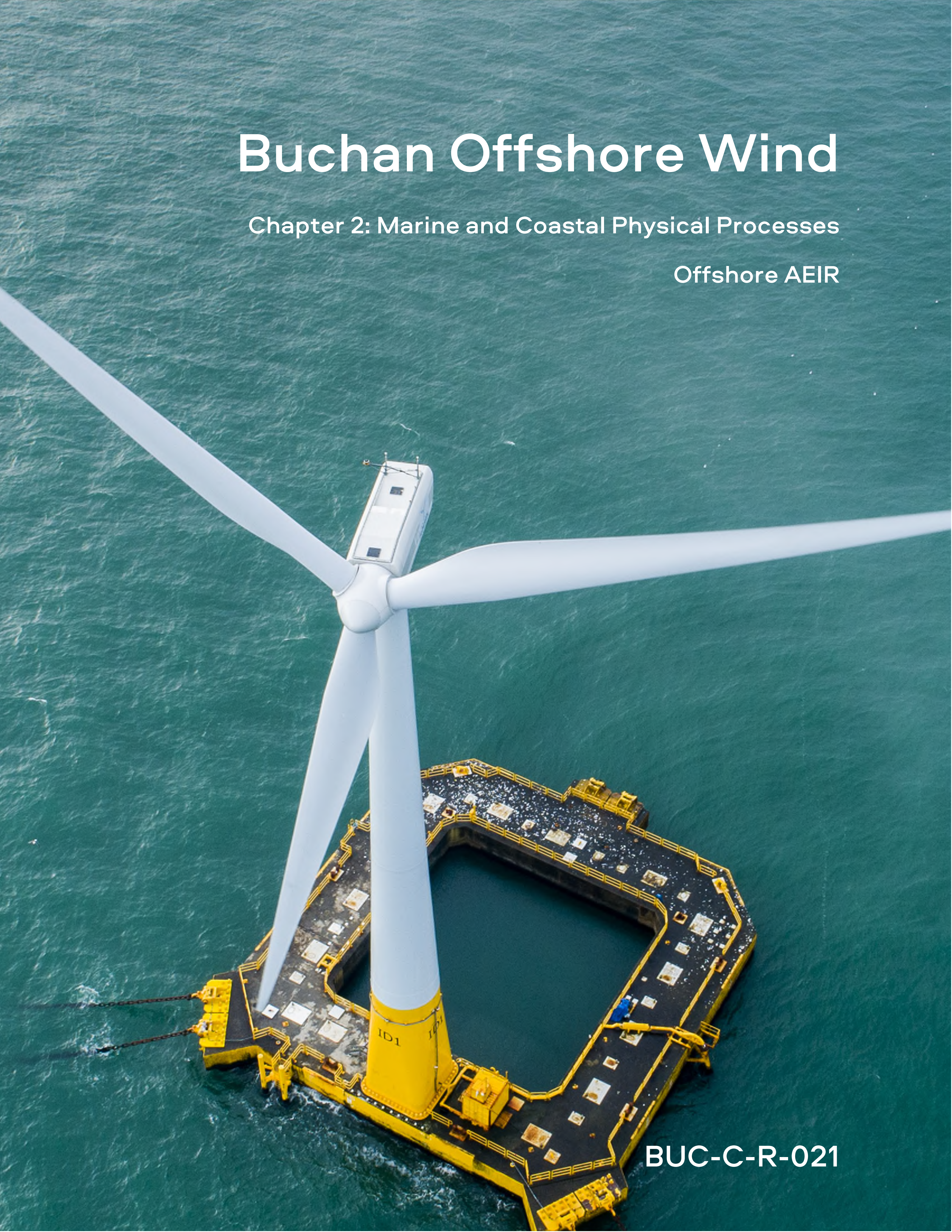
Buchan Offshore Wind

Chapter 2: Marine and Coastal Physical Processes

Offshore AEIR



BUC-C-R-021

Buchan Offshore Wind

Additional Environmental Information Report

Chapter 2 Marine and Coastal Physical Processes

QMS Review

Name	Company	Date	Reviewed	Approved
MWT/ASR	Partrac	11/06/2026	LJN	SMM
CMO	BOW	11/06/2026	CMO	DON

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2.1 INTRODUCTION

2.1.1 Overview

2-1 This Additional Environmental Information Report (AEIR) Chapter has been prepared to provide targeted additional environmental information in response to Requests for Additional Environmental Information (RAEI) issued by Marine Directorate – Licensing Operations Team (MD-LOT) on 18 December 2025, informed by consultation responses from Marine Directorate – Science, Evidence, Data and Digital (MD-SEDD) and NatureScot, in relation to Marine and Coastal Physical Processes. An overview of the Proposed Offshore Development and Application, and approach to responding to the RAEI is presented in **AEIR Chapter 1: Introduction**.

2-2 This chapter has been prepared to supplement the Environmental Impact Assessment Report (EIAR) submitted in support of the Application and should be read alongside the relevant EIAR chapter (Volume 2, Chapter 6: Marine and Coastal Physical Processes).

2.1.2 Relationship to the Environmental Impact Assessment Report

2-3 This chapter supplements Volume 2, Chapter 6: Marine and Coastal Physical Processes of the EIAR and provides additional environmental information or clarification in response to matters raised through the RAEI issued by MD-LOT on 18 December 2025, informed by representations from MD-SEDD (30.09.2025) and NatureScot (01.10.2025) and subsequent consultation undertaken during the determination period.

2-4 Except where explicitly stated within this report, the assessment methodology, baseline information, and conclusions presented within the EIAR remain valid and unchanged.

2-5 This chapter should be read in conjunction with the following documents:

- Volume 2, Chapter 6: Marine and Coastal Physical Processes of the EIAR; and
- Volume 3, Appendix 6.1: Marine and Coastal Physical Processes Modelling Technical Appendix of the EIAR.

2.1.3 Scope of This Report

2-6 This chapter addresses those matters raised through the RAEI issued by MD-LOT on 18 December 2025 and subsequent consultation undertaken during the determination period, in relation to Marine and Coastal Physical Processes. This chapter provides targeted additional environmental information or further clarification in response to requests raised by MD-LOT and matters discussed through subsequent consultation where relevant.

2-7 In particular, the AEIR provides an expanded characterisation of water-column stratification and frontal systems within the Proposed Offshore Development Site[1] recognising that this is the area where project infrastructure will directly interact with, and has the potential to locally influence,

[1] Defined by the boundaries of the Array Area, and the Export Cable Corridor (ECC) seaward of Mean High-Water of Spring Tides 'MHWS', see Section 6.5 of Volume 2 Chapter 6 of the EIAR.

stratified conditions. This includes consideration of interannual variability in the strength and patterns of stratification and the seasonal development and breakdown of the frontal systems. This expanded characterisation draws upon both observational data and outputs of regional[2] hydrodynamic modelling.

2-8 The chapter addresses further queries raised by MD-LOT within the received RAEI regarding the potential for interaction between the draft of floating WTG foundations and seasonal water-column stratification, employing an energy-based approach, alongside consideration of mixing versus advection timescales, to assess the plausibility of structure-induced mixing effects relative to natural variability.

2-9 Clarification is also provided on the assumptions and conclusions relating to sandwave clearance, confirming the temporal extent of these activities and their relevance to the assessment.

2-10 Finally, the AEIR reviews the cumulative effects assessment as it relates to marine and coastal physical processes, providing additional narrative to explain how the conclusions of no significant cumulative effects were reached.

2-11 The conclusions made within this chapterare consistent with, and do not alter those presented in Volume 2, Chapter 6: Marine and Coastal Physical Processes of the EIAR.

2.2 CONSULTATION AND REQUESTS FOR ADDITIONAL ENVIRONMENTAL INFORMATION

2.2.1 Approach to Consultation and RAEI

2-12 A summary of all consultation undertaken so far during the determination phase is provided in **AEIR Chapter 1: Introduction**. For detail on consultation undertaken to inform the EIAR please refer to EIAR Volume 2, Chapter 6: Marine and Coastal Physical Processes.

2-13 In accordance with the RAEI issued by MD-LOT on 18 December 2025, this chapter of the AEIR focuses on responding to the RAEI items identified by the regulator in relation to marine and coastal physical processes. These items form the primary basis of the additional environmental information presented within this chapter.

2-14 Consultation matters relevant to the provision of additional environmental information (informed by MD-LOT, MD-SEDD and NatureScot) for this topic are presented in a single consolidated table (see **Table 2-1** for detail). This approach ensures consistency in how consultation feedback has been captured and addressed within this AEIR.

2-15 All items raised during the determination period on marine and coastal physical processes by NatureScot and MD-SEDD are presented and addressed in full in **Appendix 2.1 – Consultation**

[2] Defined as the North Sea, a body of water bounded by the east coast of the UK and western Europe and open to the North Atlantic in the north. Processes that are occurring within the North Sea shape hydrodynamic, wave, and sediment transport processes occurring within the Proposed Offshore Development Site.

Log. These matters are addressed, where relevant, through clarification, signposting to the EIAR, or provision of additional supporting information.

2-16 Summary of Consultation Relevant to Marine and Coastal Physical Processes

2-17 **Table 2-1** presents a consolidated summary of consultation issues relevant to marine and coastal physical processes.

2-18 For each item, the following table provides a summary of the issue raised and sets out how and where the matter has been addressed within this AEIR.

2.2.2 Summary of Consultation Relevant to Marine and Coastal Physical Processes

2-19 The following table presents the RAEI issued by MD-LOT on 18 December 2025, together with relevant consultation responses and subsequent consultation undertaken with MD-SEDD and NatureScot. For each item, the table identifies the source of the issue raised and describes how and where it has been addressed within this AEIR.

Table 2-1: Summary of Requests for Additional Environmental Information and consultation matters relevant to Marine and Coastal Physical Processes and responses provided in this AEIR

Consultee	Date / consultation type	Summary	Where / how this has been considered
Sub-topic 1: Sandwave Clearance – Impact Significance			
a. Operational Phase Sandwave Clearance			
MD-LOT	18.12.2025 RAEI (via email correspondence)	Clarification on whether sandwave clearance is required throughout the operational phase. Should this be the case, further assessment of 'Impact 2' (as described in the NatureScot representation) may then be necessary, as well as further consideration of potential impacts from increased seabed disturbance across other related receptors.	The requirement for sandwave clearance during the operational phase has been confirmed as not required or anticipated. Sandwave clearance is limited to installation activities only. This is clarified in **Section 2.3**, which confirms that no operational-phase clearance is required and that the EIAR assessment assumptions remain valid. As a result, no assessment of operational seabed disturbance or additional receptors is considered necessary.
NatureScot	01.10.2025 EIAR Representation	Unclear whether sandwave clearance will be required during operation as well as construction, and whether this has been assessed as a long-term impact.	The requirement for sandwave clearance has been reviewed and clarified. No sandwave clearance is anticipated during the operational phase; clearance is limited to

Consultee	Date / consultation type	Summary	Where / how this has been considered
			installation activities only. This is confirmed in **Section 2.3**
b. Recovery Timescales for Sandwaves			
NatureScot	01.10.2025 EIAR Representation	Recovery timescales for sandwaves may not be suitably justified for site-specific depths and conditions.	The sandwave clearance assessment has been reviewed in the context of site-specific depths, sediment mobility and natural seabed reworking. The review confirms that recovery timescales adopted in the EIAR are appropriate and conservative. This is addressed in **Section 2.3**, with no change to conclusions.
Sub-topic 2: Water Column Stratification and Frontal Systems			
a. Interannual Variability in Stratification			
MD-LOT	18.12.2025 RAEI (via email correspondence)	Clarification as to whether there is interannual variability in the stratification.	Interannual variability in water-column stratification has been explicitly assessed using potential energy-based diagnostics derived from ten years (2010–2019) of Scottish Shelf Waters Reanalysis Service (SSW RS) model output, supported by observational water-column Conductivity, Temperature, and Depth (CTD) profile measurements. The analysis demonstrates that interannual variability primarily affects stratification intensity rather than seasonal timing or

Consultee	Date / consultation type	Summary	Where / how this has been considered
			spatial configuration. This is addressed in **Section 2.4.1**.
MD-SEDD	30.09.2025 EIAR Representation 08.04.2026 Marine and Coastal Physical Processes MD-SEDD workshop (video conference meeting)	Likely interannual variability in stratification strength; strength should be characterised using surface–bottom temperature difference or potential energy anomaly.	Interannual variability in stratification strength has been explicitly quantified and assessed using Potential Energy Anomaly-based diagnostics (PEA) derived from ten years (2010–2019) of SSW RS output data, supported by observational water-column CTD profiles. These diagnostics provide a physically based measure of stratification strength and variability. This is addressed in **Section 2.4.1**
b. Baseline Stratification Characterisation			
MD-SEDD	30.09.2025 EIAR Representation 08.04.2026 Marine and Coastal Physical Processes MD-SEDD workshop (video conference meeting)	Baseline stratification assessment relied on mixed layer depth (MLD) rather than direct temperature and salinity fields, contrary to scoping advice.	The baseline stratification characterisation has been expanded beyond mixed layer depth to incorporate direct analysis of temperature and salinity profiles from CTD data, alongside PEA-based metrics derived from regional model output. This enhanced approach is described in **Section 2.4.1** and provides additional context to the MLD based assessment of stratification
c. Dynamic Nature of the Buchan and East Orkney Fronts			

Consultee	Date / consultation type	Summary	Where / how this has been considered
MD-LOT	18.12.2025 RAEI (via email correspondence)	Clarification as to whether, in relation to stratification impacts, the dynamic nature of both the Buchan and East Orkney fronts has been considered.	The seasonal development, persistence, and breakdown of the Buchan Front, and its relationship to the wider East Orkney and Fair Isle frontal system, have been explicitly characterised using PEA diagnostics. The analysis demonstrates predictable seasonal frontal behaviour, limited interannual migration, and strong regional controls governed by tidal mixing, bathymetry, and circulation. This is addressed in **Section 2.4.1**.
MD-SEDD	08.04.2026 Marine and Coastal Physical Processes MD-SEDD workshop (video conference meeting)	Dynamic behaviour of the Buchan and East Orkney fronts, including seasonal formation and migration through the Array Area, may not be fully considered.	
d. Foundations and Interaction with Stratification			
MD-LOT	18.12.2025 RAEI (via email correspondence)	Clarification as to whether the foundations were included in the stratification assessment and, if not, the justification for not including them.	An assessment of the interaction between floating foundation draft and water-column stratification has been performed using an energy-based turbulence framework and is now included in the AEIR . Foundation-induced turbulence was evaluated against the magnitude of seasonal PEA signals to determine whether interaction with, or modification of, stratification is plausible. This

