Rampion 2 Wind Farm

Category 6: Environmental Statement

Volume 4, Appendix 6.2: Coastal processes model design and validation

Date: August 2023

Revision A

Document Reference: 6.4.6.2
Pursuant to: APFP Regulation 5 (2) (a)
Ecodoc number: 004866466-01

Document revisions

Revision	Date	Status/reason for issue	Author	Checked by	Approved by
A	04/08/2023	Final for DCO Application	ABPmer	RED	RED

Executive summary

Purpose of this report

This report has been produced for the purpose of describing the design and validation of the wave model used to undertake related impact assessments in relation to Rampion 2.

Page intentionally blank

Contents

Tables

Figures

Page intentionally blank

1. Introduction

1.1 Overview

1.1.1 ABPmer has been commissioned by GoBe Consultants to undertake numerical modelling to inform the Environmental Impact Assessment (EIA) for the proposed Rampion 2 Offshore Wind Farm (hereafter referred to as Rampion 2).

1.1.2 In particular, a numerical wave model has been developed to characterise the impact of wind farm foundations on the wave regime (wave height, period and direction) during the operation phase.

1.1.3 This report presents information about the design and validation of the above model. This report does not directly consider the potential impacts or implications of any reported changes.

1.1.4 The maximum design scenarios modelled, and presentations and discussion of the results from the modelling are not contained in this report but may be found in **Appendix 6.3: Coastal processes technical report: Impact assessment, Volume 4** of the ES (Document Reference 6.4.6.3).

1.2 General approach to modelling

1.2.1 The numerical modelling for this study has been undertaken using the MIKE21FM (flexible mesh) software package from the Danish Hydraulic Institute (DHI), which has been developed specifically for application in oceanographic, coastal and estuarine environments.

1.2.2 When used by an experienced modeller, and in conjunction with suitable data inputs, these models provide reliable and realistic representations of both baseline environmental conditions and the potential effects of offshore wind farm infrastructure and other construction related activities.

1.2.3 The wave modelling described in this report is undertaken using a spectral wave model, utilising a flexible mesh with high resolution in the study area. The model is run in a quasi-stationary mode to simulate a range of discrete representative seastates. The wave model is not required to simulate historical timeseries of actual wave conditions.

Page intentionally blank

2. Wave model design

2.1 Overview

2.1.1 This section describes the design and inputs to a spectral wave model simulating patterns of wave height, period and direction in the Zone Of Influence (ZOI) for Rampion 2. The model has been used to simulate baseline conditions, and the impact of the windfarm foundations on these conditions.

2.2 Wave model design

Overview

2.2.1 The wave model is built using the MIKE21FM Spectral Wave (SW) module, which simulates the propagation of the tidal wave and associated movements of water volume in offshore and coastal settings.

2.2.2 The wave model creates discrete simulations of wave height, period and direction throughout the domain, for a representative range of selected everyday and extreme wave conditions (return periods and directions).

Model grid

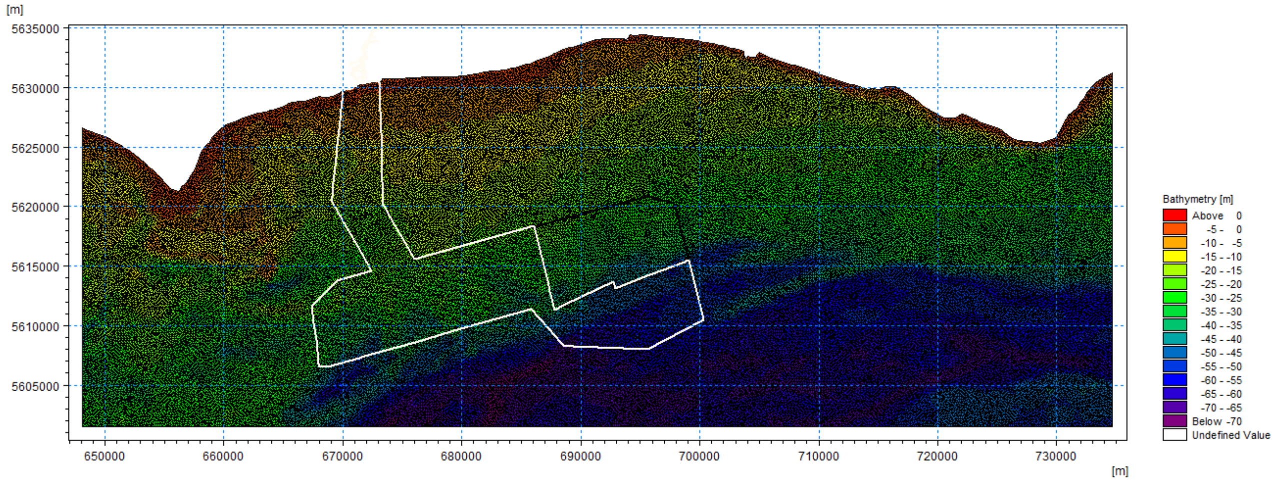
2.2.3 The extent and resolution of the model grid is shown in **Figure 6.2.1**. A flexible mesh design (interlocking triangular ‘elements’ of varying shape and orientation) is used, providing tailored spatially variable resolution within a single model mesh.

