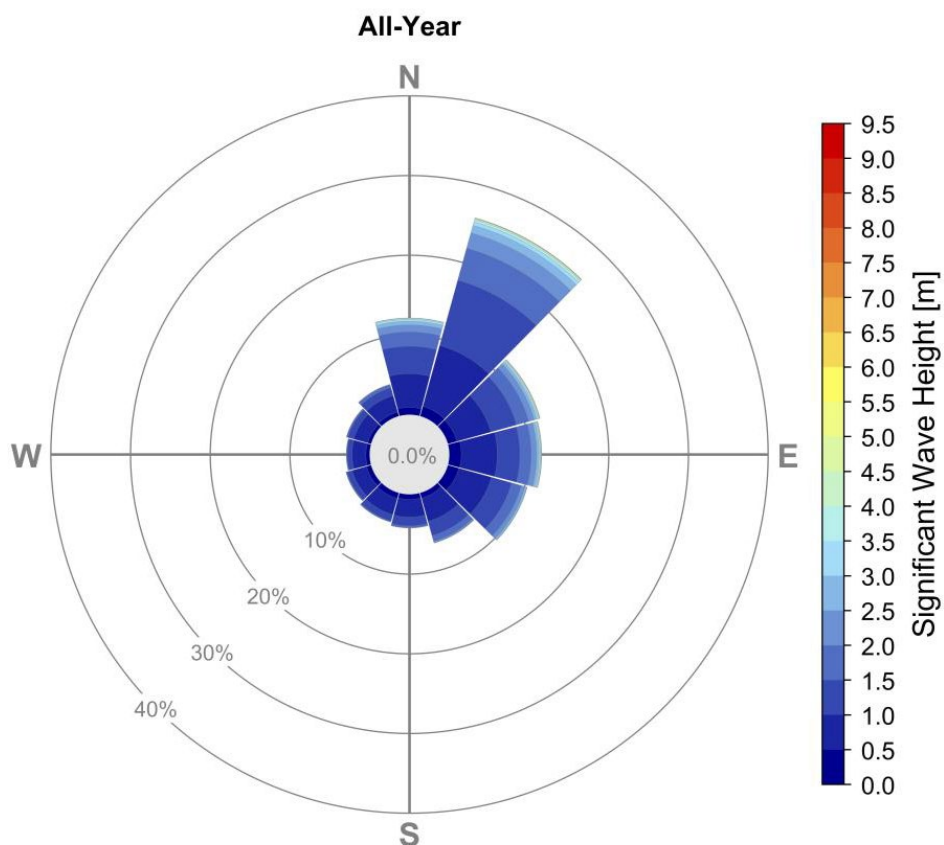


Figure 4.9: Rose plot of significant wave height and direction at ECC2 over the period 1979 to 2019 (directions indicate 'coming from'). Source: Metoceanworks (2024b, d, e)

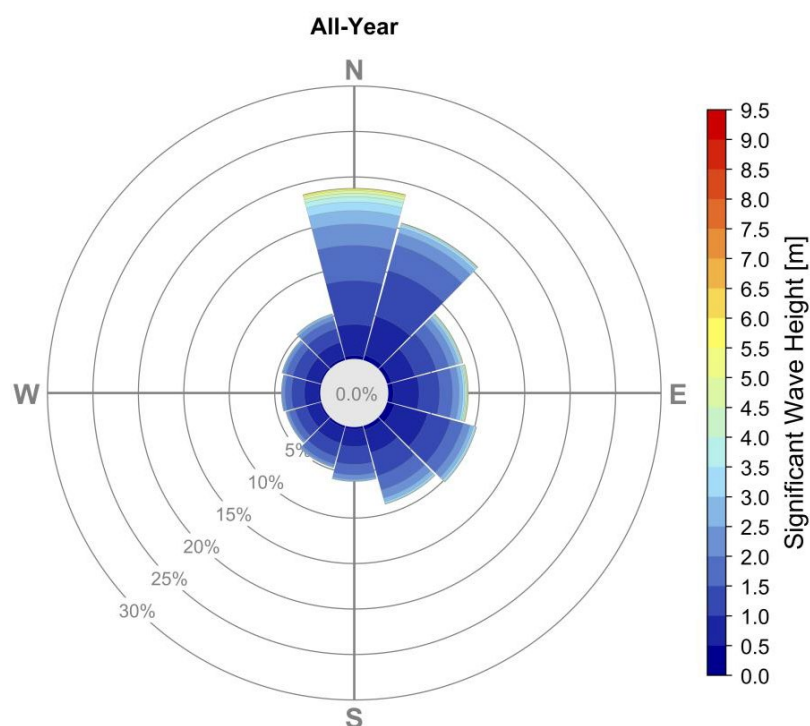


Figure 4.10: Rose plot of significant wave height and direction at ECC4 over the period 1979 to 2019 (directions indicate 'coming from'). Source: Metoceanworks (2024b, d, e)

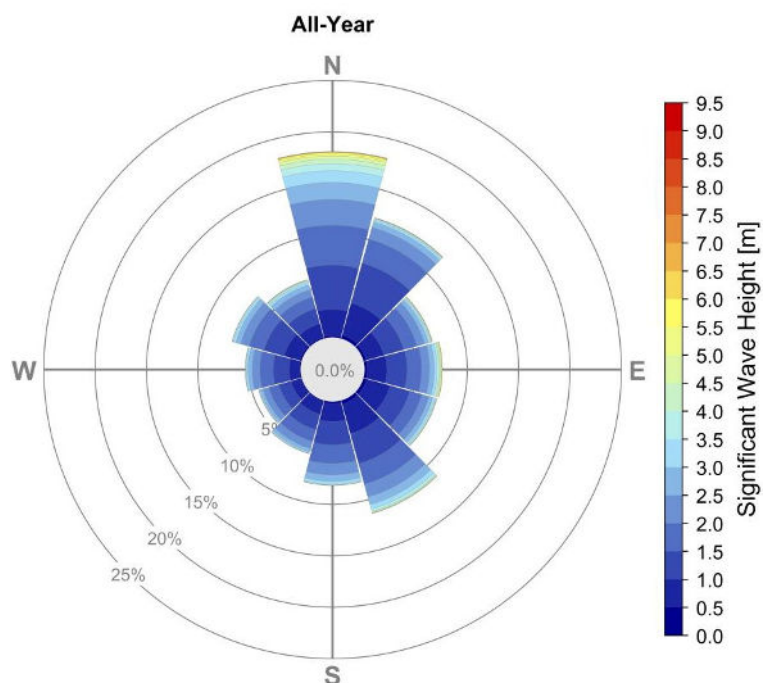


Figure 4.11: Rose plot of significant wave height and direction at ECC5 over the period 1979 to 2019 (directions indicate 'coming from'). Source: Metoceanworks (2024b, d, e)

4.1.5 Future Change

- 4.1.5.1 Information on the rate and magnitude of anticipated relative sea level change during the 21st Century is available from United Kingdom Climate Projections 2018 (UKCP18) (Palmer *et al.*, 2018). By 2075, relative sea level is predicted to have risen by approximately 0.6m above present day (2026) levels RCP 8.5, 95th percentile) at the landfall, in English waters, with rates of change increasing over time.
- 4.1.5.2 Sea level rise may result in the loss of intertidal habitat through the process of ‘coastal squeeze’, caused by the presence of coastal defences preventing natural roll back, and future equilibrium position of coastal features (Environment Agency, 2021). A rise in sea level may also allow larger waves and therefore more wave energy, to reach the coast in certain conditions and, consequently, result in an increase in local rates or patterns of erosion.
- 4.1.5.3 UKCP18 provides projections of changes to storm surge magnitude in the future as a result of climate change. These projections of change in extreme coastal water levels are dominated by the increase in MSL with only a minor (<10%) additional contribution due to atmospheric storminess changes over the 21st Century (Palmer *et al.*, 2018).

4.2 Surficial sediments, sediment transport and morphology

4.2.1 Sediment transport

- 4.2.1.1 Regional scale patterns of potential sediment transport have been inferred using sediment transport modelling. The underlying hydrodynamic model is the project-specific ABPmer Northwest European Shelf Hydrodynamic Model (ABPmer, 2017), with increased resolution across the Physical Processes Study Area (see **Volume 2, Annex 1.2: Model Design, Validation and Results, of the PEIR**). The model has been run in a tide-only mode for a representative ~15-day period (one mean spring-neap cycle). The Sand Transport module is applied to the same model run to simulate the resulting temporally and spatially varying rate of potential transport for representative 250 micrometres (μm) (0.25 millimetres (mm)) diameter sand. The resulting timeseries of instantaneous sediment transport rate and direction has been analysed to create a map of residual (long term net) potential sediment transport rate and direction (see **Figure 4.12**). Units have been converted to the estimated volumetric rate of transport (cubic metre (m^3), per day, per metre width of seabed perpendicular to the direction of net transport).

