Salamander Offshore Wind Farm

Offshore EIA Report

Volume ER.A.3, Chapter 7: Marine Physical Processes

SALAMANDER

Powered by Ørsted and
Simply Blue Group

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Table of Contents

List of Tables

List of Figures

Glossary

Term	Definition
Applicant	Salamander Wind Project Company Limited (formerly called Simply Blue Energy (Scotland) Limited), a joint venture between Ørsted, Simply Blue Group and Subsea7.
Astronomical tide	The tide levels and character which would result from the gravitational effects of the earth, sun and moon, without any atmospheric influences.
Beach	A deposit of non-cohesive material (e.g. sand, gravel) situated on the interface between dry land and the sea (or other large expanse of water) and actively "worked" by present-day hydrodynamic processes (i.e. waves, tides and currents) and sometimes by winds.
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.
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.
Cumulative effects	The combined effect of the Salamander Project with the effects from a number of different projects, on the same single receptor/resource.
Cumulative impact	Impacts that result from changes caused by other past, present or reasonably foreseeable actions together with the Salamander Project.
Design Envelope	A description of the range of possible elements that make up the Salamander Project design options under consideration, as set out in detail in the project description. This

Term	Definition
	envelope is used to define the Salamander Project for Environmental Impact Assessment (EIA) purposes when the exact engineering parameters are not yet known.
Diurnal	Having a period of a tidal day i.e. 24.84 hours.
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the importance, or sensitivity, of the receptor or resource in accordance with defined significance criteria.
Energy Balancing Infrastructure (EBI)	Energy Balancing Infrastructure which will provide services to the electrical grid, such as storing energy to meet periods of peak demand and improving overall reliability, as well as additional services such as system monitoring and computing. EBI will be housed within buildings and / or containers will be co-located with the Onshore Substation.
Environmental Impact Assessment (EIA)	A statutory process by which the likely significant effects of certain projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the Environmental Impact Assessment (Scotland) Regulations (2017), including the publication of an Environmental Impact Assessment Report (EIAR).
EIA Regulations	The regulations that apply to this project are the Electricity Works (EIA) (Scotland) Regulations 2017, the Marine Works (EIA) (Scotland) Regulations 2017, the Marine Works (EIA) Regulations 2007, and the Town and Country Planning (EIA) (Scotland) Regulations 2017.
European Marine Observation and Data Network (EMODnet)	EMODnet is a Directorate-General for Maritime Affairs and Fisheries (DG MARE) funded network of organisations supported by the European Union's integrated maritime policy. These organisations work together to observe the sea, process the data according to international standards, and make that information freely available as interoperable data layers and data products.
Erosion	Movement of material by such agents as running water, waves, wind, moving ice and gravitational creep.
Geophysical survey	Activities to obtain data on the distribution and nature of geophysical properties of the seabed (e.g. bathymetry, surficial sediment type and bedforms, sub-surface geology). Geophysical survey outputs typically include multibeam bathymetry, side-scan sonar and sub-bottom profiler data.
Habitat	The place in which a plant or animal lives. It is defined for the marine environment according to geographical location, physiographic features and the physical and chemical environment (including salinity, wave exposure, strength of tidal streams, geology, biological zone, substratum, 'features' (e.g. crevices, overhangs, rockpools) and 'modifiers' (e.g. sand-scour, wave-surge, substratum mobility)).

Term	Definition
Hindcast	The retrospective prediction of historical (wind and wave) conditions.
Horizontal directional drilling (HDD)	A trenchless method of cable installation where the duct (or ducts) is installed to allow the cable(s) to be installed at a later date.
Habitats Regulations Appraisal (HRA)	A process which helps determine likely significant effects and (where appropriate) assesses adverse impacts on the integrity of European conservation sites and Ramsar sites (when these are also an SPA or SAC). The process consists of a multi stage assessment which incorporates screening, appropriate assessment, assessment of alternative solutions and assessment of imperative reasons of over-riding public interest (IROPI) and compensatory measures.
Hydrodynamic	Of, or relating to, the motion of fluids and the forces acting on solid bodies immersed in fluids and in motion relative to them.
Intertidal zone	The zone between the highest and lowest tides. May also be referred to as the littoral zone.
Impact	An impact is considered to be the change to the baseline as a result of an activity or event related to the Salamander Project. Impacts can be both adverse or beneficial impacts on the environment and be either temporary or permanent.
Inter-array Cables	Offshore cables which link the wind turbines to each other and to the Offshore Export Cable(s).
Landfall	The generic term applied to the entire landfall area between Mean Low Water Spring (MLWS) tide and the Transition Joint Bay (TJB) inclusive of all construction works, including the offshore and onshore Export Cable Corridor, intertidal working area and landfall compound, where the offshore cables come ashore north of Peterhead.
Light Detecting and Ranging (LiDAR)	A surveying method that measures distance to a target by illuminating that target with a laser light.
Littoral drift, littoral transport	The movement of beach material in the littoral zone by waves and currents. Includes movement parallel (longshore transport) and perpendicular (onshore- offshore transport) to the shore.
Longshore drift	Or alongshore or littoral drift. Movement of sand and shingle along the shore. It takes place in two zones, at the upper limit of wave activity and in the breaker zone. Movement of beach (sediments) approximately parallel to the coastline.
Marine Physical Processes Study Area	Geographical area across which potential changes to wave, tidal and sediment transport processes (and associated changes to seabed and coastal morphology) arising from the project have been considered.

Term	Definition
Morphological	Of, or relating to, the form, shape and structure of landforms
National Tide and Sea Level Facility (NTSLF)	The NTSLF is the UK centre of excellence for sea level monitoring, coastal flood forecasting and the analysis of sea level extremes
Offshore Array Area	The offshore area within which the wind turbine generators, foundations, mooring lines and anchors, and inter-array cables and associated infrastructure will be located.
Offshore Development	The entire Offshore Development, including all offshore components of the Project (Wind Turbine Generators (WTGs), Inter-array and Offshore Export Cable(s), floating substructures, mooring lines and anchors, and all other associated offshore infrastructure) required across all Project phases from development to decommissioning, for which the Applicant is seeking consent.
Offshore Development Area	The total area comprising the Offshore Array Area and the Offshore Export Cable Corridor.
Offshore Export Cable(s)	The export cable(s) that will bring electricity from the Offshore Array Area to the Landfall. The cable(s) will include fibre optic cable(s).
Offshore Export Cable Corridor	The area that will contain the Offshore Export Cable(s) between the boundary of the Offshore Array Area and Mean High Water Springs (MHWS).
Receptor (Offshore)	Any physical, biological or anthropogenic element of the environment that may be affected or impacted by the Salamander Project. Receptors can include natural features such as the seabed and wildlife habitats as well as man-made features like fishing vessels and cultural heritage sites.
Regime	The behaviour, statistical properties and trends characterising the variability of hydrodynamic, meteorological, sedimentological and morphological parameters.
Salamander Project	The proposed Salamander Offshore Wind Farm. The term covers all elements of both the offshore and onshore aspects of the project.
Salinity	Measure of all the salts dissolved in water.
Scoping	An early part of the EIA process by which the key potential significant impacts of the Salamander Project are identified, and methodologies identified for how these should be assessed. This process gives the relevant authorities and key consultees opportunity to comment and define the scope and level of detail to be provided as part of the EIAR – which can also then be tailored through the consultation process.
Scour	Local erosion of sediments caused by local flow acceleration around an obstacle and associated turbulence enhancement.

Term	Definition
Scour protection	Protective materials to avoid sediment being eroded away from the base of the seabed infrastructure as a result of the flow of water.
Sediment	Particulate matter derived from rock, minerals or bioclastic debris.
Sediment transport	The movement of a mass of sedimentary material by the forces of currents and waves. The sediment in motion can comprise fine material (silts and clay), sands and gravels. Potential sediment transport is the full amount of sediment that could be expected to move under a given combination of waves and currents, i.e. not supply limited.
Sediment transport pathway	The routes along which net sediment movements occur.
Semi-Submersible	A Semi-Submersible structure is a buoyancy-stabilised platform which floats partially submerged on the surface of the ocean whilst anchored to the seabed. The structure gains its stability through the distribution of buoyancy force associated with its large footprint and geometry which ensures the wind loading on the structure and turbine are countered by an equivalent buoyancy force on the opposite side of the structure. Included in the Project Design Envelope, there are variations of the semi-submersible concept, such as barge, buoy, or hybrid.
Significant wave height	The average height of the highest of one third of the waves in a given sea state.
Spring tides	Tides with the greatest range which occur at or just after the new and full moon.
Seastate	The state of the sea as described using the Douglas sea scale, based on wave height and swell, ranging from 1 to 10, with accompanying descriptions.
Shoreline Management Plan (SMP)	A Shoreline Management Plan (SMP) is a large-scale assessment of the risks associated with coastal processes. It aims to lessen these risks to people and the developed, historic and natural environments.
Suspended Particulate Matter (SPM)	Close to the bed, suspended matter typically consists of re-suspended mineral matter, but higher up in the water column SPM is typically in the form of flocs – loosely bound aggregates composed of mineral matter (e.g. clay minerals) as well as organic matter.
Surficial sediments	Sediments located at the seabed surface (not necessarily of the same character as underlying sediments).
Surge	In water level as a result of meteorological forcing (wind, high or low barometric pressure) causing a difference between the recorded water level and that predicted using harmonic analysis, may be positive or negative.
Suspended sediment concentration	Mass of sediment in suspension per unit volume of water.

Term	Definition
Swell (waves)	Wind-generated waves that have travelled out of their generating area. Swell characteristically exhibits a more regular and longer period and has flatter crests than waves within their fetch.
Tension Leg Platform	A Tension Leg Platform is a semi-submerged buoyant structure, anchored to the seabed with tensioned mooring lines. The combination of the structure buoyancy and tension in the anchor/mooring system provides the platform stability. This system-driven stability (as opposed to the stability coming just from the floating substructure itself) allows for a comparatively smaller and lighter structure compared to Semi-Submersible equivalents.
Tidal excursion	The Lagrangian movement (the physics of fluid motion as an individual fluid parcel moves through space and time) of a water particle during a tidal cycle.
Tidal excursion ellipse	The path followed by a water particle in one complete tidal cycle.
Tide	The periodic rise and fall in the level of the water in oceans and seas; the result of gravitational attraction of the sun and moon.
Topography	The form of the features of the actual surface of the earth in a particular region considered collectively.
Turbidity	Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particles. Suspended sediment concentration (SSC) refers to the mineral fraction of the suspended solids load whilst SPM includes both the inorganic and organic component.
United Kingdom Climate Projections (UKCP)	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 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.
Wind Turbine Generator	All the components of a wind turbine, including the tower, nacelle, and rotor.

Acronyms

Term	Definition
ABPmer	ABP Marine Environmental Research Ltd
BERR	Department for Business Enterprise and Regulatory Reform
BGS	British Geological Survey
BSI	British Standards Institution
CBRA	Cable Burial Risk Assessment
Cefas	Centre for Environment, Fisheries and Aquaculture Science
DTI	Department of Trade and Industry
EBI	Energy Balancing Infrastructure
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMODnet	European Marine Observation and Data Network
FEPA	Food and Environment Protection Act
HDD	Horizontal Directional Drilling
HRA	Habitats Regulations Appraisal
km	Kilometres
LAT	Lowest Astronomical Tide
LiDAR	Light Detecting and Ranging
m	Metres
MFE	Mass Flow Excavator
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs

Term	Definition
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
MD-LOT	Marine Directorate - Licensing Operations Team
ncMPA	nature conservation Marine Protected Area (ncMPA)
NTSLF	National Tide and Sea Level Facility
O&M	Operation & Maintenance
ODN	Ordnance Datum Newlyn
OSPAR	Oslo and Paris Conventions
OWF	Offshore Wind Farm
SMP	Shore Management Plan
SPA	Special Protection Area
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentration
SSSI	Site of Special Scientific Interest
SWPC	Salamander Wind Project Company (formerly called SBES)
TSHD	Trailing Suction Hopper Dredger
UK	United Kingdom
UKCP	UK Climate Projections
UKCP18	UK Climate Projections 2018
UKHO	United Kingdom Hydrographic Office
WTG	Wind Turbine Generator

7 Marine Physical Processes

7.1 Introduction

7.1.1.1 The Applicant, Salamander Wind Project Company Limited (SWPC), a joint venture (JV) partnership between Ørsted, Simply Blue Group and Subsea7, is proposing the development of the Salamander Offshore Wind Farm (hereafter 'Salamander Project'). The installation of a floating Offshore Wind Farm (up to 100 megawatts (MW) capacity), approximately 35 kilometres (km) east of Peterhead, will include both offshore and onshore infrastructure including an offshore generating station (wind farm), export cables to landfall, and connection to the electricity transmission network (please see **Volume ER.A.2, Chapter 4: Project Description** for full details on the Salamander Project Design).

7.1.1.2 This chapter of the Environmental Impact Assessment Report (EIAR) presents the results of the EIA of potential effects of the Salamander Project on Marine Physical Processes. Specifically, this chapter considers the potential impact of the Salamander Project seaward of Mean High Water Springs (MHWS) during the Construction, Operation and Maintenance, and Decommissioning phases of the Offshore Development.

7.1.1.3 The chapter provides an overview of the existing environment for the proposed Offshore Development Area, followed by an assessment of significance of effect on Marine Physical Processes receptors, as well as an assessment of potential cumulative effects with other relevant projects.

7.1.1.4 This chapter should be read alongside and in consideration of the Marine Physical Processes technical annex (ABPmer, 2023) in **Volume ER.A.4, Annex 7.1: Marine Physical Processes Technical Annex.**

7.1.1.5 This chapter has been authored by ABPmer. Further competency details of the authors of this chapter are outlined in **Volume ER.A.4, Annex 1.1: Details of Project Team.**

7.2 Purpose

7.2.1.1 The primary purpose of this EIAR is for the application for the Salamander Project satisfying the requirements of Section 36 of the Electricity Act 1989 and associated Marine Licences. This EIAR chapter describes the potential environmental impacts within the Offshore Development Area and assesses the significance of their effect.

7.2.1.2 The EIAR has been finalised following the completion of the pre-application consultation (**Volume RP.A.4, Report 1: Pre-Application Consultation (PAC) Report**) and the Salamander EIA Scoping Report (SBES, 2023) (and takes account of the relevant advice set out within the Scoping Opinion from the Marine Directorate - Licensing Operations Team (MD-LOT) (MD-LOT, 2023) relevant to the Offshore Development). Comments relating to the Energy Balancing Infrastructure (EBI) will be addressed within the Onshore EIAR. The Offshore EIAR will accompany the application to MD-LOT for Section 36 Consent under the Electricity Act 1989, and Marine Licences, under the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009.

7.2.1.3 This EIAR chapter:

- Outlines the existing environmental baseline determined from assessment of publicly available data, project-specific survey data and stakeholder consultation;
- Presents the potential environmental impacts and resulting effects arising from the Salamander Project on Marine Physical Processes receptors;
- Identification of mitigation measures designed to prevent, reduce, or offset adverse effects and enhance beneficial effects on the environment; and

- Identification of any uncertainties or limitations in the methods used and conclusions drawn from the compiled environmental information.

7.3 Planning and Policy Context

7.3.1.1 The preparation of the Marine Physical Processes chapter has been informed by the following policy, legislation, and guidance outlined in **Table 7-1**.

Table 7-1 Relevant policy, legislation and guidance relevant to the Marine Physical Processes assessment

Relevant policy, legislation, and guidance
Policy
National Planning Framework 4 (NPF4) (Scottish Government, 2023)
Sectoral Marine Plan for Offshore Wind Energy (Scottish Government, 2020)
Scottish National Marine Plan (Scottish Government, 2015)
United Kingdom (UK) Marine Policy Statement (HM Government, 2011)
Aberdeenshire Local Development Plan 2023
Legislation
Marine and Coastal Access Act 2009
The Conservation (Natural Habitats, &c.) Regulations 1994
The Conservation of Offshore Marine Habitats and Species Regulations 2017
Conservation of Habitats and Species Regulations 2017
Guidance
Environmental impact assessment for offshore renewable energy projects (BSI, 2015)
Coastal and marine environmental site guide. 2nd edition (CIRIA, 2015)
Review of environmental data associated with post-consent monitoring of licence conditions of offshore wind farms. MMO Project No: 1031. (Fugro-Emu, 2014).
Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Cefas, 2012)
OSPAR Assessment of the Environmental Impacts of Cables (OSPAR, 2009)

Relevant policy, legislation, and guidance
Coastal Process Modelling for Offshore Wind farm Environmental Impact Assessment: Best Practice Guide (ABPmer and HR Wallingford 2009)
Department of Business Enterprise and Regulatory Reform (BERR) - Review of Cabling Techniques and Environmental Effects Applicable to the Offshore Wind Farm Industry (BERR, 2008);
Guidelines in the use of metocean data through the lifecycle of a marine renewables development (CIRIA, 2008)
Dynamics of scour pits and scour protection - Synthesis report and recommendations. (Sed02) (HR Wallingford et al., 2007)
Offshore Windfarms: Guidance note for Environmental Impact Assessment in Respect of FEPA and CPA requirements (Cefas, 2004)
CIRCA C584 Coastal and marine environmental site guide (CIRCA, 2003)
Potential effects of offshore wind developments on coastal processes. (ABPmer and METOC, 2002)

7.3.1.2 Further details on the requirements for EIA are presented in **Volume ER.A.2, Chapter 2: Legislative Context and Regulatory Requirements**.

7.4 Consultation

7.4.1.1 Consultation is a key part of the application process. It has played an important part in ensuring that the baseline characterisation and impact assessment is appropriate to the scale of development, as well as meeting the requirements of the regulators and their advisors.

7.4.1.2 An overview of the Salamander Project consultation process is outlined in **Volume ER.A.2, Chapter 5: Stakeholder Consultation**. Consultation regarding Marine Physical Processes has been conducted through issue of the Salamander EIA Scoping Report (SBES, 2023), where various stakeholders were given the opportunity to respond via the Scoping Opinion.

7.4.1.3 The issues raised during consultation specific to Marine Physical Processes are outlined in **Table 7-2**, including consideration of where the issues have been addressed within the EIAR.

Table 7-2 Consultation responses specific to Marine Physical Processes topic

Consultee	Date and Forum	Comment	Where it is addressed within this EIAR
Marine Directorate – Licencing Operations Team (MD-LOT)	21 June 2023; Scoping Opinion	The Scottish Ministers are content with the proposed Study Area as shown in Figure 7-1 and agree that the relevant legislation and policy have been identified.	This is noted.
MD-LOT	21 June 2023; Scoping Opinion	The Scottish Ministers broadly agree with the receptors and potential impacts for physical processes detailed in Table 7-3, however, agree with the NatureScot representation regarding the Southern Trench nature conservation Marine Protected Area ("ncMPA") feature that the 'impact on designated features' in Table 7-3 are not characterised / identified and that methods for assessing this impact are not detailed. The Scottish Ministers advise that the NatureScot representation regarding this must be fully considered and addressed in the EIA Report.	The assessments have been undertaken using semi-quantitative desk-based techniques, as set out in **Section 7.10**. The impact pathways on designated geodiversity features within the Southern Trench ncMPA – namely moraines – is set out in **Section 7.11.3.**
MD-LOT	21 June 2023; Scoping Opinion	The Scottish Ministers agree with NatureScot that the potential impacts of trenched landfall cable(s) being re-exposed by future coastal change should also be assessed. The Scottish Ministers advise that this additional impact should be addressed either stand-alone or within the 'changes to coastal landfall morphology' impact.	Project Description has now been updated to remove the option of open-cut trenching. The Salamander Project has committed to trenchless installation techniques at landfall.

Consultee	Date and Forum	Comment	Where it is addressed within this EIAR
MD-LOT	21 June 2023; Scoping Opinion	With regard to the approach to assessment, the Scottish Ministers agree with NatureScot that further detail is required on the assessment methods used for tidal and wave regimes, suspended sediment concentrations, seabed morphology and coastal and landfall morphology. The Scottish Ministers advise this must be considered and addressed in the EIA Report. Further to this, the Scottish Ministers advise that the proposed assessment method for the impact on ncMPA designated features must be set out and agreed in advance.	The methodological approach to the assessments is set out in **Section 7.10**. Project Description has now been updated to remove the option of open-cut trenching. Further details with regards to the assessment of sediment disturbance related impacts are set out in **Volume ER.A.4, Annex 7.1: Marine Physical Processes Technical Annex**. The assessments have been undertaken using semi-quantitative desk-based techniques, as set out in **Section 7.10**. The impact pathways on designated geodiversity features within the Southern Trench ncMPA – namely moraines – is set out in **Section 7.11.3.**
MD-LOT	21 June 2023; Scoping Opinion	The Scottish Ministers are content with the cumulative assessment approach however highlight NatureScot comment that the CEF tool will be available for ornithology and marine mammal cumulative assessments only.	This is noted.
MD-LOT	21 June 2023; Scoping Opinion	With regard to mitigation and monitoring as proposed in Table 7-2, the Scottish Ministers further highlight NatureScot recommendation, as above, of including an additional measure to ensure that re-exposed cable(s) would be appropriately re-buried without hard engineering/protection and advise this must be fully considered and addressed in the EIA Report.	At this stage it is not possible to commit to re-burial of any exposed cables. However, it is noted that cables will be buried as the primary cable protection method and a Cable Burial Risk Assessment (CBRA) will be completed to determine suitable depth of lowering. This will minimise the risk of cable exposure. No additional protection (outside that already outlined as the realistic worst-case in **Table 7-14** and used as the basis for the assessment) will be applied.

Consultee	Date and Forum	Comment	Where it is addressed within this EIAR
MD-LOT	21 June 2023; Scoping Opinion	The Scottish Ministers agree that there are unlikely to be any transboundary or cross border impacts in relation to impacts on marine physical processes.	No transboundary effects have been identified. This is confirmed in **Section 7.8.2**.
Green Volt Offshore Wind Farm	21 June 2023; comments on EIA Scoping Report	Based on these potential interactions with Green Volt, we would anticipate that the offshore EIA for the proposed Salamander Offshore Wind Farm would consider the following impacts on the offshore elements of the Green Volt Offshore Windfarm project, including: - Windfarm site; - Offshore export corridor between the offshore substation to the landfall, particular the St Fergus South (north of Peterhead) primary option, - Increased vessel traffic and from the physical presence of Salamander infrastructure that may lead to interactions with activities related to Green Volt.	An assessment is included in **Section 7.13** specifically to marine physical processes, other topics will discuss interactions within the relevant chapters
NatureScot	21 June 2023; comments on EIA Scoping Report	We are concerned with the likelihood of multiple offshore export cables making landfall in the area around Peterhead and the potential for cumulative impacts arising from construction and associated geophysical, geotechnical and environmental survey programmes. Therefore, we recommend that this is considered further. We welcome the recent consultation to collaborate with	Potential combined effects from multiple projects making landfall within a limited spatial extent is assessed within the Cumulative Effects Assessment (see **Section 7.13**). NatureScot's comment regarding consultation and collaboration with Muir Mhòr Wind Farm is noted.

Consultee	Date and Forum	Comment	Where it is addressed within this EIAR
		Muir Mhòr Wind Farm to reduce the number of geotechnical / geophysical surveys.	
NatureScot	21 June 2023; comments on EIA Scoping Report	Natural heritage interests to be considered. We provide advice as detailed below within receptor-specific technical appendices for key natural heritage interests to be considered within the EIAR and Habitats Regulations Appraisal (HRA): - Advice on ornithological impact assessment is provided in Appendix A. - Advice on marine mammal impact assessment is provided in Appendix B. - Advice on seascape, landscape and visual impact assessment (SLVIA) is provided in Appendix C. - Advice on benthic impact assessment is provided in Appendix D. - Advice on fish and shellfish impact assessment is provided in Appendix E. - Advice on marine physical processes is provided in Appendix F.	Advice has been provided within receptor-specific technical annexes; those specifically for Marine Physical Processes (**Volume ER.A.4, Annex 7.1: Marine Physical Processes Technical Annex**) have been reviewed.

Consultee	Date and Forum	Comment	Where it is addressed within this EIAR
NatureScot	21 June 2023; comments on EIA Scoping Report	**Appendix F – Marine physical processes** Marine physical processes are considered in Section 7.1 of the Scoping Report and we have responded to the questions raised in the Scoping Report within our advice below. [Details of Appendix F captured in the individual NatureScot comments]	Responses provided to the specific questions within this table.
NatureScot	21 June 2023; comments on EIA Scoping Report	**Appendix F – Marine physical processes** **Study Area:** We are content with the Study Area as proposed in Section 7.1 and shown in Figure 7-1, which comprises the Offshore Array area and export cable corridor plus a buffer of 15km.	The boundary of the Study Area is also shown in **Figure 7-1**. This covers a wider geographic area than the equivalent boundary shown at Scoping, reflective of a slightly more conservative approach in defining the maximum theoretical extent of change around the Offshore Array Area and the Offshore Export Cable Corridor.
NatureScot	21 June 2023; comments on EIA Scoping Report	**Appendix F - Marine physical processes** **Baseline Information:** We agree that the relevant legislation and policy (as described in Chapter 2), technical guidance (Section 7.2.1.2) and data sources (Table 7-1) have been identified.	Relevant legislation and policy as well as technical guidance is set out in **Section 7.3**. Data sources are set out in **Table 7-3** and **Table 7-4.**
NatureScot	21 June 2023; comments on EIA Scoping Report	**Appendix F – Marine physical processes** **Potential Impacts:** The impacts that are to be scoped in and out of the assessment are detailed in Table 7-3 and we are generally content subject to the following advice.	The impacts that are to be scoped in and out of the assessment are summarised in **Table 7-13.**

Consultee	Date and Forum	Comment	Where it is addressed within this EIAR
NatureScot	21 June 2023; comments on EIA Scoping Report	We welcome that the Southern Trench nature conservation Marine Protected Area (ncMPA) features are highlighted as a physical process receptor. However, the 'impact on designated features' in Table 7-3 is not characterised / identified. In addition, the methods for assessing this impact are not detailed in Section 7.10.1.1 (see further advice below). Therefore, we cannot be confident at this stage that the assessment will be adequate.	The assessments have been undertaken using semi-quantitative desk-based techniques, as set out in **Section 7.10.2**. The impact pathways on designated geodiversity features within the Southern Trench ncMPA – namely moraines – is set out in **Section 7.11.3**.
NatureScot	21 June 2023; comments on EIA Scoping Report	It appears from the feature mapping in the MPA Data Confidence Assessment that the Moraines element of the Quaternary of Scotland feature may occur within the export cable corridor. These are relict landforms that cannot re-form if impacted. If any effects on Moraines are identified as possible, an assessment should be undertaken against the relevant MPA Conservation Objectives12 as follows: • Whether the landforms would '…remain sufficiently unobscured…' with regard to installation of infrastructure (construction phase); • Whether their '...extent, component elements and integrity are maintained' with regard to both the installation (construction phase) and any hydrodynamic effects (construction and operation and maintenance phases).	An assessment of the potential for effects on moraines within the Southern Trench MPA from marine physical processes is set out in **Section 7.11.3**. Further assessment against the relevant MPA Conservation Objectives is provided in **Volume ER.A.4, Annex 9.4: Southern Trench MPA Assessment**.

Consultee	Date and Forum	Comment	Where it is addressed within this EIAR
NatureScot	21 June 2023; comments on EIA Scoping Report	We also welcome that 'changes to coastal landfall morphology' has been identified and scoped in. However, the potential impacts of trenched landfall cable(s) being re-exposed by future coastal change should also be assessed. The likelihood of expanding and accelerating erosional retreat is highlighted in the Scoping Report (Section 7.1.5. and at Figure 7-6). If hard engineering/protection of re-exposed cable(s) may be required in future, impacts on coastal morphology could arise. Therefore, this additional impact should be addressed either stand-alone or within the 'changes to coastal landfall morphology' impact. However, this may not be required if an embedded mitigation measure was included ensuring that re-exposed cable(s) would be appropriately re-buried without hard engineering/protection measures.	The Salamander Project Description has now been updated to remove the option of open-cut trenching. The Salamander Project has committed to trenchless installation techniques at landfall.
NatureScot	21 June 2023; comments on EIA Scoping Report	**Approach to assessment** The approach to assessment is set out in Section 7.10 and we provide the following advice. For tidal and wave regimes, suspended sediment concentrations, seabed morphology and coastal and landfall morphology, the proposed assessment method is noted as 'semi-quantitative desk-based analysis'. Further detail on these methods is required for us to be confident that the assessment would be adequate.	The methodological approach to the assessments is set out in **Section 7.10.2**. Further details with regards to the assessment of sediment disturbance related impacts are set out in **Volume ER.A.4, Annex 7.1: Marine Physical Processes Technical Annex.**

Consultee	Date and Forum	Comment	Where it is addressed within this EIAR
NatureScot	21 June 2023; comments on EIA Scoping Report	The proposed assessment method for the 'impact on ncMPA designated features' needs to be set out and agreed in advance.	The assessments have been undertaken using semi-quantitative desk-based techniques, as set out in **Section 7.10.2**. The impact pathways on designated geodiversity features within the Southern Trench ncMPA – namely moraines – is set out in **Section 7.11.3.**
NatureScot	21 June 2023; comments on EIA Scoping Report	**Cumulative impacts** We are generally content with the cumulative impact assessment approach as set out in Section 7.13 but highlight again the Cumulative Effects Framework (CEF) tool will be available for ornithology and marine mammal cumulative assessments only. However… we are concerned with the likelihood of multiple offshore export cables making landfall in the area around Peterhead, and the potential for cumulative impacts arising from construction and associated geophysical, geotechnical and environmental survey programmes. Therefore, we recommend that this is assessed in the EIAR.	A full cumulative effects assessment is set out in **Section 7.13**.
NatureScot	21 June 2023; Scoping Response	**Mitigation and monitoring** We welcome the embedded mitigation measures as proposed in Table 7-2 but as above recommend the consideration of including an additional measure to ensure that re-exposed cable(s) would be appropriately re-buried without hard engineering/protection.	At this stage it is not possible to commit to re-burial of any exposed cables. However, it is noted that cables will be buried as the primary cable protection method and a Cable Burial Risk Assessment (CBRA) will be completed to determine suitable depth of lowering. This will minimise the risk of cable exposure. No additional protection (outside that already outlined as the realistic worst-case in **Table 7-14** and used as the basis for the assessment) will be applied.

Consultee	Date and Forum	Comment	Where it is addressed within this EIAR
		The EIAR must clearly articulate those mitigation measures that are informed by the EIA (or HRA) and are necessary to avoid or reduce predicted significant adverse environmental effects of the proposed development.	It is also worth noting that the Salamander Project Description has been updated to remove the option of open-cut trenching. The Salamander Project has committed to trenchless installation techniques at landfall to limit any potential impacts. No additional mitigation has been put forward as no significant effects are predicted associated with the use of hard engineering/ rock protection which would require specific mitigation.
NatureScot	21 June 2023; comments on EIA Scoping Report	**Transboundary / cross border impacts:** We advise that there are unlikely to be any transboundary or cross border impacts in relation to impacts on marine physical processes.	No transboundary effects have been identified. This is confirmed in **Section 7.15.**
NatureScot	21 June 2023; comments on EIA Scoping Report	**Wet storage** Section 4.6.2 (Floating Substructures) refers to the potential for wet storage of the substructures prior to their installation within the array area, either at the initial assembly site, the wind turbine integration site or a separate dedicated storage location. Section 4.7.1 (Floating Assembly) also indicates that once operational the substructures and WTGs will form an integrated assembly piece – the replacement of any major component parts of which is expected to be achieved by towing the assembly to port. Wet storage could represent a significant impact. Consideration of the potential impacts on all receptors needs to be addressed with the EIAR and HRA. We would welcome further discussion on this as and when further details	Wet storage of the floating substructures (and integrated WTGs) prior to tow-out to the Offshore Array Area is considered to be outside the scope of this EIA and the Marine Licence applications for the Offshore Development. This is due to the fact that at this stage of the Salamander Project it is not known which port(s) will be used for wet storage and therefore it is challenging to undertake a meaningful assessment of impacts related to wet storage. The intent is that the Salamander Project will utilise the services of a port(s) that offer wet storage sites, which will have appropriate consents (obtained by the port authority) for wet storage of floating substructures, fabrication and assembly with the WTGs. To enable the availability of this option for the Salamander Project within the required timeframe, an owner of SWPC is an official member of the TS-FLOW UK-North Joint

Consultee	Date and Forum	Comment	Where it is addressed within this EIAR
		are confirmed, noting the intention to seek a separate marine licence application for any requirements for wet storage outwith the array area.	Industry Project (JIP) exploring the challenges of wet storage and identifying the opportunities and potentially suitable locations for these activities. This JIP is in collaboration with relevant ports and other floating offshore wind developers. Separate Marine Licences and associated impact assessments for wet storage areas outwith the Offshore Development Area will be applied for and undertaken as appropriate.
North Sea Transition Authority	21 June 2023; comments on EIA Scoping Report	There is potential for the export cable to interact with a number of active pipelines entering the St Fergus terminal, most likely appears to be the Fulmar A – St Fergus gas pipeline. The Applicant should also be aware of interactions with blocks currently on offer as part of the Offshore Oil and Gas 33rd Licence Round, namely Block 19/15 which part of the windfarm application area is within. Applications are currently being reviewed by the NSTA and any potential interactions with planned windfarm developments are being discussed and addressed with Crown Estate Scotland. Awards from the Round are expected from Q3 2023.	A full cumulative effects assessment is set out in **Section 7.13.** Justification for those projects scoped in (or excluded from) the assessment is also provided.
Marine Directorate	November 2022; Scoping meeting with statutory consultees	Landfall – ensure that outputs from the Dynamic Coast Project are used to characterise the baseline.	The dynamic Coast Project is included, as referenced in **Table 7-4**. A description of the coastal characteristics within the Study Area is set out in **Section 7.7.**

Consultee	Date and Forum	Comment	Where it is addressed within this EIAR
Marine Directorate	November 2022; Scoping meeting with statutory consultees	Water column mixing and stratification – describe stratification and water column characteristics in the baseline.	A description of frontal systems and water column characteristics in the Study Area is set out in **Section 7.7.**
Marine Directorate	November 2022; Scoping meeting with statutory consultees	Water column mixing and stratification - expert opinion to be formed on potential for significant effects.	An assessment of potential changes to water column processes (mixing and stratification) is set out in **Section 7.11.3.**
NatureScot	November 2022; Scoping meeting with statutory consultees	The impact of trenched cables being re-exposed by storm activity should be assessed since re-exposure could lead to requirement for hard protection and in turn lead to impacts on sediment transport.	An assessment of potential changes to sediment transport system are set out in **Section 7.11.3.** It is also worth noting that the Salamander Project Description has been updated to remove the option of open-cut trenching. The Salamander Project has committed to trenchless installation techniques at landfall to limit any potential impacts.
Marine Directorate, Marine Scotland Science (now Marine Directorate Science) and NatureScot	November 2022; Scoping meeting with statutory consultees	Assessment approach: agreement that rule based spreadsheets (rather than numerical modelling) will be used to inform the impact assessment.	The assessment methodology (which draws upon spreadsheet-based modelling and analytical techniques) is set out in **Section 7.10.**
NatureScot	November 2022; Scoping meeting with statutory consultees	Assessment approach: a clear distinction needs to be made between impacts on physical processes receptors and pathways to impacts on other receptors.	The difference between marine physical processes pathways and receptors is set out in **Section 7.10.** Where changes to pathways have been considered in **Section 7.10** no judgment of impact significance has been made.

7.5 Study Area

7.5.1.1 The Marine Physical Processes Study Area has been defined on the basis of:

- The distance away from the Salamander Project which suspended sediment plumes may be advected (and meaningfully interact with potentially sensitive receptors). This has been defined by a spring tidal excursion ellipse buffer around the Offshore Array Area and the Offshore Export Cable Corridor;
- The distance up/down drift from the landfall, that littoral processes could theoretically be impacted by Salamander Project infrastructure, has been defined through consideration of coastal sub-cell information set out in Ramsay and Brampton (2000); and
- The distance from the Offshore Array Area that wave blockage impacts could theoretically be detected has been informed by expert judgment, drawing upon (amongst other things), the evidence base from analogous projects and consideration of the prevailing wave directions.

7.5.1.2 The Study Area for Marine Physical Processes is shown in **Figure 7-1**. It is noted that the Study Area covers a wider geographic area than the equivalent boundary shown at Scoping (based on the tidal excursion extent only), reflective of a slightly more conservative approach in defining the maximum theoretical extent of change (including potential effects on far-field wave climate) around the Offshore Array Area and the Offshore Export Cable Corridor.

7.5.1.3 As well as the Marine Physical Processes Study Area, the following areas are referred to in the Marine Physical Processes chapter and shown on **Figure 7-1**.

