Awel y Môr Offshore Wind Farm

Category 6: Environmental Statement

Volume 2, Chapter 2: Marine Geology, Oceanography and Physical Processes

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Glossary of terms

TERM	DEFINITION
Beach	A deposit of non-cohesive material (e.g. sand, gravel) situated on the interface between dry land and the sea (or other large expanse of water) and actively "worked" by present-day hydrodynamic processes (i.e. waves, tides and currents) and sometimes by winds.
Bedforms	Features on the seabed (e.g. sandwaves, ripples) resulting from the movement of sediment over it.
Bedload	Sediment particles that travel near or on the bed.
Benthic	A description for animals, plants and habitats associated with the seabed. All plants and animals that live in, on or near the seabed are benthos.
[Wave] breaking	Reduction in wave energy and height in the surf zone due to limited water depth.
Clay	A fine-grained sediment with a typical grain size of less than 0.004 mm. Possesses electromagnetic properties which bind the grains together to give a bulk strength or cohesion.
Climate change	A long-term trend in the variation of the climate resulting from changes in the global atmospheric and ocean temperatures and affecting mean sea level, wave height, period and direction, wind speed and storm occurrence.
Coast	A strip of land of indefinite length and width that extends from the seashore inland to the first major change in terrain features.
Coastal processes	Collective term covering the action of natural forces on the coastline and adjoining seabed.

TERM	DEFINITION
Cohesive	Sediment containing a significant proportion of clays, the electromagnetic properties of which cause the particles to bind together.
Erosion	Movement of material by such agents as running water, waves, wind, moving ice and gravitational creep.
Geophysical survey	Activities to obtain data on the distribution and nature of geophysical properties of the seabed (e.g. bathymetry, surficial sediment type and bedforms, sub-surface geology). Geophysical survey outputs typically include multibeam bathymetry, side-scan sonar and sub-bottom profiler data.
Habitat	The place in which a plant or animal lives. It is defined for the marine environment according to geographical location, physiographic features and the physical and chemical environment (including salinity, wave exposure, strength of tidal streams, geology, biological zone, substratum, 'features' (e.g. crevices, overhangs, rockpools) and 'modifiers' (e.g. sand-scour, wave-surge, substratum mobility).
Hydrodynamic	Of or relating to the motion of fluids and the forces acting on solid bodies immersed in fluids and in motion relative to them.
Intertidal	The zone between the highest and lowest tides. May also be referred to as the littoral zone.
Light Detecting and Ranging (LiDAR)	A surveying method that measures distance to a target by illuminating that target with a laser light.
Littoral drift, littoral transport	The movement of beach material in the littoral zone by waves and currents. Includes movement

TERM	DEFINITION
	parallel (longshore transport) and perpendicular (onshore- offshore transport) to the shore.
Longshore drift	Or alongshore or littoral drift. Movement of sand and shingle along the shore. It takes place in two zones, at the upper limit of wave activity and in the breaker zone. Movement of beach (sediments) approximately parallel to the coastline.
Mean High-Water Springs	The average throughout the year of two successive high waters during those periods of 24 hours when the range of the tide is at its greatest
Morphological	Of or relating to the form, shape and structure of landforms
Neap tides	Tides with the smallest range between high and low water, occurring at the first and third quarters of the moon.
Regime	The behaviour, statistical properties and trends characterising the variability of hydrodynamic, meteorological, sedimentological and morphological parameters.
Return period	In statistical analysis an event with a return period of N years is likely, on average, to be exceeded only once every N years.
Salinity	Measure of all the salts dissolved in water.
Scour	Local erosion of sediments caused by local flow acceleration around an obstacle and associated turbulence enhancement.
Sediment	Particulate matter derived from rock, minerals or bioclastic debris.
Sediment transport	The movement of a mass of sedimentary material by the forces of currents and waves. The sediment

TERM	DEFINITION
	in motion can comprise fine material (silts and muds), sands and gravels. Potential sediment transport is the full amount of sediment that could be expected to move under a given combination of waves and currents, i.e. not supply limited.
Sediment transport pathway	The routes along which net sediment movements occur.
Significant wave height	The average height of the highest of one third of the waves in a given sea state.
Spring tides	Tides with the greatest range which occur at or just after the new and full moon.
Seastate	The state of the sea as described using the Douglas sea scale, based on wave height and swell, ranging from 1 to 10, with accompanying descriptions.
Shoreline Management Plan (SMP)	A large-scale assessment of the risks associated with coastal processes. It aims to lessen these risks to people and the developed, historic and natural environments.
Surficial sediments	Sediments located at the seabed surface (not necessarily of the same character as underlying sediments).
Surge	In water level as a result of meteorological forcing (wind, high or low barometric pressure) causing a difference between the recorded water level and that predicted using harmonic analysis, may be positive or negative.
Suspended sediment concentration	Mass of sediment in suspension per unit volume of water.
Swell (waves)	Wind-generated waves that have travelled out of their generating area. Swell characteristically

TERM	DEFINITION
	exhibits a more regular and longer period and has flatter crests than waves within their fetch.
Tidal current asymmetry	1) Relative difference in peak current speed or duration of adjacent flood and ebb half tidal cycles. 2) Relative difference in high or low water levels or duration of adjacent flood and ebb half tidal cycles.
Tidal excursion	The Lagrangian movement (the physics of fluid motion as an individual fluid parcel moves through space and time) of a water particle during a tidal cycle.
Tidal excursion ellipse	The path followed by a water particle in one complete tidal cycle.
Tidal harmonics	Component parts of the tidal (water level) signal at a location. A discrete timeseries of tides can be separated into a variable number of sinusoidal signals of known frequency, phase and amplitude. These can be used to predict values for the same location, outside of the original period of data.
Tide	The periodic rise and fall in the level of the water in oceans and seas; the result of gravitational attraction of the sun and moon.
Topographic	The form of the features of the actual surface of the earth in a particular region considered collectively
United Kingdom Climate Projections (UKCP)	UKCP18 is the name given to the latest UK Climate Projections. UKCP18 provides information on plausible changes in 21st century climate for land and marine regions in the United Kingdom.
Wave propagation	The spread of waves across the sea which in deep water will usually be in the direction of the wind

TERM	DEFINITION
	causing them. In shallow water the direction will vary due to the influence of the seabed and tidal currents.
Wave refraction	When waves approach the shoreline obliquely, the wave crests tend to conform to the bottom (bed) contours; due to the inshore portion of the wave travelling at a lower velocity than the portion in deeper water. The extent of wave refraction depends on the relative magnitudes of water depth to wavelength.

Abbreviations and acronyms

TERM	DEFINITION
AyM	Awel y Môr Offshore Wind Farm
BSI	British Standards Institution
CBRA	Cable Burial Risk Assessment
Cefas	Centre for Environment, Fisheries and Aquaculture Science
COWRIE	Collaborative Offshore Wind Research into the Environment
CPA	Coast Protection Act
CSIP	Cable Specification and Installation Plan
Defra	Department for Environment, Food and Rural Affairs
(Offshore) ECC	Export Cable Corridor
EIA	Environmental Impact Assessment
ES	Environmental Statement

TERM	DEFINITION
ETG	Expert Technical Group
FEPA	Food and Environment Protection Act
GBF	Gravity Base Foundation
GyM	Gwynt y Môr Offshore Wind Farm
HDD	Horizontal Directional Drilling
LAT	Lowest Astronomical Tide
MCZ	Marine Conservation Zone
MDS	Maximum Design Scenario
MFE	Mass Flow Excavator
MHWS	Mean High Water Springs
MMO	Marine Management Organisation
MW	Megawatt
NPS	National Policy Statement
NRW	Natural Resources Wales
O&M	Operation & Maintenance
OSP	Offshore Substation Platform
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
RCP	Representative Concentration Pathway
RIAA	Report to Inform Appropriate Assessment
cSAC	(candidate) Special Area of Conservation
SCI	Site of Community Importance

TERM	DEFINITION
SMP	Shoreline Management Plan
SPA	Special Protection Area
SSC	Suspended Sediment Concentration
SSSI	Sites of Special Scientific Interest
TSHD	Trailing Suction Hopper Dredger
SoS	Secretary of State
WTG	Wind Turbine Generator

Units

UNIT	DEFINITION
GW	Gigawatt (power)
km	Kilometre (distance)
kg	Kilogram (mass)
m	Metre (distance)
m/hr	Metres / hour (speed)
m/s	Metres / second (speed)
MW	Megawatt (power)
Mg/l	Milligram / litre (concentration)
yr	Year
%ile	Percentile

2 Marine Geology, Oceanography and Physical Processes

2.1 Introduction

1 This chapter of the Environmental Statement (ES) presents the results of the Environmental Impact Assessment (EIA) for the potential impacts of the Awel y Môr Offshore Wind Farm (AyM) on marine geology, oceanography and physical processes (hereafter referred to as physical processes). It builds upon the earlier work undertaken for the Preliminary Environmental Information Report (PEIR), taking into account feedback from statutory consultation on the published analysis. Specifically, this chapter considers the potential impact of AyM seaward of Mean High-Water Springs (MHWS) during its construction, operation and maintenance (O&M), and decommissioning phases.

2 Marine physical processes is a collective term for the following:

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

3 The assessment results presented in this chapter and in the accompanying technical annex (Volume 4, Annex 2.3: Marine Geology, Oceanography and Physical Processes Technical Assessment; application ref: 6.4.2.3) have been used to inform the impact assessments for other environmental receptors, considered within the following chapters:

- Volume 2, Chapter 3: Marine Water and Sediment Quality (application ref: 6.2.3);
- Volume 2, Chapter 4: Offshore Ornithology (application ref: 6.2.4);
- Volume 2, Chapter 5: Benthic and intertidal Ecology (application ref: 6.2.5);

- Volume 2, Chapter 6: Fish and Shellfish (application ref: 6.2.6); and
- Volume 2, Chapter 7: Marine Mammals (application ref: 6.2.7).

2.2 Statutory and policy context

4 The assessment of potential impacts upon physical processes has been made with specific reference to the relevant legislation, plans and policies. Details of legislation and policy are provided in Volume 1: Chapter 2 Policy and Legislation (application ref: 6.1.2). Those specifically relevant to this Chapter are:

- Conservation of Habitats and Species Regulations 2017;
- Overarching NPS for Energy (EN-1) (July 2011; draft review September 2021);
- NPS for Renewable Energy Infrastructure (EN-3) (July 2011; draft review September 2021);
- Welsh National Marine Plan (2019); and
- Planning Policy Wales 11 (2021).

5 Relevant legislation and policy are outlined in Table 1.

Table 1: Legislation and policy context.

LEGISLATION/ POLICY	KEY PROVISIONS	SECTION WHERE COMMENT ADDRESSED
Conservation of Habitats and Species Regulations 2017	Maintain or, where appropriate, restore habitats and species listed in Annexes I and II of the Habitats Directive to a favourable conservation status.	The study area overlaps with Liverpool Bay SPA, Dee Estuary SAC and Dee Estuary SPA and Menai Strait and Conwy SAC which contain the qualifying geological and geomorphological features (Figure 1). Constable Bank and Rhyl Flats are geomorphological features of specific importance. The impacts on Constable Bank, Rhyl Flats and site geological and geomorphological features are assessed specifically throughout this Chapter.
NPS EN-1	Paragraph 5.5.6: Where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures.	Predictions of change to physical processes that could arise from construction, O&M and decommissioning of AyM are presented in paragraphs 42 to 248.
NPS EN-1	Paragraph 5.5.7: The Environmental Statement should include an assessment of the effects on the coast. In particular, applicants should assess:	The impact of AyM on coastal processes and geomorphology is considered in paragraph 42 *et seq.* (for the construction

LEGISLATION/ POLICY	KEY PROVISIONS	SECTION WHERE COMMENT ADDRESSED
	• The impact of the proposed project on coastal processes and geomorphology, including by taking account of potential impacts from climate change. If the development will have an impact on coastal processes the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on other parts of the coast; • The implications of the proposed project on strategies for managing the coast as set out in Shoreline Management Plans (SMPs), any relevant Marine Plans…and capital programmes for maintaining flood and coastal defences; • The effects of the proposed project on marine ecology, biodiversity and protected sites; • The effects of the proposed project on maintaining coastal recreation sites and features; and The vulnerability of the proposed development to coastal change, taking account of climate change, during the project's operational life and any decommissioning period.	phase), paragraph 141 *et seq.* (for the O&M phase) and paragraph 207 *et seq.* (for the decommissioning phase). The implications of the proposed project on strategies for managing the coast are considered within the landfall assessment, presented in paragraph 102 *et seq. and* paragraph *123 et seq*. The effects of the proposed project on marine ecology, biodiversity and protected sites are set out elsewhere in the ES, in particular in Volume 2, Chapter 5; The effects of the proposed project on maintaining coastal recreation sites and features are set out in Volume 2, Chapter 12: Other Marine Users and Activities (application ref: 6.2.12). The vulnerability of the proposed development to coastal change is considered in the context of the project

LEGISLATION/ POLICY	KEY PROVISIONS	SECTION WHERE COMMENT ADDRESSED
		design, in Volume 2, Chapter 1: Offshore Project Description (application ref: 6.2.1).
NPS EN-1	Paragraph 5.5.9: The applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Conservation Zones (MCZs), candidate marine Special Areas of Conservation (cSACs), coastal SACs and candidate coastal SACs, coastal Special Protection Areas (SPAs) and potential Sites of Community Importance (SCIs) and Sites of Special Scientific Interest (SSSI).	The predicted changes to physical processes have been considered in relation to indirect effects on other receptors elsewhere in the ES, in particular in Volume 2, Chapter 5 and in Volume 2, Report 5.1: Report to Inform Appropriate Assessment (RIAA) (application ref: 5.2).
NPS EN-1	Paragraph 5.5.11: The Secretary of State (SoS) should not normally consent new development in areas of dynamic shorelines where the proposal could inhibit sediment flow or have an adverse impact on coastal processes at other locations. Impacts on coastal processes must be managed to minimise adverse impacts on other parts of the coast. Where such proposals are brought forward consent should only be granted where the SoS is satisfied that the benefits	A cable landfall assessment is presented in paragraph 102 *et seq. and* paragraph *123 et seq*. This assessment considers the nature of ongoing shoreline change at the landfall and the potential for cables and other project infrastructure to impact coastal processes. A full description of coastal processes understanding at the landfall is set out in Volume 4, Annex 2.1:

LEGISLATION/ POLICY	KEY PROVISIONS	SECTION WHERE COMMENT ADDRESSED
	(including need) of the development outweigh the adverse impacts.	Physical Processes Baseline (application ref: 6.4.2.1)
NPS EN-1	Section 4.8: The resilience of the project to climate change (such as increased storminess) should be assessed in the Environmental Statement accompanying an application.	Potential changes in climate are described in Volume 4, Annex 2.1 and are considered alongside predicted changes described in the assessment sections (paragraph 42 *et seq.*).
NPS EN-3	Paragraph 2.6.81: An assessment of the effects of installing cable across the intertidal zone should include information, where relevant, about: • Any alternative landfall sites that have been considered by the applicant during the design phase and an explanation for the final choice; • Any alternative cable installation methods that have been considered by the applicant during the design phase and an explanation for the final choice; • Potential loss of habitat;	Predictions of change to physical processes that could arise from the construction, and O&M of AyM are presented in paragraph 42 to 206. A cable landfall assessment is presented in paragraph 102 *et seq. and* paragraph *123 et seq*. This assessment considers the nature of ongoing shoreline change at the landfall and the potential for cables and other project infrastructure to impact coastal processes. Details regarding alternative landfall sites that have been considered during the

LEGISLATION/ POLICY	KEY PROVISIONS	SECTION WHERE COMMENT ADDRESSED
	• Disturbance during cable installation and removal (decommissioning); • Increased suspended sediment loads in the intertidal zone during installation; and Predicted rates at which the intertidal zone might recover from temporary effects.	design phase and an explanation for the final choice are provided in Volume 1, Chapter 4: Site Selection and Consideration of Alternatives (application ref: 6.1.4).
NPS EN-3	Paragraph 2.6.113: Where necessary, assessment of the effects on the subtidal environment should include: • Environmental appraisal of array and cable routes and installation methods; • Habitat disturbance from construction vessels' extendible legs and anchors; • Increased suspended sediment loads during construction; and Predicted rates at which the subtidal zone might recover from temporary effects.	Predictions of change to physical processes that could arise from construction, O&M and decommissioning of AyM are presented in paragraphs 42 to 248.
NPS EN-3	Paragraph 2.6.190: Assessment should be undertaken for all stages of the lifespan of the proposed wind farm in	The impact of the proposed project on coastal processes and geomorphology is considered in paragraph 42 *et seq*. (for

LEGISLATION/ POLICY	KEY PROVISIONS	SECTION WHERE COMMENT ADDRESSED
	accordance with the appropriate policy for offshore wind farm EIAs.	the construction phase), paragraph 141 *et seq.* (for the O&M phase) and paragraph 207 *et seq.* (for the decommissioning phase).
NPS EN-3	Paragraph 2.6.191 and 2.6.192: The Applicant should consult the Environment Agency, Marine Management Organisation (MMO) and Centre for Environment, Fisheries and Aquaculture Science (Cefas) on methods for assessment of impacts on physical processes.	Consultation on the approach to assessment for physical processes has been carried out with Natural Resources Wales (NRW) as the relevant marine licencing body. Details of the approach to consultation are provided in Table 2.
NPS EN-3	Paragraph 2.6.192: Mitigation measures which the Infrastructure Planning. Commission (IPC) (now the Planning Inspectorate (PINS)) should expect the applicants to have considered include the burying of cables to a necessary depth and using scour protection techniques around offshore structures to prevent scour effects around them. Applicants should consult the statutory consultees on appropriate mitigation.	The mitigation relating to cable burial and scour are set out in Table 8. Consultation is ongoing with statutory consultees and other interested parties.
NPS EN-3	Paragraph 2.6.193: Geotechnical investigations should form part of the assessment as this will enable the design	Geotechnical data was collected to inform the (adjacent) GYM assessment. This has been used alongside the project

LEGISLATION/ POLICY	KEY PROVISIONS	SECTION WHERE COMMENT ADDRESSED
	of appropriate construction techniques to minimise any adverse effects.	specific geophysical survey (Fugro, 2020a; b) to inform the assessment and project design of AyM.
NPS EN-3	Paragraph 2.6.194: The assessment should include predictions of the physical effect that will result from the construction and operation of the required infrastructure and include effects such as the scouring that may result from the proposed development.	Predictions of change to physical processes that could arise from the construction, and O&M of AyM are presented in paragraphs 42 to 206.
NPS EN-3	Paragraph 2.6.195: The direct effects on the physical environment can have indirect effects on a number of other receptors. Where indirect effects are predicted, the IPC (now the Planning Inspectorate (PINS) should refer to relevant Sections of this NPS and EN 1.	The predicted changes to the physical environment have been considered in relation to indirect effects on other receptors elsewhere in the ES, in particular within Volume 2, Chapter 5 and in Volume 2, Chapter 3.
NPS EN-3	Paragraph 2.6.196: The methods of construction, including use of materials should be such as to reasonably minimise the potential for impact on the physical environment.	The project has proposed designs and installation methods that seek to minimise significant adverse effects on the physical environment where possible. Where necessary, the assessment has set out mitigation to avoid or reduce significant adverse effects.

LEGISLATION/ POLICY	KEY PROVISIONS	SECTION WHERE COMMENT ADDRESSED
NPS EN-3	Paragraph 2.6.197: Mitigation measures which the SoS should expect the applicant to have considered include the burying of cables to a necessary depth and using scour protection techniques around offshore structures to prevent scour effects around them. Applicants should consult the statutory consultees on appropriate mitigation.	The mitigation measures relating to cable burial and scour are set out in Table 8.
Draft NPS EN-3	Paragraph 2.25.1: The construction, operation and decommissioning of offshore energy infrastructure can affect the following elements of the physical offshore environment, which can have knock on impacts on other biodiversity receptors: • water quality • waves and tides • scour effect • sediment transport • suspended solids	Predictions of change to physical processes (including all of those listed in paragraph 2.25.1 of Draft NPS EN-3) which could arise from construction, O&M and decommissioning of AyM are presented in paragraphs 42 to 248.
Draft NPS EN-3	Paragraph 2.25.3: Geotechnical investigations should form part of the assessment as this will enable design of appropriate construction techniques to minimise any adverse effects.	Geotechnical data was collected to inform the (adjacent) GYM assessment. This has been used alongside the project specific geophysical survey (Fugro,

LEGISLATION/ POLICY	KEY PROVISIONS	SECTION WHERE COMMENT ADDRESSED
		2020a; b) to inform the assessment and project design of AyM.
Draft NPS EN-3	Paragraph 2.25.5: The Secretary of State should expect applicants to have considered the best ecological outcomes in terms of potential mitigation. These might include the burying of cables to a necessary depth, using scour protection techniques around offshore structures to prevent scour effects or designing turbines to withstand scour, so scour protection is not required or is minimised.	The mitigation measures relating to cable burial and scour are set out in Table 8.
Draft NPS EN-5	Paragraph 2.6.1: Applicants should in particular set out to what extent the proposed development is expected to be vulnerable, and, as appropriate, how it has been designed to be resilient to… coastal erosion – for the landfall of offshore transmission cables and their associated substations in the inshore and coastal locations respectively.	The vulnerability of the Proposed Development to coastal change is considered in the context of the project design, in in Volume 2, Chapter 1. A cable landfall assessment is presented in paragraph 102 *et seq. and* paragraph *123 et seq*. This assessment considers the nature of ongoing and potential future shoreline change at the landfall. A full description of coastal processes

LEGISLATION/ POLICY	KEY PROVISIONS	SECTION WHERE COMMENT ADDRESSED
		understanding at the landfall is set out in Volume 4, Annex 2.1.
Welsh National Marine Plan (2019)	Policy SOC_08: Resilience to coastal change and *Flooding*: Proposals should demonstrate how they are resilient to coastal change and flooding over their lifetime.	Potential changes in climate are described in Volume 4, Annex 2.1 and are considered alongside predicted changes described in the assessment sections (paragraph 42 *et seq*).
Welsh National Marine Plan (2019)	Policy SOC_09: Effects on coastal change and flooding: Proposals should demonstrate how they: • avoid significant adverse impacts upon coastal processes; and • minimise the risk of coastal change and flooding.	Predictions of change to physical processes at the coast that could arise from the construction, O&M and decommissioning of AyM are presented in paragraphs 42 to 248. An assessment of flood risk is set out within Volume 3, Chapter 7: Hydrology and Flood Risk (application ref: 6.3.7)
Welsh National Marine Plan (2019)	SOC_11: Resilience to climate change: Proposals should demonstrate that they have considered the impacts of climate change and have incorporated appropriate adaptation measures	Potential changes in climate are described in Volume 4, Annex 2.1 and are considered alongside predicted changes described in the assessment sections (paragraph 42 *et seq*).

LEGISLATION/ POLICY	KEY PROVISIONS	SECTION WHERE COMMENT ADDRESSED
Welsh National Marine Plan (2019)	GOV_01: Cumulative effects: Proposals should demonstrate that they have assessed potential cumulative effects and should, in order of preference: a. avoid adverse effects; and/or b. minimise effects where they cannot be avoided; and/or c. mitigate effects where they cannot be minimised.	An assessment of the potential for cumulative effects with other projects in the study area is considered in paragraph 220 *et seq.*
Planning Policy Wales (2021)	Where development is considered to be justified it should be designed so as to be resilient to the effects of climate change over its lifetime and not result in unacceptable incremental increases in risk.	Potential changes in climate are described in Volume 4, Annex 2.1 and are considered alongside predicted changes described in the assessment sections (paragraph 42 *et seq*).
Planning Policy Wales (2021)	It is not appropriate for development in one location to unacceptably add to the impacts of physical change to the coast in another location.	Predictions of change to physical processes at the coast that could arise from the construction, O&M and decommissioning of AyM are considered for all phases of development and presented in paragraph 42 to 248.

6 The following guidance documents have been used to inform the assessment methodologies used in this chapter:

- ‘Marine Physical Processes Guidance to inform Environmental Impact Assessment’ (NRW, 2020)
- ‘Evidence Report No: 243 Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to inform EIA of Major Development Projects.’ For Natural Resources Wales. (Brooks et al. 2018);
- ‘Evidence Report No: 208 Advice to Inform Development of Guidance on Marine, Coastal and Estuarine Physical Processes Numerical Modelling Assessments.’ For Natural Resources Wales. (Pye et al. 2017);
- 'Environmental impact assessment for offshore renewable energy projects.' (BSI, 2015).
- 'Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects'. (Cefas, 2011);
- 'General advice on assessing potential impacts of and mitigation for human activities on Marine Conservation Zone features, using existing regulation and legislation' (JNCC and Natural England, 2011);
- 'Coastal Process Modelling for Offshore Wind farm Environmental Impact Assessment: Best Practice Guide'. ABPmer & HR Wallingford for COWRIE, 2009, [redacted];
- 'Guidelines in the use of metocean data through the lifecycle of a marine renewables development'. (ABPmer et al., 2008); and
- 'Offshore Windfarms: Guidance note for Environmental Impact Assessment in Respect of FEPA and CPA requirements'. (Cefas, 2004).

7 The following studies have also been considered:

- 'Review of environmental data associated with post-consent monitoring of licence conditions of offshore wind farms'. MMO Project No: 1031. (Fugro-Emu, 2014);
- 'Further review of sediment monitoring data'. (COWRIE ScourSed-09).’ (ABPmer et al., 2010);

- 'Review of Cabling Techniques and Environmental Effects applicable to the Offshore Wind farm Industry'. Department for Business Enterprise and Regulatory Reform in association with Defra. (BERR, 2008);
- 'Review of Round 1 Sediment process monitoring data - lessons learnt. (Sed01)' (ABPmer et al., 2007);
- 'Dynamics of scour pits and scour protection - Synthesis report and recommendations. (Sed02)' (HR Wallingford et al., 2007); and
- 'Potential effects of offshore wind developments on coastal processes'. (ABPmer and METOC, 2002).