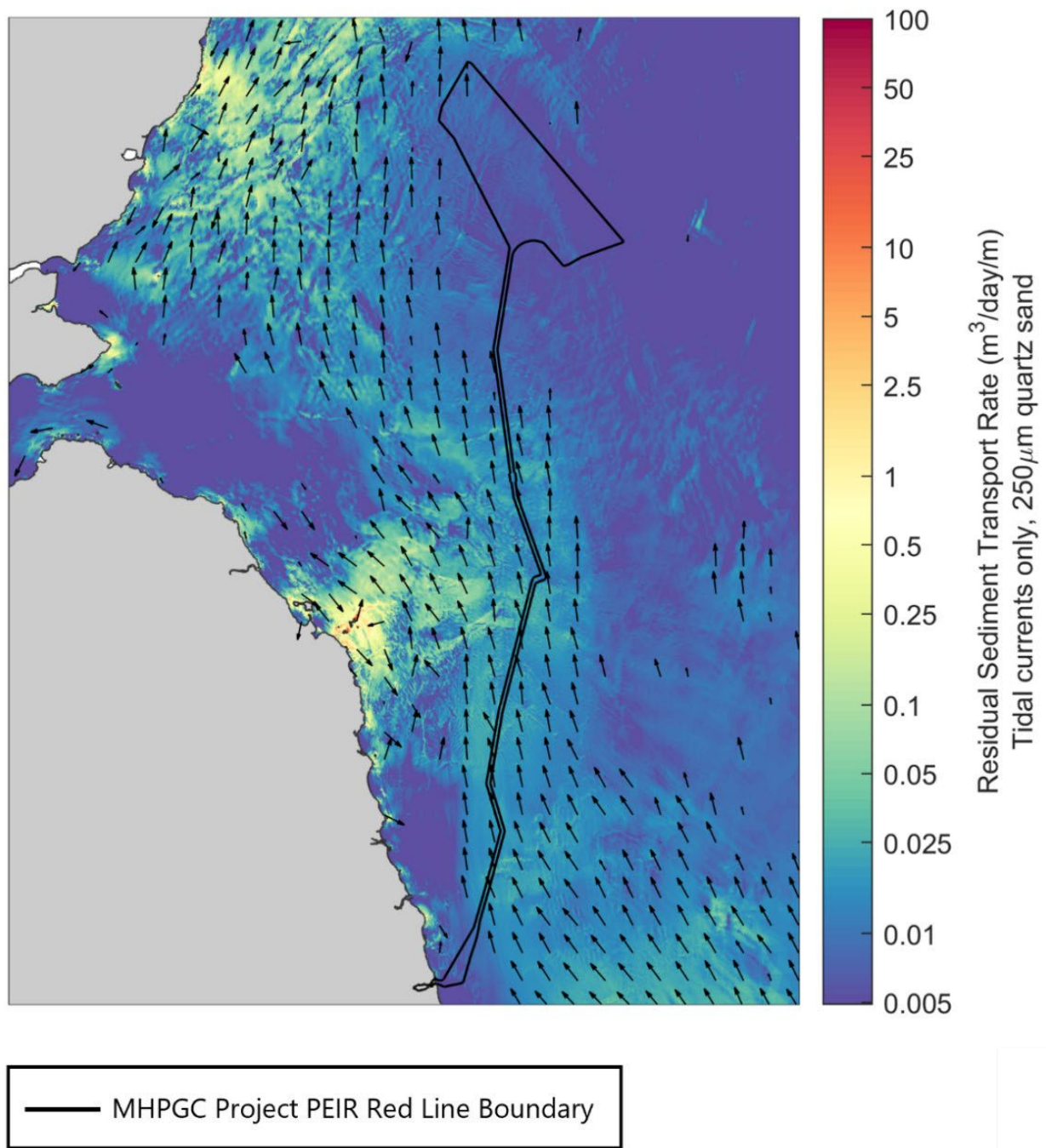


Figure 4.12: Residual sediment transport rate and direction, for $250\mu\text{m}$ quartz sand, predicted over a representative spring-neap tidal period

- 4.2.1.2 The potential sediment transport rate is that which would theoretically occur in response to the given conditions, with an unrestricted supply of sediment. In practice, some areas of the seabed may have limited or no erodible sediment remaining to transport (e.g. due to long term net transport away from that area) and so the actual rate can be lower than the maximum potential transport value in practice. However, the patterns of net transport direction and relative magnitude are still likely to apply.
- 4.2.1.3 The instantaneous rate of potential sediment transport is generally proportional to the depth average current speed excess above a threshold value for initial motion ($\sim 0.3\text{m/s}$ to 0.4m/s for $250\mu\text{m}$ diameter sand), squared. The net rate of potential sediment transport is also

sensitive to any repetitive asymmetry or difference in the peak magnitude or duration of current speed on consecutive flood and ebb tides. These factors can result in disproportionately higher transport rates in areas of higher current speed and/or tidal asymmetry.

Scottish waters

- 4.2.1.4 Potential net sediment transport rates are generally lower within the Morven North and Morven South section of the MHPGC Project PEIR Red Line Boundary, as well as across the rest of the MHPGC Project PEIR Red Line Boundary in Scottish waters. This is primarily due to naturally weaker tidal currents that are insufficient to frequently or strongly mobilise or transport sand.

English waters

- 4.2.1.5 Transport rates increase closer to the coast, in English waters, where current speeds are typically higher due to flow acceleration around the Northumberland coastline. Generally, the predominant direction of net sediment transport is towards the north.
- 4.2.1.6 Waves are not accounted for in the sediment transport model results shown in **Figure 4.12**. However, occasional additional seabed sediment disturbance might also be expected due to larger storm waves in relatively shallower water depths (<~50m water depth, i.e. close to the coastline). Wave action does not tend to cause measurable sediment transport in a particular direction but can temporarily enhance the rate of tidally induced transport, in the direction of the tidal current at the time of the storm. Wave action can also cause wave aligned seabed ripple features (up to a few tens of centimetres in height and up to a few metres wavelength).

4.2.2 Seabed sediments

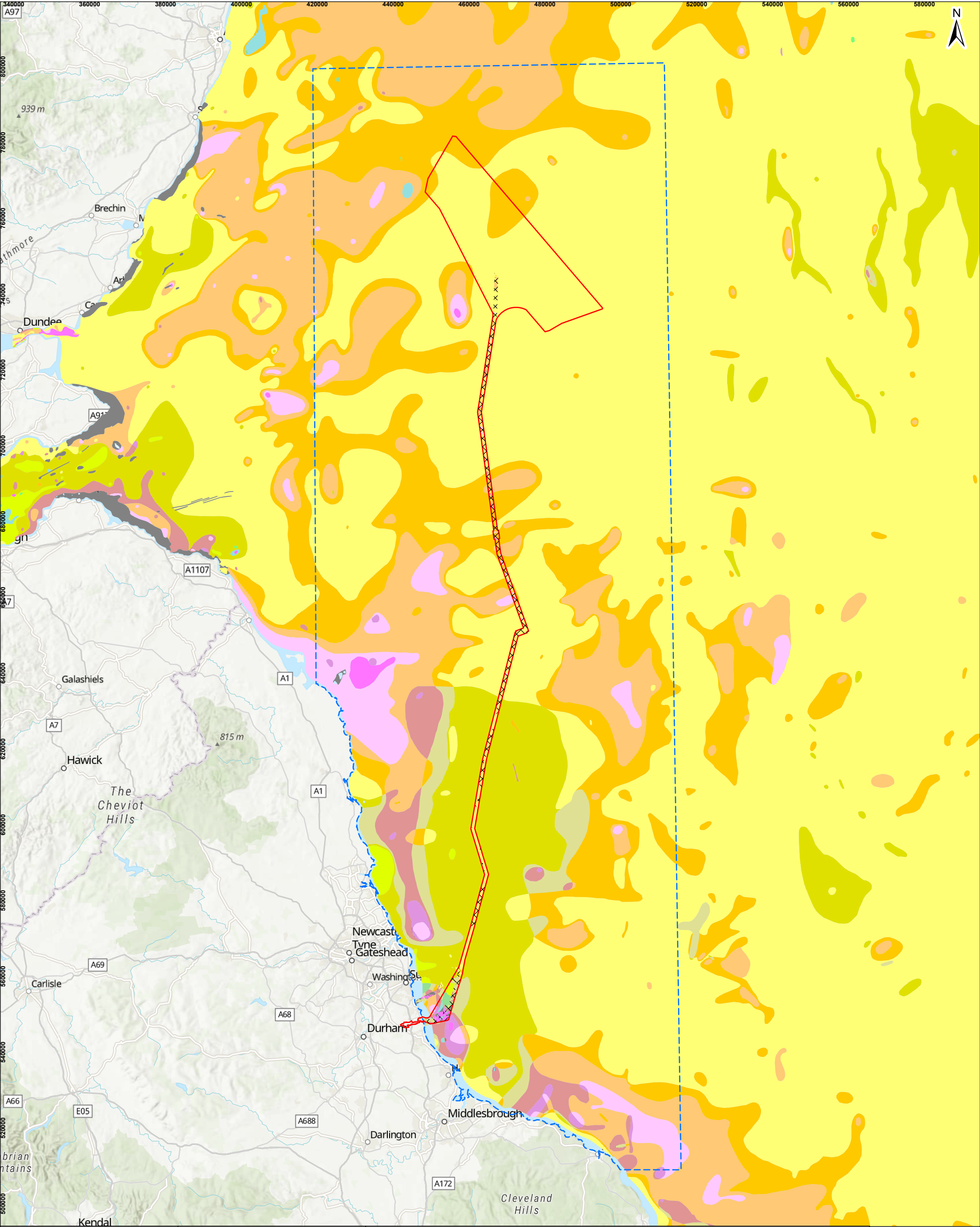
- 4.2.2.1 Seabed sediments across the Physical Processes Study Area comprise of a mixture of coarse (sand and gravels) and fine (muddy) grained sediment. The ratio between these sediment types varies marginally along the MHPGC Project PEIR Red Line Boundary (see **Figure 4.13**).

Scottish Waters

- 4.2.2.2 The seabed in Scottish waters of the MHPGC Project PEIR Red Line Boundary is characterised mainly as sand, with a small region of gravelly sand in the north-western extent of the MHPGC Project PEIR Red Line Boundary.