2.2.4 The resolution of the mesh is set to a constant value of 200m across the whole model domain. This high resolution provides a more detailed description of the key bathymetric and coastal features in the area.

2.2.5 To assist the study, individual model grid elements have been centred on the actual locations of wind turbine and offshore substation foundations in the operational Rampion 1 windfarm, as well as the proposed locations of Rampion 2.

2.2.6 The size of the individual model grid elements (200m) is greater than the size of the individual foundations. In practice, very localised wave shadowing effects will occur (under certain conditions) behind individual members or parts of a foundation. These local effects rapidly merge with the nearby ambient wave field to leave an area of slightly reduced overall wave energy within the order of metres to a few tens of metres from the foundation (within the model grid element containing the foundation). The wave model does not resolve the detail of the former detailed wave shadowing but does conservatively represent the latter overall wave energy reduction in the area immediately surrounding the individual foundations, which is then propagated downwind.

Figure 6.2.1 Extent of wave model mesh, also showing outlines of Rampion 1 (black) and the Rampion 2 DCO Order Limits (white)



Model bathymetry

2.2.7 The bathymetry of the model is sourced from EMODnet (https://www.emodnet-bathymetry.eu/), which is a freely available and generally reliable data source.

2.2.8 Spatially varying adjustments are made to convert the bathymetry data from the standard Lowest Astronomic Tide (LAT) datum at source, to Mean Sea Level (MSL), as is required for use in the model. Adjustments are made using a combination of VORF (Vertical Offshore Reference Frames, UCL and UKHO, 2005) and tidal water level statistics from tide gauges for locations elsewhere in Europe outside of the VORF data extent.

Spectral and time formulations

2.2.9 A fully spectral formulation is used. The fully spectral formulation is based on a wave action conservation relationship where the directional-frequency wave action spectrum is the dependent variable. Of the available choices, this formulation is considered to be the most accurate for the nature of the processes being simulated with respect to both general wave propagation and the effect of the wind farm foundations.

2.2.10 A quasi-stationary time formulation is used. Time is removed as an independent variable and a steady state solution is calculated for each seastate being simulated. This choice is appropriate for the limited size of the model domain, within which waves are likely to achieve an equilibrium state dependant on the input wave and wind boundary conditions.

2.2.11 A logarithmic distribution of 36 spectral frequencies are resolved, equivalent to wave periods in the approximate range from one to 30 seconds, with smaller intervals at smaller wave periods. This exceeds the default number and range (25 spectral frequencies, from 1.8 to 18 seconds) in order to better resolve a wider range of wave periods.

2.2.12 Directional calculations are made using 32 directional sectors (each sector covering a range of 11.25 degrees). This exceeds the default number (16 directional sectors, 22.5 degrees) in order to reduce the occurrence of small magnitude ‘radial artefacts’ in the scheme effect results when obstacles representing the offshore wind farm infrastructure are included in the model. The baseline wave maps are largely unaffected by the difference.

Model boundary conditions

2.2.13 The wave model is forced by wave conditions (height, period, direction and directional spreading) at the three offshore wave boundaries (along the eastern, southern and western extents of the model domain. The model is run with a constant mean water depth (no tidal water variation) and no currents.

