Spiorad na Mara Offshore Wind Farm

Offshore Project

Environmental Impact Assessment Report

Appendix 9.1: Physical and Coastal Processes Modelling Calibration & Validation Report, Volume 2c

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1 INTRODUCTION

1.1 OVERVIEW

1.1.1.1 This appendix of the Environmental Impact Assessment Report (EIAR) details the setup, calibration and validation of the hydrodynamic and spectral wave models of the proposed Spiorad na Mara Offshore Wind Farm (hereafter referred to as 'the Offshore Project') with respect to Physical Processes. This appendix accompanies **Chapter 9: Physical and Coastal Processes, Volume 2a** of the EIAR.

1.1.1.2 This appendix should be read in conjunction with the project description provided in **Chapter 3: Offshore Project Description, Volume 1a** and the relevant parts of the following chapters and appendices:

- **Chapter 9, Volume 2a;**
- **Appendix 9.2: Physical and Coastal Processes Modelling Results Report, Volume 2c.**

1.1.2 PROJECT BACKGROUND

1.1.2.1 Spiorad na Mara Limited (hereafter referred to as 'the Applicant') is proposing to develop the Project. The Project is an offshore wind farm (OWF) that will consist of up to 60 fixed-bottom wind turbine generators (WTGs).

1.1.2.2 The Project will include both offshore and onshore infrastructure. This EIAR supports the application for the offshore components of the Project as outlined in **Chapter 1: Introduction, Volume 1a**. The offshore components of the Project (the Offshore Project) includes all infrastructure and activities located seaward of Mean High Water Springs (MHWS) within the Array Area and Offshore Cable Area of Search (OCAS) (**Figure 1.2: Offshore Project Location, Volume 1b**). Further detailed information is provided in **Chapter 3, Volume 1a**.

1.1.2.3 The Offshore Project is situated off the northwest coast of Isle of Lewis/*Eilean Leòdhais* and the Array Area is located approximately 5-13 km offshore and is approximately 161 km^2 in size. It will comprise WTGs, foundations, Offshore Cables, Offshore Substation Platform (OSP) (if required), and Landfall. The Array Area combined with the OCAS is defined as the Offshore Project Boundary. The water depths across the Array Area range from 37-67 m with the southwest corner of the Array Area reaching 72 m. The proposed WTGs and fixed foundations will be located within a Turbine Area of approximately 140 km^2, within the Array Area.

1.2 PURPOSE OF THIS APPENDIX

1.2.1.1 This appendix describes the following:

- Metocean data used to develop the Hydrodynamic and Spectral wave models, including waves, tidal currents and bathymetry (Section 2);
- Modelling methodology (Section 3);
- Hydrodynamic modelling calibration and validation (Section 4);
- Spectral wave modelling calibration and validation (Section 5);
- Conclusions and recommendations (Section 6);
- Information and documentation referred to in this appendix (Section 8).

1.2.1.2 This appendix is supported by the following figures:

- **Figure 1.2, Volume 1c.**

2 METOCEAN DATA SOURCES

2.1.1.1 The metocean data used to inform the coastal process assessment, presented in **Chapter 9, Volume 2a**, is detailed within this section of the appendix.

2.2 BATHYMETRY

2.2.1.1 Bathymetry data covering the offshore region was obtained from the General Bathymetric Chart of the Oceans (GEBCO, 2024) at 100 m resolution.

2.2.1.2 All bathymetry data vertical depths are referenced to Ordnance Datum Newlyn (mODN) for use within the coastal models and British National Grid has been used as the horizontal projection system.

2.2.1.3 **Plate 2-1** shows the bathymetry local to the Offshore Project Boundary. This shows water depths relative to mODN from the GEBCO on a 15 arc-second interval grid (approximately 100 m grid). In addition, a shapefile of the coastline is included, derived from the OpenStreetMap Web Map Service (OpenStreetMap, 2025). **Plate 2-2** shows cross sections through the bathymetry at the Array Area. The locations of the cross sections are shown in **Plate 2-1**.

2.2.1.4 The proposed Array Area lies within water depths of approximately 35–70 m. The bathymetric data was processed into a format readable by MIKE by DHI modelling software and used as an input to build the mesh for the hydrodynamic and spectral wave models to assess the baseline and post-development scenarios.

2.2.1.5 A site-specific bathymetry data survey was undertaken after the development of the model. A high-level comparison of the site-specific data has been subsequently undertaken with the GEBCO dataset to determine the level of confidence with the publicly available data. **Plate 2-3** shows the delta between the 2 bathymetric data sets, indicating generally shallower depths for the GEBCO dataset. Overall, in the areas that are relevant to the study (the Turbine Area and the OCAS) the delta between the 2 surveys is generally under 5 m, which has been calculated to be between 2-5% of the total water depth. This level of variation is within the allowable tolerances for accuracy (±5 m +5% depth) specified in the Hydrographic Survey Specification (Seabed Mapping) Report for offshore surveys relevant to activities planned in water depths up to 200 m (UK Hydrographic Office, 2022). This correlation provides confidence that the GEBCO data used in model development is suitably representative and sufficiently robust for the purposes of the Environmental Impact Assessment (EIA).

Plate 2-1 Site bathymetry and location of cross sections

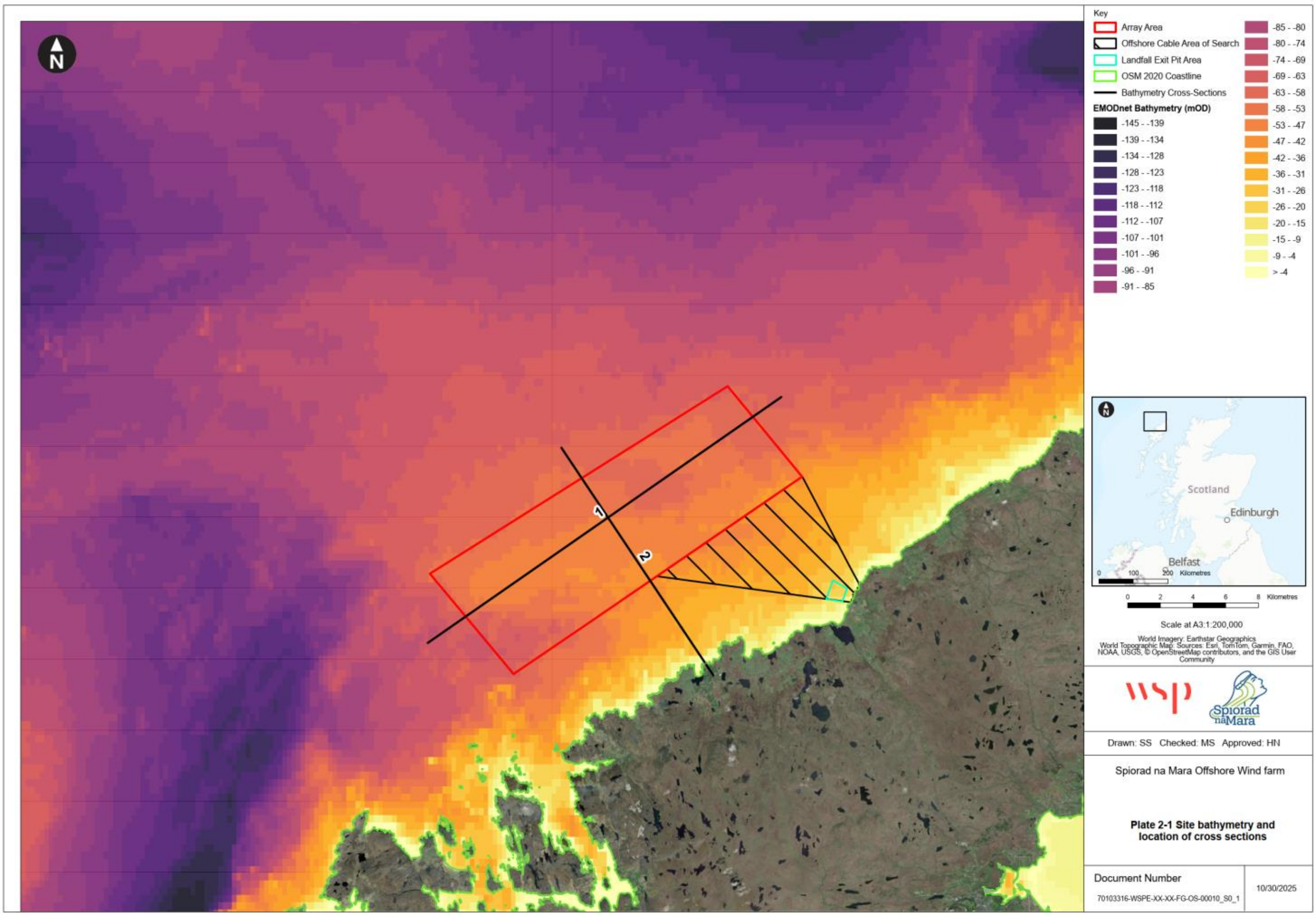
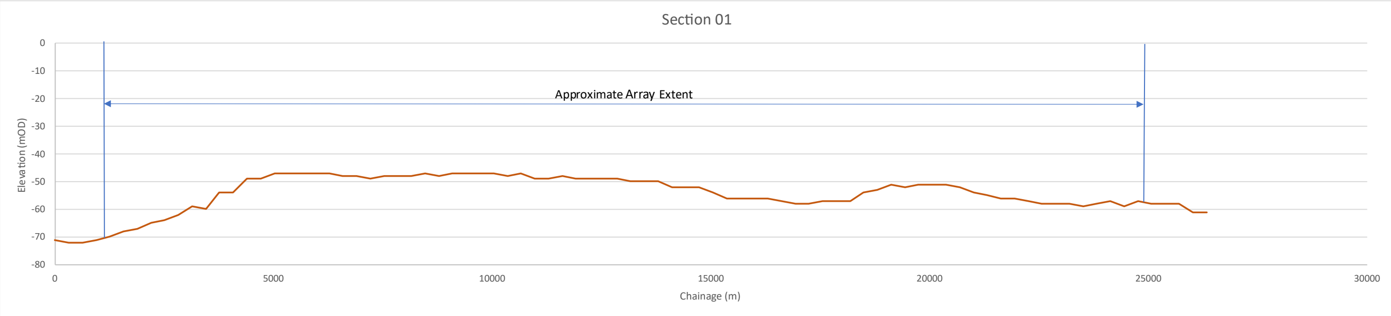


Plate 2-2: Bathymetric cross sections through the Array Area



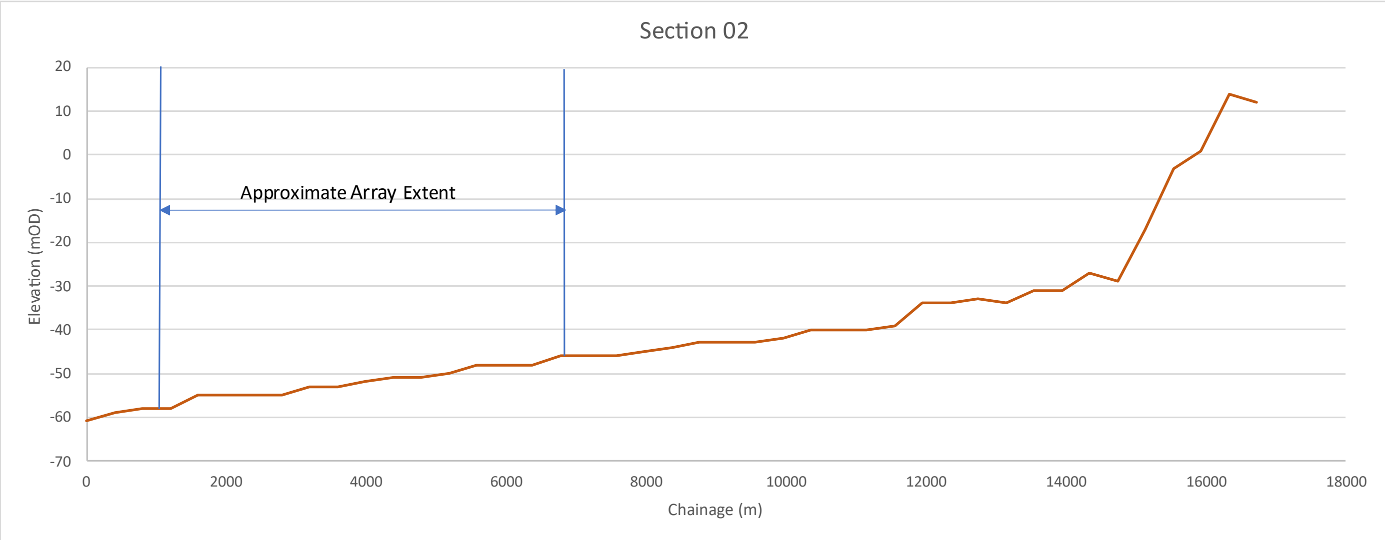
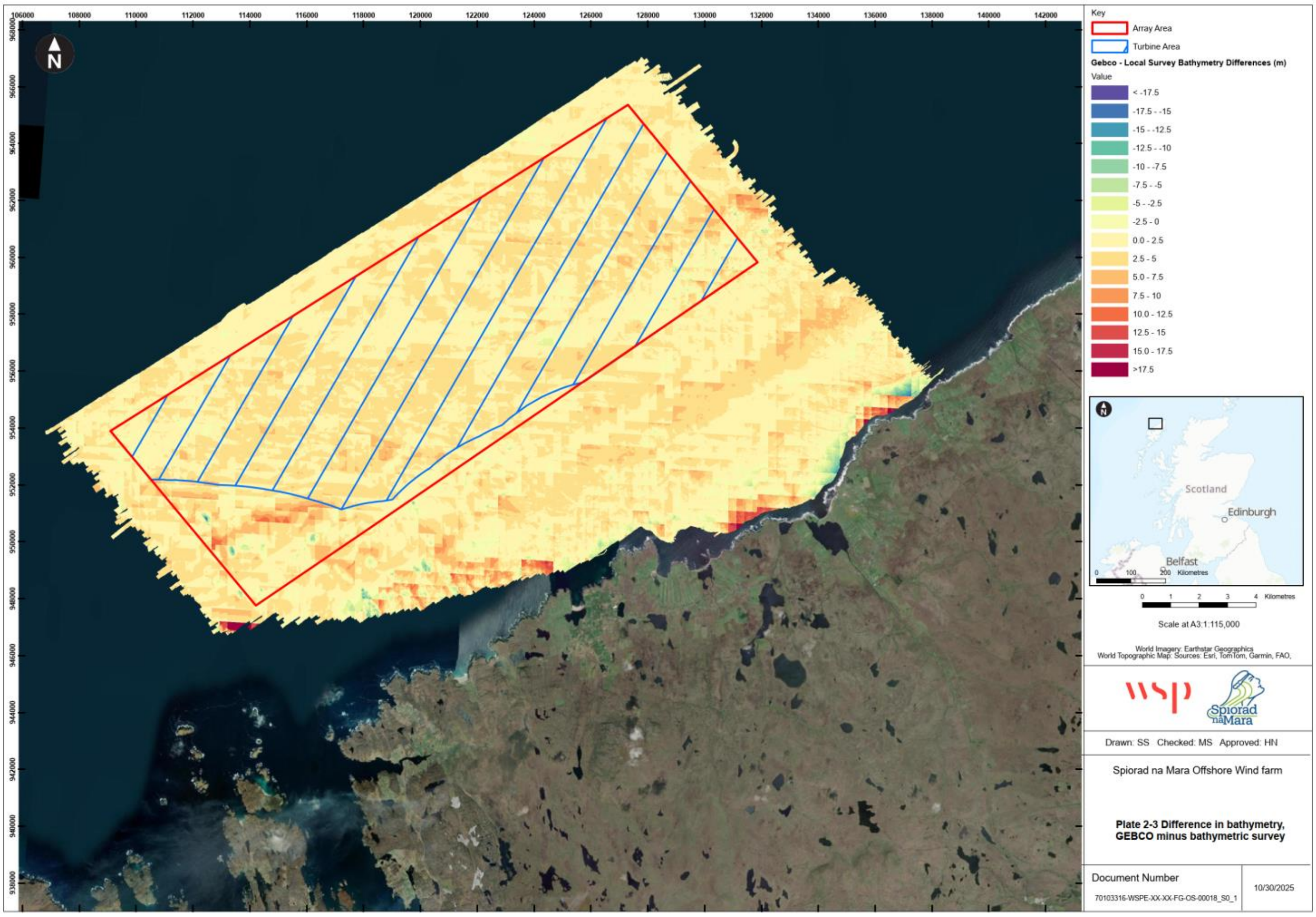


Plate 2-3: Difference in bathymetry, GEBCO minus bathymetric survey



2.3 MEASURED DATA

2.3.1.1 Current speed, current direction and water level data were obtained from the sources detailed in **Table 2-1**.

Table 2-1 Measured hydrodynamic data

Instrument	Coordinates	Period	Parameters
EOLOS FLS200 Light Detection and Ranging (LiDAR) Buoy	Easting 1454111.83, Northing 6477105.38	24 October 2023- 23 November 2024	Current Speed Current Direction
Nortek Signature 500	Easting 1454085.83, Northing 6474877.78	23 October 2023- 04 November 2024*	Current Speed Current Direction Water Level

Instrument	Coordinates	Period	Parameters
RBR Concerto Conductivity, Temperature and Depth (CTD)	Easting 1454085.83, Northing 6474877.78	23 October 2023- 04 November 2024*	Water Level

**Note: From January 2024 onwards, data for this instrument has been recorded at a separate seabed mooring location, 300m away (Easting 1453802.60, Northing 6474917.85).*

2.3.1.2 Measured data from all instruments was used in the hydrodynamic model calibration exercise, as detailed in Section 4.