Consultee	Date / consultation type	Summary	Where / how this has been considered
			assessment is presented in **Section 2.4.2**. The analysis demonstrates that any structure-induced effects are highly localised and are considered to be insufficient to influence stratification at array or wider regional scales.
MD-SEDD	08.04.2026 Marine and Coastal Physical Processes MD-SEDD workshop (video conference meeting)	Floating foundation draft (17 m) may interact with the thermocline during onset and decay of stratification; unclear whether foundations were included.	Potential interaction between floating foundation draft and seasonal stratification has been assessed using an energy-based turbulence framework. The analysis evaluates structure-induced turbulent kinetic energy relative to the magnitude of seasonal stratification (expressed through PEA), alongside consideration of mixing versus advection timescales. The results demonstrate that turbulence generated by foundations is small, spatially confined, and rapidly dissipated, with hydrodynamic conditions remaining strongly advection-dominated. As such, any effects are highly localised, transient, and insufficient to influence stratification

Consultee	Date / consultation type	Summary	Where / how this has been considered
			structure or frontal systems at array or regional scales. This is presented in **Section 2.4.2**.
e. Justification of Consultations on Stratification Effects			
NatureScot / MD-SEDD	01.10.2025 EIAR Representation 08.04.2026 Marine and Coastal Physical Processes MD-SEDD workshop (MD-SEDD, video conference meeting)	Conclusions of low or negligible impact to stratification may not be sufficiently justified given uncertainty around floating OWF effects.	The justification for conclusions on stratification impact has been strengthened through integration of long-term PEA diagnostics, observational evidence, and an energy-based assessment of foundation-induced mixing. Together, these lines of evidence are considered to demonstrate that project-related effects are small relative to natural variability and do not alter stratification or frontal systems at relevant scales, and further support the conclusions of the EIAR. This is addressed in **Section 2.4.1** and **Section 2.4.2.**
Sub-topic 3: Cumulative Effects Assessment			
a. Cumulative Effects on Stratification			
MD-LOT	18.12.2025 RAEI (via email correspondence)	Clarification on the factors considered within the assessment of cumulative effects and how the conclusion that cumulative effects are unlikely to be significant has been reached.	The cumulative assessment considers the scale, spatial extent, persistence, and magnitude of project-related effects relative to natural variability and relevant adjacent developments. The

Consultee	Date / consultation type	Summary	Where / how this has been considered
			inherently localised nature of any potential water-column stratification and/or seabed effects, combined with limited spatial overlap and strong regional controls, underpins the conclusion of no significant cumulative effects. This is reviewed and confirmed in **Section 2.5**.
MD-SEDD	08.04.2026 Marine and Coastal Physical Processes MD-SEDD workshop (video conference meeting)	Cumulative effects assessment for stratification relies heavily on project-alone conclusions and lacks supporting narrative.	The cumulative assessment has been reviewed and additional narrative provided to explain how conclusions have been reached, taking account of the scale, magnitude and spatial extent of effects relative to natural variability and other developments. This is addressed in **Section 2.5**.
Sub-topic 4: Assessment Approach			
a. Qualitative Assessment on Post-Consent Monitoring			
MD-SEDD	08.04.2026 Marine and Coastal Physical Processes MD-SEDD workshop (video conference meeting)	Qualitative assessment of stratification and cumulative effects is limited and uncertain; post-consent monitoring advised.	The qualitative, evidence-led assessment approach has been reviewed and confirmed to integrate observational data, regional modelling, published literature and conservative assumptions. The additional analyses presented in this AEIR reduce uncertainty and support the conclusions

Consultee	Date / consultation type	Summary	Where / how this has been considered
			reached in the EIAR. In addition, the Applicant commits to post-consent water-column stratification monitoring using CTD profile measurements. This is discussed in **Section 2.6**.

2.3 SANDWAVE CLEARANCE

2-20 MD-LOT requested clarification on whether sandwave clearance is required throughout the operational phase, and whether this would necessitate further assessment of 'Impact 2' and associated seabed disturbance across relevant receptors. Separately, and as raised through wider consultee engagement, consultees queried the significance of impacts associated with sandwave clearance, including whether the assessment adequately accounted for sandwave mobility, sediment recovery processes, and the spatial extent of clearance activities relative to the wider sedimentary environment. In particular, it was queried whether the recovery timescales cited in the EIAR were supported by studies that are directly comparable to the proposed construction activities within the Proposed Offshore Development Site, noting that some published case studies were undertaken in shallower water depths.

2-21 To address these points, the assumptions and evidence underpinning the sandwave clearance assessment were reviewed. It is acknowledged that the recovery timescales reported in published monitoring studies span a wide range (weeks to years), reflecting site-specific controls including water depth, sediment size, hydrodynamic energy and sandwave mobility. As such, the cited studies are not relied upon as direct analogues for the Study Area, defined as two maximum spring tidal excursion distances (25 km) beyond the bounds the Proposed Offshore Development Site (see Section 6.5 of Volume 2, Chapter 6 of the EIAR), in terms of absolute recovery timescales, but rather as evidence of the underlying physical mechanisms governing sandwave recovery following disturbance.

2-22 Within the Study Area, and particularly along the Export Cable Corridor (ECC), site-specific baseline evidence (refer to Section 6.7.8 of Volume 2, Chapter 6 of the EIAR) demonstrates that the seabed is inherently dynamic. The area is characterised by mobile sandy sediments and well-developed sandwave systems that are subject to continual transport, migration and reworking under prevailing hydrodynamic conditions. Observed and literature-supported sandwave migration rates within comparable hydrodynamic environments indicate that such features are actively evolving on timescales of months to a few years, reflecting a high-energy, mobile sediment setting.

2-23 Any sandwave clearance activities that may be required during the installation phase would be highly localised and temporary in nature, affecting only a very small proportion of the available sediment volume and a limited spatial footprint relative to the extent of the surrounding sandwave field. The activities would not modify the prevailing hydrodynamic regime (as discussed in Section 6.11.1.2 of Volume 2, Chapter 6 of the EIAR), which remains the primary control on sediment mobilisation, transport pathways and bedform evolution. No sandwave clearance is anticipated during the operational phase. During decommissioning, any seabed intervention required to facilitate cable recovery (e.g. localised deburial, jetting or similar methods) would be highly targeted and limited in extent, and would not exceed the spatial footprint, volume of disturbance, or duration of seabed disruption associated with installation activities.

2-24 In this context, and consistent with the existing observed sediment transport and bedform adjustment, any localised perturbations to seabed morphology resulting from sandwave clearance would be expected to be rapidly reworked and redistributed by ambient processes. It is acknowledged that site-specific quantitative evidence for bedform migration or recovery rates (e.g. measured migration rates or direct monitoring of recovery) is not available for the Study Area. However, the baseline evidence presented in Section 6.7.8 of Volume 2 Chapter 6 of the EIAR (including sediment mobility assessments, bed shear stress exceedance analysis, and the mapped distribution of bedforms along the Export Cable Corridor) demonstrates that the seabed is subject to active sediment transport and periodic reworking under prevailing hydrodynamic conditions.

2-25 Recovery of seabed morphology would therefore occur over relatively short timescales (anticipated to be within months to a few years), with this range derived from the interpreted sediment mobility potential of the Proposed Offshore Development Site, supported by published evidence (HR Wallingford, 2013; RPS, 2018) and expert judgement. The upper bound of this range (i.e., a few years) is considered precautionary and represents a realistic worst-case scenario, reflecting variability in hydrodynamic forcing, sediment supply and bedform response. On this basis, the assessment adopts a conservative approach, noting that recovery may occur more rapidly under typical conditions, but is not assumed to do so.

2-26 Accordingly, sandwave clearance would not be expected to give rise to any measurable or sustained alteration to sediment transport pathways, sediment budgets or the processes controlling sandwave morphology and mobility. The works would remain within the envelope of natural variability for the system and would not be anticipated to result in any long-term or regionally significant effects on seabed processes, consistent with guidance regarding the assessment of impacts in dynamic sedimentary environments (Lambkin, 2009; Pye *et al*., 2017).

2-27 Sandwave clearance activities are anticipated during construction of the Proposed Offshore Development, and there are no operational or maintenance activities that would give rise to further sandwave clearance and associated seabed disturbance ('Impact 2'). Any sandwave clearance activities anticipated during decommissioning will not exceed the scale of seabed disruption associated with installation activities, and the scale of disruption is anticipated to be significantly less due to the targeted nature of cable removal activities. In response to the MD-LOT RAEI, no additional assessment of 'Impact 2' during the operational and decommissioning phases are therefore required, as no pathway for ongoing disturbance has been identified.

2-28 On this basis, the magnitude and duration of impacts adopted in the EIAR remain conservative, and the assessment conclusions are unchanged. Likely effects associated with sandwave clearance are assessed as Not Significant at the project level, and no adverse effects on designated features are predicted.

2.4 WATER COLUMN STRATIFICATION & FRONTAL SYSTEMS

2.4.1 Baseline Conditions

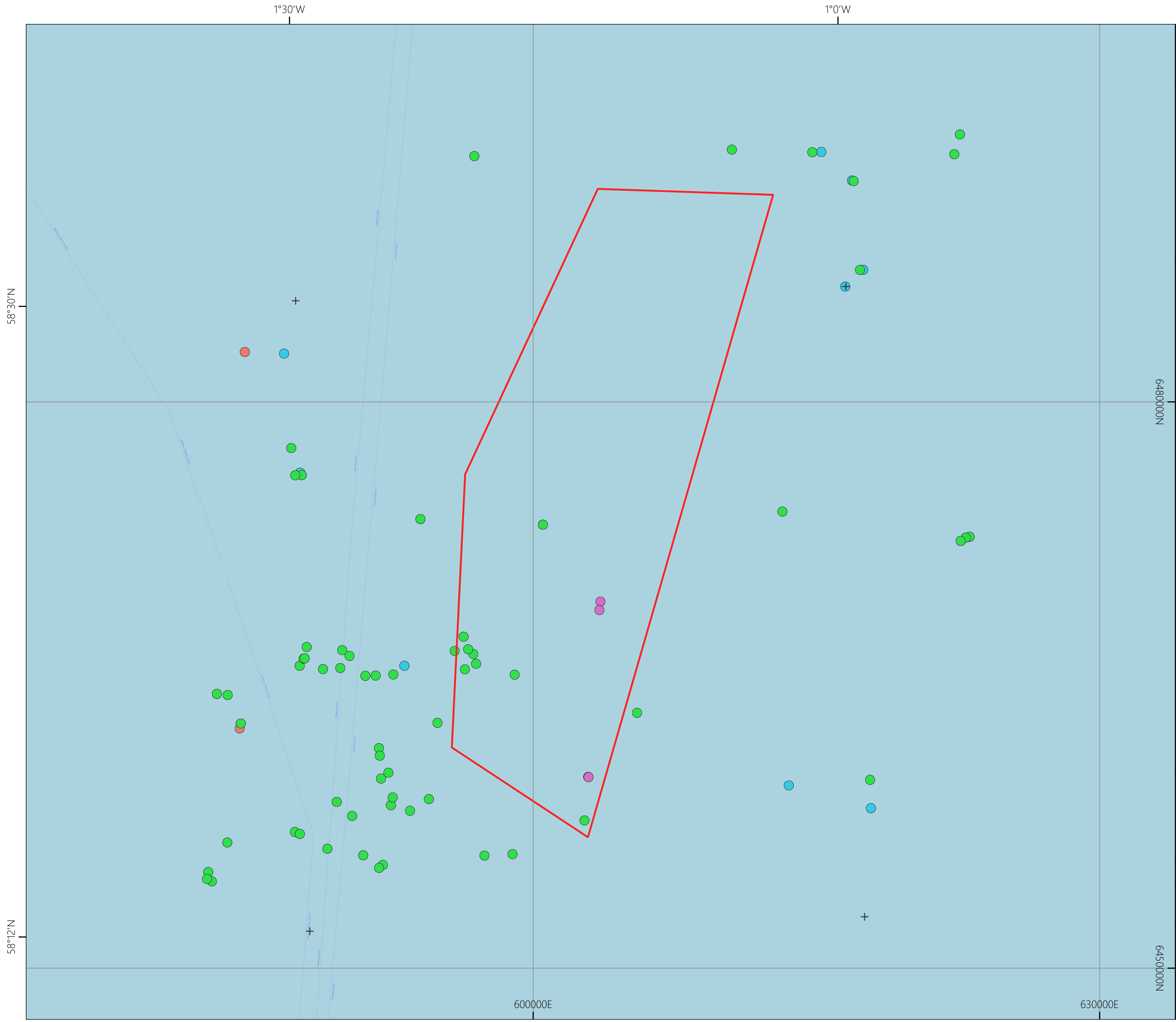
2-29 MD-LOT requested clarification as to whether interannual variability in water-column stratification has been adequately characterised within the Proposed Offshore Development Site. Separately, and as raised through wider consultee engagement, consultees raised matters regarding the characterisation of baseline water-column stratification within the Proposed

Offshore Development Site, including whether interannual variability in stratification strength, duration and spatial extent had been adequately represented using established physical metrics. Additionally, consultees queried the reliance on MLD alone as a proxy for water-column stability, and whether the seasonal development, persistence and variability of regional density fronts had been fully considered.

2-30 In response, the evidence base underpinning the EIAR assessment of stratification and frontal systems has been further supported and expanded upon. The baseline characterisation of water-column stratification now integrates potential energy-based diagnostics alongside an extended suite of observational CTD profiles and regional hydrodynamic model outputs, enabling improved description and representation of vertical density structure, seasonal evolution, and interannual variability across the Study Area. This assessment is primarily focussed on the Array Area, where the floating foundations are to be located and where interactions between infrastructure and the water column occur; accordingly, no direct or indirect impact pathway to the ECC is identified.

2-31 As part of this enhanced baseline characterisation, additional temperature and salinity profiles were compiled from available measurement data archives that include water column CTD casts sourced from the British Oceanographic Data Centre (BODC), the International Council for the Exploration of the Sea (ICES), and the World Ocean Database (WOD), supplemented by site-specific measurement survey data, performed by the Applicant, where available. Available CTD profile data was collated from a region, with a buffer incorporating surrounding waters, extending up to 20 km from the Array Area (**Figure 2-1**), incorporating a buffer of surrounding waters to maximise the number of available profiles while ensuring the dataset remained representative of hydrographic conditions relevant to the Proposed Offshore Development Site. This approach was adopted to support robust characterisation of seasonal stratification behaviour at a scale appropriate to the Proposed Offshore Development.

2-32 While this wider selection necessarily includes profiles that may not fully represent conditions at all locations within the Proposed Offshore Development Site, 15.6% of the CTD profiles are located within the Proposed Offshore Development Site itself, with the remaining profiles providing contextual information on spatial variability proximal to the Proposed Offshore Development Site. Known cross-shelf and along-shelf gradients have been considered when interpreting the data, and conclusions have been drawn with appropriate regard to the relative representativeness of profiles within and outside the Proposed Offshore Development Site.



Project:

Buchan Offshore Wind EIA

Title:

Figure 2-1: The distribution of vertical CTD profiles within 20km of the Array Area, comprising data sourced from the BODC, ICES, and WOD archives, alongside measurement data collected during site-specific surveys.

Key

Array Area

CTD profile data points

- BODC
- ICES
- Site-Specific
- WOD

Partrac (2023) © OpenSteetMap (and) contributors.