English Waters

- 4.2.2.3 The seabed in English waters of the MHPGC Project PEIR Red Line Boundary is characterised mainly as sand at the northern most extent, transitioning to gravelly sands and then to muddy sands. The transition occurs gradually along the offshore ECC and finer sediments are associated with greater water depths.
- 4.2.2.4 Close to landfall in English waters, seabed sediments mainly comprise of a mixture of fine silty sand with localised areas of more gravelly sand. The probable source of the finer material is from the erosion of colliery waste that had been disposed of in front of the cliffs along the shore from the 1860s to the 1990s (Royal Haskoning, 2014 and Pitman *et al.*, 2024). Backscatter data from the 2024 Geophysical XOCEAN Ltd survey also indicates that the presence of boulder fields and exposed bedrock within 15km of the coast: this is likely the result of high current speeds scouring the seabed (XOCEAN Ltd. 2025).





Project Name:
MORVEN HAWTHORN PIT GRID CONNECTION PROJECT

Drawing Title:
FIGURE 4.13: SEABED SEDIMENTS WITHIN THE PHYSICAL PROCESSES STUDY AREA

0 5 10 15 20 25 30 35 40 km

Scale@A3:1:900,000

Service Layer Credits:
Datum: WGS 1984
Projection: WGS 1984 UTM Zone 30N

Drawing Number:
MHPGC-ABP-PP-0003

Data Sources:
XOcean Ltd. (2024). Contains British Geological Survey materials © UKRI, 2024.

Geodetic Information:
World Hillshade: Esri, COPAC, N Robinson, NCEAS, USGS
World Topographic Map: Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community
World Hillshade: Esri, USGS

VER	DATE	DETAILS	BY	CHECK
00	18/12/25	Initial Issue	HMN	Draft
01	09/07/26	Update Issue	ALN	DOL
-	-	-	-	-
-	-	-	-	-

LEGEND

 Physical Processes Study Area

 MHPGC Project PEIR Red Line Boundary

Seabed Sediment

-  Mud
-  sandy Mud
-  (gravelly) sandy Mud
-  muddy Sand
-  (gravelly) muddy Sand
-  Sand
-  (gravelly) Sand
-  gravelly Sand
-  sandy Gravel
-  Gravel
-  gravelly Mud
-  muddy Gravel
-  gravelly muddy Sand
-  muddy sandy Gravel
-  Rock & boulders
-  Boulders



4.2.3 Geology and sub-strata

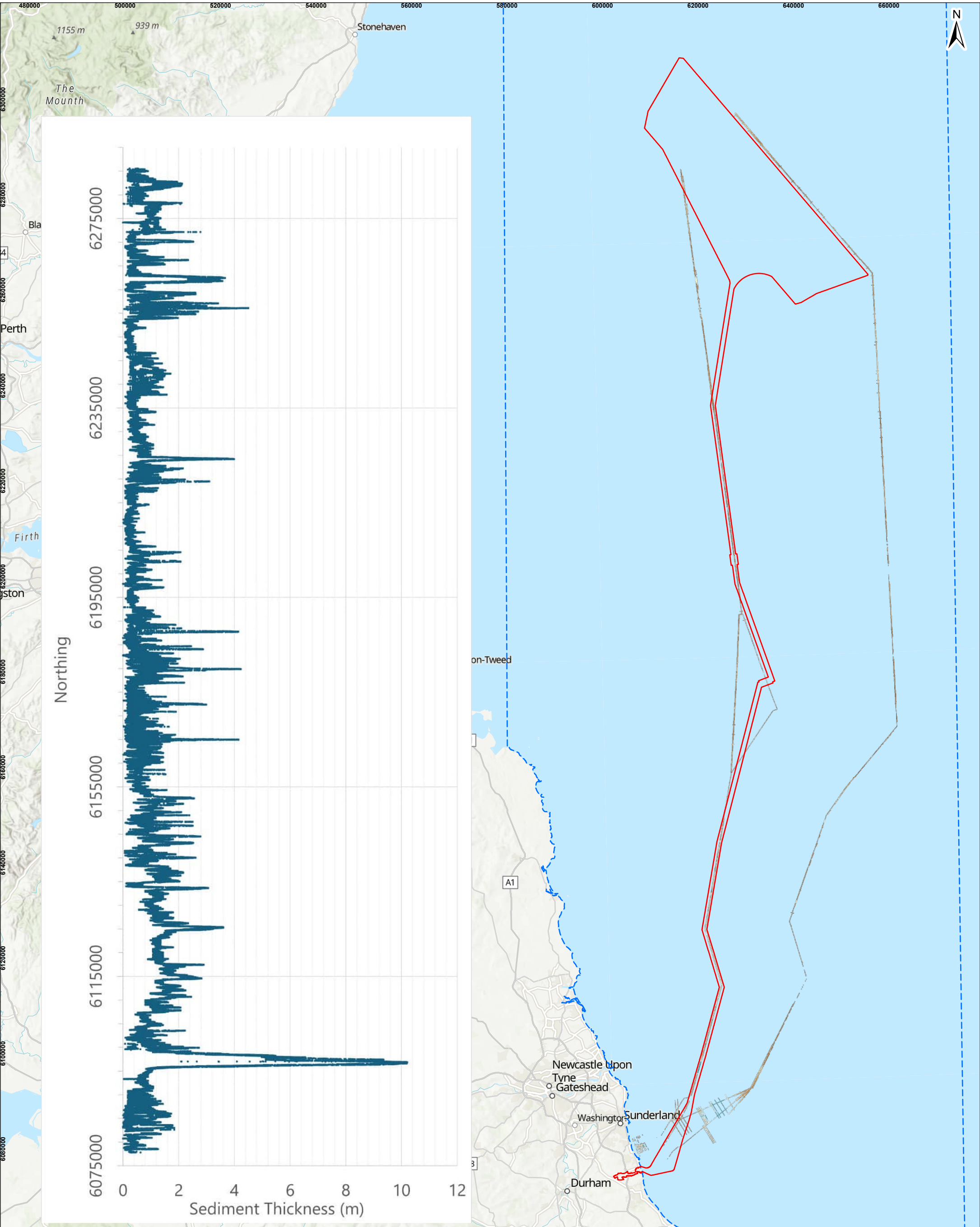
- 4.2.3.1 The seabed within the MHPGC Project PEIR Red Line Boundary can be generally described as a widely distributed but thin veneer of relatively sandy sediment, laid down and reworked during the Holocene period (the last 11,700 years since the last major glacial period). These are the sediments that are or have been actively mobile in the recent geological past. The thickness of the Holocene veneer is typically thin (<2m), but at one location (approximately KP20), within English Waters, the thickness extends to 11m (see **Figure 4.14**). Any modern-day bedforms that are present are formed of this relatively sandy Holocene sediment and are limited in size and type by the relative thickness and abundance of such sediment present locally.
- 4.2.3.2 Underneath the Holocene sediments are various other geological formations, as listed in **Table 4.4**. The uppermost layer directly beneath the Holocene veneer is variable within the MHPGC Project PEIR Red Line Boundary and likely to be disturbed during the cable burial. The geological formations, other than the loose sandy Holocene material, is likely to be resistant to erosion and transportation and will limit the depth of any scour around seabed infrastructure.

Table 4.4: Summary of geological units within the MHPGC Project PEIR Red Line Boundary

Stratigraphy					Depositional Environment	Lithology
System	Series	Stage/Group	Formation	Abbreviation		
QUATERNARY	HOLOCENE	Holocene	Holocene	Hol 3	Marine – Mobile sand	Mainly loose to medium dense, gravelly SAND*, with local CLAY
			Holocene	Hol 2	Marine – sheet (low-amp)	Loose to medium dense SAND, with local CLAY
			Holocene	Hol 1	Marine – infill depression (high-amp)	Loose to medium dense SAND, with local CLAY
	PLEISTOCENE	Devensian	Forth	Fth 3	Marine, glacio-marine, fluvio-marine, estuarine	Dense to very dense fine to medium SAND
				Fth2		Extremely low to low strength slightly sandy CLAY and clayey SAND
				Fth 1		Dense to very dense SAND, possible channel flank slump deposits
			Marr Bank	MB	Marine to glaciomarine. Sheet-like outwash deposits	Dense to very dense fine to medium SAND often with a beds of medium to high strength clay with gravels, cobbles and boulders.
			Wee Bankie	WB	Terminal and subglacial till	Medium dense to very dense, gravelly CLAY and SAND; very heterogenous in grain size; stiff, variably matrix-dominated polymictic till with some

Stratigraphy					Depositional Environment	Lithology
System	Series	Stage/Group	Formation	Abbreviation		
						interbeds of sand, pebbly sand and silty clay
TERTIARY	PALAEOGENE	Eocene	Mousa	MOUS	Delta/shelf system	MUDSTONE with possible stacked SANDSTONE / SILTSTONE. Possible lignites
		Palaeocene	Lista	LIST	Delta/shelf system	Shale with minor LIMESTONE and coarse SAND
CRETACEOUS		Upper	Chalk Group	CK	Warm oxygenated, low energy water	Autochthonous CHALK with possible flint and chert bands and hard ground CLAY
		Lower	Cromer Knoll Group	CRKN	Open marine	Soft grey to reddish grey, calcareous MUDSTONE and shales with marls and LIMESTONE. Also, possible thin SANDSTONE
TRIASSIC		Upper	Smith Bank	SMBA	Lacustrine	Red/Brown MUDSTONE dominated unit, grading into SILTSTONE, with thin bands of anhydrite occurring throughout the formation and very fine-grained SANDSTONE laminae
PERMIAN			Permian	N/A	Early Permian aeolian and dune-sands, covered by Late Permian marine transgression of a low-lying continental basin.	Upper Permian dominated by ANHYDRITE and GYPSUM; Lower Permian SANDSTONE dominated