2.3.1.3 Measured wave data were obtained at three locations detailed in **Table 2-2**.

Table 2-2 Measured wave data

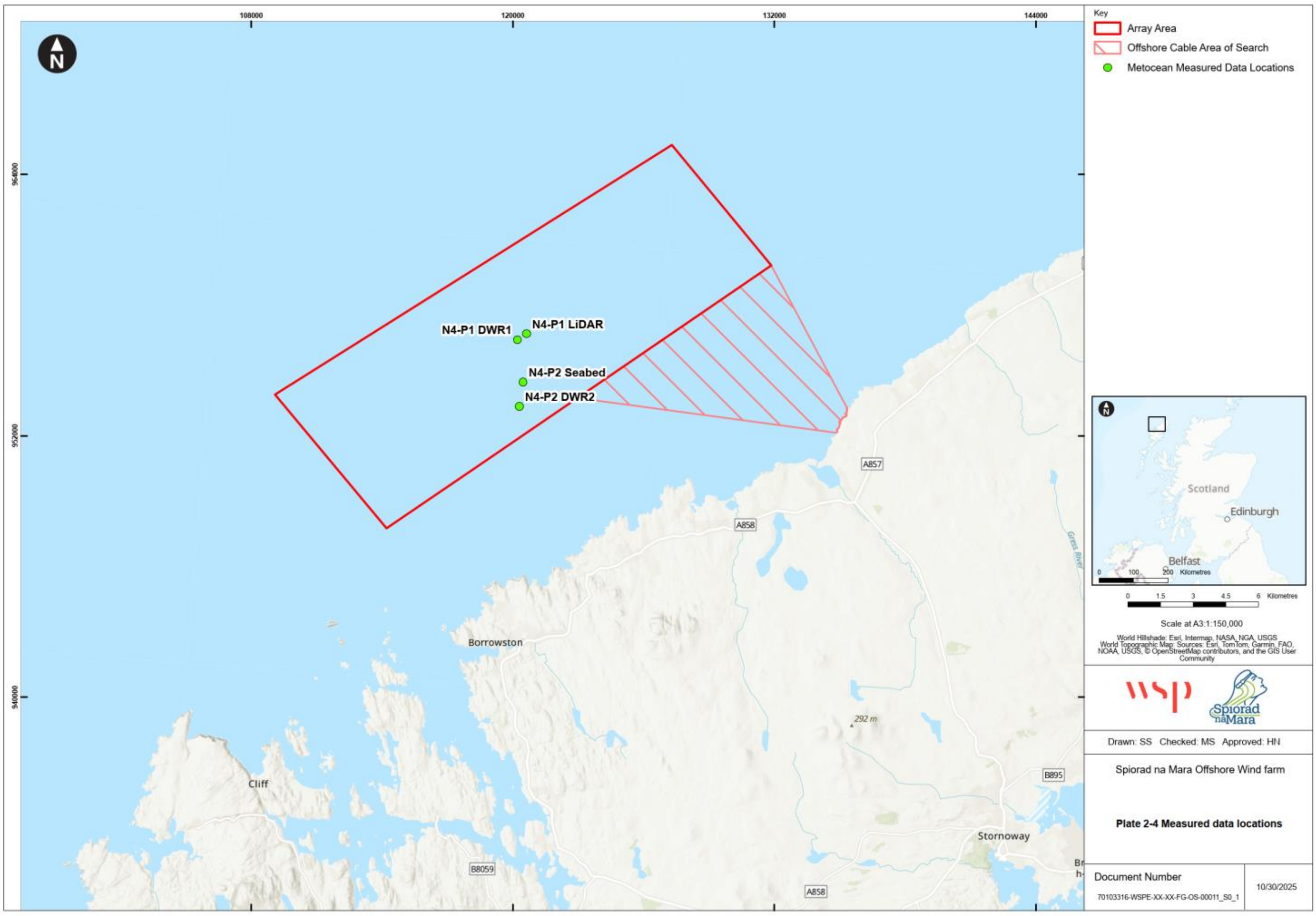
Instrument	Coordinates	Period	Parameters
EOLOS FLS200 LiDAR Buoy	Easting 1454111.83, Northing 6477105.38	24 October 2023- 23 November 2024	Wave Height Wave Period Wave Direction
Directional Waverider (DWR MKIII Wavebuoy	Easting 1453710.19, Northing 6476807.097	23 October 2023- 04 November 2024;	Wave Height Wave Period Wave Direction
DWR MKIII Wavebuoy	Easting 1453923.58, Northing 6474759.37	23 October 2023-04 November 2024	Wave Height Wave Period Wave Direction

2.3.1.4 The measured data captures several storm events for wave model calibration and is therefore appropriate for use within the wave model assessment.

2.3.1.5 A list of all variables measured using the instruments in **Table 2-1** and **Table 2-2** can be found in **Table 9-7** Site Surveys Undertaken in **Chapter 9, Volume 2a**.

2.3.1.6 **Plate 2-4** shows the location within the Array Area of deployments undertaken for the periods noted in **Table 2-1** and **Table 2-2** by the Project. The instruments are located approximately 10 km offshore in water depths of approximately 50 m. This measured data is used for calibration of both the hydrodynamic and spectral wave models detailed in Section 4 and Section 5.

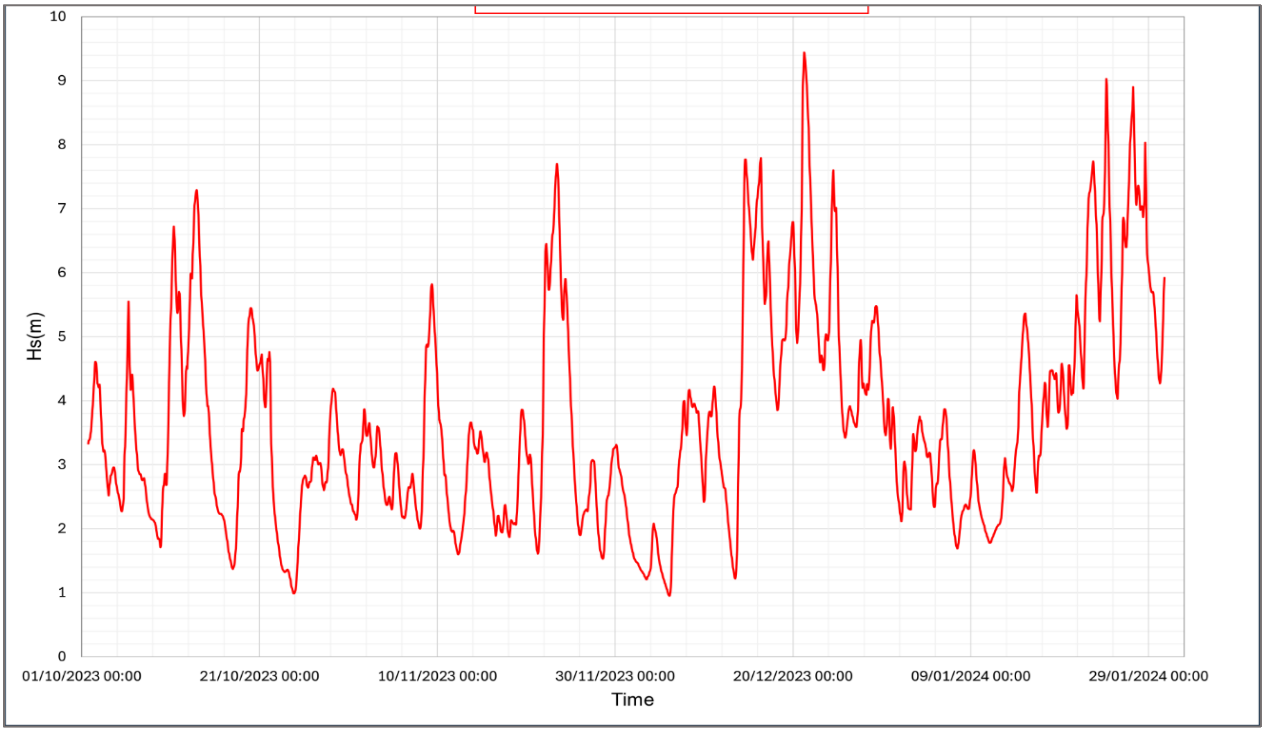
Plate 2-4: Measured data locations



2.4 MODELLED DATA

2.4.1.1 Hindcast modelled wave data was used as the model boundary condition for the calibration and validation period of the spectral wave model. Modelled data including wave height, period and direction was obtained from the global WAVEWATCH III model. WAVEWATCH III is a third-generation wave model developed at NOAA/NCEP and generated from the NCEP Climate Forecast System Reanalysis and Reforecast (CFSRR) homogeneous dataset of hourly high-resolution winds (NCEP, 2025; NCEP, 2025). Data was extracted at the edge of the model boundary (Easting: 79757, Northing: 970672) covering the period between 1 October 2023 and 30 January 2024. The hindcast model data point is located approximately 45 km offshore and 35 km away from the Array Area, in 100 m water depths, the data from this point is shown in **Plate 2-5**.

Plate 2-5: WAVEWATCH III data used as boundary condition for spectral wave model calibration



3 Hydrodynamic and Spectral Waves - Model Build and Calibration Methodology

3.1.1.1 The Danish Hydraulic Institute modelling software (DHI MIKE) 2023 modelling software suite was used for this study to simulate hydrodynamics and waves using the MIKE21 Flexible Mesh hydrodynamics and spectral wave models respectively.

3.1.1.2 A hydrodynamic model of the North Atlantic Ocean off the west coast of the Isle of Lewis/*Eilean Leòdhais* was developed with refinement of the model mesh around the Array Area and wider area of interest to provide water level and current data.

3.1.1.3 The model mesh increases from a maximum area of 1 km^2 in the outmost regions to 5,000 m^2 in the Array Area, OCAS, and nearshore region.

3.1.1.4 Using the same domain and bathymetric data, a spectral wave model was developed to transform offshore WAVEWATCH III wave data to the Array Area and OCAS for use within the local higher-resolution mesh.

3.1.1.5 **Plate 3-1** to **Plate 3-3** show the model extents used for both the hydrodynamic and spectral wave Models, as well as the variations in mesh refinement throughout the model, and the refined mesh in and around the Array Area.

3.1.1.6 The model extents were selected by considering the baseline data review, anticipated impact extents, and the geography of the Isle of Lewis/*Eilean Leòdhais*. It includes tidal ellipse extents and extends beyond the Offshore Project Boundary to allow for the appropriate evolution of hydrodynamic and wave conditions.

