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IRISH COASTAL WAVE AND WATER LEVEL MODELLING STUDY 2018

Phase 3 - Bunratty



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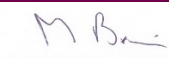
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EXECUTIVE SUMMARY

This report presents the work undertaken and the findings of Phase 3 of the Irish Coastal Wave and Water Level Modelling Study (ICWWS) 2018 at Bunratty. The Phase 3 findings provide an improvement and update to the wave climate and water level combinations of known Annual Exceedance Probability (AEP) originally presented as output from the Irish Coastal Wave and Water Level Modelling Study (ICWWS) 2013 for specific flood risk locations considered vulnerable to wave overtopping.

Overtopping of existing defences and coastal structures (both manmade and natural) as a consequence of the interaction of waves and sea level conditions, including tide and surge, may contribute to coastal flooding in areas located behind these defences. Bunratty was identified by the OPW as a coastal Flood Relief Scheme (FRS) location requiring a detailed assessment of wave climate and water level estimations to enable future wave overtopping analysis to be conducted, and was thus included as a Phase 3 study area. The outputs of this study will inform the evaluation of the risk associated with wave overtopping, resulting in coastal flooding (both now and in the future) and the detailed design of measures to mitigate and manage any such identified coastal flood risk.

To derive overtopping volumes or rates, wave climate conditions for various water levels at the shoreline or defence line are required. For this study, numerical modelling was used to simulate the local generation of wind waves. Relevant offshore wind speeds were combined with present day water levels using a joint probability analysis and these combinations were then used to provide the input to the wave model.

This Phase 3 study provides an improvement and update to the previous ICWWS 2013 study based on the inclusion of additional offshore wind data, bathymetry and topographic data. The wave modelling simulations in Phase 3 also made use of a more detailed 'fully spectral formulation' in comparison to a 'directional decoupled parametric formulation' used in the previous ICWWS 2013 study and also in Phase 2 of this study. A review and updated estimate of the extreme water levels around the coast of Ireland was also undertaken under ICWWS 2018, Phase 1. The updated water levels estimated at Bunratty were notably different than the levels previously published in the Irish Coastal Protection Strategy Study (ICPSS), however due to the significant amount of bathymetric and tide gauge data now available, there is significantly improved confidence in the ICWWS 2018 levels, which were consequently adopted for use in this Phase 3 study.

Combinations of present day wave climate (heights, periods and directions) and water levels for AEPs of 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% were derived for the Bunratty shoreline/defence line. A similar approach was undertaken to determine the corresponding wave climate and water levels for four future scenarios accounting for different projected sea level rise allowances. Spectral significant wave heights, peak spectral wave periods and mean wave directions for each AEP and water level at a series of shoreline/defence line locations comprise the key outputs of this study.

1 INTRODUCTION

Overtopping of existing defences and coastal structures (both manmade and natural) due to the interaction of waves and tidal conditions, including surge, may contribute to coastal flooding in areas behind these defences. Consequently a number of locations around the coast of Ireland have been identified as requiring detailed assessments to provide wave climate and water level estimations to enable future overtopping assessments to be conducted. The results of these assessments will subsequently inform the evaluation of the risk associated with wave overtopping, any resulting coastal flooding (both now and in the future) and the detailed design of measures to mitigate and manage any such identified coastal flood risk.

The locations which the Office of Public Works (OPW) identified as requiring detailed assessment under Phase 3 of the ICWWS 2018 include;

- Tralee
- Shannon
- Bunratty
- Carlingford
- Dundalk

This report focuses on the detailed modelling undertaken for Bunratty and builds upon more limited wave modelling undertaken for the original Irish Coastal Wave and Water Level Modelling Study (ICWWS) (Reference 1), which provided a strategic indication of the variation in wave exposure around the coast of Ireland. The original study made use of Shannon airport wind data from 1990 to 2010, in conjunction with water levels derived as part of the Irish Coastal Protection Strategy Study (ICPSS), South West Coast in 2013. The model used for the original ICWWS lacked detailed bathymetric and topographic survey within the Shannon Estuary and made use of wave simulations based on a less detailed parametric formulation. Hence the outputs were not considered sufficient to inform a detailed assessment of wave overtopping at Bunratty and a more detailed modelling approach was taken for this Phase 3 study.

The primary aim of the ICWWS 2018 Phase 3 was to generate a series of detailed wave climate conditions (heights, periods and directions) for various water levels at the shoreline or defence line, for a range of annual exceedance probability (AEP) events and to derive joint probability detailed wave climate and water level conditions for wave overtopping analysis/modelling to inform scheme design standard and hydraulic performance of any proposed flood defence measures for Bunratty.

To ensure that the output of this study was as robust as possible, it was vital that input model data was up-to-date. Consequently bathymetric survey data that had become available within the Shannon Estuary since the original ICWWS project were reviewed. In general the bathymetry for the outer sections of the Shannon Estuary model remained largely unchanged however the inner part was updated using additional OSi LiDAR data within the estuary which had become available in the interim period.

Bunratty is subject to locally generated wind waves only, hence the nearshore wave climate along the Bunratty frontage was established using extreme value analysis and joint probability analysis of present day water levels with wind speeds. Due to the enclosed nature of the Shannon Estuary corrections were applied to the wind speeds from selected directions to account for the wind travelling over large areas of land. Output from the extreme value analysis provided input conditions to the computational modelling which utilised the MIKE Spectral Wave (SW) Flexible Mesh module developed by the Danish Hydraulic Institute (DHI), to generate wind waves over the model domain.

Combinations of present day wind speeds and water levels corresponding to AEPs of 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% were derived at Bunratty. A similar approach was undertaken in order to determine the corresponding wind speeds and water levels for four future scenarios accounting for different projected sea level rise allowances. Spectral significant wave heights, peak spectral wave periods and mean wave directions for each AEP and water level at a series of inshore locations comprise the key output of this study. For locations within the Shannon Estuary not included as estimation locations in this study, combinations of water levels and wave conditions for various AEPs can be found in the ICWWS 2018, Phase 2 report, (Reference 2).

2 KEY INFORMATION ON STUDY OUTPUTS

The Phase 3 study outputs include combinations of wave climate and extreme sea level estimates for a series of shoreline/defence line locations in the study area. These outputs are based on analysis and modelling, including:

- Statistical extreme value analysis and joint probability analysis of offshore wind data and inshore water levels at ICPSS / ICWWS 2018 coastal boundary estimation points.
- Numerical Modelling to simulate the formation of wind waves relevant to the shoreline/defence line of the site.

The following key information should be taken into consideration in conjunction with the outputs/results.

- 1) Combinations of wave climate and water level estimates have been produced at each shoreline / defence line location. These combinations are joint probability occurrences, in which the two elements, wave climate and water level are likely to simultaneously occur for a given AEP-. This represents the probability of a combined wave climate and water level event of this, or greater, severity occurring in any given year. For example a 0.5% AEP event has a 0.5% probability (or 1 in 200 chance) of occurring or being exceeded in any one year.
- 2) For each AEP from 50% to 0.1%, six combinations of waves and water levels were produced representing the complete joint probability spectrum.
- 3) Wave climate and water level combinations were derived for present day sea levels, as well as the Mid-Range Future Scenario (MRFS), High End Future Scenario (HEFS), High+ End Future Scenario (H+EFS) and High++ End Future Scenario (H++EFS) which represent a 0.5m, 1.0m, 1.5m and 2.0m increase in mean sea level, respectively. These future scenario results do not account for any potential changes to the meteorological systems which may affect the offshore wind speeds.
- 4) The wave climate and water level combinations output from the study are representative of a point situated at approximately half the shallow water wavelength seaward from the toe of the defence structure or shoreline.
- 5) Wave climate conditions are presented in terms of spectral significant wave height (H_{m0}) in metres, spectral peak wave period (T_p) in seconds, and mean wave direction (MWD) in degrees measured from North. H_{m0} is representative of the mean of the highest third of the waves, whilst T_p is associated with the most energetic wave in the spectrum.
- 6) The extreme water levels refer to total water levels, which include the effects of astronomic tides and storm surge residual. Astronomic tides are the daily change in sea levels due to the rotation of the earth and the gravitational forces of the sun and moon along with the hydrodynamic response to the bathymetry, whilst storm surge residual refers to the change in sea level caused by the effect of pressure variations and persistently strong winds.
- 7) The extreme water levels are also inclusive of local wind set-up or seiching, where abrupt changes in meteorological conditions, such as the passage of an intense depression, may cause oscillations in sea level (or seiches).
- 8) The study concluded that the extreme water levels are unlikely to be influenced by the effects of wave action, due to the absence of long period waves at the site.
- 9) The extreme water levels are produced to Mean Sea Level (MSL) and Ordnance Datum Malin (OD Malin) OSGM02 and OSGM15. Mean Sea Level refers to the average sea surface level of all tides over a period of time, whilst OD Malin is the vertical land levelling datum currently used in Ireland, based on the mean sea level recorded between January 1960 and December 1969 at Malin Head tide gauge. This is propagated across the country via the spatial surfaces of the transformation models OSGM02 and OSGM15 produced by the Ordnance Survey of Great Britain (OS), Ordnance Survey Ireland (OSi) and Land & Property Services.