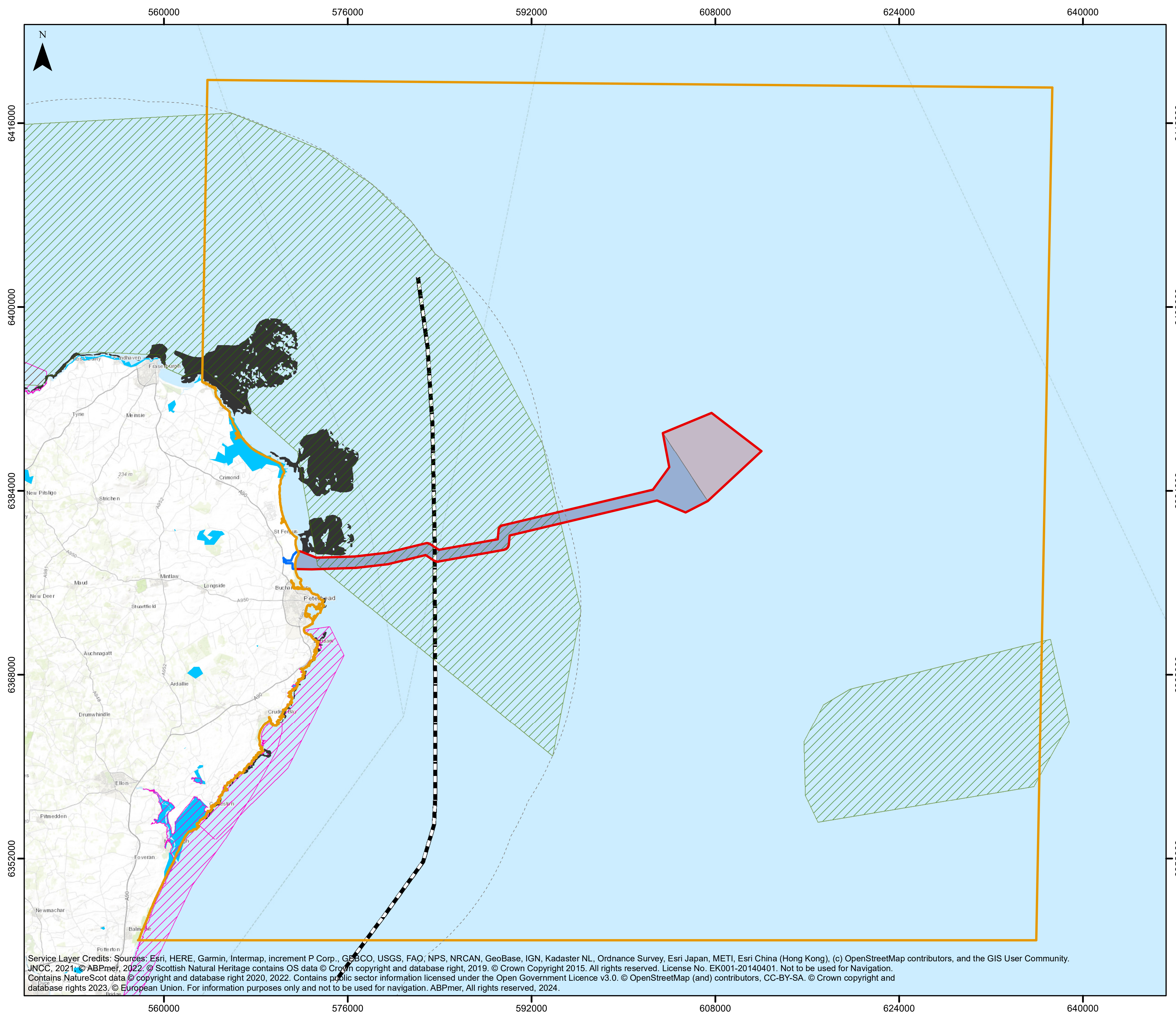
- Offshore Array Area. (This comprises the offshore area within which the Wind Turbine Generators (WTGs), foundations, mooring lines and anchors, and inter-array cables and associated infrastructure will be located);
- Offshore Export Cable Corridor. (This comprises the area that will contain the Offshore Export Cable(s) between the boundary of the Offshore Array Area and Landfall); and
- Offshore Development Area. (This comprises the entire Offshore Development, including all offshore components of the Salamander Project WTGs), Inter-array and Offshore Export Cable(s), floating substructures, mooring lines and anchors, and all other associated offshore infrastructure) required across all Salamander Project phases from development to decommissioning, for which the Applicant is seeking consent.)

7.5.1.4 The Study Area overlaps with a number of nationally and internationally designated nature conservation sites, some of which are designated on the basis of the geological and geomorphological features contained within them. These designated sites are shown in **Figure 7-1**.

Salamander

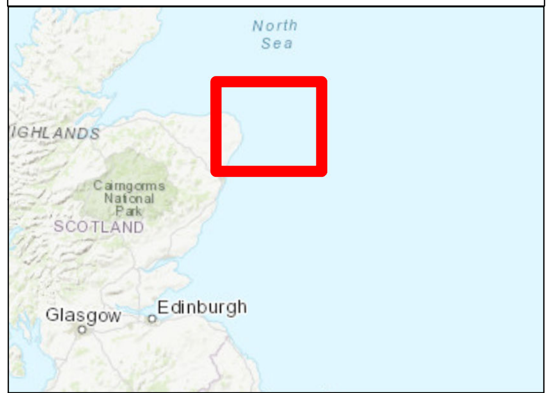
Figure 7-1

Marine Physical Processes Study Area and Protected Sites / Features



Legend

- Offshore Development Area
- Offshore Array Area
- Offshore Export Cable Corridor
- Indicative Onshore development area
- Study Area
- Marine Protected Area
- JNCC Annex 1 Reefs (Bedrock and/or Stony Habitat)
- Special Protection Area with Marine Component
- Site of Special Scientific Interest
- Buchan Front (Approx. Position)
- 12 nm limit



Coordinate System: WGS 1984 UTM Zone 30N

Vertical Datum : MLLW

Scale @ A4 : 300,000

0 3.75 7.5 15 Kilometers

0 1.75 3.5 7 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Marine Physical Processes Study Area and Protected Sites/ Features.

Doc. No : SWF01ER0361

Created by : BO

Checked by : IW

Approved by : SS

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7.6 Methodology to Inform Baseline

7.6.1 Site Specific Surveys

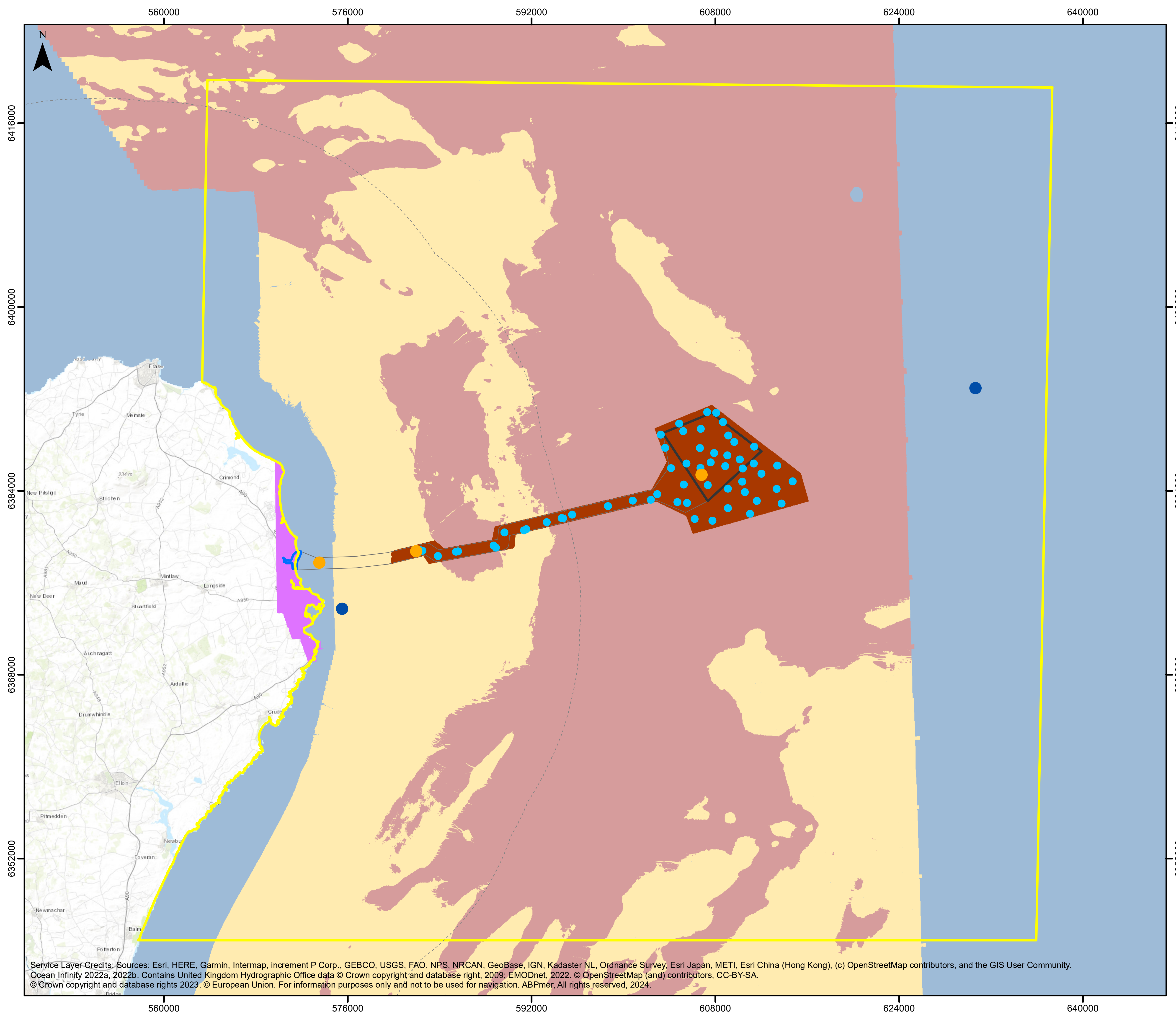
7.6.1.1 In order to provide site specific and up to date information on which to base the impact assessment, a geophysical survey was conducted, as presented in **Table 7-3.**

Table 7-3 Site specific surveys of relevance to Marine Physical Processes

Survey	Conducted by	Outcome of Survey
Geophysical and environmental survey	Ocean infinity (2022a)	Geophysical survey conducted for all of the Offshore Array Area and most of the Offshore Export Cable Corridor (up to a distance of circa 8 km from the coast). Multibeam, benthic grab sample, side-scan sonar, sub-bottom profile and magnetometry data collected.
Intertidal Report	Ocean infinity (2022b)	Phase I and Phase II intertidal biotope mapping to obtain standardised information on the presence and extent of the broad scale habitats and habitats of conservation importance.
Environmental Baseline Report	Ocean infinity (2022c)	Survey conducted for all of the Offshore Array Area and most of the Offshore Export Cable Corridor (up to a distance of circa 8 km from the coast). Included sediment sampling (inc. particle size) and imagery to establish a baseline for the habitats and faunal communities in the survey area. The survey was performed using drop down video, Day grab and Hamon grab samplers.

7.6.2 Data Sources

7.6.2.1 The available data that have been used to inform this Marine Physical Processes chapter of the EIAR are presented within **Figure 7-2** and **Table 7-4**.



Salamander

Figure 7-2

Location of key datasets

Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Indicative Onshore development area
- Study Area
- 12 nm limit

Project Specific Data (2022)

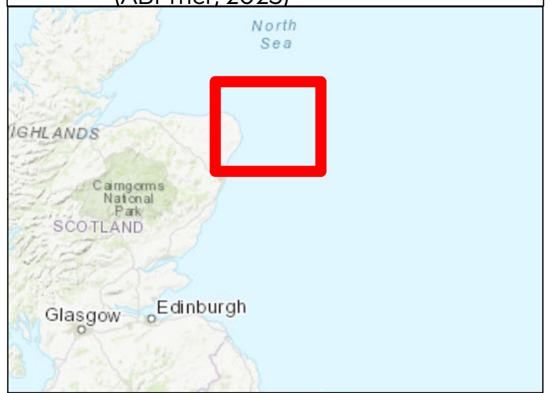
- Geophysical Survey
- Sediment Grab Samples

Bathymetric / Topographic Data

- UKHO (2009) 4m Gridded Bathymetry
- UKHO (2009) 8m Gridded Bathymetry
- EMODnet (2022) Bathymetry
- Scotland Phase 1 LiDAR (2011/12)

Metocean

- Temperature and Salinity Data (Copernicus, 2023)
- SEASTATES wave and wind data (ABPmer, 2023)



Coordinate System: WGS 1984 UTM Zone 30N

Vertical Datum : MLLW

Scale @ A4 : 300,000

0 3.75 7.5 15 Kilometers

0 2 4 8 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Locations of key datasets

Doc. No : SWF01ER0362

Created by : BO

Checked by : IW

Approved by : SS

Table 7-4 Summary of key publicly available datasets for Marine Physical Processes

Source	Year	Spatial Coverage	Summary
General information			
Marine Directorate Data Portal	Accessed May 2023	Partial coverage of the Marine Physical Processes Study Area	Data layers of bathymetry, ocean climate, waves, sea level, seabed geology, surface and subtidal sediments. [Source: www.marine.gov.scot]
Scottish Environment Protection Agency	Accessed May 2023	Partial coverage of the Marine Physical Processes Study Area	A range of datasets related to the environment including flood risk management. [Source: https://www.sepa.org.uk/]
Key publications	[various]	Partial coverage of the Marine Physical Processes Study Area	Academic papers relating to tidal fronts and stratification such as van Leeuwen *et al*. (2015) 'Stratified and non-stratified areas in the North Sea: Long-term variability and biological and policy implications' and Hill *et al*. (1993) 'Dynamics of Tidal Mixing Fronts in the North Sea', as well as other key publications such as Hansom et al. (2004) 'Shoreline Management Plans and Coastal Cells in Scotland. Coastal Management'.
Hydrodynamics, waves and water column structure			
National Tide and Sea Level Facility (NTSLF)	Accessed May 2023	Partial coverage of the Marine Physical Processes Study Area	Tidal water levels from point locations within the Study Area. [Source: www.ntslf.org]
British Oceanographic Data Centre	Accessed May 2023	Partial coverage of the Marine Physical Processes Study Area	Hydrodynamic data (inc. current speed and direction, Conductivity, Temperature, and Depth (CTD) profile data) from point locations within the Study Area. [Source: www.bodc.ac.uk]

Source	Year	Spatial Coverage	Summary
Cefas WaveNet data	Accessed May 2023	Partial coverage of the Marine Physical Processes Study Area	Wave records from point locations within the Study Area. [Source: www.cefas.co.uk/cefas-data-hub/wavenet/]
ABPmer SEASTATES	1979 to 2022	Full coverage of the Marine Physical Processes Study Area	Modelled hindcast wave and hydrodynamic data from across the Study Area. [Source: www.seastates.net/]
Marine Renewables Atlas	2008	Full coverage of the Marine Physical Processes Study Area	Modelled hindcast wave and hydrodynamic data from across the Study Area [Source: ABPmer et al. (2008)]
Climate change projections	2018	Partial coverage of the Marine Physical Processes Study Area	Sea level rise predictions for coastal locations within the Study Area. [Source: Met Office (2018)]
Suspended Sediment Climatologies around the UK	2016	Partial coverage of the Marine Physical Processes Study Area	Monthly and seasonal Suspended Particulate Matter maps for the Study Area. [Source: Cefas (2016)]
Copernicus	Accessed May 2023	Partial coverage of the Marine Physical Processes Study Area	Three locations providing representative temperature and salinity data for the Offshore Array Area, Offshore Export Cable Corridor and landfall. [Source: https://www.copernicus.eu/en/copernicus-services/marine]
Atlantic - European North West Shelf - Ocean Physics Analysis and Forecast [from Copernicus]	Accessed May 2023	Full coverage of the Marine Physical Processes Study Area	1.5 km horizontal resolution coupled hydrodynamic and wave model which can provide vertical profiles of temperature and salinity [https://marine.copernicus.eu/]
Bathymetry, geology and seabed sediments			
British Geological Survey (BGS) offshore geoindex	Accessed May 2023	Full coverage of the Marine Physical Processes Study Area	Seabed sediment maps (based on Folk classification) and borehole records from point locations within the Study Area. [Source: www.bgs.ac.uk/GeoIndex/offshore.htm]

Source	Year	Spatial Coverage	Summary
Strategic Environmental Assessment Data Portal	Accessed May 2023	Partial coverage of the Marine Physical Processes Study Area	Seabed mapping data collected on behalf of the Department of Trade and Industry (DTI) to support Strategic Environmental Assessment in Project Area 5. [Source: https://webapps.bgs.ac.uk/data/sea/app/search]
United Kingdom Hydrographic Office	Accessed May 2023	Partial coverage of The Marine Physical Processes Study Area	Bathymetric data for the Study Area in the form of multibeam and single beam data, as well as Admiralty Charts.
EMODnet	Accessed May 2023	Full coverage of the Marine Physical Processes Study Area	Bathymetry data and seabed sediment maps. [Source: https://emodnet.ec.europa.eu/en]
Characterising Scotland's marine environment to define search locations for new Marine Protected Areas. Part 2, the identification of key geodiversity areas in Scottish waters (Brooks et al. 2011)	Accessed June 2023	Partial coverage of the Marine Physical Processes Study Area	GIS mapping of geodiversity interests within the Study Area
Coastal characteristics			
Dynamic Coast: The National Overview	2021	Partial coverage of the Marine Physical Processes Study Area	The Dynamic Coast project aims to provide the strategic evidence base on the extent of coastal erosion in Scotland. [Source: www.dynamiccoast.com/]
Coastal Cells in Scotland: Cell2 Fife Ness to Cairnbulg Point	2000	Partial coverage of the Marine Physical Processes Study Area	Description of sediment transport at the coast within the context of coastal cells and sub-cells (Ramsay and Brampton, 2000).
Scottish Coastal Observatory	Accessed May 2023	Partial coverage of the Marine Physical Processes Study Area	Monitoring data collected as part of the Scottish Coastal Observatory, covering a range of marine environmental variables including

Source	Year	Spatial Coverage	Summary
			temperature and salinity. [Source: https://marine.gov.scot/data/scottish-coastal-observatory-data]
Coasts and seas of the United Kingdom, Region 3 North east Scotland: Cape Wrath to St. Cyrus	1996	Partial coverage of the Marine Physical Processes Study Area	Description of coastal characteristics and frontal systems within the Study Area.
Scottish Remote Sensing Portal	Accessed May 2023	Partial coverage of the Marine Physical Processes Study Area	Light Detecting and Ranging (LiDAR) datasets to inform past coastal change. [Source: https://remotesensingdata.gov.scot/]
Key publications	[various]	Partial coverage of the Marine Physical Processes Study Area	Public and grey literature considering coastal morphology and behaviour at sensitive coastal locations within the Study Area e.g. Hansom *et al.* (2017); Hansom *et al.* (2004) and Baxter *et al.* (2011).

7.7 Baseline Environment

7.7.1 Existing Baseline

7.7.1.1 Physical processes have been sub-divided into the following categories:

- Water levels;
- Currents;
- Wind and wave climate;
- Stratification;
- Sediments and geology;
- Seabed and geomorphology; and
- Coastal geomorphology and characteristics.

7.7.1.2 Characteristics of the designated sites within the Study Area are also included within this section.

7.7.1.3 The natural variability of physical processes is explored in the absence of any of the proposed structures for the Salamander Project. Consequently, this provides the 'baseline' conditions within the Study Area upon which impacts from the Salamander Project can be assessed against; however, it should also be noted that a Future Baseline, under climate change scenarios, is presented in **Section 7.7.2** of this chapter.

Water Levels

<u>Tidal Water Levels</u>

7.7.1.4 The Study Area is located within a semi-diurnal tidal environment with tidal range, generally, increasing from east to west. Within the Offshore Array Area, the spring tidal range is typically around 2.35 to 2.45 m, with a neap range of approximately half this (ABPmer *et al.*, 2008). At the landfall, the spring tidal range is approximately 3.3 m with a neap range of approximately 1.6 m (**Table 7-5**).

Table 7-5 Standard water levels at Peterhead, near the landfall (height values quoted relative to Lowest Astronomical Tide (LAT) in metres) (Source: UKHO, 2023)

Datum	Description	Water levels at Peterhead (m)
HAT	Highest Astronomical Tide	4.4
MHWS	Mean High Water Spring	4.0
MHWN	Mean High Water Neap	3.20
MSL	Mean Sea Level	2.45
MLWN	Mean Low Water Neap	1.60
MLWS	Mean Low Water Spring	0.70
LAT	Lowest Astronomical Tide	0.00

Non-tidal Water Levels

7.7.1.5 Extreme water levels at the proposed development typically result from storm surge propagation within the North Sea. The processes associated with storm surge propagation in the North Sea are generally well understood, having been extensively studied (e.g. Horsburgh & Wilson, 2007). In brief, a storm surge is produced when high winds build up a wall of water, further exacerbated by the effects of atmospheric pressure (Prichard, 2013). Estimates of the 50-year return period (positive) storm surge elevation are available from HSE (2002) for the Offshore Array Area and are approximately 1.25 m above expected tidal levels. At the landfall, the 1 in 10-year extreme surge water level is 2.6 mODN (metres above Ordnance Datum Newlyn), whilst the 1 in 50-year extreme surge water level is 2.74 mODN (EA, 2018); at Peterhead, Chart Datum (CD), similar to the Lowest Astronomical Tide (LAT), is 2.2 m below ODN, yielding a 1 in 10-year extreme surge water level of approximately 4.8 mLAT and a 1 in 50-year extreme surge water level of approximately 4.94 mLAT.

Currents

Tidal Currents

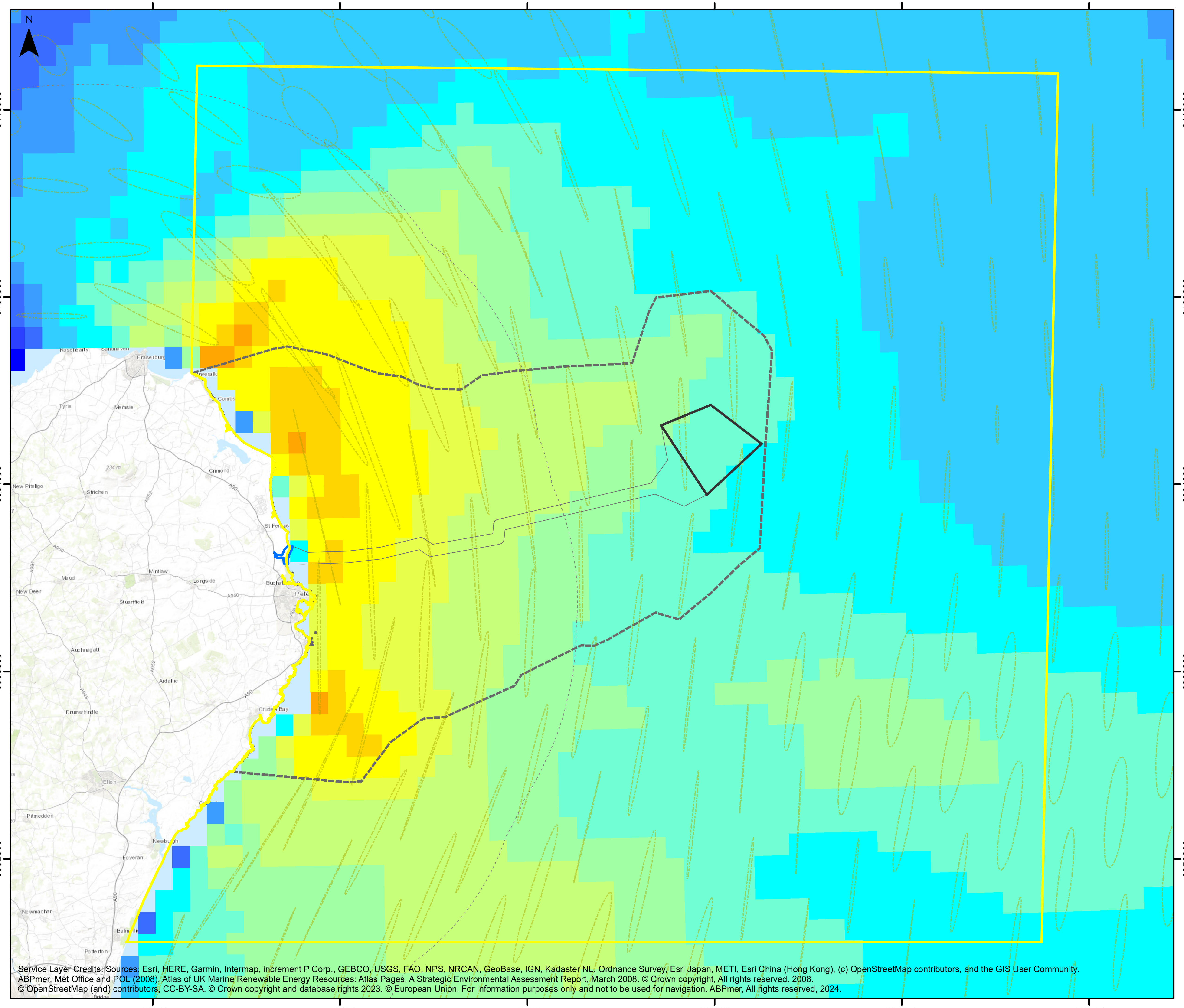
7.7.1.6 Regional-scale information on tidal currents is available from the UK Atlas of Marine Renewable Energy Resources (ABPmer *et al.*, 2008). The current regime is illustrated as **Figure 7-3**, which shows the depth averaged mean spring peak current speeds, along with the spring tidal excursion buffer. In general, the depth averaged mean spring peak current speed ranges from *circa* 0.5 m/s offshore, increasing to *circa* 1.0 to 1.5 m/s at the coast. The flow direction is generally south (flood) to north (ebb) offshore but changes closer inshore as the flow aligns with the coastline. Tidal ellipses are quite strongly rectilinear throughout the Offshore Export Cable Corridor and Offshore Array Area. Further details of the tidal current characteristics within (i) the Offshore Array Area; (ii) the Offshore Export Cable Corridor; and (iii) the Study Area as a whole are provided as follows:

Offshore Array Area:

- Flows are slightly stronger along the western edge of the Offshore Array Area, as might be expected due to having a slightly higher tidal range; and
- Depth averaged mean spring currents within the Offshore Array Area are in the approximate range 0.5 to 0.8 m/s, with equivalent neap flows of between approximately 0.2 to 0.4 m/s.

Offshore Export Cable Corridor:

- Flows are stronger closer the coast due to general acceleration of flow around the Peterhead/Rattray/Fraserburgh headland;
- Depth averaged mean spring currents within the Offshore Export Cable Corridor are in the approximate range 0.6 to 1.1 m/s, with equivalent neap flows of between approximately 0.4 to 0.6 m/s; and
- Tidal flow is relatively rectilinear close to the Offshore Array Area, with tidal current direction to the north during the ebb and to the south during the flood. Closer inshore, flows become increasingly more closely aligned to the adjacent coastline, with spring tidal excursion distances also increasing (to over 12 km) in response to the faster current speeds (ABPmer *et al.*, 2008).



Salamander

Figure 7-3

Mean spring peak tidal currents within the Study Area

Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Indicative Onshore development area
- Study Area
- Salamander Spring Tidal Excursion Buffer
- Spring Tidal Excursion Ellipse
- 12 nm limit

Current Speed (Mean Spring Peak Flow) (m/s)

	0.81 to
0.11 to	0.91 to
0.21 to	1.01 to
0.31 to	1.21 to
0.41 to	1.41 to
0.51 to	1.61 to
0.61 to	1.81 -
0.71 to	

Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW
Scale @ A4 : 300,000

0 3.75 7.5 15 Kilometers
0 2 4 8 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Mean spring peak tidal currents within the Study Area
Doc. No : SWF01ER0363
Created by : BO
Checked by : IW
Approved by : SS

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Study Area:

- Flows are slightly stronger along the northern parts of the coast within the Study Area and the lowest current speeds are along the northeast of the Study Area;
- Depth averaged mean spring currents within the Study Area are in the approximate range 0.4 to 1.6 m/s, with equivalent neap flows of between approximately 0.2 to 0.9 m/s; and
- The axis of tidal flows across the Study Area is generally south (flood) to north (ebb), and fairly well aligned with the adjacent coastline.

Non-tidal Currents

7.7.1.7 The processes associated with storm surge propagation in the North Sea are generally well understood, having been extensively studied. In brief, a storm surge is produced when high winds build up a wall of water, further exacerbated by the effects of atmospheric pressure (Prichard, 2013). Estimated, depth-averaged, hourly-mean current speeds associated with a 50-year return period surge event are approximately 0.8 to 1 m/s, in a southerly direction (HSE, 2002; Flather, 1987).

7.7.1.8 On local scales, the current within the surface layer is highly sheared and approximately follows the wind direction. The speed at the surface is of the order of 3% of the wind speed (HSE, 2002). On larger scales, sea surface slopes are generated, resulting in associated currents.

7.7.1.9 There is also a pronounced stratification front, known as the Buchan Front, which is found in a transitional zone off Buchan and the Aberdeenshire coast (as illustrated in **Figure 7-1**). More details on this tidal front, in the context of water column stratification, are provided in **Sections 7.7.1.19** to **7.7.1.26**.

Wind and Wave Climate

Winds

7.7.1.10 An understanding of the wind climate is relevant to Marine Physical Processes, in so far as it is a controlling parameter in the prevailing wave regime and non-tidal water levels and currents. The relationship between wave generation and meteorological forcing means that the wind and wave regimes are similarly episodic and exhibit both seasonal and inter-annual variation, in proportion with the frequency and magnitude of changes in wind strength and direction.

7.7.1.11 Long-term hindcast records of wind data within the Study Area have been derived from ABPmer's SEASTATES models. A frequency analysis of the data is presented as wind roses in **Figure 7-4** (for the Offshore Array Area) and **Figure 7-5** (landward end of the Offshore Export Cable Corridor), and as joint probability tables in **Table 7-6** and **Table 7-8** respectively. The data show that winds in the Offshore Array Area most frequently come from the south (just under 20% of the time), but also regularly come from southwesterly around to northwesterly directions (accounting for approximately 50% of the record). Stronger winds (>16 m/s) tend to also come from these directional sectors. Wind speeds within the Offshore Export Cable Corridor are lower and most frequently come from the south (just over 20% of the time), but also regularly come from south-west around to north-west directions (accounting for approximately 50% of the record). Stronger winds (>16 m/s) tend to also come from the south around to north-west (ABPmer, 2023).

7.7.1.12 Monthly statistics of wind speed, based on SEASTATES hindcast data for the period 1979 to 2022 at the landward end of the Offshore Export Cable Corridor and the Offshore Array area, are illustrated by the monthly statistics presented in **Table 7-6** and **Table 7-8** respectively. The seasonality in wind speed can be seen at both sites with larger monthly mean values for the winter months October to March. As seen in the rose plots and joint probability tables wind speeds are overall larger at the Offshore Array area location compared to the more landward location.

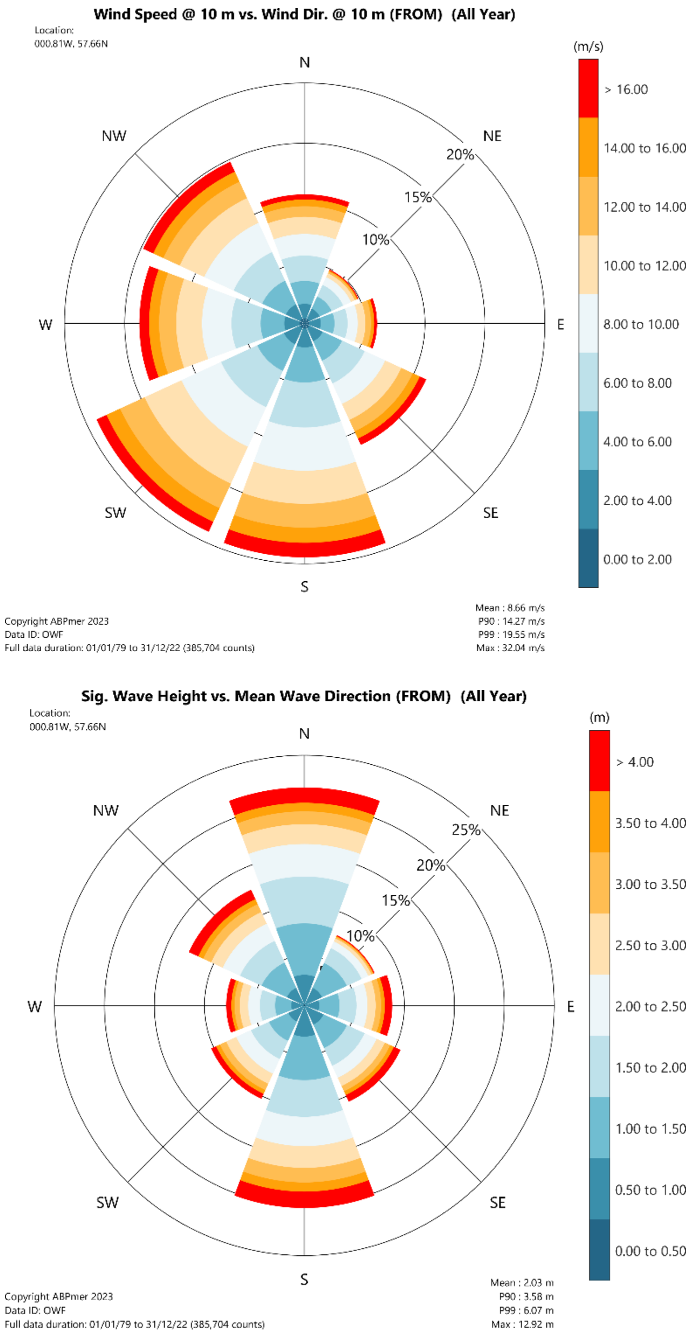


Figure 7-4 Rose plots of wind (top) and significant wave height and direction (bottom) for the period 1979-2022, for a location representative of the Offshore Array Area (source: ABPmer, 2023)

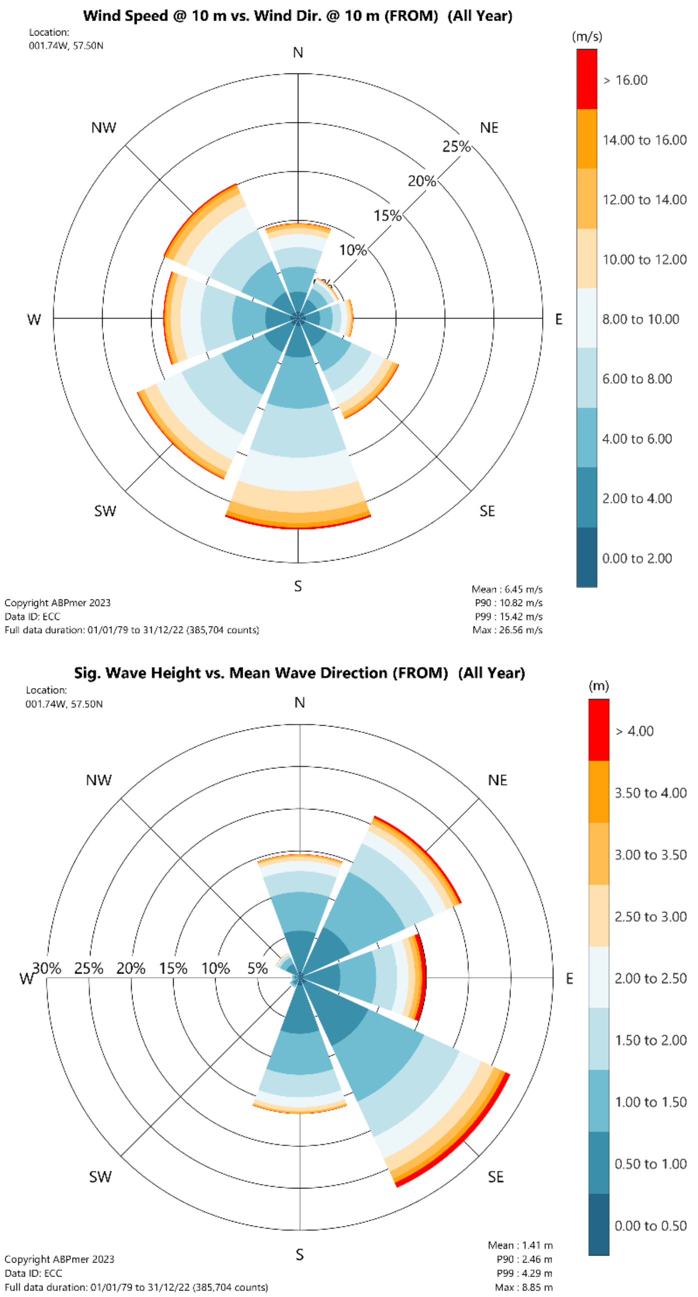


Figure 7-5 Rose plots of wind (top) and significant wave height and direction (bottom) for the period 1979-2022, for a location representative of the landward end of the Offshore Export Cable Corridor (Source: ABPmer, 2023)

Table 7-6 Joint probability table of wind speed and direction at 10 m above surface for the period 1979 to 2022, for a location representative of the Offshore Array Area (Source: ABPmer, 2023)

OWF - Wind Speed Wind Dir. Scatter Table - All Year - Percentage (occurrences as proportion of all time in year)

Wind Speed at 10 m (m/s)	Wind Dir. at 10 m (degrees FROM)												
	Lower (>=)		*337.5*	*22.5*	*67.5*	*112.5*	*157.5*	*202.5*	*247.5*	*292.5*	**Sum**	*Cum. Sum*	*Exced.*
		Upper (<)	*22.5*	*67.5*	*112.5*	*157.5*	*202.5*	*247.5*	*292.5*	*337.5*			
	33	*36*										**100.00**	0.00
	30	*33*		**0.00**					**0.00**	0.00	0.00	100.00	0.00
	27	*30*	0.00	0.00				**0.00**	0.00	0.00	0.01	100.00	0.00
	24	*27*	0.00		**0.00**	0.00	0.01	0.01	0.02	0.02	0.07	99.99	0.01
	21	*24*	0.02	0.01	0.01	0.04	0.08	0.05	0.07	0.07	0.37	99.91	0.09
	18	*21*	0.13	0.03	0.08	0.23	0.41	0.28	0.29	0.31	1.75	99.54	0.46
	15	*18*	0.52	0.08	0.24	0.60	1.26	1.07	0.76	0.90	5.44	97.79	2.21
	12	*15*	1.19	0.22	0.63	1.42	2.68	3.00	1.92	2.03	13.09	92.35	7.65
	9	*12*	2.29	0.67	1.02	2.38	4.49	5.19	3.35	3.58	22.97	79.26	20.74
	6	*9*	3.06	1.47	1.56	3.05	5.61	5.14	3.68	3.99	27.57	56.29	43.71
	3	*6*	2.60	1.62	1.65	2.48	3.85	3.32	2.72	2.94	21.18	28.72	71.28
	0	*3*	0.92	0.84	0.82	0.94	1.06	1.03	0.95	0.97	7.54	7.54	92.46
	Sum		**10.73**	**4.93**	**6.02**	**11.14**	**19.47**	**19.10**	**13.78**	**14.82**	**100.00**		

Table 7-7 Joint probability table of significant wave height and mean wave direction for the period 1979 to 2022, for a location representative of the Offshore Array Area (Source: ABPmer, 2023)

OWF - Hs Mdir Scatter Table - All Year - Percentage (occurrences as proportion of all time in year)