Plate 3-1: Isle of Lewis west coast model extent

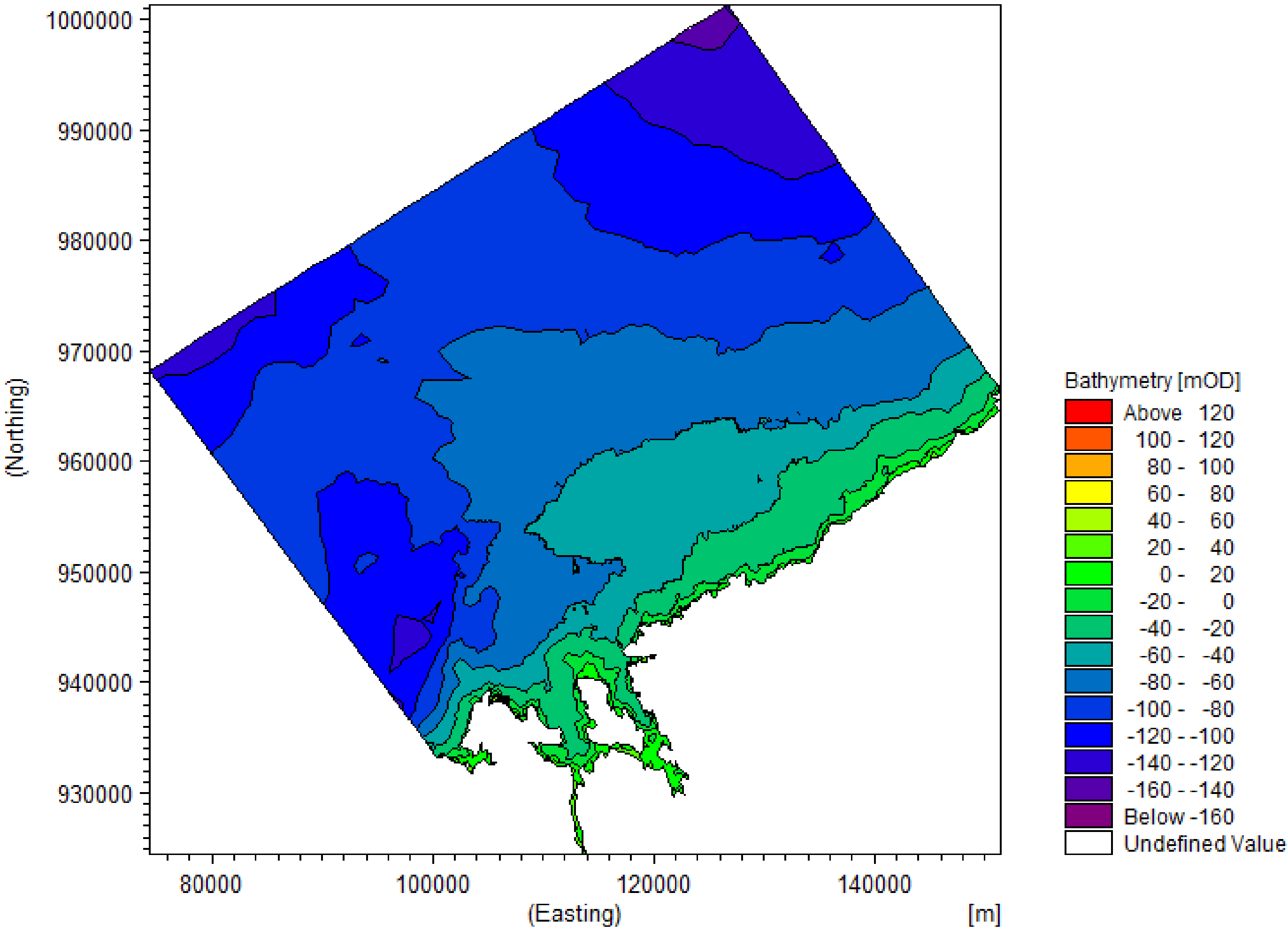


Plate 3-2: Variations in mesh refinement

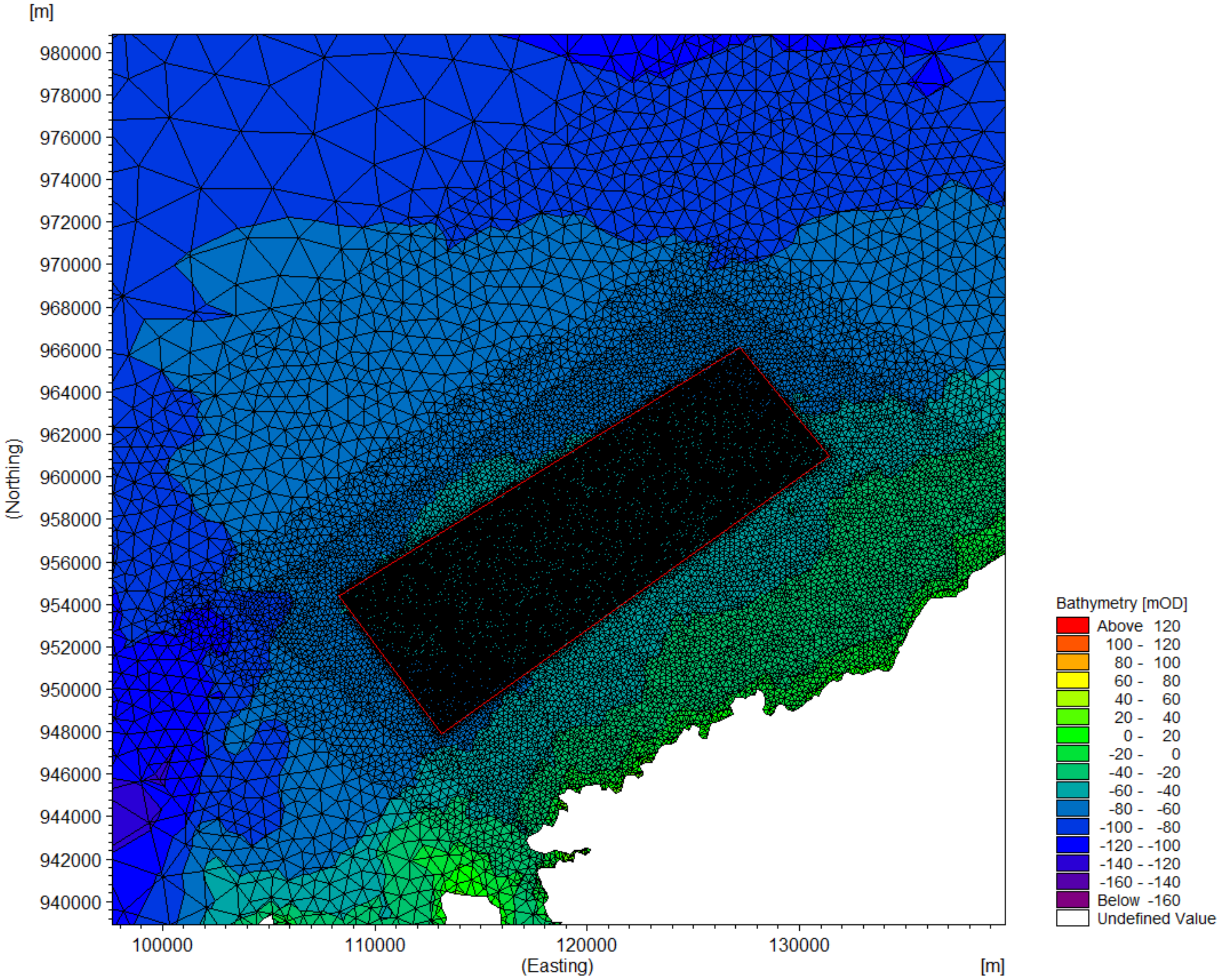
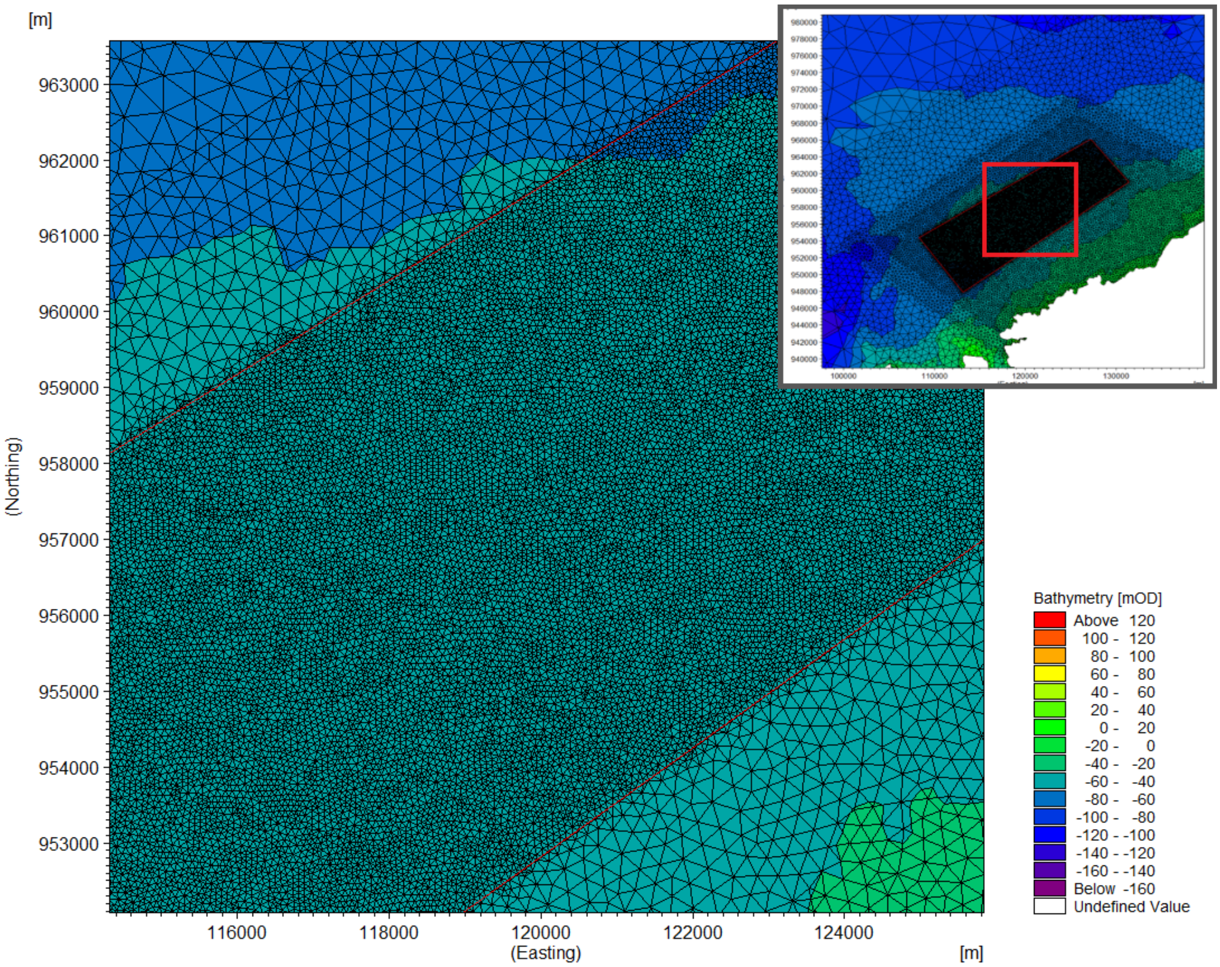


Plate 3-3: Refined mesh in and around Array Area



4 HYDRODYNAMIC MODELLING – MODEL BUILD AND CALIBRATION

4.1.1.1 Water level boundary conditions were obtained from the DHI MIKE Global Tide Model at 0.125 degree resolution. The period between 14 November and 5 December 2023 was simulated to provide tidal conditions specific to the Offshore Project Boundary. The 21-day long calibration period was selected to ensure this would cover both a neap and spring tide. This allows the model to be adequately calibrated against a wide tidal range for both levels and currents.

4.1.1.2 The Hydrodynamic Model was calibrated against measured tidal water levels, tidal currents, and current directions from the instruments presented in **Table 2-1** for the period between 14 November and 5 December 2023.

4.1.1.3 Results for this calibration period were assessed against ABPmer goodness of fit standards for Tidal Hydrodynamic Models calibration as described in Pye *et al*. (2017).

4.1.1.4 The metrics and requirements relating to the Hydrodynamic parameters are as follows:

- **Percentage water levels** within +/-10% of spring tidal ranges and 20% of neap tidal ranges;
- **Phase difference at high and low water** within +/- 20 minutes;
- **Root Mean Square Error (RMSE)** values below 0.2;
- **Current Speed** within +/- 20% or within 0.2 m/s of observed speeds;
- **Current Direction** within +/- 20% of observed directions;
- **Phase Difference in flow direction** within +/- 20 minutes;
- **Scatter Index values** <0.5.

4.1.1.5 The qualitative descriptions described relate to these tolerances in the following way:

- **'Excellent' fit** – specified tolerances achieved >90% of the time;
- **'Very Good' fit** – specified tolerances achieved >80% of the time;
- **'Good' fit** – specified tolerances achieved >70% of the time;
- **'Reasonable' fit** – specified tolerances achieved >60% of the time;
- **'Poor' fit** – specified tolerances achieved <60% of the time.

4.1.1.6 The overall aim of the calibration and validation and calibration process is to ensure their accuracy and reliability in predicting coastal processes to inform the EIAR. It may not be possible to achieve an 'Excellent' fit for every calibration period and parameter assessed. The overall suite of calibration runs will be assessed to confirm they are suitable to inform the key coastal processes of **Chapter 9, Volume 2a**.

4.1.1.7 A tolerance of 'Good' or higher provides confidence that the models are considered suitable and robust. However, it is noted that expert judgement will also be used to assess the model calibration results as well as the above metrics and qualitative descriptions.

4.1.1.8 The following sections describe how the modelled and measured currents and water levels compare, based on the above metrics, at the location of the 3 instruments (see **Plate 2-4**). Each parameter was calibrated against measured data from 2 different deployed instruments.

4.1.1.9 A summary of the accuracy of the hydrodynamic models and whether they are deemed to accurately represent tidal conditions within the Offshore Project Boundary can be found in Section 6.

4.2 NORTEK 500 CALIBRATION

4.2.1.1 **Plate 4-1** to **Plate 4-3** show a comparison of the modelled and measured water level and current speed data for the Nortek 500 instrument for the period between 14 November and 5 December 2023.

Plate 4-1: Water depth calibration, Nortek 500

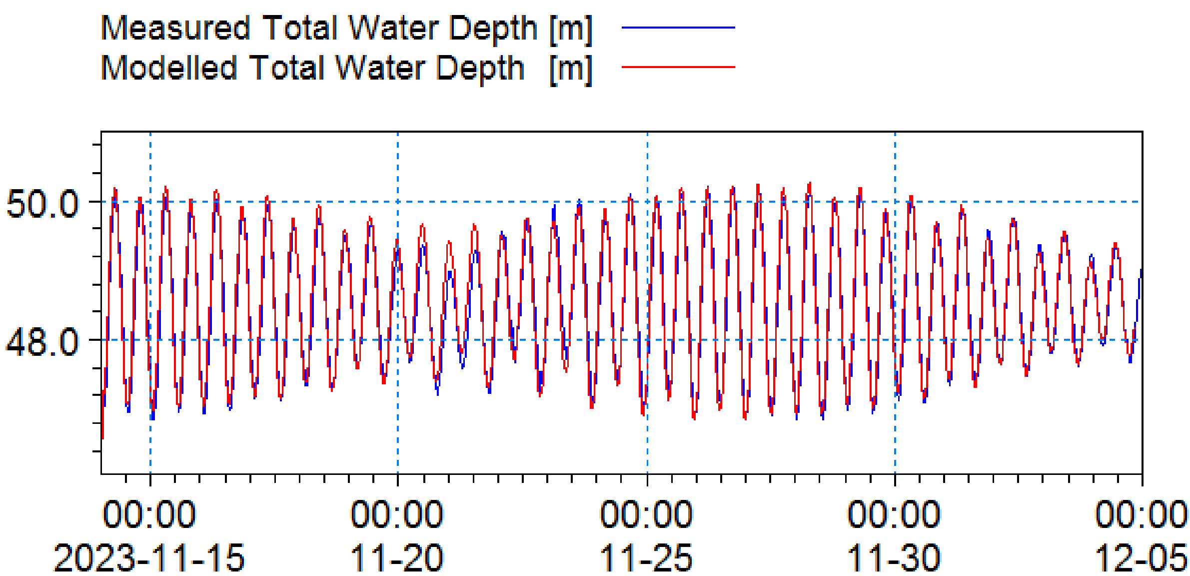


Plate 4-2: Current speed calibration, Nortek 500

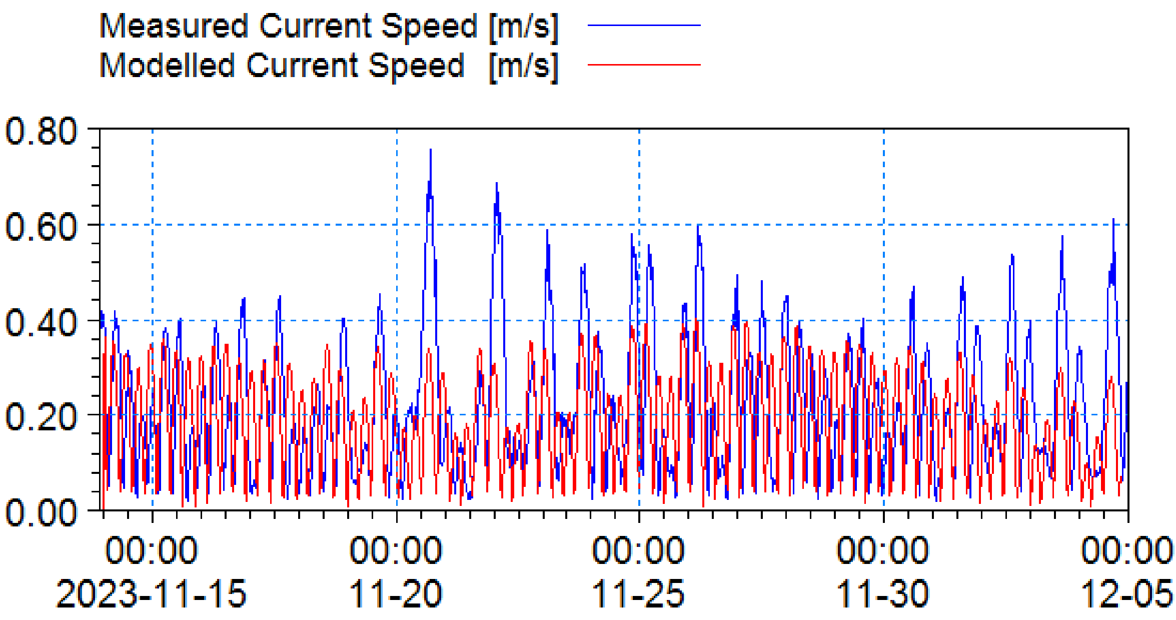
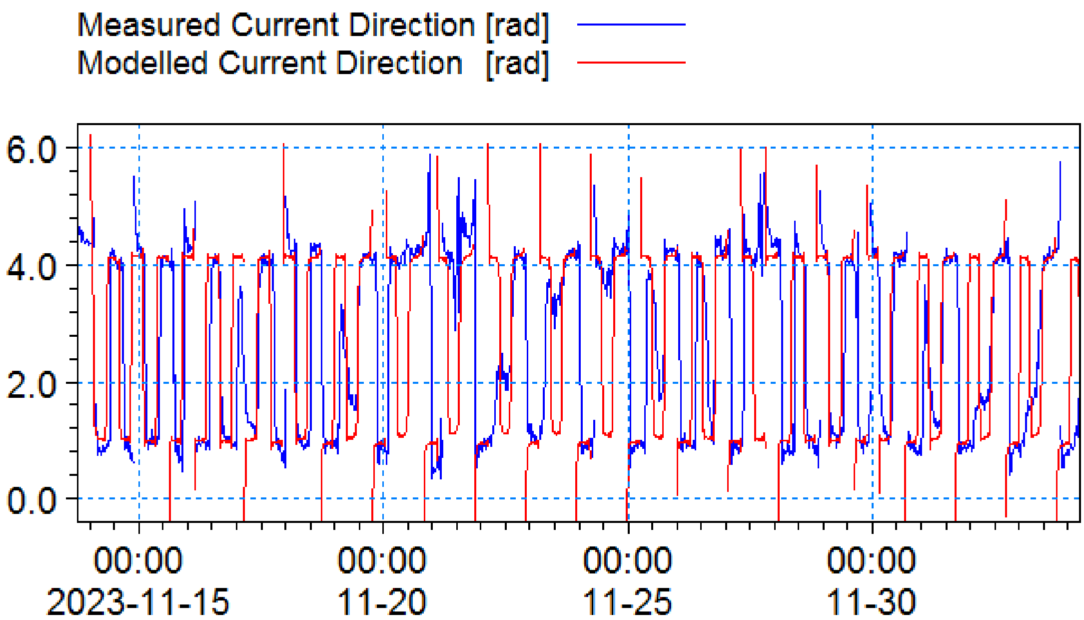


Plate 4-3: Current direction calibration, Nortek 500



4.2.1.2 The results show that the model performs well against Nortek 500 data between 14 November and 5 December 2023. Water levels showed an 'Excellent' agreement between modelled and measured data, being within 20% of the measured neap tidal range and 15% of the measured spring tidal range for more than 92% of the time.

4.2.1.3 The RMSE for the total water depth only slightly exceeds the ideal metrics by 0.01, with a value of 0.21. This should have no impact on the overall model accuracy, due to the water depth having an 'Excellent' fit (see paragraph 4.1.1.2). A 'Very Good' fit was achieved for current speed which was within +/- 20% or within 0.2 m/s of observed speeds for >80% of the time. The RMSE was 0.15, within the suggested range of <0.2.

4.2.1.4 The modelled current direction also shows 'Good' agreement against the measured data which was within +/- 20% of observed directions.

4.2.1.5 Overall, based on visual inspection, the modelled results accurately picked up directional variation associated with flood and ebb tides.

4.3 FLIDAR CALIBRATION

4.3.1.1 **Plate 4-4** and **Plate 4-5** show a comparison of the modelled and measured current speed and current direction data for the Floating Light Detection and Ranging (FLiDAR) instrument for the period between 14 November and 5 December 2023.

Plate 4-4: Current speed calibration, FLiDAR

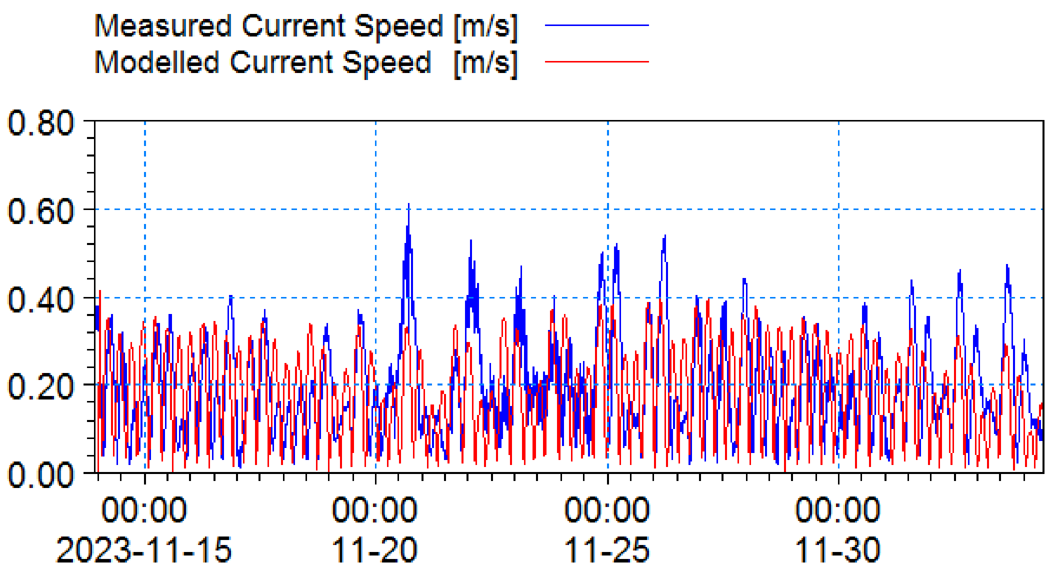
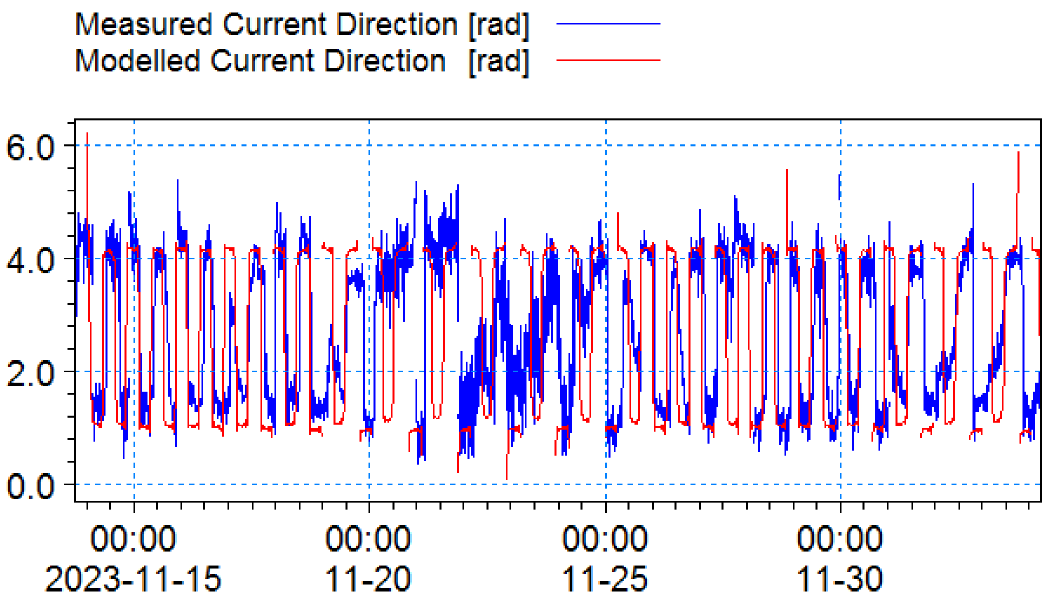