- 10) Although widely accepted methods have been used to derive the combinations of extreme wave climate and water levels, there are a number of limitations which should be considered when using this data for subsequent analysis. These include uncertainties in the derivation of the individual extreme values associated with uncertainties in topographic and other survey data, inaccuracy in meteorological data, assumptions and / or approximations in the hydraulic / hydrodynamic models in representing physical reality, assumptions and / or approximations in the statistical analysis and uncertainties in datum conversions. Further uncertainty arises from the use of the FD2308 joint probability method in the absence of defined and agreed dependence values for waves and tidal levels around Ireland. Further detail on the uncertainties associated with the derivation of extreme tidal levels is given in Reference 3.

3 DATA SOURCES

3.1 Wave and Wind Data

The Bunratty study area is subject to locally generated wind waves only, therefore offshore wave data was not required.

RPS utilised hind cast data from the DHI Metocean Data Portal, in order to determine appropriate wind data for use in the detailed computational model for Bunratty. The available database contained 40 years, from 1979 to 2018 inclusive, of hourly wind data for the west of Ireland. For Bunratty, wind data was extracted from the DHI Metocean Data Portal at an offshore location; **52.5°N 11°W**, as shown in Figure 3.1.

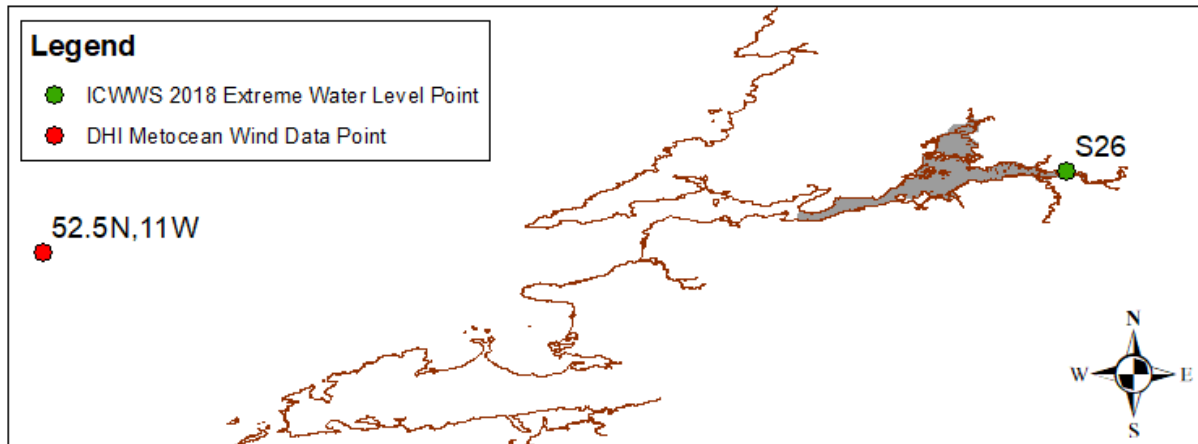


Figure 3.1: Location of DHI Metocean Wind Data Point and ICWWS 2018 Extreme Water Level Estimation Point

The DHI Metocean data at the offshore location was directionally discretised and analysed to create profiles of the wind speeds. These wind speeds were applied across the entire model domain.

Onshore wind data supplied by Met Éireann was also used to inform the establishment of the correlation between the wind speed and water level around the coast of Ireland, including the Shannon Estuary.

3.2 Bathymetric Data

In order to facilitate the transformation of wind speed data into an inshore wave climate relevant to the assessment of wave overtopping, detailed inshore bathymetric and topographic information was required to ensure the reliable transfer of wave energy and generation of the wind-wave climate in the Bunratty area. Sufficient data was also required to represent the various channels, drying zones and offshore banks within the model domain.

Large areas of the bathymetry information used in the model were obtained from INFOMAR survey data, a joint project between Geological Survey Ireland (GSI) and the Marine Institute, along with LiDAR data of the Fergus Estuary and Shannon/Bunratty areas captured by OSi. OPW LiDAR is the primary source of inshore data at the site, and numerous localised hydrographic surveys were used to define the bathymetry in other areas where available. Admiralty Chart data, as digitally supplied by C-Map of Norway was used to supplement the survey data to ensure coverage of the entire model domain. Figure 3.2 shows the coverage of the various datasets in the Bunratty model.

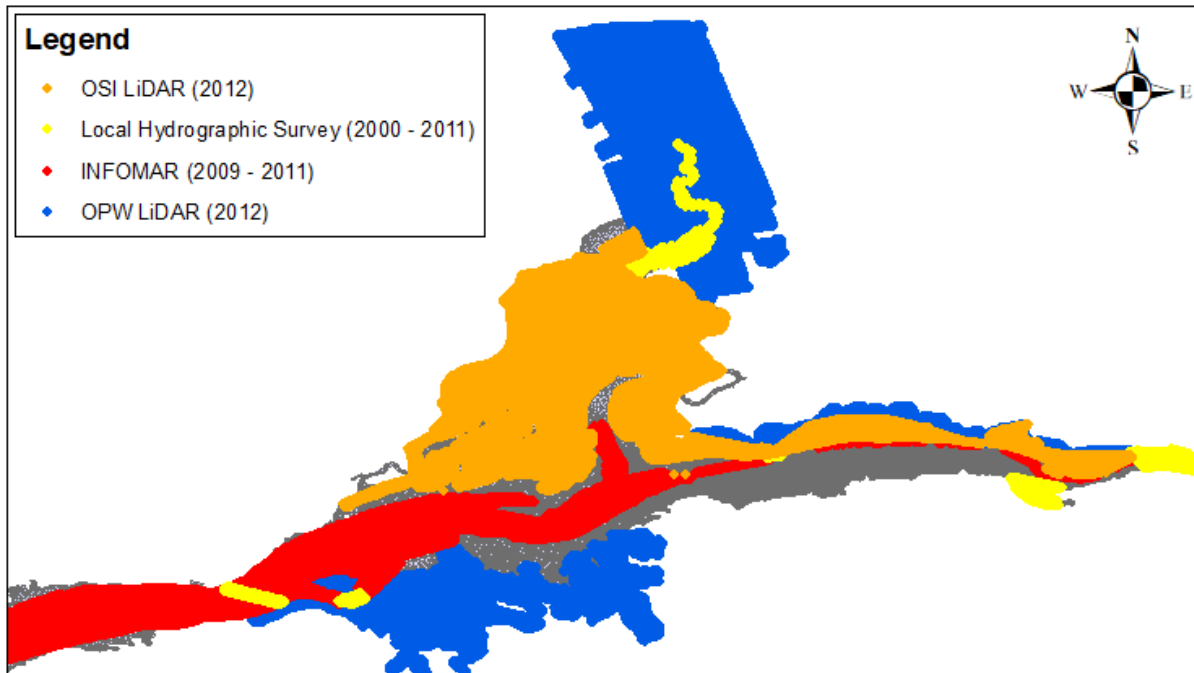


Figure 3.2: Survey Coverage in the Bunratty Model

RPS processed and quality checked all bathymetric data to ensure its suitability for use within the Bunratty modelling system, consistently ensuring that any model interpolation processes produced valid meshes which were representative of the input data.

3.3 Water Level Data

The extreme water levels used to inform the joint probability analysis and wave modelling were taken from the ICWWS 2018 Phase 1 results at estimation point S26, close to Bunratty and covered the full range of required AEPs. The location of this point can be seen in Figure 3.1.

During Phase 1 of the ICWWS 2018, new bathymetric information was input to the Irish Seas Tidal Surge Model and Shannon Estuary model, and the models revalidated to ensure the updated models were producing reasonable results and a series of “extreme” events simulated. Once all these events were simulated, an extreme value analysis was undertaken by fitting various standard statistical distributions to the resulting water level datasets for each estimation point within the Shannon Estuary. Refer to the Phase 1 Report for further detail on how these water levels were estimated (Reference 3). The updated water levels estimated at Bunratty were notably different than the levels previously published in the Irish Coastal Protection Strategy Study (ICPSS), however the significant amount of additional bathymetric and tide gauge data now available, significantly improved the confidence in the ICWWS 2018 levels, which were subsequently adopted for use in this Phase 3 study.

4 STATISTICAL ANALYSIS

The offshore wind data from the DHI Metocean Data Portal was directionally discretised to identify the critical directions relevant to Bunratty. Corrections were applied to the wind speeds from selected directions to account for the wind travelling over large areas of land using guidance from BS EN 1991-1-4 Annex 1 (Reference 4), and Extreme Value Analysis and Joint Probability Analysis of wind speeds and water levels performed.

The resulting joint probability pairings of wind and water levels were then applied across the entire model domain of a series of wave model simulations to estimate the inshore wave climate. Figure 4.1 shows the wind rose plot for the DHI Metocean Data Portal point **52.5°N 11°W**.