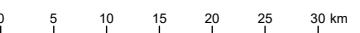
Data source: Adapted from Norwegian Geotechnical Institute (NGI) (2024) and BGS (2020)





Project Name:
MORVEN HAWTHORN PIT GRID CONNECTION PROJECT

Drawing Title:
FIGURE 4.14: SURFICIAL SEDIMENT THICKNESS WITHIN THE MHPGC PROJECT PEIR RED LINE BOUNDARY



Scale@A3:1:715,000

Service Layer Credits:
Datum: WGS 1984
Projection: WGS 1984 UTM Zone 30N

Drawing Number:
MHPGC-ABP-PP-0004

Data Sources:
XOcean, Ltd. 2023

Geodetic Information:
World Topographic Map: Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community
World Hillshade: Esri, USGS

VER	DATE	DETAILS	BY	CHECK
00	02/12/25	Initial Issue	HMN	Draft
01	09/07/26	Update Issue	ALN	DOL
-	-	-	-	-
-	-	-	-	-

LEGEND

 Physical Processes Study Area

 MHPGC Project PEIR Red Line Boundary

Surficial Sediment Thickness (m)

-  < 0.5
-  0.5 to 1
-  1 to 1.5
-  1.5 to 2
-  2 to 2.5
-  2.5 to 3
-  3 to 3.5
-  3.5 to 4
-  4 to 4.5
-  > 4.5



4.2.4 Suspended sediments

4.2.4.1 Monthly-averaged satellite imagery of SPM concentration in surface waters suggests that the average (surface) SPM within the MHPGC Project PEIR Red Line Boundary is generally very low, between approximately 0.5mg/l to 2mg/l.

4.2.4.2 Values naturally vary over time and may be temporarily and locally elevated in response to larger spring tides and storm conditions. Sufficiently energetic stirring of the seabed leads to natural resuspension and upward mixing of sediment into the water column, resulting in a (usually logarithmic) vertical profile of SPM concentration. Relatively higher suspended sediment concentrations are therefore likely to be present closer to the seabed at any given time.

Scottish waters

4.2.4.3 Further offshore, in the deeper regions of the MHPGC Project PEIR Red Line Boundary that overlaps with Scottish waters, SPM concentration is generally low (<1mg/l).

English waters

4.2.4.4 SPM concentration is typically greater closer to the landfall, with values ranging between 3mg/l in summer months and 10mg/l in winter months (Cefas, 2016).

4.2.5 Morphology

4.2.5.1 Key information from the MHPGC Project-specific geophysical survey (XOCEAN Ltd. 2025), NGI (2024) and from that contained within relevant publicly available reports is summarised below.

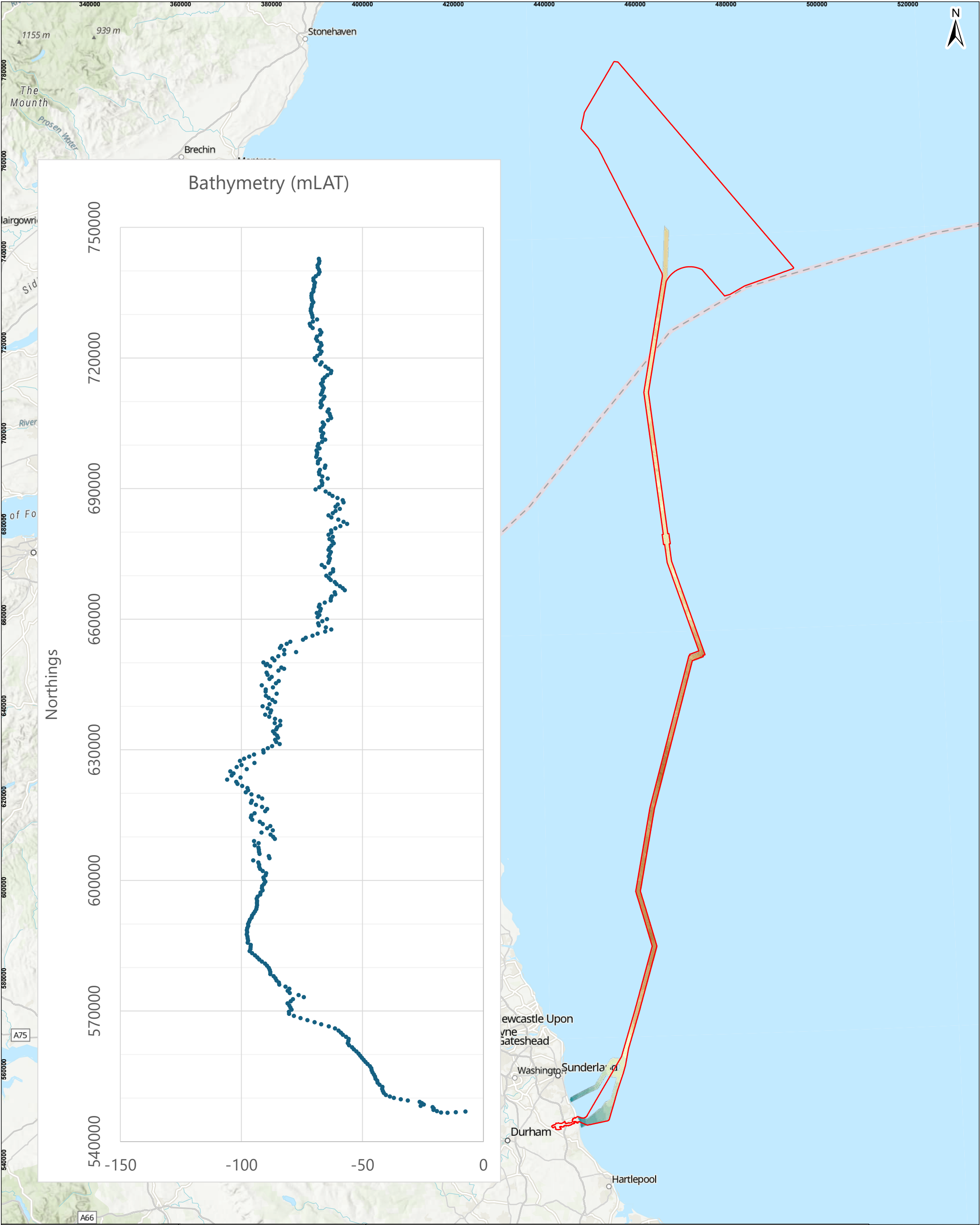
Scottish waters

4.2.5.2 The MHPGC Project-specific geophysical survey data shows that water depths within the MHPGC Project PEIR Red Line Boundary that overlaps with Scottish waters range between approximately ~72m LAT and ~60m LAT. The average gradients within the Scottish waters of the Physical Processes Study Area are gentle (<1°) (**Figure 4.15**).

English waters

4.2.5.3 The MHPGC Project-specific geophysical survey data shows that water depths within the MHPGC Project PEIR Red Line Boundary that overlaps with English waters range between approximately ~107m LAT and ~0m LAT at landfall. The steepest gradients within the Physical Processes Study Area (~50°) are associated with a boulder field close to the coast (**Figure 4.15**).

4.2.5.4 A range of active and relict bedforms have been identified in **Figure 4.16**. Large-scale flow-transverse bedforms such as sand waves are observed from approximately 55km offshore near the midpoint of the cable corridor. In places, the height of the sandwave features exceeds 5m; the morphology of these features is considered further in **Section 4.2.6**, in relation to potential seabed mobility and net sediment transport. Ripples and megaripples were also observed intermittently throughout the MHPGC Project PEIR Red Line Boundary. Glacial moraines, although anticipated on the basis of the regional characterisation work presented in Brooks *et al.* (2011), were not mapped by the MHPGC Project geophysical survey.





Project Name:
MORVEN HAWTHORN PIT GRID CONNECTION PROJECT

Drawing Title:
FIGURE 4.15: BATHYMETRY WITHIN THE MHPGC PROJECT PEIR RED LINE BOUNDARY

Drawing Number:
MHPGC-ABP-PP-0005

Data Sources:
XOcean Ltd, 2024

Geodetic Information:
World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS
World Topographic Map: Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community
World Map: Esri, USGS

VER	DATE	DETAILS	BY	CHECK
00	09/12/25	Initial Issue	HMN	Draft
01	10/02/26	Update Issue	HMN	-
02	09/07/26	Update Issue	ALN	DOL
-	-	-	-	-