2.3 Consultation and scoping

8 As part of the EIA process for AyM, a formal Scoping Opinion (PINS, 2020) was sought from PINS following submission of the Scoping Report (RWE, 2020).

9 Ongoing consultation has taken place through the Marine Ecology and Marine Mammals Expert Topic Group (ETG) of which covers (amongst other topics) marine physical processes. This process supports the development of the AyM Evidence Plan (the Evidence Plan) within which agreement has been sought as to the suitability of available evidence, assessment methodologies, and forthcoming guidance where appropriate.

10 Consultation responses and responses received through the development of the Evidence Plan have been important in informing this ES chapter and in the development of the technical supporting annexes.

11 Responses relating to physical processes are addressed throughout this chapter. Table 2 provides a summary of key points raised and describes how they have been addressed.

Table 2: Summary of consultation relating to physical processes.

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
July 2020 Scoping	The Scoping report does not provide sufficient justification for new numerical modelling to be ruled out	This issue has been progressed through the Evidence Plan process and new numerical modelling has been undertaken to inform the AyM assessment of changes to the wave and tidal regime, as well as the characterization of sediment plumes. Details of the model set up are provided in Volume 4, Annex 2.2: Physical Processes Model Calibration (application ref: 6.4.2.2)
July 2020 Scoping	The ES should include an assessment of cumulative effects for all aspects and matters where significant effects are likely to occur. The assessment of cumulative effects should not be limited to one particular development type and should instead focus on the potential for overlapping impacts and likely significant effects.	A cumulative effects assessment has been undertaken which takes into consideration the potential for effects arising from a range of activities including aggregate extraction, tidal lagoon development and Round 4 offshore wind farms. The assessment is presented in paragraph 220 *et seq*.

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
July 2020 Scoping	The PEIR/ ES needs to clearly explain how spreadsheet assessments will use existing baseline data and site-specific surveys to assess impacts on suspended sediment concentrations, bed levels and sediment type.	This issue has been progressed through the Evidence Plan process with spreadsheet-based assessments now used alongside new numerical modelling to impacts on suspended sediment concentrations, bed levels and sediment type. The assessment approach is set out in Volume 4, Annex 2.3.
July 2020 Scoping	The PEIR/ ES needs to clearly explain how the assessment will use existing baseline data to assess impacts resulting from scour.	A full scour assessment is set out in Volume 4, Annex 2.3 with summary results presented in paragraph 141 *et seq*. The assessment draws on a range of baseline data described in Volume 4, Annex 2.1 including water depths, seabed sediment type, thickness of surficial sediment horizons and wave data.
July 2020 Scoping	The assessment should take into account the impacts associated with the use of scour protection.	Impacts associated with the use of scour protection are considered in the scour assessment presented in Volume 4, Annex 2.3 and in paragraph 141 et *seq*.

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
July 2020 Scoping	The PEIR/ ES should address the potential overlap between onshore geology and ground assessment in the ES and ensure that any significant effects on the intertidal area are assessed.	The potential for significant effects at the landfall is considered in paragraph 102 *et seq. and* paragraph *123 et seq*. The results of this assessment have subsequently been taken into consideration within Volume 3, Chapter 6: Ground Conditions and Land Use (application ref: 6.3.6).
July 2020 Scoping	The PEIR/ ES should describe the mitigation measures relied upon in the assessment and include a justification for the quantity of scour protection required and the area to be covered.	mitigation measures adopted by the Project are set out in paragraph 40 *et seq*. The spatial footprint and volume of scour protection which may be required is set out in Volume 2, Chapter 1.
July 2020 Scoping	The PEIR/ ES should include an assessment of the effects to relevant designated sites resulting from impacts (direct and indirect) to physical processes.	Designated sites are identified as physical processes receptors (Section 1.7) and are considered within the assessment of impacts arising during construction, O&M and decommissioning of AyM set out in paragraph 42 to 248.

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
July 2020 Scoping	The PEIR/ ES should include an assessment of the impacts associated with dredging and Horizontal Directional Drill (HDD) activities where significant effects are likely to occur.	An assessment of potential impacts associated with trenchless installation techniques (including HDD) is set out in paragraph 102 *et seq*. Potential changes in SSC and bed levels associated with dredging activities are set out in paragraph 45 *et seq*. Potential morphological changes to Constable Bank/ Rhyl Flats and along the adjacent coast arising from dredging activities are set out in paragraph 73 et seq.
July 2020 Scoping	The ES should include an assessment of the impacts associated with changes to tidal, wave and the sediment transport regime during the construction and decommissioning phase where significant effects are likely to occur.	Potential changes to Constable Bank/ Rhyl Flats and along the adjacent coast, arising from blockage effects associated with (partially) installed infrastructure are considered in paragraph 98 *et seq*.
July 2020 Scoping	Llandudno Town Council has concerns with regards to:	The potential for long-term damage to the marine environment arising from

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
	(i) the potential for long-term damage to the marine environment arising from construction related impacts; and (ii) the potential for impacts to Rhyl Flats and Constable Bank, resulting in an enhanced risk of coastal erosion and flooding	construction related impacts are set out in paragraph 42 *et seq*. The potential for impacts to Rhyl Flats and Constable Bank, resulting in an enhanced risk of coastal erosion and flooding are considered in paragraph 42 *et seq*.
December 2020 Evidence Plan consultation	It is important to ensure that the WFD assessment is linked to Physical Processes impacts.	Outputs from the marine physical processes assessment have been used to inform the WFD assessment which is presented in Volume 2, Chapter 3.
December 2020 Evidence Plan consultation	The potential for impacts at the landfall associated with cable installation must be explicitly defined	A cable landfall assessment is presented in paragraph 102 *et seq and* paragraph *123 et seq*.
December 2020 Evidence Plan consultation	The ground preparation works defined in the project Design Statement should include the amount (volume) of sediment removed through sand wave clearance in preparation for laying	The volumes of sediment removed through sand wave clearance in preparation for laying the export cable, as well as the Wind Turbine Generator (WTG) foundation preparation are set out in Table 7

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
	the export cable, as well as the Wind Turbine Generator (WTG) foundation preparation	
December 2020 Evidence Plan consultation	NRW is not comfortable ruling out the potential need for new numerical modelling of suspended sediment plumes to inform the AyM assessment	New numerical modelling has been undertaken to inform the AyM assessment of changes to the wave and tidal regime, as well as the characterization of sediment plumes. Details of the model set up are provided in Volume 4, Annex 2.2.
December 2020 Evidence Plan consultation	Any requirement for cable protection at the landfall could result in long-term morphological change. This must be considered in the PEIR/ ES.	The potential for long-term morphological change associated with the use of cable protection at the landfall is considered in paragraph 102 *et seq and* paragraph 123 *et seq*.
December 2020 Evidence Plan consultation	The assessment must clearly identify any impacts to Constable Bank and assess the potential for onward impacts to the coast	Constable Bank is recognized as a potentially sensitive receptor (Section 1.7). The potential for onward impacts to the coast arising from modification of the Bank is set out in paragraph 199 *et seq*.

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
December 2020 Evidence Plan consultation	If the existing evidence base is used to inform assessment, it must be clearly demonstrated that the activities under consideration are sufficiently analogous to those proposed for AyM.	The evidence base has been used alongside new numerical modelling and other analytical techniques to inform the assessments presented in paragraph 42 *et seq*. Where the evidence base has been used to help inform the assessment, consideration of the degree to which the setting is similar to AyM has been made.
December 2020 Evidence Plan consultation	Modelling scenarios used to inform the assessment should factor in the naturally occurring variability in, and long-term changes to marine processes during the AyM lifetime.	The modelling scenarios set out within the impact assessment (paragraph 42 *et seq*.) have deliberately considered a range of environmental conditions to reflect natural system variability. These include: water levels at high/ low water spring tides; high magnitude/ low frequency wave events and low magnitude/ high frequency wave events.
December 2020	The potential for in-combination effects associated with multiple concurrent construction	The potential for in-combination effects is considered within paragraph 71.

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
Evidence Plan consultation	related activities in the array and offshore Export Cable Corridor (ECC) should be clearly assessed in the PEIR/ ES.	
December 2020 Evidence Plan consultation	If cable protection is used at the landfall, its removal during the decommissioning phase could result in longer term impacts as the coast stabilises to a new equilibrium post removal.	Potential changes to the coast arising from cable removal at the landfall are considered within paragraph 214 *et seq.* This assessment takes into consideration the potential for longer term impacts.
March 2021 Evidence Plan consultation	An assessment of scour should be undertaken including any secondary scour associated with cable protection measures	A full scour assessment is presented in Volume 4, Annex 2.3 with a summary of the results presented in paragraph 141 *et seq*.
March 2021 Evidence Plan consultation	The modelling should show how changes to hydrodynamics and waves alter patterns of bed shear stress and sediment transport	The model developed to inform this investigation (Volume 4, Annex 2.2) has been used to determine the magnitude and extent of change in bed shear stress within the study area in response to the Maximum Design Scenario (MDS). This is discussed in the context of potential

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
		changes to sediment transport (paragraph 184 *et seq*.)
November 2021 Section 42 response	Further consideration of the transport links between Constable Bank/Rhyl Flats and the coast is required.	Further information on baseline sediment transport on and around Constable Bank/ Rhyl flats (as well as in adjacent nearshore waters) has been presented Volume 4, Annex 2.1.
November 2021 Section 42 response	It is not clear if a thorough assessment has been conducted to determine the time it will take for any dredge spoil mounds (deposited under the hopper constituting up to 90% of dredge spoil) to reach background seabed levels under prevailing hydrodynamic conditions. Further investigation is required to assess the recoverability of spoil mounds comprising coarse (gravel sized) material.	An assessment of the degree to which any spoil mounds will persist on the seabed has been presented in paragraph 61 *et seq.*
November 2021	NRW advise that in the event that cable protection is used at the landfall it should be monitored post construction and over the life	A Cable Management Plan will be developed. It will include details of the need, type, quantity and installation

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
Section 42 response	time of the project following an adaptive management approach so that any exposure of the protection will be reburied to ensure it will not cause morphological alteration to beach processes through potential interaction with waves and currents and causing a barrier to alongshore sediment transport in either direction.	methods for cable protection to help ensure robust design and minimize the risk of exposure. Requirements for monitoring will be considered as part of the Cable Management Plan.
November 2021 Section 42 response	The assessment of impact caused by presence of the rock berms is based on expert judgement. No quantitative analysis has been conducted to determine the potential for wave focusing (proximity to shore, water depth, wave height etc.) caused by the presence of the berm and whether over time prolonged wave focusing could cause areas of the beach to erode (depending on the stability of the beach face and sediment composition) potentially resulting in long-term lowering and the requirement for beach management intervention. Depending on its location in the intertidal/subtidal, the	Further assessment of the potential for rock berms to interfere with sediment transport and beach morphology has been presented in paragraph 130 *et seq.*

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
	presence of the berm will also determine the magnitude of impact to down drift locations caused by interruption to sediment transport alongshore.	
November 2021 Section 42 response	Consideration should be given as to how Constable Bank will behave in response to a potentially small but long-term reduction in wave energy and its potential impact on the sediment transport links towards the coast.	Further assessment of the potential for wave attenuation through the array area to affect Constable Bank and the surrounding seabed and coastline has been presented in paragraph 178 *et seq.*
November 2021 Section 42 response	The decommissioning assessment should consider impacts associated with removing scour protection and/or cable protection: it is not clear if the rock protection used for scour protection and cable protection will remain on the seabed following decommissioning.	An assessment of the potential impacts associated with the removal of rock protection around infrastructure during the decommissioning phase has been presented in paragraph 214 *et seq.*
November 2021 Evidence Plan consultation	Discussed the Section 42 responses from NRW (also listed above) relating to: baseline description of sediment transport pathways; potential impact of cable protection in	Further information on baseline sediment transport on and around Constable Bank/ Rhyl flats (as well as in adjacent nearshore

DATE AND CONSULTATION PHASE/ TYPE	CONSULTATION AND KEY ISSUES RAISED	SECTION WHERE COMMENT ADDRESSED
	nearshore areas; and the evolution or persistence of spoil disposal mounds over time.	waters) has been presented Volume 4, Annex 2.1. Further assessment of the potential for rock berms to interfere with sediment transport and beach morphology has been presented in paragraph 122 *et seq*. An assessment of the degree to which any spoil mounds will persist on the seabed has been presented in paragraph 61 *et seq*.

2.4 Scope and methodology

12 The study area encompasses Liverpool Bay, as well as adjacent seabed areas up to mean high-water springs (MHWS) and includes the AyM array and offshore ECC (Figure 1). Included within this area is the landfall for the export cable, which is proposed to be located at Ffirth, just to the east of Rhyl.

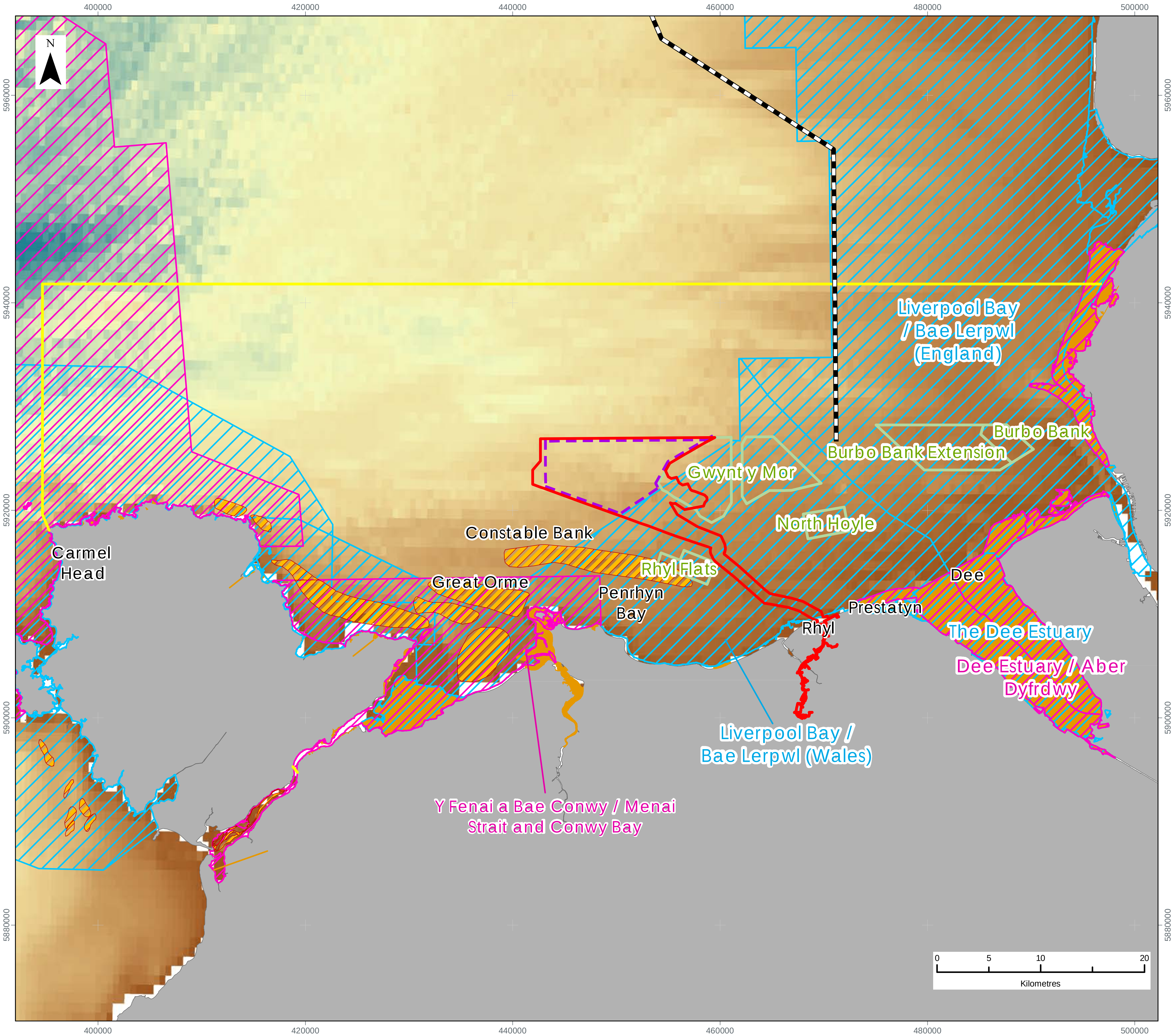
13 The study area overlaps with a number of nationally and internationally important nature conservation sites, which contain qualifying geological and geomorphological features. These sites are also illustrated in Figure 1.

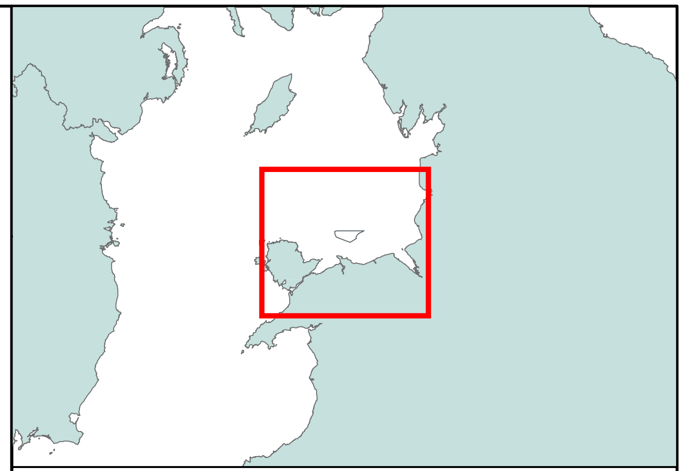
14 Baseline understanding of physical processes within the study area been developed through consideration of a range of project-specific and existing data sources. These are summarised in Table 1 and Figure 2 of Volume 4, Annex 2.1 and include:

- AyM project specific geophysical survey data collected in 2020 (Fugro, 2020a; b);
- Geophysical, geotechnical, benthic and oceanographic data collected to inform the GyM OWF EIA;
- Data available from a number of marine data portals;
- Existing marine process investigations from across the study area; and
- Numerical modelling of hydrodynamic, wave and sediment transport processes developed to inform the assessment (Volume 4, Annex 2.2).

15 In order to assess the potential effects upon the marine physical environment relative to the existing (baseline) coastal environment, a combination of analytical methods has been used. These include:

- AyM project specific numerical modelling;
- The 'evidence base' containing monitoring data collected during the construction and O&M of other OWF developments;
- Analytical assessments of project-specific data; and
- Standard empirical equations describing (for example) the potential for scour development around structures (e.g. Whitehouse, 1998).





LEGEND

- Order Limits
- Array Area
- Wind Farm (Active/In Operation)
- Article 17 Sandbanks
- Special Area of Conservation
- Special Protection Area
- Site of Special Scientific Interest
- Liverpool Bay Front
- Physical Processes Study Area

EMODnet bathymetry (m LAT)

5, -6.54, -18.08, -29.62, -41.16, -52.7, -64.24, -75.78, -87.32, -98.86, -110.4

PROJECT TITLE:

AWEL Y MÔR OFFSHORE WINDFARM

FIGURE TITLE:

Physical processes study area

VER	DATE	REMARKS	Drawn	Checked
2	02/03/2022	For Issue	CRB	DLW

FIGURE NUMBER:

Figure 1

SCALE:	PLOT SIZE:	DATUM:	PROJECTION:
1:380,000	A3	WGS84	UTM30N

Fferm Wynt Alltraeth AWEL Y MÔR Offshore Wind Farm

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16 The assessment has been undertaken in accordance with industry best practice and guidance, as previously described (paragraph 6). Full details of the methodological approach to the assessment of sediment disturbance related effects and scour are set out in Volume 4, Annex 2.3.

17 The assessment also considers likely naturally occurring variability in, or long-term changes to, physical processes within the project lifetime due to natural cycles and/ or climate change (e.g. sea level rise). This is important as it enables a reference baseline level to be established against which the potentially modified physical processes can be compared, throughout the project lifecycle. Baseline conditions are described in detail within Volume 4, Annex 2.1 (application ref: 6.4.2.1) and include for the potential effects of climate change.

18 The assessment of impacts on the marine physical environment has been considered over two spatial scales. These are:

- Far-field. Defined as the area surrounding the AyM array and offshore ECC over which indirect changes may occur (i.e. the study area); and
- Near-field. Defined as the footprint of the AyM array and offshore ECC.

2.5 Assessment criteria and assignment of significance

19 For the most part, physical processes are not in themselves receptors but are instead ‘pathways’. However, changes to physical processes have the potential to indirectly impact other environmental receptors (Lambkin et al., 2009). For instance, the creation of sediment plumes (the potential for which is considered in the physical processes assessment) may lead to settling of material onto benthic habitats. The potential significance of this particular change is assessed in Volume 2, Chapter 5. This distinction between assessments of pathways and receptors is summarised in Table 3, for each of the potential impacts/ changes considered within the assessment section.

Table 3: Summary of potential impacts/ changes considered in the physical processes assessment.

POTENTIAL IMPACTS/ PATHWAY EFFECTS	PATHWAY/ RECEPTOR
Construction	
Potential changes to suspended sediment concentrations (SSC), bed levels and sediment type/ character arising from construction related activities including dredging, drilling and cable installation.	Pathway
Potential changes to Constable Bank/ Rhyl Flats and designated sites owing to the combined influence of sediment removal activities e.g. dredging and sandwave clearance.	Pathway/ Receptor
Potential changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast, arising from dredging/ disposal induced bed level change and associated modification of waves, tides and sediment transport.	Pathway/ Receptor
Potential changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast, arising from blockage effects associated with (partially) installed infrastructure.	Pathway/ Receptor
Potential changes to the coast arising from HDD and trenching at the landfall.	Pathway/ Receptor
Potential for long-term changes to the coast arising from the use of cable protection at the landfall.	Pathway/ Receptor
Potential for long-term changes to the coast arising from cable protection within nearshore areas.	Pathway/ Receptor
Operation	
Potential for scour of seabed sediments, including that around scour protection structures.	Pathway

POTENTIAL IMPACTS/ PATHWAY EFFECTS	PATHWAY/ RECEPTOR
Potential for changes to Constable Bank/ Rhyl Flats and designated sites arising from modification of the tidal regime.	Pathway/ Receptor
Potential for changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast arising from modification of the wave regime.	Pathway/ Receptor
Potential for changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast arising from modification of the sediment transport regime.	Pathway/ Receptor
Potential for changes to the coast arising from any modification of Constable Bank and Rhyl Flats.	Receptor
Decommissioning	
Potential changes to SSC, bed levels and sediment type.	Pathway
Potential changes to the coast arising from the removal of infrastructure and associated rock protection.	Pathway/ Receptor
Cumulative	
Potential for cumulative temporary increases in SSC and seabed levels as a result of AyM foundation installation and aggregate dredging.	Pathway
Potential for cumulative temporary increases in SSC and seabed levels as a result of AyM foundation installation and dredge spoil disposal at licensed disposal grounds.	Pathway
Potential for cumulative changes in hydrodynamics, waves and sediment transport arising from interaction with proposed Round 4 OWF projects.	Pathway/ Receptor
Potential for cumulative changes in hydrodynamics, waves and sediment transport arising from interaction with Flagstaff Tidal Lagoon.	Pathway/ Receptor

POTENTIAL IMPACTS/ PATHWAY EFFECTS	PATHWAY/ RECEPTOR
Potential for cumulative changes in hydrodynamics, waves and sediment transport arising from interaction with new coastal defence works.	Pathway/ Receptor

20 Whilst physical processes can largely be considered as pathways, a small number of features have been identified as potentially sensitive physical processes receptors. These are:

- The coast;
- Nearby offshore sand banks (including Constable Bank and Rhyl Flats); and
- Seabed areas contained within nationally or internationally important sites. (The locations of these sites are shown in Figure 1 whilst brief site descriptions and distances from AyM are provided in Volume 4, Annex 2.1.

21 These receptors have been identified on the basis of:

- Professional judgement, local and regional specialist experience;
- The Scoping Opinion (PINS, 2020);
- Outcomes from the consultation process; and
- Reference to best practice guidance.

22 Where these receptors have the potential to be affected by changes to physical processes, a full impact assessment (i.e. assigning sensitivity, magnitude and significance) has been carried out.

23 The assessment of effects upon physical processes receptors is a systematic process that is determined by taking into account the 'magnitude of the impact' and 'sensitivity and importance' of the receptor. These assessment criteria are described in more detail within this Section.

24 The magnitude of impact describes the extent or degree of change that is predicted to occur to a receptor. It has been assessed using expert judgement and described qualitatively with a standard semantic scale. Definitions for each term are provided in Table 4. These expert judgements regarding the magnitude of effect relative to baseline conditions have been made by experienced marine physical process specialists and formed following consideration of the information sources previously set out in paragraph 15.

Table 4: Impact magnitude definitions.

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

25 The importance and sensitivity of each receptor has been assessed using expert judgement and described with a standard semantic scale using the terms negligible, low, medium and high. Definitions for each term are provided in Table 5. The characterisation of receptor sensitivity/importance is closely guided by the conceptual understanding of regional-scale physical processes, developed during the baseline characterisation process (Volume 4, Annex 2.1).

Table 5: Sensitivity/importance of the environment.

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

26 The significance of potential effects has been determined by taking into account the magnitude of the impact and the sensitivity and importance of the receptor and applying to construction, O&M and decommissioning stages of the project (Table 6).

Table 6: Matrix to determine effect significance.