	Mean Wave Direction (degrees FROM)												
	Lower (>=)		*337.5*	*22.5*	*67.5*	*112.5*	*157.5*	*202.5*	*247.5*	*292.5*	*Sum*	*Cum. Sum*	*Exced.*
		Upper (<)	*22.5*	*67.5*	*112.5*	*157.5*	*202.5*	*247.5*	*292.5*	*337.5*			
Significant Wave Height (m)	*13*	*14*										100.00	0.00
	12	*13*	0.00							0.00	0.00	100.00	0.00
	11	*12*	0.00					0.00	0.00	0.00	0.00	100.00	0.00
	10	*11*	0.00				0.00	0.00	0.00	0.00	0.01	100.00	0.00
	9	*10*	0.01		0.00		0.01	0.00	0.00	0.01	0.04	99.99	0.01
	8	*9*	0.03		0.01	0.01	0.02	0.01	0.01	0.02	0.10	99.94	0.06
	7	*8*	0.07	0.00	0.04	0.03	0.06	0.01	0.02	0.04	0.26	99.84	0.16
	6	*7*	0.16	0.01	0.07	0.08	0.15	0.04	0.04	0.09	0.64	99.58	0.42
	5	*6*	0.39	0.02	0.19	0.19	0.40	0.13	0.14	0.25	1.70	98.94	1.06
	4	*5*	0.88	0.08	0.44	0.43	1.01	0.35	0.30	0.61	4.10	97.24	2.76
	3	*4*	2.14	0.25	0.91	0.99	2.37	1.11	0.83	1.42	10.02	93.14	6.86
	2	*3*	5.23	1.08	1.93	2.23	5.10	2.74	2.02	3.19	23.53	83.12	16.88
	1	*2*	9.83	4.36	3.72	4.52	8.03	4.11	3.16	5.16	42.89	59.59	40.41
	0	*1*	3.05	1.94	1.49	2.11	3.10	1.77	1.30	1.94	16.71	16.71	83.29
	Sum		**21.79**	**7.74**	**8.79**	**10.59**	**20.25**	**10.28**	**7.82**	**12.74**	**100.00**		

Table 7-8 Joint probability table of wind speed and direction at 10 m above surface for the period 1979 to 2022, for a location representative of the landward end of the Offshore Export Cable Corridor (Source: ABPmer, 2023)

ECC - Wind Speed Wind Dir. Scatter Table - All Year - Percentage (occurrences as proportion of all time in year)

Wind Speed at 10 m (m/s)	Wind Dir. at 10 m (degrees FROM)											
	Lower (>=)		*337.5*	*22.5*	*67.5*	*112.5*	*157.5*	*202.5*	*247.5*	*292.5*	*Sum*	*Cum. Sum*	*Exced.*
		Upper (<)	*22.5*	*67.5*	*112.5*	*157.5*	*202.5*	*247.5*	*292.5*	*337.5*			
	27	*30*										100.00	0.00
	24	*27*	0.00						0.00	0.00	0.00	100.00	0.00
	21	*24*	0.00			0.00	0.00	0.01	0.00	0.00	0.02	100.00	0.00
	18	*21*	0.01	0.00	0.00	0.01	0.05	0.02	0.03	0.04	0.16	99.98	0.02
	15	*18*	0.07	0.03	0.04	0.15	0.34	0.13	0.14	0.20	1.10	99.81	0.19
	12	*15*	0.42	0.09	0.21	0.56	1.35	0.65	0.57	0.87	4.72	98.72	1.28
	9	*12*	1.20	0.23	0.63	1.53	3.68	2.57	1.91	2.57	14.33	94.00	6.00
	6	*9*	2.76	0.88	1.23	3.10	6.94	6.19	4.40	5.08	30.59	79.67	20.33
	3	*6*	3.70	1.94	2.03	4.18	7.20	6.61	4.84	4.77	35.27	49.09	50.91
	0	*3*	1.56	1.40	1.50	1.83	2.03	1.98	1.88	1.64	13.82	13.82	86.18
	Sum		**9.72**	**4.57**	**5.63**	**11.36**	**21.61**	**18.15**	**13.78**	**15.17**	**100.00**		

Table 7-9 Joint probability table for significant wave height and mean wave direction, for the period 1979 to 2022, for a location representative of the landward end of the Offshore Export Cable Corridor (Source: ABPmer, 2023)

ECC - Hs Mdir Scatter Table - All Year - Percentage (occurrences as proportion of all time in year)

	Mean Wave Direction (degrees FROM)												
Significant Wave Height (m)	*Lower (>=)*		*337.5*	*22.5*	*67.5*	*112.5*	*157.5*	*202.5*	*247.5*	*292.5*	*Sum*	*Cum. Sum*	*Exced.*
		Upper (<)	*22.5*	*67.5*	*112.5*	*157.5*	*202.5*	*247.5*	*292.5*	*337.5*			
	9	*10*										100.00	0.00
	8	*9*		0.00		0.00					0.00	100.00	0.00
	7	*8*		0.00	0.01	0.01					0.02	100.00	0.00
	6	*7*		0.00	0.03	0.03	0.00				0.07	99.98	0.02
	5	*6*	0.00	0.05	0.12	0.14	0.00			0.00	0.32	99.91	0.09
	4	*5*	0.04	0.22	0.32	0.46	0.04	0.00	0.00	0.01	1.07	99.59	0.41
	3	*4*	0.27	0.80	0.83	1.47	0.25	0.00	0.00	0.03	3.65	98.52	1.48
	2	*3*	1.71	2.56	2.12	4.51	1.67	0.05	0.04	0.19	12.83	94.87	5.13
	1	*2*	7.05	10.91	6.73	11.90	7.54	0.39	0.31	1.16	45.99	82.04	17.96
	0	*1*	5.54	6.60	4.81	8.96	6.68	0.99	0.68	1.80	36.05	36.05	63.95
	Sum		**14.62**	**21.14**	**14.96**	**27.47**	**16.18**	**1.43**	**1.03**	**3.18**	**100.00**		

Table 7-10 Annual and monthly statistics for wind speed at 10 m above surface (left), significant wave height (middle) and wave peak period (right), for a period 1979 to 2022, for a location representative of the Offshore Array Area (Source: ABPmer, 2023)

Offshore Array Area - Annual and Monthly Statistics									
Month	*Wind Spd. at 10 m (m/s)*			*Sig. Wave Height (m)*			*Wave Peak Period (s)*		
	Mean	*Min.*	*Max.*	*Mean*	*Min.*	*Max.*	*Mean*	*Min.*	*Max.*
January	10.93	0.08	29.16	2.86	0.55	11.59	8.94	3.12	23.92
February	10.34	0.10	32.04	2.65	0.46	12.49	8.75	3.26	22.71
March	9.48	0.02	27.71	2.38	0.43	9.93	8.64	2.77	21.28
April	7.78	0.03	22.88	1.84	0.43	9.29	8.06	2.57	19.20
May	7.05	0.05	24.07	1.50	0.35	6.52	7.27	2.55	18.04
June	6.70	0.06	19.83	1.32	0.27	4.93	6.67	2.47	15.15
July	6.40	0.00	22.03	1.17	0.26	6.70	6.14	1.90	16.33
August	6.88	0.03	22.62	1.30	0.27	6.67	6.48	2.05	16.96
September	8.19	0.04	24.43	1.74	0.37	9.13	7.45	2.44	22.70
October	9.58	0.06	25.45	2.31	0.41	9.98	8.26	2.72	19.11
November	10.29	0.07	30.99	2.58	0.49	12.92	8.64	2.61	22.38

Offshore Array Area - Annual and Monthly Statistics

Month	*Wind Spd. at 10 m (m/s)*			*Sig. Wave Height (m)*			*Wave Peak Period (s)*		
	Mean	*Min.*	*Max.*	*Mean*	*Min.*	*Max.*	*Mean*	*Min.*	*Max.*
December	10.37	0.01	29.70	2.69	0.48	10.67	8.95	3.07	22.24
All-Year	8.66	0.00	32.04	2.03	0.26	12.92	7.85	1.90	23.92

Table 7-11 Annual and monthly statistics for wind speed at 10 m above surface (left), significant wave height (middle) and wave peak period (right), for the period 1979 to 2022, for a location representative of the landward end of Offshore Export Cable Corridor (Source: ABPmer, 2023)

Offshore Export Cable Corridor - Annual and Monthly Statistics									
Month	*Wind Spd. at 10 m (m/s)*			*Sig. Wave Height (m)*			*Wave Peak Period (s)*		
	Mean	*Min.*	*Max.*	*Mean*	*Min.*	*Max.*	*Mean*	*Min.*	*Max.*
January	8.31	0.07	25.57	1.90	0.27	7.92	9.22	2.15	24.42
February	7.92	0.08	24.35	1.81	0.30	8.85	8.97	2.68	23.35
March	7.12	0.07	20.62	1.63	0.30	7.76	8.70	1.87	22.04
April	5.84	0.05	17.79	1.34	0.20	7.64	7.91	2.05	19.96
May	5.23	0.02	18.36	1.14	0.22	5.24	7.06	2.11	18.73
June	4.92	0.07	15.68	0.99	0.21	3.51	6.52	2.16	15.29
July	4.64	0.03	17.27	0.86	0.16	4.55	6.07	1.83	16.61
August	4.98	0.01	16.79	0.94	0.14	3.88	6.34	1.40	17.02
September	5.94	0.02	19.99	1.20	0.22	6.67	7.34	2.14	22.97
October	7.04	0.06	20.02	1.60	0.23	6.64	8.30	2.37	22.76
November	7.64	0.17	26.56	1.76	0.33	8.77	8.77	2.36	21.70

Offshore Export Cable Corridor - Annual and Monthly Statistics									
Month	*Wind Spd. at 10 m (m/s)*			*Sig. Wave Height (m)*			*Wave Peak Period (s)*		
	Mean	*Min.*	*Max.*	*Mean*	*Min.*	*Max.*	*Mean*	*Min.*	*Max.*
December	7.87	0.04	24.28	1.80	0.26	7.50	9.12	2.65	22.60
All-Year	6.45	0.01	26.56	1.41	0.14	8.85	7.85	1.40	24.42

<u>Waves</u>

7.7.1.13 The wave climate is the result of the transfer of wind energy to the sea, creating sea-states and the propagation of that energy across the water surface by wave motion. The amount of wind energy transfer and wind-wave development is a function of the available fetch distance across which the wind blows, wind speed, wind duration and the original state of the sea. The longer the fetch distance, the greater the potential there is for the wind to interact with the water surface and generate waves.

7.7.1.14 Waves within the Study Area are a combination of locally generated wind waves, and waves generated elsewhere in the North Sea. Long-term hindcast records of wave data from ABPmer's SEASTATES model are shown in **Figure 7-4** (Offshore Array Area) and **Figure 7-5** (landward end of the Offshore Export Cable Corridor). A frequency analysis of the data (**Table 7-7** and **Table 7-9**) shows that waves in the Offshore Array Area predominantly come from northerly and southerly directions (approximately 20% of time, each). Analysis of the data shows that waves in the Offshore Export Cable Corridor predominantly come from southerly round to northwesterly directions (approximately 95% of time) (ABPmer, 2023).

7.7.1.15 Wave heights across the Study Area will tend to reduce with distance towards the coast due, primarily, to decreasing water depth. Close to shore, the local predominant wave direction also varies in response to sheltering and refraction.

7.7.1.16 Monthly statistics of wave height and period, based on SEASTATES hindcast data for the period 1979 to 2022 at the landward end of the Offshore Export Cable Corridor and the Offshore Array area, are illustrated by the monthly statistics presented in **Table 7-10** and **Table 7-11** respectively. The seasonality in both parameters can be seen at the two sites, with larger monthly mean values for the winter months October to March. Lower wave heights are seen landwards as discussed above.

7.7.1.17 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).

Stratification

7.7.1.18 Stratification is a naturally occurring seasonal hydrodynamic feature related to the vertical and horizontal distribution of sea water temperature and salinity, which influences the availability of nutrients, and the distribution and growth rates of pelagic flora and fauna.

7.7.1.19 During the summer, increased heat input from solar irradiation and higher air temperatures preferentially warms the upper part of the water column. Temperature differences of up to 10 ^{0}C between the warmer (and so more buoyant) surface waters and colder (denser) bottom waters can be established in the North Sea, with a relatively steep vertical gradient in temperature between the two layers. The gradient in temperature (sometimes enhanced by vertical gradients in salinity) corresponds to a gradient in water density (the pycnocline), which acts as a physical barrier to vertical mixing and diffusion processes within the water column. Where vertical stratification is present, depending on the strength of the density gradient, the availability of nutrients can be enhanced or reduced in certain parts of the water column, affecting the distribution of pelagic flora and fauna, and leading to complex cycles and patterns of ecosystem development.

7.7.1.20 The tendency for vertical stratification to develop is balanced against the ambient rate of turbulent mixing across the density gradient. Turbulence is developed at the seabed by friction with currents, and at the water surface by friction with winds (and any wave breaking). As a result, stratification is more likely to develop in relatively deeper water areas, but may also occur in shallower areas with sufficiently low current speeds and exposure to winds and waves.

7.7.1.21 The North Sea is characterised by significant spatial and temporal variation in the vertical distribution of temperature and salinity. An assessment of intra-annual patterns of stratification in the North Sea has been undertaken by van Leeuwen *et al.* (2015), using a long term (51 year) regional scale hydrobiogeochemical model simulation. The Offshore Array Area is located in an area described by van Leeuwen *et al.* (2015) as being "*seasonally stratified*", defined as >120 days in the year where the water column is stratified and >90 days in the year where the water column is fully mixed.

7.7.1.22 A stratification front is the transition between areas of vertically stratified and non-stratified water. Fronts are also associated with (typically relatively enhanced) local patterns of nutrient distribution and ecosystem development. Fronts are relatively widespread features within the North Sea and (at certain times during the year) may extend for a distance of several hundred kilometres (e.g. Hill *et al.*, 1993; 2005).

7.7.1.23 A pronounced tidal front (the Buchan Front) is found in a transitional zone off Buchan and the Aberdeenshire coast, where shallow (well mixed) coastal water meets deeper, seasonally stratified North Sea water (Edwards and John, 1996) (**Figure 7-1**). Tidal mixing fronts typically establish during the summer months and play an important part in shelf-sea biophysical processes, including facilitation of primary productivity.

7.7.1.24 The strength of a front is also defined by the strength of the (horizontal) gradients in density (temperature and salinity) between the well mixed and vertically stratified sides. The position and strength of the front may vary on timescales of weeks to months, and from year to year, due to differences in the factors controlling vertical stratification, including: the rates of warming and any freshwater input; the speed of tidal currents (overall and neap vs spring); the short-term wind and wave climate; and the balance of these factors in conjunction with the local water depth. The position of the front is also variable on shorter timescales of hours to days, as the water body containing the feature is advected back and forth by local (ebb and flood) tidal currents.

7.7.1.25 To further explore the characteristics of stratification and frontal systems within the Study Area, temperature and salinity data have been extracted from a high-resolution 3D ocean model covering the European North West Shelf – available through the Copernicus data portal (Copernicus, 2023). Variation in temperature and salinity with depth over an example spring-neap period in February (2022) and August (2022) is shown in **Figure 7-6** and **Figure 7-7**. The three locations from which data have been extracted are shown in **Figure 7-2**; these locations from inshore, nearshore and offshore locations have been chosen with due consideration to the approximate location of the Buchan Front. Monthly average temperature differences between surface and near bed waters across the Study Area are shown in **Figure 7-8**. Collectively, these data show that:

- In offshore areas, there is clear evidence for vertical stratification (with respect to temperature) in summer months, but vertical stratification is weaker (or absent) in winter months. This seasonal variation in stratification is largely due to change in the level of wave activity, as set out in the previous section;
- Close to the coast, waters are largely well mixed throughout the year;
- A semi-diurnal signal in water temperature is seen throughout the record, reflecting regular tidal advection of the regional scale patterns, gradients and features; and
- The position of the front separating well mixed waters inshore from stratified waters offshore varies in strength and position throughout the summer months although when present, typically overlaps with the Offshore Export Cable Corridor.

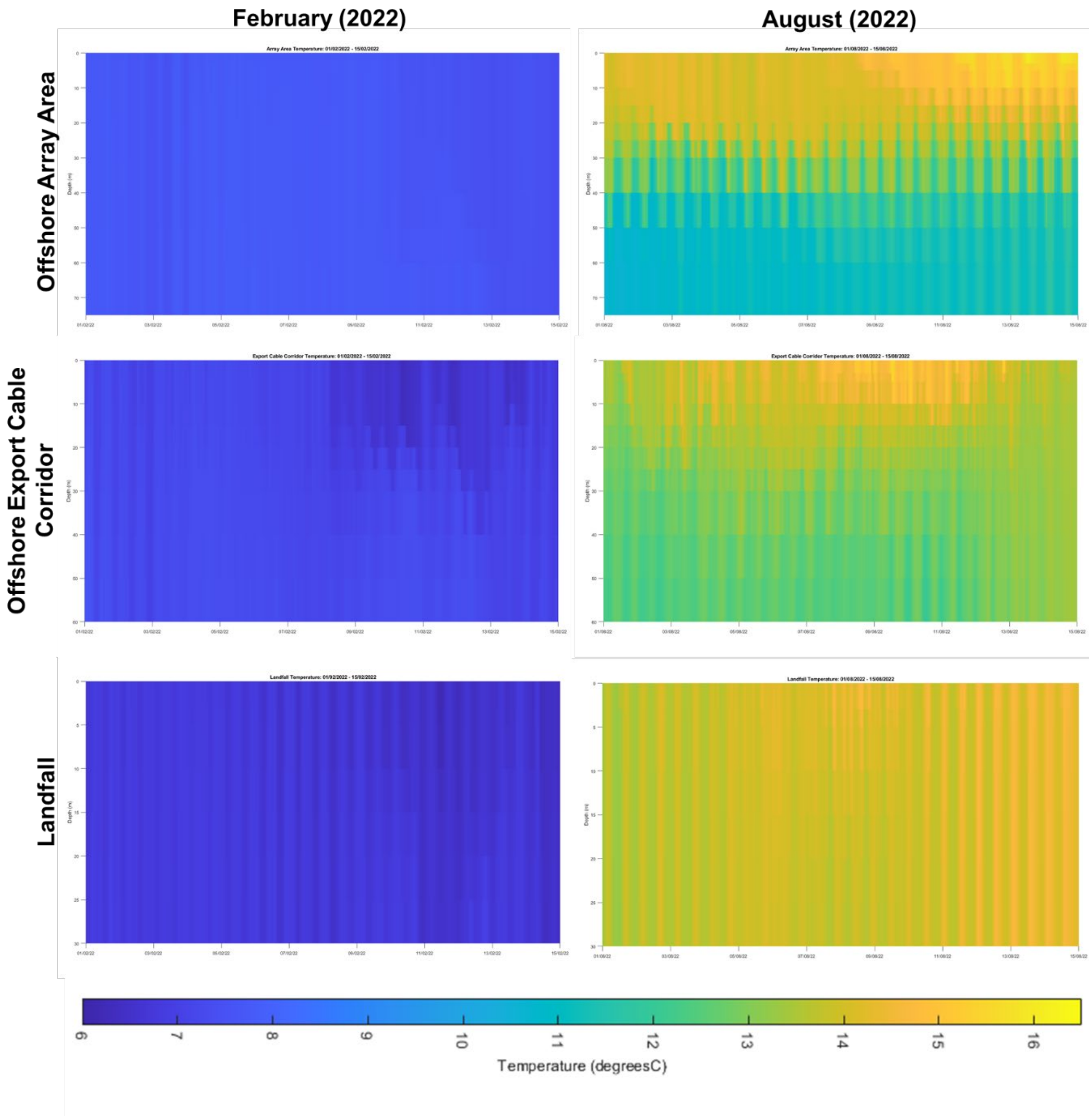


Figure 7-6 Variation in temperature with depth over a spring – neap period in February (2022) and August (2022) for inshore and offshore locations within the Offshore Development Area. (Source: Copernicus, 2023)

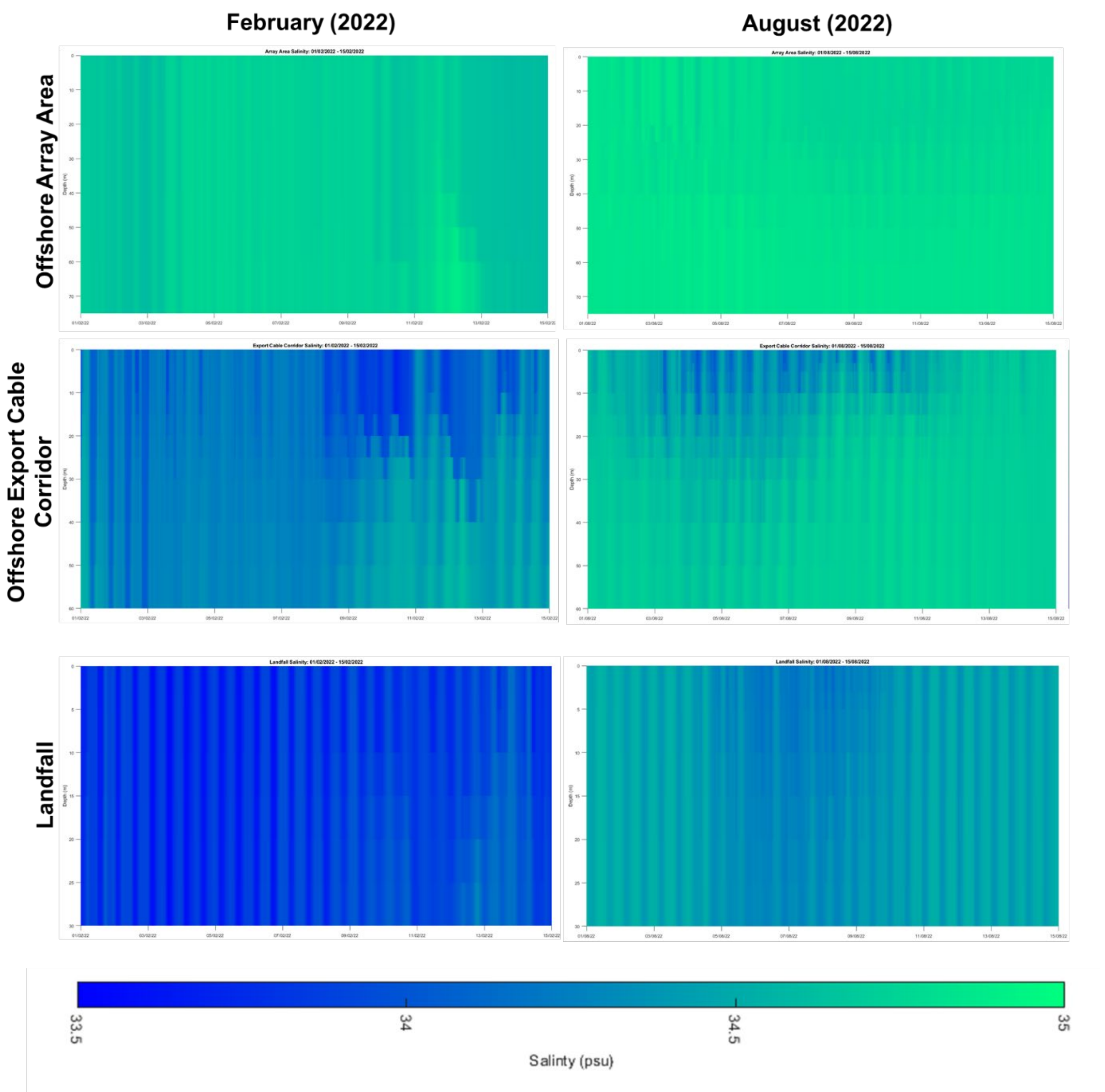


Figure 7-7 Variation in salinity with depth over a spring–neap period in February (2022) and August (2022) for inshore and offshore locations within the Offshore Development Area. (Source: Copernicus, 2023)

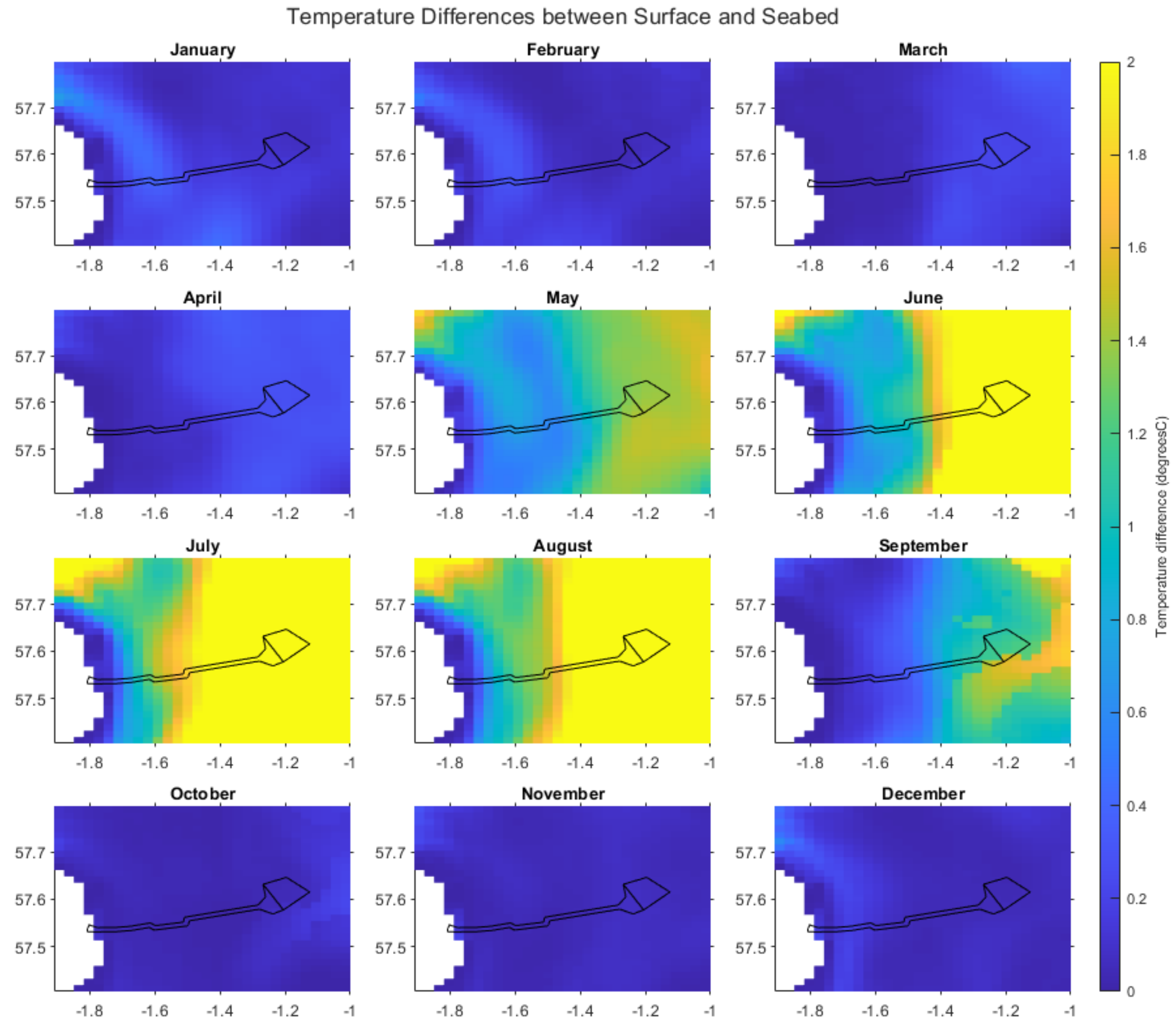


Figure 7-8 Monthly average near-surface to near-bed temperature differences across the Study Area throughout 2022. (Source: Copernicus, 2023)

Sediments and Geology

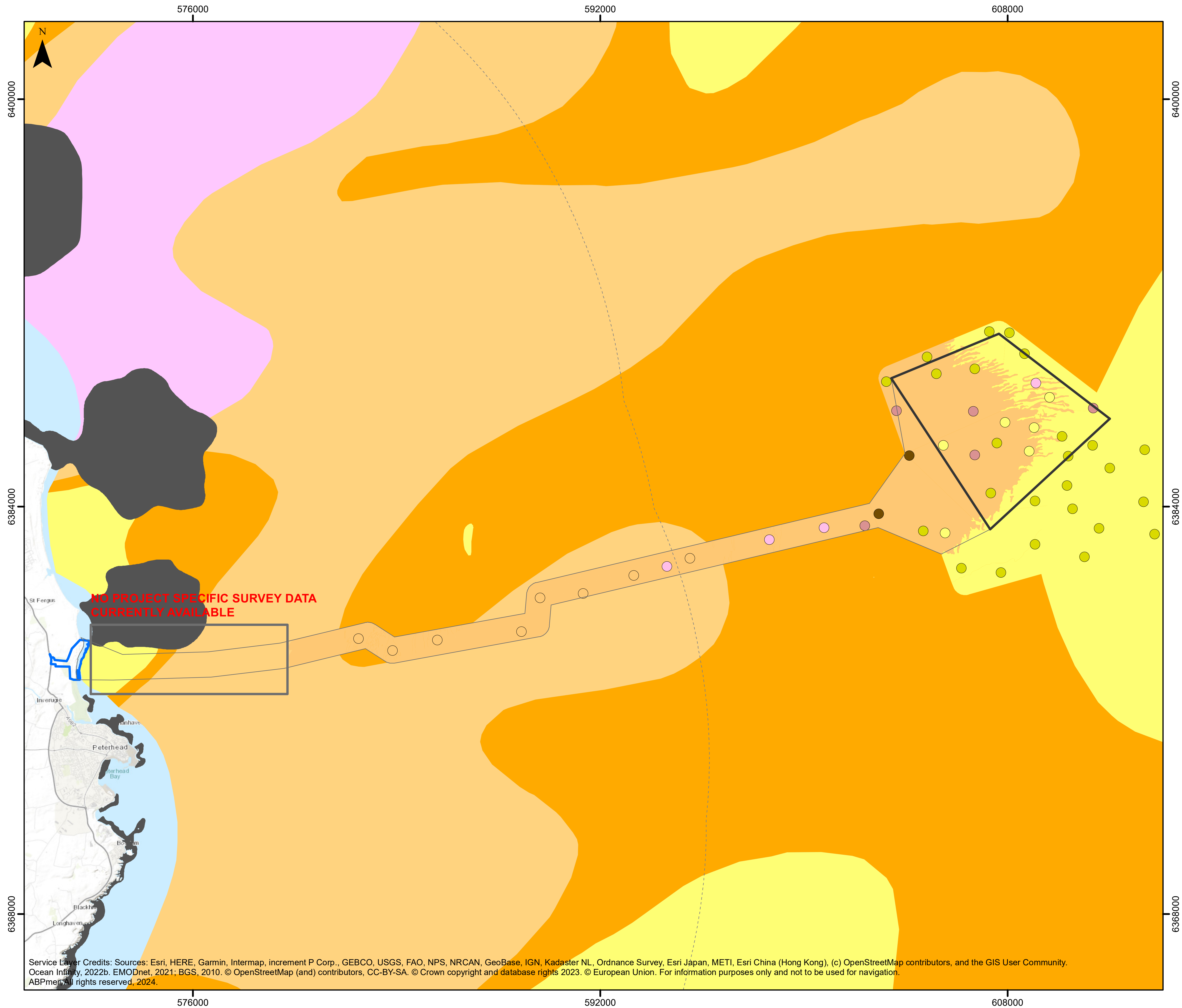
Seabed Sediments

7.7.1.26 On the basis of the data from the Salamander geophysical and benthic surveys (Ocean Infinity, 2022a, 2022c), it is found that sediments within the Offshore Array Area mainly consist of sand and variable proportions of gravel and mud (**Figure 7-9**). The east of the Offshore Array Area consists of sand, developing into gravelly sand towards the west reflecting the spatial variation in current speeds. Particle Size Analysis (PSA) of the grab samples shows that sands are typically medium or fine grained in nature, with a mud content generally between 10 to 20%.

7.7.1.27 Sediments along the Offshore Export Cable Corridor comprise mostly of gravelly sand towards the coast, with patches of sand where current speeds are highest. The mud content generally reduces to the west along the Offshore Export Cable Corridor, with proximity to the coast and typically constitutes less than 10% of the sediment fraction (Ocean Infinity, 2022c). Large areas of exposed bedrock and stony habitat are present immediately to the north of the landfall (**Figure 7-9**).

7.7.1.28 Within the Study Area, there are also areas of sandy gravel along the northern coast, areas of muddy sand within the Southern Trench and in the northeast of the Study Area. Otherwise, the Study Area mainly consists of sand with variable contributions of gravel.

7.7.1.29 A lack of major river sediment input and the resistance of most of the shorelines to erosion, has resulted in only minor amounts of clastic sediment (rock) input from the coastal areas to offshore areas over the last 10,000 years. This, coupled with strong tidal and non-tidal currents, has provided favourable environments for the proliferation of calcareous seabed biota meaning, in places, the biogenic carbonate content of the sand fraction in seabed sediments may be up to 50% (Holmes *et al.*, 2004).



Salamander

Figure 7-9

Seabed sediments within the Offshore Development Area

Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Indicative Onshore development area
- 12 nm limit

Seabed sediments (EMODnet)

- Sand
- (Gravelly) Sand
- Gravelly Sand
- Sandy Gravel
- Rock

Project Specific Grab Samples

- Gravelly Muddy Sand
- Gravelly Sand
- Muddy Sand
- Sand
- Slightly Gravelly Muddy Sand
- Slightly Gravelly Sand

Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW

Scale @ A4 : 135,000

0 1.75 3.5 7 Kilometers

0 0.75 1.5 3 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Seabed sediments within the Offshore Development Area and across the Study Area
Doc. No : SWF01ER0364
Created by : BO
Checked by : IW
Approved by : SS

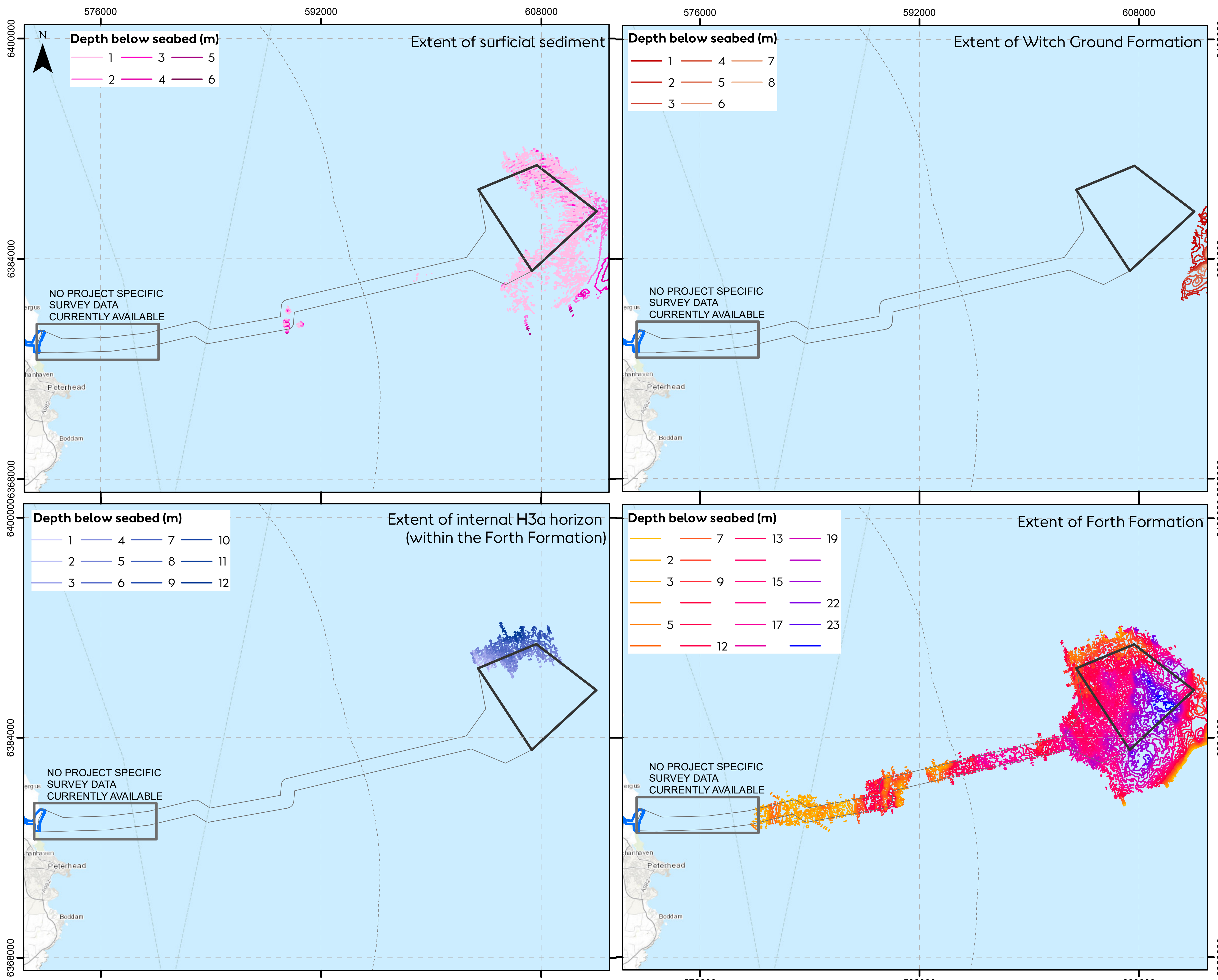
Geology and Substrata

7.7.1.30 The geological structure of the underlying bedrock in this region is characterised by a complex pattern of down-faulted basins separated by platforms (relatively uplifted areas). The uplifted platforms formed approximately 420 million years ago and underlie the modern coastline and nearshore parts of the Study Area. The Mesozoic basins found further offshore formed more recently during faulting, approximately 142 to 250 million years ago (Holmes *et al.*, 2004). The modern-day seabed configuration reflects the combination of this large-scale geological structure and burial by younger sediments, in particular those deposited during the Quaternary period, in response to the growth and decay of Pleistocene ice sheets and associated changes in relative sea level.

7.7.1.31 The pre-Quaternary solid bedrock within the region is predominantly Chalk, but Sandstone and Mudstone are also present. These bedrock groups are: Lower Cretaceous Cromer Knoll Group, Upper Cretaceous Chalk Group, Hidra Formation; Undifferentiated Palaeocene Sandstone and Mudstone, Undifferentiated Eocene to Pliocene Sandstone. These pre-Quaternary units were not observed via sub-bottom profiler during the project-specific geophysical survey (Ocean Infinity, 2022a).

7.7.1.32 The Quaternary geology of the area comprises the Witch Ground Formation (late Weichselian to Holocene, marine sand and glaciomarine mud) and the Forth Formation (late Saalian to Weichselian, marine sand and glaciomarine mud and sand). The Forth and Witch Ground Formations are, in part, laterally equivalent. These units overlay the Coal Pit Formation (late Saalian to Weichselian, marine sand and glaciomarine sand and mud), the Fisher Formation (Saalian, glaciomarine sand, silt and clay), Ling Bank formation (Holseinian to Saalian, marine silt and clay) and the Aberdeen Ground Formation (Waalian to Elsterian) (Ocean Infinity, 2022a).