LEGEND

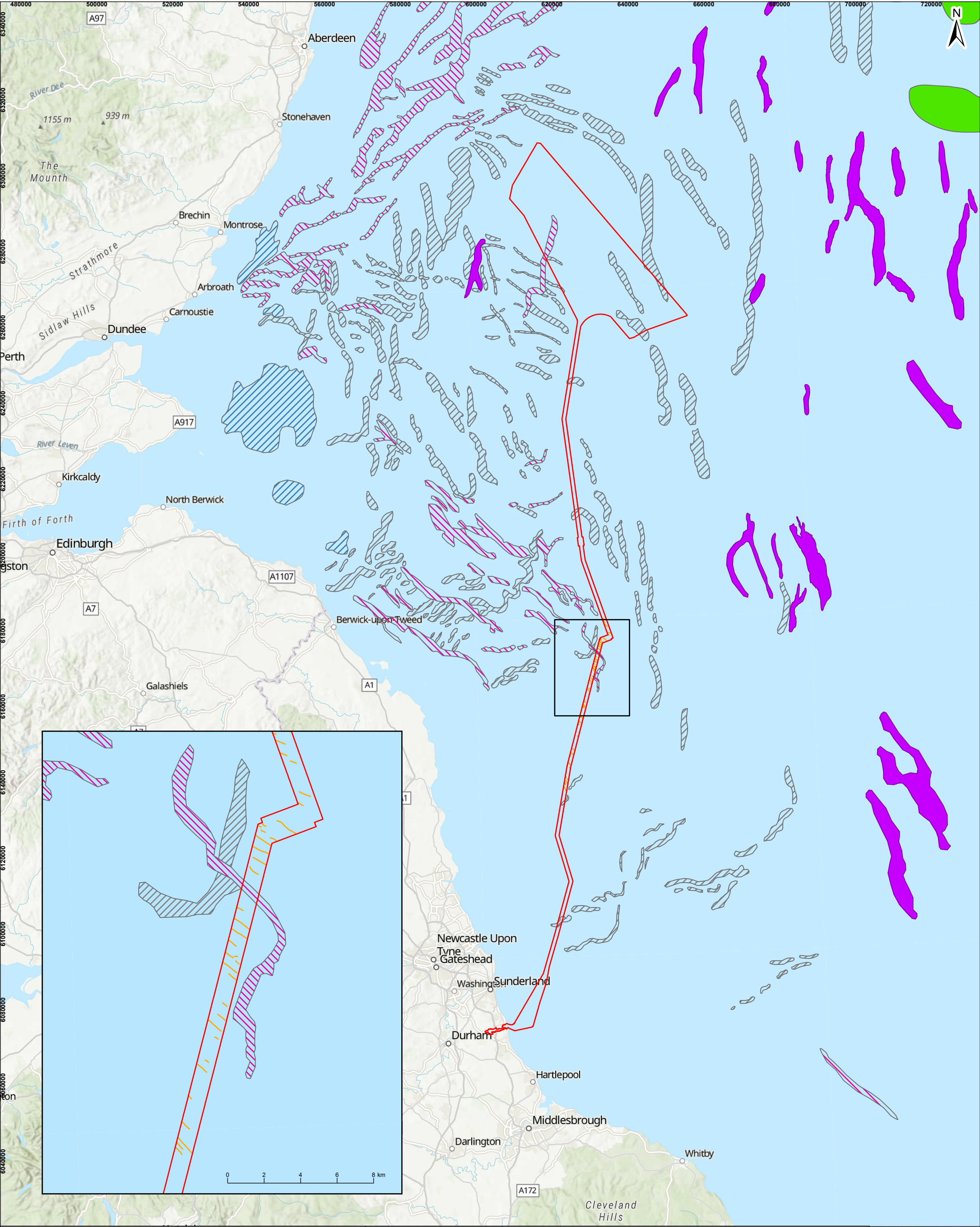
Project Bathymetry Data 2024 (mLAT)

< -105	-52.5 to -45
-105 to -97.5	-45 to -37.5
-97.5 to -90	-37.5 to -30
-90 to -82.5	-30 to -22.5
-82.5 to -75	-22.5 to -15
-75 to -67.5	-15 to -7.5
-67.5 to -60	-7.5 to 0
-60 to -52.5	

English/Scottish Waters Boundary

MHPGC Project PEIR Red Line Boundary







Project Name:
MORVEN HAWTHORN PIT GRID CONNECTION PROJECT

Drawing Title:
FIGURE 4.16: MORPHOLOGICAL FEATURES WITHIN THE PHYSICAL PROCESSES STUDY AREA

0 5 10 15 20 25 30 35 40 km

Scale@A3:1:900,000

Service Layer Credits:
Datum: WGS 1984
Projection: WGS 1984 UTM Zone 30N

Drawing Number:
MHPGC-ABP-PP-0006

Data Sources:
XOcean Ltd, 2024. EMOdnet, 2025. Contains BGS materials ©UKRI, 2000.

Geodetic Information:
World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS
World Hillshade: Esri, CGIAR, N Robinson, NCEAS, USGS
World Topographic Map: Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community
World Hillshade: Esri, USGS

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01	09/02/26	Update Issue	HMN	-
02	09/07/26	Update Issue	ALN	DOL
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LEGEND

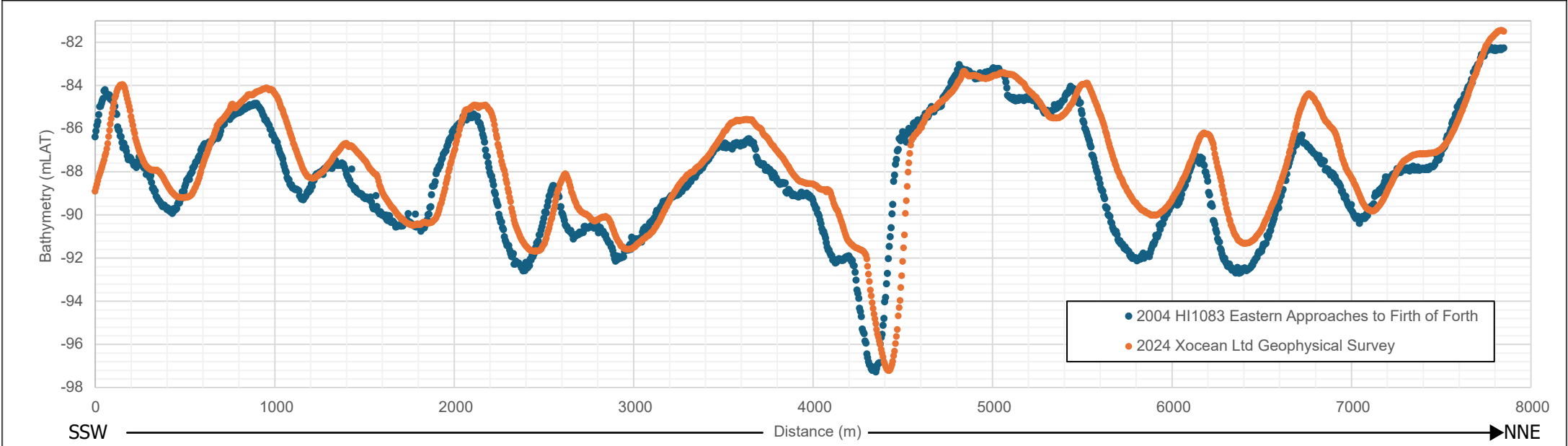
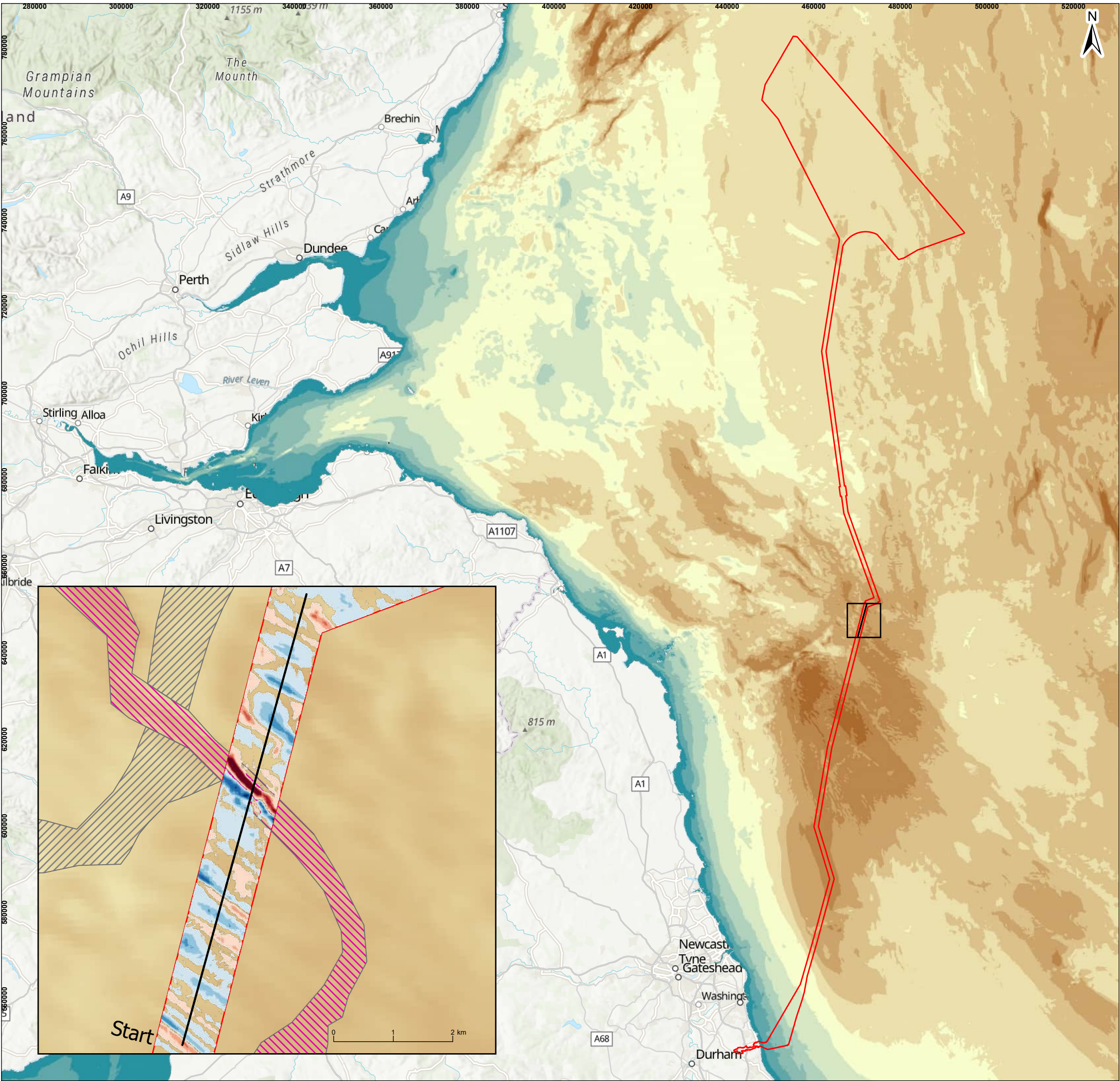
Sea Floor Geomorphology