2.2.14 The wave condition scenarios considered by the model for the assessment are:

- wave coming directions (southwest, south-southwest, south, south-southeast, southeast); and
- return periods (50 percent non-exceedance, 0.1 year; 1 year; 10 year; 50 year; 100 year).

2.2.15 An understanding of the potential impacts of the infrastructure (outlined in **Chapter 4: The Proposed Development, Volume 2** of the ES (Document Reference: 6.2.4) within this range of conditions will inform the assessments regarding potential impacts on sedimentary and coastal processes and flood risk. These conditions were determined using Extreme Value Analysis (EVA) for a central location approximately 5km south of the Rampion 2 Offshore Array Areas, using hindcast timeseries data from the separately validated ABPmer SEASTATES North West European Shelf Wave Hindcast Model (ABPmer, 2013).

2.2.16 The wave boundary condition is applied uniformly along the three offshore wave boundaries. The condition is defined by the significant wave height (Hs), peak wave period (Tp), mean wave direction (DirM) and directional standard deviation (DirStd).

2.2.17 The directional return period wave boundary conditions tested are listed in **Table 2-1**. The shortest return period is the wave condition not exceeded 50 percent of the time, representing a relatively frequent, everyday wave condition; more severe but infrequent conditions are described by the associated ‘return period’ (RP) or likelihood of occurrence expressed in years.

2.2.18 The wind boundary condition is applied uniformly across the whole model domain area, representing the wind speed at 10m above sea level normally associated with the target seastate. The associated wind direction is the same as the wave direction at the boundary. The wind boundary condition is required for natural patterns of wave propagation and development through the model domain from the offshore boundaries. Wind is also a realistic mechanism contributing to wave recovery in the lee of the wind farm. The associated directional return period values of wind speed and direction are also shown in **Table 2-1**.

Table 2-1 Wave and wind boundary conditions for each of the directional return period seastate conditions tested

Directional Sector	Case (Return Period)	Significant Wave Height (m)	Peak Wave Period (Tp, s)	Mean Wave Direction (°N)	Wind Speed @10 m (m/s)	Wind Direction (°N)
Southwest	50% no exc	1.4	5.8	225	9.3	225
	0.1yr RP	3.4	7.6	225	16	225
	1yr RP	5.2	9.5	225	21	225
	10yr RP	7.4	11.3	225	27	225
	50yr RP	8.4	12	225	26	225
	100yr RP	8.7	12.2	225	28	225
South-southwest	50% no exc	1.2	4.8	205	8.5	205
	0.1yr RP	2.6	6.2	205	14	205
	1yr RP	4.6	8.1	205	19	205
	10yr RP	7.3	10.3	205	26	205
	50yr RP	8.4	11.1	205	26	205
	100yr RP	8.7	11.3	205	28	205
South	50% no exc	0.9	4.2	180	6.7	180
	0.1yr RP	1.6	4.9	180	9	180
	1yr RP	3.3	7	180	16	180
	10yr RP	6.3	9.7	180	23	180
	50yr RP	7.4	10.5	180	24	180
	100yr RP	7.7	10.7	180	26	180
South-southeast	50% no exc	0.8	4.1	167	5.8	167
	0.1yr RP	1.3	4.6	167	7	167
	1yr RP	2	5.7	167	12	167
	10yr RP	4.2	8.2	167	18	167

Directional Sector	Case (Return Period)	Significant Wave Height (m)	Peak Wave Period (Tp, s)	Mean Wave Direction (°N)	Wind Speed @10 m (m/s)	Wind Direction (°N)
	50yr RP	5.3	9.2	167	20	167
	100yr RP	5.6	9.5	167	22	167
Southeast	50% no exc	0.7	3.9	135	5.1	135
	0.1yr RP	1.1	4.2	135	6	135
	1yr RP	1.7	5.2	135	9	135
	10yr RP	3.4	7.4	135	16	135
	50yr RP	4.1	8.1	135	17	135
	100 yr RP	4.3	8.3	135	18	135

Wave breaking, bottom friction and other wave transformation parameters

2.2.19 The settings and values below are either default settings or within the range of normally recommended values and are consistent with numerous similar recent offshore wind farm modelling studies undertaken by ABPmer.