		SENSITIVITY			
		HIGH	MEDIUM	LOW	NEGLIGIBLE
ADVERSE MAGNITUDE	HIGH	Major	Major	Moderate	Minor
	MEDIUM	Major	Moderate	Minor	Negligible
	LOW	Moderate	Minor	Minor	Negligible
	NEGLIGIBLE	Minor	Minor	Negligible	Negligible
BENEFICIAL MAGNITUDE	NEGLIGIBLE	Minor	Minor	Negligible	Negligible
	LOW	Moderate	Minor	Minor	Negligible
	MEDIUM	Major	Moderate	Minor	Negligible
	HIGH	Major	Major	Moderate	Minor

Note: Effects of 'moderate' significance or greater are defined as significant with regard to the EIA Regulations.

27 It is noted here that a distinction is made throughout the assessment between the magnitude, extent and duration of 'impacts' and the resulting significance of the 'effects' upon physical processes receptors. Various actions may result in impacts: for instance, the installation of the export cable at the landfall, causing a localised and short-term change to intertidal morphology (which is defined as a physical process receptor). The significance of effect associated with the impact will be dependent upon the sensitivity/ importance of the receptor, with particular consideration given to the receptor's ability to tolerate and recover from the impact, as well as status.

2.6 Uncertainty and technical difficulties encountered

28 Uncertainty exists with regard to characterisation of the future baseline. Key areas of uncertainty include the extent to which future changes in storminess may occur and the potential associated changes to the wave regime. There is also considerable uncertainty with regard to exactly how the coast may respond to a modified wave climate acting in combination with higher than present sea levels.

29 Discussion relating to the performance of the models developed to support the assessment is also set out in Volume 4, Annex 2.2.

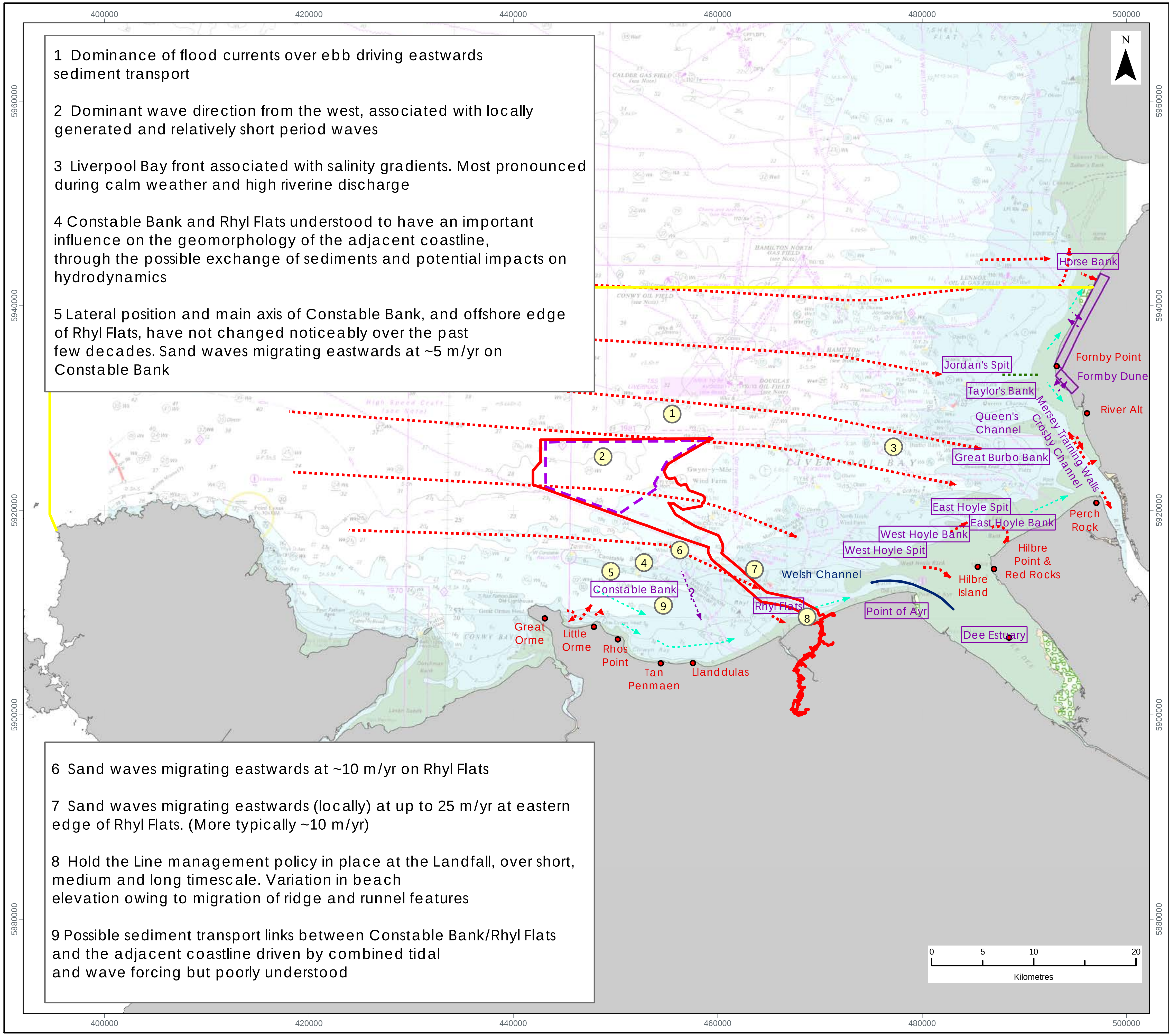
2.7 Existing environment

30 The existing environment across the study area is described in detail within Volume 4, Annex 2.1. This has been achieved through the combined analysis of project specific survey data, information previously collected to inform the construction and operation of the adjacent GyM OWF, as well as data collected as part of regional coastal monitoring programmes.

31 It is noted that many of the datasets used to inform the baseline post-date the construction of GyM OWF and therefore any localised changes associated with the operational GyM are captured within the baseline for AyM.

32 A summary of key findings is set out below and an overarching conceptual understanding of marine physical processes within the study area is shown in Figure 2.

33 A technical report and Environmental Statement (ES) chapter were produced for the area of the GyM array (RWE, 2005). A review of the key findings from that study has been incorporated into the description of the existing environment.



LEGEND

- Order Limits
- Array Area
- Physical Processes Study Area
- Saltmarsh
- Sediment Sink/Store
- Sediment Direction
- Channel
- Drift Divide
- Wave driven littoral transport pathway
- Tidally driven intertidal/subtidal transport pathway
- Control/Influencing Feature

PROJECT TITLE:

AWEL Y MÔR OFFSHORE WINDFARM

FIGURE TITLE:

Conceptual understanding of regional scale marine physical processes. Adapted from Halcrow (2010a)

VER	DATE	REMARKS	Drawn	Checked
2	02/03/2022	For Issue	CRB	DLW

FIGURE NUMBER:

Figure 2

SCALE:	PLOT SIZE:	DATUM:	PROJECTION:
1:380,000	A3	WGS84	UTM30N

Fferm Wynt Alltraeth AWEL Y MÔR Offshore Wind Farm

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2.7.1 The Array

Hydrodynamics and waves

- AyM is located in a macro-tidal setting, with a spring tidal range of around 6.5 m. This range increases from west to east. Currents speeds are approximately 0.75 to 1.0 m/s;
- The AyM array is open to north-westerly offshore waves that are generated within the Irish Sea. Locally generated waves related to the prevailing winds come from westerly, north-westerly and northern sectors.

Stratification

- To the northeast of the AyM array is the permanent Liverpool Bay front which extends northwards from the River Dee. Stratification related to this front is predominantly associated with salinity gradients, although temperatures associated with outflows from the Dee, Mersey and Ribble estuaries can also have a seasonal effect.

Sediments and geology

- The seabed within the AyM array and wider Liverpool Bay largely consists of either sandy gravel or gravely sand. The seabed is relatively free of fines (defined as particles of less than 0.063 mm), with waves generally preventing the deposition of mud or silt, whilst tidal currents prevent the deposition of mud further offshore within Liverpool Bay;
- Net sediment transport along the north Wales coastline is predominantly by bedload in an easterly direction, at a moderate to high rate for sands, with some transport of finer material in suspension. In offshore areas, the direction is the result of the tidal current asymmetry; in shallower nearshore areas and on the beaches, the direction is the combined result of tidal current asymmetry and the relative angle of approach of waves;

- The Quaternary geology of the AyM array has been shaped and influenced by a series of glacial events during the retreat of the British Isles ice sheet and Irish Sea Ice Stream. Overlying the bedrock is an extensive sequence of Quaternary glaciogenic and seabed sediments. These comprise a range of coarse- and fine-grained sediments.

Seabed geomorphology

- Water depths within the AyM array generally increase towards the north west, between 15.2 and 41.9 m below LAT;
- Both sand waves and megaripples are present in the array and offshore ECC and are over 4 m high in places. Within inshore areas of the offshore ECC, rates of migration are typically around 10 m/yr and may reach 25 m/yr locally;
- The offshore sand banks of Constable Bank and Rhyl Flats are located immediately to the south of the array and are crossed by the offshore ECC. They are understood to have an important influence on the geomorphology of the adjacent coastline, through the possible exchange of sediments and potential impacts on hydrodynamics.

2.7.2 The offshore export cable corridor

Hydrodynamics and waves

- Mean spring tidal range increases from approximately 6.5 m at the offshore end of the offshore ECC, to around 7 m at the landfall. Tidal currents generally decrease with proximity to the coast, with peak surface currents at ~0.3 m/s at the landfall;

Sediments and geology

- The seabed within the offshore ECC comprises mostly sand with varying proportions of gravel;

Seabed geomorphology

- Water depths within the offshore ECC generally increase towards the north west, reaching depths of 23.8 m below LAT close to where it meets the array;

- Sand waves and megaripples are present in many areas and have been shown to be actively migrating.

Coastal geomorphology

- The beach at the landfall predominantly comprises sand, with areas of muddy sand interspersed across the mid shore. Peat is also locally present;
- The shoreline policy at the landfall (as well as along much of the coastline in the study area) is ‘Hold the Line’ (Halcrow, 2011), with a seawall and groynes in place. However, comparison of the topographic data available from the landfall shows vertical change in beach elevation occurring, in response to the migration of ridge and runnel features across the foreshore alternatively covering and exposing underlying cohesive deposits.

2.7.3 Evolution of the baseline

34 The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 require that “A description of the relevant aspects of the current state of the environment (baseline scenario) and an outline of the likely evolution thereof without implementation of the development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge.” is included within the ES (EIA Regulations, Schedule 4, Paragraph 3).

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

36 By 2060, relative sea level may have risen by approximately 0.35 m above present day (2021) levels (Representative Concentration Pathway (RCP) 8.5, 95%ile)) (Palmer et al., 2018). A rise in sea level may allow larger waves, and therefore more wave energy, to reach the coast in certain conditions and consequently result in an increase in local rates or patterns of erosion and the equilibrium position of coastal features. Modification of the wave regime may also occur in response to changing patterns of atmospheric circulation although this is associated with much uncertainty (Palmer et al., 2018).

37 The shoreline adjacent to the project is heavily defended. As a result, the future evolution of the coastline will depend to some extent on any changes to the existing management strategies, including:

- Deliberate or accidental breaches, damage or loss of existing coastal defences;
- Replacement or maintenance of existing coastal defences;
- Introduction of new or modified coastal defences;
- Beach replenishment (addition of new sediment volume);
- Beach reprofiling (redistribution of sediment volume within the existing beach); and
- Activities that propagate to larger scale changes of behaviour of the Clwyd or Dee estuaries.

2.8 Key parameters for assessment

38 This section identifies the maximum design scenario (MDS) for physical processes. This is provided in Table 7 for each of the potential effects identified during Scoping and from subsequent discussions with stakeholders as part of the Evidence Plan process.

39 The MDS is defined by the project design envelope (Volume 2, Chapter 1) and includes mitigation. The method adopted is in accordance with the requirements of the Rochdale Envelope approach to environmental assessment as set out in the PINS Advice note nine: 'Using the Rochdale Envelope' (The Planning Inspectorate, 2018).

Table 7: Maximum design scenario.

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
CONSTRUCTION		
Potential changes to SSC, bed levels and sediment type/ character arising from construction related activities including dredging, drilling and cable installation.	Pre-lay trenching Maximum rate of sediment disturbance: 1,000 kg/s (Mass Flow Excavator (MFE)) Construction phase duration: up to 36 months Sandwave clearance Maximum rate of sediment disturbance: 1,000 kg/s (MFE) Length of export and GyM interlink cable requiring clearance: 63 km total Maximum width of sand wave clearance corridor: 70 m Maximum depth of dredging: up to 5 m Total dredge/ disposal volume of 7,600,000 m^3 (for sandwave levelling for array cabling) Total dredge/ disposal volume of 500,000 m^3 (for WTG foundation bed preparation, in the case of multi-leg GBS foundations)	Defining the MDS for sediment disturbance activities is highly complex as the actual disturbance will be temporally and spatially variable (depending upon the metocean conditions at the time). For sediment plumes, the MDS is intended to be representative in terms of peak concentration, plume extent and plume duration but will not correspond to a single sediment disturbance activity. The same holds true for sediment deposition at the bed, where the MDS is a representation of maximum

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
	Total dredge/ disposal volume of 6,281,000 m^3 (for sandwave levelling in the offshore ECC and along GyM interlink) Total dredge/ disposal volume of 86,400 m^3 for Offshore Substation Platform (OSP) foundation bed preparation - (associated with gravity-based jacket foundation installation) Construction phase duration: up to 36 months Drilling for foundation installation Maximum % of locations using drilling: 100% Maximum drilling rate: 2 m/hr Maximum volume of drill arisings released per WTG foundation: 13,572 m^3 (largest WTG) Maximum volume of sediment released in the array from WTG foundations: 276,862 m^3 (based on array comprising 34 of the largest WTGs; drilling to 68 m with drill diameter of 16 m at 60% of locations) Construction phase duration: up to 36 months Dredge spoil disposal	deposit thickness, maximum footprint extent or likely duration. The justification for the MDS is set out in Volume 4; Annex 2.3

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
	Disposal technique: carried out using a representative Trailing Suction Hopper Dredger (THSD) (11,000 m^3 hopper capacity with split bottom for spoil disposal). Multiple dredgers to be working simultaneously. Disposal location: 'close' to the installation works Maximum volume of sediment released in the array from WTG foundations: 500,000 m^3 (based on array comprising 50 of the smallest WTGs on multi-leg GBS foundations; 2 m indicative average depth of seabed preparation; seabed preparation diameter of 50 m) Construction phase duration: up to 36 months HDD Drilling fluid discharge Number of bores: three Maximum volume of drilling fluid and cuttings released per HDD conduit release event: 7,677 m^3. Maximum volume of drilling fluid released for all three HDD conduits assuming worst case methodology: 18,117 m^3 Release to take place over approximately 10-14 days, equating to 284 m^3 to 560 m^3 per tidal cycle.	

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
Potential changes to Constable Bank/ Rhyl Flats and designated sites owing to the combined influence of sediment removal activities e.g. dredging and sandwave clearance.	Maximum volume displaced during sandwave levelling for array cabling: 7,600,000 m^3 Maximum volume displaced during sandwave levelling along the offshore ECC and GyM interlink cable: 6,281,000 m^3 Maximum volume displaced during WTG foundation bed prep: 500,000 m^3 (based on array comprising 50 of the smallest WTGs on multi-leg GBS foundations; 2 m seabed preparation; seabed preparation diameter of 50 m) Maximum volume displaced during OSP foundation bed preparation: 86,400 m^3 - (associated with gravity-based jacket foundation installation)	Corresponds to the maximum volume of displaced material arising from all Project construction activities. These are dredging for: Sandwave levelling Bed preparation prior to WTG foundation installation Bed preparation prior to OSP foundation installation
Potential changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast, arising from dredging/	Maximum volume dredged/ disposed of during sandwave levelling for array cabling: 7,600,000 m^3 Maximum volume dredged/ disposed of during sandwave levelling along the offshore ECC and GyM interlink cable: 6,281,000 m^3.	Corresponds to the maximum dredge volume arising from all Project construction activities. These are dredging for: Sandwave levelling

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
disposal induced bed level change and associated modification of waves, tides and sediment transport.	Maximum volume dredged/ disposed of during WTG foundation bed preparation: 500,000 m^3 (based on array comprising 50 of the smallest WTGs on multi-leg GBS foundations; 2 m seabed prep; seabed preparation diameter of 50 m) Maximum volume dredged/ disposed of during OSP foundation bed preparation: 86,400 m^3 Disposal technique: carried out using a representative Trailing Suction Hopper Dredger (TSHD) (11,000 m^3 hopper capacity with split bottom for spoil disposal). Multiple dredgers to be working simultaneously. Disposal location: ‘close’ to the installation works	Bed preparation prior to WTG foundation installation Bed preparation prior to OSP foundation installation
Potential changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast, arising from blockage effects associated with (partially) installed infrastructure.	N/A	The MDS for blockage associated with partially installed infrastructure cannot readily be defined. However, it will be no greater than that set out for the fully built and operational project.

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
		Refer to the operation section of this table (below).
Potential changes to the coast arising from HDD and trenching at the landfall	Trenching Burial technique: plough Maximum burial depth: 5 m Indicative width of (post-lay) ploughing: 10 m Minimum trench separation distance: 20 m HDD (or alternative trenching techniques) Punch-out location for HDD: intertidal or below LAT. Three HDD exit pits Size of HDD exit pits: 75 m long x 10 m wide x (up to) 2.5 m deep Total volume of HDD exit pit: 1,875 m^3 (each) Duration exit pits may remain open: up to 30 months	Sets out construction activities that give rise to the greatest (direct) disturbance to the beach and provide the greatest potential to interact with coastal processes responsible for maintaining the baseline form and function of the beach.
Potential for long-term changes to the coast arising from the use of	Two export cables Cable protection: buried mattressing (Indicative width of 3 m; length of 6 m and height of 0.3 m) used out to 1,000 m seaward of MHWS	The use of rock dump within intertidal areas at the landfall has been ruled out, therefore concrete mattressing

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
cable protection at the landfall.		represents the option with the greatest blockage potential
Potential for long-term changes to the coast arising from cable protection within nearshore areas.	Two export cables and GyM interlink cable Cable protection out to 1,000 m from MHWS: mattressing (Indicative width of 3 m; length of 6 m and height of 0.3 m) Cable protection seaward of 1,000 m from MHWS: rock berm protection with Height: 1.4 m and Total width: 15.2 m	Rock protection has the highest profile relative to the seabed and therefore has the greatest potential to influence the behavior of waves, tides and sediment transport in nearshore areas.
OPERATION		
Potential for scour of seabed sediments, including that around scour protection structures.	Defined from the outputs of the scour assessment (see Volume 4, Annex 2.3).	Each foundation type may produce different scour patterns therefore monopiles, gravity base and jacket foundations have been considered. The foundation type, size and number producing the greatest area and/ or volume of influence

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
		cannot be identified in advance of the assessment.
Potential for changes to Constable Bank/ Rhyl Flats and designated sites arising from modification of the tidal regime. Potential for changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast arising from modification of the wave regime. Potential for changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast arising from modification	Foundations Array comprising the largest number (50) of the smallest size gravity base foundations for turbines (45 m base diameter) and two OSPs (jacket foundations with suction buckets; 6 legs, 3.5m diameter. One met mast (maximum 5 m diameter monopile foundation); Scour protection: 2 m rock berm with maximum extent at top of scour protection of 113 m diameter (including foundation) and 121 m at the base; Minimum foundation spacing of 830 m (for layout containing the smallest sized WTGs); and Project operational lifespan: 25 years (but noting some blockage will also occur during the construction and decommissioning period, each lasting up to three years) Cable protection measures	The greatest total in-water column blockage to currents, waves and sediment transport processes is presented by an array comprising the largest number (50) of smallest size gravity base WTG foundations. This combination was determined via calculations that quantitatively compare the blockage presented by a range of minimum and maximum sizes of varying foundation types and numbers.

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
of the sediment transport regime.	Options include rock placement, concrete mattresses, flow energy dissipation devices, protective aprons and bagged solutions Sloped profile above seabed level: Assumed 15.2 m overall width and 1.4 m maximum height Indicative maximum proportion of export cable length requiring remedial protection: 20% of route Seven offshore cable crossings/ circuit (i.e. 14 no. in total) plus one in the GyM interlink area Total crossing footprint area for Project = 39,500 m^2)	
Potential for changes to the coast arising from any modification of Constable Bank and Rhyl Flats.		
DECOMMISSIONING		
Potential changes to SSC, bed levels and sediment type.	Array comprising the largest number of WTG foundations (50) and OSP foundations (2) Buried cables to be cut and left in situ (but to be determined in consultation with key stakeholders as part of the decommissioning plan and following best practice at the time) Scour and cable protection left *in situ* Decommissioning activities lasting up to three years.	When removing foundations, the greatest disturbance will be associated with the layout containing the greatest number of structures.

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
Potential changes to the coast arising from the removal of infrastructure and associated rock protection.	Removal of all infrastructure (and associated rock protection) and including export cables from trenches within intertidal/ shallow subtidal Decommissioning activities lasting up to three years	Maximum disturbance of seabed and change in blockage resulting from removal of infrastructure.
CUMULATIVE EFFECTS		
Potential for cumulative temporary increases in SSC and seabed levels as a result of AyM foundation installation and aggregate dredging.	MDS for AyM construction phase (as previously defined) Three aggregate extraction sites (Area 392/3; Area 457; and Area 1808)	Sediment plume interaction generally has the potential to occur if the activities generating the sediment plumes are located within one spring tidal excursion ellipse from one another and occur at the same time. Identified sites are within 12 km as this distance represents the largest spring tidal excursion ellipse observed in the array and offshore ECC.
Potential for cumulative temporary increases in SSC and seabed levels as a result of AyM foundation installation and dredge spoil	MDS for AyM construction phase (as previously defined) One dredge spoil disposal site (Site IS150)	

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
disposal at licensed disposal grounds.		
Potential for cumulative changes in hydrodynamics, waves and sediment transport arising from interaction with proposed Round 4 OWF projects.	MDS for AyM operation phase (as previously defined) Mona & Morgan Round 4 OWF sites (EnBW and BP) Morecambe R4 OWF site (Cobra & Flotation Energy)	Operational wind farms within the study area (GyM, North Hoyle, Rhyl Flats, Burbo Bank & Burbo Bank Extension) are considered part of the baseline environment and assessed within the project-alone assessment (paragraphs 42 to 219.
Potential for cumulative changes in hydrodynamics, waves and sediment transport arising from interaction with Flagstaff Tidal Lagoon.	MDS for AyM Project operation phase (as previously defined) Flagstaff Tidal Lagoon	Maximum potential for cumulative changes to hydrodynamics, waves and sediment transport.
Potential for cumulative changes in hydrodynamics, waves	MDS for AyM Project operation phase (as previously defined)	

POTENTIAL EFFECT	MAXIMUM DESIGN SCENARIO ASSESSED	JUSTIFICATION
and sediment transport arising from interaction with new coastal defence works.	Coastal defence works	

2.9 Mitigation measures

40 Mitigation measures that were identified and adopted as part of the evolution of the project design (embedded into the project design) and that are relevant to physical processes are listed in Table 8. The mitigation includes embedded measures such as design changes, and applied mitigation which is subject to further study or approval of details. These include avoidance measures that will be informed by pre-construction surveys, and necessary additional consents where relevant. The composite of embedded and applied mitigation measures apply to all parts of the AyM development works, including pre-construction, construction, O&M and decommissioning.

41 The subsequent assessment stage of the EIA for physical processes (Section 1.10 onwards) is based on the 'mitigated' design.

Table 8: Mitigation measures relating to physical processes.

PARAMETER	MITIGATION MEASURES
GENERAL	
Project design	Routing of the offshore ECC to avoid Constable Bank.
Project design	A reduction in the maximum number of turbines proposed, from 107 during the scoping phase, to 91 in the PEIR, and 50 in this application, to reduce the potential environmental impact of the proposed project.
CONSTRUCTION	
Offshore cables	A detailed Cable Burial Risk Assessment (CBRA) will be undertaken to enable informed judgements with regard to burial depth. This should maximize the chance of cables remaining buried whilst limiting the amount of sediment disturbance to that which is necessary.

PARAMETER	MITIGATION MEASURES
Offshore cables	Where practicable, cable burial will be the preferred means of cable protection. This will minimise the requirement for surface laid protection.
Offshore cables	Route avoids Constable Bank thereby minimises adverse impact to the sensitive receptor. Development of, and adherence to, a Cable Specification and Installation Plan (CSIP) and Cable Route Burial Protocol post consent (if granted), which sets out measures to minimise adverse impacts to potentially sensitive receptors.
Landfall	Use of open-cut trenching in the intertidal and HDD (or alternative trenchless techniques) to minimise disturbance to beach.
Foundations and offshore cable	The project array area and offshore ECC will be licensed as disposal sites for the deposition of dredgings and drill arisings. All material that is dredged from the seabed will be disposed of within these sites to ensure material is retained within the local sediment transport system.
OPERATION	
WTGs, OSPs and cables	Scour protection will be used in areas where the bed is erodible. This will limit the volume of material that may be eroded and released into the water column.
DECOMMISSIONING	
Turbine foundations	Foundations would be cut below seabed level and protruding sections removed. This would minimise disturbance of material. Buried cables to be cut and left in situ (but to be determined in consultation with key stakeholders as part of the decommissioning plan and following best practice at the time to minimize environmental impacts)

2.10 Environmental assessment: construction phase

42 The changes to physical processes in response to construction of the AyM project have been described in this section. The MDS against which each construction phase change has been assessed is set out in Table 7.

43 Within this section, an assessment of change to pathways is presented first followed by the assessments of potential impacts to physical process receptors. The assessments of potential change to pathways are not at this stage accompanied by a conclusion regarding the significance of effect.

44 Where the potential for effects on physical process receptors are identified, the assessment of the magnitude of the impact on the receptor is presented along with a judgement on receptor sensitivity/ value. This is followed by a conclusion of significant effect.

2.10.1 Potential changes to suspended sediment concentrations, bed levels and sediment type/ character arising from construction related activities including dredging, drilling and cable installation.