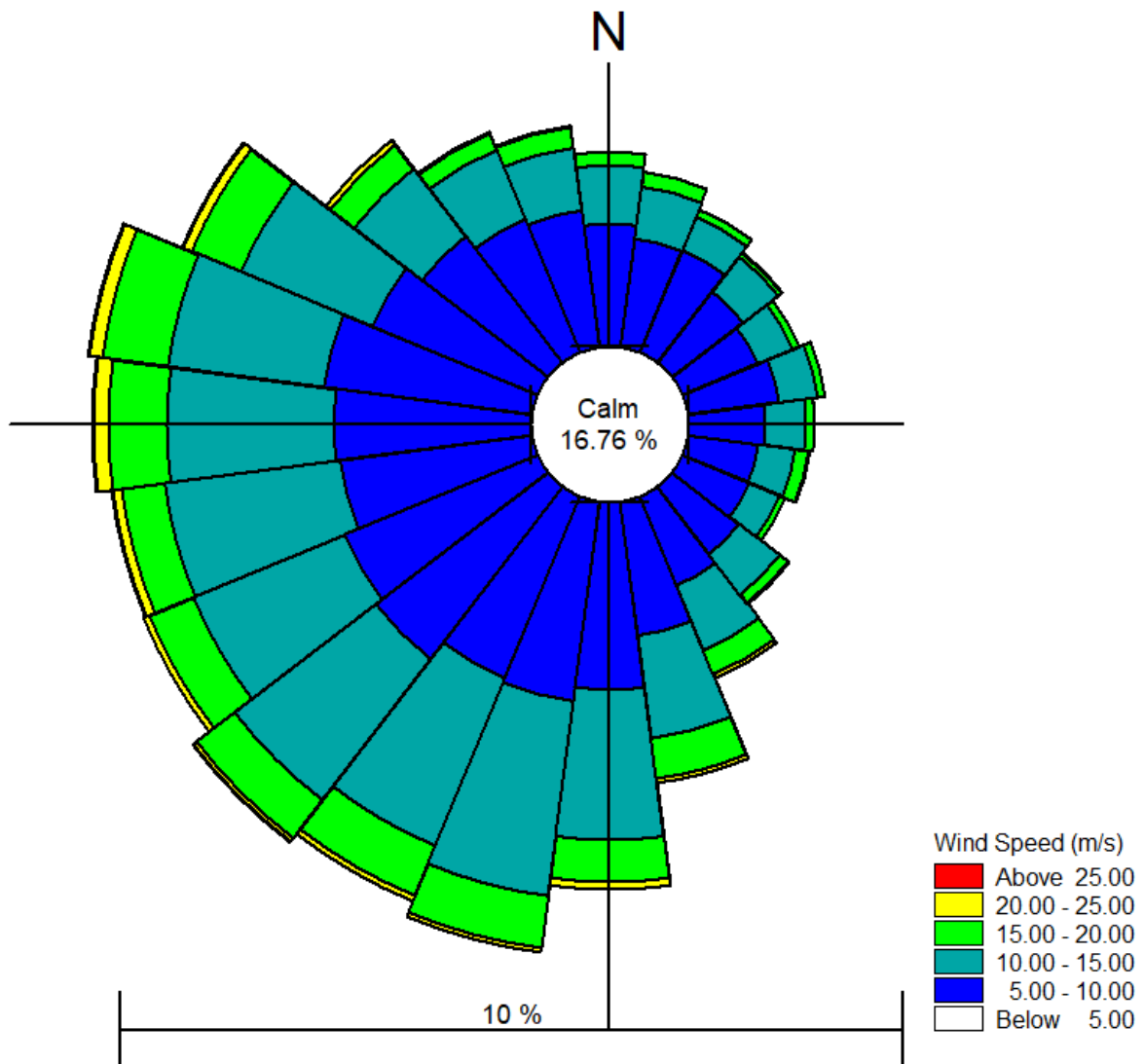


Figure 4.1: Wind Rose for DHI Metocean Data Portal point 52.5°N 11°W (1979 – 2018)

4.1 Extreme Value Analysis

For the Extreme Value Analysis (EVA) a partial duration series, also known as peak over threshold model, was used to select the largest events which occurred within the dataset. A theoretical probability distribution (Truncated Gumbel) was then fitted to the resultant extreme values and a Jackknife re-sampling technique, used to derive a series of return period wind speeds, based on the omnidirectional dataset.

A derivation of the latest methodology developed by the UK Met Office was implemented to allocate return periods to wind speeds from various directions. With this method the directional sector containing the largest wind speed(s) was allocated the omnidirectional series of return period wind speeds, while the remaining sectors had the omnidirectional return period wind speed(s) proportioned according to their largest wind speed(s) in comparison to the largest omnidirectional wind speed(s).

The UK Met Office suggest basing the analysis on the single maximum value for each directional sector, however RPS considered that this approach placed a lot of emphasis on individual values, and hence the analysis could easily be skewed by any outliers. As such, RPS have undertaken sensitivity testing, comparing the approaches of using single peak values only, or using the mean values of the largest three wind speeds in the sector. Following this assessment, RPS deemed the latter approach the most robust and appropriate for this length and type of dataset.

The results from the EVA are shown in Table 4-1 for point 52.5N, 11.0W. Further details are provided in Appendix A.

Directional Sectors		230°	260°	280°	50°
Return Period (years)	0.1	18.94	20.86	20.86	13.05
	0.2	20.61	22.71	22.71	14.21
	0.5	22.67	24.97	24.97	15.62
	1	24.17	26.63	26.63	16.66
	2	25.64	28.25	28.25	17.68
	5	27.59	30.39	30.39	19.02
	10	29.06	32.01	32.01	20.03
	20	30.52	33.61	33.61	21.03
	50	32.45	35.74	35.74	22.37
	100	33.91	37.36	37.36	23.38
	200	35.37	38.96	38.96	24.38
	500	37.30	41.09	41.09	25.71
	1000	38.77	42.70	42.70	26.72

Table 4-1: EVA results for wind speed (in metres/second) at 52.5N, 11.0W

4.2 Joint Probability Analysis

The Joint Probability analysis of wind speeds and water levels was undertaken using the spreadsheet and simplified methodology derived during the JOIN-SEA project, which is described in Section 5.7 of the DEFRA/Environment Agency RSD Guidance on Joint Probability Analysis, FD2308 (Reference 5). This methodology involves selecting a correlation coefficient between each pair of variables. This is normally based on established relationships (e.g. wind speed and water level) for a particular area, however there are no pre-determined correlation coefficients available for the coast of Ireland. Therefore RPS made use of the available wind and tidal data to derive joint event matrices between wind speeds and water levels and subsequently determine appropriate correlation coefficients for wind speeds at Bunratty.

Once an appropriate correlation coefficient was selected, the relevant set of AEP water levels and wind speeds were input into the JOIN-SEA spreadsheet for analysis. Extreme water levels were taken from the ICWWS 2018 Phase 1 results at Bunratty (Section 3.3), whilst the wind speeds were derived during the EVA stage of this study (Section 4.1).

BUNRATTY – PHASE 3 REPORT

Combinations of wind speeds and water levels for joint AEPs of 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% were derived for each sector relevant to Bunratty. For each joint AEP and direction, six water levels with corresponding wind speeds were generated from the joint probability analysis to illustrate the complete joint probability range.

A sample plot of the offshore joint wind and water level exceedance curves at 52.5N, 11.0W for the 260° sector is shown in Figure 4.2, with full results from the joint probability analysis included in Appendix B.