2.2.20 Depth-induced wave breaking is the process by which waves dissipate energy when the waves are too high to be supported by the water depth, namely reaching a limiting wave height and depth ratio. Wave breaking is described in MIKE21SW by standard equations that are scaled by a coefficient Gamma. A constant Gamma value of 0.8 was used.

2.2.21 Bottom friction is relevant where, as waves propagate into shallow water, the orbital wave velocities penetrate throughout the full water depth and the source function due to wave-bottom interaction becomes important. A large part of the model domain (towards the adjacent coastlines) is shallow enough, relative to the waves being simulated, to be affected by choices relating to the implementation of bottom friction. The dissipation source function used in the spectral wave module is based on the quadratic friction law and linear wave kinematic theory. The dissipation coefficient depends on the hydrodynamic and sediment conditions. Sediment roughness is characterised in the MIKE21SW wave model by a Nikuradse Roughness length value of 0.04m.

2.2.22 The MIKE21SW wave model also takes account of the following wave transformation processes (using default settings):

- white capping (Dissipation coefficients, constant Cdis = 4.5, constant DELTAdis = 0.5); and
- quadruplet-wave interaction.

2.3 Model validation

2.3.1 The wave model is not required to provide historical (hindcast) predictions of wave conditions in a timeseries mode, therefore, no direct validation of the new wave model against measured timeseries data is required.

2.3.2 Hindcast data from the ABPmer SEASTATES NW European Shelf Wave Hindcast Model are used to inform the boundary conditions described in the previous section. The SEASTATES wave hindcast model has already been regionally validated against numerous wave buoys (ABPmer, 2013). The SEASTATES wave hindcast model is also further locally validated in **Figure 6.2.3** to **Figure 6.2.5**, against measured data from three offshore locations within the Rampion study area (L1, L2 and L3, shown in **Figure 6.2.2**), originally collected during November and December 2010 to inform the Rampion 1 OWF EIA.

2.3.3 The SEASTATES wave hindcast model data has been adjusted downwards by ten percent for Hs and √10% for wave period at L1 and L2 (20 percent at L3), to optimise agreement with the measured Hs values at the three locations and to evenly scale the overall wave energy. **Figure 6.2.3** to **Figure 6.2.5** show that the adjusted SEASTATES wave hindcast model provides a close representation of the overall magnitude, timing and variance of Hs, Tp and DirM at these three offshore locations within and nearby to the main Rampion 2 study area during mid to larger wave conditions. Calmer conditions exhibit more difference, as discussed below.

2.3.4 Some of any apparent differences in Hs (at any time) may be due to the relatively coarser resolution of the SEASTATES hindcast model (approximately 5km) in this coastal region. Other differences, mainly during a relatively calm period validation period, are attributed to practical limitations of the seabed mounted Nortek Aquadopp acoustic profilers used to make the wave measurements, as follows.

2.3.5 The data from L1 and L2 (**Figure 6.2.3** and **Figure 6.2.4**), contain an extended calm period between 20 November 2010 and 16 December 2010, characterised by low wave heights (0.5 to 1m) and small wave periods (two to four seconds); the calm period is briefly interrupted by a more energetic event around 5 November 2010. The model provides a suitably good and consistent representation of wave height and peak period throughout the full survey period at L1 and L2, and also outside of the calm period at L3. Measured and modelled wave direction are closely matched when wave height and period are larger (when wave action extends deeper into the water column – Aquadopp profilers measure wave period and direction by acoustically measuring water movement at 2/3 the water depth above the seabed). However, greater differences in measured and modelled wave direction occur when wave height and period are very low. This is likely due to practical limits on the accuracy of the measured data (when limited or no wave action extends to the measurement height of the Aquadopp) and general difficulty (for both measurements and models) in defining wave direction in very low energy seastates.

2.3.6 At L3, the measured wave height during the calm period is also consistently 0.5m higher than the coincident modelled data, and higher than all of the measured and modelled data at the nearby L1 and L2 locations. Although site L3 is notably deeper (55m) than L1 and L2 (25m), the wave height and period in this time are too small for the waves to penetrate to the seabed in order to experience any depth dependant attenuation effects. Instead, it is likely that the greater water depth at L3 is limiting the ability of the Aquadopp to make accurate measurements of wave height when the wave period is very small. Aquadopp profilers measure wave height by acoustically measuring vertical variation in the water surface over the instrument. Greater spreading of the acoustic beam over the greater water depth at L3 results in a larger acoustic footprint at the surface. The instrument will make a less accurate measurement of local water level elevation when the wave length (proportional to wave period) is small relative to the acoustic footprint. For this reason, the measured data from L3 during the calm period are marked as potentially inaccurate in **Figure 6.2.5**. More information may be found on the Nortek website (Nortek, 2021).