Overview

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

- Pre-lay cable trenching using a MFE tool at the seabed;
- Sandwave clearance using an MFE tool at the seabed;
- Cable installation using a jetting tool;
- Dredge spoil disposal at the water surface related to seabed preparation for cables or foundations (including sandwave clearance); and
- Drill arisings release at the water surface during drilling for monopile foundations, or for pin piles for jacket foundations.

46 Details of the MDS for sediment disturbance events are set out in Table 7. These sediment release events have subsequently been considered using numerical modelling, at locations in the Array, along the length of and in the middle of the export cable corridor, and near to the landfall and occurring (separately) on and around representative spring and neap tidal periods. A total of 18 release events have been considered which together, capture the full range of sediment disturbance activities as defined under the MDS, carried out during spring and neap tidal conditions. A full description and discussion of each event is set out in Volume 4; Annex 2.3 whilst details of the sediment plume model design are set out in Volume 4; Annex 2.2. A desk-based assessment of the potential persistence of disposal mounds has been presented in paragraph 61 *et seq.*

47 The modelled sediment release events described in Volume 4; Annex 2.3 have been designed to capture the full range of realistic worst-case outcomes in terms of:

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

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

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

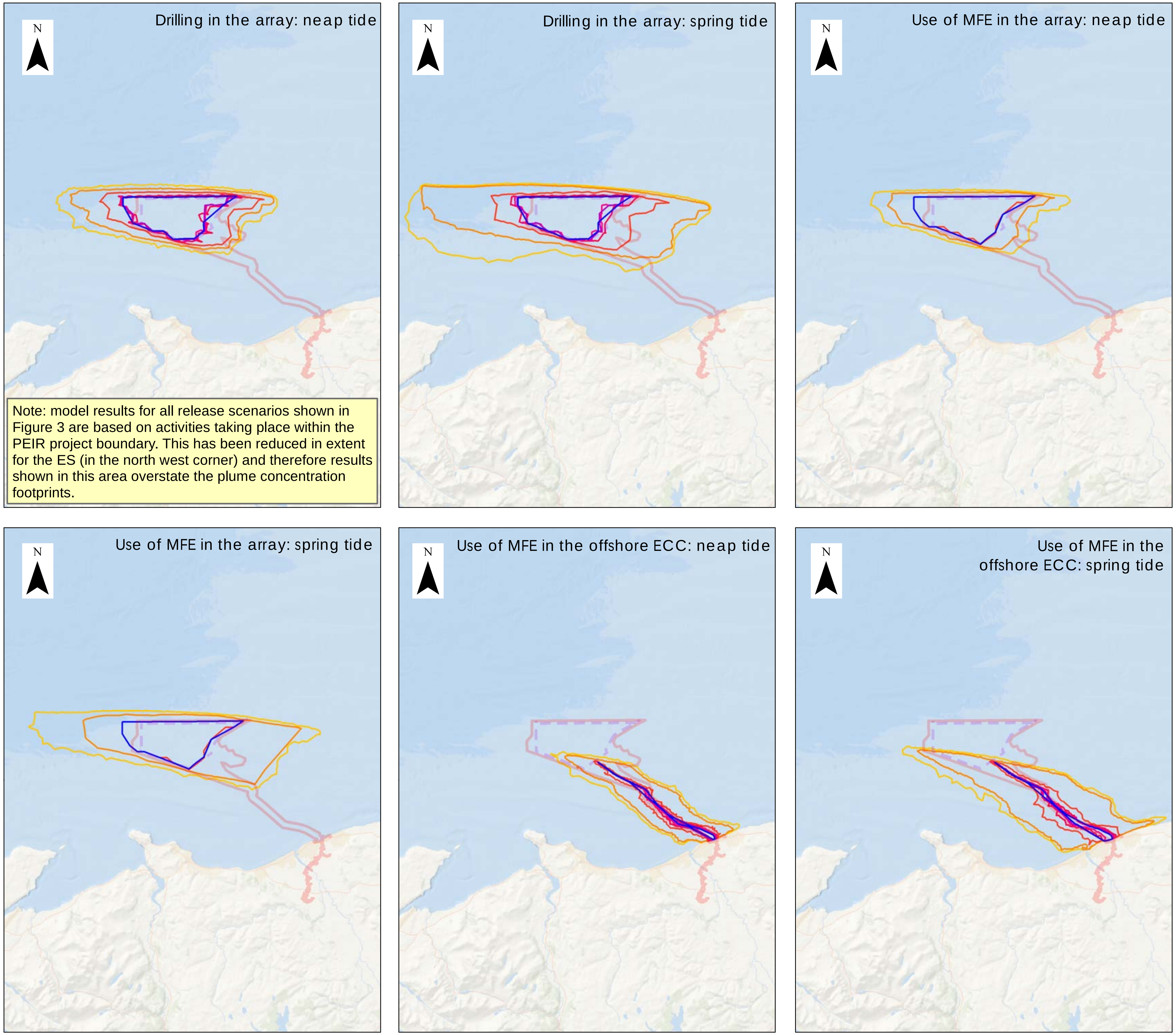
49 Key findings from the modelling are summarised below.

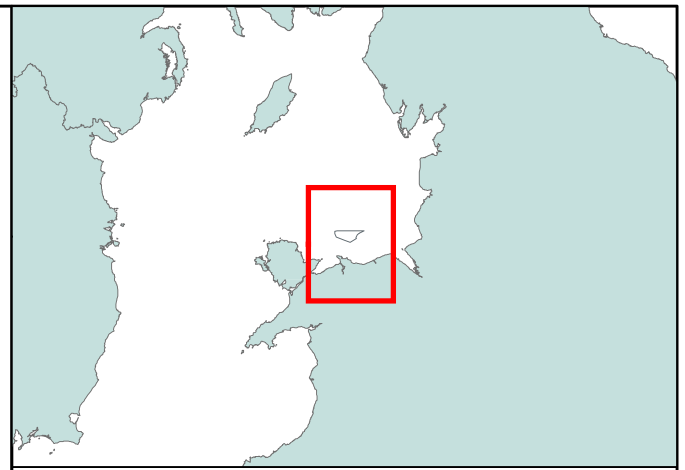
Conceptual understanding of change

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

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

52 The values below have been determined based on the observed advection of the plume features in the sediment plume model results, based on an indicative turbine layout. The model has been run over multiple flood and ebb cycles, during representative neap and spring tidal range conditions (Figure 3).





LEGEND

- Order Limits
- Array Area

Suspended Sediment Concentration

- 1 mg/l
- 5 mg/l
- 50 mg/l
- 100 mg/l
- 150 mg/l
- 250 mg/l
- 500 mg/l

0 10 20 40

Kilometres

PROJECT TITLE:

AWEL Y MÔR OFFSHORE WINDFARM

FIGURE TITLE:

Summary plots showing SSC contours associated with sediment disturbance activities representative of the Maximum Design Scenario

VER	DATE	REMARKS	Drawn	Checked
2	02/03/2022	For Issue	DLW	CRB

FIGURE NUMBER:

Figure 3

SCALE: 1:600,000	PLOT SIZE: A3	DATUM: WGS84	PROJECTION: UTM30N

Fferm Wynt Alltraeth
AWEL Y MÔR
Offshore Wind Farm

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53 In the AyM array area:

- On neap tides, the tidal excursion distance is between ~5-6 km, depending on the peak flow speed during that half tidal cycle.
- On spring tides, the tidal excursion distance is between ~11-12 km, depending on the peak flow speed during that half tidal cycle.

54 In the middle part of AyM export cable corridor:

- On neap tides, the tidal excursion distance is between ~4-5 km, depending on the peak flow speed during that half tidal cycle.
- On spring tides, the tidal excursion distance is between ~9-10 km, depending on the peak flow speed during that half tidal cycle.

55 In the nearshore area close to the landfall of the AyM export cable corridor:

- On neap tides, the tidal excursion distance is ~2.5-3 km depending on the peak flow speed during that half tidal cycle.
- On spring tides, the tidal excursion distance is ~6-7 km depending on the peak flow speed during that half tidal cycle.

SSC of plumes from longer duration disturbance (moving and static point sources over multiple flood/ebb cycles)

56 The following activities are all associated with longer duration disturbance:

- Pre lay cable trenching using an MFE;
- Sandwave clearance using an MFE; and
- Drilling for foundation installation.

57 For these release scenarios (which are shown in Figure 3), it is found that:

- The sediment releases associated with these activities result in a long, relatively thin plume extending downstream from the point of active disturbance. Where the source is moving, the path of active disturbance in the simulation period is visible in the results images as a line of higher maximum instantaneous SSC.

- The level of SSC caused by all sediment types together is realistically expected to be locally very high at the location of active drilling or trenching (where in the latter sediment is being put into suspension at a rate of (up to) 1,000 kg/s).
- Within 5 m of the activity, SSC might be millions of mg/l or more locally, i.e. more sediment than water in parts of the local plume. The effect is very localised and of very short duration.
- As sediment in the plume is redeposited and dispersed both vertically and horizontally with distance and time downstream. SSC is expected to reduce to thousands or high hundreds of mg/l within tens to low hundreds of metres.
- During the first half tidal cycle (~6 hours), the width of the plume increases through dispersion to 50-100 m, all non-silt sediments have settled to the seabed, and SSC consequentially reduces rapidly to 5-10 mg/l.
- After three days, the width of the measurable plume will spread to 250-500 m wide and SSC reduces to 12 mg/l as a result of ongoing sediment dispersion and settlement.
- During spring tidal conditions, the disturbed sediment is carried away from the working area at a faster rate, dispersing the sediment mass over a larger area and water volume, and so the resulting SSC in the plume is relatively lower than on a comparable neap tide.
- During slack water (on both neap and spring tides), water is not moving sediment away from the area of disturbance, resulting in suspended sediment accumulating in a local area of relatively higher SSC (approximately 100-200 m across, order of 5-10 mg/l). This local area of higher SSC is subsequently advected by the tide and may take longer to reduce to background levels than other parts of the plume generated during non-slack water conditions.
- The limited width/footprint of the plume feature means that specific locations will only be affected by the described increase in SSC for the limited duration it takes for the plume to be advected past by the tide.

- The path followed by the tidal ellipse is not the same on every tide, so it is unlikely that the same area of seabed will be affected by higher SSC more localised plume for more than one or two consecutive tides.

SSC of plumes from spoil disposal

58 Seabed preparation via the use of TSHD may be required prior to the installation of foundations. The disposal of the dredged sediment back to the seabed will take place at a nearby location (Table 8). The following summary provides a general description of the resultant plumes:

- During spoil disposal, the TSHD opens large doors on the bottom of the hull and the full volume of dredged material is released into the water column near to the water surface in a relatively short time. Approximately 90% of the total volume will descend rapidly and directly to the seabed as a single mass under gravity, forming the 'active phase' of the plume. The remaining 10% of material will enter suspension in the water column, settling out more slowly at the rate of the individual sediment grains, forming the 'passive phase' of the plume. The active and passive phases will contain a similar representative distribution of all grain sizes present in the originally dredged sediments. The active phase is almost solid sediment and is rapidly deposited to the seabed, so is not assessed in terms of SSC. The following assessment mainly describes the SSC associated with the passive phase of the plume.
- The level of SSC associated with the active and passive phases during the initial release is realistically expected to be locally very high at the location of the spoil release (millions of mg/l within 5 m of the activity, i.e. more sediment than water in the local plume).
- Gravels and sands will settle relatively rapidly towards the seabed. From the maximum expected height of initial suspension (approximately 35 m above bed within the AyM array area), sediment of these grain sizes is likely to resettle to the seabed (no longer contributing to an increase in SSC) within approximately one to 60 minutes.

- At a representative higher current speed of 0.9 m/s on spring tides, gravels and sands will settle to the bed (and so will not cause any effect on SSC) within approximately ~60-70 m for gravel, ~310-320 m for coarse sand, ~1,000 m for medium sand and ~3,200 m for finer sands. This distance will be proportionally reduced during periods of lower current speed (e.g. times other than peak flow speed and generally around neap tides).
- Fine sand and silt sized sediments persist in suspension for longer than relatively coarser sediment grain sizes (i.e. medium sand, coarse sand and gravels) and so control most of the effect on SSC beyond the above durations/distances.
- Due to ongoing dispersion and the settlement of non-silt sediment to the seabed during the first half tidal cycle, the level of SSC associated with the remaining silt in the advected plume will reduce with time from 50-100 mg/l in central parts of the plume after one day, to less than 2 mg/l after three days.
- The plume model indicates that dispersion will increase the width of the plume to approximately 1-2 km after one tidal cycle (approximately 12 hours), 3 km after one day and to approximately 5 km after three days, with an associated reduction in SSC.
- Prior to wider dispersion, the limited width/footprint of the plume feature means that specific locations will only be affected by the described increase in SSC for the limited duration it takes for the plume to be advected past by the tide. The limited width of the spoil disposal plume also means that only locations closely aligned to the disposal location along the tidal axis are likely to be measurably affected.
- The proportion of silt in the seabed sediment being disturbed is lower in the array area (2%) than in the cable corridor (5%), and the water depth is also greater, leading to proportionally lower SSC in the plume in the array from otherwise similar activities (a smaller proportion of the total disturbed sediment might persist in suspension for longer periods and the plume can be more dispersed, to lower concentrations, through the greater water depth).

SSC of plumes from drilling fluid discharge

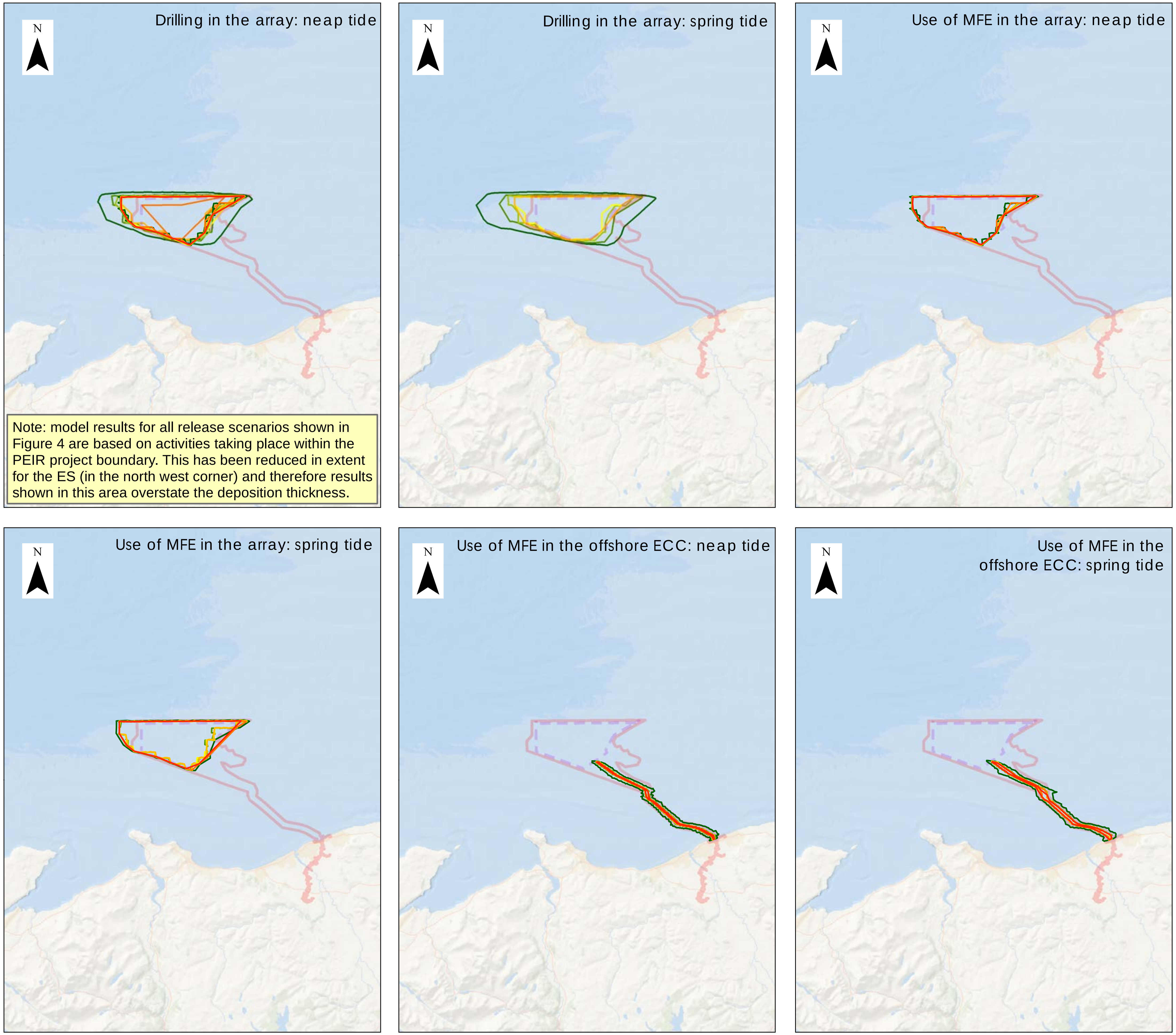
59 The potential changes caused by a release of drilling fluid at the HDD punch-out near the landfall are set out below:

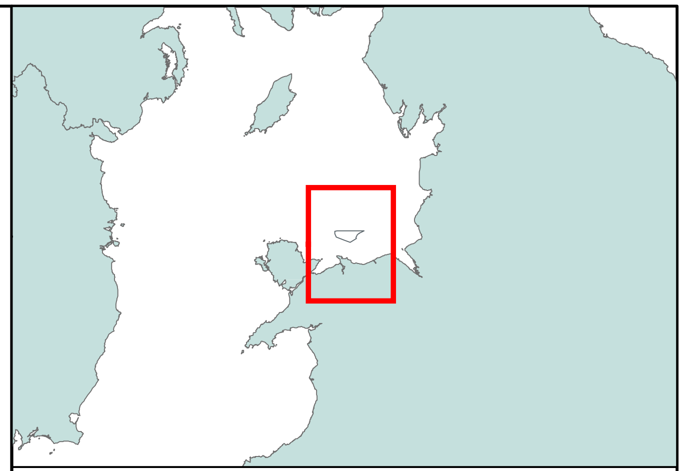
- The release of drilling fluids (which typically contain a lubricating natural clay mineral such as bentonite) along with drill cuttings from the planned HDD operations will result in a localised and temporary plume of elevated SSC. The majority of the plume will be advected in the direction of the ambient tidal currents, which are broadly aligned to the coast. The direction of transport (either to the northeast or southwest) will depend on the state of the tide (flood or ebb) at the time of the release.
- It is expected that the plume would be dispersed to relatively low concentrations within hours of release and to background concentrations within a few tidal cycles;
- The drilling fluid is expected to remain in suspension for at least hours or days and will be widely dispersed before settling. Therefore, it is not expected to accumulate anywhere in measurable thicknesses. If, however, drilling fluid and/or drill cuttings did accumulate initially in or around the HDD exit pit, the volume of the pit could theoretically contain the majority of that material. Any such locally accumulated material is expected to be subsequently reworked and redistributed to not-measurable concentrations and thicknesses over time by wave and tidal action; and
- Lubricating clay in the drilling fluid (typically bentonite or similar) normally has an overall density and viscosity similar to seawater and so is expected to behave (advect, mix and disperse) in a similar manner. If the drilling fluid behaves as a slightly denser fluid, it may either accumulate in the HDD exit pit or move over the adjacent seabed downslope under gravity, i.e. in an offshore direction and away from nearshore areas.

Settlement thickness resulting from plumes from MFE trenching

60 Following disturbance of the seabed by MFE, it is found that:

- The coarser sand and gravel fractions at each site settle to the seabed within a limited time of release (from seconds up to five minutes, i.e. within the ten-minute timestep of the sediment plume model). As such, they tend to be deposited within a relatively smaller footprint than for the deposition of fine-grained material, resulting in a relatively greater local average thickness of the deposit. Maximum average sediment deposit thickness for a range of realistic downstream dispersion distances for coarse grained material is set out in Table 9.
- The predicted thickness of settlement for only the finer sediments dispersed more widely in the passive phase plume is very limited, in the order of <1 mm in all sites, over a dispersed area of effect (Figure 4).
- Sediment accumulation of <1 mm would not cause a measurable change in bed level or sediment type in practice. Fine sediments that do settle are also likely to be subject to further erosion and dispersion during subsequent tides.





LEGEND

Order Limits

Array Area

Bed Level Deposition

- 1 mm
- 5 mm
- 10 mm
- 50 mm
- 100 mm
- 300 mm
- 500 mm

0 10 20 40

Kilometres

Data Source:

PROJECT TITLE:

AWEL Y MÔR OFFSHORE WINDFARM

FIGURE TITLE:

Summary plots showing bed level deposition contours associated with sediment disturbance activities representative of the Maximum Design Scenario

VER	DATE	REMARKS	Drawn	Checked
2	02/03/2022	For Issue	DLW	CRB

FIGURE NUMBER:

Figure 4

SCALE: 1:600,000	PLOT SIZE: A3	DATUM: WGS84	PROJECTION: UTM30N

Fferm Wynt Alltraeth AWEL Y MÔR Offshore Wind Farm

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Table 9: Maximum average sediment deposit thickness for a range of realistic downstream dispersion distances.

DOWNSTREAM DISPERSION DISTANCE (M)	MAXIMUM AVERAGE THICKNESS OF SEDIMENT ACCUMULATION (MM) FOR VARYING TRENCH CROSS SECTIONS		
	4 m²	5 m²	6 m²
5	800	1,000	1,200
10	400	500	600
25	160	200	240
50	80	100	130
100	40	50	60
150	27	33	40
200	20	25	30
250	16	20	24
300	13	17	20

Settlement thickness resulting from plumes from spoil disposal

61 The actual shape and thickness of the seabed deposit resulting from the release of material from the dredger at the water surface cannot be predicted accurately in advance and in any case is likely to vary. A range of possible configurations of area and thickness are presented in Volume 4; Annex 2.3. From this range, the following examples represent a relatively widely spread deposit which is the MDS for the area of seabed affected (by a nominal average thickness of 50 mm (0.05 m)). In practice, the deposit may comprise several individual releases from multiple dredging cycles and the deposits are likely to be relatively thicker (actual thickness dependant on the local thickness of each of the deposits in the area of overlap, which cannot be predicted in advance), with a correspondingly smaller area of effect:

- If up to 11,000 m^3 of material is released from a representative large hopper, an area measuring 220,000 m^2 (nominally 469 x 469 m) could potentially be covered by an average thickness of 50 mm (0.05 m);
- A greater average thickness of material would lead to a smaller area of impact and vice versa. For example, a 100 mm (0.10 m) average thickness deposit would affect an area two times smaller than that described above (for an average deposition thickness of 50 mm (0.05 m)); and
- Deposits resulting from fine sediment that is much more widely dispersed in the passive phase of the plume will have an average thickness less than the diameter of a grain of sand, and therefore would not be measurable in practice (Figure 4). Furthermore, this material would be readily re-mobilised and dispersed further away from the release location, in the direction of the ambient tidal flow.

Persistence of disposal mounds

62 The causes and dimensions of potential seabed deposits forming disposal mounds on the seabed is described in the previous section. The persistence and evolution of these disposal mounds in either the array or offshore ECC will be dependent upon a range of factors, principally:

- The type of material in the mound;
- The size/ shape of the mound; and
- The level of bed shear stress exerted on the mound by tidal currents and waves (water depth being a key determinant of the latter).

63 Arguably the most important of these is the type of material in the mound and this is likely to differ between the array and ECC. For this reason, the potential evolution of disposal mounds in these two areas is considered separately, below.

Disposal mounds in the array

64 Gravity base foundations installed in the array may require seabed preparation, with dredging to an average depth of ~2 m. The nature of the material to be dredged will vary, depending on foundation location: in central and southern areas of the array, excavated material is expected to largely comprise Holocene sands and gravels whereas in northern areas, sands, gravels and stiff boulder clay (belonging to the Western Irish Sea formation) are likely to be encountered (Volume 4, Annex 2.3).

65 In those areas where disposal mounds comprise less mobile disaggregated glacial material (boulder clay) and gravels, it can reasonably be assumed that these mounds will become semi-permanent or permanent seabed features that persist for the lifetime of the Project and potentially beyond. The actual shape and thickness of disposal mounds resulting from the release of material from the dredger cannot be predicted accurately in advance and in any case is likely to vary. However, a range of possible configurations of area and thickness are presented in Volume 4; Annex 2.3. Over time, it can be expected that fine grained material will be further disaggregated and winnowed away, lowering the profile of the mound. Ultimately, this could result in only (largely immobile) gravel sized material remaining, potentially forming an 'armoured' seabed layer.

66 It is noted however, that whilst the disposal mounds might be topographically different from the surrounding seabed, their surficial sediment character may be similar. This is because only a thin veneer - (max. thickness in the order of tens cm's) - of surficial mobile sand is generally present overlying the pre-Holocene surface. This mobile sand would likely be transported onto the disposal mound, creating a similar surficial seabed type and smoothing local topography over time.

67 In those areas where disposal mounds are comprised largely of sandy material similar to the surrounding seabed, given the prevailing hydrodynamic and wave conditions it can reasonably be expected that the sand will be re-mobilised and re-incorporated into the active sediment regime over time. The amount of time it would theoretically take to displace the volume of the mound can be broadly estimated using outputs from the baseline sediment transport model developed to inform baseline understanding (Volume 4, Annex 2.3). Estimates are set out in Table 10 for a nominal disposal mound for one full dredge hopper of ~ 0.5 m height with a footprint of 150 m by 150 m: given that rates of net sand transport in the array are in the approximate range 0.1 to 0.5 m^3/day/m, disposal mounds comprising sand may be expected to persist (with a gradually decreasing volume) for a period of at least a few (~4) months to a few (~2) years.