Scale @ A3: 1:200,000

Coordinate System: WGS 84 UTM Zone 30N
Graticules: WGS84

0 1 2 3 4 5 km

N

Date: 12-06-26	Prepared by: AS	Checked by: MRW

Map Ref: BUC-NP-D0001-FINAL

BUCHAN OFFSHORE WIND

Notes: a) Information on this plan is directly reproduced from digital and other material from different sources. Minor discrepancies may therefore occur. Where further clarification is considered necessary, this is noted through the use of text boxes on the plan itself. b) For the avoidance of doubt and unless otherwise stated: 1. this plan should be used for identification purposes only, unless otherwise stated in accompanying documentation. 2. Buchan Offshore Wind Ltd accepts no responsibility for the accuracy of data supplied by third parties. 3. Buchan Offshore Wind Ltd accepts no liability for any use which is made of this plan by a party other than its client. No third party who gains access to this plan shall have any claim against Buchan Offshore Wind Ltd in respect of its contents.

2-33 The hydrographic regime across the region is governed by a well-defined and repeatable seasonal cycle, which is clearly expressed in observational CTD profile data. The compiled profile datasets demonstrate that during winter (typically December to March), the water column is fully mixed. Monthly temperature profiles (**Plate 2-1**) show near-vertical structure with negligible thermal gradients, while salinity profiles (**Plate 2-2**) similarly exhibit little to no vertical variation. The available data indicate limited vertical salinity gradients at the Proposed Offshore Development Site; consistent with published evidence, stratification in the northern North Sea is predominantly temperature-driven, with salinity making only a minor contribution to density structure. Long-term analyses confirm that thermal gradients dominate seasonal stratification patterns in this region (e.g. van Leeuwen *et al*., 2015). These observations indicate that during winter potential density fronts are locally absent, and that the Array Area lies within a regionally mixed hydrographic regime, maintained by strong wind forcing and persistent tidal mixing (see Section 6.7.2 and 6.7.3 of Volume 2, Chapter 6 of the EIAR).

2-34 During the spring (typically April to May), profile data indicate the initial onset of stratification, evident as weak near-surface thermal gradients. April profiles show early surface warming relative to deeper waters, while salinity remains largely vertically uniform through the water column, confirming that this early stratification is primarily thermal in origin. At this stage, stratification is generally weak and spatially variable, with the contrast between developing offshore stratification and persistently mixed (shallower) inshore waters marking the formation of the Buchan Front during the spring transition period (April to May).

2-35 By early to mid-summer (typically June to August), profile data show that a consistently stratified water column persists across the Array Area. July and August temperature profiles exhibit a well-developed thermocline, indicative of strong and persistent stratification, while salinity profiles continue to show only weaker vertical gradients, confirming temperature as the dominant control on density structure. These data reliably demonstrate that the Array Area lies within the stratified offshore regime during summer.

2-36 During autumn (typically September to October), stratification weakens as surface cooling and increased wind forcing enhance vertical mixing. Temperature gradients diminish, the thermocline deepens and ultimately collapses, returning the water column to vertically homogeneous winter conditions.

2-37 This sequence of winter mixing, spring onset, peak stratification in summer and autumnal breakdown is consistently observed across the available profile dataset, despite interannual variability in stratification strength and duration.

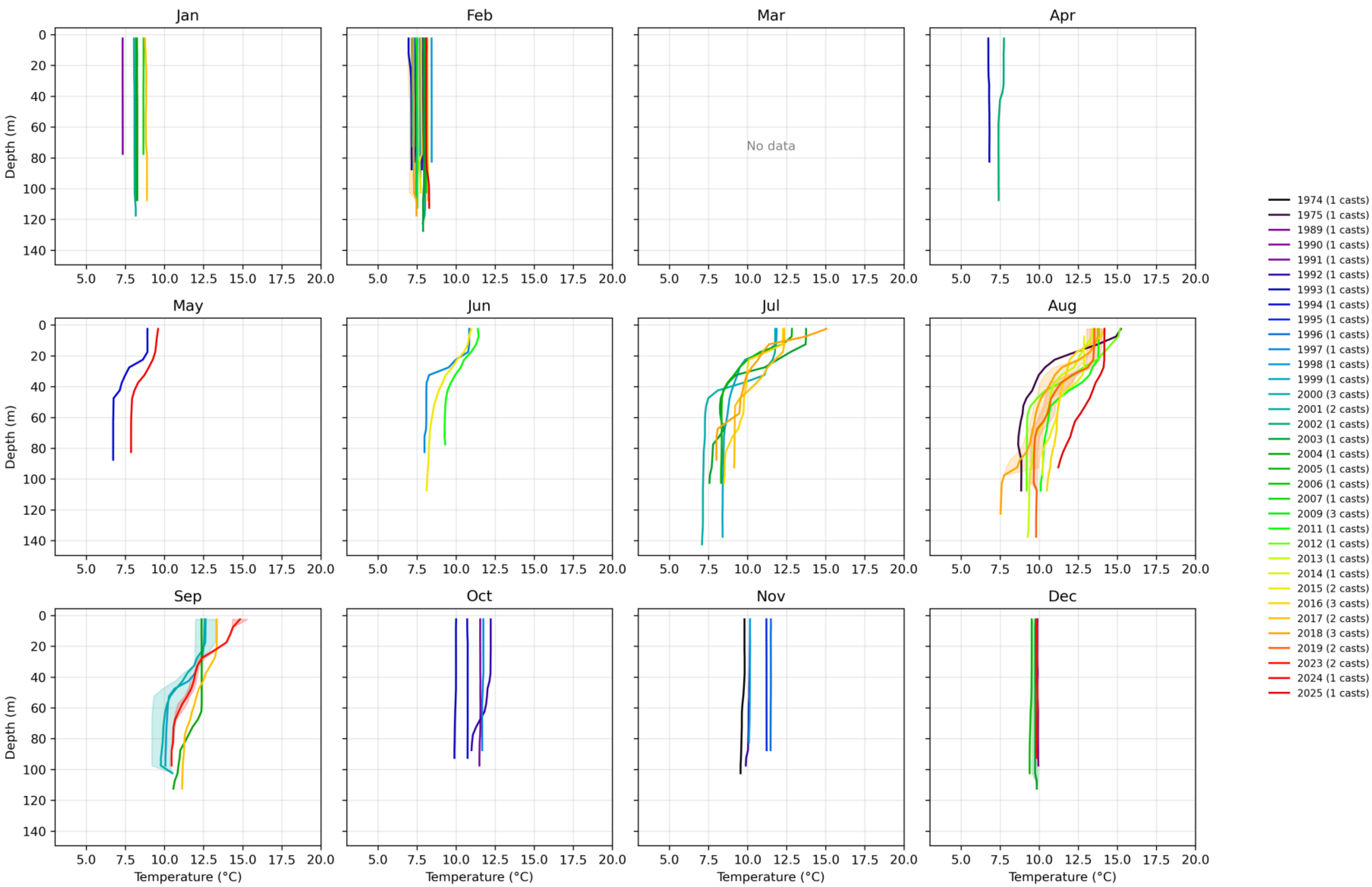


Plate 2-1: Monthly water column temperature profiles (for the period 1974-2025) proximal to the Array Area of the Proposed Offshore Development.

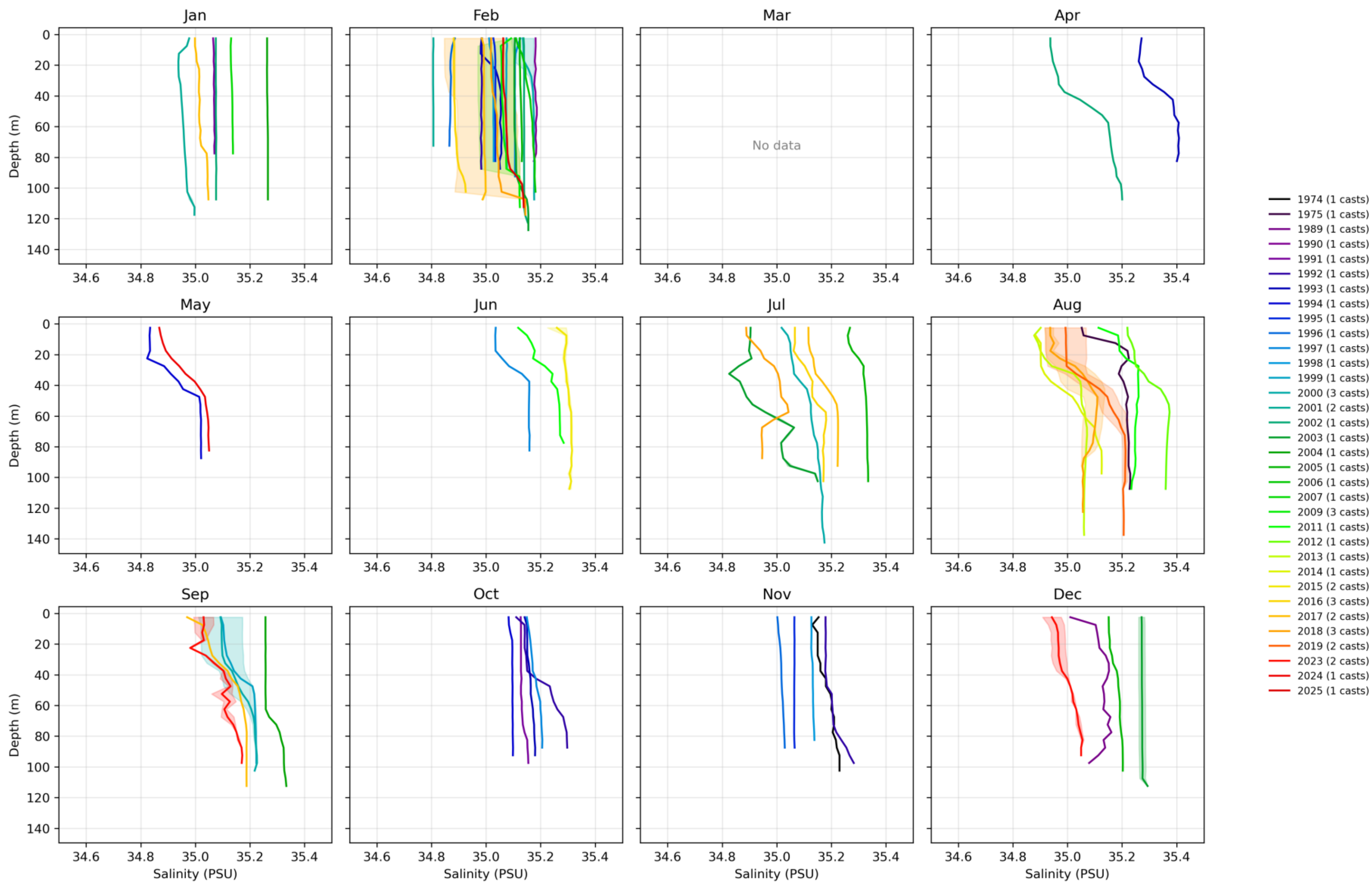


Plate 2-2: Monthly water column salinity profiles (for the period 1974-2025) proximal to the Array Area of the Proposed Offshore Development.

2-38 While the water column profile measurements data clearly demonstrate the seasonal evolution and structure of stratification, direct comparison of stratification strength between years and locations is limited by variability in profile timing, depth coverage and spatial distribution. For this reason, stratification strength and interannual variability have been quantified using potential energy-based diagnostics which provide a consistent, physically based measure of water-column stability, and this approach has been applied in line with, and agreed through, consultation with MD-SEDD.

2-39 PEA (ϕ), is a sophisticated and widely accepted method of quantifying stratification, and is defined as:

$$\phi = \frac{1}{H}\int_{z_{\text{bed}}}^{z_{\text{surf}}} (\rho_0 - \bar{\rho_0}) g z \, dz \tag{1}$$

where ρ_0 is the potential density, $\bar{\rho_0}$ is the depth-mean potential density, g is gravitational acceleration, dz is a vertical distance element used in the integration, and H is the total water depth (Simpson, 1981). The potential energy anomaly, ϕ, represents the minimum mechanical energy per unit volume (J m^{-3}) that must be supplied to homogenise the water column against buoyancy forces. As a depth-normalised quantity, ϕ provides an intensive measure of the local strength of stratification and allows direct comparison of stratification intensity across locations and periods that differ in water depth.

2-40 Multiplying ϕ by the total water depth H yields ϕH, the potential energy of stratification per unit area (J m^{-2}), which represents the total energy required to fully homogenise the entire water column at a given location. Unlike ϕ, ϕH explicitly accounts for water depth and therefore captures the integrated resistance of the full water column to complete mixing. Deeper water columns with comparable density structure will exhibit higher ϕH values, reflecting the greater energy required to erode stratification throughout the depth.

2-41 Together, ϕ and ϕH provide complementary diagnostics of stratification, with ϕ describing the intensity of vertical density structure and ϕH describing the depth-integrated energetic barrier to mixing. Both metrics are therefore used as the primary stratification diagnostics within this assessment.

2-42 **Plate 2-3** to **Plate 2-6** present potential energy–based stratification diagnostics derived from ten years of output (2010 – 2019) from the SSW-RS, a modelled three-dimensional hydrodynamic reanalysis of shelf-sea circulation and hydrography around Scotland (Barton *et al.*, 2022).