Plate 4-5: Current direction calibration, FLiDAR



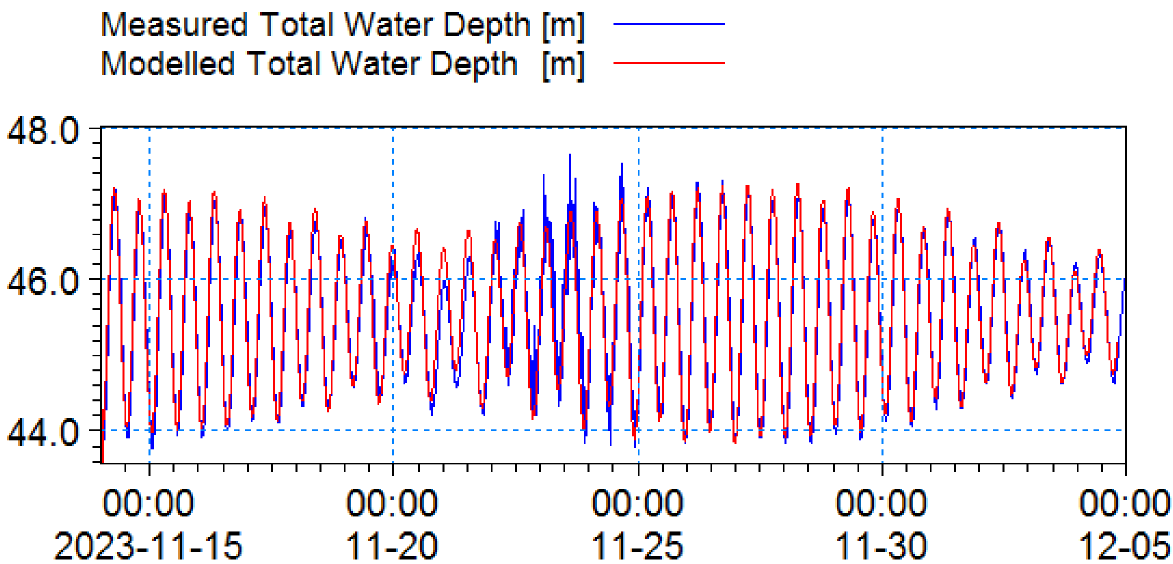
4.3.1.2 The results show that the model performs well against FLiDAR data between 14 November and 5 December 2023. Current speeds showed a 'Very Good' agreement between modelled and measured data, being within 20% of measured data for more than 87% of the time. Current Speeds show a RMSE of 0.13, sitting within the ideal range of <0.2.

4.3.1.3 The modelled current direction also shows 'Good' agreement against the measured data, with the modelled results accurately picking up directional variation associated with flood and ebb tides.

4.4 CTD CALIBRATION

4.4.1.1 **Plate 4-6** shows a comparison of the modelled and measured water level data for the CTD instrument for the period between 14 November and 5 December 2023.

Plate 4-6: Water depth calibration, CTD



4.4.1.2 The results show an 'Excellent' agreement between measured and modelled data for water depth. Levels were within 20% of the neap tidal range and within 15% of the spring tidal range for more than 90% of the time. The RMSE for total water depth is slightly above the ideal metrics, with a value of 0.24.

5 SPECTRAL WAVE MODELLING – MODEL BUILD AND CALIBRATION

5.1.1.1 Wave data were extracted from the global WAVEWATCH III hindcast model at a point approximately 50 km offshore and 42 km away from the Array Area (at its closest point) to provide boundary conditions for the wave model.

5.1.1.2 The resolution of the spectral wave model varies from 1,000 m^2 at the boundary shown in **Plate 3-1**, to 50 m^2 around the Array Area. The period between October 2023 and January 2024 was used to run the model, with data available at 1-hour intervals.

5.1.1.3 The spectral wave model was calibrated against measured wave heights, wave periods, and wave direction from the instruments presented in **Table 2-2** for 3 storm periods during 21-26 November 2023; 18-20 December 2023 and 20-22 December 2023 (for further information see Section 5.2, Section 5.3 and Section 5.4 respectively).

5.1.1.4 The results for these calibration periods were assessed against ABPmer goodness of fit standards for spectral wave models calibration as described in 'Advice to Inform Development of Guidance on Marine, Coastal and Estuarine Physical Processes Numerical Modelling Assessments' (Natural Resources Wales, 2017). This document reports ABPmer internally developed guidance used in previous EIAs.

5.1.1.5 The metrics and requirements relating to the spectral wave parameters are as follows:

- **Significant Wave Height** within +/-10% of observed significant wave height;
- **Mean Wave Period** within +/- 20% of observed period;
- **Mean Wave Direction** within +/- 30% of observed directions;
- **Scatter Index values** <35 for both Significant Wave Height (Hs) and Peak Wave Period (Tp).

5.1.1.6 The qualitative descriptions described relate to these tolerances in the following way:

- **'Excellent' fit** – specified tolerances achieved >90% of the time;
- '**Very Good' fit** – specified tolerances achieved >80% of the time;
- **'Good' fit** – specified tolerances achieved >70% of the time;
- '**Reasonable' fit** – specified tolerances achieved >60% of the time;
- **'Poor' fit** – specified tolerances achieved >50% of the time.

5.1.1.7 The following sections describe how the simulated and measured wave parameters compare, based on the above metrics, at the location of the 3 instruments.

5.1.1.8 A summary of the accuracy of the spectral wave models and whether they are deemed to accurately represent wave conditions within the Offshore Project Boundary can be found in Section 6.

5.2 STORM PERIOD 21-26 NOVEMBER 2023

5.2.1.1 The period between 21-26 November 2023 presents storm conditions with wave heights ranging from 2-8 m, allowing for an appropriate analysis of how accurately the model can simulate large wave conditions within the Offshore Project Boundary.

5.2.2 FLIDAR CALIBRATION

5.2.2.1 **Plate 5-1** to **Plate 5-3** show a comparison of the measured and modelled significant wave height, period and direction for the FLiDAR instrument for calibration period 21-26 November 2023.

Plate 5-1: Significant wave height calibration, FLiDAR, 21-26 November 2023

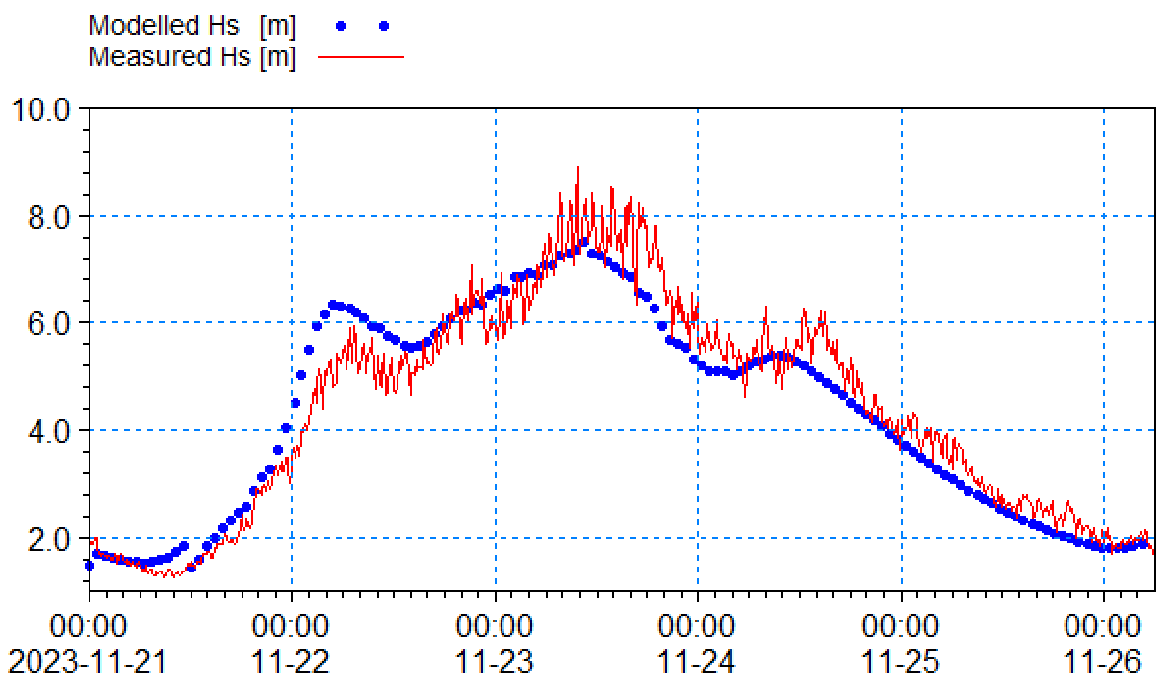


Plate 5-2: Peak wave period calibration, FLiDAR, 21-26 November 2023

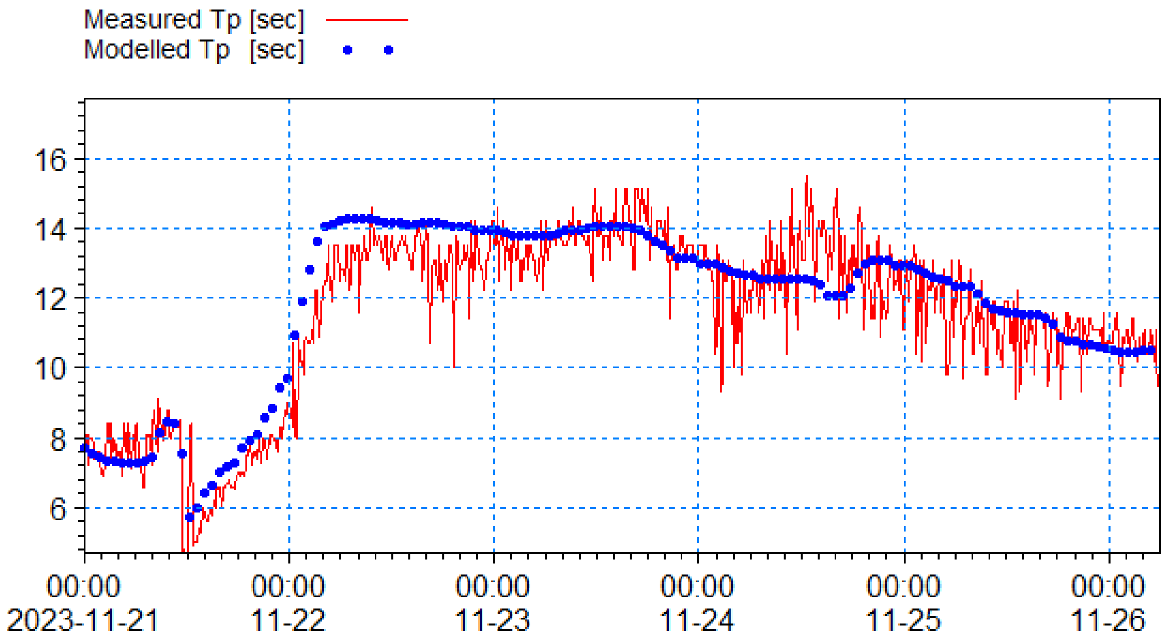
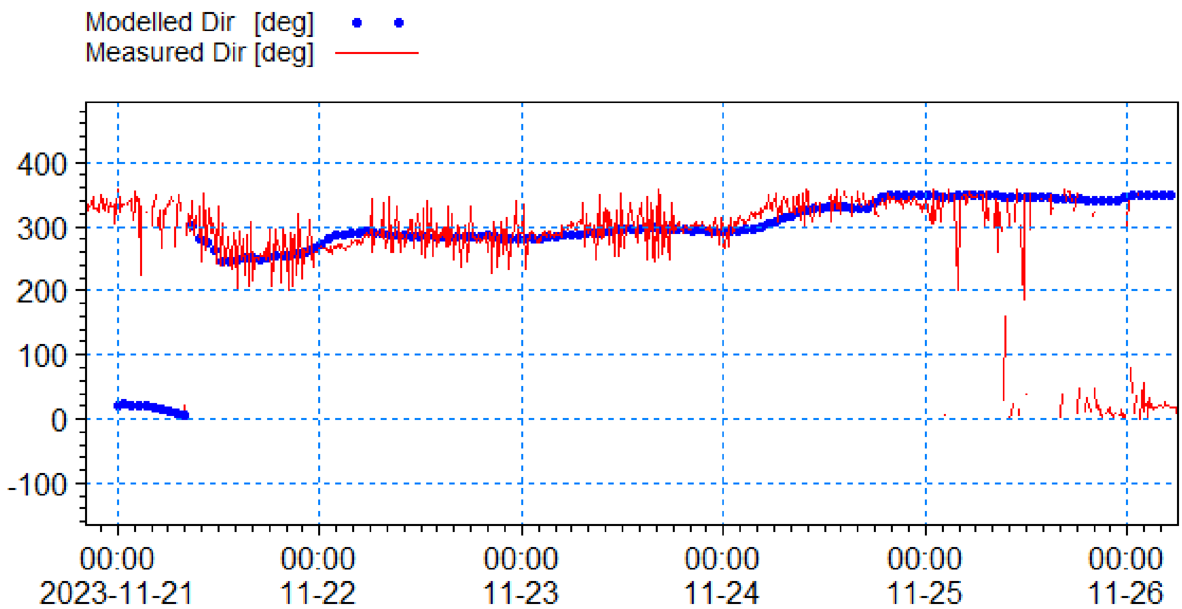


Plate 5-3: Direction calibration, FLiDAR, 21-26 November 2023



5.2.2.2 The results show that the model performs well against FLiDAR data between 21-26 November 2023. Significant wave height showed a 'Very Good' agreement between modelled and measured data, being within 10% of measured data for more than 80% of the time. An 'Excellent' fit was achieved for mean wave period, and a 'Very Good' fit for wave direction. Scatter Indices for Hs and Tp were 13% and 9% respectively.

5.2.3 DWR1 CALIBRATION

5.2.3.1 **Plate 5-4** to **Plate 5-6** show a comparison of the measured and modelled significant wave height, period and direction for DWR1 for calibration period 21-26 November 2023.