2.3.7 The above information validates the (adjusted) SEASTATES hindcast model data to provide a realistic representation of wave conditions and climate within the Rampion array and near to the offshore boundary of the wave model and general study area. As the adjustment is only a slight reduction, the EVA to determine boundary conditions is based on unadjusted data to provide a slightly more conservative yet still representative condition.

2.3.8 The local wave model performance is not validated explicitly. However, the important components of the model design and inputs (extent, resolution, bathymetry, coastlines and boundary conditions) have been individually validated above to be realistic, accurate and detailed. The resulting model is therefore expected to perform to a similar level and will provide a reliable basis for assessment of the relative effect of foundations on representative seastate conditions.

Figure 6.2.2 Locations of the measured data used for model validation, also showing outlines of Rampion 1 (black) and the Rampion 2 DCO Order Limits (white)

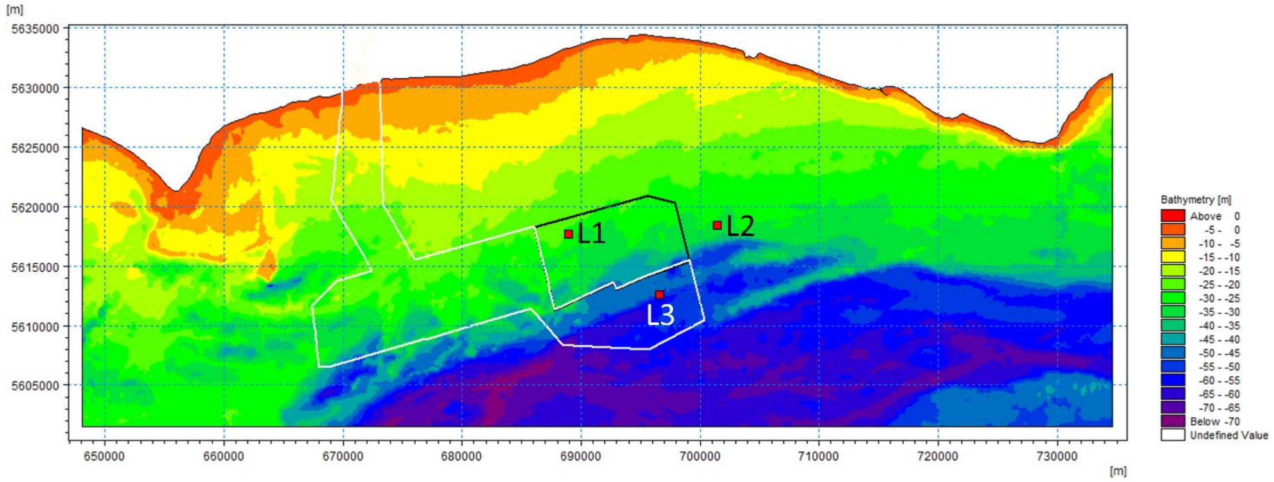


Figure 6.2.3 Comparison of measured and modelled wave parameters at Location L1

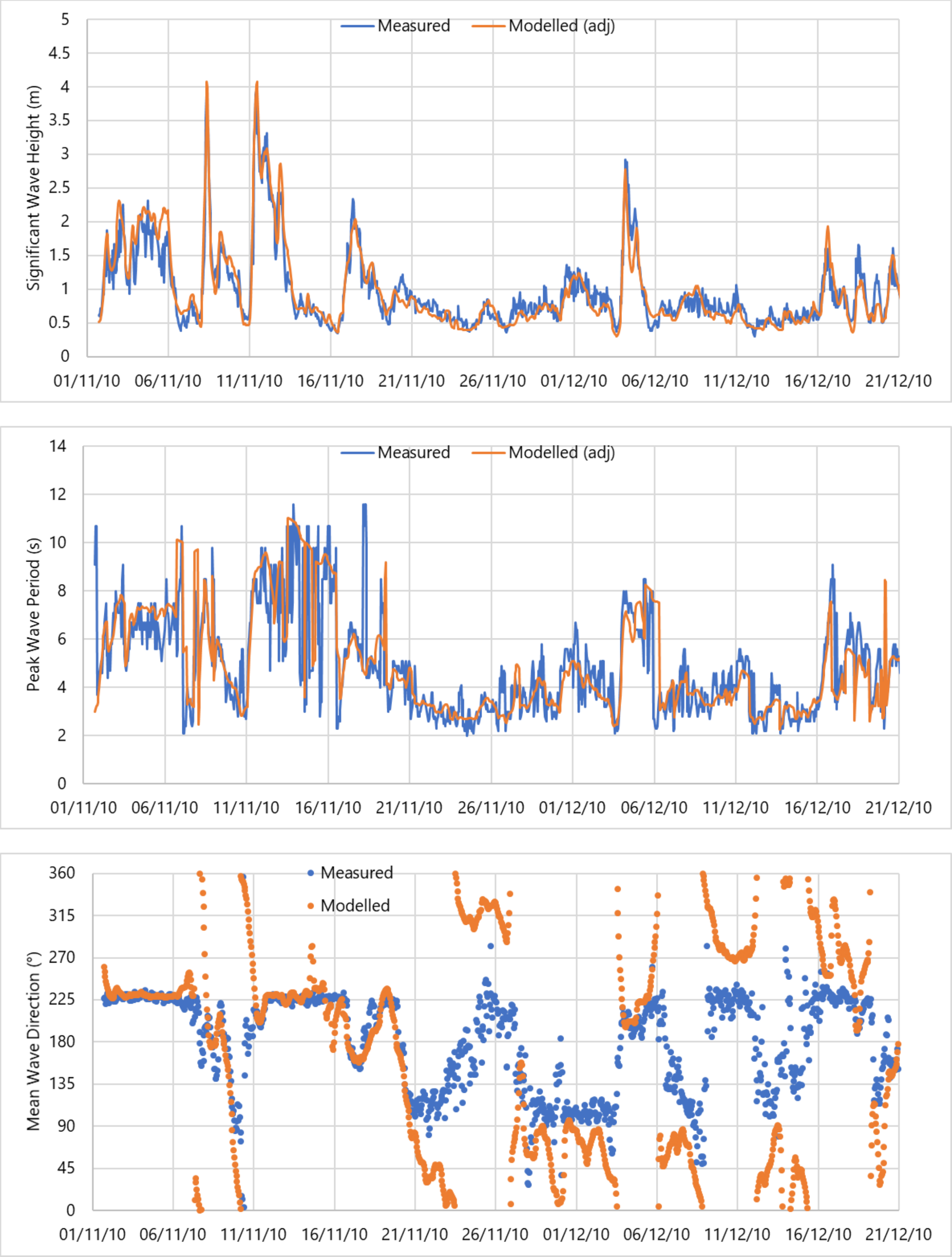


Figure 6.2.4 Comparison of measured and modelled wave parameters at Location L2

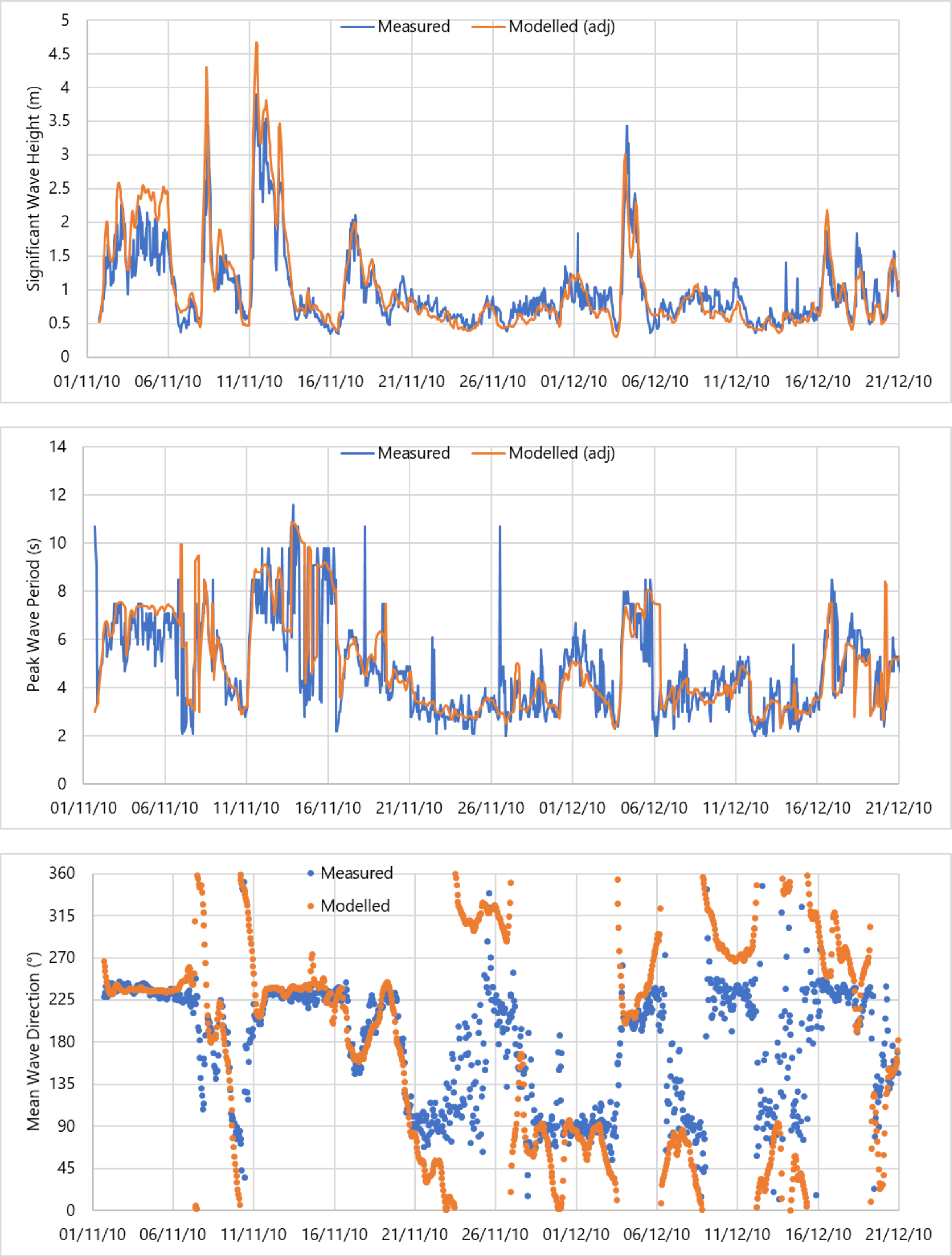
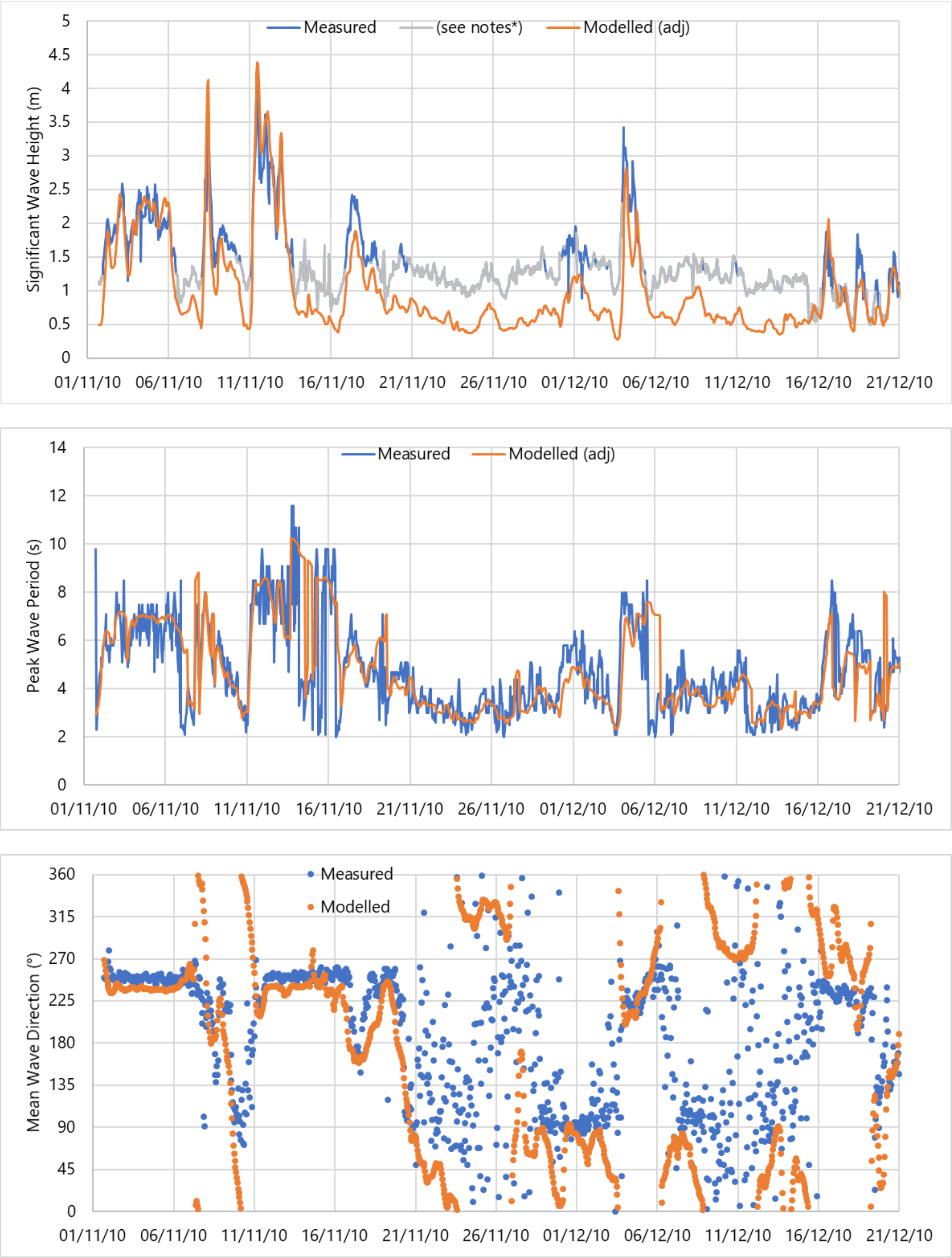