7.7.1.33 Interpretation of the thickness of Quaternary sediments within the Offshore Array Area is derived from the Salamander geophysical survey (Ocean Infinity, 2022a). The mapped distribution of the interpreted units is provided in **Figure 7-10** and summarised in **Table 7-12**. Surficial sediments have a maximum thickness of 5 m but are more typically 0 to 2 m thick. They are of greatest thickness in the southeast of the Offshore Array Area but are absent in most areas of the Offshore Export Cable Corridor. Where present, they are typically associated with small sandwaves and megaripples.



Salamander

Figure 7-10

Depth below seabed of sedimentary units

Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Indicative Onshore development area
- 12 nm limit

Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW
Scale @ A4 : 260,164

0 2.5 5 10 Kilometers

0 1.25 2.5 5 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Depth below seabed of sedimentary units within the Offshore Development Area
Doc. No : SWF01ER0365
Created by : BO
Checked by : IW
Approved by : SS

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Table 7-12 Summary of sedimentary units encountered within the Offshore Development Area (Source: Offshore Infinity, 2022a)

Unit ID	Subsurface Geology Description	Horizon ID	Horizon Description	Depth below LAT (m)	Depth Below Sea Bed (m)
U10 'Surficial Sediments'	Low amplitude to transparent reflections. Occasional parallel sediments and occasional interbedding.	H1 – Base of Surficial Sediment	Base of Unit 10. Good lateral continuity in the southeast of the Offshore Array Area	Min: 76 Max: 124	Min: 0 Max: 5
U20	Well-layered parallel reflectors – basin infill. The formation shows an upward transition from pebbly glaciomarine muds to temperate-marine fine sands and silts. Further characterised by the presence of pockmarks.	H2 – Base of Witch Ground Formation.	Highly irregular and erosive base. Only seen in the southeast of the Offshore Array Area.	Min: 91 Max: 115	Min: 1.2 Max:14.8
U30	Unit compromised of mixed sediments including well-layered sands (base of which is H3a) or clays with mixed gravels and sands showing more chaotic structure.	H3a – Internal Forth Formation	Base of internal layer within Unit 30. Seen in the north of the Offshore Array Area.	Min: 95 Max:109	Min: 0.8 Max:12.8
		H3b – Base of Forth Formation	Base of Unit 30 High amplitude reflector. In the southeast of the Offshore Array Area, overlain/adjacent to Witch Ground Formation.	Min:65 Max: 130	Min: 0.8 Max:25.6

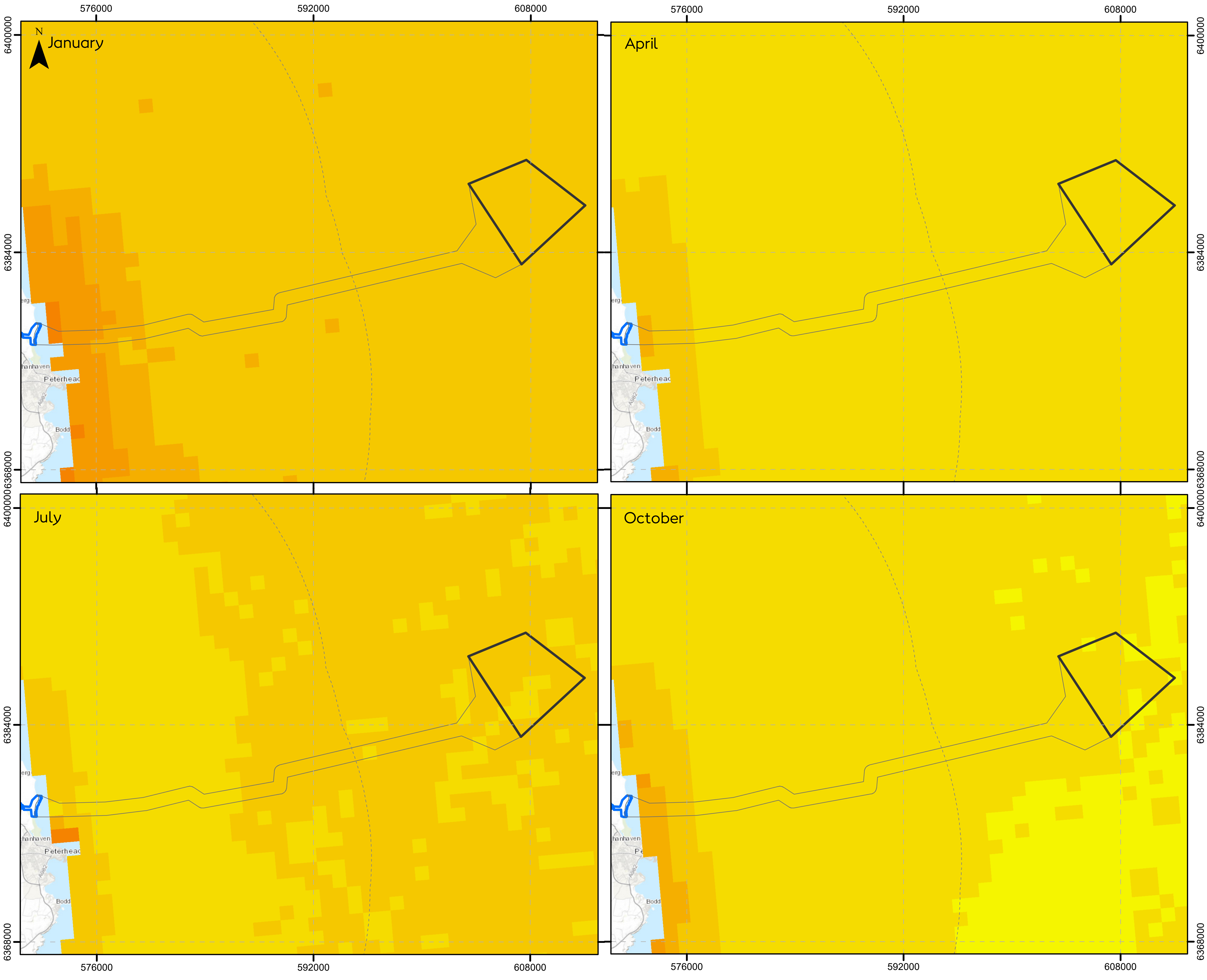
Unit ID	Subsurface Geology Description	Horizon ID	Horizon Description	Depth below LAT (m)	Depth Below Sea Bed (m)
U40	Generally chaotic and structureless unit with one well-layered and structured internal layer. The sediments comprise marine sands and pebbly glaciomarine muds and sands.	H4a – Internal reflector within coal pit formation	Base of internal layer within Unit 40. High amplitude reflector. Only observed in the southwest of the Offshore Array Area.	Min:107 Max: 138	Min: 15.5 Max: 34.5
		H4b – Base of Coal Pit formation	Base of Unit 40. High amplitude reflector. Observed across most of the Offshore Array Area and Offshore Export Cable Corridor, except the nearshore section.	Min: 95	Min: 12 Max 41.6
U50	Marine silts with sand a clay interbeds infill deep erosive features. Generally chaotic to oblique asymmetric or onlapping in character.	H5 – Base of Ling Bank Formation	Base of Unit 50. Observed across most of the Offshore Array Area and Offshore Export Cable Corridor, except the nearshore section. Base is an erosional surface.		Min: 4.5 Max: 60
U60	Reflection pattern varies from chaotic to parallel and laterally continuous. Sediments vary from marine muds with thin sands to glaciomarine muds, sands and gravels. Gravels are most common towards the top of the formation.	H6 – Base of Aberdeen Ground Formation	Base of Unit 60. Only observed in nearshore sections of the Offshore Export Cable Corridor. Dipping parallel reflectors (dipping east) which become horizontal in the Offshore Array Area.		Min: 25.5 Max:76.5

Source: Ocean Infinity (2022a)

Suspended Sediments

7.7.1.34 Monthly averaged satellite imagery of Suspended Particulate Matter (SPM) suggests that within the Offshore Array Area average (surface) SPM is generally very low, between 0.5 to 1.5 mg/l (Cefas, 2016). During the summer months, values within the Offshore Array Area peak around 1 mg/l, increasing slightly in the winter months to 1.6 mg/l (**Figure 7-11**). Still small, but relatively higher values, are anticipated during larger spring tides and storm conditions. The Marine Directorate has undertaken seabed tows in this region between 2010 and 2013, collecting videos and images of the seabed (Marine Directorate, 2023). The available imagery suggests reasonably high levels of sediment in the water column (near to the bed), although this is to be expected since higher suspended sediment concentrations are likely to be observed at any given time closer to the seabed.

7.7.1.35 SPM values along the Offshore Export Cable Corridor are also generally very low but increase slightly from the Offshore Array Area towards the landfall in the winter months, ranging from 1.4 to 2.0 mg/l. However, during summer months SPM values decrease towards the coast ranging from 0.6 to 1.2 mg/l.



Salamander

Figure 7-11

Average suspended particulate matter concentration 1998 - 2015

Legend

Offshore Array Area

Offshore Export Cable Corridor

Indicative Onshore development area

12 nm limit

Suspended Particulate Matter (1998-2015) mg/l

- < 0.5
- 0.51 to 1.0
- 1.01 to 2.0
- 2.01 to 3.0
- 3.01 to 5.0
- 5.01 to 10.0

Coordinate System: WGS 1984 UTM Zone 30N

Vertical Datum : MLLW

Scale @ A4 : 260,000

0 2.5 5 10 Kilometers

0 1.25 2.5 5 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Average suspended particulate matter concentration for the period 1998 to 2015

Doc. No : SWF01ER0366

Created by : BO

Checked by : IW

Approved by : SS

Sediment Transport

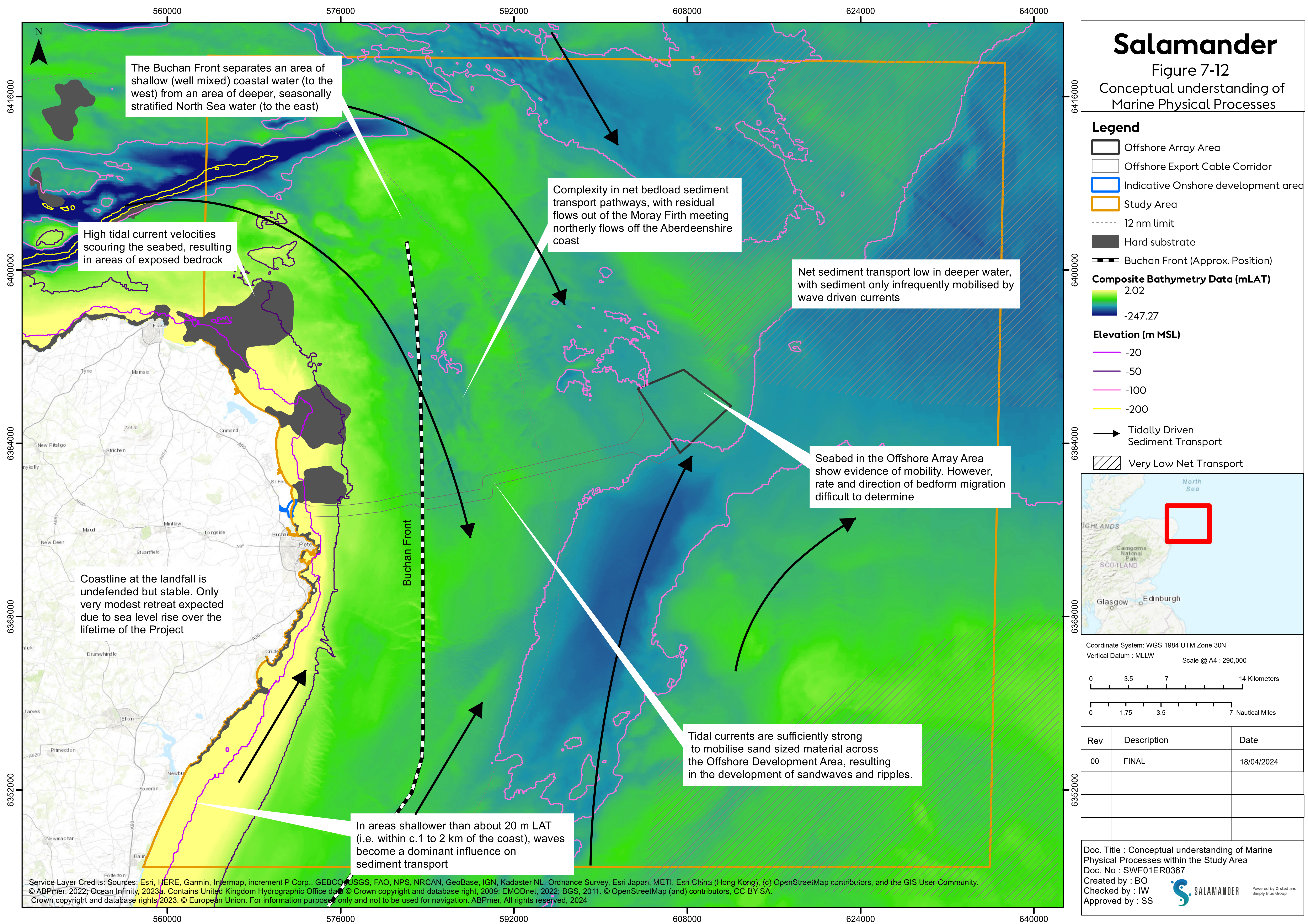
7.7.1.36 Across the Study Area, tidal currents, together with the agitation of the seabed by wave action, are sufficiently high to induce shear stresses at the seabed which exceed the critical shear stress for initiating the movement of sand. The direction of bedload transport and the type and size of resulting bedforms is controlled by the net effect of peak currents, which are described by Kenyon and Cooper (2005).

7.7.1.37 Net bedload sediment transport is largely to the south in central/northern areas of the Study Area and to the north in southern parts of the Study Area. These region-scale patterns are driven by tidal current asymmetry and result in the development of a bed load convergence zone off the coast of Peterhead, characterised by net long term sediment accretion. Wave driven transport dominates offshore, where tidal currents are weaker (**Figure 7-12** and **Figure 7-13**) (e.g. Kenyon and Cooper, 2005).

7.7.1.38 Sediment transport at the coast is described within the context of coastal cells and sub-cells in Ramsay and Brampton (2000). The Study Area is within sub-cell 2d (Cairnbulg Point to Girdle Ness) and sub-cell 3a (Portknockie to Cairnbulg Point), with a major cell divide at Cairnbulg Point. Within sub-cell 2d, net littoral drift is low, as northward wave-induced drift is generally cancelled-out by southward tidal currents. Within sub-cell 3a, there are many small pocket beaches that tend to be isolated from one another, with little accretion and little evidence of significant longshore drift (Barne *et al.*, 1996). Longshore sediment transport is dominated by wave action but tidal currents, particularly at high tide, may also transport sediment.

7.7.1.39 The regionally validated ABPmer SEASTATES North West European Shelf Tide and Surge Hindcast model (https://www.seastates.net/) has been used in a tide-only mode, in conjunction with a non-cohesive (sand) sediment transport model, to inform the required understanding of patterns of tidal currents and associated sediment mobility and transport within the Study Area. Results of the modelling are shown in **Figure 7-13**. The model simulates a time series of total load transport rate and direction for representative 250 µm diameter quartz sand in response to bed shear stress caused by the tidal currents described by the hydrodynamic model over a representative spring-neap cycle. A grain size of 250 µm is representative of fine to medium sand which is the dominant mean particle size of the grab samples collected across the Offshore Array Area and Offshore Export Cable Corridor (Ocean Infinity, 2022c). It is apparent from the modelling that this is a complex area for sediment transport, with residual flows out of the Moray Firth meeting northerly flows off the east Aberdeenshire coast. This results in a high degree of spatial variability in the rate and direction of inferred sediment transport.

7.7.1.40 Within the Offshore Array Area, modelled residual sediment transport rates are in the approximate range 0.025 to 0.05 m^3/day per m. Transport direction varies within and around the Offshore Array Area, but is broadly to the northeast along the western margin, and southeasterly in central/eastern areas. Residual rates of sediment transport along the Offshore Export Cable Corridor are in the approximate range 0.05 to 2.5 m^3/day/m, with the direction of residual transport, along the route, generally towards the south. Sediments become increasingly more mobile towards the coast, with residual transport rates reaching approximately 2.5 m^3/day/m close to the landfall (**Figure 7-13**).



Salamander
Figure 7-12
Conceptual understanding of Marine Physical Processes
The Buchan Front separates an area of shallow (well mixed) coastal water (to the west) from an area of deeper, seasonally stratified North Sea water (to the east)
High tidal current velocities scouring the seabed, resulting in areas of exposed bedrock
Complexity in net bedload sediment transport pathways, with residual flows out of the Moray Firth meeting northerly flows off the Aberdeenshire coast
Net sediment transport low in deeper water, with sediment only infrequently mobilised by wave driven currents
Seabed in the Offshore Array Area show evidence of mobility. However, rate and direction of bedform migration difficult to determine
Coastline at the landfall is undefended but stable. Only very modest retreat expected due to sea level rise over the lifetime of the Project
Tidal currents are sufficiently strong to mobilise sand sized material across the Offshore Development Area, resulting in the development of sandwaves and ripples.
In areas shallower than about 20 m LAT (i.e. within c.1 to 2 km of the coast), waves become a dominant influence on sediment transport
Buchan Front
N
560000
576000
592000
608000
624000
640000
6416000
6400000
6384000
6368000
6352000
Legend
Offshore Array Area
Offshore Export Cable Corridor
Indicative Onshore development area
Study Area
12 nm limit
Hard substrate
Buchan Front (Approx. Position)
Composite Bathymetry Data (mLAT)
2.02
-247.27
Elevation (m MSL)
-20
-50
-100
-200
Tidally Driven Sediment Transport
Very Low Net Transport
North Sea
HIGHLANDS
Cairngorms National Park
SCOTLAND
Glasgow
Edinburgh
Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW
Scale @ A4 : 290,000
0 3.5 7 14 Kilometers
0 1.75 3.5 7 Nautical Miles
Rev | Description | Date
00 | FINAL | 18/04/2024
Doc. Title : Conceptual understanding of Marine Physical Processes within the Study Area
Doc. No : SWF01ER0367
Created by : BO
Checked by : IW
Approved by : SS
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Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community.
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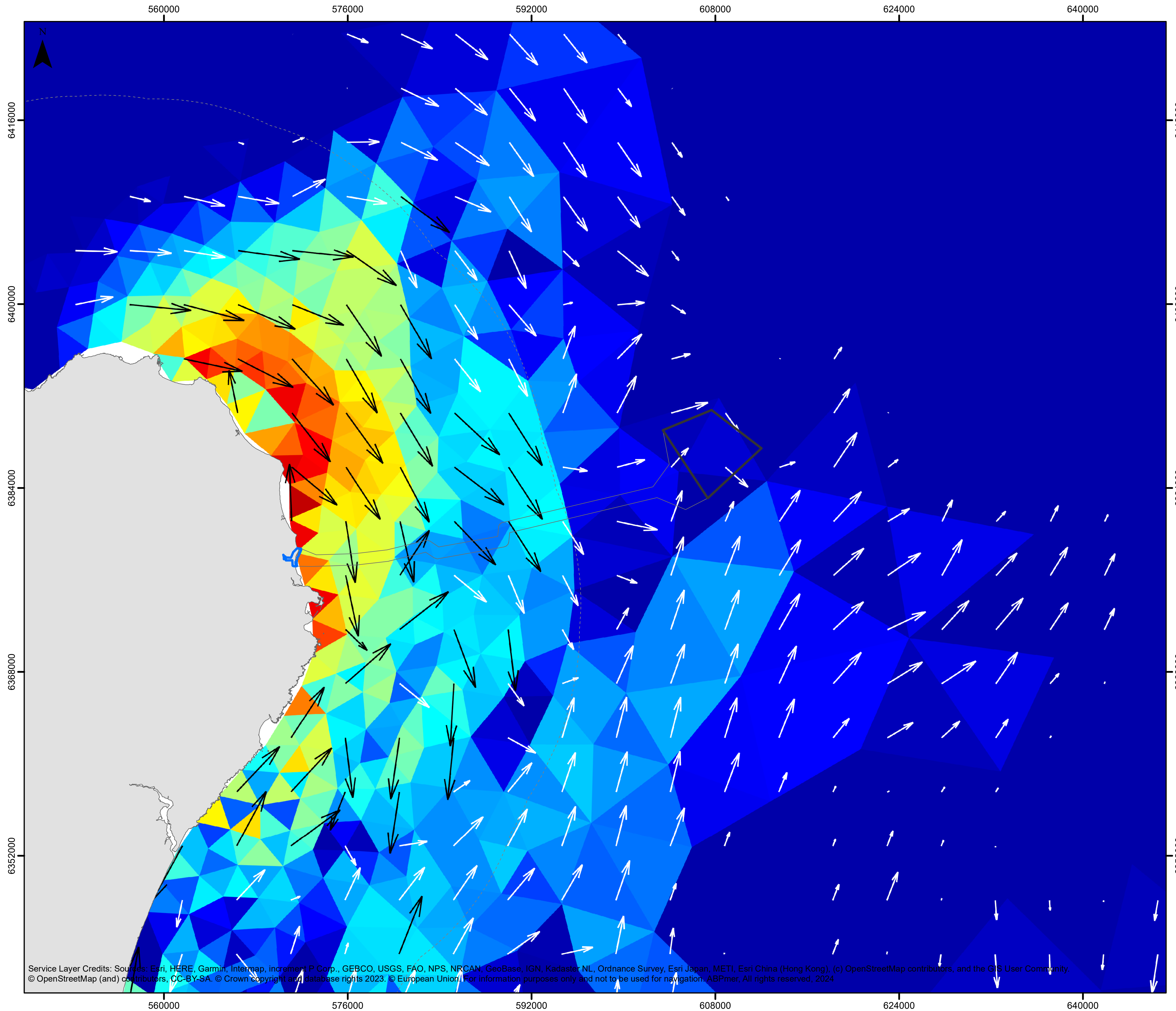


Salamander

Figure 7-13

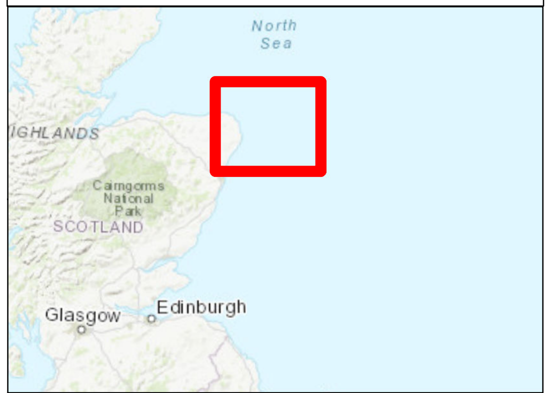
Baseline residual sediment transport rate and direction

Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Indicative Onshore development area
- 12 nm limit

Net sediment transport (m3/day/m)

10, 5, 2.5, 1, 0.5, 0.25, 0.1, 0.05, 0.025, 0.01



Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW

Scale @ A4 : 300,000

0 3.75 7.5 15 Kilometers
0 2 4 8 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Baseline residual sediment transport rate and direction across the Study Area, calculated over a representative spring-neap tidal period
Doc. No : SWF01ER0368
Created by : BO
Checked by : IW
Approved by : SS

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Seabed Geomorphology

7.7.1.41 Throughout the Offshore Array Area water depths range between 87 to 110 m below LAT (**Figure 7-14**). The southern part of the Offshore Array Area is generally deepest, with the shallowest depths observed in the middle of the Offshore Array Area.

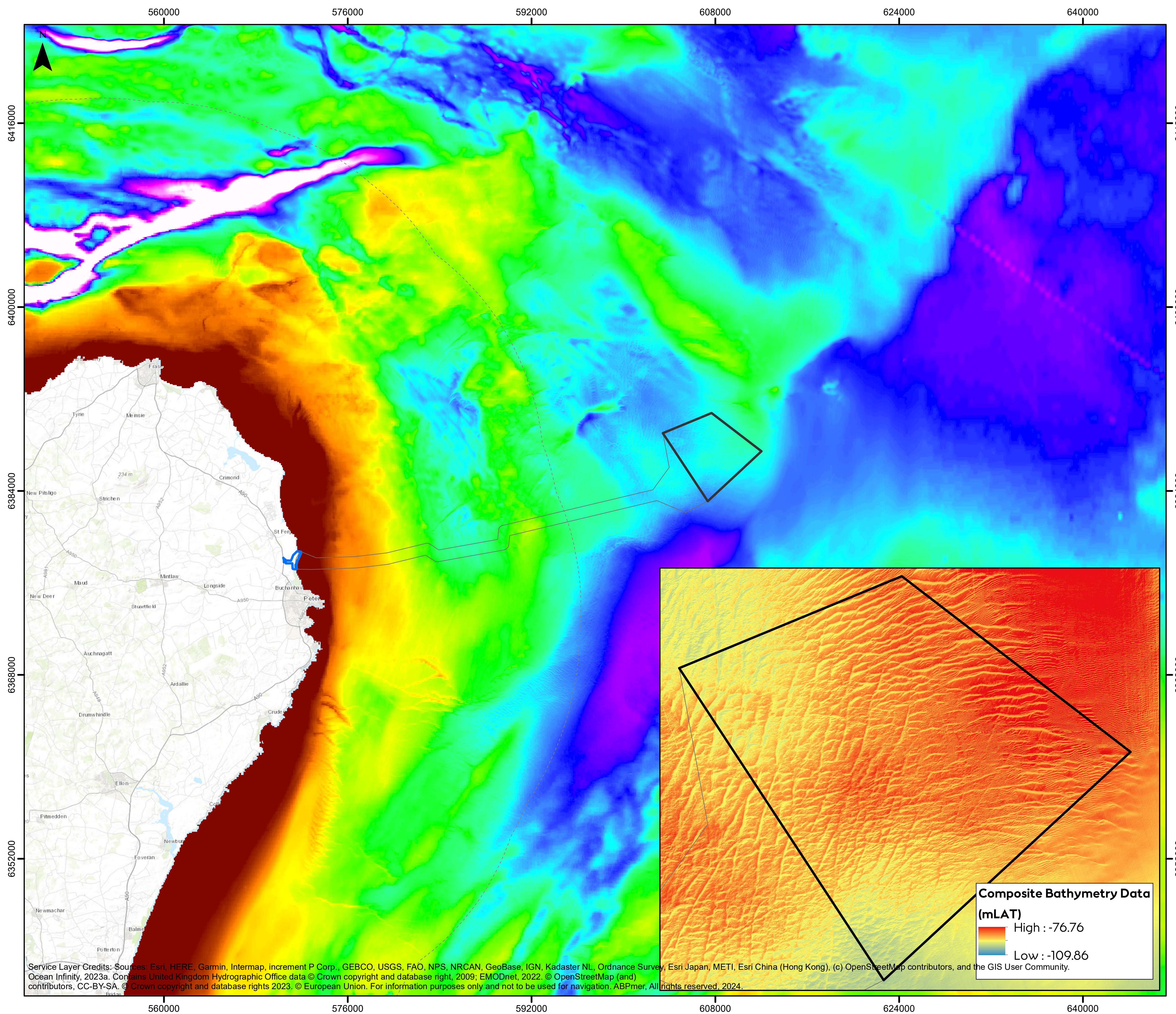
7.7.1.42 Within the Offshore Export Cable Corridor depths range from 0 to 96 m below LAT. The deepest depths are observed at the boundary of the Offshore Array Area, with depths generally shallowing towards the coast. There is, however, a shoal just before the first 'elbow' along the Offshore Export Cable Corridor towards the shore, where depths are around 68 m below LAT.

7.7.1.43 Across much of the Study Area, water depths are more typically in the range 50 to 100 m below LAT, although this increases to over 200 m below LAT in the Southern Trench in the Outer Moray Firth.

7.7.1.44 A range of active and relict (i.e. no longer active) bedforms and geomorphological features are present within the Study Area, reflecting contemporary seabed processes and past glacial and geological activity (**Figure 7-15** to **Figure 7-17**):

- The most distinctive seabed feature within the Study Area is the Southern Trench, located in the Outer Moray Firth, running parallel to the Aberdeenshire coast. The main trench, and its sub-trenches, are of glacial origin, formed from at least two erosion events in different directions (Holmes *et al*., 2004; Brooks *et al*., 2011).
- In the west of the Offshore Array Area, linear bedforms with crests in a north-south direction - typically 2 to 3 m in height and with a spacing of around 200 to 400 m between crests - are observed in the geophysical survey which have been interpreted by Ocean Infinity (2022a) as relict sandwaves which developed under a different hydrodynamic regime than encountered today (**Figure 7-17**). However, it is perhaps more likely that they are depositional glacial features aligned with former Quaternary ice flows, and which have been mapped within this region (e.g. Bradwell *et al*., 2008; Clark *et al*., 2018). Indeed, the formation of sandwaves would require the presence of relative strong east-west flows in this region, which are unlikely, even at a time of higher or lower relative sea level and differently configured seabed/coastline. One would also expect any relict sandwaves to have been re-worked, given the occurrence of active sandwaves and sufficiently energetic hydrodynamic conditions to mobilize sand sized sediment.
- Across the Offshore Array Area, east to west aligned bedforms with crest heights of up to 3 m and average wavelengths of 220 to 280 m have been mapped by the project-specific geophysical survey data (**Figure 7-15**). These are interpreted as sandwave features (wavelength >25 m) and megaripple features (wavelength 5-25 m) with their distribution and occurrence consistent with observed flow speeds and direction in this region (**Section 7.7.1.6**). Comparison of the 2022 project-specific bathymetry with earlier (2009) UK Hydrographic Office (UKHO) bathymetry data provides tentative evidence for migration of these features, although the rate and direction of movement is difficult to accurately discern, given the coarser resolution (8 m grid) of the older 2009 data (**Figure 7-16**).
- At the eastern end of the Offshore Export Cable Corridor, along the edge of the Offshore Array Area, sandwaves and megaripples are also present with some patches of smaller ripples (<0.05 m height; wavelength <0.3 m) (**Figure 7-15**). These features have a typical height of 2 to 3 m, with some sandwave features along the Offshore Export Cable Corridor greater than 4 m in height, and with average wavelengths of 100 to 200 m (Ocean Infinity, 2022a) (**Figure 7-17**).

- A series of distinctive large ridge features, orientated perpendicular to the main axis of flow, have been mapped *circa* 20 km offshore from the landfall, and are also interpreted as sandwaves (**Figure 7-16** and **Figure 7-17**). The asymmetric profile of these features is indicative of southerly transport – an observation which is consistent with the sediment transport modelling shown in **Figure 7-13**. However, a comparison of the project specific 2022 bathymetry data with earlier (2009) UKHO bathymetry data suggests that the sandwaves are either not migrating or migrating extremely slowly (<1 m/yr) (**Figure 7-16**).
- Within the Study Area, north of the Offshore Array Area, analysis from the EMODnet bathymetry shows there are much larger sandwave features, with heights of up to 8 to 10 m. Pockmarks - shallow seabed hollows originating from the release of shallow gas or fluids at the sediment/water interface – are also widespread in the Study Area, as well as moraines and channels of glacial origin (Judd, 2001; Bradwell et al. 2008; Clark et al. 2018) (**Figure 7-15**).



Salamander

Figure 7-14

Bathymetry across the Offshore Development Area and Study Area

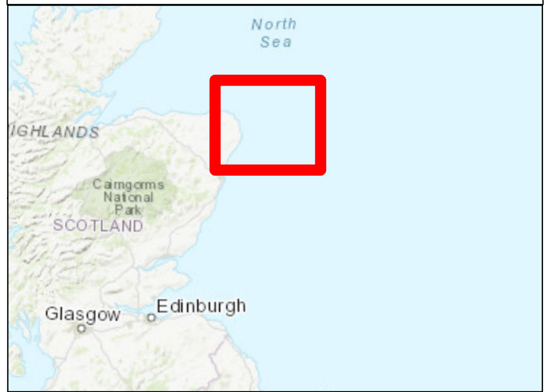
Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Indicative Onshore development area
- 12 nm limit

Composite Bathymetry Data (mLAT)

High : 2.02

Low : -247.27



Coordinate System: WGS 1984 UTM Zone 30N

Vertical Datum : MLLW

Scale @ A4 : 300,000

0 3.75 7.5 15 Kilometers

0 2 4 8 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Bathymetry across the Offshore Development Area and Study Area

Doc. No : SWF01ER0369

Created by : BO

Checked by : IW

Approved by : SS

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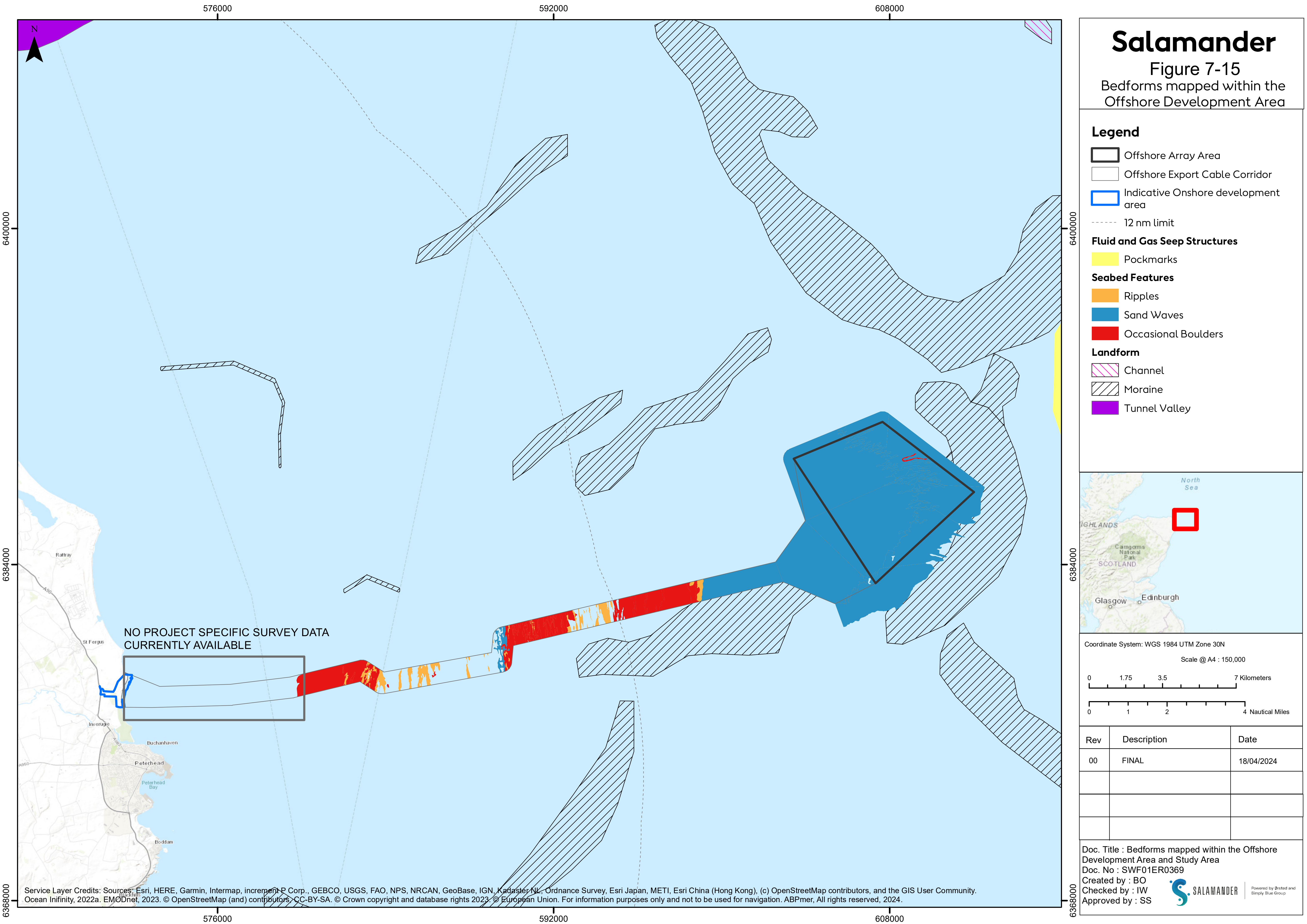
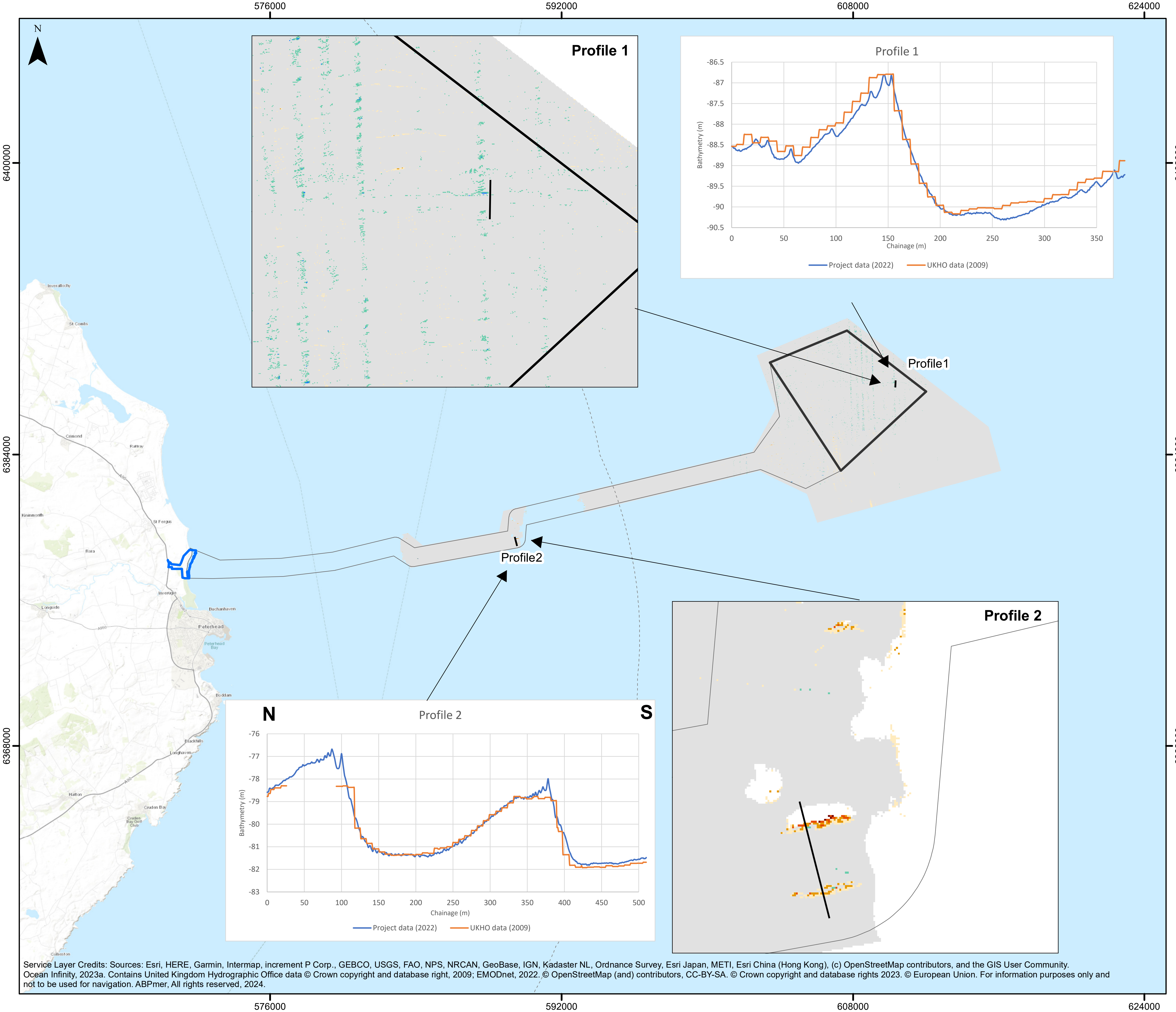