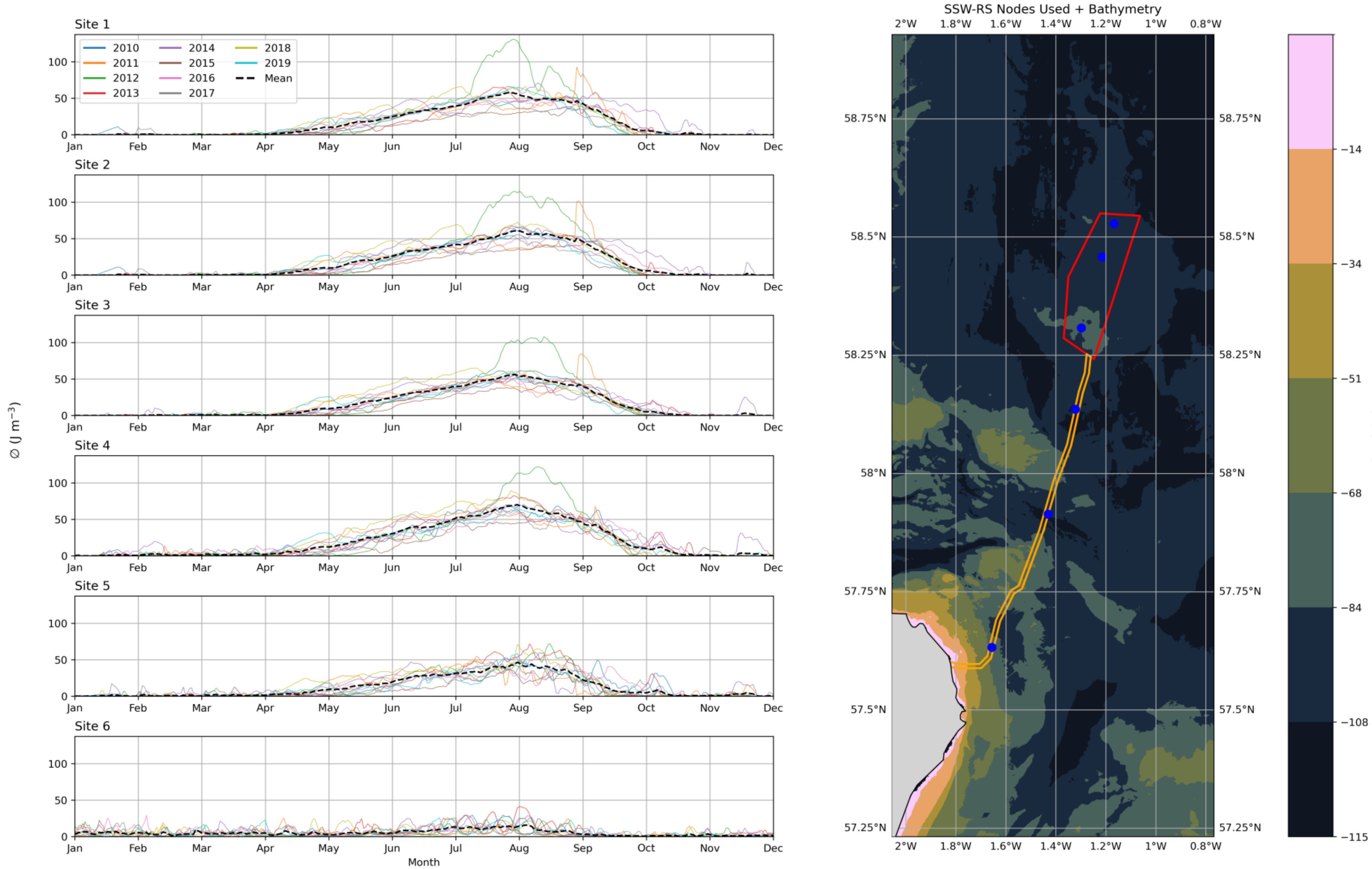


Plate 2-3: Spatial distribution of PEA (ϕ) for select grid points of the SSW-RS from within the Array Area and along the ECC. Diagnostics are derived from ten years (2010–2019) of SSW-RS output. Sites 1 – 6 are numbered from north to south.

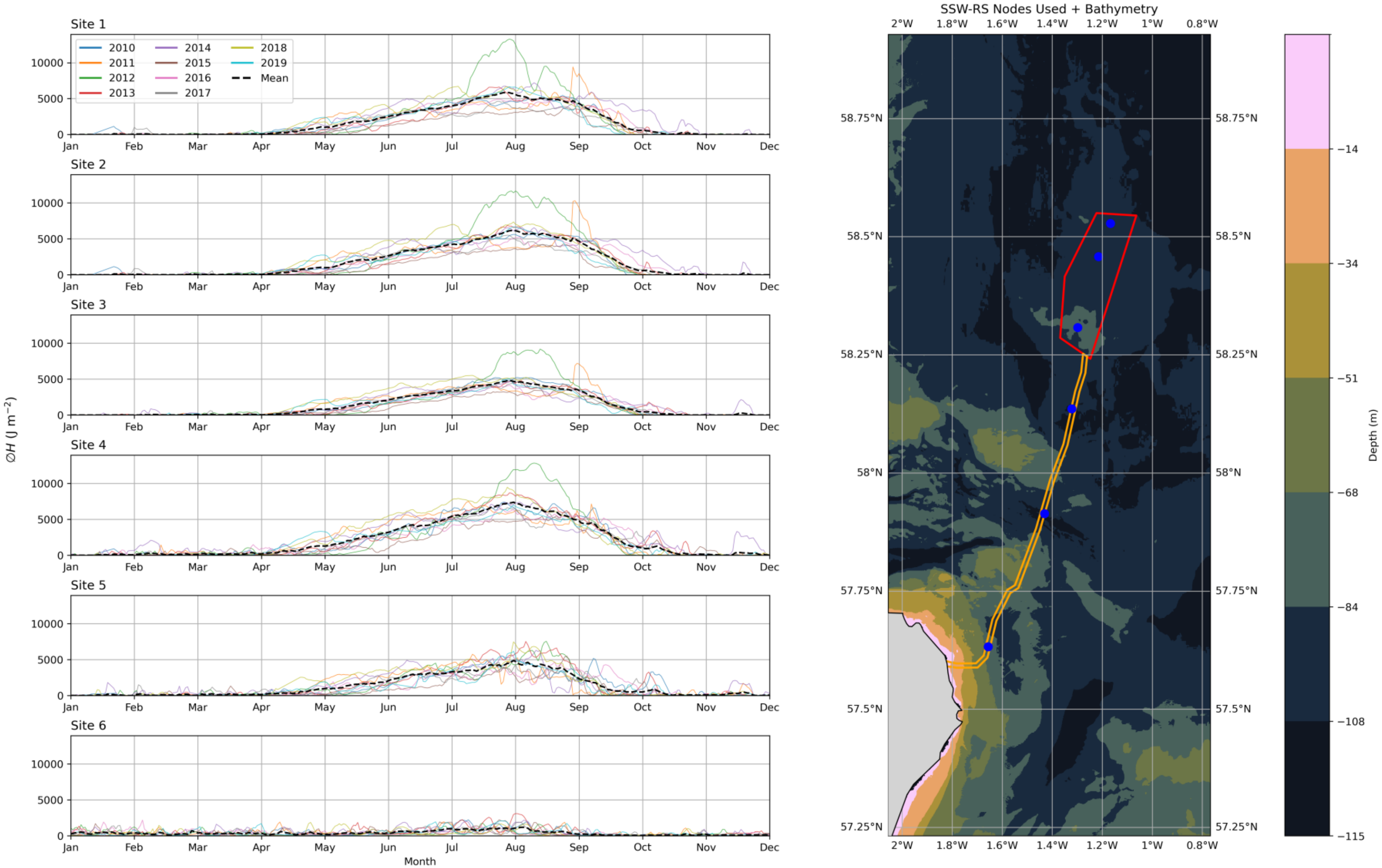


Plate 2-4: Spatial distribution of PEA per unit area (ϕH) for select grid points of the SSW-RS from within the Array Area and along the ECC. Diagnostics are derived from ten years (2010–2019) of SSW-RS output. Sites 1 – 6 are numbered from north to south.

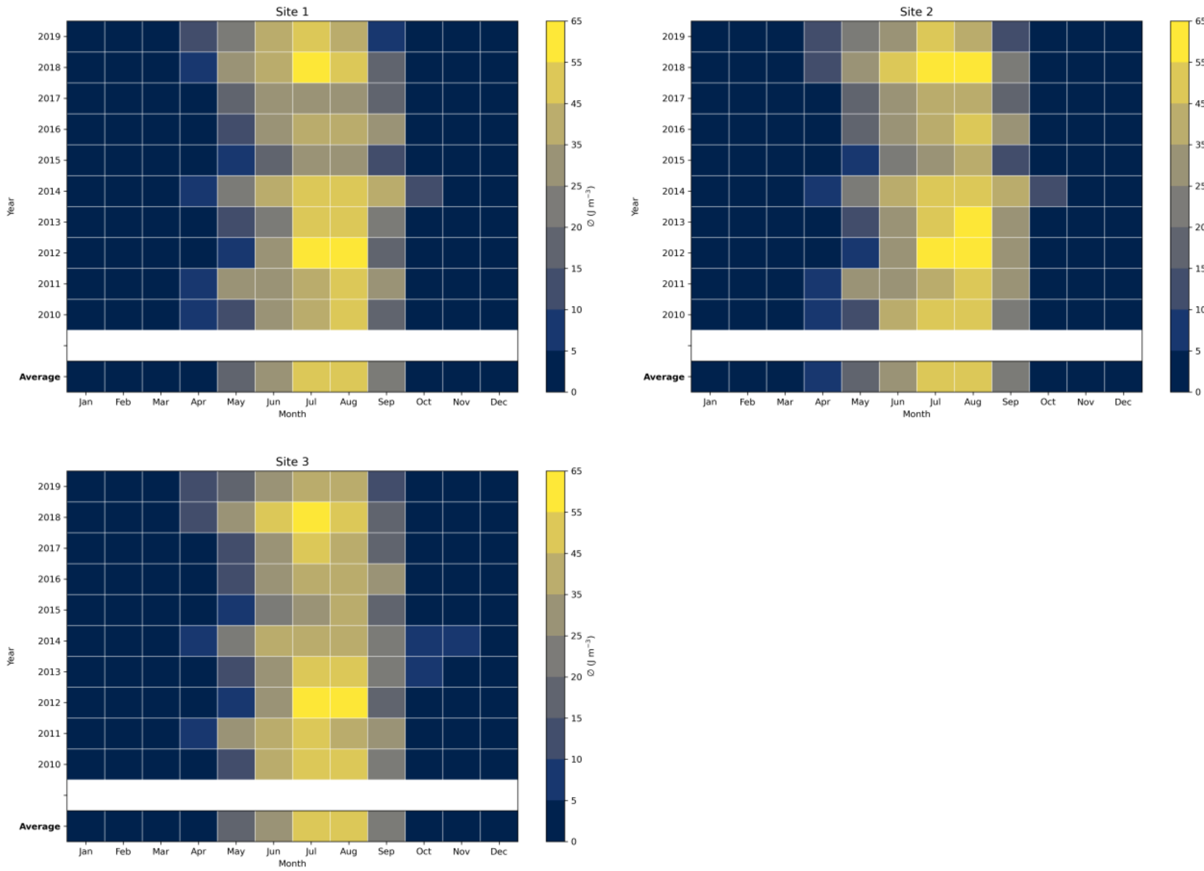


Plate 2-5: Monthly mean distribution of potential energy anomaly data (ϕ) for Sites 1-3 (location shown in above Plates) within the Array Area (see Plate 2-3), derived from the SSW-RS dataset (2010–2019).

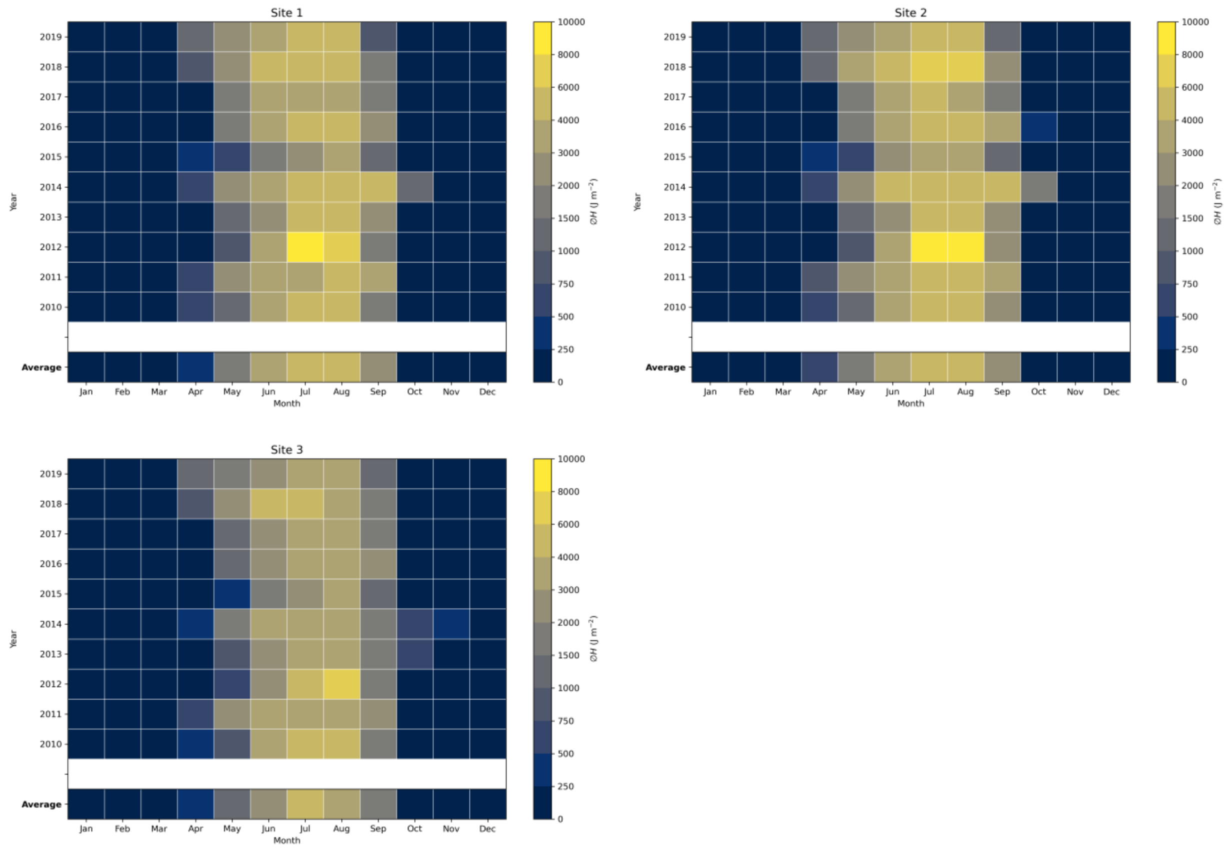


Plate 2-6: Monthly mean distribution of potential energy of stratification per unit area (ϕH) for Sites 1-3 within the Array Area (see Plate 2-3), derived from the SSW-RS dataset (2010–2019).

2-43 Application of these diagnostics confirms that stratification in the region follows a well-defined and repeatable seasonal cycle. During winter (typically December to March), PEA values are close to zero across the Array Area and ECC, indicating a vertically homogeneous (well mixed) water column with negligible thermal or haline stratification. CTD profiles from this period also show minimal vertical gradients in temperature (**Plate 2-1**) and salinity (**Plate 2-2**), consistent with strong wind- and tide-driven mixing acting through the full water depth. Under these conditions, density fronts are locally absent at the scale of the Array Area, and the hydrographic regime is regionally well mixed, reflecting the dominance of strong tidal mixing believed to be associated with upstream constricted channels around Orkney and Fair Isle.

2-44 PEA diagnostics show the emergence of positive values from April onwards, initially offshore of the Array Area, reflecting the development of thermal stratification in deeper, lower-energy waters. In contrast, nearshore waters and large parts of the ECC retain low PEA values during this period, indicating that tidal and wave-induced mixing continues to dominate in these shallower coastal waters. This spatial divergence in PEA marks the seasonal development of the Buchan Front, separating stratified offshore waters from persistently mixed inshore waters. During the spring transition period, the frontal boundary may intermittently intersect the outer parts of the Array Area, reflecting the evolving balance between increasing surface buoyancy input offshore and continued energetic mixing inshore. The persistence of mixed coastal water during this phase is reinforced by upstream supply from the East Orkney and Fair Isle frontal system, which limits the landward advance of stratified waters.