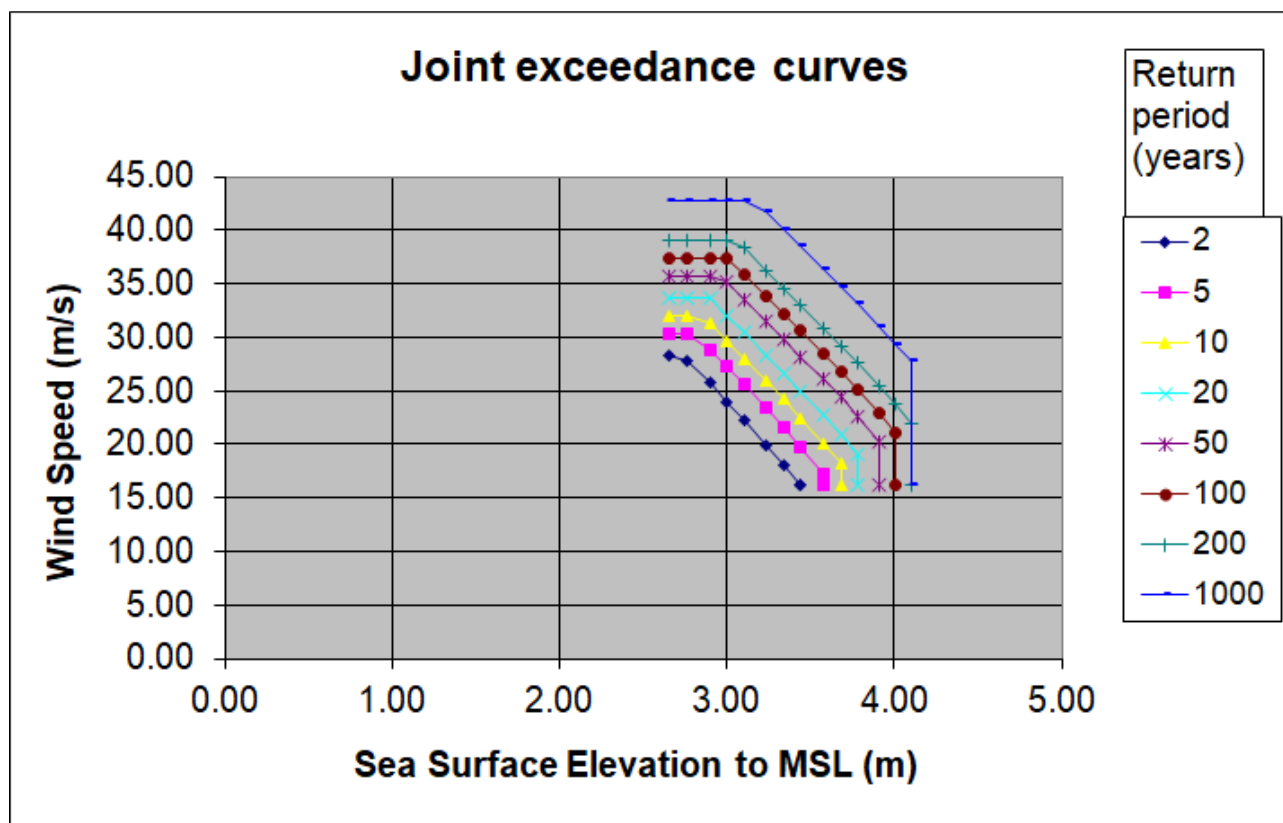


Figure 4.2: Offshore joint wind and water level exceedance curve at 52.5N, 11.0W (260° sector)

4.2.1 Correlation Coefficients

The correlation between wind speeds and water levels varies with storm direction around the coast of Ireland. The Joint Probability analysis was therefore undertaken for a range of storm direction sectors with the correlation coefficients derived for each direction shown in Table 4-2.

For Bunratty there was a strong correlation between wind speeds and water levels for events from the west and south west, with moderate correlation from the north west through to the south.

Table 4-2: Derived Correlation Coefficients between Wind Speeds and Water Levels

Direction (°)	Correlation Coefficients
0	0.46
45	0.4
90	0.43
135	0.5
180	0.55
225	0.62
270	0.62
315	0.48

5 MODEL DEVELOPMENT

5.1 Modelling System

Following the statistical analysis, the derived wind speeds and water levels were applied across the entire domain and transformed to inshore wave conditions using the MIKE21 Spectral Wave (SW) Flexible Mesh model. This is a third generation spectral wind-wave model with two modes of operation, using either the directional decoupled parametric or fully spectral formulations. As Phase 3 is intended to provide detailed information, the fully spectral formulation was used. The SW module describes the propagation, growth and decay of waves in nearshore areas and can take into account the effects of refraction and shoaling due to varying depth, local wind generation and energy dissipation due to bottom friction, white capping and wave breaking. It may also include non-linear wave-wave interaction, wave-current interaction and the effect of time varying water depth and flooding and drying. The SW model has an optimal degree of flexibility in describing bathymetry and ambient flow conditions due to the use of a depth-adaptive and boundary-fitted unstructured mesh.

5.2 Model Bathymetry

In order to adequately and efficiently model wave generation at Bunratty, a wave model of the Shannon Estuary was set up. The grid resolution of the model varied spatially depending on location and was selected to ensure that the variation and rate of change in the seabed topography due to banks, rocky shoals and particularly at the approaches to the shorelines/defence lines were adequately resolved so that the changes in wave conditions due to shoaling, refraction and wave breaking were accurately modelled. This required fine grid resolution in places, down to circa 10m, particularly around banks and shoals and in the vicinity of areas of interest, with coarser grid resolution in deeper water and areas of more consistent bathymetry.

The Shannon Estuary model was also used in Phase 2 of the ICWWS 2018 to simulate locally generated wind waves for Coonagh, Foynes and Tarbert, and in the ICWWS 2018 Phase 3 analysis for Shannon. The model extent and included bathymetry to Mean Sea Level (MSL) of the Shannon Estuary model can be seen in Figure 5.1.

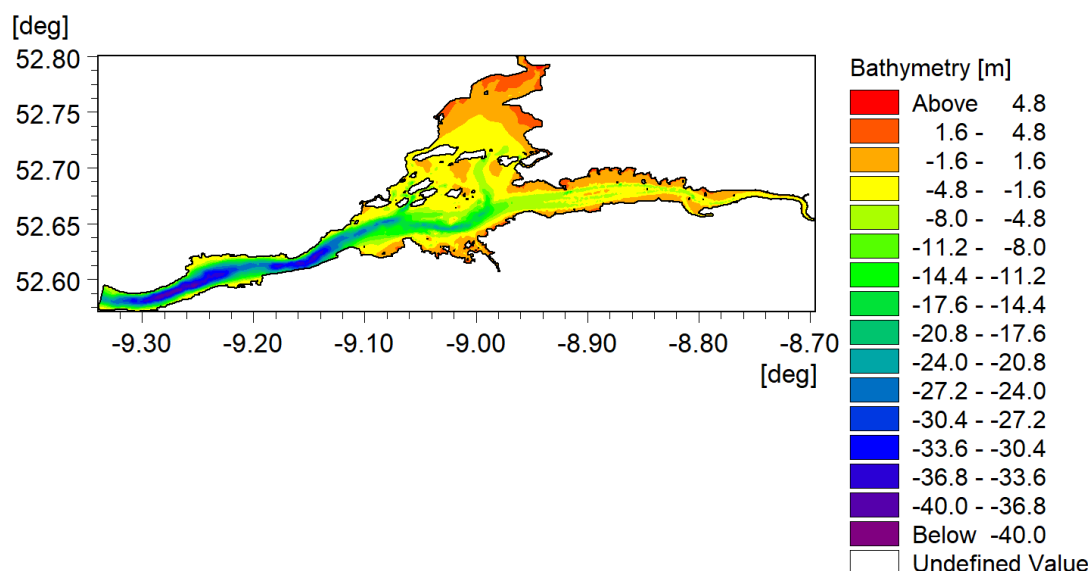


Figure 5.1: The Shannon Estuary Model Extent and Bathymetry (to MSL), used for Bunratty simulations

5.3 Model Simulations

Bunratty is exposed to locally generated wind wave conditions, from a range of directions, consequently the MIKE SW module was used to test the formation of wind waves for a range of exposure directions, to determine the relevant critical directions. The direction which resulted in the most arduous conditions along each

particular section of coastline was used to determine the inshore wave climate to be presented as the output from this study. It should be noted that for Bunratty, the critical storm direction changed along the coast, resulting in the need to output data at a number of estimation locations.

The final critical storm directions simulated were 260 and 280 degrees for a wind wave, where the waves were generated by the immediate local wind. Simulations were undertaken for six combinations of wind speeds and water levels for joint AEPs of 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% for each critical direction.

6 IMPACT OF SEA LEVEL RISE

The predicted increase in sea levels due to global warming has the potential to increase the wave climate at Bunratty due to greater water depths being available in the nearshore area. At present there is uncertainty about how global warming will actually affect wind conditions in the future, thus the effects of climate change in this study has been restricted to the consideration of four sea level rise scenarios.

For the purposes of flood risk assessment the current standard future scenario values adopted in Ireland for sea level rise are 0.5m for the Mid Range Future Scenario (MRFS) and 1.0m for the High End Future Scenario (HEFS), and thus these values were adopted for this study. Two additional climate change scenarios corresponding to sea level rise of 1.5m (H+EFS) and 2.0m (H++EFS) were also included.

Wave modelling scenarios undertaken for the present day were re-run for these four climate change scenarios. The simulations were undertaken for the wave directions established as the critical directions for Bunratty during the present day simulations but with the water level increased by the relevant amount.

7 MEAN SEA LEVEL TO OD MALIN CONVERSION

A review of the Mean Sea Level (MSL) to OD Malin datum relationship in the Bunratty area was undertaken as part of Phase 4 of the ICWWS 2018.

For Bunratty, the most reliable way to achieve this was considered to be by analysing data from an existing tide gauge of known datum or alternatively to deploy a temporary gauge in the local vicinity. A review of available tide gauges nearby in the Shannon Estuary found none with an established reliable datum, therefore OPW installed a new tide gauge at Shannon Airport, which has been operational since December 2019.

Under Phase 4, the Shannon Airport gauge data was analysed for the period December 2019 to April 2020. With the gauge accurately levelled to OD Malin (OSGM15), an analysis of the records allowed the mean water level relative to OD Malin to be obtained directly. Using the Mike 21 toolbox 'Tide Analysis of Heights', the data was analysed and yielded a set of harmonics including a Z0 value which is equivalent to the mean sea level. The estimation of Z0 at the Shannon Airport gauge was made for the duration of the available record, which was less than six months at the time of analysis. RPS consider a three year period to be the optimum length of data required, with a minimum of one year of data for a reasonable estimate of Z0 due to seasonal variations. However, the Shannon Airport gauge data was the best available information in the area at the time of analysis.