- channel
- drumlin field
- moraine
- pockmark field
- tunnel valley
- Sand Wave Crest
- MHPGC Project PEIR Red Line Boundary



4.2.6 Seabed mobility

- 4.2.6.1 Observations of historical changes in seabed level can be used to help identify areas where the seabed may potentially be mobile over the lifetime of the MHPGC Project. Historic bathymetric data is available from the UKHO (2004): this historic bathymetry data can be compared directly with the high resolution multibeam bathymetry collected for during the project's geophysical survey (XOCEAN Ltd., 2025).
- 4.2.6.2 A comparison between the MHPGC Project bathymetric survey undertaken in 2024 (XOCEAN Ltd., 2024) and the earlier UKHO survey (2004) indicates that the peaks and troughs shown in the profile of **Figure 4.17** have migrated northwards at rates of up to approximately 4m per year. This movement aligns with the residual sediment transport direction described in **Section 4.2.5**.
- 4.2.6.3 Where present, smaller ripple and megaripple features (not resolved by the UKHO data) are likely to migrate and evolve over shorter timescales of weeks to months, depending on the strength of tidal conditions. As they migrate, the local seabed level will locally vary about the mean seabed level over time, by half the crest to trough height (i.e. approximately $\pm 0.15\text{m}$ to 0.3m).





Project Name:
MORVEN HAWTHORN PIT GRID CONNECTION PROJECT

Drawing Title:
FIGURE 4.17: BATHYMETRIC CHANGE IN THE MHPGC PROJECT PEIR RED LINE BOUNDARY BETWEEN 2004 (UKHO) AND 2024 (XOCAN LTD.)

0 5 10 15 20 25 30 km
Scale@A3:1:900,000

Service Layer Credits:
Datum: WGS 1984
Projection: WGS 1984 UTM Zone 30N

Drawing Number:
MHPGC-ABP-PP-0007

Data Sources:
EMODnet (2025), UKHO (2025), XOcean Ltd. 2024

Geodetic Information:
World HiBath: Esri, CGIAR, N Robinson, NCEAS, USGS
World HiBath: Esri, Intermap, NASA, NGA, USGS
World Topographic Map Sources: Esri, TerraTron, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community
World Topographic Map: Esri, HERE, Garmin, FAO, NOAA

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02	09/07/26	Update Issue	ALN	DOL
-	-	-	-	-

LEGEND

— Transect
MHPGC Project PEIR Red Line Boundary

Bathymetry (mLAT)

- 0 to -10
- 10 to -20
- 20 to -30
- 30 to -40
- 40 to -50
- 50 to -60
- 60 to -70
- 70 to -80
- 80 to -90
- 90 to -100
- < -100

Bathymetry Difference: 2024 - 2004 (m)

Erosion ↑
↓ Accretion

- < -5
- 5 to -4
- 4 to -3
- 3 to -2
- 2 to -0.5
- 0.5 to 0.5
- 0.5 to 2
- 2 to 3
- 3 to 4
- 4 to 5
- > 5

Sea Floor Geomorphology

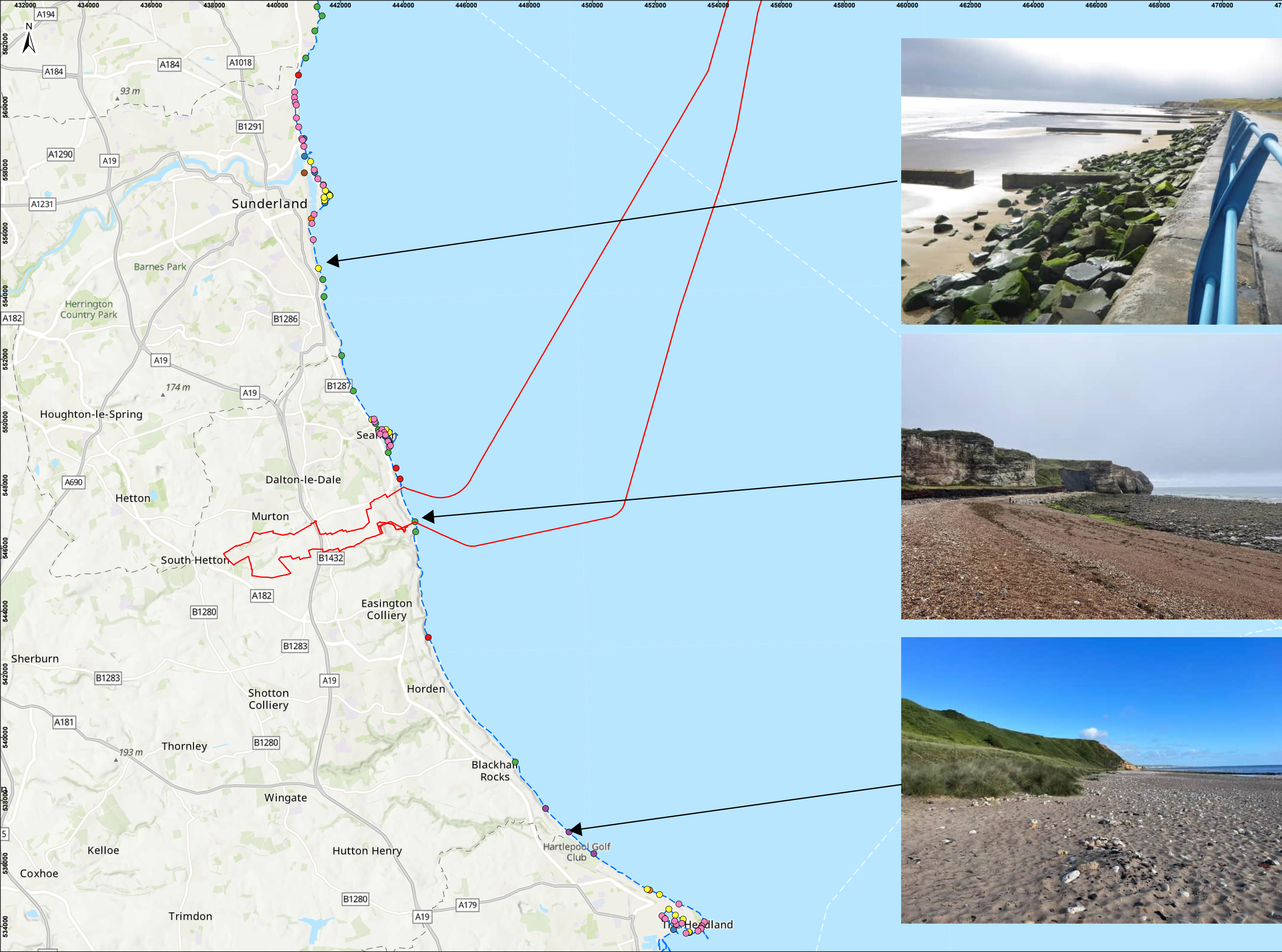
- channel
- moraine



4.3 Coastal geomorphology and characteristics

4.3.1 Regional overview

- 4.3.1.1 The Physical Processes Study Area coastline (which extends from Bamburgh in the North to Whitby in the South) is characterised by the presence of cliffs and dune covered beaches which tend to be resistant to marine erosion (see **Figure 4.18**). Much of this coastline is characterised by the presence of protected habitats and geomorphological features, with are contained within the following designated sites present:
- Durham Coast SAC:
 - Vegetated sea cliffs;
 - Coquet to St Mary's Marine Conservation Zone (MCZ):
 - Inter-tidal and shallow sub-tidal rock, sand, mud and sediment;
 - Northumbria Coast SPA
 - Designated for internationally important bird species whose presence directly relates to the coastal geological and geomorphological characteristics (namely rocky shores, bedrock reefs, and cobble beaches, interspersed with small sandy bays.);
 - Durham Coast SSSI:
 - Vegetated sea cliffs.
- 4.3.1.2 Between Seaham and Hartlepool - the stretch of coastline in which the landfall is located, much of the coastline is undefended with vegetated cliffs and species-rich dune systems present. It is because of these characteristics that this section of coast is designated as both a SSSI and SAC, with the region being the only UK example of 'vegetated sea cliffs on magnesian limestone exposures' (JNCC, 2025) which support populations of important shore and sea birds (Natural England, 1999).
- 4.3.1.3 The general transport of sediment along the coastline is from North to South within the study area with beaches having formed where headlands have interrupted transport and allowed sediment to accumulate (Royal Haskoning, 2007).
- 4.3.1.4 Between Sunderland and Hartlepool the coastline can be split into three distinct sections. Between Sunderland and Seaham Harbour beaches consist of sand and shingle. Between Seaham Harbour and Blackhall rocks (landfall located within this stretch) beaches are contaminated with colliery waste and described as being poorly sorted sediment with mean particles sizes of fine to medium-fine pebbles. Between Blackhall Rocks and Hartlepool, beaches are described as sandy with particles of coal distributed within the sand (Posford Duvivier Environment, 1994; Royal Haskoning, 2007) demonstrating the southwards sediment transport.
- 4.3.1.5 The coastline encompasses two Shoreline Management Plans ("Scottish Border to the River Tyne" and "The Tyne to Flamborough Head"). These plans provide a range of coastal protection policies for both the present and future. The 'Hold the Line' approach tends to be recommended in more populated areas such as in Sunderland and Hartlepool and where valuable infrastructure requires protecting. For example, north of the MHPGC Red Line Boundary Seaham Harbour (SMP2, PDZ3, MA09.4) has a 'Hold the Line' policy recommended for the present and future plans (2055 and 2105) in order to protect current and future port activities (Royal Haskoning, 2007).