Salamander

Figure 7-15
Bedforms mapped within the Offshore Development Area

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Bedforms mapped within the Offshore Development Area and Study Area
Doc. No : SWF01ER0369
Created by : BO
Checked by : IW
Approved by : SS



Salamander

Figure 7-16

Bathymetric change 2009 to 2022

Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Indicative Onshore development area
- 12 nm limit
- Analysis Profile Location

Elevation Difference 2009 to 2022

- < -2.00
- -1.99 to -1.00
- -0.99 to -0.75
- -0.74 to -0.5
- -0.49 to 0.5
- 0.51 to 0.75
- 0.76 to 1.00
- 1.01 to 2.00
- >2.01

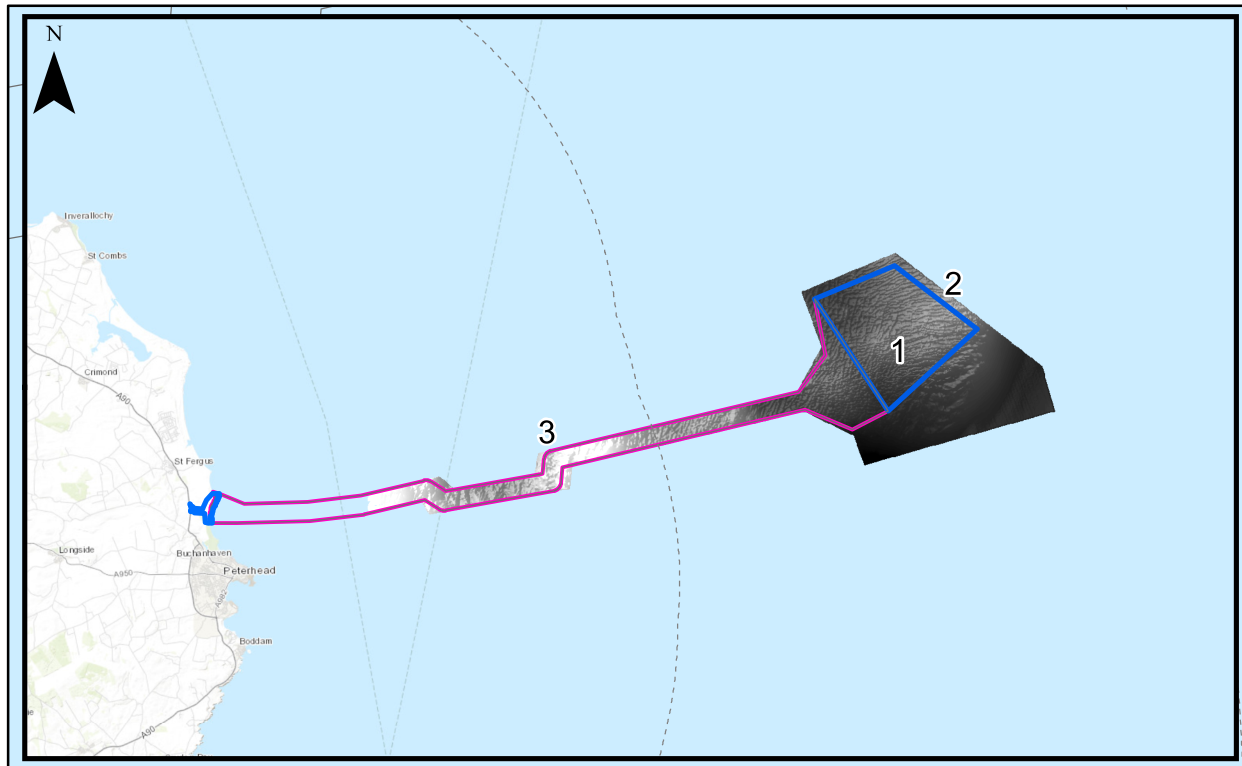
Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW
Scale @ A4 : 190,000

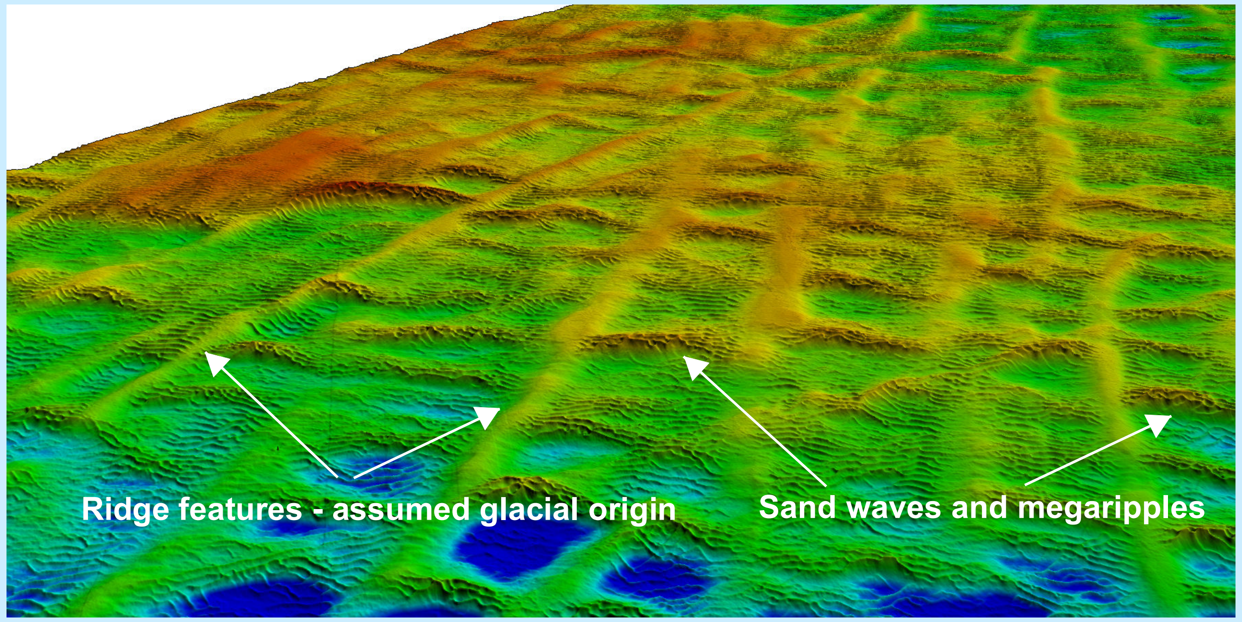
0 2.25 4.5 9 Kilometers

0 1.25 2.5 5 Nautical Miles

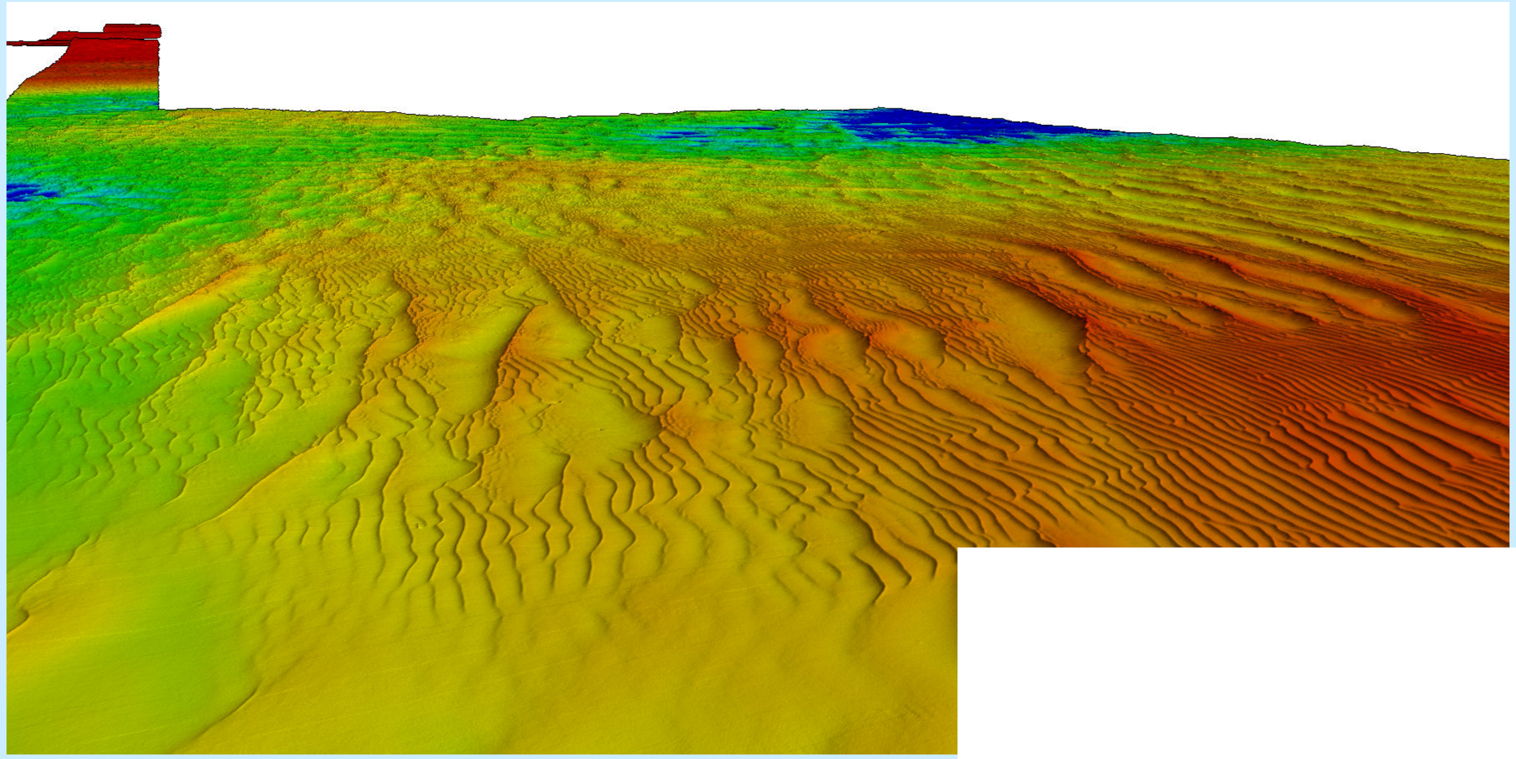
Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Difference plot summarising bathymetric change within the Offshore Development Area over the period 2009 (UKHO) to 2022 (Ocean Infinity)
Doc. No : SWF01ER0371
Created by : BO
Checked by : IW
Approved by : SS



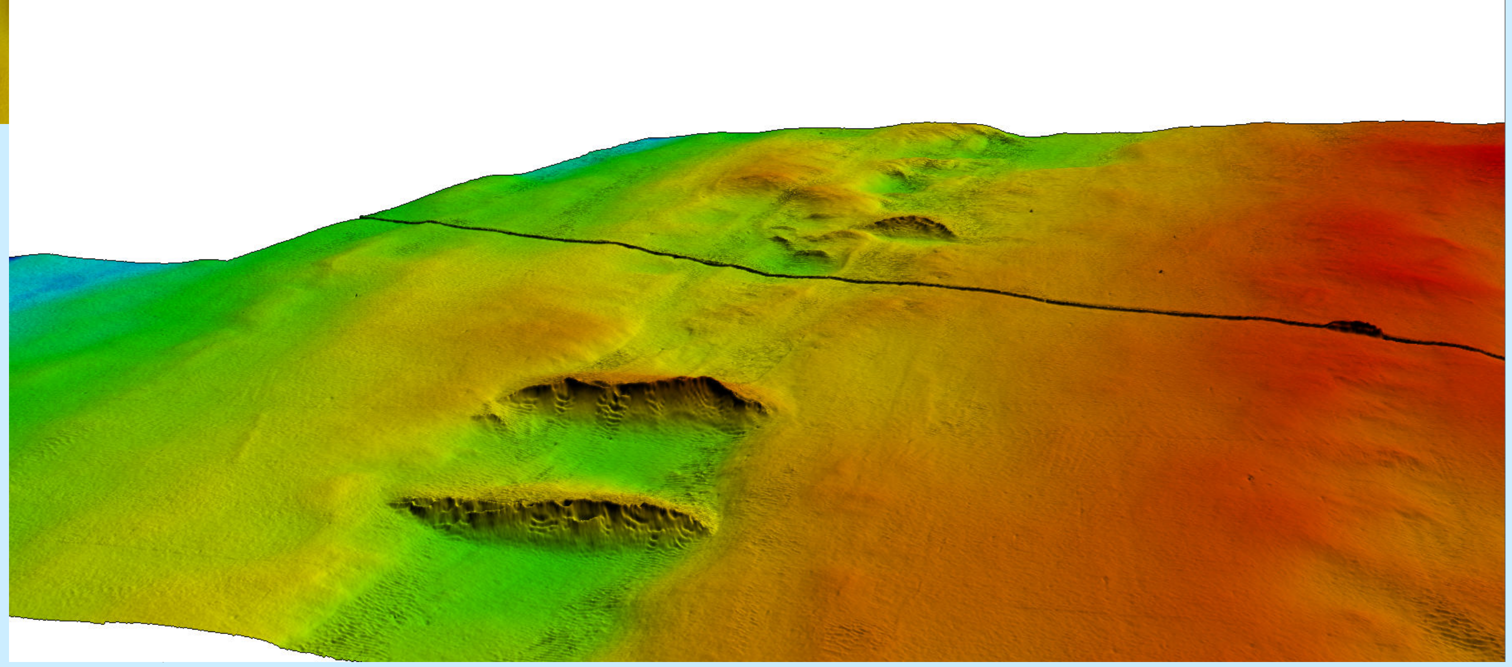


1: Ridge, sand wave and megaripple features within the Offshore Array Area



2: Sand wave and megaripple features within the Offshore Array Area

3: Sand wave features within the Offshore Export Cable Corridor



User: Bethan.Owens Date: Name:

Salamander

Figure 7-17

Sandwave and ridge features within the Offshore Development Area

Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Indicative Onshore development area
- 12 nm limit

Bathymetry Data (m LAT)

Value

-62.01
-70
-80
-90
-100
-111.88

Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW

Scale @ A4 : 400,000

0 5 10 20 Kilometers

0 2.5 5 10 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Sandwave and ridge features within the Offshore Development Area
Doc. No : SWF01ER0372
Created by : BO
Checked by : IW
Approved by : SS

<u>Coastal Geomorphology and Characteristics</u>

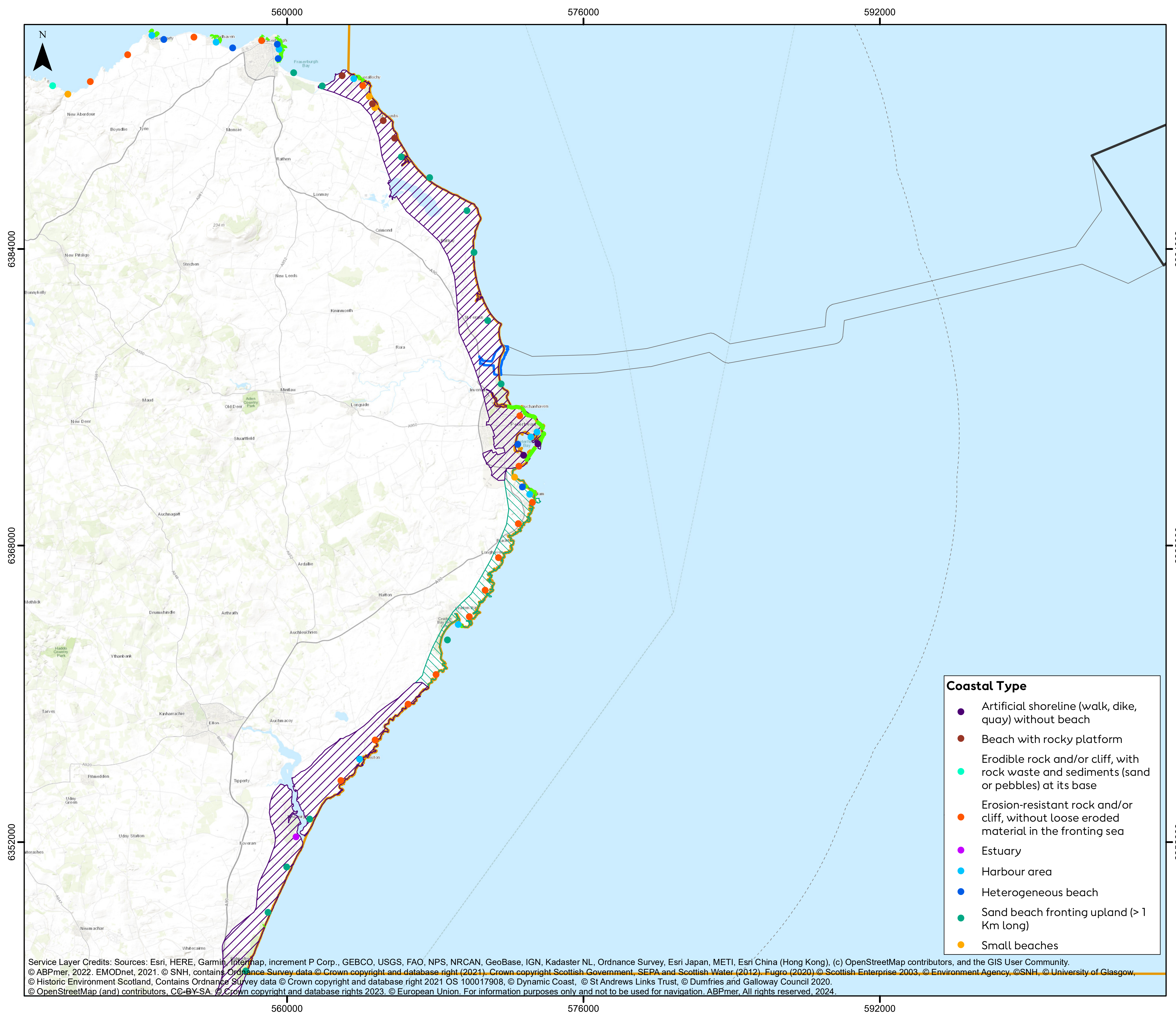
7.7.1.45 The coastline in the Study Area extends from Cairnbulg Point (in the northwest) to Balmedie (in the southeast). Extensive sandy beaches with accompanying dune systems are present in many areas, in particular between Cairnbulg Point and Peterhead (associated with the Loch of Strathbeg Site of Special Scientific Interest (SSSI)) and to the south of Hackley Head. Rocky/cliffed coastlines which are resilient to marine erosion are also present, most notably to the south of Peterhead, between Boddam and Rockend (**Figure 7-18**). Most of the coastline within the Study Area is undefended, reflecting a combination of generally low rates of erosion and a sparsely populated coastal zone. However localised artificial defences are in place, especially around the larger coastal settlement of Peterhead.

7.7.1.46 The Offshore Export Cable Corridor makes landfall at Scotstown Beach, between Lunderton and Kirkton, just to the north of Peterhead. The frontage here is characterised by a sandy beach backed by a dune complex, with boulders and cobbles present on the lower foreshore (**Figure 7-19** and **Figure 7-20**). Localised development has occurred on the dunes, including the installation of a hard path laid down as an access route.

7.7.1.47 Coastal process information obtained from Coastal Cells Reports, NatureScot (2000) and from Dynamic Coast (Rennie *et al*., 2021) show that at the landfall littoral drift is towards the north. Although the coastal type is erodible, a comparison of the MHWS contours over the period 1900 to present day shows general stability of the beach over this period, with seaward migration of the MHWS contour (i.e. accretion) over this period by about 50 m (i.e. a rate of *circa* 0.4 m/yr) (Rennie *et al*., 2021). This pattern of general stability is consistent with aerial imagery from the landfall for the period between 2005 and 2021, available from Google Earth (**Figure 7-21**).

7.7.1.48 Despite evidence of historic advances in the position of the MHWS contour, modest erosion is predicted over the lifetime of the Salamander Project, with retreat of the MHWS by up to approximately 15 m by 2065, in response to sea level rise (Rennie *et al.*, 2021) (**Figure 7-19**).

7.7.1.49 No formal Shoreline Management Plan (SMP) has been announced by Aberdeenshire Council for coastlines within the Study Area (Hansom *et al.*, 2017).



Salamander

Figure 7-18
Coastal characteristics within the Study Area

Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Indicative Onshore development area
- 12 nm limit
- Study Area
- Coastal Defences

Landscape Character

- Beaches, Dunes and Links - Aberdeenshire
- Fragmented Rocky Coast

Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW
Scale @ A4 : 186,000

0 2.25 4.5 9 Kilometers
0 1 2 4 Nautical Miles

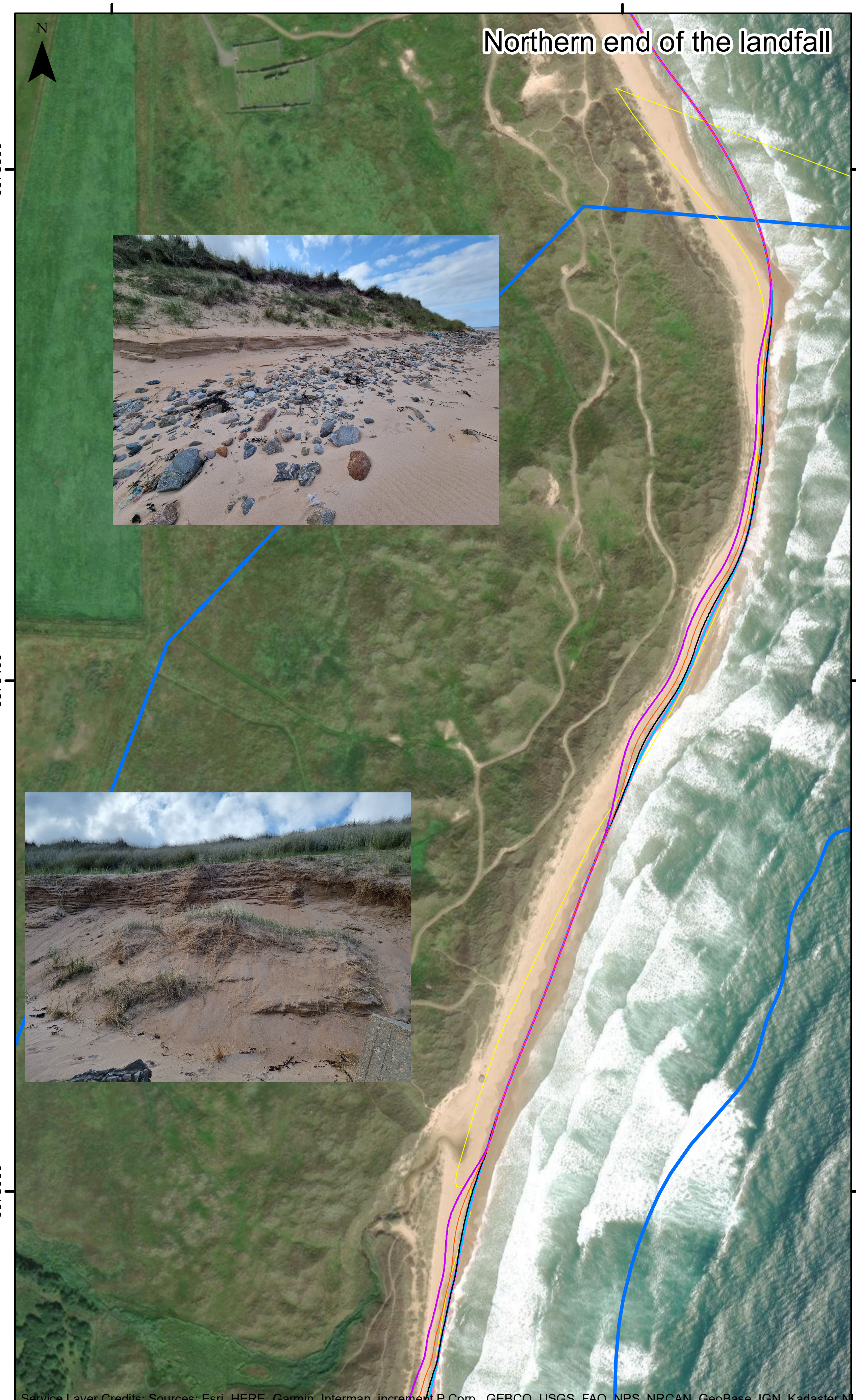
Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Coastal characteristics within the Study Area
Doc. No : SWF01ER0373
Created by : BO
Checked by : IW
Approved by : SS

Salamander

Figure 7-19

Aerial imagery and fixed-point photography of the landfall



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Contains Ordnance Survey data © Crown copyright and database right 2021 OS 100017908, Met Office Hadley Centre (2018), © BGS © Scottish Association for Marine Science (SAMS)
© Scottish Government, © Dynamic Coast, © Historic Environment Scotland, © SNH, © St Andrews Links Trust; Rennie et al., 2021. © University of Glasgow. Esri et al. © OpenStreetMap (and) contributors, CC-BY-SA. © Crown copyright and database rights 2023. © European Union.

Legend

- Offshore Export Cable Corridor
- Indicative Onshore development area

Future MHWS for High Emissions Scenario

Year

- 2020
- 2030
- 2040
- 2050
- 2060

Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW
Scale @ A4 : 4,000

0 0.05 0.1 0.2 Kilometers

0 0.025 0.05 0.1 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Aerial imagery and fixed-point photography of the Offshore Export Cable Landfall
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Salamander

Figure 7-20

Coastal topography and nearshore bathymetry of the landfall

Legend

- Offshore Export Cable Corridor
- Indicative Onshore development area
- 12 nm limit
- MHWS contour
- MLWS contour

Topographic Contour (m ODN)

- 5
- 10
- 20

Bathymetric Contour (mLAT)

- -5
- -10
- -20

Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW
Scale @ A4 : 7,000

0 0.075 0.15 0.3 Kilometers
0 0.045 0.09 0.18 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Coastal topography and nearshore bathymetry of the Offshore Export Cable Landfall
Doc. No : SWF01ER0375
Created by : BO
Checked by : IW
Approved by : SS

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Figure 7-21 Morphological change at the landfall over the period 2005 to 2021 (Source: Google Earth)

Designated sites

7.7.1.50 The Study Area overlaps with several nationally and internationally designated nature conservation sites, the locations of which are shown in **Figure 7-1**. The sites are designated for the habitats they contain as well as (in some instances) for the presence of geological and geomorphological features. At all sites, changes to the physical characteristics of these sites have the potential to impact the habitats they support and, therefore, consideration is given to them in the Marine Physical Processes assessment. Marine Protected Areas (MPAs) and Special Protection Areas (SPAs) within the Study Area are listed below, noting that a full assessment of potential impacts to the species and habitats they contain is presented elsewhere in the EIAR, including in **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology** and **Volume ER.A.3, Chapter 12: Offshore and Intertidal Ornithology**:

- The Southern Trench Marine Protected Area (MPA) is an important geodiversity feature of glacial origin, which covers most of the northwest of the Study Area, and some of the Offshore Export Cable Corridor close to shore. The trench also hosts a wide variety of marine species and is a prominent feeding ground for minke whales.
- Southeast of the Offshore Array Area lies Turbot Bank MPA, a significant breeding ground for sandeels, which play an important role in the wider North Sea ecosystem.
- Ythan Estuary, Sands of Forvie and Meikle Loch Special Protected Area (SPA), south of the Offshore Export Cable Corridor, is an important breeding ground for many bird species of European importance.
- Buchan Ness to Collieston Coast SPA, also south of the Offshore Export Cable Corridor, contains Annex I 'Vegetated Sea Cliffs of the Atlantic and Baltic Coasts' habitat and also supports a wide variety of marine and terrestrial fauna.

7.7.1.51 There are several SSSIs along the coast within the Study Area. These include:

- Foveran Links;
- Cairnbulg to St Combs Coast;
- Loch of Strathbeg;
- Bullers of Buchan Coast;
- Sands of Forvie and Ythan Estuary; and
- Collieston to Whinnyfold Coast.

7.7.2 Future Baseline

7.7.2.1 The climate change and carbon impact assessment for the Salamander Project is set out in **Volume ER.A.3, Chapter 20: Climate Change and Carbon.** Key aspects of the future baseline which are of relevance to the assessment of marine and coastal processes are set out below.

7.7.2.2 Based on the climate change projections set out in Palmer *et al.* (2018), the baseline environment for the Marine Physical Processes assessment is expected to evolve over the lifetime of the Salamander Project. These climate driven changes will also occur alongside natural variation (e.g. lunar nodal cycle, North Atlantic Oscillation etc.), and change arising from anthropogenic management of the coast. These are discussed below.

7.7.2.3 Mean sea level is likely to rise during the 21st Century, as a consequence of either vertical land (isostatic) movements, or changes in eustatic sea level. It is predicted in UK Climate Projections 2018 (UKCP18) that by 2065, relative sea level at the landfall will have risen by approximately 0.35 m above present day (2023) levels, (based on Representative Concentration Pathway (RCP) 8.5; 95th percentile), with rates of change increasing over time (Palmer *et al*., 2018) (Using RCP 8.5 is considered to represent a realistic worst-case). This is because the rate of rise in eustatic sea level will be greater than that of (ongoing) isostatic rebound over this period.

7.7.2.4 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. Sea level rise may also result in a loss of intertidal habitat through the process of 'coastal squeeze' caused by the presence of coastal defences preventing natural roll back.

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

7.7.2.6 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).

7.7.2.7 Most of the coastline within the Study Area is undefended, reflecting (at least in part) either a resilience to erosion or the absence of conditions leading to its occurrence. However localised artificial defences are in place, especially around Peterhead and other towns and villages. In defended areas, the future evolution of the coastline will depend to some extent on any changes to the existing management strategies. Despite evidence of historic advances in the position of the MHWS contour, modest erosion is predicted over the lifetime of the development, with retreat of the MHWS by up to approximately 15 m by 2065, in response to sea level rise (Rennie *et al.*, 2021) (**Figure 7-19**).

7.7.3 Summary of Baseline Environment

7.7.3.1 A summary of the relevant baseline characteristics within, and nearby to, the Offshore Development Area is provided below, based on the data sources described in **Table 7-3**, **Table 7-4** and **Figure 7-2;**

- Peak depth averaged current speed on a mean spring tide within the Offshore Array Area is approximately 0.5 to 0.8 m/s, increasing gradually along the Offshore Export Cable Corridor to between approximately 0.8 and 1.1 m/s at the coast, near Peterhead;
- During mean spring tidal conditions, the approximate overall tidal excursion distance is: 8 km in the Offshore Array Area; 12 to 14 km in the middle of the Offshore Export Cable Corridor and up to 17 km close to the landfall. Tidal excursion distances on a mean neap tide are approximately half the corresponding mean spring value;
- Waves within the Offshore Array Area are typically from north and south, while waves within the Offshore Export Cable Corridor are predominantly from the southeast, but frequently come from directions from north round to the south;
- Monthly averaged satellite imagery of SPM suggest that average (surface) SPM concentration is generally very low throughout the Offshore Export Cable Corridor and Offshore Array Area during summer months (1.1 mg/l within the Offshore Array Area, to around 0.7 mg/l at the landward end of the Offshore Export Cable Corridor). SPM concentrations increase slightly during winter

but are still relatively low in absolute terms, increasing from around 1.5 mg/l at the Offshore Array Area to approximately 4.5 mg/l in the vicinity of the landfall;

- Suspended Sediment Concentration (SSC) is expected to vary naturally with height in the water column. Sediment is naturally re-suspended by the action of currents and waves at the seabed, so SSC levels are higher at the bed, lower in the water column. High SSC values (potentially several tens or hundreds of mg/l for short periods of time) are realistically anticipated in some locations during larger spring tides and storm conditions, with the greatest concentrations generally encountered closer to the seabed, especially where and when wave action penetrates to the seabed; and
- Based on the results of the geophysical survey of the Offshore Export Cable Corridor and Offshore Array Area, coupled with existing available data (from the BGS), seabed sediments are characterised as coarse grained, with sandwaves and megaripples present across much of the Offshore Array Area and in localised parts of the Offshore Export Cable Corridor. These bedforms are expected to be active, given the prevailing hydrodynamic conditions. However surficial sediment cover is limited or absent in many areas, restricting overall net sediment transport.

7.8 Limitations and Assumptions

7.8.1.1 The following limitations and assumptions have been identified for the Marine Physical Processes topic:

- Data coverage: The Salamander Project has been unable to acquire project specific, or secondary survey data, within the nearshore ~8 km area of the Offshore ECC (referred to as Nearshore ECC), in a timeframe suitable to undertake the EIA in 2023 for submission of the EIAR in early 2024. This current 'data gap' covers the area from the MLWS at the Landfall location, through to the 1°40 line approximately 8 km east. The rest of the Offshore ECC from the 1°40 line to the Offshore Array Area (and the Offshore Array Area itself) has been surveyed. However robust, quality assured data are available for this locality from (amongst others) UKHO, BGS and EMODnet, and these data have been used to characterise the baseline to a level of detail that is suitable for the EIAR;
- Data accuracy: It is recognised that all data (including survey data) are subject to varying levels of uncertainty. The datasets have been reviewed, and levels of accuracy considered in the assessment process, along with the application of appropriate assessment methods and the use of multiple datasets, where available;
- Reliability of numerical models: The baseline characterisation has been informed by the development and use of numerical hydrodynamic and sediment models. These models are robust tools but are subject to a number of assumptions. These include the input parameters (using a representative sediment grain size for sediment transport for example), as well as uncertainty in the underpinning datasets (e.g. wave data and bathymetry data). Such uncertainty is managed in the design of the modelling study and the interpretation of the model results in the context of the baseline and using expert judgement; and
- Characterisation of the future baseline with respect to global climate change: Key limitations include determination of how the coastline may respond to a changed future wave climate acting in combination with higher than present sea levels.

7.8.1.2 Notwithstanding the identified limitations and assumptions set out above, the available data is nonetheless sufficient for the purposes of carrying out a robust assessment.

7.8.2 Impacts Scoped out of the Environmental Impact Assessment Report

7.8.2.1 The Marine Physical Processes assessment covers all potential impacts identified during scoping, as well as any further potential impacts that have been highlighted as the EIA has progressed, as outlined in **Section 7.10.**

7.8.2.2 However, following consideration of the baseline environment, the Salamander Project description outlined in **Volume ER.A.2, Chapter 4: Project Description** and response to the Scoping Opinion a number of impacts are not considered in detail within this EIAR, as illustrated in **Table 7-13** and listed below:

- Impact on geology (construction, operation and maintenance (O&M) and decommissioning phases);
- Impacts on designated features within designated sites (decommissioning phase);
- Loss / alteration of seabed morphology (bathymetry and sediment type) (decommissioning phase);
- Increase in suspended sediments (O&M phase); and
- Change to coastal landfall morphology (decommissioning phase).

Table 7-13 Impacts scoped out of the Marine Physical Processes assessment

Potential Impact	Project Aspect	Project Phase	Justification
Impacts on geology from physical presence of infrastructure	Offshore Array and Offshore ECC	Construction, Operation and Maintenance and Decommissioning	No impacts on geology are anticipated as a result of Project activities. Given the anticipated localised nature of the changes in tidal currents and waves for the Salamander Project, there is expected to be no local or regional changes to geology.
Impacts on designated features within designated sites	Offshore ECC	Decommissioning	No impacts on designated features are anticipated by decommissioning activities, as decommissioning activities will restore the site towards baseline conditions.
Loss / alteration of seabed morphology (bathymetry and sediment type)	Offshore Array and Offshore ECC	Decommissioning	No impacts on physical seabed characteristics are anticipated by decommissioning activities as decommissioning activities will restore the site towards baseline conditions.
Potential increases in suspended sediment concentrations and associated changes to seabed substrate	Offshore Array and Offshore ECC	Operation and Maintenance	There is the potential for operation and maintenance activities to result in increased suspended sediment concentrations which may result in indirect impacts on marine physical processes receptors. The nature of works associated with operation and maintenance activities and the discrete areas within which these activities will be undertaken, will result in significantly lower suspended sediment concentrations than those associated with

Potential Impact	Project Aspect	Project Phase	Justification
			construction activities. For this reason, this impact has been scoped out for further assessment within the EIA.
Change to coastal landfall morphology	Offshore ECC	Decommissioning	No impacts on coastal landfall morphology are anticipated by decommissioning activities as decommissioning activities will restore the site towards baseline conditions.