68 It is recognised that the timescales set out above are based on the assumption that material is removed from the mounds and not replaced by sediment transported towards the mounds. Actual timescales may therefore be longer as this assumption will not hold true for all areas. On the other hand, the estimates of mound persistence are based on sediment transport modelling which doesn't factor in the influence of waves which would naturally erode material in the mounds. This will become increasingly important in shallower water depths such as those along inshore sections of the offshore ECC, as discussed below.

Table 10: Indicative estimates for the persistence of disposal mounds in the array and offshore ECC comprising sand, based on modelled rates of net tidally driven sediment transport

NET RATE OF SEDIMENT TRANSPORT (M^3/M/DAY)*	TIME TO DISPLACE MOUND**		
	Expressed in Days	Expressed in Months	Expressed in Years
0.5	132	4.4	0.4
0.25	264	8.8	0.7
0.1	660	22	1.8

NET RATE OF SEDIMENT TRANSPORT ($M^3/M/DAY$)*	TIME TO DISPLACE MOUND**		
	Expressed in Days	Expressed in Months	Expressed in Years
0.05	1,320	55	3.7
0.025	1,640	88	7.3

*Does not account for influence of waves which may reduce the likely time required to displace the mound.

**Based on a disposal mound of ~ 0.5 m height with a nominal footprint of 150 m by 150 m.

Disposal mounds in the offshore ECC

69 Unlike within the array, it can reasonably be expected that disposal mounds in the offshore ECC will comprise entirely (or almost entirely) of sand. This is because any dredging will be associated with sand wave levelling/ clearance and will not involve the excavation of stiff clays and gravels. On the basis of the estimates set out in Table 10, mounds comprising of sand may persist for a period of a few (~4) months to a few (<10) years, depending upon location.

70 It is noted that the lowest rates of net (tidally-driven) sediment transport are encountered closer inshore in very shallow (<5 m below LAT) waters. Whilst net rates of tidally driven sediment transport may be low here, waves will also frequently stir the seabed and contribute to sediment mobility – especially during winter months where material contained within the mounds may be dispersed rapidly during storm events. This is confirmed by observational evidence of change in seabed levels between recently (2019 and 2020) collected multibeam bathymetric surveys from inshore areas of the offshore ECC which show areas of both erosion and accretion (see Volume 4, Annex 2.3).

In-combination considerations

71 If multiple activities causing sediment disturbance (such as dredging, drilling or cable installation) are undertaken simultaneously at two or more locations that are aligned in relation to the ambient tidal streams, then there is potential for overlap between the areas of change in SSC and sediment deposition. The change in SSC in areas of overlap will be additive if the downstream activity occurs within the area of effect from upstream (i.e. sediment is disturbed within the sediment plume from the upstream location). The change in SSC will not be additive (i.e. the effects will be as described for single occurrences only) if the areas of effect only meet or overlap downstream following advection or dispersion of the effects. Effects on sediment deposition will be additive if and where the footprints of the deposits overlap.

Assessment of significance

72 All the identified physical processes receptors will be insensitive to localised changes in SSC and bed levels associated with the sediment disturbance activities described in this section. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the ES, in particular:

- Volume 2, Chapter 3;
- Volume 2, Chapter 4;
- Volume 2, Chapter 5;
- Volume 2, Chapter 6; and
- Volume 2, Chapter 7.

2.10.2 Potential changes to Constable Bank/ Rhyl Flats and designated sites owing to the combined influence of sediment removal activities e.g. dredging and sandwave clearance

Overview

73 During the construction phase, seabed sediment may be removed during the following:

- Bed preparation in advance of WTG or OSP foundation installation
- Sand wave pre-sweeping/ levelling prior to cable installation.

74 This may be achieved through a range of techniques, including via TSHD. Full details of the MDS are provided in Table 7.

75 In theory, the removal of (mobile) seabed material could impact identified physical process receptors either directly (if the activity is located on the receptor) or indirectly, through a change in sediment supply to downdrift locations. These are considered further in this section.

Conceptual understanding of change

Direct impacts to features

76 Both Rhyl Flats and Liverpool Bay SPA are coincident with the offshore ECC and direct disturbance to either receptor could occur. Detailed analysis of the geophysical data available from the offshore ECC shows that where bedforms are presented, they tend to be migrating at relatively fast rates (~10 m/yr in places), in an easterly direction (Fugro, 2020b; Volume 4; Annex 2.1). In shallow nearshore areas it is more difficult to discern migration characteristics although a comparison of available bathymetric survey data clearly demonstrates that the seabed is highly mobile, with sediment being regularly mobilised by the action of wave and tidal currents.

77 The available observational evidence all suggests that where sandwaves and megaripples are present in the offshore ECC, the seabed is highly mobile. Therefore, any direct disturbance resulting from bedform removal will likely only result in short-term change in seabed morphology. In very shallow areas (e.g. on and inshore of Rhyl Flats) where waves are regularly re-working the bed, it is likely that recover to baseline conditions may occur over a period of weeks to months. In deeper areas the recovery timescale is likely to be slightly longer due to more limited wave action but offset by a higher tidally driven net sediment transport rate (order of months to a few years).

Indirect impact (changes in sediment supply)

78 The available observational and modelling evidence presented in Volume 4, Annex 2.1 suggests that regional scale bedload sediment transport is broadly from west to east, a finding that is consistent with previous sediment transport studies undertaken in this region (e.g. Kenyon & Cooper, 2005; Halcrow, 2010). These patterns are most clearly observed in the offshore ECC and on Constable Bank/ Rhyl Flats, to the south of the AyM array. There is also predicted to be (southerly) net fine sediment transport links between Constable Bank and Rhyl Flats and the adjacent coastline, driven by the residual effect of combined tidal and wave forcing, but this process is poorly understood (Halcrow, 2010).

79 It is important to note that unlike aggregate dredging (which removes sediment from the local sediment transport system), no sediment would be lost from the coastal process system because of the TSHD activity being proposed. This is because the dredged material would only be locally displaced by transporting it a short distance before depositing it back to the bed, as set out in the mitigation table (Table 8). Accordingly, the net supply of material to down drift locations along with overall sediment availability will remain largely unaltered. This is a particularly relevant consideration because Constable Bank is known to act as a pathway for sediment supply to Rhyl Flats and both banks may potentially provide an onshore directed supply of finer sediment, as noted above.

80 The use of MFE would also result in material being retained within the local sediment transport system. This is because the coarse grained (sandy) material that would be displaced would rapidly settle out of suspension relatively nearby to the disturbance location (see Section 1.10.1; paragraph 45 *et seq.*)

Assessment of significance

81 Using the criteria presented in Table 5, Constable Bank and Rhyl Flats are considered to be of **medium** sensitivity/ importance because of their influence on the geomorphology of the adjacent coastline and role in reducing flood risk.

82 The Liverpool Bay SPA (immediately adjacent to the array and overlapping with the offshore ECC), Menai Strait and Conway Bay SAC (6 km from the offshore ECC) and Dee Estuary SAC/ SPA (3.5 km from the offshore ECC) are all internationally important. However, the seabed in these areas is highly dynamic and is assessed to have some capacity to recover from disturbance. Accordingly, they, are assessed as of **medium** sensitivity/ importance.

83 Where the offshore ECC is coincident with the Liverpool Bay SPA and Rhyl Flats, the magnitude of impact to the seabed in these areas is considered **low**. This is because although direct impacts to the seabed will occur, the seabed is expected to recover quickly, owing to the high degree of sediment mobility and rapid movement of bedforms in these areas.

84 Outside of these areas, impacts to all receptors will be **negligible**. This is because no material will be removed from the local system and sediment transport to these areas will therefore remain unaltered from baseline conditions.

85 The overall level of effect significance has been assessed according to the EIA methodology set out in Section 1.5 (paragraph 19 *et seq.*). Effect significance has been determined by combining the assigned rating for receptor sensitivity/ importance and impact magnitude, as shown in Table 6. The effect is assessed to be ***minor adverse*** significance in terms of the EIA Regulations which is not significant in EIA terms.

2.10.3 Potential changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast, arising from dredging/ disposal induced bed level change and associated modification of waves, tides and sediment transport

Overview

86 As set out in the MDS Table (Table 7), dredging and disposal activities associated with sand wave clearance (prior to cable installation) and bed levelling (prior to WTG and OSP foundation installation) could result in localised changes in bed levels. In theory, such changes could locally alter hydrodynamic and wave conditions with associated changes to morphology. This section considers the potential for changes to these pathways to impact the morphology of banks, designated sites and the adjacent coastline.

Conceptual understanding of change

Dredging

87 Dredging can be expected to result in localised lowering of the seabed by up to ~5 m in some places in responses to the presence of mobile sandwave features. More typically, (and given the known characteristics of sandwaves within the array and offshore ECC following the project specific geophysical survey), dredging to depths of between 1- 3 m is more realistic in most areas.

88 Following dredging, tidal currents may be expected to be locally modified as the increased water depths will locally attract a slightly greater tidal discharge through the dredged area. As the increased discharge enters and leaves the dredged areas, it will cause faster current speeds over the un-dredged areas of the seabed in the upstream and downstream direction. Within the dredging areas themselves, the increase in water depths and discharge is expected to result in little change in the depth-averaged current speeds. In terms of waves, lowering of the bed will reduce the frictional dissipation of wave energy, potentially allowing greater wave energy to be transmitted across the dredged area of seabed.

89 However, whilst highly localised changes to waves and tidal currents may potentially occur in the vicinity of the dredged seabed areas, it is important to note that the dredging activity would be focused on levelling sections of sand waves. These features have been demonstrated to be moderately to highly mobile (Volume 4; Annex 2.1), with water depths in areas where they are present varying in response to their migration. Accordingly, the dredging activity is not expected to cause changes in water depths that are outside of the range that would be occurring naturally over time.

Disposal

90 The persistence of any disposal mounds in either the array or offshore ECC has been discussed in detail in paragraph 62 *et seq*. The actual shape and thickness of the seabed deposit resulting from the release of material from the dredger at the water surface cannot be predicted accurately in advance and in any case is likely to vary. A range of possible configurations of area and thickness are presented in Volume 4; Annex 2.3 and could realistically be in the order of several metres high immediately beneath the dredger.

91 In terms of potential changes to Constable Bank, Rhyl Flats and the adjacent coast, it is the disposal mounds which may be present along the offshore ECC that are of most relevance, owing to their proximity to these receptors. However, here the dredged material will comprise coarse grained (primarily) sandy material which is known to be naturally highly mobile under baseline conditions (Volume 4; Annex 2.1). The material in the spoil mounds is expected to be readily remobilised by the action of waves and tidal currents and fairly rapidly re-incorporated into the mobile surficial sediment unit. Accordingly, the mounds are not expected to become persistent seabed features in these locations.

Assessment of significance

92 Using the criteria presented in Table 5, both Constable Bank and Rhyl Flats are considered to be of **medium** sensitivity/ importance as they are both understood to have an important influence on the geomorphology of the adjacent coastline, through the possible exchange of sediments and potential impacts on hydrodynamics and waves.

93 The closest designated sites (namely the Liverpool Bay SPA, Menai Strait & Conwy SAC and Dee Estuary SAC/ SPA) are all internationally important. However, the seabed in these areas is highly dynamic and is assessed to have some capacity to recover from disturbance. Accordingly, they are assessed to of **medium** sensitivity/ importance.

94 The coast itself is also considered to be of **medium** sensitivity/ importance. Although it has a number of important functions and is designated (in places), the shoreline is typically a dynamic environment which is often subject to a large amount of natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance.

95 The magnitude of impact is predicted to be **negligible**. This is because any reductions in bed level in response to dredging will be within the range of that occurring naturally in response to migration of the bedform features that may be dredged. Any increases in bed level in response to spoil disposal are expected to be of short-term duration and modest in relation to total water depth at any given location.

96 Accordingly, the resultant change in wave and hydrodynamic processes are expected to be very small and highly localised, not resulting in morphological impacts to either Constable Bank, Rhyl Flats, designated sites or the coast.

97 The overall level of effect significance has been assessed according to the EIA methodology set out in Section 1.5 (paragraph 19 *et seq.*). Effect significance has been determined by combining the assigned rating for receptor sensitivity/ importance and impact magnitude, as shown in Table 6. Overall, the effect is assessed to be ***minor adverse*** significance which is not significant in EIA terms.

2.10.4 Potential changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast, arising from blockage effects associated with (partially) installed infrastructure

Overview

98 The installation of any turbine foundations, OSP foundations and cable protection measures all have the potential to result in a localised blockage of waves, tides and sediment transport. This blockage will commence when offshore construction begins, increasing incrementally up to the MDS which is represented by the fully operational project. WTG and OSP foundation installation is expected to commence in 2027 and be complete within 36 months.

Conceptual understanding of change

99 Numerical modelling has been undertaken to quantify change in currents and waves in response to (full) operation of AyM. Full details are set out in Section 1.11.2 and in Section 1.11.3. In brief, Changes in depth average current speed and direction are predicted to be very small in absolute and relative terms, (<± 0.01 m/s current speed and <3 deg current direction, which is within the range of natural variability and not measurable in practice) away from the immediate vicinity of the WTG and OSP foundations. For waves, the greatest relative change arising from AyM and other operational wind farms acting together is between 5 and 10% of the baseline wave height, within and immediately downwind of the AyM array. Short narrow current wakes and local wave shadow features (measurable change within metres to tens of metres of individual foundations) are likely but are not resolved in detail by the model.

100 The predicted magnitude of change to these parameters will not be exceeded during the construction (or decommissioning) phase since the number of installed foundations will be less than for the MDS.

Assessment of significance

101 The effect significance of potential impacts to Constable Bank, Rhyl Flats and along the adjacent coast will be no greater than that identified for the operational phase arising from changes to:

- The tidal regime (Section 1.11.2);
- The wave regime (Section 1.11.3);
- The sediment transport regime (Section 1.11.4).

2.10.5 Potential changes to the coast arising from HDD and trenching at the landfall

Overview

102 The landfall is at Ffrith Beach on the Prestatyn coastline, immediately to the east of the town of Rhyl (see Figure 5). This is also the landfall location for the Burbo Bank Extension export cable which was successfully installed in 2016. The method for AyM export cable installation broadly follows that used for Burbo Bank Extension, which to date is understood not to have encountered any issues at its landfall. Full details of the MDS are provided in Table 7. The assessment below separately considers the potential for impacts associated with:

- Beach access;
- Trenchless installation techniques;
- The construction of HDD exit pits; and
- Trenching across the intertidal.

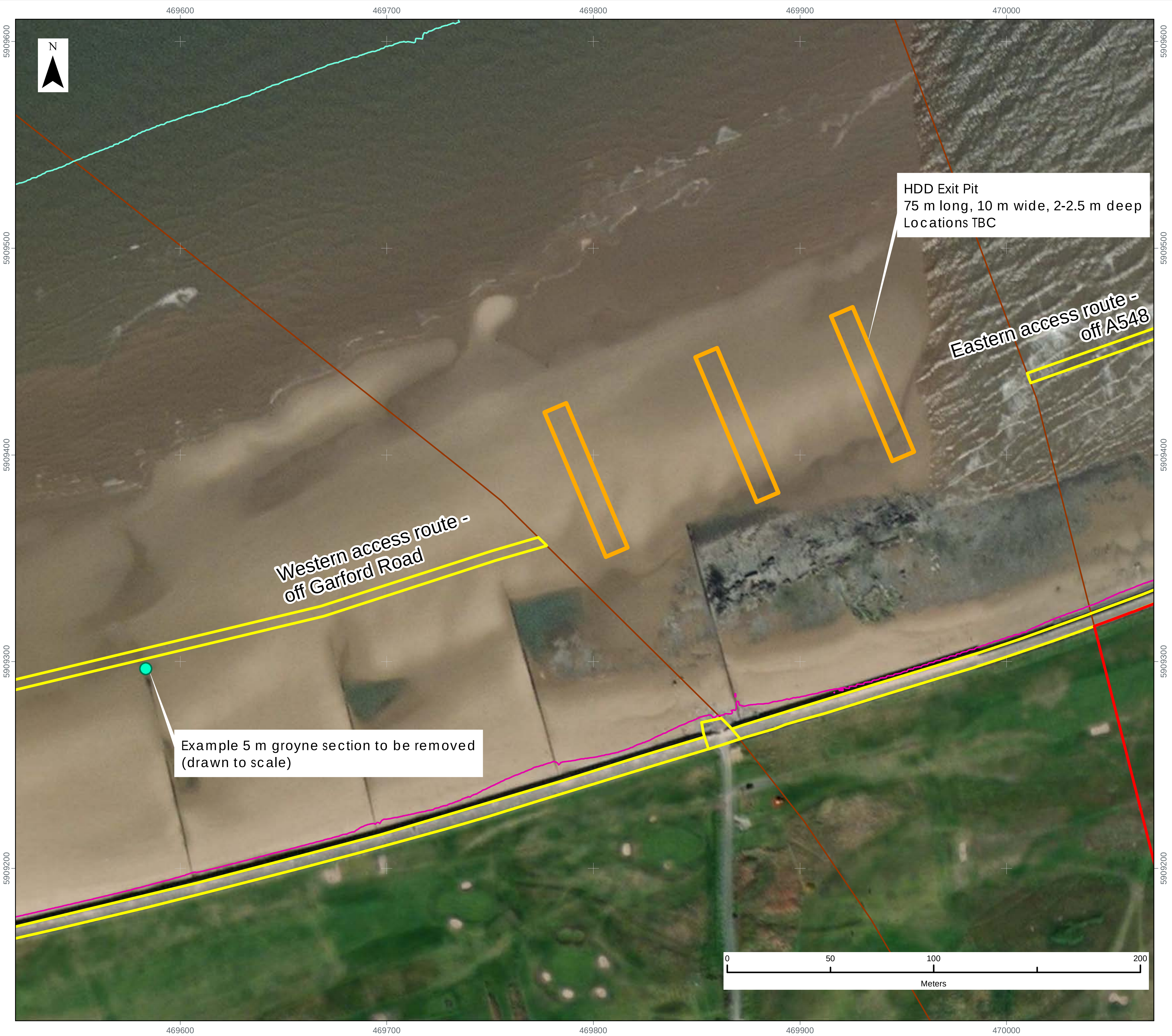
Conceptual understanding of change

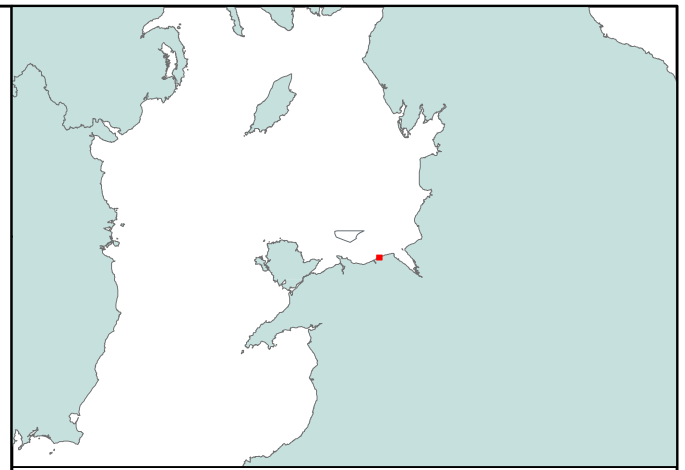
Beach access

103 Vehicular access to the upper beach would be achieved via either an eastern or western access route (Figure 5). Both routes may require the crossing of groynes, either by ramp (for those constructed with rock armour) or by removal of a small section of the groyne (for those constructed with wood). For the eastern access route, five groynes have been identified between the beach slipway access point and the HDD Zone, three of which are constructed with loose rock armour (boulders) and two comprise of wooden posts. For the western access route, nine groynes have been identified between the beach slipway access point and the HDD Zone, all constructed with wooden posts with boards between them.

104 Where wooden groynes are to be crossed, c. 5 m wide sections could be removed to a depth of c. 1 m: this would comprise removal of wooden boarding and likely at least one wooden post. The excavation would then be backfilled with local beach sediment and when used for vehicular access wooden ‘sleepers’, steels or pre-cast reinforced concrete or platforms used to spread the load of vehicles when crossing over the buried groynes. Following completion of the works the groyne would then be reinstated to original condition with securing of new section of wooden post and replacement of boarding. The maximum period with gaps in the groynes would be 10 months. If construction is split into two stages, then the longest stage would be 6 months.

105 The net movement of sediment along the coastline is from west to east. The groynes present on the beach locally intercept sand, thereby increasing the beach volume in front of the concrete sea defence. This material in turn has a role to play in flood risk management via the dissipation of wave energy.





LEGEND

- Order Limits
- MHWS Contour
- MLWN Contour
- Route Accesses
- 40m Cable Corridor
- HDD Exit Pit

Data Sources: RWE, 2020. Basemap: Esri et al. © ABPmer, All rights reserved, 2022.

PROJECT TITLE:

AWEL Y MÔR OFFSHORE WINDFARM

FIGURE TITLE:

Offshore ECC landfall at Frith

VER	DATE	REMARKS	Drawn	Checked
2	02/03/2022	For Issue	CRB	DLW

FIGURE NUMBER:

Figure 5

SCALE:	PLOT SIZE:	DATUM:	PROJECTION:
1:1,900	A3	WGS84	UTM30N

Fferm Wynt Alltraeth AWEL Y MÔR Offshore Wind Farm

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106 It is reasonable to assume that the temporary removal of short sections of the groynes has the potential to locally alter net rates of sediment transport with the possibility of small-scale changes in beach morphology immediately adjacent to the modified groynes in front of the sea wall. The extent of these changes is difficult to quantify precisely and will depend upon (amongst other things):

- The availability of mobile sediment in the vicinity of the modified groynes; and
- The environmental conditions that occur during the time period that the groynes are in their modified state.

107 In theory, a reduction of sediment volume and beach level in front of the coastal defences could marginally increase flood risk through the exposure of the sea defence to greater wave energy. However, the overall reduction in material is expected to be very small and therefore any associated (theoretical) increase in flood risk is also expected to be similarly limited.

HDD drilling operations

108 The physical characteristics of the beach at the landfall have been described in Volume 4; Annex 2.1. It is broad and sandy, with ridge and runnel morphology present which influences vertical change in beach elevation over time. Areas of exposed rocky ground are visible over large areas at the back of the beach, suggesting that the beach is a thin sandy veneer overlying a hard rock platform. The distribution of the sand veneer is evidently spatially variable in thickness and controlled in part by the presence of regular cross-shore wooden groynes and a high vertical concrete seawall at the back of the beach. Another feature in the nearshore area is the presence of a concrete outfall that extends beyond the surrounding groynes. A greater width of sediment accumulation on the western side of the outfall is consistent with the conceptual understanding of net sediment transport to the east in this area.

109 Trenchless techniques will likely be used to create an underground conduit for each of the two cables between the beach and onshore parts of the route. HDD is likely required in this case due to the presence of the high concrete sea defences at the back of the beach, with the exit points potentially located somewhere within the (intertidal) beach.

110 HDD will cause minimal direct disturbance to the existing coastline because it will not interact directly with, or leave any infrastructure exposed in, the active parts of the beach (between the entry and exit points of the drill) and so will not impact upon littoral processes in these areas. Provided that the cable remains buried beyond the exit of the HDD, there is no possibility for it to interact with, or have any effect on nearshore beach processes or morphology. The design of the HDD operation will take this into account.

111 The presence of the seawall coastal defences means that the choice of location for the onshore HDD works and jointing bay is unaffected by the possibility of coastal retreat due to either natural erosion or sea level rise due to climate change.

Construction of HDD exit pits

112 Up to three HDD exit pits may be excavated on the beach between the existing seawall and up to ~1,000 m seaward (below LAT). The dimensions of the HDD exit pits will be up to 10 m wide, 75 m long and 2.5 m deep. This corresponds to a total volume of excavated material of ~1,875 m^3 for each pit, 5,625 m^3 in total. It is anticipated that the excavated material would be stored nearby as temporary spoil mounds. The excavated material will comprise sands, gravels and (potentially) cobbles. There is also potential for peat to be excavated as this is known to be locally present.

113 Once the duct has been installed, the pit may be secured by infilling with temporary rock bags (or similar) to prevent collapse and manage natural infill. The period between duct installation and cable installation may be up to 18 months. Prior to cable installation, any loose sediment which has accumulated in the pits would be removed, with the pits back filled once the cables have been installed.

114 Although the pits may be present for up to 18 months, the potential for these temporary features to modify the wave regime will be limited as they will be temporarily infilled with rock bags. Accordingly, water depths within their footprint will remain similar to baseline levels. Depending upon the position of the spoil mounds in the intertidal and the rate and pattern of any redistribution of the material (controlling the change of water depth in their footprint), there may be potential for these to locally modify the nearshore wave regime through the differently distributed transmission of wave energy across the beach. This could theoretically result in a morphological response although this would be highly localised to the area around mounds. The onward propagation of any change would also be somewhat limited by the presence of the groynes.

115 If the HDD exit pits do remain open for 18 months, it will necessarily mean that they will be present during winter months. During this period, the likelihood that the material comprising the spoil mounds will be at least partially redistributed across the beach is considered high.

Trenching operations

116 Trenching across the intertidal/ shallow subtidal could be achieved using several techniques although ploughing is expected to displace the greatest volume of material out of the trench and therefore is considered to represent the MDS. Excavation of the trench with a plough would result in the formation of berms either side of the trench. The size of these berms will be dependent upon the trench width, cable burial depth and nature of the disturbed sediments.

117 The disturbed sediments are anticipated to primarily comprise coarse grained material whilst the likely trench dimensions are not presently known. These will be established once more knowledge of the site has been gathered and processed and a detailed Cable Burial Assessment and cable landfall study has been performed. Notwithstanding the above, consideration of the available evidence for morphological change at the landfall suggests burial of ~3 m may well be required in some areas (Volume 4; Annex 2.1).