- LEGEND**
- MHPGC Project PEIR Red Line Boundary
 - Physical Processes Study Area
 - Coastal Defence
 - Beach
 - Breakwater
 - Cliff
 - Dunes
 - Embankment
 - Engineered high ground
 - Natural high ground
 - Wall



Project Name:
MORVEN HAWTHORN PIT GRID
CONNECTION PROJECT

Drawing Title:
FIGURE 4.18: COASTAL CHARACTERISTICS WITHIN THE PHYSICAL PROCESSES
STUDY AREA

0 1 2 km
Scale@A3: 1:111,628

Geodetic Information:
Datum: WGS 1984
Projection: WGS 1984 UTM Zone 30N

Data Sources:
Images and data courtesy of the National Network of Regional Coastal Monitoring Programmes. Image ID: 121AC901C0301C02 (bottom), 121AC901C0107C01 (middle), 121AB901B0803C02 (top). Available from www.coastalmonitoring.org

Service Layer Credits:
World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS
World Hillshade: Esri, Ordnance Survey, NASA, NGA, USGS
World Topographic Map: Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Drawing Number:
MHPGC-ABP-PP-0008

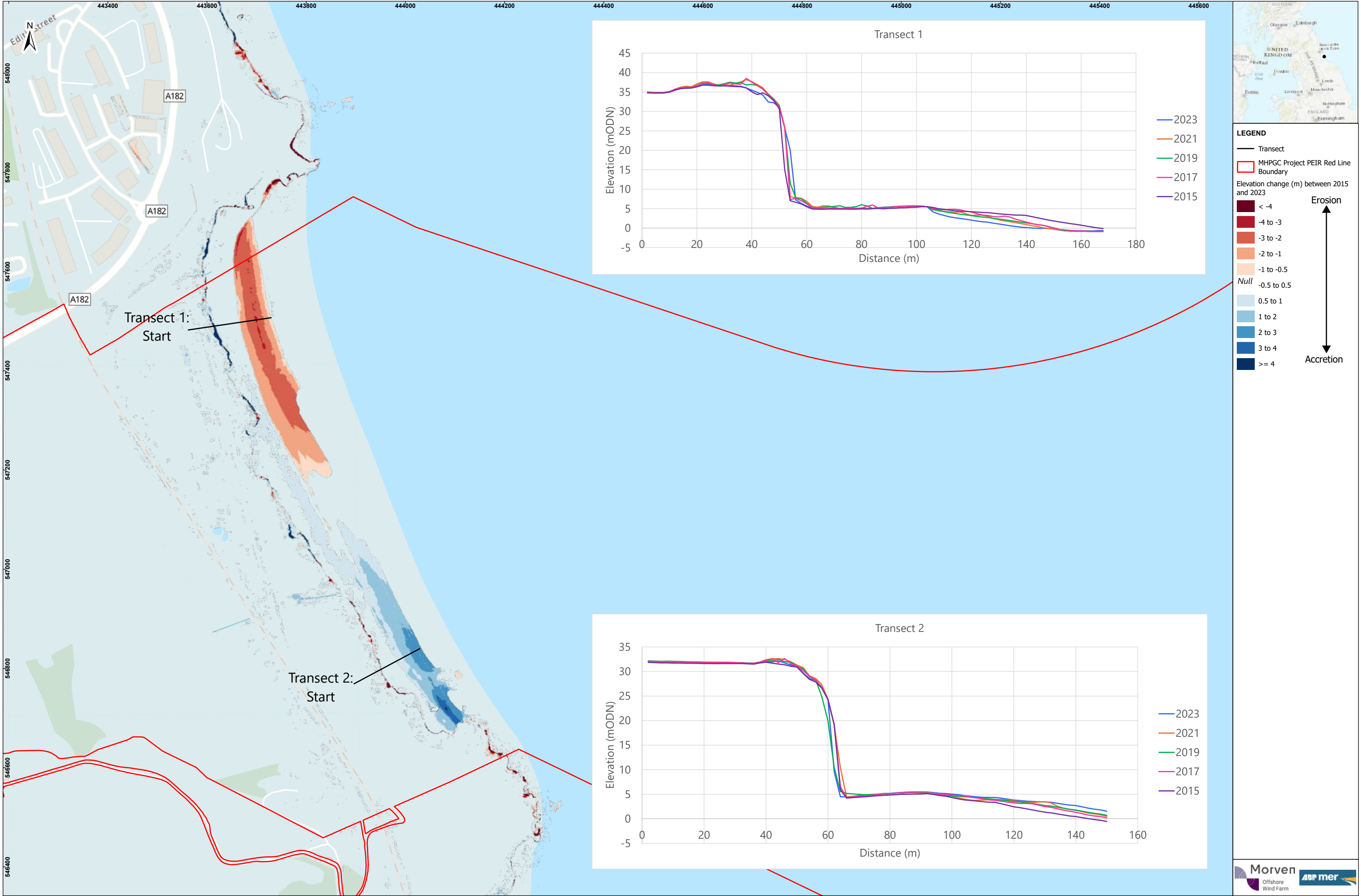
VER	DATE	DETAILS	BY	CHECK
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01	09/07/26	Update Issue	ALN	DOL