7.8.3 Embedded Mitigation

7.8.3.1 The embedded mitigation relevant to the Marine Physical Processes assessment is presented in **Table 7-14**.

Table 7-14: Embedded mitigation for the Marine Physical Processes assessment

Potential Impact and Effect	Mitigation ID	Mitigation	Project Aspect	Project Phase
Primary				
Potential changes in morphology of the coast and seabed (including scour)	Co14	Avoidance of sensitive features during cable routing wherever practicable. Cables will be buried as the primary cable protection method, however other cable protection methods will be used where adequate burial cannot be achieved. A Cable Burial Risk Assessment (CBRA) will be completed to determine suitable cable protection measures, and will be implemented within relevant Project plans.	Offshore Array Area and Offshore ECC	Construction
Potential changes to the morphology of the seabed (including scour)	Co1	Appropriate scour protection will be put in place where required following the completion of a scour assessment.	Offshore Array Area and Offshore ECC	Construction, Operation & Maintenance and Decommissioning
Potential changes in morphology of the coast and seabed (including scour)	Co52	The Salamander Project has taken the decision to remove trenched landfall solutions from the design envelope as a landfall installation methodology and has committed to using a trenchless installation solution between Mean Low Water Springs (MLWS) and the landward side of the foredunes.	Offshore ECC	Construction and Operation & Maintenance

Potential Impact and Effect	Mitigation ID	Mitigation	Project Aspect	Project Phase
Tertiary				
Potential changes in morphology of the coast and seabed (including scour)	Co2	A pre-construction geophysical cable route survey will be undertaken, the results of which will also be used to identify presence of seabed features of interest that may require further consideration prior to construction works.	Offshore Array Area and Offshore ECC	Construction
Potential changes in morphology of the coast and seabed (including scour)	Co9	Construction Environmental Management Plan (CEMP) will be developed and will include details of: - A Marine Pollution Contingency Plan (MPCP) to address the risks, methods and procedures to protect the Offshore Development Area from potential polluting events associated with the Salamander Project; - A chemical risk review to include information regarding how and when chemicals are to be used, stored and transported in accordance with recognised best practice guidance; - A biosecurity plan (offshore) detailing how the risk of introduction and spread of invasive non-native species will be minimised; - Waste management and disposal arrangements; and - Protocol for management of Dropped Objects.	Offshore Array Area and Offshore ECC	Construction
Potential changes in morphology of the coast and seabed (including scour)	Co30	A Cable Plan will be produced prior to construction of the Offshore Export Cable(s) which will include; details of cable depth of lowering; a detailed cable laying plan which ensures safe navigation is not compromised; details of cable protection for each cable crossing; and proposals for monitoring of offshore cable.	Offshore ECC	Construction, Operation & Maintenance and Decommissioning

7.9 Project Design Envelope Parameters

7.9.1.1 Given that the realistic worst-case scenario is based on the design option (or combination of options) that represents the greatest potential for change, as set out in **Volume ER.A.2, Chapter 4: Project Description,** confidence can be held that development of any alternative options within the Salamander Project design envelope parameters will give rise to no effects greater, or worse, than those assessed in this impact assessment. The Salamander Project Design Envelope parameters, relevant to the Marine Physical Processes assessment, are outlined in **Table 7-15**.

Table 7-15 Project Design Envelope parameters for Marine Physical Processes

Potential Impact and Effect	Project Design Envelope parameters
Construction	
Potential increases in SSC and associated changes to seabed substrate.	Drilling for anchor installation • Maximum number of pile anchors: 56 (max foundations = 7; max anchors per foundation = 8) • Maximum dimensions of drilled pile section: 3.0 m diameter, 70 m max penetration depth. • Maximum volume of material per pile: 495 m^3 • Maximum volume of material all piles: 27,800 m^3 Inter-array cable installation • Maximum total length of cable trenches: <35 km • Typical trench dimensions: 7.5 m wide (at seabed); 2 m deep; 'V' shape profile • Excavation method: Jetting, Vertical Injection, Mass Flow Excavation, Ploughing / Pre-Ploughing, Trenching / Pre-Trenching (incl. dredging, cutting) (with or without backfill) Offshore export cable installation • Maximum number of trenches: 2 • Maximum total length of trench: ≤85 km (i.e. up to 2 x 42.5 km trench) • Typical trench dimensions: 7.5 m wide (at seabed); 2 m deep; 'V' shape profile • Excavation method: [as above for inter-array]

Potential Impact and Effect	Project Design Envelope parameters
	Subsea Hub Parameters • Maximum number of subsea hubs: 2 • Seabed hub dimensions: ≤ 15 x 15 m • Height of subsea hub: ≤ 10 m • Number of anchor piles: ≤ 12 • Anchor pile dimensions: ≤ 1.5 x 30 m • Total seabed disturbance from subsea hubs: ≤ 7,000 m^2 • Height of scour protection: ≤ 2 m • Total volume of scour protection on seabed: ≤ 4,200 m^3 • Height of cable protection: ≤ 1.5 m • Total volume of cable protection material: ≤ 4,125 m^3 Seabed levelling associated with anchor installation • Maximum Spoil Volume: ≤48,600 m^3 (for gravity base anchors) Sandwave levelling (within Offshore Array Area) • Localised Sandwave Height (in sandwave areas) = 2 m • Maximum volume of material that will be subject to levelling / temporary removal for offshore inter-array cables: Total = 1,624,000 m3. • Levelling method: Trailing Suction Hopper Dredger (TSHD) or Mass Flow Excavator (MFE)

Potential Impact and Effect	Project Design Envelope parameters
	<u>Sandwave levelling (within Offshore Export Cable Corridor)</u> • Localised Sandwave Height (in sandwave areas) = 4 to 5 m • Maximum volume of material that will be subject to levelling / temporary removal: ≤5,576,000 m^3 • Levelling method: TSHD or MFE <u>Trenchless installation techniques) / Drilling fluid release (at landfall)</u> • Number of exit/release events: 2 • Maximum volume of drilling fluid in one conduit: 1,964 m^3 (i.e. 2,500 m duct length x 1 m diameter duct). • Representative maximum concentration of bentonite in drilling fluid: ~80,000 mg/l. • Wet punch-out (i.e. an exit below MLWS), no closer than 200 m from MHWS • Number of exit pits: 2 (<5,000 m^3 of spoil in total for both pits combined) [No requirement for nearshore floatation pits]
Potential changes to sediment transport system by changes in wave and current climate	The realistic worst-case for blockage associated with partially installed cable protection, floating turbines and / or the presence of anchoring structures cannot readily be defined. However, it will be no greater than that set out for the fully built and operational project. Refer to the operation section of this table (below).
Potential changes to the morphology of the seabed (including scour)	<u>Sandwave levelling (within Offshore Array Area)</u> • Localised Sandwave Height (in sandwave areas) = 2 m • Maximum volume of material that will be subject to levelling / temporary removal for offshore inter-array cables: Total = 1,624,000 m^3. • Levelling method: TSHD or MFE

Potential Impact and Effect	Project Design Envelope parameters
	Sandwave levelling (within Offshore Export Cable Corridor) • Localised Sandwave Height (in Sandwave Areas) = 4 to 5 m • Maximum volume of material that will be subject to levelling / temporary removal: 5,576,000 m^3 • Levelling method: TSHD or MFE
Potential changes in morphology of the coast	Trenchless installation techniques • Number of routes: 2 (subtidal punch-out) • Installation duration: order of several months total (for 2 trenchless cable installations) • Number of nearshore exit pits: 2 • Exit pit dimensions: ≤50 m long x ≤10 m wide x ≤5 m deep (each) (<5,000 m^3 of spoil in total for both pits combined) Cable protection • Rock protection not currently anticipated within the intertidal region. From the exit pits going offshore, the export cable(s) may be stabilised within the trench using rock placement, concrete mattress, grout / rock bag, frond mattress or articulated pipe

Potential Impact and Effect	Project Design Envelope parameters
Operation and Maintenance	
Potential changes to sediment transport system by changes in wave and current climate	Floating substructures • Maximum number of units: 7 • Maximum width: 140 m • Maximum draught (during operation): 15-40 m (for tension leg platforms) and 10–24 m for (semi-submersible foundations) Mooring system and Electrical cables • Maximum number of mooring lines present in the water column: 56 mooring lines (7 units x 8 lines); • Maximum number of electrical cables present in the water column: 8 array electrical cables • Mooring line (wire / rope / cable): Diameter ≤300 mm • Diameter of electrical cable: ≤320 mm (in Offshore Array Area and Export Cable Corridor) • Electrical cables may include buoyancy modules up to 1.5 m diameter. • Total surface area of cable without buoyancy modules in water column: 2,111 m^2 • Total surface area of cable with buoyancy modules in water column: 6,601 m^2 Anchors • Max no. of gravity base anchors on seabed: 8 • Dimensions of gravity base anchors once installed: 13.5 m diameter, ≤5 m above seabed.
Potential changes to the morphology of the seabed (including scour)	Mooring system and electrical cables • Maximum number of mooring lines per foundation: 8 (max 56 total for the Offshore Array Area)

Potential Impact and Effect	Project Design Envelope parameters
	• Mooring line (wire/ rope/ cable): Diameter ≤300 mm • Total swept area on seabed: up to 3,920,000 m^2 (based on catenary mooring system) • Dimensions of individual clump weights: 2.5 m long x 2.5 m wide x 2.5 m high. (Up to 10 mooring clumps per line, 8 mooring lines per floating substructure therefore 560 mooring clumps in total) • Total Seabed Footprint of Mooring Clumps: 0 m^2 (included in the mooring line swept area) • Diameter of electrical cable: up to 320 mm • Dimensions of gravity base anchors once installed: 13.5 m diameter, ≤5 m above seabed. • Total Seabed Footprint of cable tethers: 22,400 m^2. (Up to four tethers per cable and two cables per turbine) <u>Subsea hubs</u> • Maximum number: 2 • Maximum dimension: 15 m x 15 m • Maximum height above seabed: 10 m <u>Cable protection</u> • Applied to up to 20% (≤17 km) of the total export cable length • Applied to up to 20% (≤7 km) of the total inter-array cable length in contact with the seabed • Rock Placement, concrete mattress, grout / rock or sand bag, frond mattress, articulated pipe (for export cable only) • Maximum dimensions: 10 m base width x 1.5 m height
Potential changes in morphology of the coast	<u>Cable protection (nearshore areas)</u> • Subtidal areas: ≤1.5 m height • Duration: 35 years (Salamander Project lifespan)

Potential Impact and Effect	Project Design Envelope parameters
	Trenchless installation techniques - Rock protection not expected to be required at exit pit(s). From the exit pits going offshore, the export cable(s) may be stabilised within the trench using rock placement, concrete mattress, grout / rock bag, frond mattress or articulated pipe
Potential changes to water column processes (mixing and stratification)	Floating substructures • Maximum number of units: 7 • Maximum width: 140 m • Maximum draught (during operation): 15-40 m (for tension leg platforms) and 10–24 m for (semi-submersible foundations) Mooring system and Electrical cables • Maximum number of mooring lines and electrical cables present in the water column: 56 mooring lines (7 units x 8 lines; 8 electrical cables • Mooring Line Bar Diameter (Chain): ≤300 mm • Diameter of electrical cable: 320 mm (in Offshore Array Area and Export Cable Corridor) Anchors • Max no. of gravity base anchors on seabed: 8 • Dimensions of gravity base anchors once installed: 13.5 m diameter, 5 m above seabed.
Decommissioning	
Potential increases in SSC and associated	At this stage, the worst-case scenario envelope during decommissioning is considered equal to the worst-case scenario during construction, with the exception of vessel movements, where more detailed information is available. Noting this, it is assumed that the worst-case scenario

Potential Impact and Effect	Project Design Envelope parameters
changes to seabed substrate	will involve full removal of all infrastructure placed during the construction phase. This assumption is subject to best practice methods and technology appropriate at the time of decommissioning.
Potential changes to sediment transport system by changes in wave and current climate	
Potential changes to the morphology of the seabed (including scour)	

7.10 Assessment Methodology

7.10.1.1 **Volume ER.A.2, Chapter 6: EIA Methodology** sets out the general approach to the assessment of potentially significant effects that may arise from the Salamander Project.

7.10.1.2 Whilst **Volume ER.A.2, Chapter 6: EIA Methodology** provides a general framework for identifying impacts and assessing the significance of their effects, in practice the approaches and criteria applied across different topics vary.

7.10.1.3 The proposed approach to the Marine Physical Processes that has been addressed in the EIA is outlined below. The assessment has been based on the existing baseline environment, as described in **Section 7.7**, and the Design Envelope as detailed in **Volume ER.A.2, Chapter 4: Project Description**. Specific parameters that have formed the basis of this assessment are provided in **Table 7-15**.

7.10.1.4 Impacts have been assessed for the following three distinct phases of the Salamander Project:

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

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

7.10.2 Desk Study

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

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

7.10.2.2 The assessments consider likely naturally occurring variability in, or long-term changes to, Marine Physical Processes within the lifetime (35 years) of the Offshore Development due to natural cycles and/or climate change (e.g. sea level rise). This is important as it enables a reference baseline level to be established, against which the potentially modified marine and coastal processes can be compared, throughout the Salamander Project lifecycle.

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

- Far-field. Defined as the area surrounding the Offshore Array Area and Offshore Export Cable Corridor over which indirect changes may occur (i.e. the Study Area); and
- Near-field. Defined as the footprint of the Offshore Array Area and Offshore Export Cable Corridor.

7.10.3 Approach to Assessment of Potential Increases in Suspended Sediment Concentrations and Associated Changes to Seabed Substrate

7.10.3.1 A large evidence base exists with regards to the potential environmental effects of cable installation activities (including increases in suspended sediment concentrations (SSC), e.g. BERR, 2008). This has been considered in conjunction with spreadsheet-based tools (providing estimates of plume extent, concentration and associated changes in bed levels) to inform the assessment. Spring tidal excursion ellipse buffers (based on outputs from the ABPmer SEASTATES hydrodynamic model) have also been used to help inform the potential spatial extent of suspended sediment plumes associated with project-related construction/decommissioning activities. (Although it is possible that over successive tidal cycles, material could advect further than this distance, by this time any plume is expected to be of such low concentration as to be immeasurable in practice).

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

7.10.3.3 Full details of the approach to the assessment of potential increases in SSC and associated changes to seabed substrate are set out in **Volume ER.A.4, Annex 7.1: Marine Physical Processes Technical Annex.**

7.10.4 Approach to Assessment of Potential Changes to Sediment Transport System by Changes in Wave and Current Climate

7.10.4.1 The maximum surface and subsurface cross section of each foundation have been considered, to assess the potential local extent and magnitude of effect on waves or currents. The assessment has been a semi-quantitative, desk-based, consideration of the potential for local wave energy or current blockage and recovery downstream. The potential for array scale effects has been considered with respect to the spacing of the individual foundations, in conjunction with the predicted extent of effect from individual foundations. The potential for array scale effects to extend to either the seabed (locally) or to the relatively distant adjacent coastlines has also been considered. The desktop assessment has been informed by knowledge of the local wave and current regimes, relevant wave and hydrodynamic theory, and the many offshore wind farm and engineering related studies that have considered the effect of similar size full water column depth foundations, including numerical modelling.

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

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

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

7.10.5 Approach to Assessment of Potential Changes to the Morphology of the Seabed

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

7.10.5.2 The spatial extent of potential morphological change to the seabed associated with anchoring structures has been characterised using the information in **Volume ER.A.2, Chapter 4: Project Description** with consideration given to the size of anchors/anchor chains and potential for any associated scour. This assessment also considers the impact of any mooring line catenary, along with scour associated with clump weights and/or cable protection deployed on both the inter-array and export cables.

7.10.6 Approach to Assessment of Potential Changes in Morphology at the Coast

7.10.6.1 Where the offshore export cable(s) makes landfall, they must transition through the intertidal zone. The methods proposed for installing cables in this environment (trenchless cabling techniques) may physically disturb or disrupt the present intertidal morphology to differing degrees. At the time of construction, any disturbance will be localised to the landfall site.

7.10.6.2 The short-term physical impacts have been assessed as a desktop analysis. The physical nature and extent of the likely disturbance is characterised using the information in **Volume ER.A.2, Chapter 4: Project Description** and with reference to the wider evidence base. The potential impact on beach morphology, hydrodynamics and sediment transport has been assessed by an experienced coastal geomorphologist in the context of the baseline environment of the landfall site.

7.10.7 Assessment of Potential Effect Significance

7.10.7.1 The assessment of effects upon marine physical process receptors is a systematic process, that is determined by considering specific criteria relating to Marine Physical Processes that have been developed for the sensitivity and importance of the receptor (**Table 7-16**) and the magnitude of impact (**Table 7-17**). Each aspect (sensitivity and magnitude) has been considered using the available evidence, including official data sources, feedback from consultation and expert judgement.

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

Sensitivity

7.10.7.3 The sensitivity of the receptor is considered in terms of its ability to avoid, adapt, accommodate or recover from potential impacts, as well as its importance. Expert judgement has been used to inform the assessment of sensitivity of marine physical process receptors. The criteria of sensitivity used in relation to marine and coastal processes receptors are defined in **Table 7-16**.

Table 7-16 Sensitivity levels for receptors (Marine Physical Processes)

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

Magnitude

7.10.7.4 The magnitude of the impact is based on the spatial extent and duration. Data sources, feedback from consultation, and expert judgement are used to inform the assessment of the magnitude of impacts to marine physical process receptors. The criteria for defining magnitude used in relation to marine physical process receptors are defined in **Table 7-17**.

Table 7-17 Magnitude of impact (Marine Physical Processes)

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

Significance of Effect

7.10.7.5 The significance of the effect upon marine physical process receptors is determined by correlating the magnitude of the impact and the sensitivity of the receptor, as presented in **Table 7-18**. On this basis, potential impacts are assessed as of negligible, minor, moderate and major significance (definitions are provided in **Volume ER.A.2, Chapter 6: EIA Methodology**. For the purposes of this assessment, any effects with a significance level of major and/or moderate have been deemed significant in EIA terms, while those of minor or negligible are deemed non-significant.

Table 7-18 Significant of effect matrix

Significance of effect		Receptor Sensitivity			
		High	*Medium*	*Low*	*Negligible*
Magnitude of Effect	*High*	Major	Moderate	Minor	Negligible
	Medium	Moderate	Moderate	Minor	Negligible
	Low	Minor	Minor	Negligible	Negligible
	Negligible	Negligible	Negligible	Negligible	Negligible

Receptors and Pathways

7.10.7.6 In most cases, Marine Physical Processes are not in themselves receptors but are, instead, 'pathways' which have the potential to indirectly impact other environmental receptors, i.e. benthic ecology, fish ecology etc. Accordingly, whilst potential changes assessed in this chapter may not themselves be significant, it may be the case that they have potential to cause significant impacts to other EIA topic receptors. For example, the creation of sediment plumes (which is considered in the Marine Physical Processes assessment) may lead to settling of material on to benthic habitats. The topic chapters relevant to Marine Physical Processes are:

- **Volume ER.A.3, Chapter 8: Water and Sediment Quality;**
- **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology;**
- **Volume ER.A.3, Chapter 10: Fish and Shellfish Ecology;**
- **Volume ER.A.3, Chapter 13: Commercial Fisheries;**
- **Volume ER.A.3, Chapter 17: Marine Archaeology and Cultural Heritage; and**
- **Volume ER.A.3, Chapter 18: Other Users of the Marine Environment.**

7.10.7.7 It is important to note that where the impact is considered to be a marine physical process pathway (such as hydrodynamics, waves and sediment transport processes) without any associated receptors, this chapter of the EIA does not consider the resulting significance of effects. This is assessed in the respective chapters where the receptors are identified. Only receptors linked to Marine Physical Processes are fully assessed in this chapter.

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

7.10.7.9 The Study Area also overlaps with several nationally and internationally designated nature conservation sites, which contain qualifying geological and geomorphological (geodiversity) features. Of particular note is the Southern Trench MPA which contains geodiversity features including moraines, tunnel valleys and slide scars. These qualifying features are identified and assessed as marine physical process receptors. However, the potential significance of effect on the Conservation Objectives of the Southern Trench MPA designation is assessed in **Volume ER.A.4, Annex 9.4: Benthic Features Impact Assessment Southern Trench MPA**.

7.10.7.10 Although the potential significance of effect on the Southern Trench MPA is assessed in **Volume ER.A.4, Annex 9.4: Benthic Features Impact Assessment Southern Trench MPA**, this assessment does consider those objectives (as outlined in (NatureScot, 2019) which are:

- So far as already in favourable condition, remain in such condition; or
- So far as not already in favourable condition, be brought into such condition, and remain in such condition.

7.10.7.11 Favourable condition, with respect to a feature of geomorphological interest, means that a) its extent, component elements and integrity are maintained; b) its structure and functioning are unimpaired; and c) its surface remains sufficiently unobscured for the purposes of determining whether the criteria in paragraphs (a) and (b) are satisfied.

7.10.7.12 Finally, the Buchan Front is also included as a receptor. This is a regional-scale oceanographic feature which supports high biological primary productivity and biodiversity. Further information on the feature can be found in **Sections 7.7.1.19** to **7.7.1.26**.

7.11 Impact Assessment

7.11.1.1 Impacts will be assessed separately for the Construction, Operation and Maintenance and Decommissioning phases of the Offshore Development.

7.11.2 Construction

7.11.2.1 Under the construction phase, the following potential impacts have been assessed:

- Potential increases in SSC and associated changes to seabed substrate;
- Potential changes to sediment transport system by changes in wave and current climate;
- Potential changes to the morphology of the seabed (including scour); and
- Potential changes in morphology of the coast.

Potential Increases in Suspended Sediment Concentrations and Associated Changes to Seabed Substrate

Overview

7.11.2.2 This section provides a description of the realistically possible combinations of magnitude and extent of impact for local increases in SSC and seabed deposition, due to sediment disturbance potentially caused by:

- Drilling for pile anchors;
- Seabed preparation (levelling and/or dredging) prior to installation of suction caisson and gravity anchors;
- Sandwave levelling by dredging and/or Mass Flow Excavation (MFE);

- Cable burial by ploughing, trenching and jetting (including initial installation and any subsequent cable repairs and/or remediation in the Operational phase); and
- Release of drilling fluid during trenchless cable installation punch out.

7.11.2.3 The following other activities may cause some localised disturbance of sediment, but at a rate, scale and duration less than, or similar to, the activities above, and so are not explicitly assessed:

- Installation of anchor/mooring systems; and
- Deployment of cable protection.

7.11.2.4 The potential change in SSC is considered to be a pathway and the assessment of the magnitude of potential change resulting from the above activities, including the methodological approach used to assess the characteristics of sediment plumes and associated changes in bed level arising from settling of material is set out in **Volume ER.A.4, Annex 7.1: Marine Physical Processes Technical Annex.**

7.11.2.5 Summary findings are set out below.

Conceptual Understanding of Change

7.11.2.6 The actual magnitude and extent of change in SSC and bed levels will depend, in practice, on a range of factors, such as the actual total volumes and rates of sediment disturbance, the local water depth and current speed at the time of the activity, the local sediment type and grain size distribution, the local seabed topography and slopes, etc. There will be a wide range of possible combinations of these factors and so it is not possible to predict specific dimensions with complete certainty. To provide a robust assessment, a range of realistic combinations have been considered, based on conservatively representative locations (environmental) and project-specific design information, including a range of water depths, heights of sediment ejection/initial resuspension, and sediment types.

7.11.2.7 This wider range of results can be summarised broadly in terms of four main zones of effect, based on the distance from the activity causing sediment disturbance. These zones are entirely consistent with the results of observational (monitoring) evidence and numerical modelling of analogous activities (e.g. BERR, 2008; Navitus Bay Development Ltd, 2014; Awel y Môr Offshore Wind Farm Ltd, 2022):

- 0 to 50 m
  - Zone of highest SSC increase and greatest likely thickness of deposition. All gravel sized sediment likely deposited in this zone, also a large proportion of sands that are not resuspended high into the water column, and also most or all dredge spoil in the active phase. Plume dimensions and SSC, and deposit extent and thickness, are primarily controlled by the volume of sediment released and the manner in which the deposit settles;
  - At the time of active disturbance - very high SSC increase (tens to hundreds of thousands of mg/l) lasting for the duration of active disturbance plus up to 30 minutes following end of disturbance; sands and gravels may deposit in local thicknesses of tens of centimetres to several metres; fine sediment is unlikely to deposit in measurable thickness; and
  - More than one hour after the end of active disturbance - no change to SSC; no measurable ongoing deposition.

- 50 to 500 m
  - Zone of measurable SSC increase and measurable, but lesser, thickness of deposition. Mainly sands that are released or resuspended higher in the water column and resettling to the seabed whilst being advected by ambient tidal currents. Plume dimensions and SSC, and deposit extent and thickness, are primarily controlled by the volume of sediment released, the height of resuspension or release above the seabed, and the ambient current speed and direction at the time;
  - At the time of active disturbance - high SSC increase (hundreds to low thousands of mg/l) lasting for the duration of active disturbance plus up to 30 minutes following end of disturbance; sands and gravels may deposit in local thicknesses of up to tens of centimetres; fine sediment is unlikely to deposit in measurable thickness; and
  - More than one hour after end of active disturbance - no change to SSC; no measurable ongoing deposition.
- 500 m to the tidal excursion buffer distance
  - Zone of lesser but measurable SSC increase and no measurable thickness of deposition. Mainly fines that are maintained in suspension for more than one tidal cycle and are advected by ambient tidal currents. Plume dimensions and SSC are primarily controlled by the volume of sediment released, the patterns of current speed and direction at the place and time of release and where the plume moves to over the following 24 hours;
  - At the time of active disturbance - low to intermediate SSC increase (tens to low hundreds of mg/l) as a result of any remaining fines in suspension, only within a narrow plume (tens to a few hundreds of metres wide), SSC decreasing rapidly by dispersion to ambient values within one day after the end of active disturbance; fine sediment is unlikely to deposit in measurable thickness;
  - One to six hours after end of active disturbance - decreasing to low SSC increase (tens of mg/l); fine sediment is unlikely to deposit in measurable thickness; and
  - Six to 24 hours after end of active disturbance - decreasing gradually through dispersion to background SSC (no measurable local increase); fine sediment is unlikely to deposit in measurable thickness. No measurable change from baseline SSC after 24 to 48 hours following cessation of activities.
- Beyond the tidal excursion buffer distance, or anywhere not tidally aligned to the active sediment disturbance activity - there is no expected impact or change to SSC, nor a measurable sediment deposition.

7.11.2.8 It is noted here, that in shallower waters (*circa* <30 m) during storm events, wave driven currents can naturally cause very high SSC (thousands of mg/l or more) close to the bed in areas where mobile sediment is present. Accordingly, even when SSC increases occur in response to wind farm construction activities, they are expected to be comparable to (or less than) the increases which can occur naturally under storm conditions.

7.11.2.9 **Figure 7-22** provides a summary of the spatial extent of these zones in relation to the Salamander Project. Designated nature conservation sites within the Study Area are also shown. **Figure 7-23** illustrates sediment deposition footprints associated with a single disposal activity at an indicative location in the Offshore Array

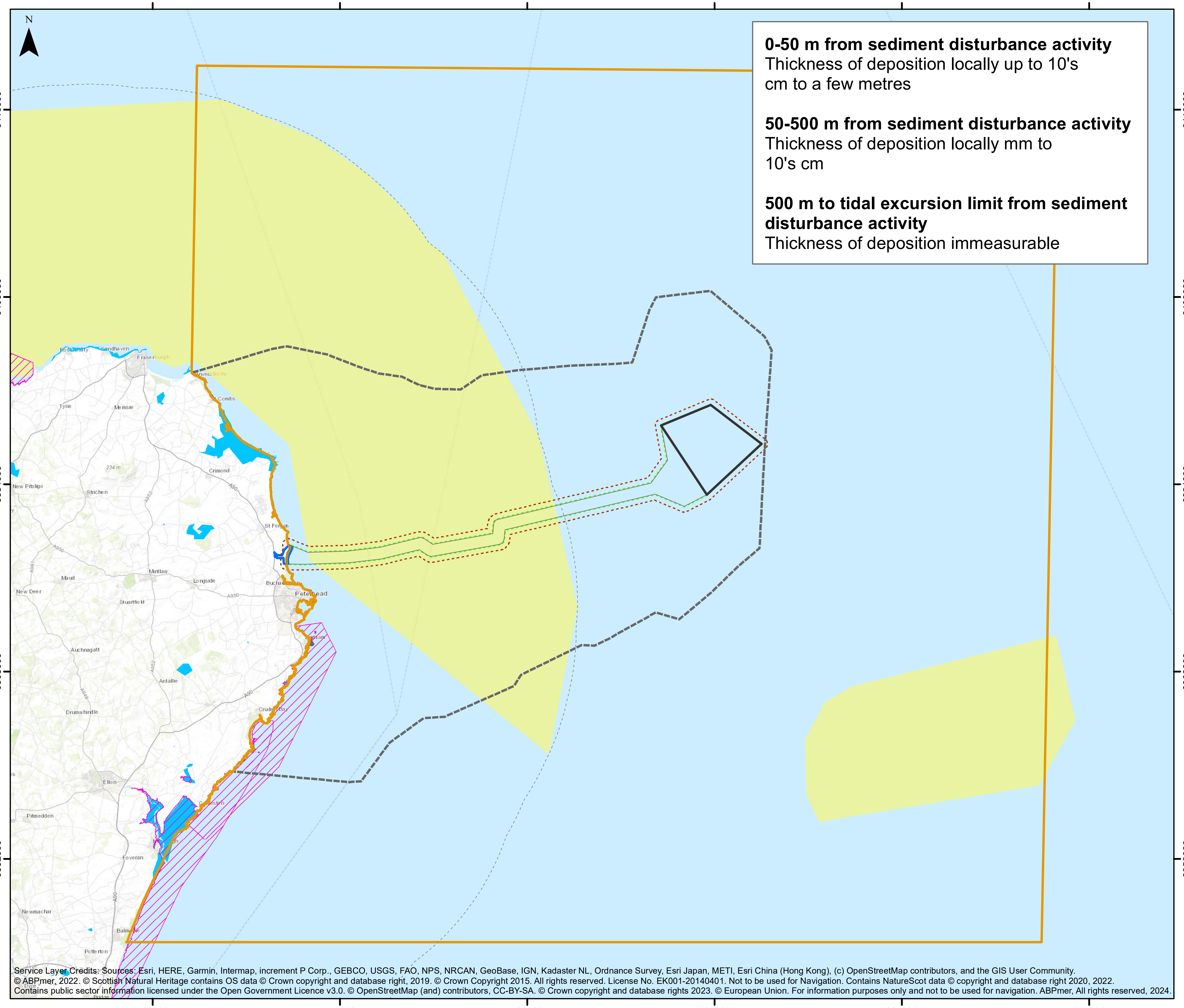
Area. The 0 to 50 m and 50 m to 500 m footprints are based on a representative current speed of 0.5 m/s. Assuming a higher value (such as for locations closer inshore) will increase dispersion in the near to medium field (0 to 50 m and 50 m to 500 m), proportionally decreasing SSC and the thickness of subsequent deposits and *vice versa*.

7.11.2.10 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 already affected (i.e. sediment is disturbed within a sediment plume from an upstream location). The change in SSC will not be additive if the affected areas only meet or overlap following advection or dispersion of the upstream effects. Effects on sediment deposition will be additive if and where the footprints of the deposits overlap.

Significance of Effect

7.11.2.11 The assessment set out in this section has considered potential changes to pathways, rather than impacts on receptors. Accordingly, no assessment of significance is provided. However, the potential for these changes to impact other EIA receptor groups is considered elsewhere within the EIAR, in particular:

- **Volume ER.A.3, Chapter 8: Water and Sediment Quality;**
- **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology;**
- **Volume ER.A.3, Chapter 10: Fish and Shellfish Ecology;**
- **Volume ER.A.3, Chapter 13: Commercial Fisheries;**
- **Volume ER.A.3, Chapter 17: Marine Archaeology and Cultural Heritage; and**
- **Volume ER.A.3, Chapter 18: Other Users of the Marine Environment.**

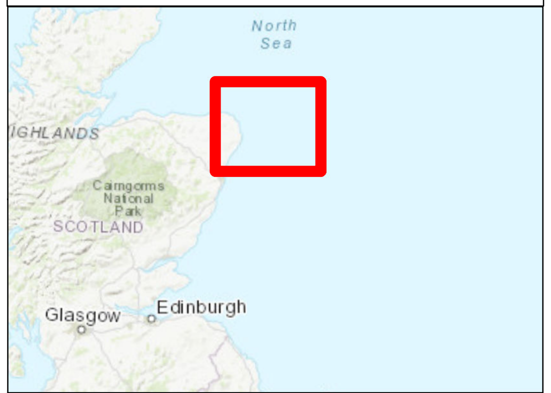


Salamander

Figure 7-22
Spring tidal excursion buffer, 50 m and 500 m buffers

Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Study Area
- 12 nm limit
- Salamander Spring Tidal Excursion Buffer
- Array 50 m Buffer
- Array 500 m Buffer
- Indicative Onshore development area
- Special Protection Area with Marine Component
- Site of Special Scientific Interest
- Marine Protected Area



Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW

Scale @ A4 : 300,000

0 3.75 7.5 15 Kilometers
0 2 4 8 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Spring tidal excursion buffer, 50 m and 500 m buffers outside of the Offshore Export Cable Corridor and Offshore Array Area
Doc. No : SWF01ER0376
Created by : BO
Checked by : IW
Approved by : SS

SALAMANDER
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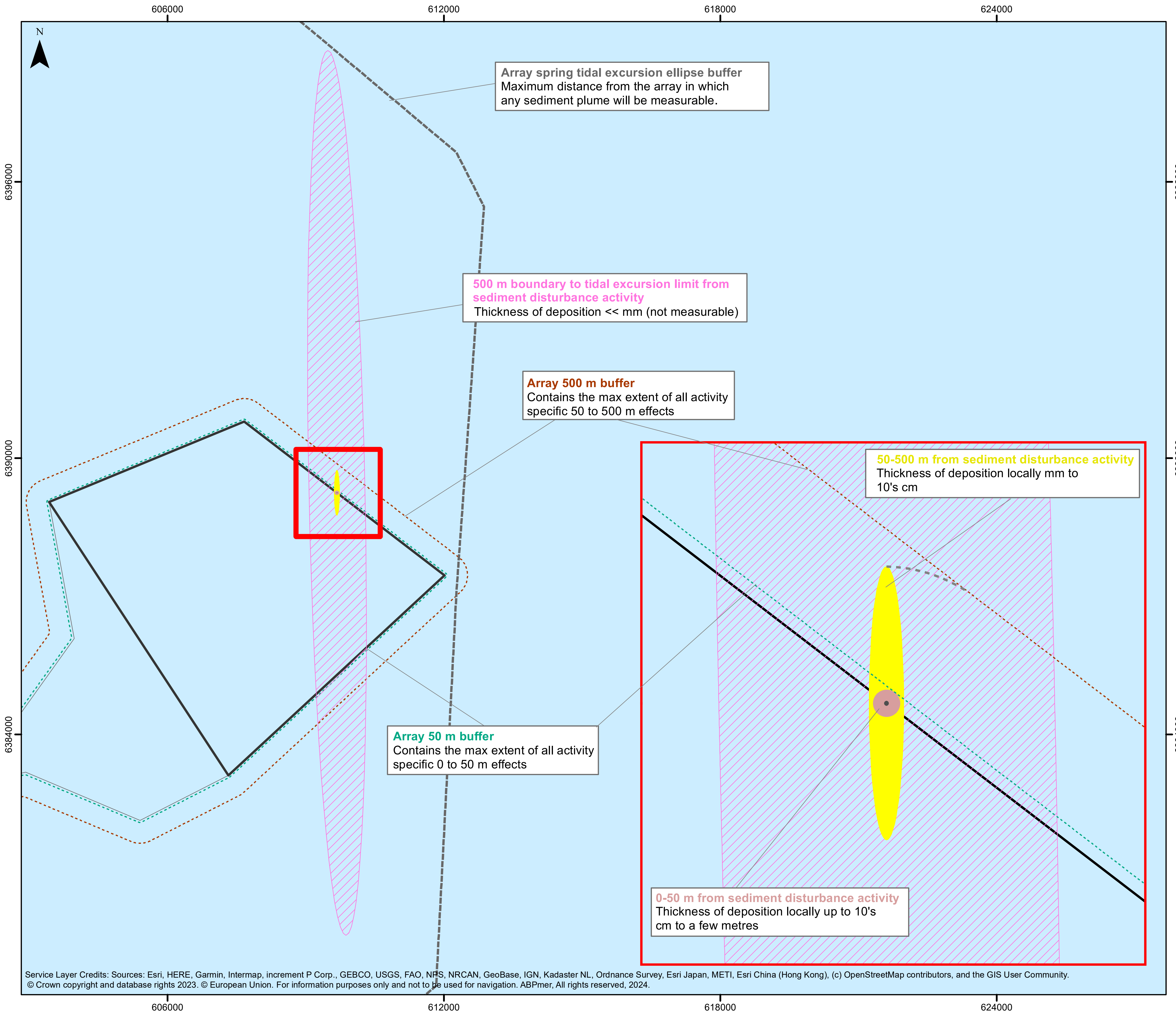

Salamander

Figure 7-23

Sediment deposition footprints - installation of a single foundation

Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Array 50 m Buffer
- Array 500 m Buffer
- Activity Sediment Release Location
- Activity 50 m Buffer
- Activity 500 m Buffer
- Activity Tidal Excursion Ellipse Maximum Zone of Influence
- Salamander Spring Tidal Excursion Buffer
- 12 nm limit

Coordinate System: WGS 1984 UTM Zone 30N
Vertical Datum : MLLW

Scale @ A4 : 75,000

0 0.75 1.5 3 Kilometers

0 0.5 1 2 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

Doc. Title : Sediment deposition footprints associated with installation of a single foundation at an example location in the Offshore Array Area
Doc. No : SWF01ER0377
Created by : BO
Checked by : IW
Approved by : SS

SALAMANDER
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Potential Changes to Sediment Transport System by Changes in Wave and Current Climate

Overview

7.11.2.12 The installation of cable protection, floating turbines, subsea hubs and/or the presence of anchoring structures all have the potential to result in a localised blockage of waves, tides and sediment transport. This blockage will commence when offshore construction begins, increasing incrementally up to the Design Envelope, which is represented by the fully operational Salamander Project. Offshore construction is expected to commence in 2027 at the earliest and has a window of 2.5 years, however, construction will only take place over a period of 18 months (excluding pre-construction surveys). Pre-construction surveys will occur prior to the 18 month construction period.

7.11.2.13 All changes to sediment transport systems due to modification of the wave and current climate will be no greater than that identified for the operational phase and, therefore, are discussed in **Sections 7.11.3.19** and not considered further here.

Potential Changes to the Morphology of the Seabed (including Scour)

Overview

7.11.2.14 Cable installation, as well as the installation (and subsequent presence) of cable protection measures, subsea hubs and anchoring structures all have the potential to impact seabed morphology. This impact will commence when offshore construction begins, increasing incrementally up to the Design Envelope, which is represented by the fully operational Salamander Project. However, morphological change arising from the installation and presence of these structures will be no greater than that identified for the operational phase and, therefore, is discussed in **Sections 7.11.3.2 to 7.11.3.14** and not considered further here.