Figure 6.2.5 Comparison of measured and modelled wave parameters at Location L3



3. Glossary of terms and abbreviations

Table 3-1 Glossary of terms and abbreviations

Term	Abbreviation
50% no exc.	50% probability of no exceedance (the median value)
ABP	Associated British Ports
ABPmer	ABP Marine Environmental Research (Ltd)
DCO	Development Consent Order
DHI	Danish Hydraulic Institute
DirM	mean wave direction
DirStd	Directional standard deviation of wave energy
EVA	Extreme Value Analysis
FM	Flexible Mesh
Hs	Significant wave height
LAT	Lowest Astronomical Tide
MSL	Mean Sea Level
OWF	Offshore Wind Farm
RP	Return Period
SW	Spectral Wave
Tp	Peak wave period
UCL	University College London
UKHO	United Kingdom Hydrographic Office
ZOI	Zone Of Influence

Unless otherwise stated, this report using standard SI unit conventions and abbreviations. Standard directional abbreviations (e.g. N, NNE, NE, etc) are used to indicate cardinal directions relative to true North.

Page intentionally blank

4. References

ABPmer, 2013. SEASTATES Wave Hindcast Model, Calibration and Validation Report, August 2013.[Online]. Available at: https://www.seastates.net/downloads/ [Accessed 01 August 2023].

European Marine Observation and Data Network (EMODnet), (n.d.). *Bathymetry*. [Online] Available at: https://www.emodnet-bathymetry.eu/ [Accessed 01 August 2023].

Nortek, (n.d.). *Your guide to understanding and measuring ocean waves*. [Online] Available at: https://www.nortekgroup.com/knowledge-center/wiki/new-to-waves [Accessed 01 August 2023].

UCL and UKHO, (2005). *Vertical Offshore Reference Frames (VORF).* [Online] https://www.ucl.ac.uk/civil-environmental-geomatic-engineering/research/groups-and-centres/vertical-offshore-reference-frames-vorf [Accessed 01 August 2023].

Rampion 2
WIND FARM