2-45 Stratification strengthens through late spring and early summer, with PEA reaching peak values typically during June to August. The heatmap diagnostics demonstrate that, during this period, the Array Area consistently lies within the offshore stratified domain. Elevated PEA values indicate strong water-column stability across the Array Area, with the Buchan Front typically positioned inshore of the Array Area and aligned approximately parallel to the regional coastline. Interannual variability is evident in the magnitude of PEA, with warmer summers exhibiting higher values and hence stronger stratification; notably, the enhanced peaks observed in 2012 (**Plate 2-3** to **Plate 2-6**) are consistent with sustained summer surface buoyancy input combined with reduced wind-driven mixing, allowing strong and persistent stratification to develop. However, limited variation in the seasonal timing of stratification onset, peak and breakdown is evident across all analysed years.

2-46 Importantly, the PEA diagnostics demonstrate that interannual variability primarily demonstrates a varying intensity of stratification rather than the spatial configuration of the frontal system. While PEA values vary between years in response to atmospheric forcing and surface heat flux, the position of the transition between stratified offshore waters and mixed inshore waters remains relatively stable. Across the period of analysis, the position of the Buchan Front typically varies by no more than circa 10 – 15 km, even in years characterised by strong stratification. In the context of the regional-scale frontal system, which operates over spatial scales in excess of 100 km, this represents a relatively limited degree of variability. This behaviour is consistently reproduced in PEA diagnostics and is supported by the observational CTD data.

2-47 The limited meridional excursion of the Buchan Front reflects the influence of the wider regional frontal system. The East Orkney and Fair Isle fronts, maintained by strong tidal mixing within constricted inter-island channels (Miller *et al.*, 2015), act as a persistent source of vertically mixed coastal water that is advected southwards via the Scottish Coastal Current. This process sustains a nearshore mixed regime along the Scottish coast and across the inshore portions of the ECC, effectively anchoring the inshore boundary of the Buchan Front. As a result, although stratification strength varies interannually, the large-scale frontal geometry and its interaction with the Array Area are governed primarily by bathymetry, tidal energy gradients and regional circulation, rather than by year-specific meteorological conditions.

2-48 In addition to their physical role in structuring the hydrographic regime, regional frontal systems are widely recognised as zones of enhanced biological productivity within shelf seas. Frontal boundaries form where tidally mixed, nutrient-rich inshore waters are juxtaposed with seasonally stratified offshore waters, facilitating vertical and lateral exchanges of nutrients into the euphotic zone (Simpson, 1981). These conditions promote elevated primary production relative to surrounding waters, with increased phytoplankton biomass often concentrated along frontal zones due to both nutrient supply and physical retention processes (Miller *et al*., 2015; van Leeuwen *et al*., 2015). Within the regional context, the East Orkney-Fair Isle-Buchan frontal system therefore represents not only a persistent hydrographic feature, but also a broad zone of enhanced ecological activity. While the present assessment focuses on physical processes, this established linkage provides important context for understanding the wider environmental significance of frontal behaviour in the Study Area.

2-49 During autumn (typically September to October), PEA values decline as surface cooling and increased wind force enhance the processes of vertical water column mixing. This corresponds to the weakening and eventual breakdown of the Buchan Front as the contrast between offshore stratified waters and inshore mixed waters diminishes, returning the Array Area to vertically homogeneous winter conditions.

2-50 Together, the potential energy-based diagnostics confirm that the Array Area experiences predictable seasonal transitions between mixed and stratified states, governed by the development and decay of the Buchan Front within the wider East Orkney-Fair Isle-Buchan frontal system. Stratification within the Array Area is therefore a recurrent and well-defined seasonal feature, characterised by strong but naturally variable summer stratification that is robustly captured by PEA diagnostics. While the intensity of stratification varies between years in response to atmospheric forcing, interannual variability remains well within the bounds of natural variability and does not indicate instability or large-scale or irregular migration of frontal systems through the Array Area. Frontal behaviour occurs at spatial and temporal scales substantially larger than those relevant to the Proposed Offshore Development, and the interaction of frontal systems with the Array Area remains stable and predictable across the analysed time period.

2.4.2 Interaction Between Floating Foundation Draft and Water-Column Stratification

2-51 MD-LOT requested clarification as to whether the draft of the proposed floating foundations (circa 17 m below mean sea level) could interact with the seasonal thermocline and whether structure-induced turbulence could influence local stratification or frontal behaviour. Separately, through wider consultee engagement, similar queries were raised regarding the potential for the floating foundation draft to interact with the thermocline during the onset and breakdown of stratification, and whether associated turbulence could plausibly influence local stratification or frontal behaviour.

2-52 Section 6.11.2.4 of Volume 2, Chapter 6 of the EIAR previously considered potential interactions between floating foundations and water-column stratification, with effects assessed as localised and Not Significant. To provide additional clarity and supporting evidence in response to the above queries, the following assessment expands upon that evaluation through a targeted, process-based analysis of foundation–stratification interaction. This assessment adopts an established energy-based framework to examine structure-induced turbulence relative to the stability of the surrounding water column, and to determine whether any such interaction would be sufficient to alter stratification strength or frontal behaviour at spatial or temporal scales relevant to the assessment.

2-53 The seasonal stratification regime within the Study Area is characterised by a surface-intensified thermocline that typically develops from late spring and persists through summer, as demonstrated by the observational CTD data and the PEA diagnostics presented in **Section 2.4.1**. During periods of peak stratification, the strongest density gradients in the water column are typically located below the draft of the floating foundations. During the onset and breakdown of stratification, the thermocline may temporarily shoal into the upper water column, bringing it closer to the floating foundations. However, these periods are generally characterised by weaker stratification (low PEA) and enhanced ambient mixing driven by wind stress and tidal forcing.

2-54 Analysis of the extended CTD dataset and regional model outputs further demonstrates pronounced natural variability in thermocline depth and stratification strength across seasonal and monthly timescales. Importantly, substantial variations in thermocline depth are observed interannually even within individual months, with depths during August, for example, spanning from circa 20 to 60 m (**Plate 2-1**), illustrating the highly dynamic and non-stationary nature of stratification within the Array Area. This inherent variability precludes definition of a single representative baseline against which small, localised and transient project-related effects could be robustly isolated.

2.4.2.1 Energy-based assessment of foundation-induced turbulence

2-55 To assess whether interaction between the floating foundations and the upper water column could influence stratification, turbulence generation, resulting from the presence of the structures in the water-column, has been evaluated using an energy-based framework, in which offshore structures are treated as sources of turbulent kinetic energy (TKE) through the conversion of mean flow kinetic energy into turbulence. In this context, the rate of turbulence generation associated with an individual foundation is expressed as a power input:

$$P_{\text{foundation}} = \frac{1}{2}\,\rho_0 c_D A |u|^3$$

(2)

where ρ_0 is seawater density, c_D is an effective drag coefficient, A is the projected area of the structure interacting with the flow, and $|u|^3$ is the ambient current speed. This expression represents an upper-bound estimate of the rate at which kinetic energy may be transferred from the mean flow into turbulent motions in the immediate vicinity of a foundation. The formulation follows established approaches for estimating structure-induced turbulence in stratified shelf seas, as set out by Carpenter *et al.* (2016), in which offshore structures are parameterised as sinks of momentum and sources of turbulent kinetic energy acting on the surrounding flow. Values for the drag coefficient were selected following Carpenter *et al.* (2016), who adopted a range of approximately 0.35 to 1.0 to represent low- and high-drag limits for offshore structures. All calculations presented here adopt $c_D = 1.0$ and therefore represent a conservative, high-drag scenario. As turbulence generation scales linearly with the drag coefficient, uncertainty in the value of c_D can be directly interpreted in terms of proportional uncertainty in the estimated TKE supply. This approach is aligned with methodologies applied in comparable studies (SAMS, 2024).

2-56 More spatially and temporally resolved estimates of turbulence generation would require detailed, fully resolved modelling of the evolving stratification, current field, and detailed foundation geometry, including interaction with internal waves and thermocline dynamics, as discussed by Carpenter *et al.* (2016). Such modelling would involve substantial computational requirements and is not considered to be commensurate with the scale or purpose of the present assessment. The energy-based parameterisation adopted here therefore is considered to represent a pragmatic and precautionary approach for evaluating the plausibility of structure-driven impacts on stratification, consistent with the approach agreed with MD-SEDD during consultation **Table 2-1** and aligned with that applied in comparable studies (SAMS, 2024).

2-57 Within the assessment, the projected area (A) was defined on a per-foundation basis as an effective frontal area interacting with horizontal currents, consistent with the Maximum Design Scenario. A value of 2,000 m² (cross sectional area) per foundation was adopted. This comprises approximately 1,950 m² associated with the semi-submersible floating foundation, derived from the maximum width (114.5 m) and maximum design draft (17 m) reported in Volume 2, Chapter 6 of the EIAR. A small additional contribution was included to represent interaction between the mooring system and the energetic portion of the water column. This was estimated assuming nine mooring lines per foundation, each with a diameter of 0.3 m, and an effective interaction length of approximately 50 m per line, reflecting only the upper portion of the moorings exposed to strong currents. The resulting projected mooring area was resolved relative to the flow direction and averaged over all possible orientations by integrating the directionally varying projected width (proportional to the sine of the alignment angle) over 360°, yielding a reduction factor of $2/\pi$, representing the mean effective frontal width under isotropic flow conditions. When expressed on a per-foundation basis, the orientation-averaged mooring contribution is small (on the order of a few tens of square metres) relative to the foundation area. This approach provides a conservative, upper-bound representation of the structural area contributing to momentum extraction and wake-generated turbulence. Modelled depth-mean current speeds from the SSW-RS dataset were used to evaluate the cubic velocity term numerically.

2-58 The efficiency with which TKE is converted into irreversible mixing, commonly expressed through the flux Richardson number, is subject to considerable uncertainty. Under well-mixed winter conditions there is no stratification to erode, and turbulent energy is ultimately dissipated as heat, whereas under stratified conditions, the relative depths of the thermocline and the foundation draft influence the physical mechanisms governing mixing efficiency. Consistent with the discussion of Carpenter *et al.* (2016), values exceeding approximately 0.2 (i.e., more than 20 % of TKE contributing to mixing) are rarely observed, further reinforcing the conservative nature of the present assessment.

2-59 Temporal distributions of foundation-related turbulence power derived from the SSW-RS dataset are presented in **Plate 2-7**. The magnitude of foundation -induced TKE is small and episodic, reflecting relatively low current speeds and limited projected area when compared with the spatial scale of the Array Area of the Proposed Offshore Development and the strength of seasonal stratification.

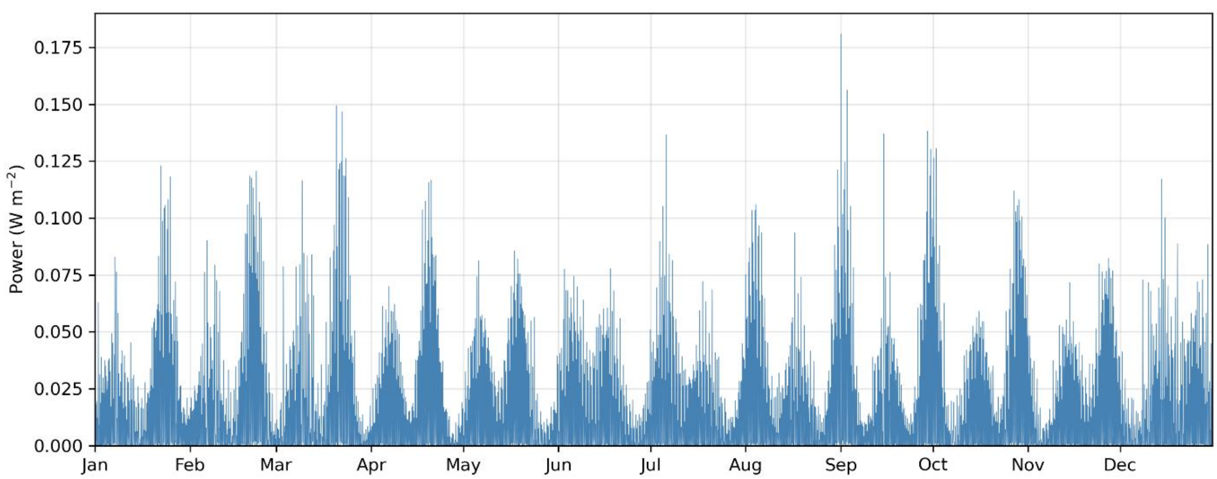


Plate 2-7: Time series of array-averaged, vertically integrated foundation-induced TKE production in the water column, expressed as a power flux per unit horizontal area (W m^{-2}). Values are shown at hourly resolution for 2019[3].

[3] 2019 represents the most recent full year of SSW-RS model data available at the time of analysis. The assessment is not considered sensitive to the specific year selected, as interannual variability in the metocean conditions controlling turbulence generation (e.g. current speeds) is modest relative to the conservative parameterisation adopted here; consequently, the use of 2019 is considered as representative for the purposes of this assessment.

2-60 To place foundation-generated turbulence into wider context, it is informative to compare it with background turbulence generated by natural seabed friction, which represents a primary and persistent source of turbulent energy in shelf-sea environments. Background turbulence is parameterised as:

$$P_{\text{bot}} = \rho_0 c_{D,\text{bot}} |u|^3 \tag{3}$$

2-61 where $c_{D,\text{bot}}$ is the seabed drag coefficient, applied as $c_{D,\text{bot}} = 2.5 \times 10^{-3}$ following Carpenter *et al.* (2016). This formulation highlights that bed stress generates turbulence continuously over large spatial extents and throughout the tidal cycle. Comparison of $P_{\text{foundation}}$ and P_{bot} (**Plate 2-8**) indicates that foundation-related turbulence represents only a minor perturbation to the existing natural mixing regime.

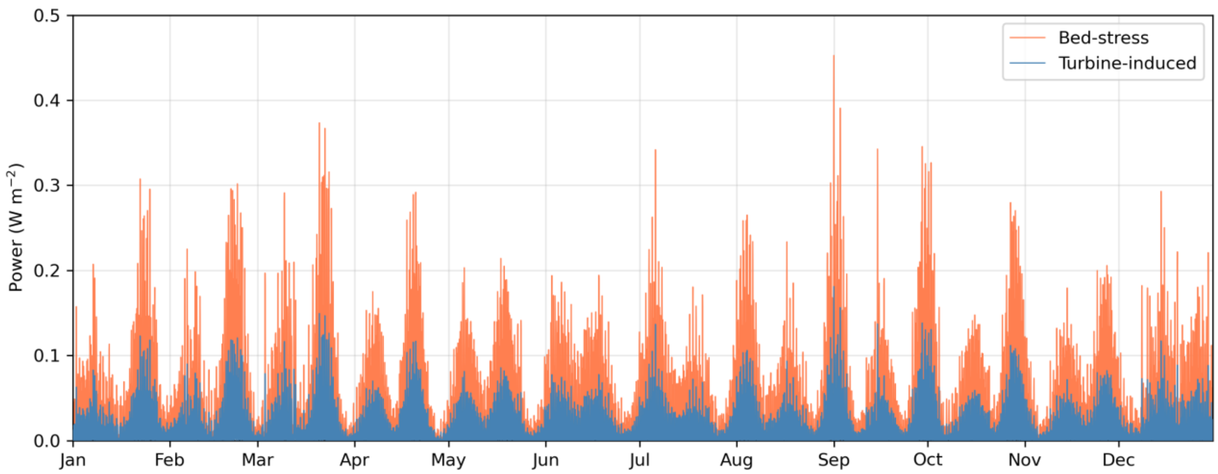


Plate 2-8: Time series of array-averaged, vertically integrated TKE production in the water column induced by foundation structures and bed-stress, expressed as a power flux per unit horizontal area (W m⁻²). Values are shown at hourly resolution for 2019.