118 It is possible that whilst the trenches are open (assumed to be a period of days to a few weeks), the material in the berms could be mobilised by the action of tidal currents and waves and locally redistributed. Accordingly, the potential extent of change to beach/ intertidal morphology could extend across a wider area than the immediate footprint of the trench and berms. However, it is anticipated that the full volume of the berms adjacent to the trench would only be present on the seabed/ beach for a relatively short period of time (order of days to a few weeks, depending on the pattern of tidal inundation and wave action in that time) and therefore the extent to which this redistribution of material could occur is anticipated to be limited. Furthermore, given that the berms would only be present for a very short period of time, any changes to hydrodynamics and sediment transport would also be highly localised and there would be no potential for longer term change to coastal morphology.

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

Assessment of significance

120 Using the criteria presented in Table 5, the coast at the landfall is of **medium** sensitivity/ importance. The coast plays a number of important roles (including influencing flood risk) but the shoreline here has been shown to be highly dynamic and subject to a large amount of natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance.

121 Whilst the activity of HDD itself is not expected to have any impact on the coast or the morphology of the beach, it is expected that the excavation of HDD exit pits, (possible) trenching across the beach as well as the temporary removal of some groynes could all result in short-term and localised morphology change. These changes would not be expected to persist once the HDD exit pits and trenches backfilled, and the groynes repaired, following cable installation. On this basis, the magnitude of change is assessed to be **low**.

122 Overall, the effect on the coast at the landfall is assessed as ***minor adverse*** significance which is not significant in EIA terms.

2.10.6 Potential for long-term changes to the coast arising from the use of cable protection at the landfall

Overview

123 The MDS for cable installation at the landfall will involve HDD punch-out in an intertidal setting with the use of a plough to achieve cable burial across the intertidal area. The cable trench would be back-filled with the displaced sediment to achieve protection, returning the elevation of the beach to its baseline level as assessed above. However, concrete mattressing may also be installed to offer additional cable protection.

Conceptual understanding of change

124 Consideration of topographic, LiDAR and aerial photography demonstrates that the beach at the landfall is dynamic, with vertical change locally in excess of 2 m over relatively short periods of time. Beach elevation is driven by seasonal offshore-onshore sediment exchange and migration of ridge and runnel features (Volume 4; Annex 2.1).

125 The appropriate depth of cable burial across the mobile intertidal areas at the landfall will be informed by a detailed CBRA alongside analysis of geophysical and geotechnical data. It is anticipated that burial of the cable will provide sufficient protection to ensure exposure does not occur throughout the lifetime of the project. However, following the detailed review of the potential for morphological change at the landfall, it may be considered prudent to install additional concrete mattressing (dimensions 6 m length x 3 m width x 0.3 m height) to offer additional protection in vulnerable locations.

126 The installation of any cable protection measures could cause a morphological response via modification of the local nearshore wave regime and associated patterns of sediment transport, as well as via localised scour. However, it is expected to be the case that if cable protection was installed at the landfall it would be installed below the (winter) beach level therefore presenting no barrier to the passage of waves and so cause no change to long-term patterns of sediment transport.

Assessment of significance

127 Using the criteria presented in Table 5, the coast at the landfall is of **medium** sensitivity/ importance.

128 The magnitude of impact is predicted to be **negligible**. This assessment assumes any cable protection measures will remain buried and therefore not interact with hydrodynamic, wave or sediment transport processes. As such, there will be no resulting morphological change to the beach.

129 The overall level of effect significance has been assessed according to the EIA methodology set out in Section 1.5 (paragraph 19 *et seq*.). Effect significance has been determined by combining the assigned rating for receptor sensitivity/ importance and impact magnitude, as shown in Table 6. Overall, the effect on the coast is ***minor adverse*** significance which is not significant in EIA terms.

2.10.7 Potential for long-term changes to the coast arising from cable protection within nearshore areas

Overview

130 Cable protection within shallow subtidal areas will primarily be achieved via burial to a depth below the level of the mobile bed. However, given the dynamic nature of the seabed in this area, additional protection may be required to ensure that the cables do not become exposed.

131 From the outset, it should be noted that the Applicant has committed to not using rock berm protection within a distance of 1,000 m from the existing sea defence (the toe of which is approximately at the MHWS mark). The use of rock berms would provide the greatest potential for the modification of nearshore wave and hydrodynamic processes. Instead, cable mattressing (which has an indicative width of 3 m; a length of 6 m and a height of only 0.3 m) would be used in these areas, as set out in Table 7.

132 At a distance of greater than 1,000 m from the sea defence, rock berms could potentially be used to protect the export cables. The rock berms are expected to have a base width of ~15.2 m, 1.4 m overall height and sloped sides up to a 4.5 m wide berm crest. The exact location of the rock berms and orientation relative to the beach is presently unknown. However, given the route of the offshore ECC, it is probable that the long axis of the rock berms will be orientated generally across the main tidal current axis but broadly aligned with the direction of waves as they approach the coast. Two berms may theoretically be installed, one for each export cable.

Conceptual understanding of change

133 Cable protection in shallow areas could theoretically work in a similar way to a submerged offshore breakwater, affecting wave transformation processes closer to shore. This in turn could potentially alter the wave approach to the shore leading to wave focussing on areas of the beach not presently eroding, resulting in long-term lowering. The structures themselves could also locally intercept sediment being transported by wave and tidal driven currents. However, whilst it can reasonably be expected to be the case that there will be some localised change to waves and hydrodynamics immediately within the vicinity of the rock berms, the potential for wider morphological change to the beach at the landfall is considered to be limited.

134 The landfall is located in a macro-tidal setting, with a mean spring range in excess of 7 m. Whilst some wave breaking can be expected in the lee of the berms at lower states of the tide, for the majority of the time when total water depth is greater, waves are unlikely to interact with or be affected by the small and localised relative change in total water depth.

135 Water depths immediately offshore from the landfall are shallow: at ~5 km offshore, they are still only ~1-2 m below LAT in many areas. These shallow areas will attenuate the larger waves which would have greater potential to interact with the rock berms.

136 The (probable) shore-normal orientation of the rock berms could in theory, temporarily intercept the longshore movement of sediment. However, regular re-working by waves at lower states of the tide is likely to mean that this material would be rapidly re-distributed and could easily pass over the obstacle in suspension. Accordingly, the degree to which the rock berms will physically block the movement of sediment is expected to be very limited.

137 It should also be noted that it is the upper beach which plays the most critical role in coastal defence and moderating flood risk. Any morphological changes arising from the presence of the berms would be restricted to the lower beach and localised.

Assessment of significance

138 Using the criteria presented in Table 5, the coastline is of **medium** sensitivity/ importance. Although designated (in places), the shoreline is typically a dynamic environment which is often subject to a large amount of natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance.

139 The magnitude of change to the beach at the landfall is assessed to be **low**. Although some longer-term morphological change can reasonably be expected to occur to lower areas of the foreshore in the vicinity of the rock berms, the spatial extent is expected to be limited. Vertical changes in beach elevation as a result of subtidal morphological change and/or modification of waves, are also expected to be similarly limited.

140 Using the sensitivity matrix, a low magnitude of change to the coastline receptor of medium importance results in an effect of ***minor adverse*** significance which is not significant in EIA terms.

2.11 Environmental assessment: operational phase

2.11.1 Potential for scour of seabed sediments, including that around scour protection structures

Overview

141 The term scour refers here to the development of pits, troughs or other depressions in the seabed sediments around the base of wind turbine foundations. Scour is the result of net sediment removal over time due to the complex three-dimensional interaction between the foundation and ambient flows (currents and/or waves). Such interactions result in locally accelerated mean flow and locally elevated turbulence levels that also locally enhance sediment transport potential. The resulting dimensions of the scour features and their rate of development are, generally, dependent upon the characteristics of the:

- Obstacle (dimensions, shape and orientation);
- Ambient flow (depth, magnitude, orientation and variation including tidal currents, waves, or combined conditions); and
- Seabed sediment (geotextural and geotechnical properties).

142 Scour assessment for EIA purposes is considered here for monopile, (piled) jacket and GBF. The potential concerns include the seabed area that may be modified from its natural state (potentially impacting sensitive receptors through habitat alteration) and the volume and rate of additional sediment re-suspension, as a result of scour.

143 The seabed area directly affected by scour may be modified from the baseline or ambient state in several ways, including:

- A different (coarser) surface sediment grain size distribution could develop due to winnowing of finer material by the more energetic flow within the scour pit;
- Seabed slopes could be locally steeper in the scour pit; and
- Flow speed and/or turbulence would be locally elevated, on average.

144 The scale of change would vary depending upon the foundation type, the local baseline oceanographic and sedimentary environments and the type of scour protection implemented (if needed). In some cases, the modified sediment character within a scour pit may not be so different from the surrounding seabed. However, changes relating to bed slope and elevated flow speed and (near-field) turbulence are still likely to apply. As such, depending upon the sensitivities of the particular ecological receptor, not all scouring necessarily correspond to a loss of habitat. This is discussed further in Volume 2, Chapter 5.

145 Suction bucket foundations (along with suction bucket & gravity base jacket foundations) have not been considered separately in the assessment below because these will fall within the envelope of change associated with the other three foundation types.

Conceptual understanding of change

146 In order to quantify the area of seabed that might be affected by scour (either the footprint of scour or scour protection), the following provides an estimate of the theoretical maximum depth and extent of scour. This assessment is based upon empirical relationships described in Whitehouse (1998) and is a summary of a more detailed assessment presented in Volume 4; Annex 2.3. Importantly, these estimates are highly conservative as they assume an unlimited depth of erodible sediment at all final foundation locations. In practice, the thickness of erodible sediments overlying erosion resistant glacial tills is less than 2 m over much of the north and western parts of the array area, which will naturally limit the maximum potential scour depth and volume for foundations located in these areas.

147 Results conservatively assume maximum equilibrium scour depths are symmetrically present around the perimeter of the structure in a uniform and frequently mobile sedimentary environment. Derivative calculations of scour extent, footprint and volume assume an angle of internal friction is 32º. Scour extent is measured from the structure's edge. Scour footprint excludes the footprint of the structure. Scour pit volumes for GBF structures are calculated as the volume of an inverted truncated cone, minus the structure volume; scour pit volumes for the jacket foundations are similarly calculated but as the sum of that predicted for each the corner piles.

148 The term ‘local scour’ refers to the local response to individual structure members. ‘Global scour’ refers to a region of shallower but potentially more extensive scour associated with a multi-member foundation resulting from the change in flow velocity through the gaps between members of the structure and turbulence shed by the entire structure. Global scour does not imply scour at the scale of the wind farm array.

149 Key findings are summarised below and in Table 11 and Table 12:

- Overall, scour development within the AyM array area is expected to be dominated by the action of tidal currents;
- In practice, the thickness of unconsolidated (and more easily erodible) surficial Holocene sediment is spatially variable across the AyM array, with the greatest thicknesses found in central and eastern areas of the array (Fugro, 2020a). In the west, pre-Holocene material is at or close to the surface and may limit the extent to which scour can occur. (Detailed geotechnical information is not currently available so the extent to which this is the case remains unknown at this stage);
- Of all of the turbine foundation options under consideration, a 15 m diameter monopile foundation has the potential to cause the greatest equilibrium local scour depth (19.5 m), footprint (4,530 m^2) and volume (up to 34,224 m3), but only in areas where the seabed is potentially erodible by the action of scour to that depth;

Table 11: Summary of predicted maximum scour dimensions for largest individual turbine foundation structures.

PARAMETER		FOUNDATION TYPE		
		MONOPILE (15 M DIAMETER)	MULTI-LEG (40 M BASE, 4 X 3.5 M LEGS)	GRAVITY BASE (55 M DIAMETER)
Equilibrium Scour Depth (m)^	Steady current	19.5	4.6	3.1
	Waves	Insufficient for scour	Insufficient for scour	2.2
	Waves & current	19.5	4.6	3.5
	Global scour		1.4	
Extent from foundation* (m)	Local scour	31.2	7.3	4.9
	Global scour	N/A	40.0	N/A
Footprint* (m^2)	Structure alone	177	38	2,376
	Local scour (exc. Structure)	4,530	987	929
	Global scour (exc. Structure)	N/A	4,988	N/A
Volume* (m^3)	Local scour (exc. Structure)	34,224	1,739	1,392

PARAMETER		FOUNDATION TYPE		
		MONOPILE (15 M DIAMETER)	MULTI-LEG (40 M BASE, 4 X 3.5 M LEGS)	GRAVITY BASE (55 M DIAMETER)
	Global scour (exc. local scour and structure)	N/A	6,983	N/A

^ Results assume erodible bed and absence of geological controls

* Based upon the scour depth for steady currents. Footprint and volume values are per foundation.

Table 12: Total seabed footprint of the different foundation types with and without Scour.

PARAMETER	MONOPILES		MULTI-LEG		GRAVITY BASE	
	(13 M DIAMETER)	(15 M DIAMETER)	(30 M BASE LENGTH)	(40 M BASE LENGTH)	(45 M DIAMETER)	(55 M DIAMETER)
Maximum number of foundations	50 x WTG 2 x OSP	34 x WTG 2 x OSP	50 x WTG 2 x OSP	34 x WTG 2 x OSP	50 x WTG 2 x OSP	34 x WTG 2 x OSP
Seabed footprint of all foundations (m^2)	6,990	6,362	2,040	1,424	84,273	85,530
Proportion of array area* (%)	<0.1	<0.1	<0.1	<0.1%	0.1	0.1
Seabed footprint of all local scour (m^2)	179,187	163,080	52,286	36,502	32,291	33,439
Proportion of array area* (%)	0.2	0.2	0.1	<0.1%	<0.1%	<0.1%
Seabed footprint of all foundations + local scour (m^2)	186,177	169,442	54,326	37,926	116,564	118,969

PARAMETER	MONOPILES		MULTI-LEG		GRAVITY BASE	
	(13 M DIAMETER)	(15 M DIAMETER)	(30 M BASE LENGTH)	(40 M BASE LENGTH)	(45 M DIAMETER)	(55 M DIAMETER)
Proportion of array area* (%)	0.2	0.2	0.1	<0.1%	0.1	0.2
Seabed footprint of all global scour (m^2)	NA	NA	155,040	185,187	NA	NA
Proportion of array area* (%)	NA	NA	0.2	0.2	NA	NA
Seabed footprint of all scour protection (m^2)	185,415	188,420	78,548	54,836	519,190	513,045
Proportion of array area* (%)	0.2	0.2	0.1	0.1	0.7	0.7
Seabed footprint of all foundations + scour protection (m^2)	192,405	194,782	80,588	56,260	603,463	598,575

PARAMETER	MONOPILES		MULTI-LEG		GRAVITY BASE	
	(13 M DIAMETER)	(15 M DIAMETER)	(30 M BASE LENGTH)	(40 M BASE LENGTH)	(45 M DIAMETER)	(55 M DIAMETER)
Proportion of array area* (%)	0.2	0.2	0.1	0.1	0.8	0.8

All scour dimensions are based upon the scour depth for steady currents.

Results assume erodible bed and absence of geological controls

* Corresponding proportion of the AyM array area (78.0 km^2).

- The greatest individual turbine foundation global scour footprint is associated with the larger (40 m base length) piled jacket foundation (4,002 m^2), although with a relatively small average depth (1.4 m);
- For the AyM array as a whole, the greatest total turbine foundation local scour footprint is associated with an array of 50 smaller (13 m diameter) WTG monopile foundations and two OSP monopile foundations (15 m diameter) (179,187 m^2, equivalent to only approximately 0.2% of the array area); and
- For the AyM array as a whole, the greatest total turbine foundation global scour footprint is associated with an array of 34 larger (40 m base length) piled jacket foundations and two OSP piled jacket foundations (50 m base length) (185,187 m^2), equivalent to only approximately 0.2% of the array area.

150 Scour protection may be used to protect the stability of foundations if necessary. Where scour protection is used, primary scour is unlikely to occur, although a small amount of secondary scour may develop at the edges of the scour protection in response to the interaction between the scour protection materials and foundation, and the hydrodynamic and sediment transport regimes. However, the extent and volume of secondary scour will be considerably less than that described for monopile, multileg and gravity base foundations. This observation is consistent with the available monitoring data from the adjacent GyM OWF, at which 70 of the 160 WTG monopile foundations (5 m diameter) have rock protection installed.

151 For all foundations, the footprint area of scour protection is larger than the predicted footprint of local scour. However, at most, the maximum footprint of scour protection for the MDS (which is an array comprising of a larger number of smaller sized gravity base foundations) is equivalent to only approximately 0.7% of the array area (0.8% including the footprint of the foundations also).

152 Scour depth can vary significantly under combined current and wave conditions through time (Harris *et al.*, 2010). Monitoring of scour development around monopile foundations in UK offshore wind farm sites suggest that the timescale to achieve equilibrium conditions can be of the order of 60 days in environments where the seabed is mobile (Harris *et al.*, 2011). These values account for tidal variations as well as the influence of waves. (Near) symmetrical scour will only develop following exposure to both flood and ebb tidal directions.

153 Under waves or combined waves and currents an equilibrium scour depth for the conditions existing at that time may be achieved over a period of minutes, whilst typically under tidal flows alone equilibrium scour conditions may take several months to develop.

154 Any elevations in SSC because of scour will be short lived and localised and within the range of natural variability.

155 Finally, highly localised scour may also occur in areas where rock placement is used to protect cables. The raised profile of the protection may cause a limited amount of localised secondary scouring at the edges of the protection in line with the dominant flow or wave direction. The depth and extent of scour will be limited in proportion to the diameter of the individual rocks used (typically graded between 0.05 m to 0.5 m) which may be reduced by embedment or settling over time.

Assessment of significance

156 All the identified physical processes receptors will be insensitive to localised changes in bed levels around the turbine foundations, as well as any associated localised and short-term elevated levels of SSC. However, an assessment of significance with regards to the potential alteration of seabed habitat associated with the scour pits is presented in Volume 2, Chapter 5.

2.11.2 Potential for changes to Constable Bank/ Rhyl Flats and designated sites arising from modification of the tidal regime

Overview

157 The interaction between the tidal regime and the foundations of the wind farm infrastructure will result in a general reduction in current speed and an increase in levels of turbulence in a narrow, localised wake due to frictional drag and the shape of the structure. Changes to the tidal regime may indirectly impact seabed morphology (including bedforms) in several ways. There exists a close relationship between flow speed and bedform type (e.g. Belderson et al., 1982) and thus any changes to flows have the potential to alter seabed morphology over the lifetime of the Project.

158 Within the extent of the array, the effect on tidal currents will be evident as a series of narrow and discrete wake features extending downstream along the tidal axis from each foundation. For smaller structures such as wind farm foundations, the wake signature is expected to naturally dissipate within a distance in the order of ten to twenty obstacle diameters downstream (e.g. Li et al., 2014; Cazaneve et al., 2016; Rogan et al., 2016). This wake length distance will be much less than the corresponding 11-12 km spring tidal excursion distance in the array area (see Paragraph 53) - the distance over which water is displaced during each flood or ebb tide.

159 The MDS identified for the modification is set out in Table 7 and corresponds to an array comprising of 50 of the smallest sized WTGs on 45 m diameter GBFs and two OSPs. Within the modelled representative layout, WTGs are generally spaced 880 m apart (in the north-south direction) and 1098 (in the east-west direction).

Conceptual understanding of change

160 Hydrodynamic flow modelling has been undertaken to assess the potential extent of change to tidal currents associated with the MDS. Full details of the model used to inform the assessment are presented in Volume 4; Annex 2.2.

161 On the basis of the modelling undertaken (which also includes the influence of the adjacent operational GyM (Figure 1), it is found that:

- The potential for localised changes in current speed is spatially limited to narrow wakes of (slightly) reduced current speed and proportionally increased turbulence, extending downstream of individual foundations. The presence of wake features will be contained within the AyM array itself and a narrow region just outside of the boundary (no more than 1 km along the tidal axis);
- Outside of the individual wake features, changes in currents due to foundation blockage are less than ±0.01 m/s current speed and 1degree current direction. The change is very small in absolute and relative terms, is within the range of natural variability and would not be measurable in practice.
- Measurable changes to the tidal regime are not predicted to extend to either Constable Bank or Rhyl Flats; and
- There is very little potential for interaction between AyM and GyM, not least because wakes associated with the GyM WTG monopile foundations will be very narrow and of limited length due to their narrow (6.0 m) diameter, also because individual turbines would have to be exactly aligned along the tidal axis (which varies slightly throughout the tide in any case) for any overlap of wake features to occur.

162 Although foundations within the AyM (and GyM) array area may be expected to cause some very minor localised modification to current speeds, there will be minimal (<0.01 m/s) change in general current speeds within the array area, or the overall rate at which water passes through the array area, relative to baseline conditions (e.g. spring tidal range of ~6.5 m within the array).

163 The model also shows that local and regional water level variation will not be measurably affected by the presence of the AyM (and GyM) array areas (<0.01m), including both tidal and non-tidal (surge) contributions.

164 These conclusions are consistent with other numerical modelling studies previously undertaken to inform a wide range of Round 3 developments of comparable or larger scale (e.g. East Anglia Offshore Wind, 2012; Moray Offshore Renewables Ltd, 2012, Navitus Bay Development Ltd, 2014).

Assessment of significance

165 Using the criteria presented in Table 5, both Constable Bank and Rhyl Flats are considered to be of **medium** sensitivity/ importance as they are both understood to have an important influence on the geomorphology of the adjacent coastline, through the possible exchange of sediments and potential impacts on hydrodynamics and waves. Nearby designated sites (notably the Liverpool Bay SPA which is immediately adjacent to the AyM array) are also considered to be of medium sensitivity/ importance. Although internationally important, the seabed in these areas is highly dynamic and is assessed to have some capacity to recover from disturbance.

166 Liverpool Bay SPA which is located immediately adjacent to the AyM array and the turbulence associated with foundations located on the boundary of the array could theoretically result in a **low** impact to seabed morphology.

167 A negligible magnitude impact rating is assigned to all other receptors because the maximum spatial extent across which changes to tidal currents could theoretically occur will be in the order of tens to a few hundreds of metres downstream.

168 The next closest receptors to the AyM array after Liverpool Bay SPA are Constable Bank and Rhyl Flats and these are located approximately 4 km and 6 km to the south of the AyM array, respectively. At this distance from the array area, no measurable changes in current speed are expected and mean spring peak tidal currents (which are an important determinant of bedform distribution - Belderson et al. (1982)) will remain unaltered.

169 Using the EIA methodology, the low magnitude of effect on the Liverpool Bay SPA results in an effect of ***minor adverse*** significance which is not significant in EIA terms. For all receptors, although there is a negligible magnitude of impact, the medium receptor sensitivity also results in an effect of ***minor adverse*** significance which is not significant in EIA terms.

2.11.3 Potential for changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast arising from modification of the wave regime

Overview

170 The interaction between waves and the foundations of the wind farm infrastructure may result in a reduction in wave energy locally around foundations. The combined changes arising from all foundations may give rise to an array-scale change that could extend outside of the AyM array and into the wider study area. Where the wave climate is important to local processes and is persistently modified, these changes may potentially alter the frequency or pattern of sediment transport and therefore seabed morphology in affected offshore areas, and/or the rate and direction of longshore sediment transport and therefore coastal morphology on affected coastlines.

171 An array comprising 50 gravity base turbine foundations (base diameter of 45 m) and 2 OSPs (jacket foundations with suction buckets) represents the MDS for the blockage of waves through the AyM array. Further details regarding the MDS are provided in Table 7.

172 This section also reports change associated with other operational wind farms in the study area alongside AyM. These wind farms are listed below and shown in Figure 1:

- GyM;

- Rhyl Flats;
- North Hoyle;
- Burbo Bank; and
- Burbo Bank Extension.

173 Finally, it is noted that the potential for morphological change at the coast as a consequence of Project-induced change to either Constable Bank or Rhyl Flats is considered separately, in Section 1.11.5.

Conceptual understanding of change

174 The wind farm has the potential to impact on the wave regime as individual waves interact with the foundation structures. The blockage caused by the foundation structures has the potential to impact on the following wave characteristics:

- Wave height;
- Wave period; and
- Wave direction.

175 To quantify the likely magnitude and extent of interaction between the operational scheme and the hydrodynamic regime, a numerical wave model has been developed (Volume 4; Annex 2.2).

176 The assessment of potential changes to the wave regime has been undertaken for a series of frequently occurring and extreme return period conditions with and without the turbine foundations in place, in order to obtain a generic measure of the extent and magnitude of any change likely to occur during the lifetime of the Project. These are presented in terms of the difference between the baseline wave environment and that predicted to occur with the operational AyM project. The full set of results is presented in Volume 4; Annex 2.2, with a subset of results (associated with 50% no exceedance wave conditions) for a range of directions shown in Figure 6.

177 From the outset, it is noted that changes of less than 5% of the baseline wave height would be indistinguishable from natural variability both within the seastate (difference between individual waves) and compared to normal rates of change (over timescales of one hour or less); such small differences would not be measurable in practice. Changes less than 2.5% are also less than the reasonably expected accuracy of the model and so are excluded from the colour scale.