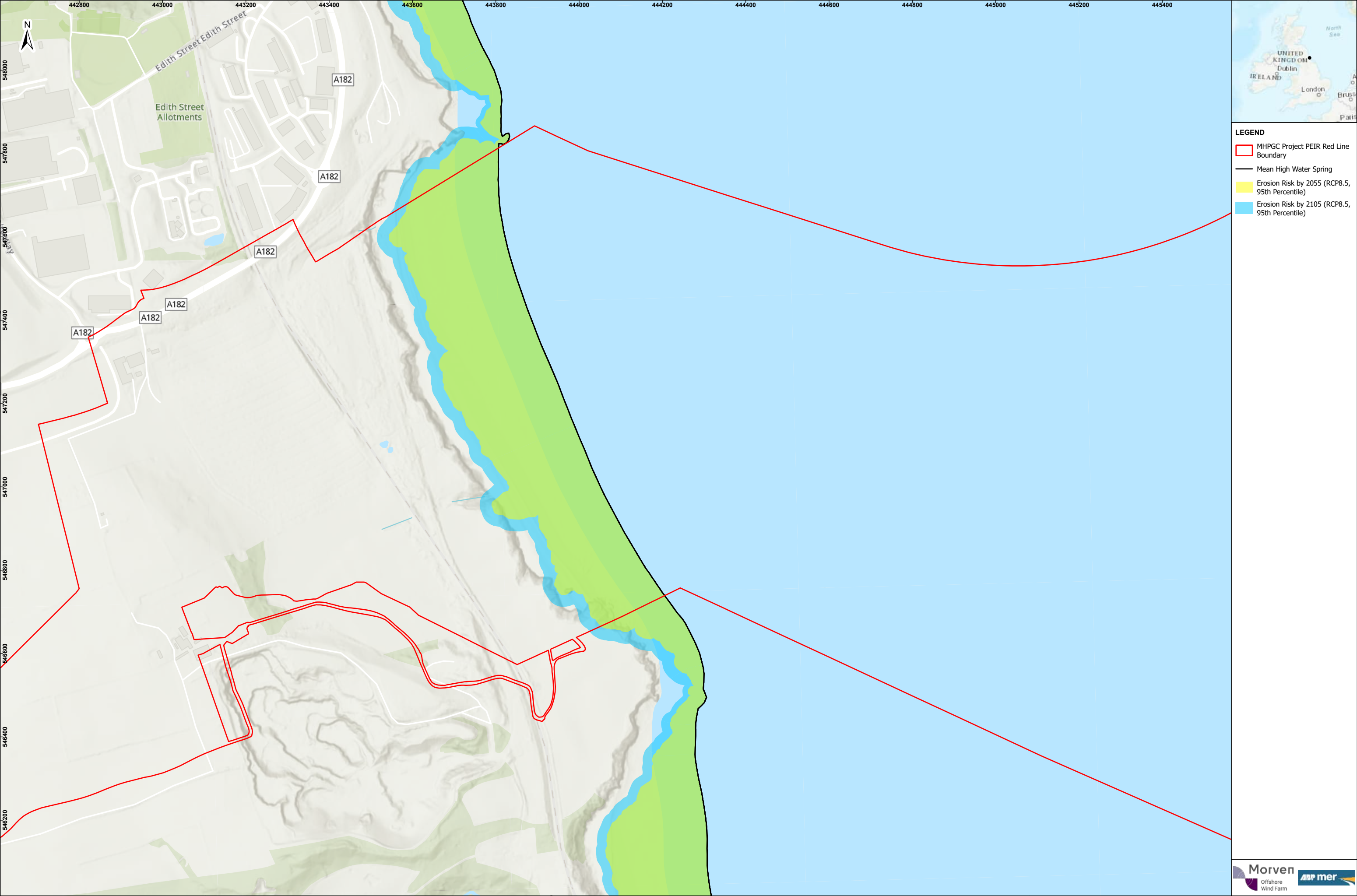
4.3.2 Landfall

- 4.3.2.1 The offshore export cables will make landfall at Blast Beach (just south of Seaham) and be jointed to the onshore export cables within the Transition Jointing Bay. This landfall site extends from Dolostone cliffs, through a man-made platform of soil and colliery waste, to a beach of gravelly sands. A thin sediment veneer is present, however areas of rock outcrop both in the intertidal and nearshore areas as shown in **Figure 4.18** (Royal Haskoning, 2007).
- 4.3.2.2 The historic use of the beach as a colliery dump (operations starting in the 1860s and ceasing in the 1990s) resulted in the progradation of the shoreline during this period and development of a spoil platform in front of the cliffs. The northern end of the site has extended up to 300m offshore. Since the cessation of disposal activities in 1993 this material has been eroding but the shoreline remains seaward of the pre-1860s level, with cliff erosion extremely limited (Pitman *et al*, 2024).
- 4.3.2.3 Aerial imagery in **Figure 4.19**, available from Google Earth, reflects the above, with the landfall coastline appearing stable between 2001 and 2025, in terms of beach extent and cliff location. However, the imagery should be interpreted with caution as the difference in resolution may introduce interpretation errors as stated in Fugro (2024).
- 4.3.2.4 LiDAR data shows that material is transported southwards as the southern end of the beach has accreted material while the northern end has eroded (see **Figure 4.20**), this is evidenced further in the “Cell 1 Regional Coastal Monitoring Programme” which states that material from Blast Beach (the Landfall location) is transported southwards through longshore transport (see **Section 4.3.1**).
- 4.3.2.5 The 2010 Shoreline Management Plan 2 (SMP2) recommends “No Active Intervention” across all time periods (to 2025, to 2055 and to 2105) within the redline boundary. Consequently, it is unlikely that coastal defences will be implemented and the coast will erode naturally. The National Coastal Erosional Risk Mapping dataset, published by the Environment Agency, forecasts the extent of coastline at risk of erosion by 2055 and 2105 at the 95th percentile of RCP 8.5 (see **Figure 4.21**). Areas within a distance of (up to) 270m landwards of the present day Mean High Water Spring (MHWS) mark may be at risk of erosion by 2075 (RCP 8.5, 95th Percentile) (Environment Agency, 2024).



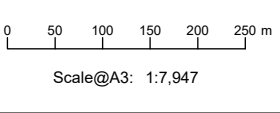
Figure 4.19: Aerial imagery of landfall south of Seaham (Source: Google Earth)





Project Name:
MORVEN HAWTHORN PIT GRID
CONNECTION PROJECT

Drawing Title:
FIGURE 4.21: AREAS AT RISK OF FUTURE COASTAL EROSION WITHIN THE
MHPGC PROJECT PEIR RED LINE BOUNDARY



Geodetic Information:
Datum: UTM Projections
Projection: UTM-30

Data Sources:
Data courtesy of the National Network of Regional Coastal Monitoring Programmes and the Environment Agency (2025). Available from www.coastalmonitoring.org

Service Layer Credits:
World Hillshade: Sources: Esri, Vantor, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NOAA, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap, and the GIS user community
World Topographic Map: Sources: Esri, HERE, Garmin, FAO, NOAA, USGS
World Topographic Map: Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Drawing Number: MHPGC-ABP-PP-0016				
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01	09/07/26	Update Issue	ALN	DOL



5 Summary

- 5.1.1.1 This Technical Report provides a summary of the existing environment across the Physical Processes Study Area, in the absence of any transmission infrastructure. Consideration is given to bathymetry, water levels, currents, waves, seabed sediments and geomorphology. This information has been used to inform the technical assessment of effects on physical processes for the MHPGC Project.

5.2 Scottish waters

- 5.2.1.1 The Physical Processes Study Area is located within a semi-diurnal tidal environment. The furthest northern extent of the MHPGC Project PEIR Red Line Boundary, in Scottish waters, has a spring tidal range of ~2.5m.
- 5.2.1.2 Current speed is relatively uniform in space across the MHPGC Project PEIR Red Line Boundary, with Scottish and English regions of the MHPGC Project PEIR Red Line Boundary showing similar current speed values. Tidal currents are relatively weak, with depth-averaged mean spring peak current speeds typically less than 0.6m/s. During peak flows coinciding with (close to) LW, current direction is approximately northwards in Scottish waters. During peak flows coinciding with (close to) HW, flow directions are reversed.
- 5.2.1.3 Waves in the Scottish waters of the Physical Processes Study Area predominantly come from the north. Mean and extreme significant wave height values are greatest in Scottish waters, mean significant wave height is 1.9m.
- 5.2.1.4 Seabed sediments within the Physical Processes Study Area vary with distance offshore. Further offshore, seabed sediments in Scottish waters tend to comprise sands, gravelly sands and muddy sands, with the sand component originating from Holocene deposits. The thickness of the surficial Holocene veneer within the Physical Processes Study Area is typically thin (<2m). These surficial units are underlain by various sequences of Pleistocene age (the period between approximately 2.6 million years ago and 11,700 years ago).
- 5.2.1.5 The MHPGC Project-specific geophysical survey data shows that water depths within the MHPGC Project PEIR Red Line Boundary that overlaps with Scottish waters range between approximately ~72m LAT and ~60m LAT. The average gradients within the Scottish waters of the Physical Processes Study Area are gentle (<1°).
- 5.2.1.6 The predominant direction of net sediment transport across the Physical Processes Study Area is towards the north, driven by tidal currents. Over much of the Scottish waters Physical Processes Study Area, water depths are too great for waves to cause sediment mobility on a regular basis.
- 5.2.1.7 Potential net sediment transport rates are generally lower across the MHPGC Project PEIR Red Line Boundary in Scottish waters. This is primarily due to naturally weaker tidal currents that are insufficient to frequently or strongly mobilise or transport sand.

5.3 English waters

- 5.3.1.1 The spring tidal range increases as the offshore cable corridor runs southward, into English waters and to the landfall. Near the central point of the MHPGC Project PEIR Red Line Boundary, in English waters, the spring tidal range is ~3.3m. At the landfall the spring tidal range further increases to ~4.3m.
- 5.3.1.2 Tidal currents are relatively weak, with depth-averaged mean spring peak current speeds typically less than 0.6m/s. During peak flows coinciding with (close to) LW, current direction is approximately north northwesterly in English waters. During peak flows coinciding with (close to) HW, flow directions are reversed.
- 5.3.1.3 Waves in the English waters of the Physical Processes Study Area predominantly come from the north-northeast closer to the landfall, with a northward rotation further offshore in English waters. Mean and extreme significant wave height values reduce towards the Landfall, with generally lower

values in English waters compared to further northwards and offshore Scottish waters. For the closest point to the landfall in English waters, the mean significant wave height is 0.9m.

- 5.3.1.4 In offshore English waters seabed sediments tend to comprise sands, gravelly sands and muddy sands. Closer to landfall, seabed sediments mainly comprise fine silty sand, with the occasional isolated regions of more gravelly sand, boulder fields and exposed bedrock close to the coast. The thickness of the surficial Holocene veneer within the Physical Processes Study Area is typically thin (<2m). These surficial units are underlain by various sequences of Pleistocene age (the period between approximately 2.6 million years ago and 11,700 years ago).
- 5.3.1.5 The MHPGC Project-specific geophysical survey data shows that water depths within the MHPGC Project PEIR Red Line Boundary that overlaps with English waters range between approximately ~107m LAT and ~0m LAT at landfall. The steepest gradients within the Physical Processes Study Area (~50°) are associated with a boulder field close to the coast.
- 5.3.1.6 Over much of the English waters Physical Processes Study Area, water depths are too great for waves to cause sediment mobility on a regular basis. However, occasional additional seabed sediment disturbance might be expected due to larger storm waves in relatively shallower water depths (i.e. close to the coastline).
- 5.3.1.7 Sediment transport rates increase closer to the coast, in English waters, where current speeds are typically higher due to flow acceleration around the Northumberland coastline. Generally, the predominant direction of net sediment transport is towards the north. Comparison between the MHPGC Project bathymetric survey and an earlier UKHO survey indicates that bed features have migrated northwards at rates of up to approximately 4m per year.
- 5.3.1.8 The coastline, entirely within English waters, in the Physical Processes Study Area extends from Bamburgh to Whitby. Much of the coastline in this area is natural with cliffs, beaches and dunes present. The export cable is expected to make landfall directly south of Seaham to then join up to the National Grid Substation at the Hawthorn Pit. The landfall site extends from Dolostone cliffs, through a man-made platform of soil and colliery waste, to a beach of gravelly sands. The landfall is located within the Durham Coast SAC and SSSI, which contain designated geomorphological features (vegetated sea cliffs).
- 5.3.1.9 The baseline is expected to evolve in response to natural variation (e.g. lunar nodal cycle, North Atlantic Oscillation), longer-term changes in climate expected over the lifetime of the project, and anthropogenic management of the coast.
- 5.3.1.10 By 2075, relative sea level may have risen by approximately 0.6m above baseline (1981-2000) levels (RCP 8.5)) (Palmer *et al.*, 2018). Sea level rise may result in (for example) loss of intertidal habitat and greater wave energy reaching inter-tidal areas, resulting in morphological change at the coast.

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