7.11.2.15 In addition to the above, some levelling of sandwaves may be necessary during the construction phase, which has the potential to alter the local seabed morphology within the Offshore Development Area. This would be achieved by MFE or dredging (**Table 7-15**), although it is noted that any sediment removed from the seabed would, preferentially, be deposited in close proximity to the dredge location. The potential extent of change and likely timescales over which sandwave feature recovery may occur is considered further in this section. It is noted here that levelling of moraines cannot be ruled out at this stage; however the potential location, footprint and volume of any dredging activity is unknown at this stage.

7.11.2.16 Finally, where dredging is required, material will be disposed of nearby on the seabed. These disposal events may leave mounds which locally change the morphology of the seabed and (depending on the nature of the material and local hydrodynamic setting) may persist in time. The persistence and evolution of these mounds is considered in this section.

Conceptual Understanding of Change

7.11.2.17 **Installation of cables:** Cables may be buried into surficial sediments or more consolidated Quaternary material. Once buried, the cables will not have any potential to impact seabed morphology unless exposed. Should this occur, the maximum depth of scour will be between one and three times the cable diameter (i.e. up to ~1 m) and the maximum horizontal extent of any scour effect will be up to 50 times the cable diameter i.e. up to ~15 m).

7.11.2.18 In theory, cables may be installed into moraines which are protected geodiversity features within the Southern Trench MPA. However, based on existing mapping of geodiversity features within the Southern Trench MPA (NatureScot, 2019), at present, no classified moraines are defined along the section of the Offshore Export Cable Corridor within the MPA boundary (**Figure 7-15**). Even if moraines are found to be present, the localised nature of any works will be small relative to the size and extent of features and overall favourable condition should be maintained, according to the criteria set out in **Sections 7.10.7.10**. A full assessment of the potential significance of effect on the Conservation Objectives of the Southern Trench MPA designation is assessed in **Volume ER.A.4, Annex 9.4: Benthic Features Impact Assessment Southern Trench MPA**.

7.11.2.19 **Sandwave levelling:** The maximum total volume of material which may require removal from the Offshore Array Area is 1,624,000 m^3 (for offshore inter-array cables) and 48,600 m^3 (for anchors), whilst the corresponding figure for the Offshore Export Cable Corridor is 5,576,000 m^3. The volume of material to be displaced from individual sandwaves will vary according to the local dimensions of the sandwave (height, length and shape) and the level to which the sandwave must be reduced (also accounting for stable sediment slope angles and the capabilities and requirements of the cable burial tool being used). Based on the available geophysical data, it is anticipated that the bedforms requiring localised levelling are likely to be up to 3 m in height in the Offshore Array Area and 5 m in the Offshore Export Cable Corridor. Indicative locations of sandwave fields within the Offshore Development Area are shown in **Figure 7-15**; the exact location of sandwaves which may require levelling is not yet known.

7.11.2.20 The sediments comprising the sandwave features will be predominantly sand, although a small proportion of fines and gravel may, potentially, also be present. Individual sandwaves will require removal via MFE or by multiple dredging cycles to complete the required corridor. If dredging is undertaken, the preference is for the dredge spoil to be returned to the seabed in the vicinity of the dredged area. Given that surficial sediment cover is limited in many areas (**Figure 7-10**), maintaining the local total sediment volume will enable levelled sandwaves to reach a new equilibrium which is as similar as possible to the pre-levelled feature. The equilibrium position should also be reached more quickly than if the material was removed from the system.

7.11.2.21 The tidal current regime (peak current speeds on a mean spring tide of 0.5 to 0.8 m/s within the Offshore Array Area and 0.8 to 1.1 m/s along the Offshore Export Cable Corridor) is sufficiently strong at and around each location to cause mobility of sand on a regular basis. The tidal current regime will not measurably change as a result of the localised levelling, or as a result of any other aspect of the Salamander Project. The volume of sediment available in each local system will be locally redistributed by the local levelling (via MFE) and/or dredging, and disposal of removed material back into the water column nearby, but will not change in an overall net sense. As the controlling factors will also not change, the levelled areas and sandwave features will recover in time to a new (dynamically evolving) natural state.

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

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

- In the Offshore Array Area: sediments are mobile (up to 0.036 m^3/m/hr during peak spring tidal currents), but with no or very slow rates of bedform migration (<1 m/yr) due to relatively symmetrical flood and ebb transport patterns (see **Figure 7-16** for supporting evidence);
- In the Offshore Export Cable Corridor: sediments are increasingly mobile towards the coast (up to 0.36 to 3.6 m^3/m/hr during peak spring tidal currents);

- The width of the dredged corridor (<40 m);
- The wavelength of the features (in the order of 200 m);
- The (potentially) relatively large volume of sediment being displaced due to the large height (up to ~ 5m) of some sandwave features; and
- Where the dredge spoil is returned to the seabed in the vicinity of the dredged area, the volume and supply of sediment in the local system will not be changed.

7.11.2.24 The exact timescale for recovery cannot be calculated with certainty. Based only on the overall rate of observed bedform migration (which is not the main or only mechanism for recovery and is proportional to the long-term net sediment transport rate), the timescale for recovery may be in the order of many decades. This is based on the very low (<1 m/yr) observed rates of bedform migration in the Offshore Development Area. However, short-term sediment mobility will also contribute to local sandwave recovery, and these rates are expected to be higher than negligible in these areas.

7.11.2.25 A shorter estimated timescale is obtained when considering the instantaneous rate of transport during higher flow periods. As shown by the detailed sand transport modelling, instantaneous transport rates (increasing from the Offshore Array Area along the Offshore Export Cable Corridor) of 0.036 to 3.6 m^3/m/hr may be active up to four times per day (peak flood and ebb) for a few days either side of the peak of spring tides. At a representative rate of 0.5 m^3/m/hr, and assuming a representative 40 m wide corridor and a nominal volume of 25,000 m^3 sediment displaced for an individual sandwave, it could take in the order of (25,000 m^3 / [1 m^3/m/hr x 40 m x 4 hr/day x 4 days]) 78 spring tidal cycles (~3.2 years) to move the displaced volume of sediment back into the levelled area. The overall rate of recovery would also vary in proportion to the volume displaced (relative to the representative value of 25,000 m^3).

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

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

7.11.2.28 The levelled areas are not considered likely to create a barrier to onward sediment transport. Evidence from aggregate dredging activities indicates that if any changes occur to the flow conditions or wave regime, these are localised in close proximity to the dredge pocket (with widths and lengths of several kilometres) (e.g. AODA, 2011; TEDA, 2011). The proposed works will be at a much smaller scale and footprint, with trench widths expected to be in the order of up to 40 m. This means there is likely to be little to no influence on the flow or wave regime in the surrounding area which, in turn, means little to no change to the regional scale sediment transport processes across the Offshore Development Area.

7.11.2.29 **Disposal mounds**: Levelling of sandwaves (and potentially moraines) via dredging are likely to be associated with the formation of disposal mounds adjacent to the dredged areas, following the release of material from the hopper. The persistence and evolution of these disposal mounds in either the Offshore Array Area or Offshore Export Cable Corridor 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).

7.11.2.30 Arguably the most important of these is the type of material in the mound and this is expected to differ markedly, depending upon whether the dredged material originates from sandwaves (comprising sand) or moraines (likely comprising consolidated boulder clay).

7.11.2.31 It can reasonably be assumed that any disposal mounds comprised of material dredged from moraines (boulder clay) will become semi-permanent or permanent seabed features that persist for the lifetime of the Salamander 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, any mounds could reasonably be expected to be up to a few metres in height and a few tens of metres in diameter. 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.

7.11.2.32 It is noted however, that whilst the disposal mounds might be topographically different from the surrounding seabed, their surficial sediment character may become similar. This is because surficial (sandy) sediment is limited or absent in many areas. This mobile sand would likely be transported onto the disposal mound, creating a similar surficial seabed type and smoothing local topography over time.

7.11.2.33 In those areas where disposal mounds are comprised largely of sandy material (i.e. derived from sandwaves) similar in character 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.

Significance of Effect

7.11.2.34 The Offshore Export Cable Corridor passes through the Southern Trench MPA and cable installation (possibly as well as sandwave levelling) will be undertaken inside the boundary of the MPA. The site is of national importance and the geodiversity features of interest are relict (subglacial tunnel valleys, moraines and scars evidencing mass movement) with no ability to recover from impact. Accordingly, the site is assessed to be of **High** sensitivity.

7.11.2.35 The magnitude of impact to the designated seabed features (moraines) resulting from cable trenching activities would be negligible. This is because although it is recognised that impacts would be permanent, they would be extremely localised and impact an extremely small proportion of the total footprint of the feature.

7.11.2.36 The magnitude of impact to moraines within the Southern Trench MPA as a result of any sandwave levelling is also considered to be **Negligible**. This is because partial removal of sandwaves would not disturb the underlying moraines upon which they would be located.

7.11.2.37 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity (**High**) and impact magnitude (**Negligible**), as shown in **Table 7-18**. The result is a **Negligible** effect and, therefore, **Not Significant**.

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

Potential Changes in Morphology of the Coast

Overview

7.11.2.39 The offshore export cable(s) will make landfall between Lunderton and Kirkton, just to the north of Peterhead (**Figure 7-1**). Full details of the Design Envelope parameters are provided in **Table 7-15**, whilst a full description of coastal characteristics (including observed historic change and existing management policies) are set out in **Sections 7.7.1.46 to 7.7.1.50**. The assessment below separately considers the potential for impacts associated with:

- Trenchless installation techniques; and
- Construction of exit pits.

7.11.2.40 The potential for impacts to coastal morphology arising from the use of cable protection measures during the operational phase is assessed in **Sections 7.11.3.35 to 7.11.3.45**.

Conceptual Understanding of Change

7.11.2.41 **Trenchless installation techniques**: The coastline within the landfall area is characterised by the presence of a sandy beach backed by an (undefended) dune complex. The available evidence suggests that the coastline is stable; however, modest erosion is anticipated over the lifetime of the Salamander Project in response to climate change and sea level rise (**Section 7.7.2**).

7.11.2.42 As stated in **Volume ER.A.2, Chapter 4: Project Description**, the Salamander Project is currently considering a number of trenchless landfall techniques, including Horizontal Directional Drilling (HDD) which is an established solution for trenchless installation and one of the most commonly used forms for this type of operation. HDD involves drilling a long borehole underground, using a drilling rig located within the landfall compound. This technique avoids interaction with surface features and is used to install ducts through which cables can be pulled. HDDs can vary in length depending on the ground conditions: the maximum length proposed for the Salamander Project is ≤2,500 m, with a burial depth of 5 to 40 m.

7.11.2.43 Trenchless cable installation 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 point, there is no possibility for it to interact with, or have any effect on, nearshore beach processes or morphology. The design of the trenchless operations will take this into account.

7.11.2.44 The choice of location for the onshore trenchless operation works and jointing bay will take into consideration projected rates of coastal erosion to ensure that infrastructure is unaffected by the possibility of coastal retreat.

7.11.2.45 **Construction of exit pits:** As the trenchless installation is carried out between a start and end point, entry and exit pits (up to two) must be excavated at either end of the borehole: one in the landfall compound and one on the offshore side. The exit will occur no closer than 200 m below MHWS.

7.11.2.46 The dimensions of the exit pits will be up to 10 m wide, 50 m long and 5 m deep. This corresponds to a total volume of excavated material of approximately 2,500 m^3 for each exit pit, and approximately 5,000 m^3 in total.

7.11.2.47 Exit pits will be excavated or dredged to the required depth, and side-cast material for backfilling will be stored adjacent to the exit pit. Once the drilling operation has taken place, the ducts will be installed in the drilled holes.

7.11.2.48 Once installation is complete, the exit pits will either be backfilled using side-cast material or left to naturally backfill. If the exit pits remain open during winter months, there will be a high likelihood that the material comprising the spoil mounds will be at least partially redistributed offshore and across the beach during storm events.

<u>Significance of Effect</u>

7.11.2.49 Using the criteria presented in **Table 7-16**, the coastline is of **Medium** sensitivity/importance, since it is typically a dynamic environment which is subject to natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance and accommodate change.

7.11.2.50 Based on the criteria set out in **Table 7-17**, the magnitude of change to the beach at the landfall is assessed to be **Low**.

7.11.2.51 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity (**Medium**) and impact magnitude (**Low**), as shown in **Table 7-18**. The result is a **Minor** effect, and therefore **Not Significant**.

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

7.11.3 Operation and Maintenance

7.11.3.1 Under the operation and maintenance phase, the following potential impacts have been assessed:

- Potential changes to sediment transport system by changes in wave and current climate;
- Potential changes to the morphology of the seabed (including scour);
- Potential changes in morphology of the coast; and
- Potential changes to water column processes (mixing and stratification).

Potential Changes to Sediment Transport System by Changes in Wave and Current Climate

<u>Overview</u>

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

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

7.11.3.4 The potential for cable protection to cause changes to coastal morphology at the landfall are assessed separately later in this section (**Sections 7.11.3.35** to **7.11.3.45**).

Conceptual Understanding of Change

7.11.3.5 **Installation of cable protection within the Offshore Array Area and along the Offshore Export Cable Corridor:** Cable protection might be applied to (up to) 20% of inter array cables (≤7 km) and up to 20% of the Offshore Export Cable (≤17 km total). Exact locations where cable protection may be required are presently unknown. The protection will most likely take the form of a rock berm, with a crest height of up to 1.5 m.

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

7.11.3.7 The seabed in this region shelves relatively steeply away from the coast, such that water depths are around 20 m below LAT at a distance of ~1 to 2 km offshore. At this distance offshore (and in deeper areas of the Offshore Development Area found to the east of here):

- The cable protection height (max. 1.5 m) is only a small proportion of the total water depth. On the limited occasions, during large storm events, when waves are sufficiently large to interact with the berm, it is still unlikely that the berm will present a sufficient obstacle to cause changes to their size or direction;
- The long axis of any potential berm may be more or less aligned to, or perpendicular to, the main tidal current axis, depending on exact location within the Offshore Array Area or along the Offshore Export Cable Corridor. However, the cable protection height (max. 1.5 m) is a very small proportion of the total water depth and so, together with the sloped sides of the berm, will present a minimal obstruction to tidal currents (no measurable effect more than a few tens of metres from the berm and restricted only to the near bed);
- The berm axis also, therefore, may lie across the natural sediment transport pathways, which may present some obstruction to sediment transport as bedload (sediment transport in suspension will not be affected);
- An initial period of sediment accumulation may occur within and around the berm, as a limited volume of sediment in bedload transport is trapped within any open surface voids. A surface accumulation of sediment may develop over the updrift side (appearing similar to a groyne on a beach). The volume of sediment accumulated will vary in proportion to the size of the voids and so the clast size used, and will likely vary by location across the Offshore Development Area, in response to sediment availability and transport rate (see **Sections 7.7.1.37** to **7.7.1.41**). When sufficient sediment volume has been accumulated on the updrift surface to present a naturally stable sediment slope and surface, sediment transport will thereafter continue over the berm at the natural ambient rate and direction;

- No measurable change to the seabed is expected more than a few metres from the updrift edge of the berm. A small local depression (scour) of proportionally small dimensions (i.e. a few tens of centimetres depth and within a few metres of the berm edge) may form on the downdrift side of the berm as a result of the temporary reduction in sediment supply during the initial accumulation process;
- The patterns and dimensions of sediment accumulation or scour may vary over the operational lifetime of the berm, due to natural fluctuations in sediment supply and transport rates and directions. Changes may be seasonal or episodic in nature (e.g. during or following larger storms, then gradually returning to another state associated with purely tidal conditions); and
- The nature of the seabed (sediment type and texture) around the berm, including within any areas of local accretion or scour, is not expected to be measurably very different to the surrounding seabed.

7.11.3.8 In shallower areas (<20 m below LAT):

- The installation of cable protection measures could (depending upon sediment availability) result in an initial accumulation of sediment against the berm, in exactly the same way as described for offshore areas (above). As with the installation of rock protection in deeper offshore areas, the presence of the rock protection is not expected to result in a permanent long-term change in the rate and/or direction of sediment transport across nearshore areas;
- If rock protection were to be installed in nearshore areas, for the majority of the time, and in all but the shallowest locations, waves are unlikely to interact with, or be affected by, the small and localised relative change in total water depth; and
- At lower states of the tide and during storm conditions, it is theoretically possible that some wave breaking could occur if rock protection were to be installed in very shallow (~0 to 5 m below LAT) subtidal locations. However, the potential for wider morphological change across nearshore areas resulting from any associated short-term change in sediment transport is considered to be limited, owing to the scale of the rock protection proposed. The potential for morphological change will also be highly dependent upon the presence of surficial (mobile) sediment. Where absent (i.e. with rock exposed at the seabed), minimal/ no change will be expected to occur.

7.11.3.9 **Presence of floating substructures**: The effect of the substructures on tidal currents within the Offshore Array Area will be to locally reduce current speed and increase turbulence in a narrow wake behind each foundation (which are up to 140 m wide, with a draught in the range of 10 to 24 m in the case of semi-submersible foundations; and 125 m wide, with a draught in the range 15 to 40 m for tension leg platforms).

7.11.3.10 Currents passing underneath the foundations will not be directly affected by the main structure but will interact to a much lesser extent with the relatively small local blockage presented by the mooring lines (up to eight per foundation, 0.30 m diameter) and electrical cable (8 no in total; 0.32 m diameter) with buoyancy modules between the base of each foundation and the seabed. The majority of the mooring line length will be on the seabed and so will not interact with currents. The majority of any pile, gravity or suction caisson anchors, and the entirety of any embedment anchors, will be buried, and so will not interact with currents. However, the top 5 m of gravity base (13.5 m diameter) and 3 m of either suction caisson (7 m diameter), or drilled /driven piles (3 m diameter) may remain above the seabed and so may interact locally with currents.

7.11.3.11 Chain links and clump weights, anchor pile tops, and cable protection that are above seabed and interact with nearbed currents may result in local flow patterns and seabed scour effects (considered in **Sections**

7.11.3.23 to 7.11.3.29) but are, individually, of relatively small scale and so are unlikely to cause a change in overall patterns of flow or sediment transport through the Offshore Array Area. Measurable effects on currents are, therefore, likely to only be associated with the main floating substructures, and so largely confined to surface and near surface waters. Therefore, any change to currents caused by individual foundations, or the array, will have no consequential effect on the overall rate or direction of sediment transport at the seabed.

7.11.3.12 The surface and upper water column wake features behind each column of the floating substructures may remain separate or may coalesce depending on the relative angle of the current to the foundations individually, and to the array as a whole. Overlapping wake features may become slightly more pronounced, but will recover in the same manner and will also have a smaller overall extent. The wake features/effects will recover rapidly with distance downstream, likely becoming not measurable within a few hundreds of metres (less than the distance between the floating foundations, which will be a minimum of 1 km apart). The maximum theoretical distance to which any (cumulative) effect might propagate from the Offshore Array Area is, in any case, limited to one tidal excursion distance (the distance over which water is displaced during one flood or ebb tidal cycle, approximately 8 to 10 km in the Offshore Array Area on a mean spring tide, or half this distance on a mean neap tide), as shown in **Figure 7-22**). In reality, measurable change to currents will be restricted to a far smaller area than this (likely extending no more than a few hundreds of metres outside of the boundary of the Offshore Array Area.

7.11.3.13 The local effects of the floating substructures on waves will be limited to an area downwind of the Offshore Array Area, to a distance up to approximately the width of the site (relative to the wave coming direction). Since the dominant wave directions within the Offshore Array Area are from the north and south (**Figure 7-4**) the greatest changes to the wave regime will generally be observed to the north and south of the array. Beyond a distance equivalent to the approximately the width of the Offshore Array Area, the seastate will recover to the ambient condition through natural spreading and dispersion of wave energy (see other offshore wind farm impact modelling studies including Navitus Bay Development Ltd, 2014; Awel y Môr Offshore Wind Farm Ltd, 2022; Five Estuaries Offshore Wind Farm Ltd, 2023). Any blockage related changes to waves will therefore not extend to the adjacent coast which is circa 35 km to the west of the Offshore Array Area.

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

7.11.3.15 **Subsea electrical hubs**: Subsea electrical hubs mainly comprise a flat base plate (up to 15 m x 15 m area) resting on the seabed and a centrally mounted junction box (a narrow elongated approximately square cross-section, up to 10 m high above the seabed). A roof may be designed to allow for protection from dropped objects and/or fishing equipment, the exact design is unknown. Inter-array Cables will enter the hub(s) , with a short suspended catenary section between the adjacent seabed and an elevated entry point on the sides of the junction box. Up to two export or interconnector cables will also exit at a low level from one end of the junction box. Additional weight might be added to the base plate to stabilise the structure on the seabed, and/or additional scour protection might be applied around the edges of the base plate and/or on the various cables up to 500 m from the hub (see section above on Installation of cable protection – **Section 7.11.3.20** et seq.).

7.11.3.16 The effect of the subsea electrical hubs on tidal currents within the Offshore Array Area will be to locally reduce time mean current speed and increase turbulence in a narrow nearbed wake. The wake features/effects will recover rapidly with distance downstream, likely becoming not measurable within a few hundreds of metres behind each unit. Close to the hubs, the wake effects may result in local seabed scour effects (considered in **Sections 7.11.3.23** et seq.). Currents passing more than a few metres over the subsea hubs will not be directly affected. The small height of the structure (10 m above seabed) is only a small proportion of the overall water depth (87 to 110 mLAT) and so no measurable changes to current speed or direction are expected anywhere in the upper ~85% of the water column. Localised changes to currents are therefore unlikely to have any consequential effect on the rate or direction of sediment transport within the wider Offshore Array Area.

7.11.3.17 The subsea hubs will have no measurable effect on surface waves, due to the small height of the structure (10 m above seabed) relative to the overall water depth (87 to 110 mLAT), and so are unlikely to have any consequential effect on the rate or direction of sediment transport.

Significance of Effect

7.11.3.18 The changes described in this section on the sediment transport system by changes in wave and current climate (and summarised in **Table 7-19**) are to 'pathways' as opposed to receptors. The significance of potential impacts to Marine Physical Processes receptors arising from modification of the sediment transport regime is considered within **Sections 7.11.3.19** onwards.

Table 7-19: Summary of sediment transport impacts via key Salamander Project infrastructure (Operational Phase)

Project Component	Location	Summary of Potential Impact on Tidal Currents, Waves and Associated Sediment Transport Processes
Inter-array/export cable protection	Offshore Array Area and Offshore Export Cable Corridor (in water depths >20 m below LAT)	Changes in sediment transport extending (up to) 10's of metres from cable protection. Water depths too great for cable protection measures to measurably alter the passage of waves and tides.
Export cable protection	Water depths <20 m below LAT)	Localised changes to waves and hydrodynamics immediately within the vicinity of the rock berms, but associated morphological change limited by the small scale/low profile of the rock protection.
Floating substructures (and associated anchors) and subsea hubs	Offshore Array Area	Wake effects extending (up to) hundreds of metres from substructures and associated mooring/anchor systems and subsea electrical hubs. Associated changes in sediment transport theoretically possible in this footprint, mainly in the form of local scour.

Project Component	Location	Summary of Potential Impact on Tidal Currents, Waves and Associated Sediment Transport Processes
		Scour around gravity base, suction caisson or drilled pile anchors and subsea electrical hubs, extending (up to) several metres from the structure.

Potential Changes to the Morphology of the Seabed (including Scour)

Overview

7.11.3.19 This section describes impacts to seabed morphology, focusing on areas within designated sites arising from changes to sediment transport associated with the presence of cables, cable protection, anchoring systems, subsea hubs and the floating foundations during the operational phase. Seabed areas within the Southern Trench MPA – see **Figure 7-1** for location – are given particular consideration within this assessment.

Conceptual Understanding of Change

7.11.3.20 **Installation of cable protection:** the presence of cable protection berms during the operational phase has the potential to cause changes to the local seabed level (scour) as a result of local flow interaction between the body and surface of the berm, and any nearbed current and wave action. The potential for cable protection to cause larger scale changes to the tidal, wave or sediment transport regimes is very limited, as discussed in **Sections 7.11.3.2** to **7.11.3.8**.

7.11.3.21 The purpose of cable protection is to maintain stable cover over the lifetime of the Salamander Project. By design, it aims to minimise the risk of scour associated with both the cable and the protection itself. The low overall height of the rock berm relative to the water depth, along with relatively shallow gradient side slopes will limit the potential for form-related flow disturbance and scour, even when flows are perpendicular to the berm. The individual rock armour units that comprise the berm are expected to be up to a few 10's of centimetres diameter. Turbulence may become locally elevated in water flowing close to the surface of the berm, which may result in a limited depth and extent of secondary scour (this could be of the order of a few tens of centimetres deep and up to a few metres from the berm where material is unconsolidated but far less in areas where mobile surficial material is absent and more erosion resistant Quaternary material is present (**Figure 7-10**)).

7.11.3.22 The seabed surface in the scoured area will generally be similar to the surrounding seabed, but may develop an overall slightly coarser texture due to preferential winnowing of finer sediment grains over time. This is most likely to occur where gravelly sands are present: on the basis of the project-specific geophysical survey data (Ocean Infinity, 2022a), these sediments are encountered within central and western areas of the Offshore Array Area and along the Offshore Export Cable Corridor (**Figure 7-9**).

7.11.3.23 **Presence of subsea electrical hubs:** the presence of up to two subsea electrical hubs during the operational phase has the potential to cause changes to the local seabed level (scour) within the Offshore Array Area as a result of local flow interaction between the body of the hub, and any nearbed current and wave action.

7.11.3.24 The overall design of the subsea hub aims to minimise scour, which would otherwise be a risk to its long term on-bottom stability. The base plate acts as the primary scour protection, largely preventing the development of local scour as a direct result of the main obstacle presented by the junction box and suspended cables. Turbulence may become locally elevated in water flowing over the hub, over the edges of the base plate, and around the suspended sections of cable where they meet the surrounding seabed, which may result in a limited depth and extent of local secondary or wider dishpan scour. Such scour is realistically estimated to be of the order of a few tens of centimetres to one metre deep and extending up to ten metres from the edges of the base plate if and where seabed sediments are sufficiently thick and erodible (i.e. thicknesses of sandy material more than the potential scour depth). Scour dimensions are likely to be relatively reduced from these estimates in areas where erodible seabed sediments are thin, or where the seabed surface comprises more erosion resistant Quaternary material (**Figure 7-10**)).

7.11.3.25 The seabed surface in the scoured area will generally be similar to the surrounding seabed, but may develop an overall slightly coarser texture due to preferential winnowing of finer sediment grains over time. This is most likely to occur where gravelly sands are present: on the basis of the project-specific geophysical survey data (Ocean Infinity, 2022a), these sediments are encountered within central and western areas of the Offshore Array Area and along the Offshore Export Cable Corridor (**Figure 7-9**).

7.11.3.26 **Presence of floating turbines and associated mooring/anchoring systems:** the presence of the floating foundations during the operational phase has the potential to cause changes to the local seabed level (scour) within the Offshore Array Area as a result of local flow interaction between the near-bed elements of the foundation moorings and electrical cables, and any near-bed current and wave action. The potential for the main body of the floating foundations themselves to cause larger scale changes to the tidal, wave or sediment transport regimes is very limited, as discussed in **Sections 7.11.3.9** to **7.11.3.14**.

7.11.3.27 The main body of the floating foundation is located in the upper water column and is too distant from the seabed to cause a change in the near-bed local flow field or, therefore, any local scour. If and where the moorings meet the seabed, the mooring lines may comprise large chain links with clump weights (up to 2.5 m long x 2.5 m wide x 2.5 m height). Buried sections of the mooring, will not interact at all with the local flow field and so will not cause any scour. Where mooring lines, chain links or clump weights are partially or completely exposed at seabed level, increased flow turbulence may cause local scour in proportion to the size of the object (order of a few tens of centimetres deep and up a few metres from the obstacle).

7.11.3.28 Non-buried anchors, such as exposed ends of pile anchors (<3 m diameter, ≤3 m high), suction caisson anchors (<7 m diameter, ≤3 m high) and gravity base anchors (<13.5 m diameter, ≤5 m high), may cause a greater depth of local scour in proportion to their diameter; however, the limited height of these obstacles disrupts and limits the patterns of flow acceleration that can form, reducing the likely maximum dimensions of scour to the order of a few metres depth and up to *circa* 10 m extent, which is less than would be expected from a full water column height obstacle.

7.11.3.29 A section of each mooring line may occasionally move in response to the movement of the floating foundation, resulting in a ‘swept’ area of seabed. The frequency and distance of movement for individual moorings will depend on the particular mooring configuration and the scale and direction of the force being applied to the floating foundation. The movement of the line over or through the seabed is expected to be generally slow (not causing energetic sediment resuspension) and may include both lateral and vertical movement. This action may cause a ‘ploughing’ or ‘sweeping' of sediment, redistributing sediment volume locally into linear accumulations with a maximum height proportional to the dimensions of the line and clump weights (up to 2.5 m high). The net effect may be an area of disturbed seabed morphology up to a maximum of 3,920,000 m^2 within the Offshore Array Area. Any patterns formed will be gradually redistributed to a natural state by ambient sediment transport processes over time. The nature of the seabed sediments and the rate of sediment transport through the affected area are unlikely to be changed by this process.

<u>Significance of Effect</u>

7.11.3.30 It is not yet known where cable protection will be required but could potentially be installed within the boundary of the Southern Trench MPA. The site is of national importance and the geodiversity features of interest are relict (subglacial tunnel valleys, moraines and scars evidencing mass movement), meaning no potential for recoverability. Accordingly, it is considered to have a moderate capacity to accommodate this change and is assessed to be of **High** overall sensitivity.

7.11.3.31 The magnitude of impact to the seabed within the Southern Trench MPA resulting from the presence of buried cables and cable protection is considered **Negligible**. This is because the area of rock protection proposed is very small when compared to the designated feature area and there will be no measurable change to the morphology of the seabed expected more than a few metres either side of the rock protection berm.

7.11.3.32 With regards to morphological impacts to the Southern Trench MPA arising from the presence of subsea hubs, floating platforms and associated mooring/anchor systems, impacts are expected to be negligible. This is because changes to tidal currents and waves are expected to be very small and localised. Any related changes to the surrounding seabed are expected to be difficult to discern from those which may occur under baseline conditions and will not extend to the Southern Trench MPA. The assertion that changes to hydrodynamics, waves and sediment transport will be very small in absolute and relative terms is entirely consistent with numerical modelling and observational evidence from wind farms constructed with monopiles whose total water column blockage far exceeds that of the Salamander Project.

7.11.3.33 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity and impact magnitude, as shown in **Table 7-18**. The result is a **Negligible** effect, and therefore **Not Significant**.

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

Potential Changes in Morphology of the Coast

<u>Overview</u>

7.11.3.35 This section describes potential impacts to the morphology of the coast. These could arise from changes to currents, waves and associated sediment transport (or other coastal processes) potentially caused by the presence of exposed cables and/or cable protection measures in intertidal/ nearshore areas.

7.11.3.36 Potential impacts on the morphology of the coast from other Salamander Project infrastructure further offshore (including all the infrastructure within the Offshore Array Area) have been scoped out due to the distance between any effects created by these structures and adjacent coastlines.

<u>Conceptual Understanding of Change</u>

7.11.3.37 As part of the embedded mitigation for the Salamander Project (**Section 7.8.3**), it is noted that a full CBRA will be undertaken to ensure that all cables will be buried to an appropriate depth (or surface laid and protected) to minimise the chance of exposure during the lifetime of the Salamander Project. If exposure does occur, cables will be re-buried. However, no additional protection (outside that already outlined as the realistic worst-case in **Table 7-15** and used as the basis for the assessment) will be applied. Where rock protection has been employed during the construction phase, this may be replenished during operation, as necessary.

7.11.3.38 **Presence of exposed cables:** Once the offshore export cable is buried in the (nearshore) seabed and not protected, there is no potential for cable related scour to occur. If and where the export cable becomes exposed due to natural seabed erosion, then a small, localised, area of additional scour may occur, as a result of currents interacting with the exposed part of the cable. The exact dimensions of the scour will depend on the height of the offshore export cable relative to the seabed but will be in proportion to the small diameter of the cable (up to 0.3 m diameter) and no more than described for the cable protection in **Section 7.11.3.21** (which stated scour could be up to a few tens of centimetres deep and up to a few metres from the cable protection).

7.11.3.39 **Presence of cable protection measures:** In nearshore subtidal areas, rock protection could potentially be used to protect the export cables. The exact location of the rock berms and orientation relative to the beach is presently unknown. However, given the route of the Offshore Export Cable Corridor, 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.

7.11.3.40 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 focusing on areas of the beach not presently eroding. This could result in long-term lowering in areas where surficial mobile material is present whilst localised accretion may also occur in other areas, as material is redistributed. If and where exposed bedrock platforms are present, the presence of any cable protection is not expected to lead to enhanced erosion.

7.11.3.41 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 at the landfall, especially to the upper beach and adjacent dunes is considered to be limited. This is primarily due to the fact that any rock berms would be relatively distant from the upper beach (minimum distance of approximately 100 to 250 m away from the MHWS contour) and have a relative low profile (<1.5 m), meaning the ability to trap sediment would be limited.

Significance of Effect

7.11.3.42 Using the criteria presented in **Table 7-16**, the coastline is of **Medium** sensitivity/importance, since it is typically a dynamic environment which is subject to natural change under baseline conditions. Accordingly, it is assessed to have some capacity to recover from disturbance and accommodate change.

7.11.3.43 Based on the criteria set out in **Table 7-17**, the magnitude of change to the beach at the landfall is assessed to be **Low**.

7.11.3.44 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity (**Medium)** and impact magnitude (**Low**), as shown in **Table 7-18**. The result is a **Minor** effect, and therefore **Not Significant**.

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

Potential Changes to Water Column Processes (Mixing and Stratification)

Overview

7.11.3.46 A pronounced tidal front (the Buchan front) is found in a transitional zone off Buchan and the Aberdeenshire coast, where shallower (well mixed) coastal water meets deeper, seasonally stratified North Sea water (Edwards and John, 1996) (**Figure 7-1**). Tidal fronts – and seasonally stratified shelf seas, where water density varies with depth - have an important role in primary production, marine ecosystem and biogeochemical cycling (Dorrell *et al.*, 2022).

7.11.3.47 As currents move water past the individual WTG foundations (and subsea hubs), a turbulent wake is formed. Within the turbulent wake, vertical mixing can be enhanced above ambient levels: the >20 m draft of floating foundations is large enough to penetrate the thermocline and directly mix seasonally stratified water passing in close proximity. This increase in turbulence intensity has the potential to contribute to a local reduction in the strength of vertical stratification (e.g. Carpenter *et al*., 2016; Cazenave *et al*., 2016; and Dorrell *et al*., 2022).

7.11.3.48 In addition to the potential for direct disturbance of the water column by wind farm infrastructure, it has also been suggested that atmospheric wakes associated with wind turbines have the potential to affect sea surface currents, altering the temperature and salinity distribution in areas of wind farm operation (Christiansen *et al*., 2022).

7.11.3.49 This section considers the potential for floating foundations (as well as other Salamander Project infrastructure within the Offshore Development Area) to influence regional-scale patterns of stratification via the mechanisms outlined above and any resulting change in the location of fronts. The potential for cumulative impacts to water column mixing and stratification are set out in **Section 7.13.1.17**.

Conceptual Understanding of Change

7.11.3.50 **Direct water column mixing due to the presence of sub-surface offshore wind farm infrastructure:** As described **Section 7.11.3.9** et seq, where an obstruction is introduced to a flow, complex three-dimensional interaction creates a localised narrow wake with reduced time-mean current speed and increased turbulence intensity. The most pronounced changes to the flow regime occur immediately around, but primarily downstream of, the obstruction, within approximately three times the length scale of the obstacle. The wake effect recovers towards ambient levels of time-mean flow speed and turbulence with time and distance downstream. The potential for turbine foundation wakes to enhance vertical mixing and decrease stratification within the water column is discussed below.

7.11.3.51 The potential impacts of WTG foundations on shelf sea stratification have been the focus of a number of recent academic investigations and have also been reviewed in detail by Dorrell *et al.* (2022) with the findings summarised below. (It is noted that there are ongoing studies into the interaction of offshore infrastructure and vertical stratification, including that being commissioned by the Offshore Wind Evidence and Change programme. However results are not yet available.)

7.11.3.52 To date there have been only two studies observing offshore wind foundation induced mixing of stratified waters (Floeter *et al.*, 2017; Schultze *et al.*, 2020). These studies have looked at developments in intermittently stratified regions of freshwater influence, in shallow water. Neither study has investigated the potential impacts on (deeper) seasonally, or permanently, stratified shelf seas, such as that which characterises the Study Area. Floeter *et al.* (2017) performed surveys on two wind farms in the German Bight, North Sea. Water property transects through the wind farms revealed a consistent weakening of stratification near the centre of the wind farm arrays, with effects extending into the surrounding area by approximately half the diameter of an ambient tidal excursion. However, it was not possible to determine how much of the observed change was due to "*infrastructure*" turbulence from turbine foundations rather than natural topological effects.

7.11.3.53 Field measurements were also taken by Schultze *et al.* (2020) who measured the wake from an offshore monopile at the DanTysk wind farm. The survey demonstrated that turbulence generated by monopiles reduces stratification; with pre-monopile (baseline) conditions not fully observed at the survey limit - a distance of 300 m from the (6 m diameter) monopiles.

7.11.3.54 Carpenter *et al.* (2016) used an idealised (conceptual) numerical model of structure induced turbulent mixing, in conjunction with existing environmental hindcast data, to consider the potential for large scale change to stratification of the German Bight region of the North Sea in response to planned (fixed bottom) wind farm developments. The study shows that stratification is only gradually broken down by interaction with the wind farm. A range of "*timescale for [complete] mixing*" estimates are provided (in the order of 100 to 500 days) if the same body of initially stratified water is continually passed through the wind farm. In practice, due to non-zero residual rates of tidal advection, the same body of water will not be repeatedly passed through the same wind farm for 100 to 500 days. As a result, mixing due to the foundations will only lead to some partial reduction in the strength of stratification in water that passes through the wind farm. They conclude that no large-scale changes to stratification of the North Sea are expected at the current levels of offshore wind farm construction, and extensive regions of the North Sea would need to be covered in offshore wind farms for a significant impact on stratification to occur. The study also found that the results are sensitive to the assumed type (shape and size) of foundation structure being assessed, and to the assumptions made about the evolution of the pycnocline thickness under enhanced mixing conditions.