178 On the basis of the modelling results shown in Figure 6, it is found that:

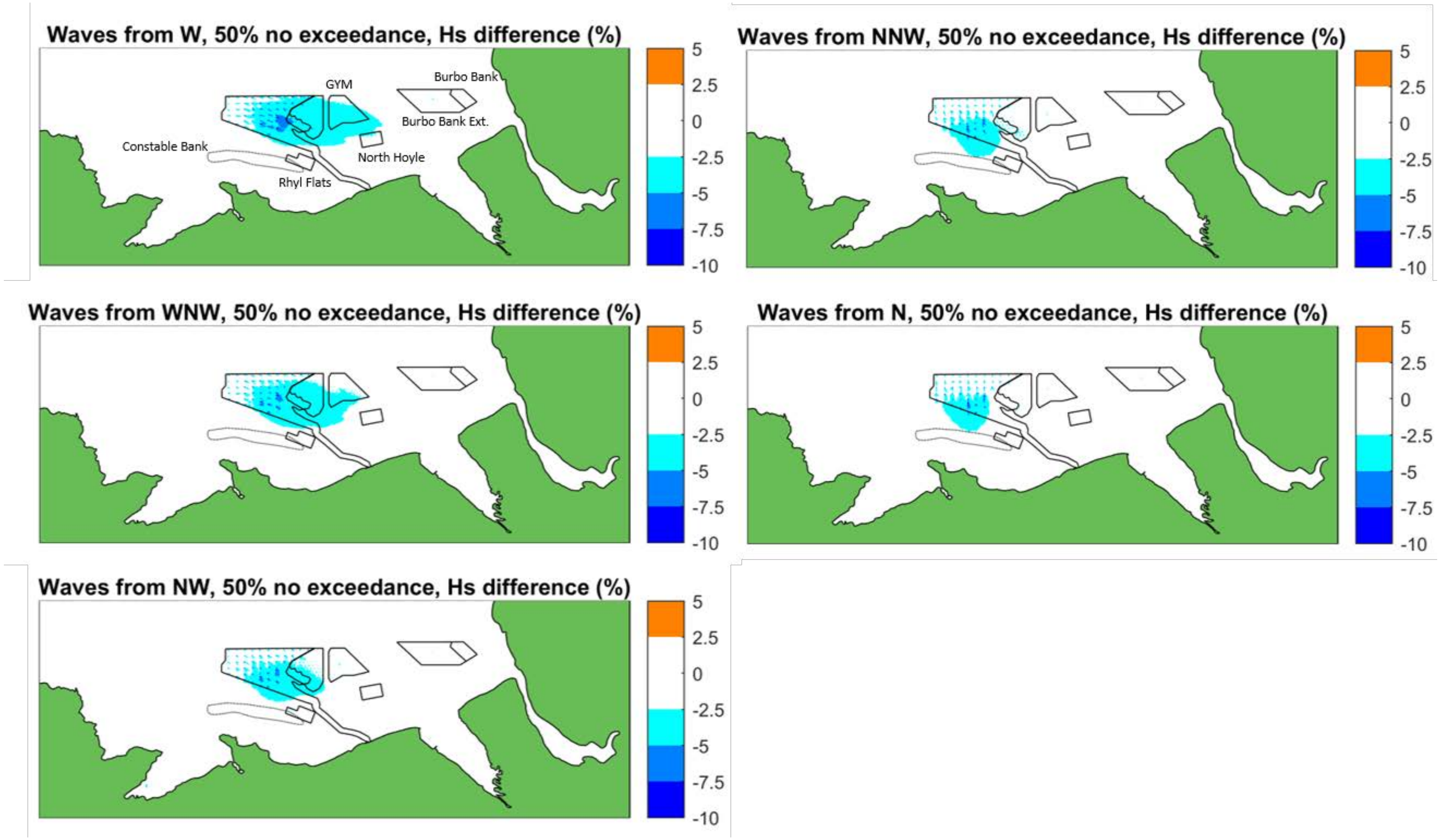


Figure 6: Percentage difference in significant wave height between baseline and the AyM operational and maintenance phase, 50% no exceedance, MDS for AyM and as bult for GyM, Rhyl Flats, North Hoyle, Burbo Bank and Burbo Bank Extension.

- The greatest relative change arising from AyM and other operational wind farms acting together is between 5 and 7.5% of the baseline wave height within the wind farm locally adjacent to individual foundations, and between 2.5 and 5% within and over a small area immediately downwind of the AyM array. The change reduces to less than 2.5% within a relatively short distance (typically 5km but up to ~10 km for waves from the west) downwind of the AyM array.
- The relative change is greatest for the 50% exceedance return period scenario (the lowest energy wave height condition considered), and progressively decreases through higher return period scenarios for all of the wave directions tested. This occurs because wave energy is proportional to the product of the wave height and the square of the wave period. A reduction in wave energy at higher energy levels will therefore result in a smaller proportional reduction in wave height. For a given return period, the relative scale of change is similar for the range of wave directions simulated.
- Some interaction with respect to waves can reasonably be expected between the AyM and GyM arrays. However, the identified sensitive receptors (Constable Bank, Rhyl Flats and nearest adjacent coast) are all located to the south of the AyM and GyM arrays and therefore the potential for enhanced change in the wave regime arising from the interaction of both projects is limited at these locations (as shown in Figure 6 and Volume 4; Annex 2.2).
- Changes in wave height over the body of Constable Bank are <2.5%, and on Rhyl Flats are <5% (more typically <2.5%) for all wave approach directions and return periods. For the prevailing waves (which are from the west and west-northwest – see Volume 4; Annex 2.1), changes in wave height are much less than 2.5% (effectively unchanged) at Constable Bank.
- Regardless of wave coming direction or return period, percentage changes in wave height are <2.5% along all coastlines adjacent to the Project.

- The wave modelling demonstrates that associated changes to wave period and direction are very small in absolute and relative terms and would not be measurable in practice (i.e. less than approximately 0.1s and 3 degrees, respectively); where present, any small scale of change to wave period and direction follows a similar spatial pattern and footprint as that shown in Figure 6 (for wave height), recovering to baseline conditions with distance downwind from the array.
- The insensitivity of the long-term sediment transport patterns between the array area, Constable Bank and Rhyl Flats, to the predicted small (<2.5%) change in wave height, was confirmed by a further quantitative assessment. A long term (31-year) hourly timeseries of harmonically predicted tidal current speed, direction and water depth, and hindcast wave height, period and direction, were prepared for 10 locations (distributed within the area of greatest effect on waves between the southern part of the array area, the crest and flanks of Constable Bank, and on and around Rhyl Flats). The timeseries data were applied to bedload and suspended load sediment transport formulae summarised in Van Rijn (2018). The results provide 31 years of predicted total instantaneous sediment transport rate and direction at hourly intervals for a 250µm diameter quartz sand, which is representative of the majority of mobile sediment present. Two scenarios of wave climate were tested (with and without the predicted '50% no-exceedance' location and wave direction specific reduction in wave height as a result of all MDS and other existing wind farm infrastructure in comparison to baseline conditions). The results show that the magnitude of long-term net transport is only slightly reduced (typically <0.3%, maximum 0.74%) as a result of the reduction in wave height and associated transport rate. For most locations, due to the relatively large water depths, mobility was normally controlled by the current speed (semidiurnal and spring-neap cycles) with waves only making infrequent episodic contributions. The direction of net transport is predominantly controlled by the current direction, so was not measurably affected (<0.05°) at any location.

Assessment of significance

179 As noted previously, all the physical process receptors, including the coastline, are considered to be **medium** sensitivity/importance. This is because Constable Bank and Rhyl Flats are understood to have an important influence on the geomorphology of the adjacent coastline and play a role in reducing flood risk. Liverpool Bay SPA (immediately adjacent to the AyM array), Menai Strait and Conway Bay SAC (6 km from the AyM array) and Dee Estuary SAC/ SPA (22 km from the AyM array) are all internationally important. However, the seabed in these areas is highly dynamic and is assessed to have some capacity to recover from disturbance.

180 The magnitude of change to Constable Bank and Rhyl Flats is assessed as **negligible**. This is because sandbanks are tidally induced bedforms, with sand bank formation principally governed by sediment availability and the prevailing tidal current regime rather than the action of waves. Instead, waves primarily influence sand banks by determining the maximum height (minimum depth) to which they can accumulate (Kenyon and Cooper, 2005). The modelling analysis suggests that when waves are coming from northerly directions (NW, NNW and N), there may be a small reduction in wave height of up to ~3-4% in the vicinity of the banks. However, waves from these sectors only occur for approximately 20% of the time and therefore whilst impacts to the banks could theoretically occur throughout the operational lifetime of AyM (i.e. be of long-term duration), any impacts would be intermittent in nature. It is also worth noting that:

- The wave events that are likely to cause the greatest impact on the offshore sand banks will occur during low-frequency high-intensity storm conditions. However, these events will be comparatively less affected by the presence of the foundations as their wavelengths will be 'long' compared to the size of the structures, meaning less energy will be lost to reflection, diffraction or breaking.
- Both banks will also be influenced by larger waves from the west-northwest which won't have travelled through the AyM array (Figure 6). These waves will contribute to flattening of the crests, thereby maintaining their existing (baseline) elevation.

181 The magnitude of change to nearby designated sites is assessed to be **negligible**. The closest designated site to the AyM array is Liverpool Bay SPA and in the areas of this SPA closest to the AyM array wave height could theoretically be reduced by up to ~10% when waves approach from westerly directions. However, water depths are typically ~20 m below LAT here and wave stirring of the bed is likely to be very limited under baseline conditions, with the action of tidal currents dominating. Furthermore, (and as previously discussed) larger waves which may have greater potential to interact with the bed in deeper water are likely to be comparatively less affected by the presence of the structures. Shallower water depths are encountered elsewhere in the SPA and in other nearby designated sites (e.g. Menai Strait & Conway Bay SAC and Dee Estuary SAC/ SPA): however, at these distances from the AyM array, changes to wave characteristics would be both small and intermittent, given that only some waves reaching these receptor locations will have travelled through the AyM array.

182 The magnitude of change to the adjacent coast is also assessed to be **negligible**. This is because reductions in wave height at the coast are predicted to be very small (<-2.5 %). Such small differences are not measurable in practice and would be indistinguishable from normal short-term natural variability in wave height (both for individual wave heights and in terms of the overall seastate). Accordingly, these changes are predicted to have minimal indirect impact on rates or patterns of coastal sediment transport, and therefore also on coastal processes and morphology.

183 Due to the medium importance of the physical process receptors, the resulting effect of the negligible magnitude of change is an effect of ***minor adverse*** significance which is not significant in EIA terms.

2.11.4 Potential for changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast arising from modification of the sediment transport regime

Overview

184 Modification of existing sediment transport pathways could occur in response to changes in the wave and tidal regimes resulting from the presence of turbine and substation foundations and/or the presence of cable protection measures. The presence of cable protection measures may also have the potential to cause a direct (albeit very localised and limited volume) blockage to sediment transport. The above changes could potentially occur over a range of timescales, depending on location and the specific project infrastructure that is interacting with the sediment transport regime.

185 The MDS with respect to the potential for changes to Constable Bank/ Rhyl Flats and the adjacent coast arising from modification of the sediment transport regime is set out in Table 7.

Conceptual understanding of change

Turbine foundations and sub-stations

186 Neither Constable Bank nor Rhyl Flats will be directly sensitive to a short-term difference in the instantaneous rate of sediment transport, if the modified condition remains consistent with the baseline range of natural variability. However, persistent changes in sediment transport patterns over longer timescales (years to decades) may have the potential to cause alterations to banks and coastal morphology. The potential for such changes to occur is assessed below.

187 Bed load transport across the AyM array and offshore ECC is dominated by the action and asymmetry of tidal currents, with wave driven transport only becoming important in shallow water close to the coast (Volume 4; Annex 2.1). The hydrodynamic modelling undertaken to inform this assessment finds that changes in current speed are anticipated to be limited in spatial extent to narrow wake features extending downstream from individual foundations, up to a maximum of ~1 km from the array area boundary in alignment with the tidal axis. The maximum change outside of the wake features is very small in both relative and absolute terms, in the range ±0.01 m/s and do not result in a meaningful change to either the residual current speed or direction (which will determine the movement of material held in suspension), nor the rate or direction of net bedload transport.

188 It is also noted that the regional bedload sediment transport pathways described in Volume 4; Annex 2.1 are aligned with the tide in a broad west northwest to east southeast direction. These transport pathways therefore do not connect the AyM array area with either Constable Bank, Rhyl Flats or the (closest) adjacent coast to the south.

Cable protection measures

189 Installation of cable protection could result in a local elevation of the seabed by up to 1.4 m (Table 7). Cable protection would be placed onto the seabed surface above the cable and therefore could directly trap sediment, locally impacting down-drift locations.

190 Observational evidence to quantify or qualify the implications of rock protection on sediment transport and bedform behaviour is relatively limited, including mainly a small number of reviews of available monitoring data from seabed areas where rock protection has been installed (e.g. JNCC, 2017; ABPmer, 2018). In the absence of a wide range of suitable analogous observations, the following theoretical description of the processes involved is considered to provide a conservatively realistic assessment of the potential nature and magnitude of impact.

191 Sandy sediments are transported in two main modes: bedload (including rolling and saltation) and suspension. Sediment grains being moved in saltation or suspension by the free-flowing water are more likely to pass directly over the protection. Sediment moving as bedload is more likely to become deposited, initially against the protection clasts at seabed level, then within open voids on the surface of the protection. When the majority of void spaces have been infilled, the cable protection presents as a local sediment bedform slope and all modes of sediment transport are expected to continue largely unaffected at the ambient rate and direction. Sufficiently large bedform features may migrate over the protection, cause cycles of local coverage and exposure.

192 The process of void infilling is expected to occur relatively quickly (in the order of a few months) due to the anticipated high rates of transport in areas of mobile seabed (where much of the cable protection is anticipated).

193 Bedload is the process by which sands move while still in contact with the seabed. Bedload will be temporarily affected up until such time that the armour is sufficiently covered by sand and the slope gradient either side has been sufficiently reduced in response to the accumulation of a sediment wedge with stable slope angles. The process of wedge formation may take place over a period of a few weeks to months, depending on rates of sediment transport. As the stable slope approaches the top of the protection, any blockage effect of the cable protection will be progressively reduced to near zero and sediment will subsequently be transported directly over the obstacle (via the sediment slope and/or in saltation or suspension) unimpeded, at the naturally occurring ambient rate and direction.

194 Assuming a maximum slope angle equal to the angle of repose for sand ~30 degrees, the maximum volume of sediment that could potentially accumulate in this wedge is limited by the dimensions of the protection to approximately 2.43 m^3 of sediment per metre of cable protection, which is small in both absolute and relative terms. The maximum dimensions of morphological change (seabed lowering) that might result from the maximum temporary reduction in sediment supply are therefore proportionally limited (e.g. a maximum of 0.1 m bed lowering might occur in an area up to 24.3 m downstream of the protection, or up to 0.5 m up to 4.86 m downstream, or 0.05 m up to 48.6 m downstream, etc) and is therefore unlikely to measurably affect the form and function of the seabed locally or regionally.

195 Accordingly, for all areas in which cable protection is used (including where sand waves are present), it is not expected that the presence of the cable protection devices will continuously affect patterns of sediment transport, following an initial period of limited sediment accumulation. It follows that any changes on seabed morphology away from the cable protection will also be very small. The extent of the cable protection measures does not constitute or cause a continuous blockage along the offshore ECC.

Assessment of significance

196 As discussed in the previous assessments, all the physical process receptors are assessed as having a **medium** sensitivity/importance.

197 Where the offshore ECC is coincident with the Liverpool Bay SPA and Rhyl Flats, the magnitude of change to the seabed in these areas is considered **low**. In all other areas and at all other receptor locations, the magnitude of change is assessed as being **negligible**. This is because any net change in tidally driven sediment transport through the AyM array resulting from flow blockage by WTG foundations is expected to be extremely small. Change in the net rate of sediment transport caused by the installation of cable protection measures in either the array of offshore ECC is also expected to be very limited, both in duration and spatial extent.

198 The overall level of effect significance has been assessed according to the EIA methodology set out in Section 1.5 (paragraph 19 *et seq*.). Overall, the effect is assessed to be of ***minor adverse*** significance which is not significant in EIA terms.

2.11.5 Potential for changes to the coast arising from any modification of Constable Bank and Rhyl Flats

Overview

199 Constable Bank and Rhyl Flats are large bodies of sand located to the south of the AyM array. Both are dynamic features, with actively migrating sandwaves transporting sediment in a general easterly direction into Liverpool Bay (Volume 4; Annex 2.1). Interaction of waves with Constable Bank and Rhyl Flats is understood to play an important role in controlling wave climate long the adjacent coastline between Great Orme and Prestatyn, affecting patterns of beach morphology, coastal evolution and flood risk (Halcrow, 2010). Accordingly, any morphological change to either feature arising from the Project is potentially of concern.

Conceptual understanding of change

200 It is widely recognised that nearshore sand banks have an important role to play in protecting the coast by changing wave direction through refraction and diffraction. Sand banks can also cause incoming waves to break by shoaling before they reach the shoreline, dissipating the wave's energy and acting to protect the coast in a manner similar to an offshore breakwater. Both Constable Bank and Rhyl Flats are likely to perform in this manner, as discussed below (Halcrow, 2010). It is also understood that sand banks can act as a source and a pathway of sediment to the coast and thus help to maintain and stabilise beaches. Beach volume, in turn, influences the level, width and plan shape of beaches. A large beach dissipates and reduces wave energy reaching the backshore and therefore the likelihood of undermining and overtopping of defence structures.

201 Constable Bank and Rhyl Flats are located approximately 5 to 6 km from the coast and are classified as offshore shelf ridges. Water depths shallow to ~ 5 m below LAT over Constable Bank and 1 m below LAT over Rhyl Flats and therefore they have the potential to frequently interact with waves. Indeed, the annual 10% exceedance significant wave height is 1 to 2.0m between Great Orme and the Flyde Peninsular (DEFRA, 2002) and according to Mason and Garg (2001) the waves in water depths less than ten times the significant wave height will act on the seabed sediments. Thus, for this area of coast any feature less than 10m below the low tide level will be acted upon at least twice a day (i.e. at low water) by waves. The crest of Constable Bank is about 11.8 m below the high spring tide level. Thus, the sediment on the bank will be affected by waves of 1.2 m and higher waves may be forced to break (Halcrow, 2010).

202 Modelling undertaken to support the development of the North West England and North Wales Shoreline Management Plan (SMP) 2 has shown that if Constable Bank were to erode or sea level rise (of 0.5 m) occurs and the banks fail to keep pace, then wave heights will increase locally over the bank. The results indicate that reducing bank elevation by 0.5m, has the potential to increase significant wave heights by 0.6m at the southern end of Constable Bank, whilst raising sea level by 0.5m, has the potential to increase significant wave heights by 0.2 m on Constable Bank. However, these changes in wave height over the bank are not felt at the shoreline for the conditions simulated. Thus, whilst Constable Bank is likely to provide a degree of sheltering, there is some uncertainty with regards to exactly how much (Halcrow, 2010).

203 Although the analysis undertaken by Halcrow (2010) clearly demonstrates the potential for changes in bank morphology to modify waves as they pass across the features, the combined analysis of potential changes to hydrodynamics, waves and sediment transport in response to the MDS suggests morphological change to the banks is very unlikely (Section 1.11.5). On this basis, it is also considered very unlikely that associated changes to the adjacent coast will occur. It is noted however, that by 2060 (i.e. end of the project lifetime) sea level may rise by ~0.35 m (Palmer et al. 2018). It is possible that if the rate of growth in the bank does not keep pace, then its role in decreasing wave energy at the coast may naturally decline. However, this change would occur regardless of the Project.

Assessment of significance

204 Using the criteria presented in Table 5, the coastline between Great Orme and Prestatyn is considered to be of **medium** sensitivity/ importance. Although the coast is considered to play a number of important roles including influencing flood risk and is designated in places, it is considered to have some capacity to recover from disturbance.

205 The magnitude of impact to the coast is predicted to be **negligible**. This assessment is based on the fact that any morphological change to Constable Bank or Rhyl Flats is expected to be (at most) Low, with any changes to the wave regime over the banks more likely to increase rather than reduce their heights by an extremely small (immeasurable) amount (Section 1.11.3). The potential for this (theoretical) scale of morphological change to modify the nearshore wave regime and subsequently the coast is considered to be extremely small.

206 Overall, the effect on the coast is of ***minor adverse*** significance which is not significant in EIA terms.

2.12 Environmental assessment: decommissioning phase

2.12.1 Potential changes to suspended sediment concentrations, bed levels and sediment type

Overview

207 The following decommissioning activities could potentially give rise to increases in SSC and associated deposition of material with in the AyM array and the offshore ECC:

- Removal of foundation structures;
- Cutting the monopiles and jacket foundation legs at or below the seabed; and
- (Possible) removal of cables from the intertidal zone.

208 Further details regarding the MDS are provided in Table 7

Conceptual understanding of change

209 The removal of wind turbine foundations is expected to result in some localised seabed disturbance accompanied by temporary increases in SSC. Foundations involving piled solutions would be cut off at or just below, potentially causing a localised disturbance of the bed and a temporary increase in SSC.

210 For the purposes of the EIA it has been assumed that all cables will be removed from the intertidal zone during decommissioning. It is probable that equipment similar to that which is used to install the cables could be used to reverse the burial process and expose the cables. Accordingly, the area of seabed impacted during the removal of the cables would be similar as the area impacted during the installation of the cables.

211 For all of the above, the changes in SSC and accompanying changes to bed levels than those associated with decommissioning activities are expected to be lesser than that associated with construction. Further information is provided in the construction phase assessment (Section 1.10, paragraphs 42 to 140).

212 It is expected that offshore cables would be left *in situ* where buried and removed where cables are exposed. However, the Project will consider the best environmental option at the time of decommissioning.

Assessment of significance

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

- Volume 2, Chapter 4: Offshore Ornithology;
- Volume 2, Chapter 5: Benthic and Inter-tidal Ecology;
- Volume 2, Chapter 6: Fish and Shellfish Ecology; and
- Volume 2, Chapter 7: Marine Mammals.

2.12.2 Potential changes to the coast arising from the removal of infrastructure and associated rock protection

Overview

214 The MDS in terms of the potential for impacts to coastal feature receptors would be the total removal of all infrastructure (including foundations, scour protection, cables, and any rock protection) within the array, along the offshore ECC and at the landfall. Details regarding the MDS are provided in Table 7.

Conceptual understanding of change

215 The removal of structures (especially rock protection) which have been in place for a long time could in theory, lead to much longer-term effects on morphodynamics. This is because the coastal and seabed morphology could have evolved to a new equilibrium state including the influence and presence of that structure. A good example of this is the outfall structure at the western end of the landfall which, on the basis of aerial photography, can clearly be seen to be influencing the local morphology of the beach. However as noted in Section 1.10.5, rock protection would not be used within the intertidal area. If protection were to be used it would be restricted to mattressing buried beneath the beach surface and therefore the potential for the structures to interact with and inhibit the movement of sediment would be greatly diminished. A detailed CBRA and landfall study will be undertaken to identify a suitable burial depth for the cable to minimise the likelihood of it (and any associated mattressing) becoming exposed during the lifetime of the project.

216 It is not expected that the removal of any rock protection from shallow sub-tidal areas would lead to substantive morphological change. This is because the presence of the rock is not expected to result in widespread change to the beach at Ffrith in the first instance, for the reasons set out in paragraph 133 *et seq*.

217 Should the cable system require removal at the end of its operational life, it will be removed through the same sediments and sub-strata disturbed during installation. This process could result in short-term elevations in SSC and localised changes in bed level. It is anticipated that the working areas for removal will also be restricted to the area used for installation; accordingly, any change would be no greater in magnitude than for the construction phase. If the cables are left in the seabed at the end of the Project lifespan, impacts will be the same as those described previously for the operational phase.

Assessment of significance

218 The coast at the landfall is considered of **medium** sensitivity/ importance and the magnitude of impact to the coast is predicted to be **low**. This assessment of magnitude is based on the fact that any changes would be temporary and spatially limited.

219 The overall level of effect of the removal of cables at the landfall during decommissioning has been assessed as being of ***minor adverse*** significance which is not significant in EIA terms.

2.13 Environmental assessment: cumulative effects

220 Cumulative effects refer to effects upon receptors arising from the AyM project when considered alongside other proposed developments and activities and any other reasonably foreseeable project(s) proposals. In this context the term projects is considered to refer to any project with comparable effects and is not limited to offshore wind projects.

221 The Cumulative effects assessment methodology is described in Volume 1, Annex 3.1: Cumulative Effects Assessment (application ref: 6.1.3.1). It takes into account the Cumulative Impact Assessment Guidelines issued by RenewableUK in June 2013, together with comments made in response to other renewable energy developments within the southern North Sea, and the Planning Inspectorate (PINS) 'Advice Note 9: Rochdale Approach'.

222 The projects and plans selected as relevant to the assessment of impacts to physical processes are based upon an initial screening exercise undertaken on a long list (see Volume 1, Annex 3.1). Each project, plan or activity has been considered and scoped in or out on the basis of effect–receptor pathway, data confidence and the temporal and spatial scales involved. The specific projects scoped into this cumulative impact assessment, and the tiers into which they have been allocated are presented in Table 13 below, whilst the locations of these projects are shown in Figure 7.

223 A small number of operational projects within the study area are not captured within the baseline characterisation (Section 1.7; paragraph 3019 *et seq*.) and as such, are included in Table 13.