The analysis of the Shannon Airport gauge data along with other similar analyses for more established gauges around the Irish coastline were used to inform the creation of a surface grid representing the conversion between MSL and OD Malin (OSGM15) around the coast of Ireland. This grid was used to transfer the MSL and OD Malin (OSGM15) relationship from the gauged location of Shannon Airport to the non-gauged location of the Bunratty frontage. Further details are included in the ICWWS 2018 Phase 4 report (Reference 6).

Using Grid Inquest II, the relationship between OD Malin OSGM15 and OD Malin OSGM02 at Bunratty was also derived. The resulting updated conversions for Bunratty as used to present the results of this study in terms of OD Malin OSGM02 and OSGM15 are presented in Table 7-1. The sign convention in Table 7-1 indicates OD Malin (OSGM02 and OSGM15) relative to MSL, with a positive value being above MSL and a negative value being below MSL. In order to convert from MSL to OD Malin, the correction stated is subtracted.

Table 7-1: Derived Conversion between MSL and OD Malin for Bunratty

MSL to OD Malin	
MSL to OSGM02	MSL to OSGM15
-0.224 m	-0.166 m

8 ADDITIONAL CONSIDERATIONS

8.1 Beach Drawdown

Beach drawdown can be a significant issue on gradually sloping sandy beaches exposed to large ocean storm waves. Where this is the case the large storm waves, which form a series of breaking waves across the surf zone, can result in high undertow currents which in combination with the breaking waves lifting the bed sediment can result in sand being stripped off the beach and carried to an offshore bar. This lowering or drawdown of the beach can result in larger reformed waves being able to directly attack shoreline structures at the back of the beach.

An initial scoping exercise was undertaken to identify the potential for beach drawdown to affect the wave climate at Bunratty and determine if detailed modelling was required to quantify this risk. The scoping exercise concluded that the potential for beach drawdown at Bunratty is low due to the limited and low energy wind wave climate within the sheltered estuary location, therefore, no further assessment was required.

8.2 Wave Setup

On wide, relatively flat, beaches where large storm waves break and reform there is usually a significant gradient in the radiation stresses across the surf zone which results in a lowering of the mean sea level under the first line of breaking waves and a subsequent increase in the mean sea levels in towards the beach. This increase or setup of the mean water levels close to the beach means that reformed waves approaching a coastal structure at the back of the beach may be slightly larger due to the locally increased water depth at the toe of the structure.

An initial scoping exercise was undertaken to identify the potential for wave setup at Bunratty and determine if detailed modelling was required to quantify the impact on wave conditions. The scoping exercise concluded that the potential for wave setup at Bunratty is low due to the predominance of locally generated wind seas in the area, and the associated limited wave heights and periods, and the consequent relatively low wave energy environment.

9 RESULTS AND STUDY OUTPUTS

Due to the location of Bunratty within the Shannon Estuary, it was found to be principally exposed to locally generated waves approaching from the westerly direction. The Shannon Estuary wave generation model was used to simulate the full range of joint probability return period events up to the 0.1% AEP, with six combinations of water levels and wind speeds modelled for each event from the appropriate directional sectors. Once these winds were transformed to inshore wave conditions, the inshore results were extracted for six locations around Bunratty.

For each AEP from 50% to 0.1%, the output of the study at the shoreline / defence line along the Bunratty frontage in areas considered potentially liable to flooding from wave overtopping is presented in terms of spectral significant wave height (H_{m0}) in metres, spectral peak wave period (T_p) in seconds and mean wave direction (MWD) in degrees measured from north, for each water level (WL).

Due to the effects of refraction, the storm wave directions at the shoreline / defence line were normally within $\pm 30^\circ$ of the direction normal to the coastline. While the wave direction at the shoreline / defence line is therefore not critical for overtopping calculations, the mean wave direction has been provided for completeness.

The output from this study is representative of a point situated at approximately half the shallow water wavelength seaward from the toe of the defence structure or shoreline. A note of the measured bed level at each estimation location and its source is also supplied.

Wave climate and water level combinations are provided for present day sea levels and for each of four sea level rise scenarios (MRFS, HEFS, H+EFS, H++EFS).

Study outputs are provided for six estimation locations at Bunratty, as shown in Figure 9.1 and detailed in Table 9-1. The recommended wave and tidal levels for standard AEPs and each of the five epochs investigated for each point are presented in Table 9-2 to Table 9-7 respectively.

For the present day sea level, Location B experienced the largest significant wave heights with a maximum of 0.62m to 1.03m for the 50% and 0.1% AEPs respectively. Corresponding peak wave periods were 2.64s and 2.91s. Location E experienced the smallest significant heights with a maximum of 0.42m to 0.76m for the 50% and 0.1% AEPs respectively and corresponding peak periods of 1.93s and 2.44s. Water levels for present day sea level ranged from 3.07m OD Malin (OSGM15) to 4.27m OD Malin (OSGM15). Bed levels at which the output data at Location B and Location E were extracted are shown as 1.256m OD Malin (OSGM15) and 2.086m OD Malin (OSGM15) respectively.

ICWWS 2018 Phase 3 Bunratty CAPO Estimation Locations

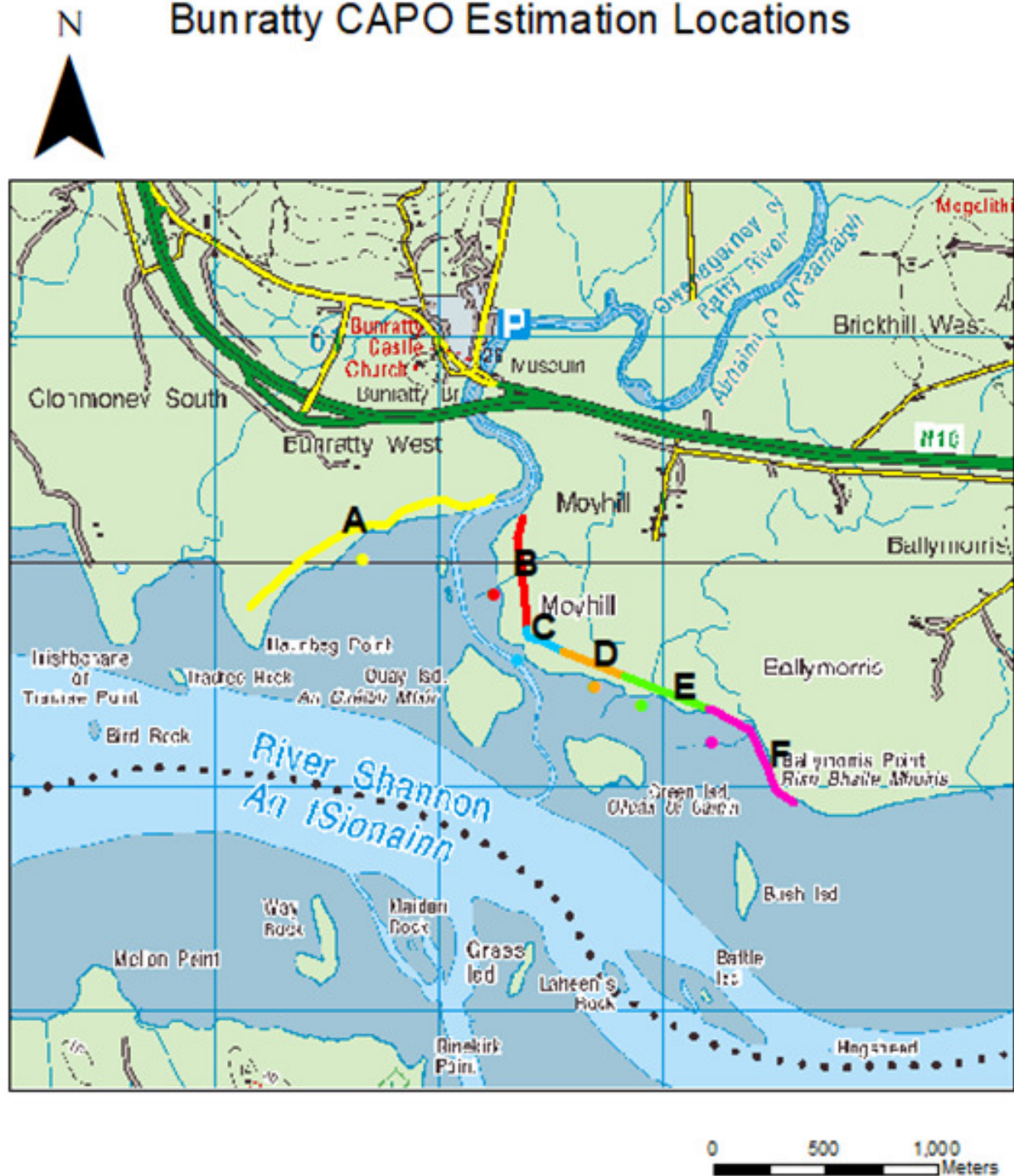


Figure 9.1: Estimation Locations for Bunratty

Table 9-1: Co-ordinates for Estimation Locations for Bunratty

Location	Co-ordinates (WGS84)	
	Latitude (°N)	Longitude (°W)
A	52.689	8.819
B	52.6877	8.8104
C	52.685	8.8088
D	52.684	8.8036
E	52.6833	8.8005
F	52.6818	8.7959