2-62 To assess the relative importance of turbulent mixing and horizontal advection in controlling stratification persistence, a diagnostic framework based on Carpenter *et al.* (2016) was applied using the SSW-RS dataset, whereby the rate of stratification destruction, and the associated timescale was compared with the advection timescale.

2-63 The rate of stratification destruction by turbulent mixing was estimated as:

$$\frac{d\phi}{dt} = -R_f \left(\frac{b}{H}\right) P_{\text{foundation}}$$

(4)

2-64 where $R_f = 0.17$ is the mixing efficiency, $P_{\text{foundation}}$ is TKE production due to the floating foundation structures (**(2**), b is pycnocline thickness, and H is water depth. The factor b/H accounts for mixing acting primarily within the pycnocline.

2-65 The mixing timescale was defined as:

$$\tau_{\text{mix}} = \frac{\phi}{d\phi/dt}$$

(5)

2-66 representing the time required for turbulent mixing to remove existing stratification, where ϕ = PEA (**Eq. (**1). The advective timescale was estimated as:

$$\tau_{\text{adv}} = \frac{L}{U}$$

(6)

where $L = 35\ km$ (the maximum length scale for the Array Area of the Proposed Offshore Development), and U is the residual depth-averaged current magnitude.

2-67 The relative importance of mixing and advection was quantified using:

$$D = \frac{\tau_{\text{mix}}}{\tau_{\text{adv}}}$$

(7)

where $D < 1$ indicates advection-dominated conditions and $D > 1$ indicates mixing-dominated conditions.

2-68 The resulting time series (**Plate 2-9**) shows that conditions are consistently advection-dominated throughout the stratified period, with $D \ll 1$. Typical values (mean = 0.016; median = 0.007) indicate that advective transport occurs one to two orders of magnitude faster than turbulent mixing, and no sustained periods of mixing-dominated conditions are observed.

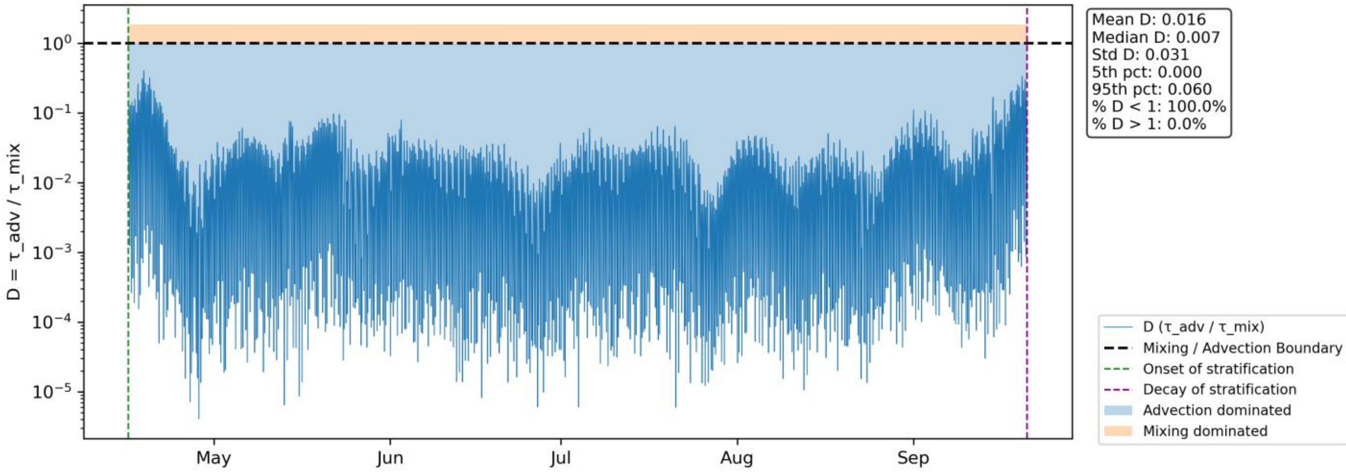


Plate 2-9: Time series of array-averaged mixing-advection dominance metric (D) throughout the stratified period.

2-69 Importantly, **Plate 2-9** demonstrates that, even when turbulent production is elevated, stratification (represented by PEA, see **Section 2.4.1**) is not significantly eroded, with $D \ll 1$ throughout the stratified period. This indicates that turbulent mixing associated with foundation-induced TKE remains weak relative to both the magnitude of the seasonal stratification and the rate of advective replenishment of stratified water masses.

2-70 The persistently low values of D display that hydrodynamic conditions within the Array Area are advection-dominated, such that water parcels interact only transiently with individual foundations before being replaced by surrounding stratified water via tidal and residual shelf circulation. Consequently, although foundation-induced turbulence contributes locally to the TKE budget, it does not produce cumulative array-scale erosion of the seasonal thermocline or materially reduce PEA. For measurable modification of stratification to occur at array scale, substantially longer residence times and repeated interaction of the same water mass with multiple structures would be required; however, the presence of this type of behaviour is not apparent, supported by the observed hydrodynamic regime and the derived D values.

2-71 Numerical modelling of hydrodynamic and wave conditions demonstrates that both current and wave field perturbations associated with the Proposed Offshore Development remain confined within the bounds of the Proposed Offshore Development Site under pre and post construction scenarios (Volume 3 Appendix 6.1, Section 3 of the EIAR). No persistent or coherent propagation of wave height or current speed beyond the Array Area footprint is evident. As mechanical energy available for turbulence generation and vertical mixing scales with local flow velocity, wave energy, and shear, the spatial extent of modelled wave and hydrodynamic modification is considered to provide a conservative proxy for the maximum extent of potential structure-induced mixing.

2-72 Consistent with this, turbulent mixing generated by foundations arises through flow separation, wake formation, and enhanced velocity shear in the near field, with TKE decaying rapidly with distance from the structure. Accordingly, where modelled wave and current changes are spatially limited, any associated enhancement of turbulence and mixing must also remain confined to the immediate vicinity of individual foundations. The absence of wave or current modification beyond the Proposed Offshore Development Site therefore indicates that there is no plausible physical pathway for structure-induced mixing to extend into adjacent North Sea waters or interact with regional frontal systems.

2-73 This conclusion is further reinforced by the dominant directionality of the regional current and wave climate (see Sections 6.7.3 and 6.7.4 of Volume 2, Chapter 6 of the EIAR), which is aligned along principal shelf pathways rather than toward the Buchan Front feature, limiting any dynamic coupling between array-scale wave energy modifications and frontal position or stability. Sustained modification of density fronts in stratified shelf seas requires either broad-scale alteration of the regional energy balance (such as tidally controlled mixing fronts linked to bathymetric gradients) or repeated interaction between the same water mass and strong mixing sources. Neither of these conditions are met here, given the confined spatial footprint of wave and current modification, the advective transport of stratified water masses through the Proposed Offshore Development Site, and the absence of flow recirculation or trapping.

2-74 Furthermore, this behaviour is consistent with established analyses of anthropogenic mixing in stratified shelf seas, which demonstrate that structure-scale turbulence decays rapidly away from the source, remains confined to the near-field, and does not propagate to depths or scales relevant to regional density fronts. Seo *et al*. (2025) indicate that offshore wind farm wakes may locally enhance upper-layer stratification through suppression of wind-driven surface mixing; however, this mechanism is physically distinct from, and does not involve, turbulence generated by foundations.

2-75 On the basis of the combined evidence from PEA, TKE, and D, stratification within the Array Area is demonstrably controlled by regional-scale advective processes rather than local turbulence. Consistent with this and supported by the turbulence and energy-budget analyses undertaken, there is no apparent credible physical mechanism by which interaction between floating foundation draft and the seasonal thermocline could materially alter water-column stratification or associated frontal systems.

2-76 The Buchan Front and the East Orkney / Fair Isle frontal system are regional-scale features extending over tens of kilometres and are governed by shelf-sea to basin-scale forcing processes. In contrast, any turbulence or mixing generated by floating turbine foundations is localised, transient, and confined to the near field, with rapid dissipation within the ambient surface mixed layer.

2-77 Accordingly, no additional impact pathways have been identified, and the conclusions of the EIAR remain unchanged. Potential cumulative effects have been further considered within the Additional Cumulative Effects Assessment (**Section 2.5**), which builds on the Section 6.12 of V olume 2 Chapter 6 of the EIAR. This addresses MD-LOT's RAEI, confirming that foundation interactions have been considered within the stratification assessment, and that the dynamic nature of the Buchan and East Orkney fronts has been explicitly accounted for; in both cases, predicted changes are small and localised, and do not affect the behaviour or persistence of these systems. Effects of the Proposed Offshore Development on water-column stratification and frontal systems are assessed as Not Significant for the purposes of EIA, both alone and cumulatively.

2.5 CUMULATIVE EFFECTS ASSESSMENT

2-78 MD-LOT requested clarification on the factors considered within the assessment of cumulative effects and how the conclusion that cumulative effects are not significant has been reached. In particular, this includes consideration of the scale, spatial extent, duration and magnitude of potential effects relative to natural variability, and the potential for interaction with other offshore wind developments and marine activities within the Study Area (as defined in Section 6.12 Volume 2, Chapter 6 of the EIAR). Separately, and as raised through wider consultee engagement, consultees queried that the cumulative effects assessment for stratification relied heavily on project-alone conclusions and lacked supporting narrative.

2-79 In response, the cumulative effects assessment presented in Section 6.12 of Volume 2, Chapter 6 of the EIAR was reviewed to confirm that relevant offshore wind developments and marine activities within the Study Area had been appropriately scoped into the assessment, and that the spatial and temporal overlap of potential impacts had been adequately considered. This review has included additional scrutiny of the physical mechanisms controlling interaction between developments, with particular emphasis on stratification, hydrodynamic processes and seabed response. This has involved re-review of the assessment presented in Section 6.12 of Volume 2, Chapter 6 of the EIAR, alongside the additional analyses presented in **Sections 2.4.1** and 2.4.2 of this AEIR, incorporating updated process-based evidence from regional model datasets and observational data, rather than redefining the project scope or baseline. The aim of this review was to ensure that the conclusions regarding limited cumulative interaction are demonstrably supported by site-specific process understanding rather than inferred solely from the magnitude of individual project effects.

2-80 The tidal regime within the Study Area is semi-diurnal and strongly oscillatory, producing tidal excursion distances of approximately 4 to 6 km under neap conditions and increasing to approximately 5 to 13 km during spring tides (see Volume 2, Chapter 6 of the EIAR). These excursions govern the movement of water masses over distances of several kilometres each tidal cycle. Consequently, water movement during the tidal cycle is characterised by oscillatory redistribution rather than sustained unidirectional transport over large spatial scales. Within this hydrodynamic regime, mixing generated by individual foundations is highly localised, typically extending over distances of tens to a few hundred metres, and results in only temporary reductions in vertical stratification (**Section 2.4.2**). As water moves beyond the immediate influence of a structure, turbulence reduces rapidly and the water column adjusts towards ambient conditions. Stratification within the Study Area is seasonally established and exhibits strong temporal variability, reflecting the balance between buoyancy forcing and tidal mixing (**Section 2.4.1**). This demonstrates that the system is inherently dynamic and responsive to changes in forcing.

2-81 The recovery of stratification following a localised disturbance is therefore rapid relative to the spatial scales of the developments. Once water exits the zone of enhanced turbulence associated with a foundation, the water column begins to recover towards ambient conditions.

In seasonally stratified shelf seas, vertical density structure is governed by the balance between surface buoyancy forcing (primarily heating) and turbulent mixing (Sharples *et al*., 2022). Following a localised mixing event, the reduction in turbulence allows buoyancy forcing to re-establish vertical density gradients. This re-stratification process is known to occur rapidly, typically over timescales of days to around one week[4] (Miracca-Lage *et al.,* 2024). In this context, perturbations to stratification generated by foundation-induced mixing are transient and short-lived, and do not persist as coherent features within the wider system.

2-82 For developments aligned along the principal tidal axis (for detail on tidal alignment within the Proposed Offshore Development Site, see Section 6.7.2 of Volume 2 Chapter 6 of the EIAR), the separation distance between developments remains greater than the tidal excursion distance (typically 5 to 13 km during spring tides; see Section 6.7.2 of Volume 2 Chapter 6 of the EIAR). For example, the closest tidally aligned development (Marram Wind) is located 24.2 km from the Array Area of the Proposed Offshore Development, corresponding to separation distances of circa 2-5 times the characteristic tidal excursion distance. As a result, water parcels are repeatedly cyclically advected along the tidal axis, alternating direction every half-tidal cycle, rather than progressing steadily from one development to another. This results in continual redistribution and reworking of the water column over successive tidal cycles. Under these conditions, any water mass influenced by localised mixing at one foundation will undergo repeated oscillatory advection and adjustment towards ambient stratification before it can traverse distances comparable to the spacing between developments. The timescale over which stratification recovers is therefore significantly shorter than the time required for tidal processes to redistribute water over tens of kilometres. As a result, there is no plausible mechanism by which a coherent region of reduced stratification could persist and interact sequentially with structures aligned along the tidal axis.

2-83 This process-based understanding also applies to the assessment of cumulative effects on the seabed and hydrodynamic processes. Changes to seabed composition, structure and morphology are confined to the immediate footprint of infrastructure and are subject to active natural reworking under the prevailing tidal regime (see Section 6.11.1.2 of Volume 2, Chapter 6 of the EIAR). Similarly, permanent loss of seabed is spatially discrete and limited to the footprint of each development, such that cumulative spatial extent remains negligible relative to the wider seabed resource (see Section 6.11.2.1 of Volume 2, Chapter 6 of the EIAR). Alterations to hydrodynamic and wave processes are also highly localised and rapidly attenuate away from structures, with the oscillatory nature of the tidal regime preventing the propagation or amplification of effects between developments (see Section 6.11.2.2 of Volume 2, Chapter 6 of the EIAR). These aspects of the cumulative assessment have been reviewed as part of the AEIR

[4] While Miracca-Lage *et al.* (2024) examines restratification in what is a slightly deeper (200m) convection setting than the Proposed Offshore Development Site, the timescales reported arise from fundamental upper-ocean processes, including surface buoyancy forcing and lateral advection. These processes are not specific to these deeper convection regions and are also operative in seasonally stratified shelf seas such as the North Sea. As such, the cited timescales are considered indicative of the rapid nature of restratification following a disturbance, rather than being dependent on the specific depth or setting of the study area.

and remain consistent with the conclusions of the EIAR; no additional impact pathways or changes to the assessment conclusions have been identified.