Plate 5-4: Significant wave height calibration, DWR1, 21-26 November 2023

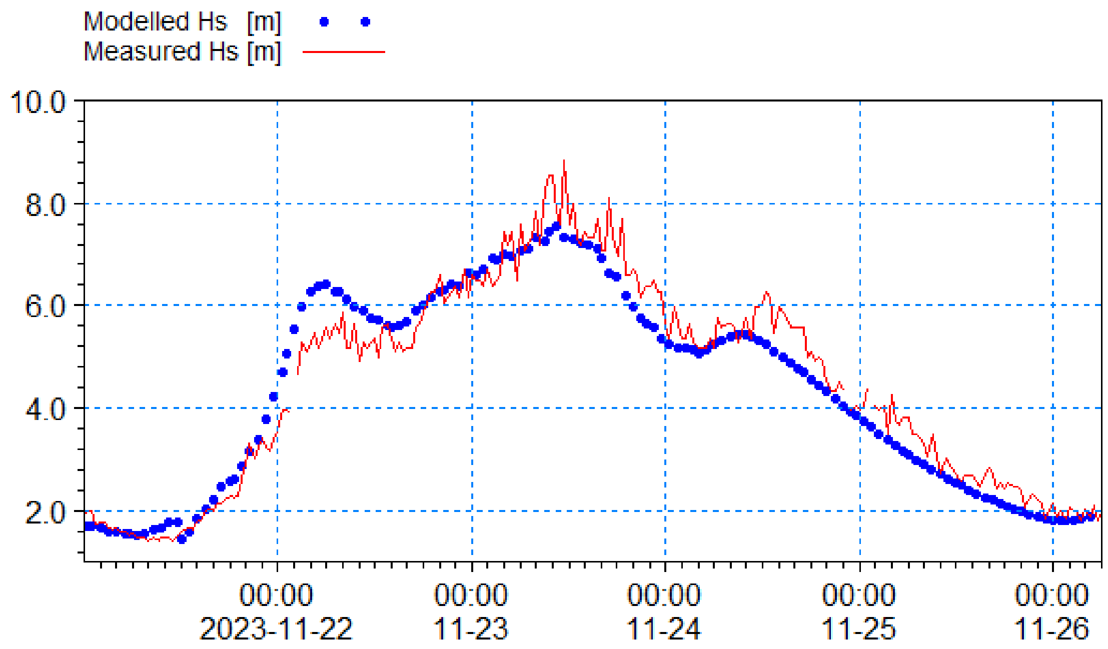


Plate 5-5: Peak wave period calibration, DWR1, 21-26 November 2023

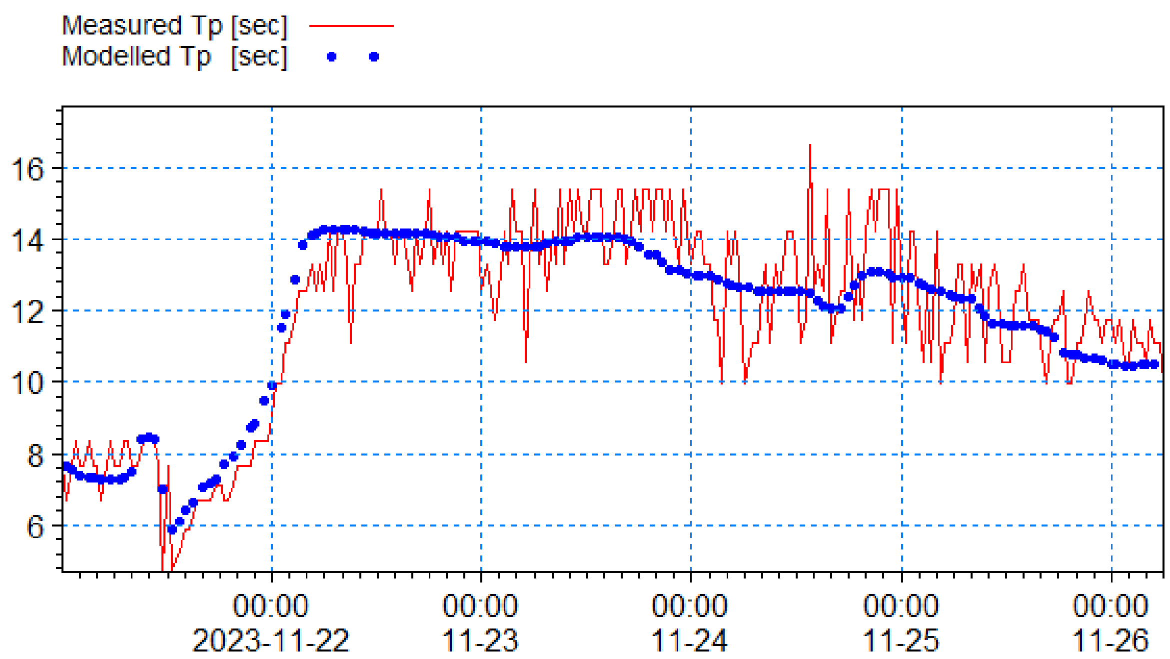
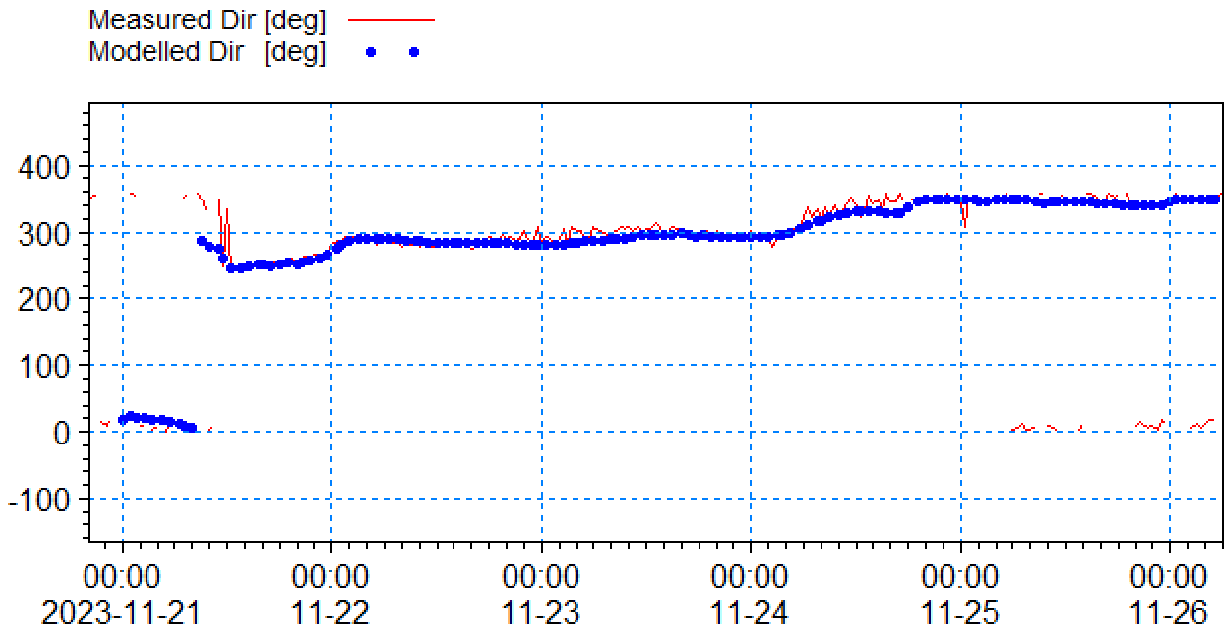


Plate 5-6: Direction calibration, DWR1, 21-26 November 2023



5.2.3.2 The calibration results show that the model performs well against DWR1 data between 21-26 November 2023. Following ABPmer goodness of fit standards, model results reached a 'Very Good' fit for Significant Wave Height and Direction, and an 'Excellent' fit for wave period. Scatter Indices for Hs and Tp were of 16% and 10% respectively, both well within the requirements.

5.2.4 DWR2 CALIBRATION

5.2.4.1 **Plate 5-7** to **Plate 5-9** show a comparison of the measured and modelled significant wave height, period and direction for DWR2 for calibration period 21-26 November 2023.

Plate 5-7: Significant wave height calibration, DWR2, 21-26 November 2023

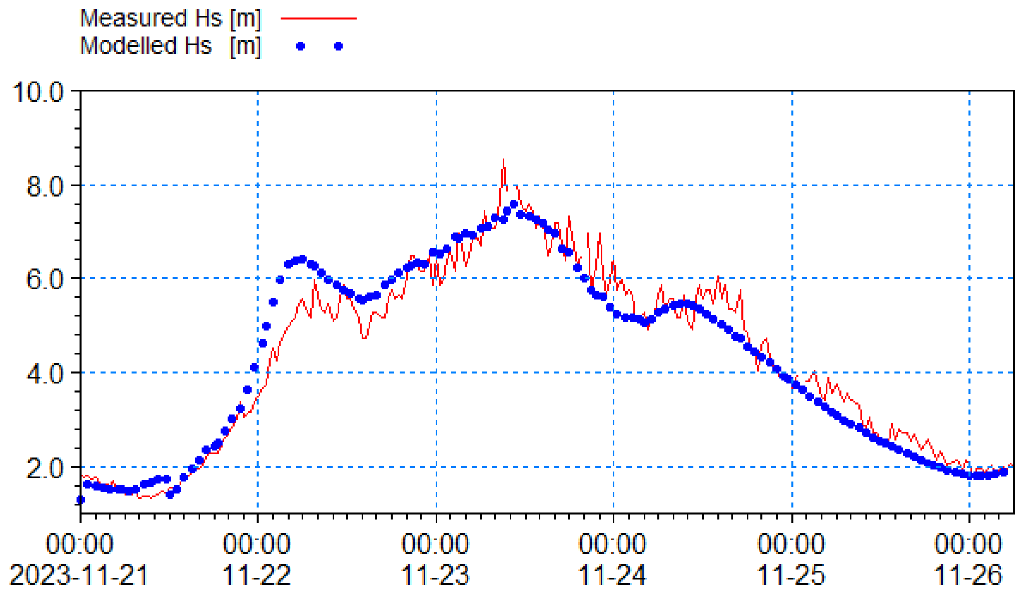


Plate 5-8: Peak wave period calibration, DWR2, 21-26 November 2023

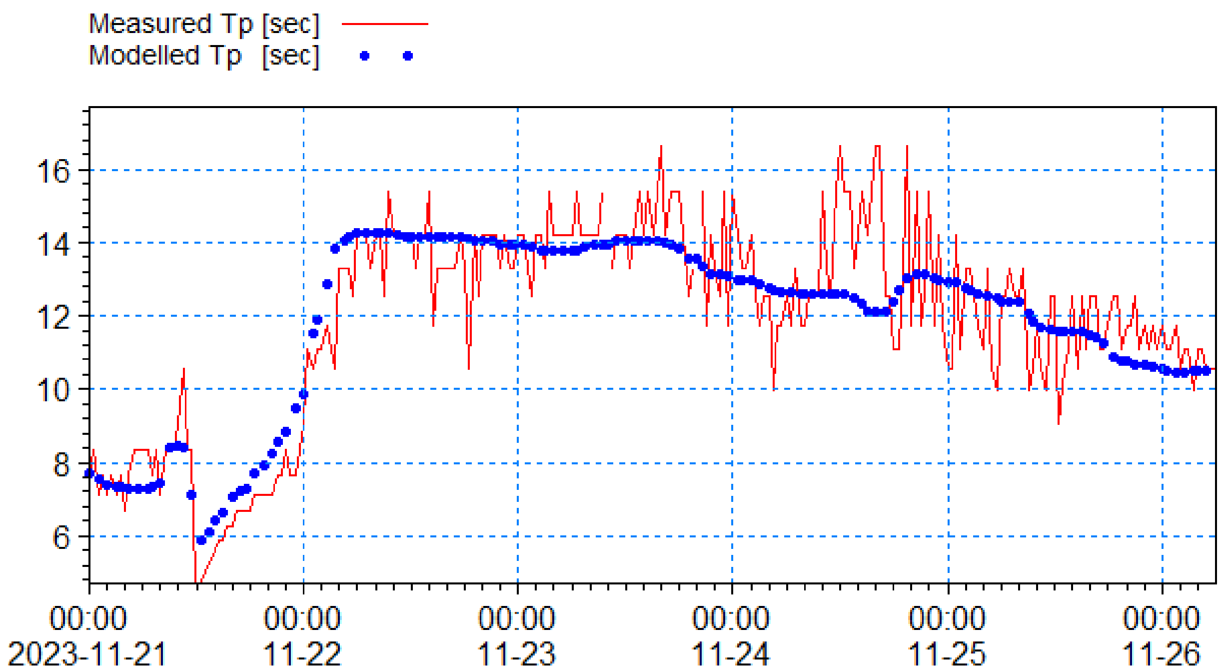
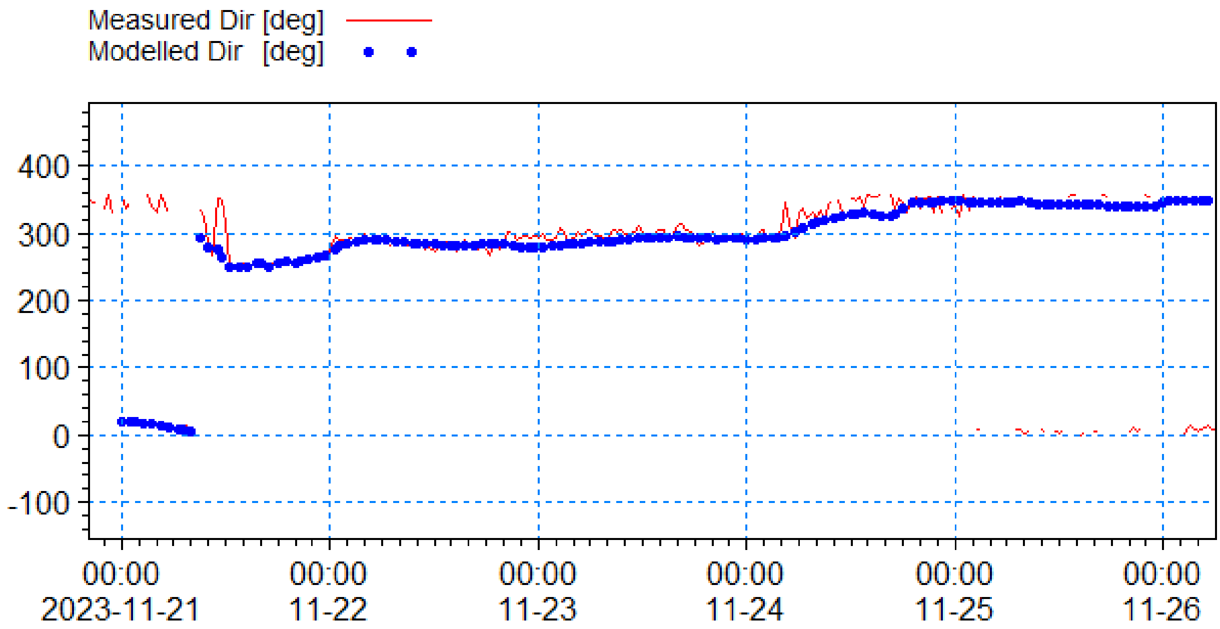


Plate 5-9: Direction calibration, DWR2, 21-26 November 2023



5.2.4.2 The model also performs well against DWR2 over the same period, with significant wave height, wave period and wave direction all resulting in a 'Very Good' fit. Scatter Indices are slightly higher, showing as 20% for Hs and 13% for Tp, but still below 35% as required.

5.3 STORM PERIOD 18-20 DECEMBER 2023

5.3.1.1 The period of 18-20 December 2023 shows a less extreme storm event but includes a longer event with significant wave heights ranging from 4-7 m for over 48 hours.

5.3.2 FLIDAR CALIBRATION

5.3.2.1 **Plate 5-10** to **Plate 5-12** show a comparison of the measured and modelled significant wave height, period and direction for the FLiDAR for the calibration period 18-20 December 2023.

Plate 5-10: Significant wave height calibration, FLiDAR, 18-20 December 2023

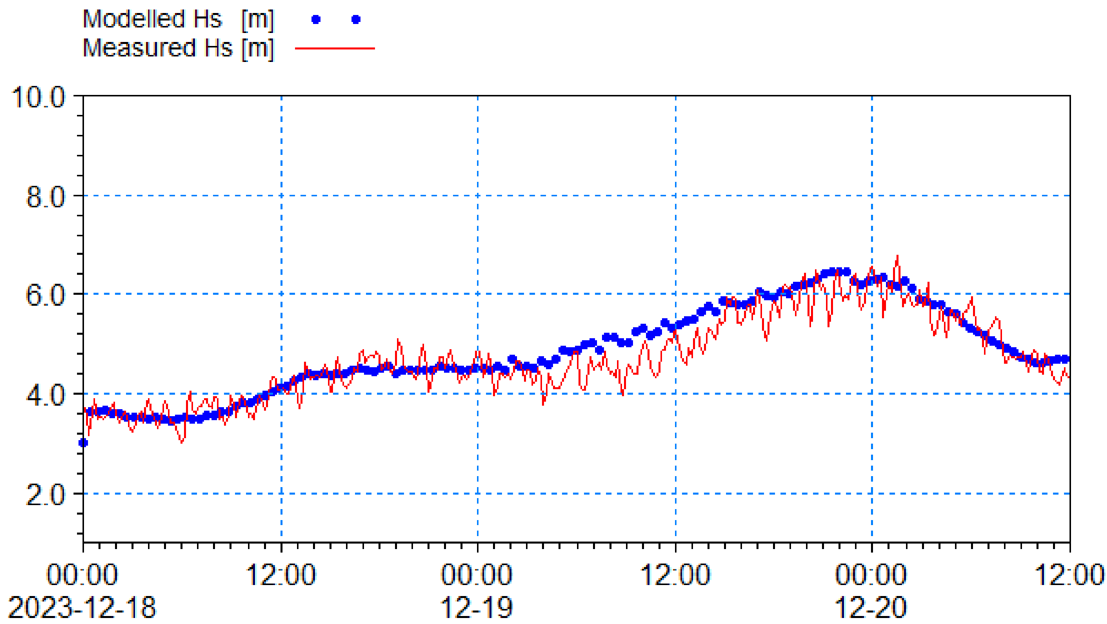


Plate 5-11: Peak wave period calibration, FLiDAR, 18-20 December 2023

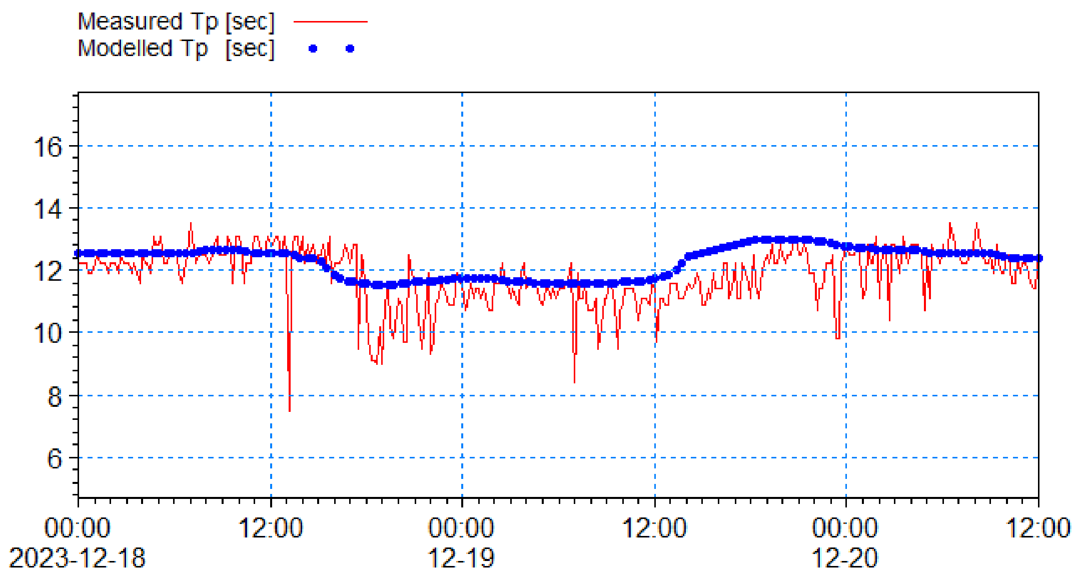
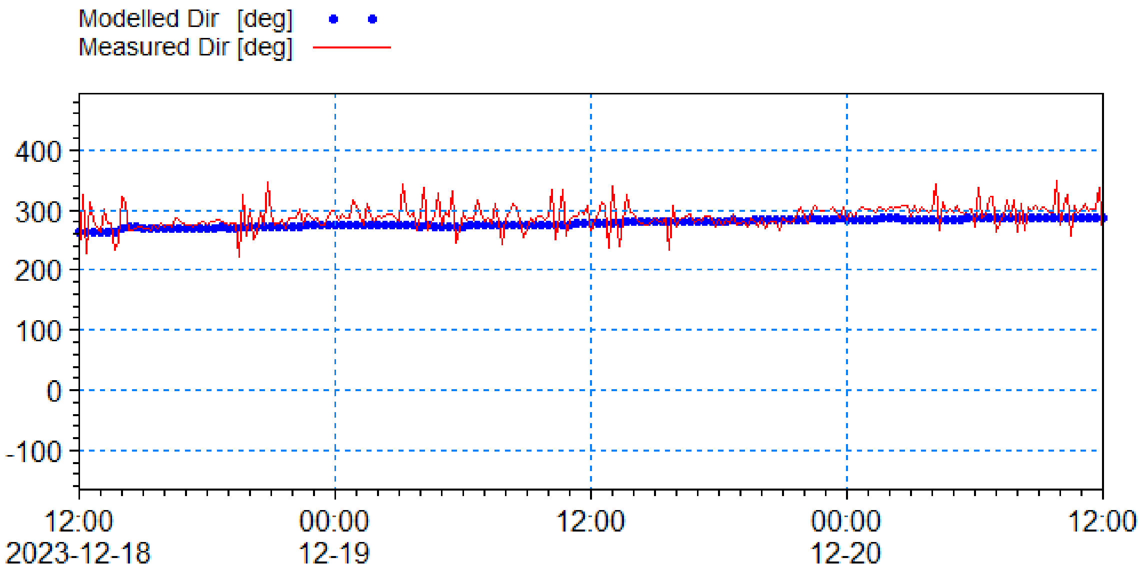