Location	Co-ordinates (ITM)	
	Eastings [m]	Northings [m]
A	544630.794	660076.399
B	545210.567	659925.189
C	545315.365	659623.578
D	545665.701	659508.386
E	545874.434	659428.172
F	546183.612	659257.84

Table 9-2: Shoreline Wave Climate and Water Level Combinations – Location A

Irish Coastal Wave & Water Level Modelling Study (ICWWS) 2018 Coastal Areas Potentially Vulnerable to Wave Overtopping (CAPO)						
Output: Shoreline Wave Climate and Water Level Combinations						
Location: Bunratty Location A						
Bed Level: 1.40m MSL						
Bed Level (OD Malin OSGM02): 1.624m						
Bed Level (OD Malin OSGM15): 1.566m						
Dated: October 2020						
Joint Probability Event (AEP): Varies from 50% to 0.1%						
Prepared By: CN			Checked By: MB			
Table Reference: ICWWS_CAPO_Shn_Bunratty						

Notes:

1

Users of this information should refer to the ICWWS 2018 Phase 3 Bunratty Technical Report for a detailed description of the derivation of the data and it's applicability

2

Bed Level taken at approximately half the shallow water wavelength from structure / shoreline

3

Bed level source: OPW LiDAR data (2012)

4

AEP denotes the combined wave and water level joint Annual Exceedance Probability

5

Wind Wave Component refers to waves generated by the immediate local wind

6

Hm0 denotes the spectral significant wave height in metres

7

Tp denotes the spectral peak wave period in seconds

8

MWD denotes the mean wave direction in degrees north

Present Day Scenario Water Level						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	2.90	3.12	3.07	0.55	3.05	199
	3.00	3.22	3.16	0.53	3.72	200
	3.10	3.33	3.27	0.49	3.69	201
	3.24	3.46	3.41	0.44	3.58	202
	3.34	3.57	3.51	0.39	3.43	205
	3.44	3.67	3.61	0.34	3.40	207
20%	3.00	3.22	3.16	0.61	2.86	200
	3.10	3.33	3.27	0.59	3.78	201
	3.24	3.46	3.41	0.54	3.78	202
	3.34	3.57	3.51	0.50	3.75	203
	3.44	3.67	3.61	0.44	3.60	205
	3.58	3.81	3.75	0.37	3.48	207
10%	3.10	3.33	3.27	0.65	3.17	201
	3.24	3.46	3.41	0.62	3.80	202
	3.34	3.57	3.51	0.58	3.79	203
	3.44	3.67	3.61	0.53	3.74	204
	3.58	3.81	3.75	0.46	3.61	206
	3.68	3.91	3.85	0.41	3.64	206
5%	3.10	3.33	3.27	0.70	2.97	201
	3.34	3.57	3.51	0.66	3.83	203
	3.44	3.67	3.61	0.62	3.85	203
	3.58	3.81	3.75	0.55	3.78	205
	3.68	3.91	3.85	0.50	3.75	206
	3.78	4.00	3.95	0.44	3.72	207
2%	3.24	3.46	3.41	0.75	3.08	202
	3.44	3.67	3.61	0.72	3.92	203
	3.58	3.81	3.75	0.66	3.88	204
	3.68	3.91	3.85	0.61	3.84	205
	3.78	4.00	3.95	0.56	3.79	207
	3.91	4.13	4.08	0.48	3.74	208
1%	3.24	3.46	3.41	0.79	3.13	202
	3.44	3.67	3.61	0.78	3.48	203
	3.68	3.91	3.85	0.70	3.94	205
	3.78	4.00	3.95	0.65	3.89	205
	3.91	4.13	4.08	0.57	3.85	207
	4.01	4.23	4.17	0.52	3.81	208
0.5%	3.34	3.57	3.51	0.83	3.20	203
	3.58	3.81	3.75	0.82	4.15	204
	3.78	4.00	3.95	0.74	4.08	205
	3.91	4.13	4.08	0.67	3.95	206
	4.01	4.23	4.17	0.61	3.90	207
	4.10	4.33	4.27	0.55	3.83	209
0.1%	3.44	3.67	3.61	0.92	3.26	207
	3.68	3.91	3.85	0.94	3.40	205
	3.78	4.00	3.95	0.92	3.91	205
	3.91	4.13	4.08	0.88	4.20	206
	4.01	4.23	4.17	0.83	4.20	207
	4.10	4.33	4.27	0.78	4.16	207

Mid-Range Future Scenario (MRFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.40	3.62	3.57	0.64	3.82	204
	3.50	3.72	3.66	0.59	3.79	204
	3.60	3.83	3.77	0.54	3.78	205
	3.74	3.96	3.91	0.46	3.68	207
	3.84	4.07	4.01	0.40	3.49	210
	3.94	4.17	4.11	0.34	3.41	211
20%	3.50	3.72	3.66	0.69	3.90	204
	3.60	3.83	3.77	0.65	3.86	205
	3.74	3.96	3.91	0.59	3.80	206
	3.84	4.07	4.01	0.54	3.81	207
	3.94	4.17	4.11	0.47	3.77	208
	4.08	4.31	4.25	0.38	3.49	211
10%	3.60	3.83	3.77	0.73	4.01	204
	3.74	3.96	3.91	0.67	3.90	205
	3.84	4.07	4.01	0.62	3.85	206
	3.94	4.17	4.11	0.57	3.84	207
	4.08	4.31	4.25	0.47	3.73	210
	4.18	4.41	4.35	0.41	3.70	211
5%	3.60	3.83	3.77	0.81	4.15	204
	3.84	4.07	4.01	0.71	3.99	206
	3.94	4.17	4.11	0.65	3.93	206
	4.08	4.31	4.25	0.57	3.86	208
	4.18	4.41	4.35	0.51	3.80	210
	4.28	4.50	4.45	0.44	3.71	212
2%	3.74	3.96	3.91	0.87	4.18	205
	3.94	4.17	4.11	0.78	4.15	206
	4.08	4.31	4.25	0.70	4.06	207
	4.18	4.41	4.35	0.64	3.97	208
	4.28	4.50	4.45	0.58	3.85	210
	4.41	4.63	4.58	0.49	3.81	211
1%	3.74	3.96	3.91	0.93	3.44	205
	3.94	4.17	4.11	0.87	4.20	206
	4.18	4.41	4.35	0.74	4.13	208
	4.28	4.50	4.45	0.68	4.01	209
	4.41	4.63	4.58	0.59	3.92	210
	4.51	4.73	4.67	0.52	3.86	211
0.5%	3.84	4.07	4.01	0.97	3.50	205
	4.08	4.31	4.25	0.89	4.23	207
	4.28	4.50	4.45	0.78	4.18	208
	4.41	4.63	4.58	0.69	4.13	209
	4.51	4.73	4.67	0.62	4.01	210
	4.60	4.83	4.77	0.56	3.92	211
0.1%	3.94	4.17	4.11	1.08	3.57	207
	4.18	4.41	4.35	1.04	4.21	207
	4.28	4.50	4.45	1.00	4.29	207
	4.41	4.63	4.58	0.92	4.28	208
	4.51	4.73	4.67	0.87	4.26	209
	4.60	4.83	4.77	0.80	4.23	210

High End Future Scenario (HEFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.90	4.12	4.07	0.68	3.93	206
	4.00	4.22	4.16	0.62	3.90	207
	4.10	4.33	4.27	0.56	3.86	208
	4.24	4.46	4.41	0.47	3.74	211
	4.34	4.57	4.51	0.41	3.62	212
	4.44	4.67	4.61	0.38	3.64	212
20%	4.00	4.22	4.16	0.75	4.12	207
	4.10	4.33	4.27	0.69	3.99	208
	4.24	4.46	4.41	0.60	3.91	209
	4.34	4.57	4.51	0.54	3.84	210
	4.44	4.67	4.61	0.47	3.81	211
	4.58	4.81	4.75	0.38	3.76	212
10%	4.10	4.33	4.27	0.79	4.17	207
	4.24	4.46	4.41	0.70	4.08	208
	4.34	4.57	4.51	0.64	4.00	209
	4.44	4.67	4.61	0.57	3.86	211
	4.58	4.81	4.75	0.48	3.81	212
	4.68	4.91	4.85	0.41	3.78	212
5%	4.10	4.33	4.27	0.88	4.22	207
	4.34	4.57	4.51	0.74	4.15	209
	4.44	4.67	4.61	0.67	4.10	210
	4.58	4.81	4.75	0.58	3.95	211
	4.68	4.91	4.85	0.51	3.88	212
	4.78	5.00	4.95	0.45	3.82	213
2%	4.24	4.46	4.41	0.94	4.26	208
	4.44	4.67	4.61	0.82	4.22	209
	4.58	4.81	4.75	0.72	4.17	210
	4.68	4.91	4.85	0.65	4.14	211
	4.78	5.00	4.95	0.58	4.01	212
	4.91	5.13	5.08	0.48	3.85	213
1%	4.24	4.46	4.41	1.02	4.28	207
	4.44	4.67	4.61	0.91	4.28	209
	4.68	4.91	4.85	0.76	4.20	210
	4.78	5.00	4.95	0.69	4.16	211
	4.91	5.13	5.08	0.59	4.10	212
	5.01	5.23	5.17	0.52	3.90	213
0.5%	4.34	4.57	4.51	1.06	4.34	207
	4.58	4.81	4.75	0.93	4.31	208
	4.78	5.00	4.95	0.80	4.23	211
	4.91	5.13	5.08	0.70	4.20	212
	5.01	5.23	5.17	0.63	4.15	212
	5.10	5.33	5.27	0.56	4.06	213
0.1%	4.44	4.67	4.61	1.21	3.88	209
	4.68	4.91	4.85	1.11	4.62	209
	4.78	5.00	4.95	1.05	4.58	209
	4.91	5.13	5.08	0.95	4.39	210
	5.01	5.23	5.17	0.88	4.33	211
	5.10	5.33	5.27	0.81	4.29	212