2-84 This review confirms that the EIAR cumulative assessment remains robust. The impacts associated with the Proposed Offshore Development are highly localised and small relative to natural variability, and there is limited spatial overlap between predicted zones of influence from different projects. When considered cumulatively, the scale of anthropogenic influence on stratification, frontal systems and sediment dynamics does not approach levels that would be expected to result in significant change. Therefore, the cumulative effects conclusions presented in the EIAR remain unchanged, with cumulative impacts assessed as Not Significant.

2.6 ASSESSMENT APPROACH

2-85 During the wider consultee engagement consultees raised points regarding the qualitative nature of the assessment and the treatment of uncertainty associated with complex physical processes such as water-column stratification and sediment transport.

2-86 In response, the assessment approach adopted in the EIAR has been reviewed to confirm its consistency with current best practice and regulatory guidance. The approach integrates multiple lines of evidence, including observational data, numerical modelling, published literature and expert judgement, and adopts precautionary assumptions where fully quantitative prediction would not materially reduce uncertainty.

2-87 The review confirms that the qualitative, evidence-based approach remains appropriate and proportionate, particularly given the strong natural variability of the marine environment and the small, localised scale of predicted project-related effects relative to regional physical processes. The additional analyses presented in this AEIR, including the use of potential energy–based stratification diagnostics and long-term model datasets, has been performed to further reduce uncertainty and provide increased confidence in the conclusions reached.

2-88 In addition, the Applicant commits to undertake post-consent monitoring of the water-column (stratification) via CTD profile measurements acquired within the Proposed Offshore Development Site, as part of the wider marine monitoring framework (as proposed under Sections 6.11.4 and 6.12.4 of Volume 2 Chapter 6 of the EIAR). This monitoring will provide additional empirical data on seasonal stratification behaviour during wind farm construction and operation to enable comparison with the baseline characterisation presented in the EIAR and this AEIR. Monitoring plans will be developed and agreed with consultees post-consent.

2-89 Post-consent monitoring therefore provides an additional quantitative mechanism to validate predictions, confirm the scale of natural variability, and manage any residual uncertainty, without altering the conclusions of the assessment.

2-90 No changes to the assessment methodology or significance conclusions reported in the EIAR are therefore deemed to be required.

2.7 SUMMARY OF CONCLUSIONS

2-91 This AEIR has provided targeted additional environmental information relating to Marine and Coastal Physical Processes in response to specific MD-LOT RAEI queries. In particular, this includes clarification on sandwave clearance, interannual variability and characterisation of stratification, inclusion of floating foundations within the stratification assessment, consideration of the dynamic nature of frontal systems , and the basis for the cumulative effects assessment. Separately, additional context and supporting analysis have been provided in response to wider consultee comments (including MD-SEDD and NatureScot), principally to strengthen the process-based justification of the original EIAR conclusions. The information presented supports and confirms the robustness of the assessment undertaken within the EIAR and re-affirms the conclusions previously reported.

2-92 In response to MD-LOT's RAEI, and supplemented by wider consultee queries, review of seabed processes confirms that sandwave clearance will be limited to only the installation phase, with no further clearance planned or anticipated during windfarm operation. As such, no long-term seabed disturbance effects are predicted, with any localised disturbances expected to be rapidly reworked within a naturally dynamic sedimentary environment, and the conclusions of the EIAR remain valid.

2-93 In response to MD-LOT and supplemented by wider consultee queries, the additional analyses performed demonstrate that stratification within the Array Area is a predictable and well-defined seasonal phenomenon. Winter conditions are characterised by a fully mixed, vertically homogeneous water column, while spring marks the onset of thermal stratification offshore. Peak stratification occurs during summer months, followed by a progressive breakdown in autumn. This seasonal cycle is robustly captured using potential energy–based diagnostics derived from ten years (2010–2019) of SSW-RS output, supported by observational water-column CTD data.

2-94 The assessment demonstrates that interannual primarily influences the intensity of stratification rather than its timing or spatial configuration. While warmer years are associated with stronger stratification, no evidence has been identified for large-scale or irregular migration of frontal systems through the Array Area. The Buchan Front exhibits a consistent seasonal pattern, with only limited lateral variability, and the Array Area lies reliably within the offshore stratified regime during periods of peak summer stratification.

2-95 In response to MD-LOT's RAEI and related consultee queries, the behaviour of the Buchan Front is shown to occur within the context of a wider regional hydrographic system. The East Orkney and Fair Isle fronts, sustained by strong tidal mixing from upstream in constricted channels, provide a persistent source of vertically mixed coastal water that is advected southwards via the Scottish Coastal Current. This regional control sustains a nearshore mixed regime and constrains the seasonal excursion of the Buchan Front, such that frontal geometry and its interaction with the Array Area are governed primarily by bathymetry, tidal energy gradients and regional circulation controls rather than year-specific meteorological forcing.

2-96 In response to MD-LOT's RAEI and related consultee queries, the interaction between the draft of the proposed floating foundations and water-column stratification has been assessed using an energy-based framework. This framework quantifies structure-induced TKE and evaluates its effect relative to the magnitude of seasonal stratification (expressed through PEA), alongside comparison of mixing and advective timescales. The analysis indicates that any turbulence generated by the Proposed Offshore Development is highly localised and small relative to natural mixing processes and the energy that would be required to significantly modify seasonal stratification. Hydrodynamic conditions are shown to be strongly advection-dominated, such that water masses interact only transiently with individual structures and are rapidly replaced by surrounding stratified waters. No credible mechanism is apparent through which the Proposed Offshore Development could materially alter stratification or influence frontal systems at array or regional scales.

2-97 In response to MD-LOT's RAEI and additional consultee comments, the cumulative effects assessment has been reviewed in light of the additional environmental information presented. Given the localised and transient nature of any potential project-related impacts, the limited spatial overlap with other plans and projects, the oscillatory nature of tidal transport and associated restricted net water mass displacement, and the dominance of strong natural variability and regional-scale physical controls, cumulative effects on marine and coastal physical processes presented in the EIAR remain unchanged, with cumulative impacts assessed as Not Significant.

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APPENDIX 2.1 – CONSULTATION LOG

This appendix provides a comprehensive record of consultation undertaken with NatureScot and MD-SEDD during the determination phase relevant to the marine coastal and physical processes AEIR.

Consultee's response	Response from applicant
MD-SEDD	
The MD-SEDD oceanography advisor has reviewed chapter 6 Marine and Coastal Physical Processes of the Buchan Offshore Wind Environmental Impact Assessment Report (EIAR) focusing on potential physical water column impacts. MD-SEDD welcome the inclusion of the baseline description of water column stratification and frontal zones (6.7.5). MD-SEDD note that advice at scoping was to perform a qualitative assessment of impact to stratification after conducting a thorough baseline assessment using temperature and salinity data from a 3D model.	Noted
Rather than using modelled temperature and salinity data to characterise the baseline stratification, a derived value of the mixed layer depth was used (Figure 6-9) which shows little interannual variability. MD-SEDD advise that there is likely to be interannual variation in the strength of stratification. Strength of stratification can be represented by either the difference between sea surface and bottom temperature or the potential energy anomaly. MD-SEDD request that the applicant clarifies whether there is interannual variability in the stratification.	Noted
Regarding the maximum design scenario for impacts to seasonal stratification and the Buchan front listed in Table 6-18. MD-SEDD are concerned that the draft of the proposed floating foundations may not be considered, as it is not mentioned in Table 6-18. The draft of the foundations is an important consideration, along with the surface area, as this will dictate the total sub-surface cross sectional area of the floating foundations. The draft is mentioned in 6-198 and compared to the thermocline depth (or surface mixed layer depth). MD-SEDD consider that the proposed foundations (17 m draft) will interact with the thermocline, especially during the onset and decay of stratification, in spring and autumn, respectively.	Noted
This increases the chance that turbulent wakes would impose mixing and alter the timing of stratification. MD-SEDD request that the applicant clarify whether the foundations were included in the assessment, and if not what the justification was for not including them.	Noted

Consultee's response	Response from applicant
Paragraph 6-200 reports that the Buchan front is > 70 km from the array area, but section 6.7.5 (e.g. Figure 6-8) suggest that the Buchan front forms within the array area and then moves south. MD-SEDD advise the East Orkney front is also likely to interact with the array area in the spring before moving west. During the summer months the array area is likely to be well stratified and the fronts are likely to be further away, closer to shore. MD-SEDD request that the applicant clarifies whether the dynamic nature of both the Buchan and East Orkney fronts has been considered, i.e. with them forming offshore potentially in the array area.	Noted
MD-SEDD are concerned that the qualitative assessment approach of Impact 7 Impacts to seasonal stratification and the Buchan Front is somewhat limiting, with considerable uncertainty around the conclusion of negligible magnitude of impact. Similarly, the qualitative cumulative impact assessment on stratification (6-284) is extremely limited. MD-SEDD therefore advise post-consent monitoring to ensure the conclusions in the EIAR are valid.	Noted
NatureScot	
The EIA assessment for marine and coastal physical processes concludes no significant impacts, both alone and cumulatively – we broadly agree with these conclusions subject to clarifications and with commitment to the Horizontal Directional Drill (HDD) landfall installation method. This would also avoid compromising the objectives of the designation and overall integrity of the Loch of Strathbeg Site of Special Scientific Interest (SSSI) coastal geomorphological feature.	Responses requested will be provided in the Additional Environmental Information Report.
Regarding the two geodiversity features of the Southern Trench ncMPA, we agree with the conclusion that the proposal will not result in a significant risk of hindering the achievement of the Conservation Objectives of the MPA.	Noted.
Further advice is provided in Appendix E, which also notes that advice should be sought from MD-SEDD on mixing and seasonal stratification	Noted, advice was sought from MD-SEDD through a workshop dated 08/04.
Marine and coastal physical processes are considered in Chapter 6 (Volume 2) and the following, relevant supporting appendices: • Marine and Coastal Physical	Noted.

Consultee's response	Response from applicant
Processes Modelling Technical Appendix, Appendix 6.1 • Marine Protected Area Nature Conservation Assessment, Volume 3, Appendix 7.3	
The assessment for marine and coastal physical processes predicts the significance of effect for each impact assessed to be either Minor or Negligible/Minor, both alone and cumulatively (see Table 623). As outlined in Section 6.15, these effects are considered Not Significant in EIA terms. We do not support the approach to several of the assessment's conclusions and do not necessarily agree with the rationale that has been presented in reaching assessment conclusions.	BOW notes NatureScot's comments regarding the assessment approach and conclusions presented within the Marine and Coastal Physical Processes assessment. BOW undertook further review and additional analysis within the AEIR. The AEIR confirms that predicted effects remain highly localised, temporary or transient in nature, and small relative to the regional-scale physical processes governing the receiving environment. The AEIR also confirmed that no additional impact pathways were identified and that the conclusions of the EIAR remain unchanged, including that effects on marine and coastal physical processes are not significant in EIA terms, both alone and cumulatively.
The advice we provide within this Appendix addresses specific elements of the assessment that we do not agree with, however, in our view, this advice does not alter the overall conclusion. Noting that we require some points of clarification, we are broadly inclined to agree with the overall conclusions reached of Not Significant in EIA terms.	Noted.
Within this Appendix, we include advice regarding the analysis of potential impacts on nationally important geodiversity features of the Southern Trench ncMPA and the Loch of Strathbeg SSSI. In our view, the analysis undertaken by the Applicant with regard to these designated sites is insufficient. However, in this instance, we have been able to carry out our own assessment.	BOW notes NatureScot's comments regarding the assessment of potential impacts on the geodiversity interests of the Southern Trench ncMPA and Loch of Strathbeg SSSI. The AEIR further reviewed and clarified the assessment approach, including confirmation that predicted physical process effects remain highly localised and small relative to regional-scale sedimentary and hydrodynamic processes, with no additional impact pathways identified and no change to the conclusions of the EIAR. BOW notes that NatureScot was able to undertake its own assessment based on the information provided and that no objection was raised in relation to these receptors. BOW therefore remains satisfied that sufficient information has been provided to support the assessment conclusions.

Consultee's response	Response from applicant
Our advice below regarding the Loch of Strathbeg SSSI is predicated on the Applicant's commitment to making landfall via HDD with exit in relatively deep water (at -10m LAT) and cable protection being limited, as set out in the Project Description (Chapter 4, Volume 1) and referred to throughout Chapter 6. We highlight that should this HDD commitment not be achieved there may be potential for significant adverse impacts on the natural functioning of the Loch of Strathbeg SSSI.	The project has committed to using HDD at landfall.
We recommend that advice should be sought from MD-SEDD on mixing and seasonal stratification. The potential impact of large-scale floating Offshore Windfarms on mixing and seasonal stratification is an emerging topic with significant uncertainties. In our view, there is opportunity for floating Offshore Wind developers to contribute towards addressing evidence gaps through pre- and post-construction monitoring and we provide further comments below.	Noted. Additional information will be included in AEIR Chapter 2: Marine and Coastal Physical Processes.
The proposed Export Cable Corridor (ECC) passes through the Southern Trench ncMPA, as per Figure 6-24 and Table 6-12. Protected features of the Southern Trench ncMPA include two geodiversity features: Quaternary of Scotland (subglacial tunnel valleys and moraines) and Submarine Mass Movement, as well as two large-scale marine features (fronts, shelf deeps)14.	Noted.
In this instance, we are content to agree with the EIA Report conclusions that geodiversity features of the Southern Trench ncMPA will not be significantly affected. However, we consider the analysis undertaken by the Applicant to reach this conclusion is generally insufficient.	BOW notes NatureScot's agreement with the conclusion that the geodiversity features of the Southern Trench ncMPA will not be significantly affected by the Proposed Offshore Development. The AEIR provided additional clarification and supporting analysis relating to physical process interactions, stratification, cumulative effects and seabed process assumptions, confirming that predicted effects remain highly localised and that the conclusions of the EIAR remain unchanged. BOW therefore remains satisfied that the assessment conclusions are robust and proportionate to the scale of predicted effects.
This is due, primarily, to the following points: • For the construction phase, effects on the geodiversity features are assessed within 'Impact 2 – Alteration to the seabed composition, structure and morphology' which has resulted in designated landforms, including the potential obscuring of these, not being properly	BOW notes NatureScot's comments regarding the assessment approach adopted for geodiversity receptors during the construction phase. The AEIR further confirmed that predicted effects on seabed morphology and sediment processes would

Consultee's response	Response from applicant
considered. Ideally, we would expect to see a separate impact assessed specifically for these geodiversity features.	remain highly localised and not of sufficient magnitude to materially alter regional geomorphological conditions. BOW notes that NatureScot agrees with the conclusion that significant effects are not predicted.
The assessment of Impact 2 (as per Paragraph 6-145) fails to recognise that the proposed ECC crosses three subglacial tunnel valleys that are one of the elements of the Quaternary of Scotland feature. Subglacial tunnel valleys are clearly mapped within Figure 6-24 but are not mentioned or considered elsewhere in Chapter 6. The reasoning for this omission is not clear, especially as the assessment clearly mentions that the ECC avoids other elements of the Quaternary of Scotland feature (moraines) and the Submarine Mass Movement landforms.	BOW notes NatureScot's comments regarding the presence of mapped subglacial tunnel valleys crossed by the proposed ECC and their relationship to the Quaternary of Scotland geodiversity feature. The AEIR further confirmed that predicted effects on seabed morphology and sediment transport processes would remain highly localised and would not result in significant alteration to regional geomorphological conditions or sedimentary processes. BOW therefore remains satisfied that the relevant impact pathways affecting the tunnel valley features were appropriately considered within the assessment and that no significant effects on the Quaternary of Scotland geodiversity feature are predicted.
As above, we consider the analysis of geodiversity features of the Southern Trench ncMPA undertaken within the MPA assessment (Appendix 7.3) to be insufficient. Within the MPA Assessment, Section 4.2.1 states that "the Proposed Offshore Development is not capable (other than insignificantly) of affecting the Favourable condition of the Quaternary of Scotland's protected feature, therefore this feature will not be carried forward to the Main Assessment". However, detailed justification is not provided to support the Applicant's findings and conclusions regarding potential effects on subglacial tunnel valleys. The MPA Assessment relies on the findings of the Marine and Physical Processes Chapter of the EIA Report which does not sufficiently consider the tunnel valley element of the Quaternary of Scotland feature (see comments above).	BOW notes NatureScot's comments regarding the assessment of geodiversity features within the Southern Trench ncMPA Assessment and the level of justification provided in relation to potential effects on subglacial tunnel valleys associated with the Quaternary of Scotland feature. The AEIR further confirmed that predicted effects on seabed morphology and sediment transport processes would remain highly localised and would not result in significant alteration to regional geomorphological conditions or physical processes. BOW therefore remains satisfied that the conclusions of the MPA Assessment are robust and that the Proposed Offshore Development is not capable of significantly affecting the geodiversity interests of the Southern Trench ncMPA.
In this instance, we have further considered the information provided within both the MPA Assessment and EIA Report and have undertaken our own assessment as follows: • The tunnel valleys are at least 10km long; the ECC, crossing them at high angles, would affect only a very small proportion of their	Noted.