Plate 5-12: Direction calibration, FLiDAR, 18-20 December 2023



5.3.2.2 Results show that the model performs well against FLiDAR data for the calibration period between 18-20 December 2023. Modelled significant wave heights are reaching a 'Very Good' level of agreement, being within 10% of measured data for more than 80% of the calibration period, and an 'Excellent' fit was achieved for mean wave period and wave direction. Scatter Indices for Hs and Tp were 8% and 7% respectively.

5.3.3 DRW1 CALIBRATION

5.3.3.1 **Plate 5-13** to **Plate 5-15** show a comparison of the measured and modelled significant wave height, period and direction for DWR1 for calibration period 18-20 December 2023.

Plate 5-13: Significant wave height calibration, DWR1, 18-20 December 2023

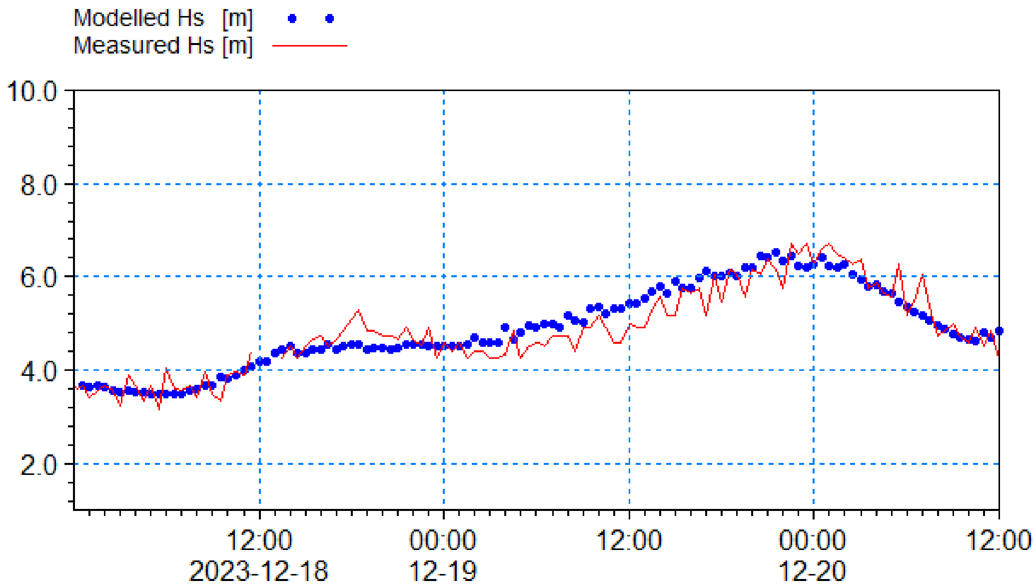


Plate 5-14: Peak wave period calibration, DWR1, 18-20 December 2023

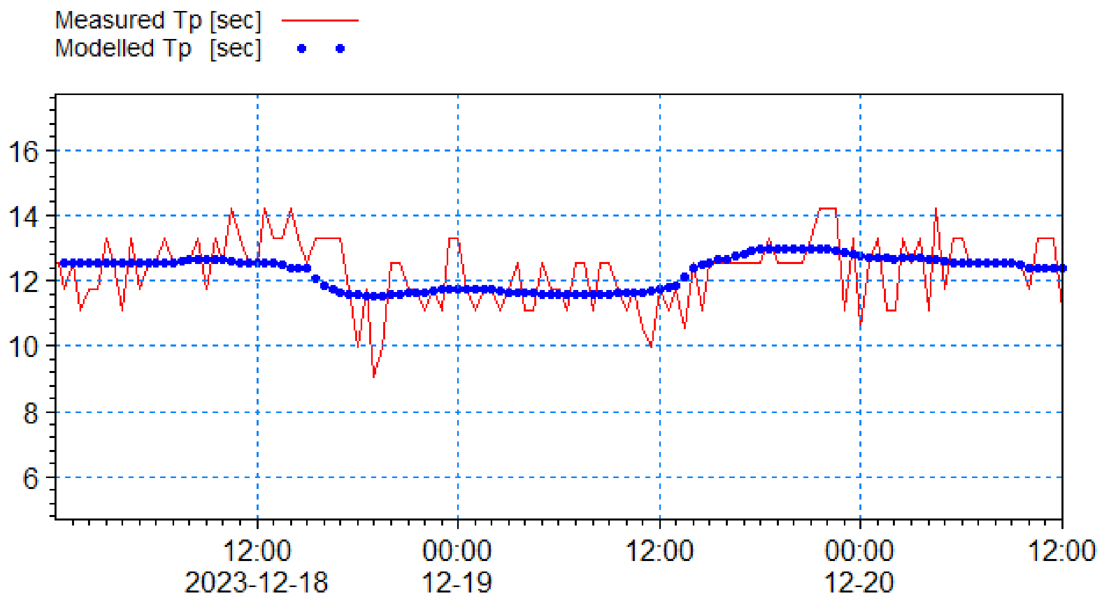
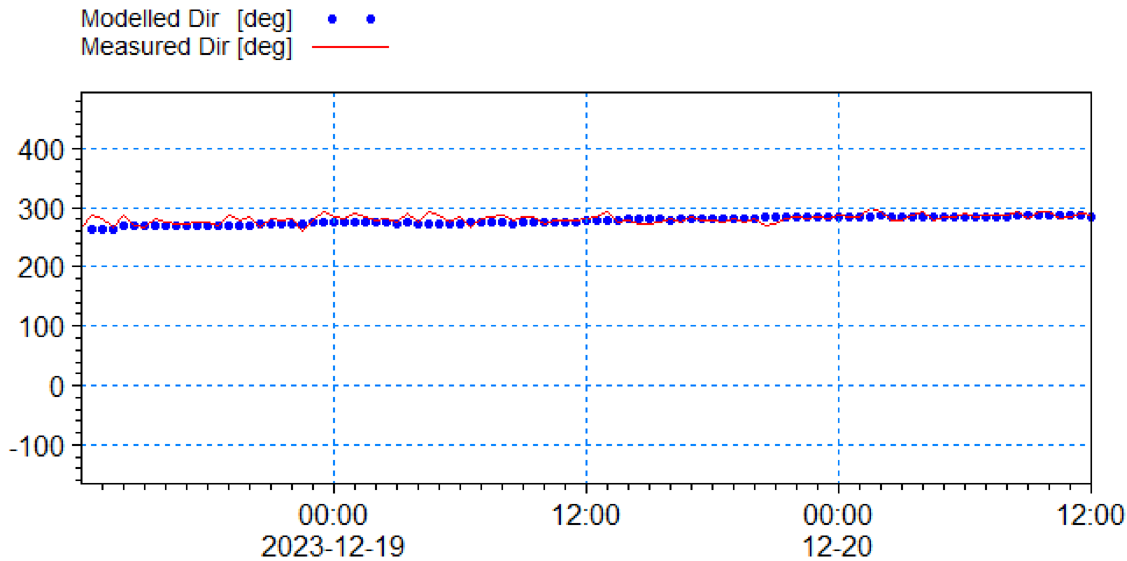


Plate 5-15: Direction calibration, DWR1, 18-20 December 2023



5.3.3.2 Results show that the model performs well against measured DWR1 data for this second calibration period. Significant wave height and direction both show a 'Very Good' fit against measured data, and wave period shows an 'Excellent' fit, being within the required range for almost 100% of the calibration period. Scatter Indices of 15% and 7% were obtained for Hs and Tp respectively.

5.3.4 DWR2 CALIBRATION

5.3.4.1 **Plate 5-16** to **Plate 5-18** show a comparison of the measured and modelled significant wave height, period and direction for DWR2 for calibration period 18-20 December 2023.

Plate 5-16: Significant wave height calibration, DWR2, 18-20 December 2023

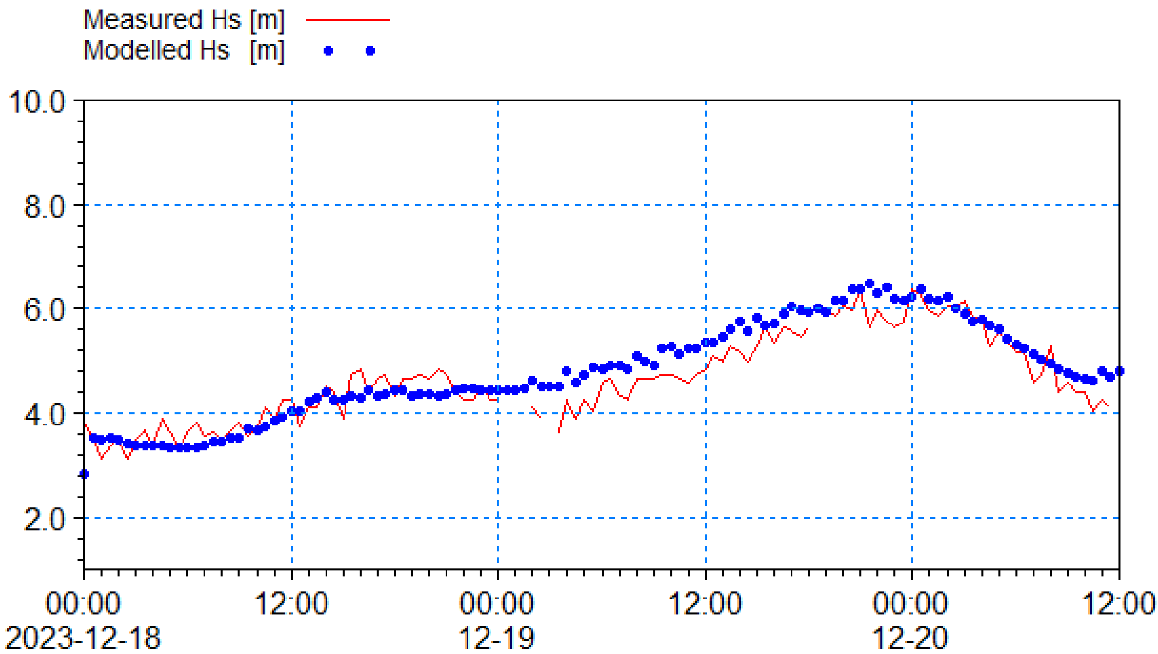


Plate 5-17: Peak wave period calibration, DWR2, 18-20 December 2023

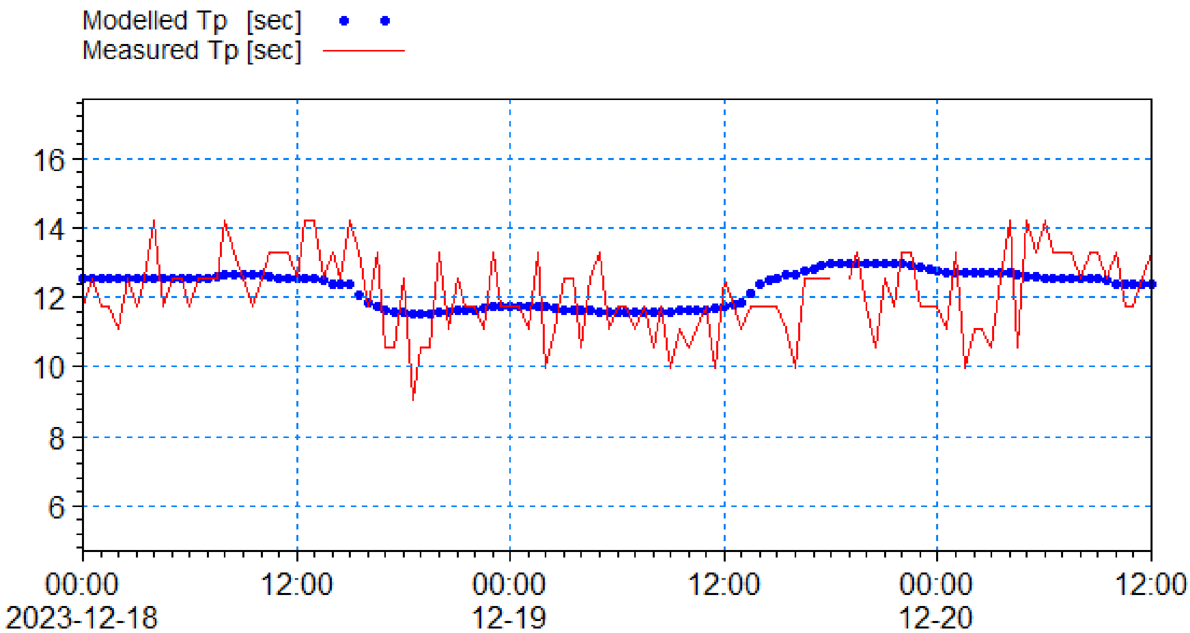
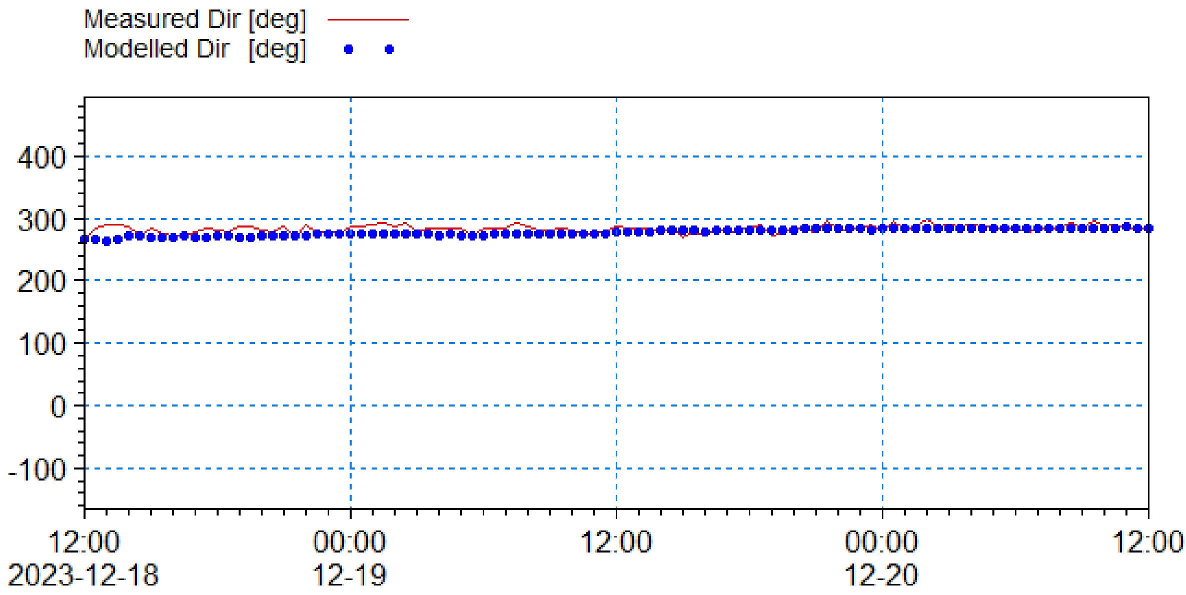


Plate 5-18: Direction calibration, DWR2, 18-20 December 2023



5.3.4.2 Results show that the model performs well against measured DWR2 data for the second calibration period. Significant wave height shows a 'Good' fit against measured data, while wave period and wave direction both show an 'Excellent' fit, being within the required range for 96% and 100% of the calibration period respectively. Scatter Indices of 28% and 10% were obtained for Hs and Tp. Calibration for Hs on DWR2 for this period indicates these as the worst performing model results out of all calibration data obtained. However, the model still performs reasonably well with Hs within the required range for 76% of the run and a scatter index value below 35% as recommended and is therefore considered reliable and robust.