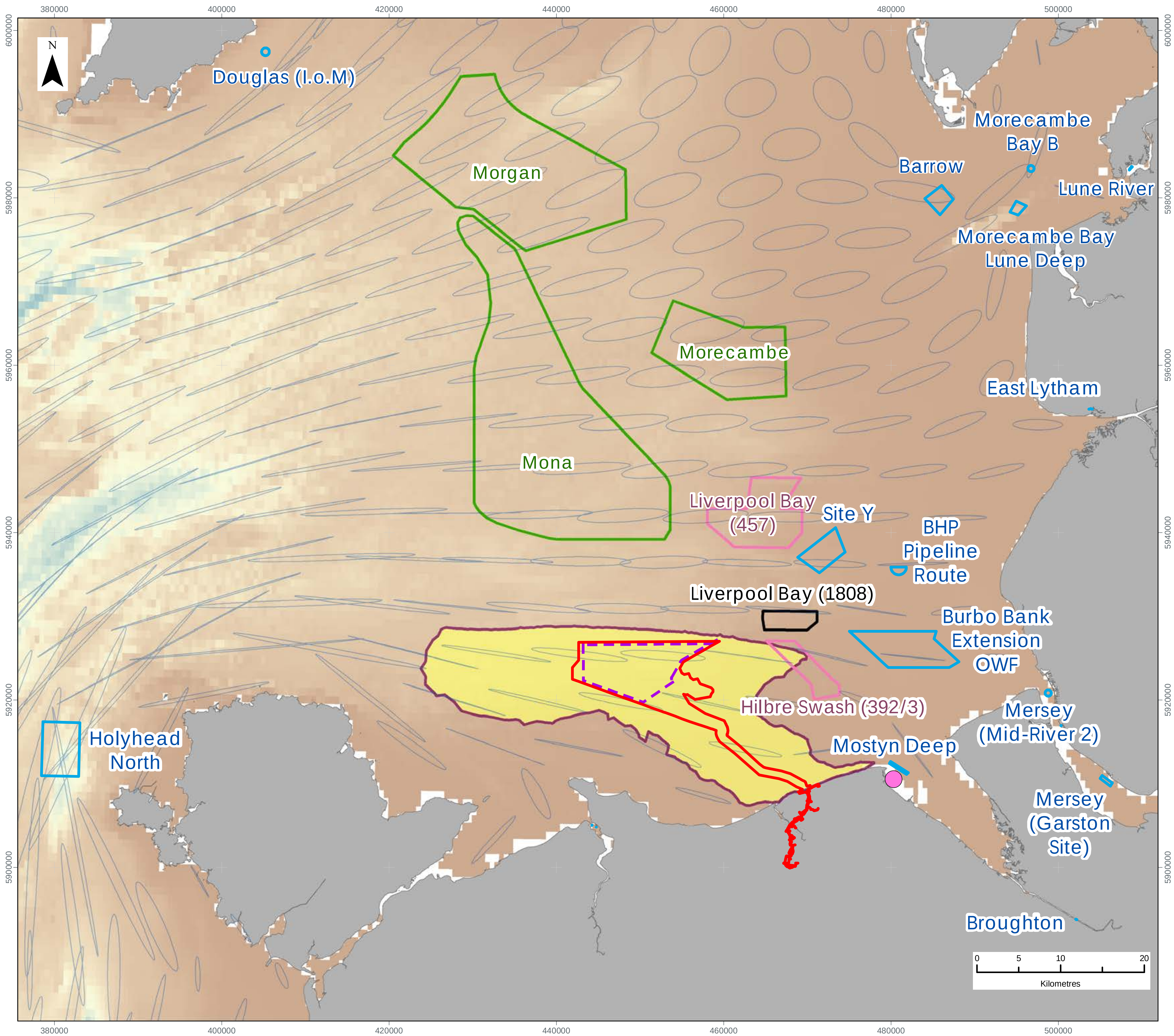
224 As previously stated, operational wind farms within the study area (GyM, Rhyl Flats, North Hoyle, Burbo Bank and Burbo Bank Extension) are not considered within the cumulative effects section as they are recognised as being part of the baseline environment and hence have already been taken into consideration within the project-alone assessment.

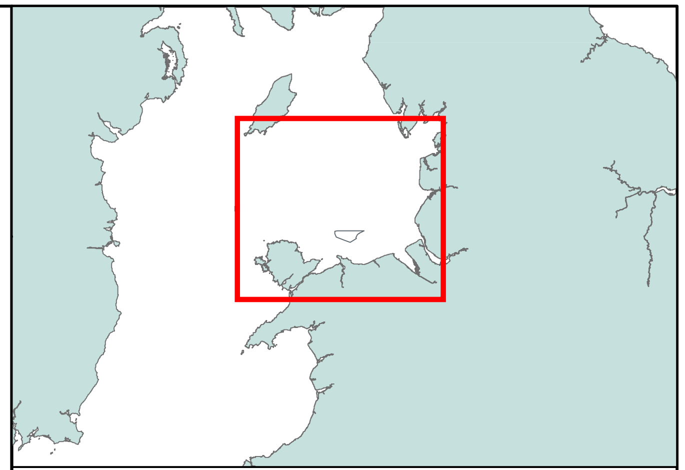
Table 13: Projects considered within the physical processes cumulative effect assessment.

DEVELOPMENT TYPE	PROJECT	STATUS	DATA CONFIDENCE ASSESSMENT/ PHASE	TIER
Aggregate Production Area	Area 392/3 'Hilbre Swash'	Active	High	Tier 1
Aggregate Production Area	Area 457 'Liverpool Bay'	Active	High	Tier 1
Aggregate Exploration and Option Area	Liverpool Bay (1808)	Active	Medium	Tier 3
Dredge Spoil Disposal Site	Site IS150 (Site Y)	Active	High	Tier 1
Offshore Wind Farm	Mona	Concept/early planning	Low	Tier 3
Offshore Wind Farm	Morgan	Concept/early planning	Low	Tier 3
Offshore Wind Farm	Morecambe	Concept/early planning	Low	Tier 3
Tidal Lagoon	Port of Mostyn Tidal	Concept/early planning	Low	Tier 3

DEVELOPMENT TYPE	PROJECT	STATUS	DATA CONFIDENCE ASSESSMENT/ PHASE	TIER
	Lagoon (Flagstaff)			
Coastal Defence Works	Various	Concept	Low	Tier 3

Douglas (I.o.M)





LEGEND

- Order Limits
- Array Area
- Dredge disposal site
- Aggregate Production Area
- Aggregate Exploration and Option Area
- Offshore Wind Leasing Round 4 Project
- AyM Maximum sediment plume extent
- Spring tidal excursion ellipses
- Flagstaff

EMODnet bathymetry (m LAT)

5, -9.43381, -22.1818, -35.4396, -48.1876, -61.4455, -74.1934, -87.4513, -100.199, -113.457, -126.205

PROJECT TITLE:

AWEL Y MÔR OFFSHORE WINDFARM

FIGURE TITLE:

Projects and plans considered within the physical processes cumulative effects assessment

VER	DATE	REMARKS	Drawn	Checked
2	02/03/2022	For Issue	CRB	DLW

FIGURE NUMBER:

Figure 7

SCALE:	PLOT SIZE:	DATUM:	PROJECTION:
1:470,000	A3	WGS84	UTM30N

Fferm Wynt Alltraeth AWEL Y MÔR Offshore Wind Farm

P:\4913_Awel_Y_Mor_EIA\GIS\MXDs\ES\Chapter\ES_Fig_Cumulative_A3.mxd

225 The cumulative MDS considered in the assessment is described in Table 14.

Table 14: Cumulative MDS.

POTENTIAL EFFECT	SCENARIO	JUSTIFICATION
Cumulative temporary increases in SSC and seabed levels as a result of AyM foundation installation and aggregate dredging	MDS as described for construction phase of AyM (for foundation drilling) assessed cumulatively with aggregate extraction operations at Area 392/3, Area 457 and Area 1808.	Identified sites are within 15 km of the Project: this distance incorporates the largest spring tidal excursion ellipse observed in the array and offshore ECC. Meaningful sediment plume interaction generally only has the potential to occur if the activities generating the sediment plumes are located within one spring tidal excursion ellipse from one another and occur at the same time.
Potential for cumulative temporary increases in SSC and seabed levels as a result of AyM foundation installation and dredge spoil disposal at licensed disposal grounds	MDS as described for construction phase of AyM (for foundation drilling) assessed cumulatively with dredge disposal operations at Disposal Site IS150.	
Cumulative changes in hydrodynamics, waves and sediment transport arising	MDS as described for operation phase of AyM (for blockage of waves, currents and sediment transport) assessed cumulatively with operation	Maximum potential for cumulative changes to hydrodynamics, waves and sediment transport.

POTENTIAL EFFECT	SCENARIO	JUSTIFICATION
from interaction with proposed Round 4 OWF projects	of proposed (Round 4) Mona, Morgan and Morecambe OWFs	
Cumulative changes in hydrodynamics, waves and sediment transport arising from interaction with Flagstaff Tidal Lagoon	MDS as described for operation phase of AyM (for blockage of waves, currents and sediment transport) assessed cumulatively with operation of the Flagstaff tidal lagoon	Maximum potential for cumulative changes to hydrodynamics, waves and sediment transport.
Cumulative changes in hydrodynamics, waves and sediment transport arising from interaction with new coastal defence works	MDS as described for AyM landfall (for blockage of waves, currents and sediment transport) assessed cumulatively with new coastal defence works	Maximum potential for cumulative changes to hydrodynamics, waves and sediment transport. Flagstaff scoped in on

2.13.1 Potential for cumulative temporary increases in SSC and seabed levels as a result of AyM foundation installation and aggregate dredging

Overview

226 The northeast margin of the AyM array is approximately 5.5 km from Aggregate Area 392/393 (‘Hilbre Swash’) and Aggregate Exploration & Option Area 1808 (‘Liverpool Bay’). On the basis of the sediment plume modelling undertaken for AyM construction related activities (paragraph 45 *et seq.* and Figure 3), it can be reasonably assumed that sediment plumes may be advected this distance from the AyM array. This means that in theory, should AyM construction related activities be occurring at the same time as aggregate extraction, there could be the potential for cumulative changes in SSC and bed levels.

227 It is noted here that Aggregate Area 457 is within 15 km of the AyM array and on this basis, are ‘scoped in’ to the physical processes cumulative effects assessment (Volume 1, Annex 3.1). However, closer inspection of the more detailed sediment plume modelling strongly suggests that sediment plumes (defined by the 1 mg/l contour) will not travel this far from either the AyM array or offshore ECC (Figure 7). Accordingly, the potential for cumulative interaction with either site is extremely limited and, therefore, has not been assessed further.

228 The target material at Area 392/393 is sand and is currently licensed to Lafarge Tarmac Marine Ltd (LTM) and Norwest Sand & Ballast Company Ltd (the latter a joint venture between CEMEX Investments Ltd and Tarmac Ltd). Aggregate dredging by these companies has taken place in the current licence area and previously in an area immediately to the south for over 50 years. All dredging operations within the Licence Area must be carried out by anchor or TSHD and the amount of material extracted must not exceed 0.8 million tonnes in any calendar year (NRW, 2013).

Conceptual understanding of change

229 The interaction between sediment plumes generated by AyM construction activities and those from nearby aggregate dredging could theoretically occur in two ways:

- Where plumes generated from the two different activities meet and coalesce to form one larger plume; or
- Where aggregate extraction occurs within the plume generated by AyM construction activities (or *vice versa*).

230 For two or more separately formed plumes that meet and coalesce, the physical laws of dispersion theory mean concentrations within the plumes are not additive but instead a larger plume is created with regions of potentially differing concentration representative of the separate respective plumes. In contrast, in the case of plumes formed by a dredging vessel operating within the plume created by foundation installation or bed preparation activities (or *vice versa*), the two plumes would be additive, creating a plume with higher SSC.

231 On the basis of the numerical modelling of construction related activities within the AyM array (Section 1.10.1), it is found that drilling for monopile installation gives rise to the greatest release of fine-grained material thereby resulting in the largest suspended sediment plumes. (The sediment plumes associated with coarser grained material are more spatially constrained as the material drops out of suspension more quickly). However, even if drilling were to occur on the north-eastern margin of the AyM, any fine-grained sediment plume will be subject to rapid dispersion, both laterally and vertically, to near-background levels (tens of mg/l) within a distance of ~ 4 km.

232 The target material at Area 392/3 is sand and it is understood that the aggregate deposits in this region have a low fine (silt and clay) content (<5%). Accordingly, the concentrations of this fraction in the overflow from the TSHD vessels operating at the site are expected to be relatively low. On the basis of numerical plume modelling undertaken for analogous aggregate extraction sites to Area 392/3, it can reasonably be expected that suspended sediment concentrations in excess of tens of mg/l will be restricted within a distance of ~2 km of the licence boundary (e.g. HR Wallingford, 2011).

233 Given the above information and the fact that the two sediment disturbance activities are located approximately 5.5 km apart – (~6.5 km if taking into consideration the alignment of the tidal axis), any cumulative increase in either the spatial footprint or peak concentration of sediment plumes is expected to be indistinguishable from background levels. Any associated changes in bed level can also be expected to be immeasurable.

234 It is also worth noting that spring tidal excursion ellipses are strongly rectilinear within and nearby to Area 392/3 and the northeast corner of the AyM array. This means that although at times during the construction phase some plume interaction may occur, the number of occurrences is expected to be less than for an equivalent setting with more rotary tidal excursion characteristics.

Assessment of significance

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

- Volume 2, Chapter 4: Offshore Ornithology;
- Volume 2, Chapter 5: Benthic and Inter-tidal Ecology;
- Volume 2, Chapter 6: Fish and Shellfish Ecology; and
- Volume 2, Chapter 7: Marine Mammals.

2.13.2 Potential for cumulative temporary increases in SSC and seabed levels as a result of AyM foundation installation and dredge spoil disposal at licensed disposal grounds

236 It is noted here that Spoil Disposal Site IS150 is within 15 km of the AyM array and on this basis, is 'scoped in' to the physical processes cumulative effects assessment (Volume 1, Annex 3.1). However, closer inspection of the more detailed sediment plume modelling strongly suggests that sediment plumes (defined by the 1 mg/l contour) will not travel this far from either the AyM array or offshore ECC (Figure 7). Accordingly, the potential for cumulative interaction with either site is extremely limited and, therefore, has not been assessed further.

2.13.3 Potential for cumulative changes in hydrodynamics, waves and sediment transport arising from interaction proposed Round 4 OWF projects

237 The EnBW & BP Mona and Morgan Round 4 projects are situated approximately 12 km and 47 km to the north of the AyM array and expected to each have an installed capacity of 1500 MW (Figure 7). Cobra & Flotation Energy are also planning on constructing a 480 MW array ('Morecambe') approximately 29 km to the north of the AyM array. At present, few details of these projects (in terms of turbine numbers, foundation type, spacing and distribution within the site boundary etc) are available which means it is not possible to undertake a meaningful cumulative effects assessment with AyM. However, it is recognised that waves approaching from the north constitute approximately 15% of the wave record at AyM and therefore there is at least theoretical potential for a cumulative reduction in wave height for waves from this direction. Whether these changes could extend to the adjacent north Welsh coast cannot be determined at this stage.

2.13.4 Potential for cumulative changes in hydrodynamics, waves and sediment transport arising from interaction with Flagstaff Tidal Lagoon

Overview

238 Mostyn SeaPower Ltd wants to build a tidal lagoon, using turbines on the Dee Estuary in Flintshire to generate electricity (Figure 7). This is a distance of ~25 km from the array and ~10 km from the offshore ECC. Very few details of the project are presently available although it is understood that it would be about 6.5 km in length, have 8 x 16 MW turbines and would run along the estuary between Mostyn and Point of Ayr.

239 The potential for cumulative changes in hydrodynamics, waves and sediment transport arising from interaction of AyM with Flagstaff Tidal Lagoon is investigated further below.

Conceptual understanding of change

240 The impoundment of water behind the lagoon wall can be expected to result in a significant reduction in tidal range inside the lagoon. Smaller reductions in water level may also be experienced outside the lagoon in response to the modification of the tide as it propagates into/ out of the Dee Estuary. However, changes in water level associated with the operation of AyM will be extremely small (order of mm's) and confined to the array (Section 1.11.2; paragraph 162). Accordingly, the potential for cumulative change to water levels is considered to be extremely small.

241 Installation of a large lagoon at the mouth of the Dee Estuary also has the potential to modify current speeds, both locally (in the vicinity of the turbines) and across a wider area (both inside and outside of the lagoon). In the absence of any project-specific modelling for Flagstaff, it is not possible to determine the spatial extent across which any change may occur. However, it is important to note that any changes in currents associated with operation of AyM have been demonstrated to be localised and confined to within less than one spring tidal excursion ellipse of the site (Figure 7). Measurable change (order of several cm/s) is expected to be limited to a distance of a few hundred metres from the location of individual wind turbine foundations and will not to extend to nearby offshore sand banks or the coast. Accordingly, there is very limited potential for cumulative changes in current speed or direction at the location of identified receptors.

242 Given the proposed location of the lagoon in the lee of the Point of Ayr, any changes in the wave regime are expected to be largely confined to the footprint of the lagoon as well as locations immediately to the southwest of Mostyn. However, modelling of the MDS for wave blockage shows that reductions in wave height will be less than 2.5 % at the mouth of the Dee Estuary (Figure 6) and as such there is very limited potential for cumulative changes in wave height or direction.

243 Sediment transport across shallow inshore areas of the offshore ECC is understood to be influenced by westward sediment transport originating from the mouth of the Dee Estuary. If flows are locally altered in response to the presence of the lagoon, it is reasonable to assume that the strength and direction of the sediment pathways may also be modified. It is not possible to determine whether these could extend to the offshore ECC; however, it is noted that the only potential change in sediment transport that could occur within this inshore region would be associated with the presence of cable protection measures. However, any change would be short-term and localised.

Assessment of significance

244 Using the criteria presented in Table 5, all of the identified receptors (namely the coast, nearby offshore sand banks and seabed areas contained within nationally or internationally important sites) are considered to be of **medium** sensitivity/ importance.

245 The magnitude of impact to all of the identified receptors is predicted to be **negligible**. This assessment is based on the fact that cumulative changes to hydrodynamics, waves and sediment transport at receptor locations will be immeasurable and insufficient to cause morphological change outside of the expected range of natural variability.

246 The overall level of effect is assessed to be of ***minor adverse*** significance which is not significant in EIA terms.

2.13.5 Potential for cumulative changes in hydrodynamics, waves and sediment transport arising from interaction with new coastal defence works

247 Much of the coastline within the study area is currently defended, with a policy of 'Hold the Line' expected to be in place in most of these defended areas through the lifetime of the Project. This is the case for the landfall (Policy Unit 4.2 'Rhyl Golf Links') as well as areas immediately to the west and east of it (Halcrow, 2011). As sea level continues to rise throughout the 21st Century, it is to be expected that the existing defences will require improvements to maintain the same standard of protection. This may include the installation of additional defence measures (such as the new rock armour currently being installed to the west of the landfall at East Rhyl), raising the heights of seawalls, beach nourishment and /or building secondary set-back defences to reduce flood risk.

248 Some of these proposals may have the potential to locally modify coastal processes via (for instance) altering rates of littoral transport to coastal locations downdrift. However, given that all Project related impacts to the coast identified in the assessment are found to be either Low or Negligible, the potential for cumulative interaction with coastal defence works is considered to be very limited. Accordingly, this has not been considered further.

2.14 Inter-relationships

249 The term 'Inter-relationship' takes into account the environmental interactions ('inter-relationships') with other receptors within the Project. These are referred to in the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009.

250 The different physical processes studied are already inter-related; in particular, sediment transport is dependent on currents and waves and therefore these linked processes have already been considered within the assessment. In turn, this information on changes to physical processes has been used to inform other ES topics such as Offshore Ornithology (Volume 2, Chapter 4) and Benthic and Intertidal Ecology (Volume 2, Chapter 5). Assessments have been undertaken separately within these individual topic Chapters and are not reported here as additional inter-relationships. A full assessment of inter-relationships between topics is presented in Volume 2, Chapter 14: Inter-relationships (application ref: 6.2.14).

2.15 Transboundary effects

251 No transboundary effects have been identified. This is because the predicted changes to the key physical process pathways (i.e. tides, waves, and sediment transport) are not anticipated to be sufficient to influence any of the identified receptors at this distance from the Project.

252 Specifically, the Isle of Man Government raised concerns during scoping about the potential effect of the proposed development on habitats and species found within Isle of Man waters. The assessments of the potential effects and pathways of change to physical processes have identified that all relevant changes will be of limited duration, magnitude and extent. No measurable change is likely to extend into Isle of Man territorial waters. Potential effects of changes to physical processes pathways on individual species and habitats are also considered by other ES topics such as Offshore Ornithology (Volume 2, Chapter 4) and Benthic and Intertidal Ecology (Volume 2, Chapter 5).

2.16 Summary of effects

253 This chapter has investigated potential changes to marine physical processes arising from the AyM project. The range of potential impacts and associated effects considered has been informed by Scoping responses and from subsequent discussions with stakeholders as part of the ETG process (Table 2). It has also drawn upon reference to existing policy and guidance.

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

- The determination of the MDS from the Offshore Project Description (Volume 2, Chapter 1);
- The determination of the baseline physical environment (including potential changes over the Project lifetime due to natural variation); and
- Assessment of changes to physical processes arising from the MDS both for AyM on its own and in conjunction with other built and consented projects.

255 In order to assess the potential changes relative to the baseline (existing) coastal and marine environment, a combination of complementary approaches have been adopted for the AyM physical processes assessment. These include:

- Numerical modelling of hydrodynamic, wave and sediment transport processes;
- The 'evidence base' containing monitoring data collected during the construction and O&M of other OWF developments (especially the adjacent GyM development);
- Analytical assessments of project-specific data; and
- Standard empirical equations describing (for example) the potential for scour development around structures (e.g. Whitehouse, 1998).

256 A wide range of potential changes to physical processes have been considered, including short-term sediment disturbance due to construction activities, scour around foundations and the potential for changes to the coast and nearby bank systems, arising from the blockage of waves and tides.

257 Even using a worst case MDS approach for the EIA, it has been found that for all receptor groups, the level of effect significance is either Negligible or Low for all phases of development (Table 15). Accordingly, all of the potential effects to physical processes receptors are therefore Not Significant in terms of the EIA Regulations (Volume 1, Chapter 3: Environmental Impact Assessment Methodology; application ref: 6.1.3).

Table 15: Summary of effects.

IMPACT	MAGNITUDE	SENSITIVITY OF RECEPTOR	MITIGATION MEASURES	RESIDUAL EFFECT
CONSTRUCTION				
Potential changes to suspended sediment concentrations, bed levels and sediment type/ character arising from construction related activities including dredging, drilling and cable installation.	(Pathway)	(Pathway)	(No mitigation measures necessary)	(Pathway)
Potential changes to Constable Bank/ Rhyl Flats and designated sites owing to the combined influence of sediment removal activities e.g. dredging and	Low	Medium	(No mitigation measures necessary)	Minor (adverse)

IMPACT	MAGNITUDE	SENSITIVITY OF RECEPTOR	MITIGATION MEASURES	RESIDUAL EFFECT
sandwave clearance.				
Potential changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast, arising from dredging/ disposal induced bed level change and associated modification of waves, tides and sediment transport.	Negligible	Medium	(No mitigation measures necessary)	Minor (adverse)
Potential changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast, arising from blockage effects associated with	Low (for Liverpool Bay SPA) Negligible (for all other receptors)	Medium	(No mitigation measures necessary)	Minor (adverse)

IMPACT	MAGNITUDE	SENSITIVITY OF RECEPTOR	MITIGATION MEASURES	RESIDUAL EFFECT
(partially) installed infrastructure.				
Potential changes to the coast arising from HDD and trenching at the landfall	Low	Medium	(No mitigation measures necessary)	Minor (adverse)
Potential for long-term changes to the coast arising from the use of cable protection at the landfall.	Negligible	Medium	(No mitigation measures necessary)	Minor (adverse)
Potential for long-term changes to the coast arising from cable protection within nearshore areas.	Low	Medium	(No mitigation measures necessary)	Minor (adverse)
OPERATION				

IMPACT	MAGNITUDE	SENSITIVITY OF RECEPTOR	MITIGATION MEASURES	RESIDUAL EFFECT
Potential for scour of seabed sediments, including that around scour protection structures.	(Pathway)	(Pathway)	(No mitigation measures necessary)	(Pathway)
Potential for changes to Constable Bank/ Rhyl Flats and designated sites arising from modification of the tidal regime	Low (for Liverpool Bay SPA) Negligible (for Constable Bank and Rhyl Flats)	Medium	(No mitigation measures necessary)	Minor (adverse)
Potential for changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast arising from modification of the wave regime	Negligible	Medium	(No mitigation measures necessary)	Minor (adverse)

IMPACT	MAGNITUDE	SENSITIVITY OF RECEPTOR	MITIGATION MEASURES	RESIDUAL EFFECT
Potential for changes to Constable Bank/ Rhyl Flats, designated sites and the adjacent coast arising from modification of the sediment transport regime	Negligible	Medium	(No mitigation measures necessary)	Minor (adverse)
Potential for changes to the coast arising from any modification of Constable Bank and Rhyl Flats.	Negligible	Medium	(No mitigation measures necessary)	Minor (adverse)
DECOMMISSIONING				
Potential changes to suspended sediment concentrations, bed	(Pathway)	(Pathway)	(No mitigation measures necessary)	(Pathway)

IMPACT	MAGNITUDE	SENSITIVITY OF RECEPTOR	MITIGATION MEASURES	RESIDUAL EFFECT
levels and sediment type.				
Potential changes to the coast arising from the removal of infrastructure and associated rock protection.	Minor	Medium	(No mitigation measures necessary)	Minor (adverse)
CUMULATIVE EFFECTS				
Potential for cumulative temporary increases in SSC and seabed levels as a result of AyM foundation installation and aggregate dredging	(Pathway)	(Pathway)	(No mitigation measures necessary)	(Pathway)
Potential for cumulative	(Pathway)	(Pathway)	(No mitigation measures necessary)	(Pathway)

IMPACT	MAGNITUDE	SENSITIVITY OF RECEPTOR	MITIGATION MEASURES	RESIDUAL EFFECT
temporary increases in SSC and seabed levels as a result of AyM foundation installation and dredge spoil disposal at licensed disposal grounds				
Potential for cumulative changes in hydrodynamics, waves and sediment transport arising from interaction proposed Round 4 OWF projects	[Not assessed; insufficient project information currently available]			
Potential for cumulative changes in hydrodynamics, waves and sediment transport arising from	Negligible	Medium	(No mitigation measures necessary)	Minor (adverse)

IMPACT	MAGNITUDE	SENSITIVITY OF RECEPTOR	MITIGATION MEASURES	RESIDUAL EFFECT
interaction with Flagstaff Tidal Lagoon				
Potential for cumulative changes in hydrodynamics, waves and sediment transport arising from interaction with new coastal defence works	[Not assessed; insufficient project information currently available]			

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