Consultee's response	Response from applicant
length. • Based on previous bathymetric surveys, detailed topography of the tunnel valleys is likely at least 0.5km2 in spatial scale. The cable installation works, or cable protection, would be an order of magnitude smaller. • Considering the previous bullet points, for any length of cable(s) that is surface laid with protection, the landform surfaces would remain sufficiently unobscured to allow the ncMPA feature attributes to be maintained. If the trench is excavated, this would be through glacial or post-glacial sediment that drapes the landform surface, and the surface of the drape would be partly or wholly re-formed by cable burial. For these reasons the extent, component elements, integrity and structure of the landform would be maintained.	
On this basis, we conclude that the proposal is capable of affecting the Quaternary of Scotland feature of the Southern Trench ncMPA, other than insignificantly. Therefore, we conclude that the proposal will not result in a significant risk of hindering the achievement of the Conservation Objectives of the MPA.	Noted.
The proposed ECC is at its closest point 0.2km from the eastern extent of the Loch of Strathbeg SSSI, as per Figure-24 and Table 6-12. Our advice and comments provided below are in relation to 'Impact 5 - Localised alteration of hydrodynamic and wave conditions across the Study Area and indirect effects on the sediment transport regime and coastal processes' during the operation phase. Impact 5 is assessed in Section 6.11.2.2. Paragraph 6-182 explains that from this impact two receptors have been assessed: • prevailing hydrodynamic, wave and sediment transport regimes, seabed morphology and coastal processes; and • the coast - due to the presence of a number of SSSIs, SPAs, and GCRs nearby that are sensitive to impacts on marine and coastal physical processes (such as the Strathbeg GCR).	Noted.
The magnitude for impact 5, as assigned in Paragraph 6-181, is based upon the commitment to HDD exit being located at the -10m contour. On the basis of the distance from shore at the -10m contour, the Applicant considers magnitude of impact on the 'coast' receptor to be 'Low'. We consider the commitment made to HDD exit being located in relatively deep water (-10m LAT) and the cable protection being limited (no greater than 0.7m) in height to be key to the Applicants conclusion and our agreement with this.	The project has committed to using HDD at landfall.

Consultee's response	Response from applicant
HDD is the only landfall installation method considered within the assessment of marine and physical processes. Within Table 6-18 it is stated that "HDD is the only method considered in the design envelope, and as such is considered as the maximum design scenario" and exit elevation is listed as "exit elevation= 10m LAT". This commitment to HDD exit at -10m LAT is referred to throughout Chapter 6. We note that whilst mitigation measure AEM50 also confirms "The use of HDD to install cable at landfall" (see Table 1-2 of Appendix 1.1 Commitments, Mitigation and Monitoring Register), the -10 m LAT commitment is not stated. Furthermore, the Project Description states "at approximately the 10m LAT contour line" (Paragraph 4-141).	The project has committed to using HDD at landfall.
The commitment to HDD exit in relatively deep water (i.e. at least -10m LAT) is key to our appraisal of Impact 5. We highlight that: • Should this commitment not be achievable and a shallower exit be required, there may be potential for significant adverse impacts on the natural functioning of the Loch of Strathbeg SSSI and further assessment would be required.	The project has committed to using HDD at landfall.
We consider the analysis regarding impacts potentially relating to the Loch of Strathbeg SSSI to be insufficient. Given the proximity of the SSSI to the ECC we would generally expect to see detailed consideration of this designated site within the assessment. Specifically, there does not appear to be any consideration of the objectives for management of the Coastal Geomorphology feature of the SSSI; to ensure continued natural evolution of the beach-dune system, particularly through maintaining longshore sediment supply15. This fundamentally underpins the SSSI's sand dune habitat feature.	BOW notes NatureScot's comments regarding the consideration of potential impacts on the Coastal Geomorphology feature of the Loch of Strathbeg SSSI. The AEIR further confirmed that predicted physical process effects would remain highly localised and would not result in significant alteration to regional sedimentary or geomorphological conditions. BOW therefore remains satisfied that the assessment appropriately considered the relevant impact pathways and that significant effects on the Loch of Strathbeg SSSI are not predicted.
In relation to cable protection measures, we highlight that both wave climate and tidal flow should have been further considered in relation to Impact 5. Whilst detail relevant to these topics has been provided within the baseline (Section 6.7), the analysis in Section 6.11.2.2 is relatively high-level and does not clearly outline the rationale behind the conclusions reached. We include our consideration of wave climate and tidal flow below:	BOW notes NatureScot's comments regarding the consideration of wave climate and tidal flow within the assessment of cable protection measures under Impact 5. The AEIR further reviewed the assessment approach and confirmed that predicted effects on hydrodynamic and sedimentary processes remain highly localised, temporary or limited in extent, and would not result in significant alteration to regional physical processes. The AEIR also confirmed that cumulative effects remain not significant and

Consultee's response	Response from applicant
	that no additional impact pathways were identified. BOW therefore remains satisfied that the assessment appropriately considered the relevant wave climate and tidal flow processes associated with cable protection measures and that the conclusions presented within the EIAR remain robust.
Nearshore wave climate The assessment mentions the potential for shore-normal export cable protection (rock mattress or berm) to change the nearshore wave climate, however, analysis of this is not clearly referred to within the conclusions set out in Paragraph 6-178.	BOW notes NatureScot's comments regarding the consideration of potential nearshore wave climate effects associated with shore-normal export cable protection measures. The AEIR further confirmed that predicted physical process effects would remain highly localised and would not result in significant alteration to regional hydrodynamic, sediment transport or geomorphological processes. BOW therefore remains satisfied that the assessment appropriately considered the relevant impact pathways associated with nearshore cable protection measures and that the conclusions presented within the EIAR remain robust.
Paragraph 6-178 states that HDD exit would be at -10m LAT (i.e. 10 m below extreme low spring tides) with a rock mattress 0.7m high, giving an effective depth of 9.3m. From our appraisal of the baseline information, particularly Figure 6-7, we consider it likely that the maximum depth at which storm waves may actively transport seabed sediment (i.e. the depth of closure) at the proposed landfall to be less than 9m. Also considering the brief duration of extreme low spring tides and the rarity of these coinciding with storm waves (noting that storms invariably raise local sea-level), we consider that the cable protection is not likely to influence wave breaking and related sediment transport.	Noted.
The assessment does not appear to consider any potential interruption of sediment transport by tidal flow, resulting from proposed cable protection. The Strathbeg coast is recognised as a convergence zone for tidal transport, however, we note that the assessment also reports modelling of residual transport to the south-southeast (see Figure 618). In the shallowest waters where cable protection might be installed (-10m LAT), although waves are unlikely to achieve seabed	Noted.

Consultee's response	Response from applicant
transport, they could significantly stir-up sediment that is then transported by storm-driven currents. However, it's likely that this would readily create a ramp that would overtop the low 0.7m rock mattress, allowing shore-parallel tidal transport to continue. As such we are content that the management objectives and the overall integrity of the SSSI will not be compromised, based on the assumptions made regarding HDD pop out depth and rock protection measures.	
In addition to our advice regarding designated sites, there are further elements of the assessment approach that we do not support. Whilst we provide comment below, and in some instances request clarification, we highlight that in general we can agree with the conclusions reached.	Noted.
The assessment of 'Impact 1 Temporary disturbance of the seabed leading to increases in suspended sediment concentrations (SSC), and associated deposition' (Section 6.11.1.1) includes consideration of sandwave clearance as part of seabed preparations. This has been deemed necessary to avoid export cables becoming exposed and/or being over-buried (see Paragraph 6-117).	Noted.
Sandwave clearance is also discussed within 'Impact 2 Alteration to seabed composition, structure, and morphology' (Section 6.11.1.2), and sandwave recovery is considered within Paragraphs 6-142 and 6-143. Paragraph 6-142 notes a range of recovery timescales. Paragraph 6-143 states that sandwaves are likely to recover within 'weeks to months', but whilst this may be correct, it has not been demonstrated that the studies referred to in 6-142 are sufficiently comparable to the proposed construction activities for Buchan. For example, it appears the studies discussed involved significantly shallower waters.	Noted. Additional information will be included in AEIR Chapter 2: Marine and Coastal Physical Processes.
We note that for 'Impact 2 - Alteration to the seabed structure, and morphology', the possibility that sandwave recovery might instead take many years would not alter the conclusion of 'Not Significant', because these undesignated bedforms are of 'low' Sensitivity regardless. Should the sandwaves be capable of recovery within 'weeks to months', this implies that clearance would need to be repeated many times during the lifetime of the development. However, this clearance activity has not been included within the consideration of operational phase impacts. If clearance	Noted. Additional information will be included in AEIR Chapter 2: Marine and Coastal Physical Processes.

Consultee's response	Response from applicant
were to be repeated throughout the operational phase, then these sandwaves would not be allowed to remain 'recovered'. As such: • We request clarification from the Applicant on whether sandwave clearance is required throughout the operational phase. Should this be required, further assessment of Impact 2 may then be necessary as well as further consideration of potential impacts from increased seabed disturbance across other related receptors.	
Regarding 'Impact 7 Impacts to stratification and the Buchan Front' (Section 6.11.2.4), we do not consider the argument that the effect Magnitude would be 'low' to be convincing. Whilst we outline our considerations of this impact below, we advise that advice should be sought from MD-SEDD on mixing and seasonal stratification.	Noted. Additional information will be included in AEIR Chapter 2: Marine and Coastal Physical Processes.
Figure 6-8 and Figure 6-9 indicate that over the summer months when stratification peaks, minimum mixed layer thickness is 10%-20% of depth. Over a substantial part of the Array Area where depths are 68m – 84m (Figure 6-3), this implies a thermocline between 7m and 17m, and hence potential for considerable interaction with the floating foundations, contrary to the statement made in Paragraph 6-198. This potential for a weakening of stratification is supported by the findings of the hydrodynamic modelling (see Paragraph 6-171), although the modelling does include a conservative assumption of turbine foundations extending through the entire water column. There is no analysis of whether the relatively local predicted changes in tidal flow mean that any weakening in stratification would be equally localised. There has also been no attempt to quantify (e.g. from published research) how much the weakening might be 'counteracted' by wind-wake effects (Paragraph 6-203).	Noted. Additional information will be included in AEIR Chapter 2: Marine and Coastal Physical Processes.
Moreover, the main reason given for assigning receptors affected by changes to seasonal stratification a 'low' Sensitivity (as a physical characteristic) is due to "strong capacity to recover from short-term disturbances" (as per Paragraph 6-207). However, we highlight that any effects would presumably occur throughout the summer, throughout the development lifetime, rather than being strictly 'short-term'.	Noted. Additional information will be included in AEIR Chapter 2: Marine and Coastal Physical Processes.
For the following cumulative impacts, 'negligible' magnitude is assigned on the basis that any effects of the Buchan proposal would not coalesce, interact or	Noted. Additional information will be included in AEIR Chapter 2: Marine and Coastal Physical Processes.

Consultee's response	Response from applicant
amplify with those of other projects: • Impact 2 Cumulative alteration to seabed composition, structure, and morphology • Impact 4 Cumulative loss of seabed under the footprint of foundations and other seabed infrastructure e.g. cable protection measures • Impact 5 Cumulative localised alteration to the hydrodynamic, wave and sediment regimes and coastal processes This approach appears to overlook the need to cumulate the effects and focusses instead on individual impacts from the project-alone. As such: • We request clarification on the factors considered within the assessment of cumulative effects and how the conclusion that cumulative effects are unlikely to be Significant has been reached. We recommend that the cumulative effects assessment is re-visited and narrative provided to support this conclusion.	
At Scoping, we highlighted our concerns regarding the likelihood of multiple offshore export cables making landfall in the area around Peterhead and the potential for cumulative impacts arising from construction as well as associated geophysical, geotechnical and environmental survey programmes. NatureScot have previously raised the need for strategic consideration by both Scottish Government (Offshore Wind and Marine Directorates) and the National Electricity System Operator (NESO). We continue to see value in pursuing a strategic approach to consideration of cumulative impacts. In our view, the ScotMER programme and / or MD Marine License conditions could present opportunity to consider monitoring outputs strategically, taking into account EIA predictions, construction and operating requirements.	Noted.
The impact of large-scale floating offshore wind farms on mixing and seasonal stratification is an emerging topic with significant uncertainties. This proposal provides an early opportunity to contribute towards this evidence gap through pre- and post-construction monitoring in alignment with the recommendation set out in Section 5.4 of the Scottish Government report "Scoping an Offshore Wind Sustained Observation Programme (OW-SOP)"16. The following ScotMER research project is currently in progress "Development of marine physical process modelling guidelines for offshore wind farm environmental impact assessments". We acknowledge the timing for this proposal may not align with the outputs of this research project however	Noted.

Consultee's response	Response from applicant
it may be useful to consider the research outputs when designing monitoring, if consented.	
The following research programmes are also underway and research outputs should be considered when designing physical processes monitoring: • ECOWind "Physics-to-Ecosystem Level Assessment of Impacts of Offshore Windfarms" (PELAgIO)17 • Enabling Sustainable Wind Energy Expansion in Seasonally Stratified Seas (eSWEETS3)18 Further advice should be sought from MD-SEDD on this topic.	Noted.