High+ End Future Scenario (H+EFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	4.40	4.62	4.57	0.70	4.11	209
	4.50	4.72	4.66	0.63	4.00	210
	4.60	4.83	4.77	0.57	3.95	211
	4.74	4.96	4.91	0.47	3.79	213
	4.84	5.07	5.01	0.40	3.76	214
	4.94	5.17	5.11	0.38	3.72	214
20%	4.50	4.72	4.66	0.78	4.19	210
	4.60	4.83	4.77	0.71	4.14	210
	4.74	4.96	4.91	0.62	3.97	212
	4.84	5.07	5.01	0.54	3.94	213
	4.94	5.17	5.11	0.47	3.87	213
	5.08	5.31	5.25	0.38	3.75	215
10%	4.60	4.83	4.77	0.82	4.23	210
	4.74	4.96	4.91	0.72	4.17	211
	4.84	5.07	5.01	0.64	4.13	211
	4.94	5.17	5.11	0.58	4.07	212
	5.08	5.31				

Table 9-3: Shoreline Wave Climate and Water Level Combinations – Location B

Irish Coastal Wave & Water Level Modelling Study (ICWWS) 2018 Coastal Areas Potentially Vulnerable to Wave Overtopping (CAPO)						
Output: Shoreline Wave Climate and Water Level Combinations						
Location: Bunratty, Location B						
Bed Level: 1.09m MSL						
Bed Level (OD Malin OSGM02): 1.314m						
Bed Level (OD Malin OSGM15): 1.256m						
Dated: October 2020						
Joint Probability Event (AEP): Varies from 50% to 0.1%						
Prepared By: CN				Checked By: MB		
Table Reference: ICWWS_CAPO_Shn_Bunratty						

Notes:						
1	Users of this information should refer to the ICWWS 2018 Phase 3 Bunratty Technical Report for a detailed description of the derivation of the data and it's applicability					
2	Bed Level taken at approximately half the shallow water wavelength from structure / shoreline					
3	Bed level source: OPW LIDAR data (2012)					
4	AEP denotes the combined wave and water level joint Annual Exceedance Probability					
5	Wind Wave Component refers to waves generated by the immediate local wind					
6	Hm0 denotes the spectral significant wave height in metres					
7	Tp denotes the spectral peak wave period in seconds					
8	MWD denotes the mean wave direction in degrees north					

Present Day Scenario Water Level						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	2.90	3.12	3.07	0.62	2.64	248
	3.00	3.22	3.16	0.60	2.69	247
	3.10	3.33	3.27	0.57	2.70	246
	3.24	3.46	3.41	0.51	2.70	244
	3.34	3.57	3.51	0.47	2.70	243
	3.44	3.67	3.61	0.43	2.71	242
20%	3.00	3.22	3.16	0.68	2.70	248
	3.10	3.33	3.27	0.66	2.80	247
	3.24	3.46	3.41	0.62	2.82	246
	3.34	3.57	3.51	0.58	2.82	245
	3.44	3.67	3.61	0.53	2.79	244
	3.58	3.81	3.75	0.47	2.79	242
10%	3.10	3.33	3.27	0.72	2.80	248
	3.24	3.46	3.41	0.70	2.95	247
	3.34	3.57	3.51	0.66	2.95	246
	3.44	3.67	3.61	0.62	2.94	245
	3.58	3.81	3.75	0.56	2.91	243
	3.68	3.91	3.85	0.52	3.02	242
5%	3.10	3.33	3.27	0.77	2.71	249
	3.34	3.57	3.51	0.74	3.02	246
	3.44	3.67	3.61	0.70	3.03	246
	3.58	3.81	3.75	0.65	3.03	244
	3.68	3.91	3.85	0.60	3.00	243
	3.78	4.00	3.95	0.55	3.02	243
2%	3.24	3.46	3.41	0.83	2.82	249
	3.44	3.67	3.61	0.80	3.09	246
	3.58	3.81	3.75	0.76	3.12	245
	3.68	3.91	3.85	0.72	3.13	245
	3.78	4.00	3.95	0.67	3.14	244
	3.91	4.13	4.08	0.59	3.14	243
1%	3.24	3.46	3.41	0.88	2.77	250
	3.44	3.67	3.61	0.86	3.07	247
	3.68	3.91	3.85	0.81	3.22	245
	3.78	4.00	3.95	0.76	3.20	244
	3.91	4.13	4.08	0.69	3.16	243
	4.01	4.23	4.17	0.63	3.17	243
0.5%	3.34	3.57	3.51	0.92	2.84	249
	3.58	3.81	3.75	0.90	3.25	247
	3.78	4.00	3.95	0.85	3.33	245
	3.91	4.13	4.08	0.79	3.28	244
	4.01	4.23	4.17	0.73	3.24	243
	4.10	4.33	4.27	0.67	3.22	243
0.1%	3.44	3.67	3.61	1.03	2.91	250
	3.68	3.91	3.85	1.02	3.16	248
	3.78	4.00	3.95	1.01	3.36	247
	3.91	4.13	4.08	0.98	3.46	246
	4.01	4.23	4.17	0.95	3.48	245
	4.10	4.33	4.27	0.90	3.50	244

Mid-Range Future Scenario (MRF5)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.40	3.62	3.57	0.72	3.03	246
	3.50	3.72	3.66	0.68	3.04	245
	3.60	3.83	3.77	0.63	3.03	244
	3.74	3.96	3.91	0.57	3.01	243
	3.84	4.07	4.01	0.52	3.08	242
	3.94	4.17	4.11	0.47	3.03	242
20%	3.50	3.72	3.66	0.79	3.11	246
	3.60	3.83	3.77	0.75	3.13	245
	3.74	3.96	3.91	0.69	3.14	244
	3.84	4.07	4.01	0.64	3.14	243
	3.94	4.17	4.11	0.58	3.13	242
	4.08	4.31	4.25	0.51	3.20	242
10%	3.60	3.83	3.77	0.83	3.21	246
	3.74	3.96	3.91	0.78	3.21	245
	3.84	4.07	4.01	0.73	3.20	244
	3.94	4.17	4.11	0.68	3.18	243
	4.08	4.31	4.25	0.60	3.29	242
	4.18	4.41	4.35	0.55	3.29	242
5%	3.60	3.83	3.77	0.90	3.27	247
	3.84	4.07	4.01	0.82	3.33	245
	3.94	4.17	4.11	0.77	3.28	244
	4.08	4.31	4.25	0.70	3.22	243
	4.18	4.41	4.35	0.64	3.27	242
	4.28	4.50	4.45	0.59	3.32	242
2%	3.74	3.96	3.91	0.96	3.37	247
	3.94	4.17	4.11	0.90	3.44	245
	4.08	4.31	4.25	0.83	3.43	244
	4.18	4.41	4.35	0.78	3.38	243
	4.28	4.50	4.45	0.72	3.35	243
	4.41	4.63	4.58	0.64	3.33	242
1%	3.74	3.96	3.91	1.02	3.30	247
	3.94	4.17	4.11	0.98	3.47	246
	4.18	4.41	4.35	0.88	3.51	244
	4.28	4.50	4.45	0.82	3.50	243
	4.41	4.63	4.58	0.74	3.40	243
	4.51	4.73	4.67	0.68	3.38	242
0.5%	3.84	4.07	4.01	1.06	3.35	247
	4.08	4.31	4.25	1.01	3.54	245
	4.28	4.50	4.45	0.92	3.55	244
	4.41	4.63	4.58	0.84	3.54	243
	4.51	4.73	4.67	0.78	3.54	243
	4.60	4.83	4.77	0.72	3.50	242
0.1%	3.94	4.17	4.11	1.18	3.24	249
	4.18	4.41	4.35	1.16	3.67	246
	4.28	4.50	4.45	1.13	3.73	245
	4.41	4.63	4.58	1.08	3.73	244
	4.51	4.73	4.67	1.03	3.69	244
	4.60	4.83	4.77	0.97	3.66	243