7.11.3.55 Cazenave *et al*. (2016) use a regional scale 3D hydrodynamic model with a number of (fixed bottom) wind farm foundations represented as small islands in the mesh. The general results of Cazenave *et al.* (2016) are that wind farm foundations may have some limited influence on the strength of stratification locally, but it does not suggest that naturally present stratification would be completely mixed by this process. It is noted that the model used in this study only considers time mean flow at a typical spatial resolution of 10 to 20 m in the horizontal plane, and more than several metres in the vertical plane. The elevation of turbulence intensity and turbulent mixing at smaller length scales in the narrow wake is important for the processes in question (as noted by Carpenter *et al*., 2016) but is only generally parameterised, and not explicitly resolved by this model, which leads to some uncertainty in the results.

7.11.3.56 Based on the available evidence, vertical stratification (and so also the presence of the Buchan Front) is expected to occur in or near to the Offshore Array Area for >120 days in the year, whereas the water column is expected to be fully mixed for >90 days in the year (van Leeuwen *et al*., 2015). When stratification is present, it is possible that the small number (up to seven) of floating foundations (and associated mooring lines and anchors) in the Offshore Array Area may cause some very minor (and highly localised) decrease in the strength of water column stratification. However, only a small proportion of water passing through the Offshore Array Area will actually interact with Salamander Project infrastructure, causing only partial and localised mixing of any stratification. Numerous repeat passes through the Offshore Array Area would be needed for an initially stratified body of water to become mixed; however, this is unlikely to happen, due to displacement of the water body out of the Offshore Array Area over shorter time periods by residual tidal currents. It is, therefore, extremely unlikely that water which is stratified entering the Offshore Array Area will become fully mixed. The location and physical characteristics of the Buchan Front will also not be affected: on the basis of the evidence presented in **Figure 7-8**, the front is typically situated *circa* 20 km to the west of the Offshore Array Area, and neither the strength of stratification nor the gradient of stratification across the front will be affected at this distance.

7.11.3.57 **Indirect water column mixing due to atmospheric offshore wind farm wake effects:** This has been investigated by Christiansen *et al*. (2022). A detailed hydrodynamic model was set up to simulate the seasonal cycle of summer stratification in the southern North Sea, with multiple wind farms in operation. The simulations show the emergence of large-scale attenuation in the wind forcing and associated alterations in the local hydro- and thermodynamics. Induced changes in the vertical and lateral flow were found to be sufficiently strong to influence the residual currents and entail alterations of the temperature and salinity distribution in areas of wind farm operation. Ultimately, these were found to affect the stratification development in the southern North Sea. In the German Bight in particular, the reduction of mixing at offshore wind farms was found to enhance stratification strength, in particular, during the decline of the period of summer stratification.

7.11.3.58 However, whilst the modelling analyses of Christiansen *et al*. (2022) provide theoretical evidence for atmospheric offshore wind farm wakes to impact water column stratification, the findings are based on the presence of a large number of wind farms with several hundred turbines in place across the model domain. In contrast, the Salamander Project is very small (up to seven turbines) and any wake effects are therefore expected to have an extremely limited aggregated spatial footprint. The potential for widespread changes in the rate of surface mixing and associated water column stratification is therefore considered to be very low.

Significance of Effect

7.11.3.59 The Buchan Front is a regional-scale oceanographic feature which supports high biological primary productivity and biodiversity. However, it is both highly dynamic and ephemeral and is therefore not considered to be vulnerable to very localised, small-scale changes in water column turbulence. The sensitivity of the receptor is therefore, considered to be **Medium**.

7.11.3.60 The magnitude of impact to the Buchan Front is considered **Negligible**. This is because it typically forms circa 20 km from the Offshore Array Area and at this distance, no measurable change to water column mixing characteristics is expected.

7.11.3.61 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity and impact magnitude, as shown in **Table 7-18**. The result is a **Negligible** effect, and therefore **Not Significant**.

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

7.11.4 Decommissioning

7.11.4.1 Under the decommissioning phase, the following potential impacts have been assessed:

- Potential increases in SSC and associated changes to seabed substrate; and
- Potential changes to sediment transport system by changes in wave and current climate.

Potential Increases in Suspended Sediment Concentration and Associated Changes to Seabed Substrate

Overview

7.11.4.2 The following decommissioning activities could potentially give rise to increases in SSC and associated deposition of material within the Offshore Array Area and Offshore Export Cable Corridor:

- Removal of WTG mooring/anchoring systems;
- Removal of the subsea hub;
- Removal of cable protection; and
- Removal of inter-array and offshore export cable from the seabed.

Conceptual Understanding of Change

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

7.11.4.4 For all of the above, the changes in SSC and accompanying changes to bed levels associated with decommissioning activities are expected to be no greater than that associated with construction. Further information is provided in the construction phase assessment (**Sections 7.11.2.2** to **7.11.2.10**).

Significance of Effect

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

- **Volume ER.A.3, Chapter 8: Water and Sediment Quality;**
- **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology;**
- **Volume ER.A.3, Chapter 10: Fish and Shellfish Ecology;**
- **Volume ER.A.3, Chapter 13: Commercial Fisheries;**
- **Volume ER.A.3, Chapter 17: Marine Archaeology and Cultural Heritage;** and
- **Volume ER.A.3, Chapter 18: Other Users of the Marine Environment** (recreation for example).

Potential Changes to Sediment Transport System by Changes in Wave and Current Climate

Overview

7.11.4.6 Cable protection, floating foundations and anchoring structures will all be (at least partially) in place during the decommissioning phase. However, they will be fully removed from the Offshore Development Area by the end of the decommissioning phase. Whilst present, these structures have the potential to result in a localised blockage of waves, tides and sediment transport. However, the number of installed structures (and, therefore, overall blockage) will be no greater than that assessed for the operational phase (see **Sections 7.11.3.2** onwards) and therefore is not considered further here.

7.11.5 Summary of Impact Assessment

7.11.5.1 A summary of the impacts and effects identified for the Marine Physical Processes assessment is outlined in **Table 7-20**.

Table 7-20 Summary of impacts and effects for Marine Physical Processes

Salamander Project Activity and Impact	Project Aspect	Embedded Mitigation	Receptor	Sensitivity	Magnitude	Significance of Effect	Additional Mitigation	Residual Significance of Effect	Significance of Effect in EIA Terms
Construction									
Potential increases in SSC and associated changes to seabed substrate	Offshore Array and Offshore ECC	N/A	N/A	N/A	N/A	Potential pathway of effect for other topics: • **Volume ER.A.3, Chapter 8: Water and Sediment Quality;** • **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology;** • **Volume ER.A.3, Chapter 10: Fish and Shellfish Ecology;** • **Volume ER.A.3, Chapter 13: Commercial Fisheries;** • **Volume ER.A.3, Chapter 17: Marine Archaeology and Cultural Heritage; and** • **Volume ER.A.3, Chapter 18: Other Users of the Marine Environment.**	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in **Table 7-14.**	[Potential pathway of effect for other topics]	N/A

Salamander Project Activity and Impact	Project Aspect	Embedded Mitigation	Receptor	Sensitivity	Magnitude	Significance of Effect	Additional Mitigation	Residual Significance of Effect	Significance of Effect in EIA Terms
Potential changes to sediment transport system by changes in wave and current climate	Offshore Array and Offshore ECC	N/A	N/A	N/A	N/A	Potential pathway of effect for other topics: • **Volume ER.A.3, Chapter 8: Water and Sediment Quality;** • **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology;** • **Volume ER.A.3, Chapter 10: Fish and Shellfish Ecology;** • **Volume ER.A.3, Chapter 13: Commercial Fisheries;** • **Volume ER.A.3, Chapter 17: Marine Archaeology and Cultural Heritage; and** • **Volume ER.A.3, Chapter 18: Other Users of the Marine Environment.**	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in **Table 7-14.**	[Potential pathway of effect for other topics]	N/A
Potential changes to the morphology of	Offshore Array and Offshore ECC	Co2, Co14, Co9, Co52 and Co30	Designated areas of seabed	High	Negligible	Negligible	No additional mitigation measures have been identified for	Negligible	Not Significant

Salamander Project Activity and Impact	Project Aspect	Embedded Mitigation	Receptor	Sensitivity	Magnitude	Significance of Effect	Additional Mitigation	Residual Significance of Effect	Significance of Effect in EIA Terms
the seabed (including scour)							this effect above and beyond the embedded mitigation listed in **Table 7-14** as it was concluded that the effect was Not Significant.		
Potential changes in morphology of the coast	Offshore Array and Offshore ECC	Co2, Co14, Co9 and Co30	The coast	Medium	Low	Minor	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in **Table 7-14** as it was concluded that the effect was Not Significant.	Minor	Not Significant
Operation and Maintenance									

Salamander Project Activity and Impact	Project Aspect	Embedded Mitigation	Receptor	Sensitivity	Magnitude	Significance of Effect	Additional Mitigation	Residual Significance of Effect	Significance of Effect in EIA Terms
Potential changes to sediment transport system by changes in wave and current climate	Offshore Array and Offshore ECC	N/A	N/A	N/A	N/A	Potential pathway of effect for other topics: • **Volume ER.A.3, Chapter 8: Water and Sediment Quality;** • **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology;** • **Volume ER.A.3, Chapter 10: Fish and Shellfish Ecology;** • **Volume ER.A.3, Chapter 13: Commercial Fisheries;** • **Volume ER.A.3, Chapter 17: Marine Archaeology and Cultural Heritage; and** • **Volume ER.A.3, Chapter 18: Other Users of the Marine Environment.**	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in **Table 7-14.**	[Potential pathway of effect for other topics]	N/A
Potential changes to the morphology of	Offshore Array and Offshore ECC	Co1 and Co52	Designated areas of seabed	High	Negligible	Negligible	No additional mitigation measures have been identified for	Negligible	Not Significant

Salamander Project Activity and Impact	Project Aspect	Embedded Mitigation	Receptor	Sensitivity	Magnitude	Significance of Effect	Additional Mitigation	Residual Significance of Effect	Significance of Effect in EIA Terms
the seabed (including scour)							this effect above and beyond the embedded mitigation listed in **Table 7-14** as it was concluded that the effect was Not Significant.		
Potential changes in morphology of the coast	Offshore Array and Offshore ECC	N/A	The coast	Medium	Low	Minor	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in **Table 7-14** as it was concluded that the effect was Not Significant.	Minor	Not Significant
Potential changes to water column processes	Offshore Array and Offshore ECC	N/A	Water column stratification /	Medium	Negligible	Negligible	No additional mitigation measures have been identified for	Negligible	Not Significant

Salamander Project Activity and Impact	Project Aspect	Embedded Mitigation	Receptor	Sensitivity	Magnitude	Significance of Effect	Additional Mitigation	Residual Significance of Effect	Significance of Effect in EIA Terms
(mixing and stratification)			the Buchan Front			Potential pathway of effect for other topics: • **Volume ER.A.3, Chapter 8: Water and Sediment Quality;** • **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology;** • **Volume ER.A.3, Chapter 10: Fish and Shellfish Ecology;** • **Volume ER.A.3, Chapter 13: Commercial Fisheries;** • **Volume ER.A.3, Chapter 17: Marine Archaeology and Cultural Heritage; and** • **Volume ER.A.3, Chapter 18: Other Users of the Marine Environment.**	this effect above and beyond the embedded mitigation listed in **Table 7-14.**		
Decommissioning									

Salamander Project Activity and Impact	Project Aspect	Embedded Mitigation	Receptor	Sensitivity	Magnitude	Significance of Effect	Additional Mitigation	Residual Significance of Effect	Significance of Effect in EIA Terms
Potential increases in SSC and associated changes to seabed substrate	Offshore Array and Offshore ECC	N/A	N/A	N/A	N/A	Potential pathway of effect for other topics: • **Volume ER.A.3, Chapter 8: Water and Sediment Quality;** • **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology;** • **Volume ER.A.3, Chapter 10: Fish and Shellfish Ecology;** • **Volume ER.A.3, Chapter 13: Commercial Fisheries;** • **Volume ER.A.3, Chapter 17: Marine Archaeology and Cultural Heritage; and** • **Volume ER.A.3, Chapter 18: Other Users of the Marine Environment.**	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in **Table 7-14**.	[Potential pathway of effect for other topics]	N/A
Potential changes to sediment transport	Offshore Array and Offshore ECC	N/A	N/A	N/A	N/A	Potential pathway of effect for other topics: • **Volume ER.A.3, Chapter**	No additional mitigation measures have been identified for	[Potential pathway of	N/A

Salamander Project Activity and Impact	Project Aspect	Embedded Mitigation	Receptor	Sensitivity	Magnitude	Significance of Effect	Additional Mitigation	Residual Significance of Effect	Significance of Effect in EIA Terms
system by changes in wave and current climate						**8: Water and Sediment Quality;** • **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology;** • **Volume ER.A.3, Chapter 10: Fish and Shellfish Ecology;** • **Volume ER.A.3, Chapter 13: Commercial Fisheries;** • **Volume ER.A.3, Chapter 17: Marine Archaeology and Cultural Heritage; and** • **Volume ER.A.3, Chapter 18: Other Users of the Marine Environment.**	this effect above and beyond the embedded mitigation listed in **Table 7-14.**	effect for other topics]	

7.12 Mitigation and Monitoring

7.12.1.1 All of the potential effects to Marine Physical Processes receptors are identified as **Not Significant** in terms of the EIA Regulations, with the current acknowledgement of the embedded mitigation (**Section 7.8.3**). Accordingly, no additional mitigation has been put forward as there are no significant effects which require mitigation.

7.13 Cumulative Effect Assessment

7.13.1.1 A Cumulative Effects Assessment (CEA) has been made based on existing and proposed developments in the Study Area **Volume ER.A.4, Annex 6.2: Cumulative Effects Assessment Technical Annex**. The approach to the CEA is described in **Volume ER.A.4, Annex 6.2: Cumulative Effects Assessment Technical Annex**. Cumulative effects are defined as those effects on a receptor that may arise when the development is considered together with other reasonably foreseeable projects.

7.13.1.2 Those projects included in and excluded from the CEA are listed in **Table 7-21** and shown in **Figure 7-24**. Brief justification for their inclusion in (or exclusion from) the assessment is provided in **Table 7-21** with greater detail provided in the assessment section below.

7.13.1.3 The potential cumulative effects considered within this section are as follows:

- Potential for cumulative temporary increases in SSC and seabed levels as a result of Salamander Project export cable laying activities and offshore wind farm export cable and interconnector/ electricity transmission infrastructure installation;
- Potential for morphological changes to the coast and/or designated features on the seabed arising from cumulative interaction with other plans or projects; and
- Potential for cumulative changes to water column processes (mixing and stratification).

7.13.1.4 In terms of the potential for wider cumulative changes in waves, tides and associated patterns of sediment transport arising from Salamander Project infrastructure in the Offshore Array Area interacting with either (i) any of the other planned or operational offshore wind farm developments within the Study Area (and shown in **Figure 7-24**); and/or (ii) offshore oil and gas infrastructure is extremely low. This is due to the highly localised nature of blockage related change arising from the Salamander Project (see **Section 7.11.3.9** et seq) and as such, has not been assessed any further here.

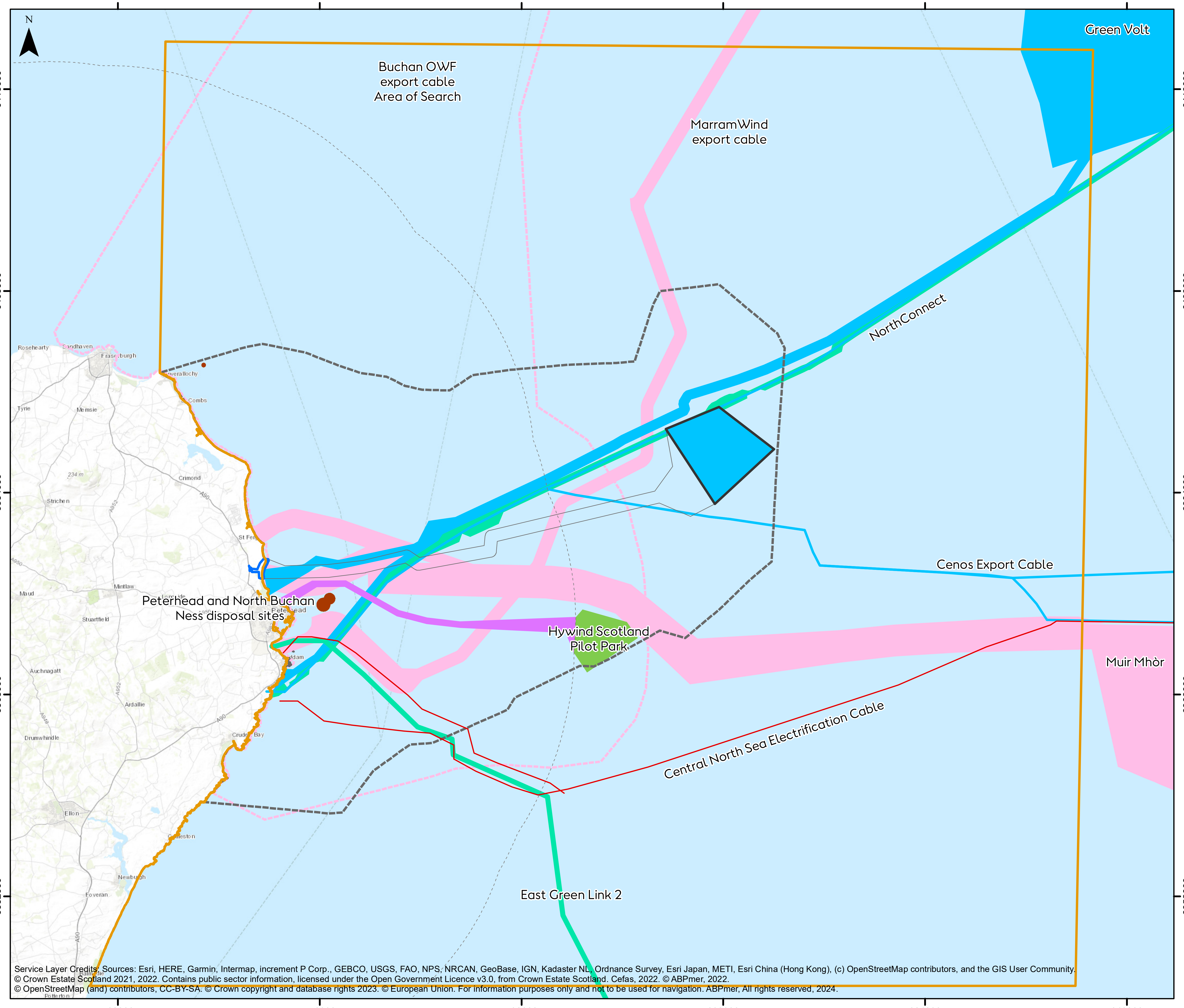
Table 7-21 External projects within the Marine Physical Processes Study Area considered within the cumulative effects assessment

Development	Type	Project Phase	Closest Distance from Project		Reasons for inclusion
			Array	*ECC*	
Hywind Scotland Pilot Park	Floating Offshore Wind Farm	Operational	11.7 km	8.1 km	**Included:** Potential for operation overlap
Green Volt Floating Offshore Wind Farm Export Cable	Floating Offshore Wind Farm	Consent Application Submitted	0.3 km	Overlaps	**Included:** Potential for construction/ operation overlap and within spring tidal excursion distance of the Offshore Development Potential landfall immediately to south of Project Landfall
MarramWind Export Cable[1]	Floating Offshore Wind Farm	Scoping Submitted	1.5 km	Overlaps	**Included:** Potential for construction/ operation overlap and within spring tidal excursion distance of the Offshore Development Potential landfall adjacent to Project Landfall

[1] Distances provided for MaramWind are based on the ECC area of search, and should not be considered necessarily indicative of the route that will subsequently be proposed.

Development	Type	Project Phase	Closest Distance from Project		Reasons for inclusion
			Array	*ECC*	
Muir Mhòr Offshore Wind Farm Export Cable	Floating Offshore Wind Farm	Scoping Submitted	5.53 km	Overlaps	**Included:** Potential for construction/ operation overlap and within spring tidal excursion distance of the Offshore Development Potential landfall adjacent to Project Landfall
Cenos Floating Offshore Wind Farm Export Cable	Floating Offshore Floating Offshore Wind Farm	Scoping Submitted	Overlaps	Overlaps	**Included:** Potential for construction/ operation overlap and within spring tidal excursion distance of the Offshore Development
Buchan Floating Offshore Wind Farm Export Cable	Floating Offshore Wind Farm	Scoping Submitted	1.4 km	Overlaps	**Included:** Potential for construction/ operation overlap and within spring tidal excursion distance of the Offshore Development
NorthConnect	Interconnector	Consented	Overlaps	Overlaps	**Included:** Potential for construction overlap and within spring tidal excursion distance of the Salamander Project

Development	Type	Project Phase	Closest Distance from Project		Reasons for inclusion
			Array	*ECC*	
Eastern Green Link 2 (EGL2)	Interconnector	Consented	26.8 km	2.9 km	**Included:** Potential for construction overlap and within spring tidal excursion distance of the Offshore Development
Central North Sea Electrification (CNSE) Project	Platform Electrification	Scoping Submitted	18.1 km	4.6 km	**Included:** Potential for construction/ operation overlap and within spring tidal excursion distance of the Offshore Development
Peterhead (CR070)	Dredge spoil disposal	Operational	3.1 km	N/A	**Excluded:** forms part of the baseline
North Buchan Ness (CR080)	Dredge spoil disposal	Operational	1.7 km	N/A	**Excluded:** forms part of the baseline



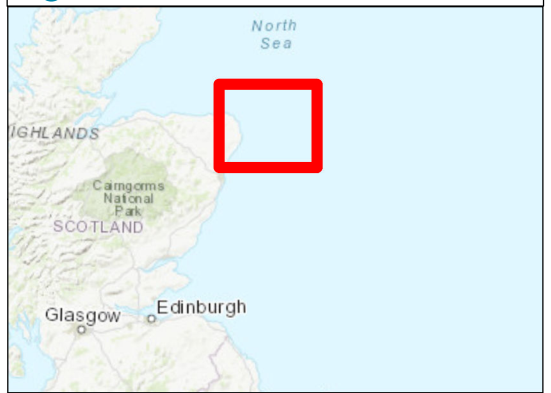
Salamander

Figure 7-24

Projects and Plans considered in the Cumulative Effects Assessment

Legend

- Offshore Array Area
- Offshore Export Cable Corridor
- Study Area
- Indicative Onshore development area
- Salamander Spring Tidal Excursion Buffer
- ScotWind Offers Crown Estate Scotland
- INTOG Application Areas Crown Estate Scotland
- Open Dredge Disposal Site
- TCE Scotland Energy Infrastructure Designated Areas
- TCE Scotland Wind Farm Agreements
- TCE Scotland Cable Agreements
- Central North Sea Electrification Cable
- 12 nm limit
- Oil & Gas Platform



Coordinate System: WGS 1984 UTM Zone 30N

Vertical Datum : MLLW

Scale @ A4 : 278,495

0 3.5 7 14 Kilometers

0 1.75 3.5 7 Nautical Miles

Rev	Description	Date
00	FINAL	18/04/2024

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Potential for Cumulative Temporary Increases in Suspended Sediment Concentrations and Seabed Levels as a result of Salamander Project Export Cable Laying Activities and Offshore Wind Farm Export Cable and Interconnector/ Electricity Transmission Infrastructure Installation

Overview

7.13.1.5 The following projects listed in **Table 7-21** could, potentially, be located within the spring tidal excursion buffer around the Offshore Development Area:

- MarramWind OWF export cable;
- CNSE HVDC cable and hub;
- Cenos OWF export cable;
- Muir Mhòr OWF Export Cable;
- Green Volt OWF export cable;
- NorthConnect; and
- Eastern Green Link 2.

7.13.1.6 Since installation of these export cables and interconnectors may fall within the proposed Salamander Project construction period, the potential for cumulative temporary increases in SSC and seabed levels has been assessed here.

7.13.1.7 Projects beyond the range of a spring tidal excursion ellipse buffer are unlikely to experience any measurable change and as such, are not included in the cumulative assessment.

Conceptual Understanding of Change

7.13.1.8 Given that the interconnector and export cables overlap are within a spring tidal excursion distance of the Salamander Project, there is some potential for sediment plume interaction during construction/installation operations. However, it is noted that export cable installation vessels typically request a vessel safety zone when installing or handling cables and the Applicant will be applying for 500 m safety zones. As set out in **Section 7.11.2.7** and **Figure 7-22**, at a distance of greater than 500 m from the source of bed disturbance, any increases in SSC are expected to be modest (tens to low hundreds of mg/l) and fine sediment is unlikely to deposit in measurable thickness. In addition to direct communications between the ships, this process will likely be managed via vessel management plans and official bulletins, such as notice to mariners. Accordingly, whilst plume interaction may still theoretically occur, the potential for much higher concentration and/or more persistent plumes than that previously described in the project-alone assessments of SSC is small.

7.13.1.9 Cumulative increases in bed level could also theoretically occur, although the potential for this to occur is expected to be very low, given the expected separation distance of the vessels and the fact that seabed sediments are regularly re-worked and transported by tidal currents in this region.

Significance of Effect

7.13.1.10 The assessment set out in this section has considered potential changes to pathways, rather than impacts on receptors. However, the potential for these changes to impact other EIA receptor groups are considered elsewhere within the EIA Report, in particular:

- **Volume ER.A.3, Chapter 8: Water and Sediment Quality;**
- **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology;**
- **Volume ER.A.3, Chapter 10: Fish and Shellfish Ecology;**
- **Volume ER.A.3, Chapter 13: Commercial Fisheries;**
- **Volume ER.A.3, Chapter 17: Marine Archaeology and Cultural Heritage; and**
- **Volume ER.A.3, Chapter 18: Other Users of the Marine Environment (recreation for example).**

Potential for Morphological Changes to the Coast and/or Designated Features on the Seabed Arising from Cumulative Interaction with Other Plans or Projects

Overview

7.13.1.11 In theory cables from both the Salamander Project and all of the other scoped-in export cables, interconnectors and electricity transmission cables listed in **Table 7-21** could be installed within the Southern Trench MPA. This could theoretically result in cumulative pressures on moraines which are protected geodiversity features. However, at present, no classified moraines are defined along the section of the Offshore Export Cable Corridor within the MPA boundary and therefore the potential for cumulative effects to moraines has not been considered further.

7.13.1.12 A number of offshore wind farm export cables and interconnectors may potentially come ashore along the Aberdeenshire coast nearby to the Salamander Project landfall. Of the developments shown in **Figure 7-24** and listed **Table 7-21**, the following could theoretically be situated at a distance close enough to the Salamander Project landfall for cumulative interaction to occur:

- Green Volt;
- MarramWind; and
- Muir Mhòr.

7.13.1.13 All of the other projects shown (including NorthConnect, Eastern Green Link 2, CNSE, Cenos, Hywind Scotland and the gas pipelines going into the St Fergus Terminal) have landfalls too far away for cumulative changes to coastal morphology to occur. (These projects are within a spring tidal excursion ellipse and so it is theoretically possible that sediment plume interaction could occur. Accordingly, they have been included within the Study Area and the potential for cumulative temporary increases in SSC assessed in **Section 7.13.1.5**.)

7.13.1.14 Landfall infrastructure for Green Volt, MarramWind and Muir Mhòr could potentially modify coastal processes via (for instance) altering rates of littoral transport to coastal locations downdrift, with associated morphological impacts. For MarramWind and Muir Mhòr, it is not possible to determine the extent to which this could happen since no detailed landfall design information (such as preferred cable installation method, proposed use of cable protection measures, construction duration etc.) is available for either of these developments. Accordingly, it is not possible to undertake a meaningful CEA with these other developments.

7.13.1.15 Green Volt is considering two potential landfall options near Peterhead with the final choice based on engineering and environmental decisions. However, HDD will connect onshore and offshore cables thereby avoiding impacts to protected sites and the beach.

7.13.1.16 Given that all Salamander Project related impacts to the coast identified in the assessment are found to be (no greater than) Minor (**Table 7-20**), the potential for cumulative interaction with these other developments is considered to be limited, given the spatial and/or temporally restricted nature of any Project related impacts. This holds, regardless of how close the landfalls for these other developments may be situated. Accordingly, this has not been considered further.

Potential for Cumulative Changes to Water Column Processes (Mixing and Stratification)

Overview

7.13.1.17 **Section 7.11.3.46** considered the potential for floating foundations (as well as other Salamander Project infrastructure within the Offshore Development Area) to influence regional-scale patterns of stratification and any resulting change in the location of fronts. Here, consideration is given to the potential for the Salamander Project to interact cumulatively with Hywind Scotland, leading to a greater level of change than for the Salamander Project acting alone.

7.13.1.18 All other proposed wind farms are located much more than one tidal excursion from the Offshore Array Area, so there is no potential for cumulative impacts on stratification arising from interaction with these projects.

Conceptual Understanding of Change

7.13.1.19 When stratification is present, it is possible that foundations in the Offshore Array Area and Hywind Scotland may cause some very minor and highly localised decrease in the strength of water column stratification. However, it is very unlikely that water which is stratified entering the array areas will become fully mixed. The Offshore Array Area is not aligned with Hywind Scotland along the tidal axis and so there is no potential for cumulative impacts on stratification. Regional scale patterns of stratification in the North Sea will be unaffected and will continue to be subject to natural processes and variability. The location and physical characteristics of the Buchan Front are therefore unlikely to be measurably affected within the range of natural variability.

Significance of Effect

7.13.1.20 The Buchan Front is a regional-scale oceanographic feature which supports high biological primary productivity and biodiversity. However, it is both highly dynamic and ephemeral and is therefore not considered to be vulnerable to very localised, small-scale changes in water column turbulence. The sensitivity of the receptor is therefore, considered to be **Medium**.

7.13.1.21 The magnitude of impact to the Buchan Front is considered **Negligible**. This is because it typically forms circa 20 km from the Offshore Array Area and at this distance, no measurable change to water column mixing characteristics is expected either from the Salamander Project alone or acting cumulatively with Hywind Scotland.

7.13.1.22 The overall level of effect significance has been determined by combining the assigned rating for receptor sensitivity and impact magnitude, as shown in **Table 7-18**. The result is a **Negligible** effect, and therefore **Not Significant.**

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

7.14 Assessment of Impacts Cumulatively with the Onshore Development

7.14.1.1 The Onshore Development components are summarised in **Volume ER.A.2, Chapter 4: Project Description**. These Project aspects have been considered in relation to the impacts assessed within this chapter. The Onshore Development will undertake trenchless cable installation operations from above mean high water spring tide, with an exit point occurring no closer than 200 m from MHWS. The impacts from the installation of the Offshore Export Cable(s) (including the landfall activities) have been assessed in full in **Section 7.11.2** et seq. It is not anticipated that there will be any additional impacts from the Onshore Development on Marine Physical Processes receptors as all other activities from the Onshore Development are fully terrestrial.

7.15 Transboundary Effects

7.15.1.1 Transboundary effects are defined as effects that extend into other European Economic Area (EEA) states. These may occur from the Salamander Project alone, or cumulatively with other plans or projects.

7.15.1.2 The predicted changes to the key marine and coastal process pathways (i.e. tides, waves, and sediment transport) are not anticipated to be sufficient to influence identified receptors at this distance from the Salamander Project. As such, transboundary effects are scoped out of assessment.

7.16 Inter-related Effects

7.16.1.1 The following assessment considers the potential for inter-related effects to arise across the three project phases (i.e. project lifetime effects), as well as the interaction of multiple effects on a receptor (i.e. receptor-led effects):

- Project lifetime effects are considered to be effects that occur throughout more than one phase of the Salamander Project, (construction, O&M, and decommissioning) to interact to potentially create a more significant effect on a receptor, than if just assessed in isolation in these three key project stages (e.g. construction phase, operational phase and decommissioning); or
- Receptor-led effects involve spatially or temporal interaction of effects, to create inter-related effects on a receptor or receptor group. Receptor-led effects might be short term, temporary or transient effects, or incorporate longer term effects.

7.16.1.2 It is important to note that the inter-related effects assessment considers only effects produced by the offshore elements of the Salamander Project and not from other projects, which are considered within **Volume ER.A.4; Annex 6.2: Cumulative Effects Assessment Technical Annex**.

7.16.1.3 Inter-related effects are effects over a project lifetime from a specific pathway, however many marine physical processes are inherently inter-related, such as sediment transport relying on currents and waves, and thus, these interlinked processes are discussed within the assessment as overarching impacts. The identified impacts, such as potential changes in morphology of the coast, may occur throughout more than one phase of the project (construction, operation and maintenance, and decommissioning), and can interact to potentially create a more significant effect on a receptor than if just assessed in isolation. **Table 7-22** summarises these for the marine physical processes.

7.16.1.4 There are also, receptor-led inter-related effects for which the marine and coastal processes, as discussed in **Volume ER.A.3, Chapter 7: Marine Physical Processes**, are notably pathways with limited physical receptors, but overlap with a broad range of other topic receptors, which are inherently inter-related. Subsequently, insights from the analysis of changes in marine and coastal processes have informed other EIAR topics, including:

- **Volume ER.A.3, Chapter 8: Water and Sediment Quality;**
- **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology;**
- **Volume ER.A.3, Chapter 10: Fish and Shellfish Ecology;**
- **Volume ER.A.3, Chapter 13: Commercial Fisheries;**
- **Volume ER.A.3, Chapter 17: Marine Archaeology and Cultural Heritage;** and
- **Volume ER.A.3, Chapter 18: Other Users of the Marine Environment** (recreation for example).

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

Table 7-22 Summary of the potential project lifetime inter-related effects for Marine Physical Processes

Impacts	**Residual Effects**			**Inter-related Effects**
	Construction *18 months*	*Operation and Maintenance* *35 years*	*Decommissioning* *18 months*	
Potential increases in SSC and associated changes to seabed substrate.	N/A	N/A	N/A	There are no receptors for Marine Processes, however this is considered a pathway for other topics. The effects of increased SSC caused by seabed disturbance will primarily occur during the construction and decommissioning phases of the Salamander Project. The spatial extent of significant seabed disturbance and associated increase of SSC and deposition is expected to be localised, only within the near-field and intermediate impact zones of the activity (up to 500 m), limited by the coarser nature of the substrate at the site. The cumulative effects of the impact over the Salamander Project lifetime are not expected to result in greater significance than those assessed separately.
Potential changes to sediment transport system by changes in wave and	N/A	N/A	N/A	There are no receptors for Marine Processes, however this is considered a pathway for other topics. The installation of infrastructure has 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 Design Envelope, which is represented by the fully operational Salamander Project. All

Impacts	Residual Effects			Inter-related Effects
	Construction *18 months*	*Operation and Maintenance* *35 years*	*Decommissioning* *18 months*	
current climate				changes to sediment transport systems due to modification of the wave and current climate will be no greater than that identified for the operational phase. Changes in sediment transport extending (up to) 10's of metres from cable protection. Localised changes to waves and hydrodynamics immediately within the vicinity of the rock berms within shallow water (<20 m), but associated morphological change limited by the small scale/low profile of the rock protection. Wake effects from offshore infrastructure extending (up to) hundreds of metres from substructures and associated mooring/anchor systems and subsea electrical hubs, with changes in sediment transport theoretically possible in this footprint, mainly in the form of local scour. Scour around gravity base, suction caisson or drilled pile anchors and subsea electrical hubs, extending (up to) several metres from the structure.
Potential changes to the morphology of the seabed (including scour)	Negligible	Negligible	None	The morphology of designated areas of seabed could theoretically be subject to project life time inter-related effects, with direct seabed disturbance occurring in the construction and decommissioning phase and indirect disturbance occurring during the operational phase due to hydrodynamic, wave and sediment transport blockage related effects. However, in all cases the extent of change is expected to be negligible and even if combined over the project lifetime, the magnitude of change (and therefore overall significance of effect) would be no greater than if assessed in isolation.
Potential changes in morphology of the coast	Minor	Minor	None	The morphology of the coast could theoretically be subject to project life time inter-related effects, with direct disturbance to intertidal/ shallow subtidal areas occurring in the construction and decommissioning phase and indirect disturbance occurring during the operational phase due to hydrodynamic, wave and sediment transport blockage related effects. However, in all

Impacts	**Residual Effects**			**Inter-related Effects**
	Construction *18 months*	*Operation and Maintenance* *35 years*	*Decommissioning* *18 months*	
				cases the extent of change is expected to be small and highly localised and even if combined over the project lifetime, the magnitude of change (and therefore overall significance of effect) would be no greater than if assessed in isolation.
Potential changes to water column processes (mixing and stratification)	None	Negligible	None	Any potential changes to water column processes are only associated with the Salamander Project, whilst in operation. No inter-related effects are determined across the other phases.
Receptor Based Effects				
The different marine 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 **Volume ER.A.3, Chapter 8: Water and Sediment Quality** and **Volume ER.A.3, Chapter 9: Benthic and Intertidal Ecology**.				

7.17 Conclusion and Summary

7.17.1.1 This chapter has investigated potential changes to Marine Physical Processes arising from Salamander Offshore Wind Farm. The range of potential impacts and associated effects considered has been informed by scoping responses (**Table 7-2**) as well as reference to existing policy and guidance.

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

- The determination of the realistic worst-case scenario from the Salamander Project Description **Volume ER.A.2, Chapter 4: Project Description**;
- The determination of the baseline physical environment (including potential changes over the Salamander Project lifetime due to natural variation); and
- Assessment of changes to physical processes arising from the realistic worst-case both for the Salamander Project on its own and in conjunction with other built and consented projects.

7.17.1.3 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 assessment. These include:

- The 'evidence base' containing monitoring data collected during the construction and operation of other OWF developments. The evidence base also includes results from numerical modelling and desk-based analyses undertaken to support other OWF EIAs;

- Analytical assessments of project-specific data, including the use of rule based numerical models; and
- Standard empirical equations describing the relationship between (for example) hydrodynamic forcing and sediment transport or settling and mobilisation characteristics of sediment particles released during construction activities (e.g. Soulsby, 1997).

7.17.1.4 A wide range of potential changes to Marine Physical Processes have been considered, including short-term sediment disturbance due to construction activities, scour around anchors, cables and subsea hubs and the potential for changes to the coast arising from cable installation at the landfall.

7.17.1.5 For the most part, Marine Physical Processes are not in themselves receptors but are, instead, 'pathways'. However, changes to Marine Physical Processes have the potential to indirectly impact other environmental receptors. Notwithstanding this, both the coast and designated areas of seabed were identified as Marine Physical Processes receptors within the Study Area.

7.17.1.6 Even using the conservative Design Envelope approach to EIA (as defined in **Table 7-15**), no residual effects are reported that are significant in terms of the EIA Regulations. Accordingly, no monitoring has been proposed.

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