5.4 STORM PERIOD 20-22 DECEMBER 2023

5.4.1.1 The period between 20-22 December 2023 shows the peak of the storm event following the previously illustrated buildup, which has a maximum Hs of more than 9 m.

5.4.2 FLIDAR VALIDATION

5.4.2.1 **Plate 5-19** to **Plate 5-21** show a comparison of the measured and modelled significant wave height, period and direction for the Floating LiDAR for the validation period 20-22 December 2023.

Plate 5-19: Significant wave height calibration, FLiDAR, 20-22 December 2023

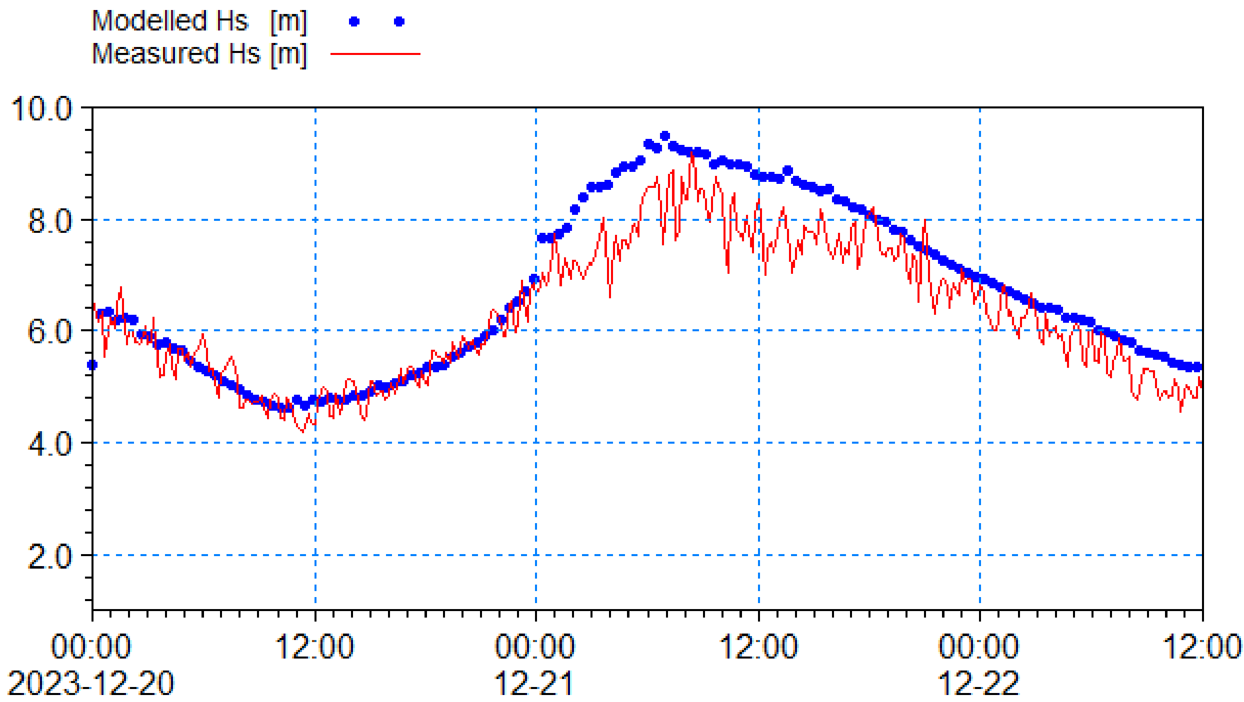


Plate 5-20: Peak wave period calibration, FLiDAR, 20- 22 December 2023

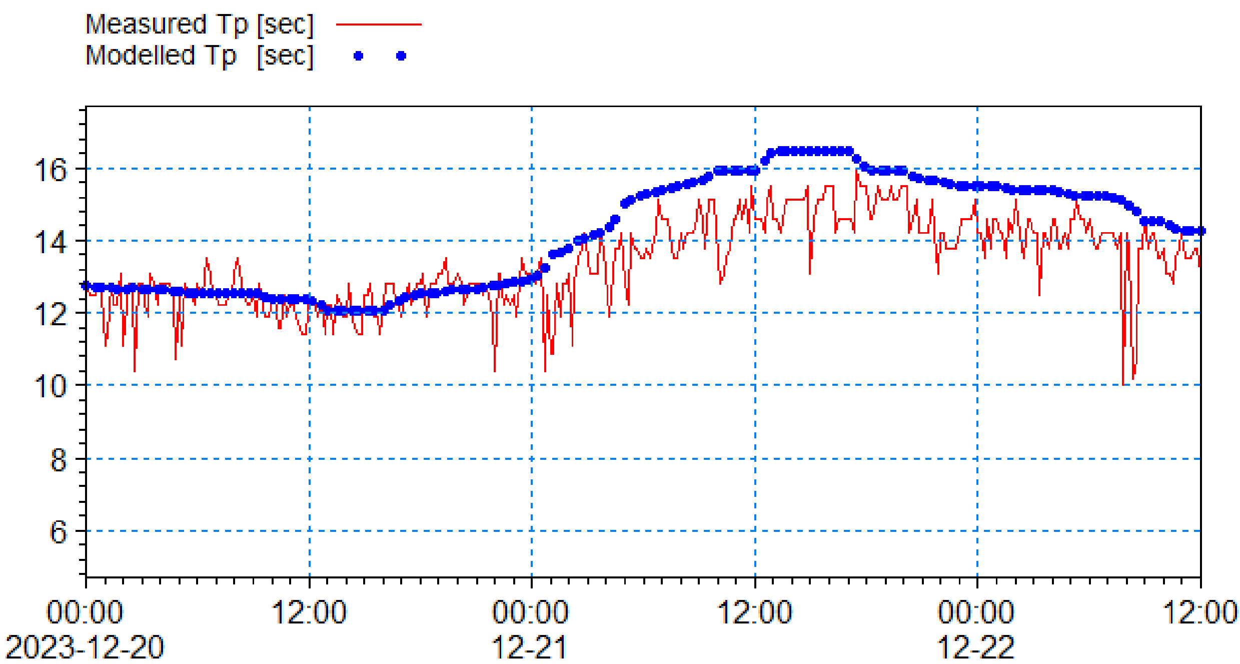
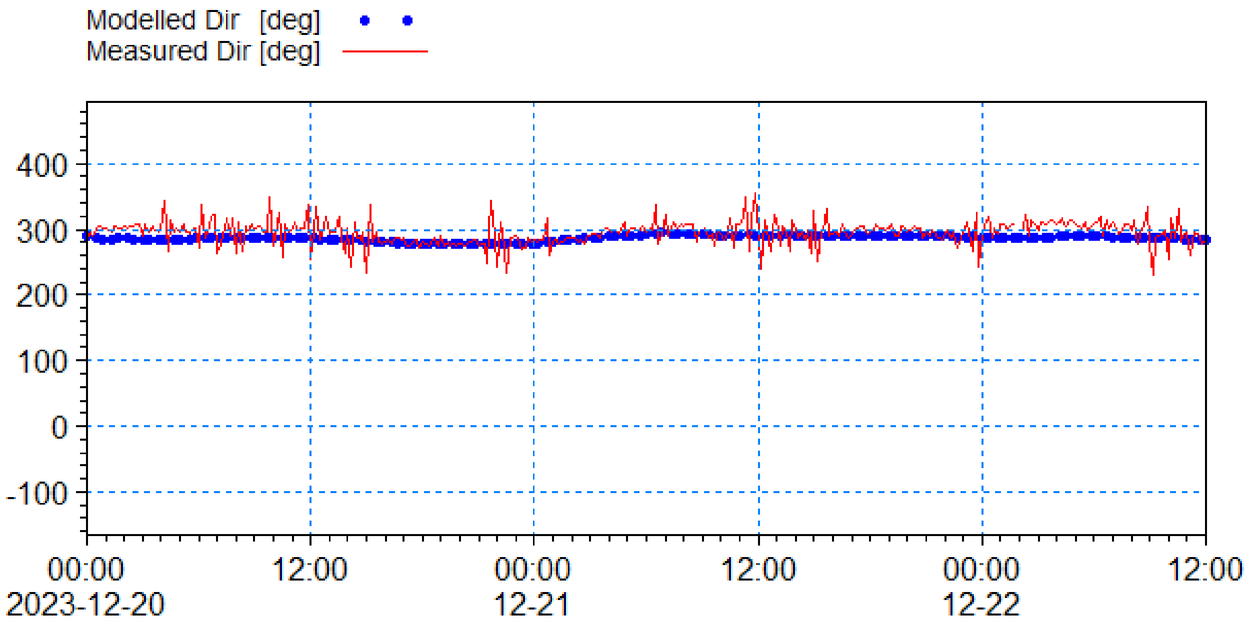


Plate 5-21: Direction calibration, FLiDAR, 20-22 December 2023



5.4.2.2 Results show that the model performs well against FLiDAR data for the calibration period between 20-22 December 2023 as well. Significant wave heights are within 10% of measured data for more than 77% of the calibration period, resulting in a 'Good' fit. An 'Excellent' fit was achieved for mean wave period and wave direction, which are within their respective metrics for 96% and 99% of the calibration period. A scatter index value of 10% was obtained for Hs and one of 8% was obtained for Tp.

5.4.3 DWR1 VALIDATION

5.4.3.1 **Plate 5-22** to **Plate 5-24** show a comparison of the measured and modelled significant wave height, period and direction for DWR1 for calibration period 20-22 December 2023.

Plate 5-22: Significant wave height calibration, DWR1, 20-22 December 2023

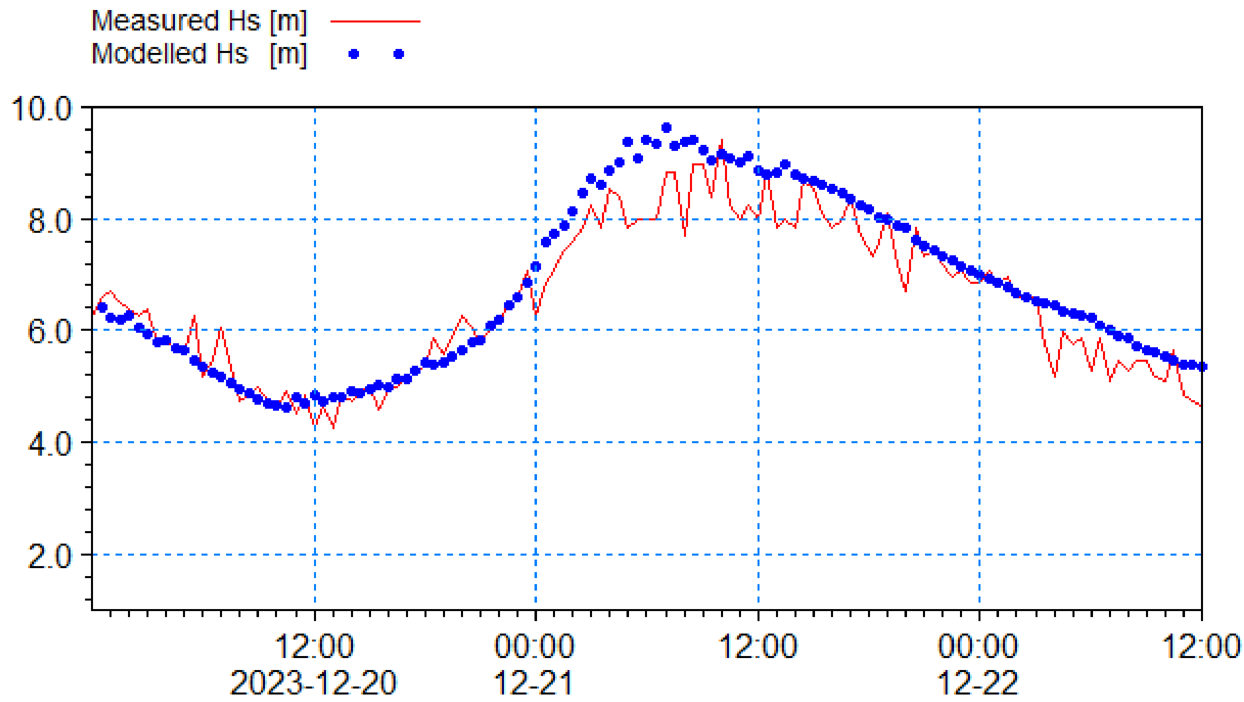


Plate 5-23: Peak wave period calibration, DWR1, 20-22 December 2023

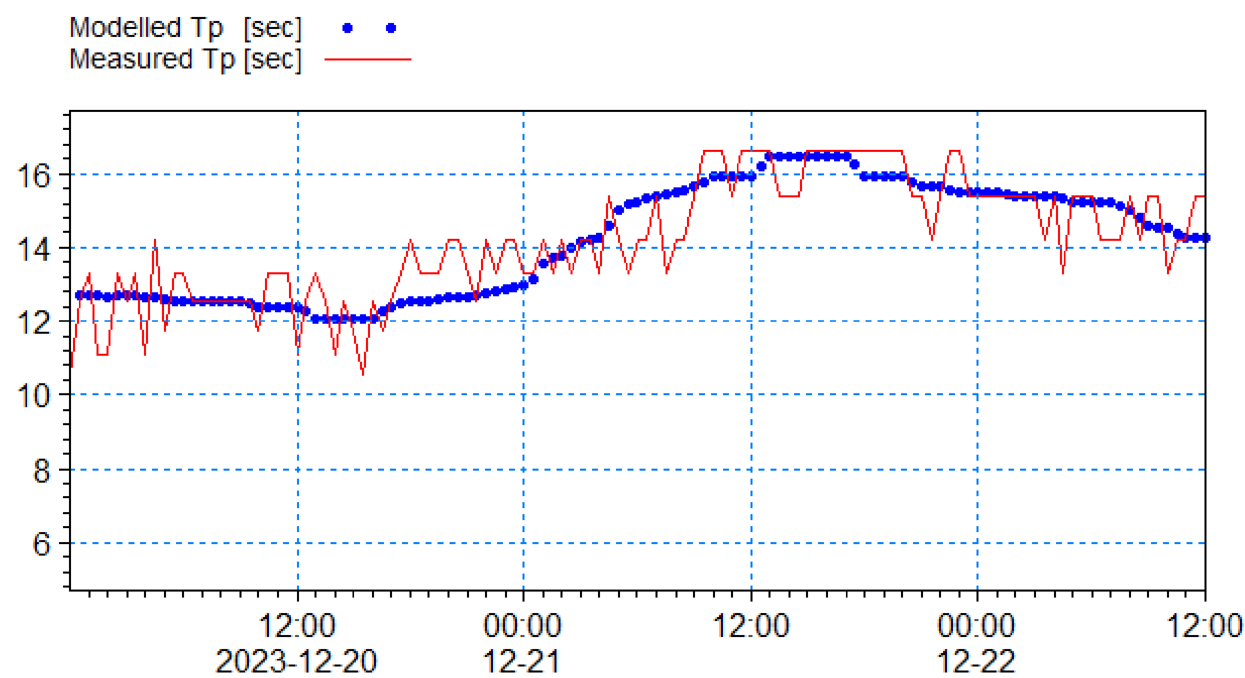
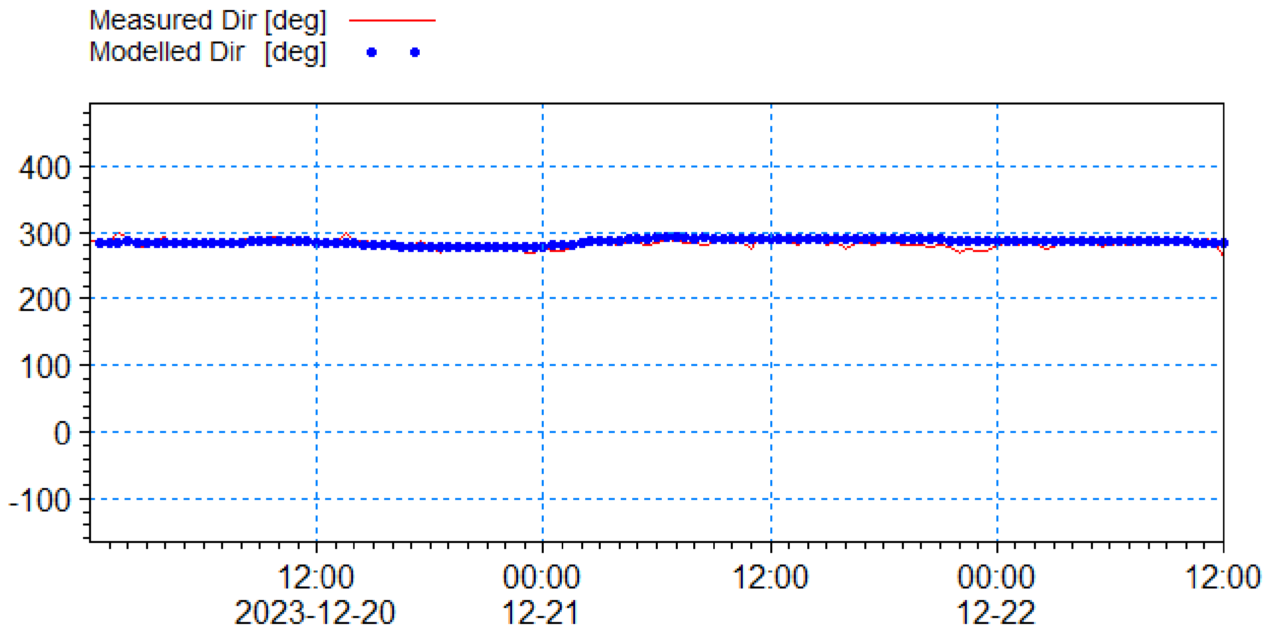


Plate 5-24: Direction calibration, DWR1, 20-22 December 2023



5.4.3.2 Results show that the model performs well against measured DWR1 data for the calibration period between 20-22 December 2023 as well. Significant wave heights achieved a 'Very Good' fit, and wave period an 'Excellent' goodness of fit, being within 20% of observed significant wave period for 99% of the calibration period. In this instance, wave direction only achieved a 'Reasonable' fit. However, this is due to the analysis being carried out on values in units of degrees, and incoming wave direction occurring predominantly from the north. The calculations utilised fail in recognising the relative closeness of values in the range 0-10 degrees to values in the range of 350-360 degrees. A scatter index value of 8% was obtained for Hs and one of 6% was obtained for Tp.

5.4.4 DWR2 VALIDATION

5.4.4.1 **Plate 5-25** to **Plate 5-27** show a comparison of the measured and modelled significant wave height, period and direction for DWR2 for calibration period 20-22 December 2023.

Plate 5-25: Significant wave height calibration, DWR2, 20-22 December 2023

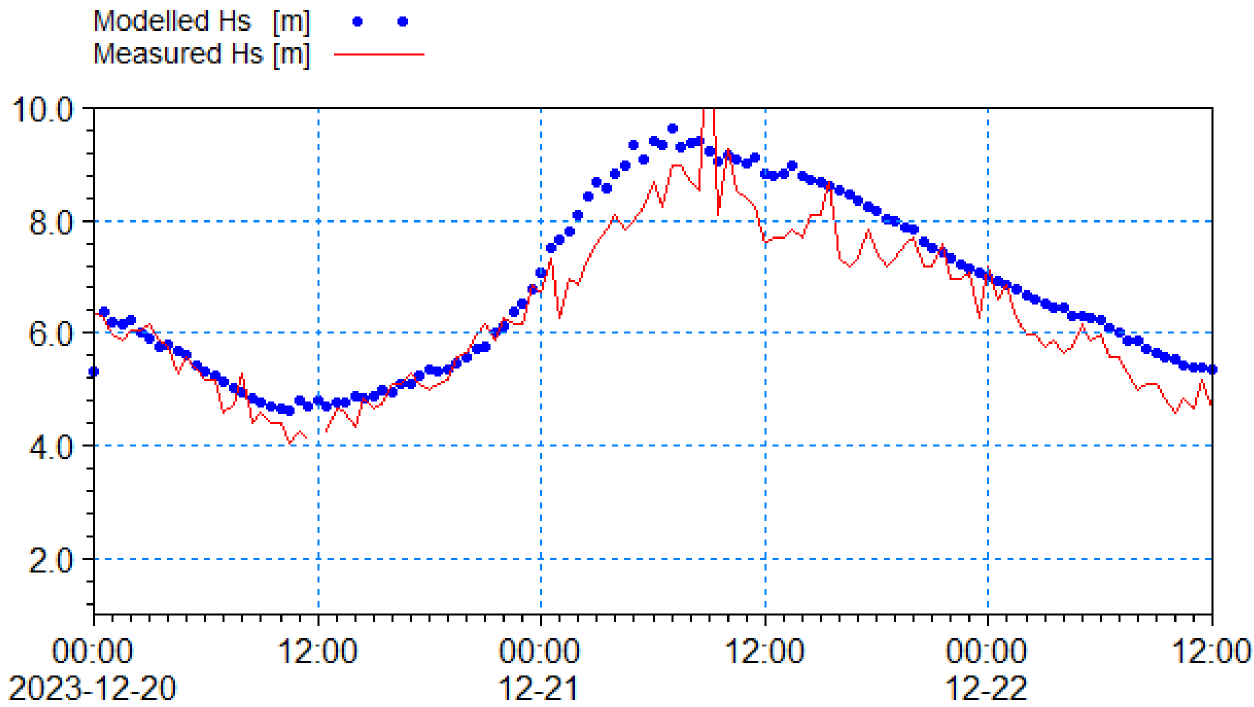


Plate 5-26: Peak wave period calibration, DWR2, 20-22 December 2023

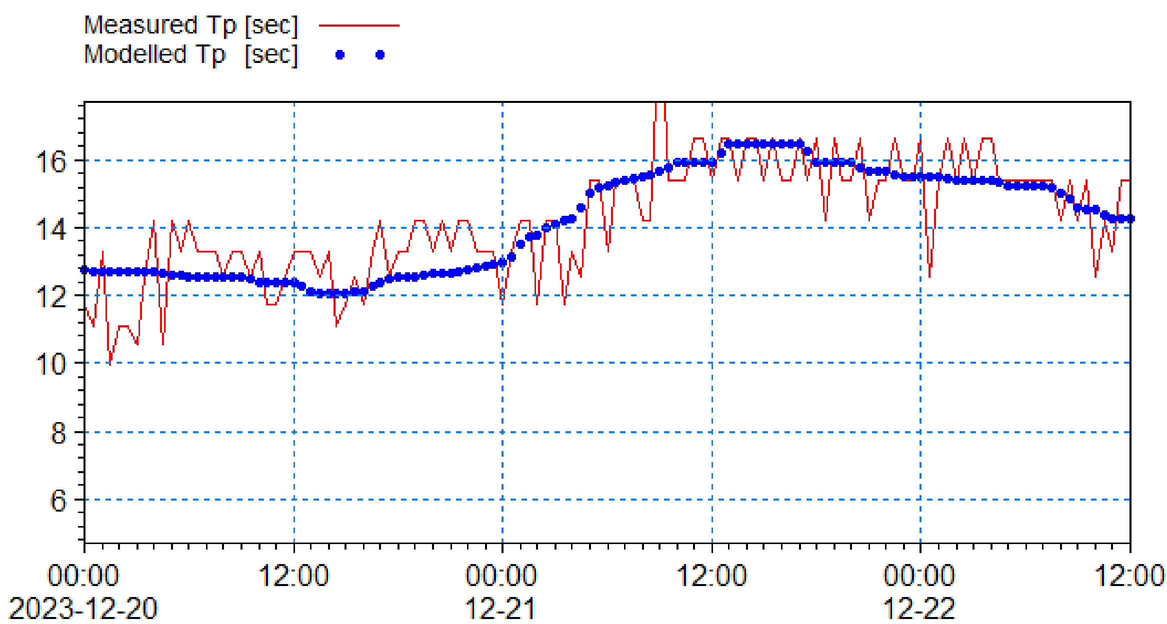
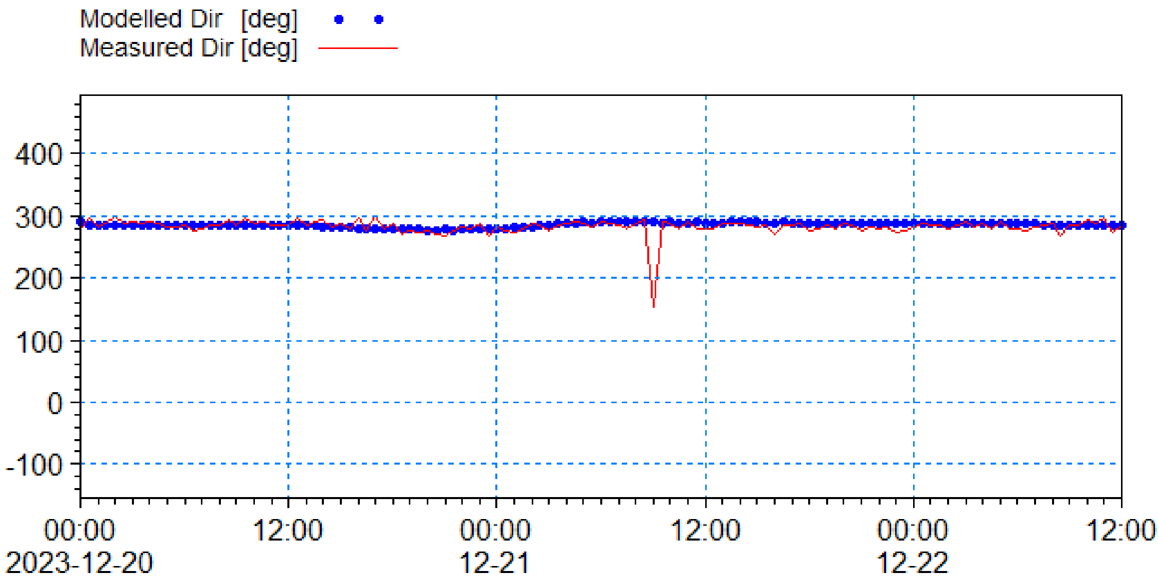


Plate 5-27: Direction calibration, DWR2, 20-22 December 2023



5.4.4.2 Model results also performed well against DWR2 data for the calibration period between 20-22 December 2023. Significant wave heights are within 10% of measured data for more than 75% of the calibration period, and an 'Excellent' fit was achieved for mean wave period and wave direction, which are within their respective metrics for 97% and 99% of the calibration period. A scatter index value of 12% was obtained for Hs and one of 8% was obtained for Tp.

6 CONCLUSIONS

6.1.1.1 The Hydrodynamic Model results show an 'Excellent' agreement between measured and modelled data for water depth. Levels were within 20% of the neap tidal range and within 15% of the spring tidal range for more than 90% of the time.

6.1.1.2 Overall, the Hydrodynamic Model accurately modelled current speeds and direction. Current speeds showed a 'Very Good' agreement between modelled and measured data, being within 20% of measured data for 87% of the time. Current Speeds show a RMSE of 0.13, sitting within the ideal range of <0.2.

6.1.1.3 The modelled current direction also shows 'Good' agreement against the measured data, with the modelled results accurately picking up directional variation associated with flood and ebb tides.

6.1.1.4 The results show that the spectral wave model simulates the peaks and timings of these storm periods accurately, with Scatter Index (Normalised Root Mean Square Error) values ranging between 8-28 for Hs, and 6-13 for Tp, never exceeding the recommended parameters of <35.

6.1.1.5 Significant Wave Height Results are categorised as 'Very Good' in most runs and did not fall below 76% of timesteps within the required metrics across the calibration/validation periods, for any of the locations/instruments.

6.1.1.6 Similarly, Wave period calibration has been 'Excellent' in all instances except one, where it was slightly below 90%, and can be considered a 'Very Good' fit. Wave Period also often approached 100% of timesteps within the required metrics.

6.1.1.7 Wave Direction achieved 'Excellent' fit, reaching 100% compliance with its metric more than once.

6.1.1.8 Overall, both hydrodynamic and spectral wave models are deemed to accurately represent tidal and wave conditions at within the Offshore Project Boundary. Therefore, they are considered appropriate to use for the post-development phase.

6.1.1.9 Results of the modelling to inform the EIA (**Chapter 9, Volume 2a**) are included in **Appendix 9.2, Volume 2c**.

7 GLOSSARY OF TERMS AND ABBREVIATIONS

7.1.1.1 A list of key terms and acronyms used in this appendix are provided in **Table 7-1** and **Table 7-2**.

Table 7-1 Acronyms and abbreviations

Term	Definition
%	Percent
±	Plus-minus
+	Plus
-	minus
>	Greater-than
<	Less-than
CFSRR	Climate Forecast System Reanalysis and Reforecast
CTD	Conductivity, Temperature and Depth
DHI MIKE	Danish Hydraulic Institute modelling software
DWR	Directional Waverider
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
FLiDAR	Floating Light Detection and Ranging
GEBCO	General Bathymetric Chart of the Oceans
Hs	Significant Wave Height
km	Kilometres
km^2	Square kilometres
LiDAR	Light Detection and Ranging
m	Metres
m^2	Square metres
mODN	Ordnance Datum Newlyn
m/s	Metres per second
MHWS	Mean High Water Springs
OCAS	Offshore Cable Area of Search
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
RMSE	Root Mean Square Error
Tp	Peak Wave Period
WTG	Wind Turbine Generator

Table 7-2 Glossary

Term	Meaning
the Applicant	Spiorad na Mara Limited (the Project owner).
Array Area	Total area within which offshore wind turbine generators (WTGs), associated foundations, Array Cables and Offshore Substation Platform (OSP) (if required) will be located.
Bathymetry/bathymetric	Topography of sea or estuary bed as measured from a fixed vertical datum.
Bed shear stress	Stress exerted by water on the seabed surface.
Coastal water	Water depths between 5 m and 20 m.
d_{50}	Median sediment particle size.
Deep water	Water depths greater than 20 m.
Depth-averaged tidal current velocity	The average velocity, over a vertical profile, in a given location.
Designated site	Areas specifically recognised for their nature conservation value, such as those protected under national or international legislation.
Directional Waverider	Directional Waverider (DWR) is a type of wave buoy equipped with sensors that capture data on the movement and characteristics of waves, such as wave height, period, and direction. In the context of the Spiorad na Mara Offshore Wind Farm project, two Directional Waverider buoys, DRWR1 and DWR2, were deployed to collect wave data over several months. This data was then used to calibrate the spectral wave model, ensuring its accuracy in simulating wave conditions within the Array Area.
Ecologically coherent network	A collection of protected sites planned and managed to deliver more effective benefits than can be delivered by individual sites.
Environmental Impact Assessment Report (EIAR)	The Environmental Impact Assessment Report (EIAR) prepared to assess the likely significant effects of the Project on the environment.
Geomorphological features	Topographic or bathymetric features generated by physical, chemical, or biological processes.
Geophysical survey	Imaging or mapping using ground-based physical sensing.
H++ scenario	Maximum sea level rise scenario; 1.9 m total sea level rise up to 2100.
Horizontal directional drilling (HDD)	A trenchless crossing engineering technique using a drill steered underground without the requirement for open trenches. This method is able to carry out the underground installation of pipes and cables with minimal surface disruption.
Hydrodynamic	The movement and forces exerted by water.
Hydrological effects	Impacts relating to water and its interaction with land/sediment.

Term	Meaning
Impact	Change that is caused by an action; for example, land clearing (action) during construction which results in habitat loss (impact).
Landfall	This consists of works from offshore Horizontal Directional Drill (HDD) exit pits to onshore at the Transition Joint Bays (TJB). The infrastructure and installation methods associated with the Landfall involves both onshore and offshore components.
Macrofauna	Organisms that are visible to the naked eye.
Macrotidal regime	A tidal range in excess of 4 m.
Mean High Water Spring	The average throughout a year of the heights of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the tidal range is greatest.
Mean High Water Neap	The average height of high-water during neap tides, which occur when the tidal range is at its smallest—typically around the first and third quarters of the moon.
Mean Low Water Neap	The average height of low water during neap tides, which occur when the tidal range is at its smallest—typically around the first and third quarters of the moon.
Mean Low Water Spring	The average throughout a year of the heights of two successive low waters during those periods of 24-hours (approximately once a fortnight) when the tidal range is greatest.
Mega-ripple	Mobile, current-generated bedforms with large wavelengths and heights.
Metocean conditions	Changes to the seabed (deepening or raising) leading to changes in tidal current flows and/or wave conditions (height/direction).
Metocean data	Meteorological and oceanographic data including wind, currents, and waves.
Morphological changes	Changes to the form or structure of the seabed.
Neap peak flow	Typical maximum current velocity during neap tides (minimum difference between high and low water levels).
Offshore Cables	Electrical and communication cables located within the OCAS and Array Area.
Offshore Cable Area of Search (OCAS)	The area within which the offshore cable infrastructure between the Array Area and Landfall will be located.
Offshore Project	The offshore components of the Spiorad na Mara offshore wind farm (the Project) located seaward of Mean High Water Springs (MHWS). The Offshore Project is the subject of this application.

Term	Meaning
Offshore Project Boundary	The ‘red line boundary’ encompassing the Offshore Project.
Offshore Substation Platform (OSP)	The optional offshore substation located within the Array Area. Includes the platform and associated components which allows the voltage to be increased to meet onward transmission requirements.
Orbital velocity	Local elliptical currents, which reduce with depth, associated with waves moving across the water surface.
Physical and Coastal Processes	Processes such as metocean conditions, seabed geology/morphology, sediment transport, and water quality which could be impacted by the Proposed Development.
Probable Effects Level	Concentration at which a large percentage of benthic organisms will show a toxic response.
Project	The Spiorad na Mara offshore wind farm development. This term describes the whole development, including all offshore and onshore components.
Qualifying interest feature	The features of a site that qualify it to be designated.
Scour protection	The protection of sediment against localised erosion e.g. by placing rock.
Seabed change	Temporary or permanent lowering or raising of seabed levels, e.g. due to scour protection.
Seabed geology and morphology	The structure (geology) and form (morphology) of the seabed.
Secondary scour	The interaction of flow (i.e. bed currents) around the edge of protection (i.e. for cables) resulting in the erosion of the seabed.
Sediment dispersion	The dilution and settling of sediment as it travels from a source.
Sediment disturbance	Disturbing/displacing sediment (contaminated or uncontaminated).
Sediment plume	A mobile area of increased suspended sediment concentration, usually generated by activities such as construction or dredging.
Sediment regime	The size, quantity, sorting, and distribution of sediments.
Shallow water	Water depths less than 5 m.
Significant wave height	Average height of the largest 1/3 of waves.
Spring peak flow	Typical maximum current velocity during spring tides (maximum difference between high and low water levels).
Suspended sediment concentration	Concentration of sediment particles entrained within the water column.
Thermocline	A distinct ocean layer separating the upper mixed layer from the calm deep water below.
Threshold Effects Level	Concentration at which a toxic response has started to be observed.

Term	Meaning
Turbidity	A measure of the level of particles such as sediment or organic by-products in a body of water.
Turbine Area	A reduced area within the Array Area where above water surface infrastructure would be located i.e. WTG or OSP. Developed and refined through environmental assessment.
Water quality	Increase in physical, chemical and biological contaminants through the suspension of contaminated sediment, tidal currents transporting disturbed sediment leading to increased turbidity and/or reduced water-quality until sediment settlement.
Wind Turbine Generator (WTG)	The wind turbines that generate electricity consisting of tubular towers and blades attached to a nacelle housing mechanical and electrical generating equipment.

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