High End Future Scenario (HEFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.90	4.12	4.07	0.80	3.31	244
	4.00	4.22	4.16	0.74	3.25	244
	4.10	4.33	4.27	0.69	3.23	243
	4.24	4.46	4.41	0.61	3.32	242
	4.34	4.57	4.51	0.55	3.30	242
	4.44	4.67	4.61	0.53	3.32	241
20%	4.00	4.22	4.16	0.87	3.44	245
	4.10	4.33	4.27	0.82	3.44	244
	4.24	4.46	4.41	0.74	3.33	243
	4.34	4.57	4.51	0.68	3.32	242
	4.44	4.67	4.61	0.62	3.35	242
	4.58	4.81	4.75	0.54	3.33	241
10%	4.10	4.33	4.27	0.92	3.50	245
	4.24	4.46	4.41	0.85	3.52	244
	4.34	4.57	4.51	0.79	3.46	243
	4.44	4.67	4.61	0.73	3.43	242
	4.58	4.81	4.75	0.64	3.37	242
	4.68	4.91	4.85	0.58	3.37	242
5%	4.10	4.33	4.27	1.00	3.54	245
	4.34	4.57	4.51	0.89	3.57	244
	4.44	4.67	4.61	0.83	3.56	243
	4.58	4.81	4.75	0.75	3.52	242
	4.68	4.91	4.85	0.68	3.46	242
	4.78	5.00	4.95	0.62	3.40	242
2%	4.24	4.46	4.41	1.07	3.65	245
	4.44	4.67	4.61	0.97	3.63	244
	4.58	4.81	4.75	0.89	3.63	243
	4.68	4.91	4.85	0.82	3.64	243
	4.78	5.00	4.95	0.76	3.65	242
	4.91	5.13	5.08	0.67	3.47	242
1%	4.24	4.46	4.41	1.15	3.71	246
	4.44	4.67	4.61	1.07	3.73	244
	4.68	4.91	4.85	0.94	3.67	243
	4.78	5.00	4.95	0.87	3.68	243
	4.91	5.13	5.08	0.78	3.68	242
	5.01	5.23	5.17	0.71	3.62	242
0.5%	4.34	4.57	4.51	1.19	3.78	246
	4.58	4.81	4.75	1.10	3.81	244
	4.78	5.00	4.95	0.98	3.72	243
	4.91	5.13	5.08	0.89	3.69	243
	5.01	5.23	5.17	0.82	3.70	242
	5.10	5.33	5.27	0.75	3.69	242
0.1%	4.44	4.67	4.61	1.33	3.77	247
	4.68	4.91	4.85	1.28	3.93	245
	4.78	5.00	4.95	1.23	3.94	244
	4.91	5.13	5.08	1.15	3.93	244
	5.01	5.23	5.17	1.09	3.89	243
	5.10	5.33	5.27	1.02	3.82	243

High+ End Future Scenario (H+EFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	4.40	4.62	4.57	0.86	3.58	243
	4.50	4.72	4.66	0.79	3.56	243
	4.60	4.83	4.77	0.73	3.54	242
	4.74	4.96	4.91	0.65	3.40	242
	4.84	5.07	5.01	0.58	3.36	242
	4.94	5.17	5.11	0.53	3.34	241
20%	4.50	4.72	4.66	0.94	3.63	244
	4.60	4.83	4.77	0.87	3.65	243
	4.74	4.96	4.91	0.79	3.67	242
	4.84	5.07	5.01	0.72	3.62	242
	4.94	5.17	5.11	0.66	3.53	242
	5.08	5.31	5.25	0.56	3.36	242
10%	4.60	4.83	4.77	0.98	3.68	244
	4.74	4.96	4.91	0.90	3.69	243
	4.84	5.07	5.01	0.83	3.68	242

Table 9-4: Shoreline Wave Climate and Water Level Combinations – Location C

Irish Coastal Wave & Water Level Modelling Study (ICWWS) 2018	
Coastal Areas Potentially Vulnerable to Wave Overtopping (CAPO)	
Output: Shoreline Wave Climate and Water Level Combinations	
Location: Bunratty_Location C	
Bed Level: -0.13m MSL	
Bed Level (OD Malin OSGM02): 0.094m	
Bed Level (OD Malin OSGM15): 0.036m	
Dated: October 2020	
Joint Probability Event (AEP): Varies from 50% to 0.1%	
Prepared By: CN	Checked By: MB
Table Reference: ICWWS_CAPO_Shn_Bunratty	

Notes:	
1	Users of this information should refer to the ICWWS 2018 Phase 3 Bunratty Technical Report for a detailed description of the derivation of the data and it's applicability
2	Bed Level taken at approximately half the shallow water wavelength from structure / shoreline
3	Bed level source: OPW LiDAR data (2012)
4	AEP denotes the combined wave and water level joint Annual Exceedance Probability
5	Wind Wave Component refers to waves generated by the immediate local wind
6	Hm0 denotes the spectral significant wave height in metres
7	Tp denotes the spectral peak wave period in seconds
8	MWD denotes the mean wave direction in degrees north

Present Day Scenario Water Level						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	2.90	3.12	3.07	0.46	2.00	280
	3.00	3.22	3.16	0.42	1.93	281
	3.10	3.33	3.27	0.38	1.87	282
	3.24	3.46	3.41	0.33	1.80	282
	3.34	3.57	3.51	0.30	1.75	282
	3.44	3.67	3.61	0.26	1.67	283
20%	3.00	3.22	3.16	0.50	2.01	281
	3.10	3.33	3.27	0.46	1.96	282
	3.24	3.46	3.41	0.41	1.90	283
	3.34	3.57	3.51	0.37	1.85	283
	3.44	3.67	3.61	0.33	1.78	284
	3.58	3.81	3.75	0.27	1.69	284
10%	3.10	3.33	3.27	0.53	2.05	281
	3.24	3.46	3.41	0.48	1.99	282
	3.34	3.57	3.51	0.44	1.95	283
	3.44	3.67	3.61	0.40	1.89	283
	3.58	3.81	3.75	0.34	1.78	284
	3.68	3.91	3.85	0.29	1.65	284
5%	3.10	3.33	3.27	0.59	2.14	281
	3.34	3.57	3.51	0.50	2.03	282
	3.44	3.67	3.61	0.46	1.99	283
	3.58	3.81	3.75	0.41	1.91	283
	3.68	3.91	3.85	0.36	1.81	284
	3.78	4.00	3.95	0.33	1.78	284
2%	3.24	3.46	3.41	0.63	2.20	281
	3.44	3.67	3.61	0.55	2.11	282
	3.58	3.81	3.75	0.50	2.04	283
	3.68	3.91	3.85	0.46	1.98	283
	3.78	4.00	3.95	0.41	1.91	283
	3.91	4.13	4.08	0.35	1.78	284
1%	3.24	3.46	3.41	0.70	2.29	280
	3.44	3.67	3.61	0.62	2.20	281
	3.68	3.91	3.85	0.53	2.09	283
	3.78	4.00	3.95	0.48	2.03	283
	3.91	4.13	4.08	0.42	1.91	283
	4.01	4.23	4.17	0.38	1.83	283
0.5%	3.34	3.57	3.51	0.73	2.33	280
	3.58	3.81	3.75	0.64	2.22	282
	3.78	4.00	3.95	0.56	2.13	283
	3.91	4.13	4.08	0.50	2.05	283
	4.01	4.23	4.17	0.45	1.97	283
	4.10	4.33	4.27	0.40	1.90	283
0.1%	3.44	3.67	3.61	0.86	2.47	280
	3.68	3.91	3.85	0.77	2.39	281
	3.78	4.00	3.95	0.73	2.35	282
	3.91	4.13	4.08	0.67	2.28	282
	4.01	4.23	4.17	0.62	2.22	283
	4.10	4.33	4.27	0.58	2.17	283

Mid-Range Future Scenario (MRFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.40	3.62	3.57	0.48	2.00	282
	3.50	3.72	3.66	0.44	1.95	283
	3.60	3.83	3.77	0.40	1.89	283
	3.74	3.96	3.91	0.33	1.75	284
	3.84	4.07	4.01	0.30	1.65	284
	3.94	4.17	4.11	0.26	1.55	283
20%	3.50	3.72	3.66	0.53	2.08	282
	3.60	3.83	3.77	0.49	2.02	283
	3.74	3.96	3.91	0.43	1.94	283
	3.84	4.07	4.01	0.38	1.87	284
	3.94	4.17	4.11	0.34	1.76	283
	4.08	4.31	4.25	0.28	1.63	283
10%	3.60	3.83	3.77	0.56	2.13	282
	3.74	3.96	3.91	0.50	2.05	283
	3.84	4.07	4.01	0.46	1.99	283
	3.94	4.17	4.11	0.41	1.91	283
	4.08	4.31	4.25	0.35	1.78	283
	4.18	4.41	4.35	0.30	1.69	283
5%	3.60	3.83	3.77	0.63	2.21	282
	3.84	4.07	4.01	0.53	2.10	283
	3.94	4.17	4.11	0.48	2.03	283
	4.08	4.31	4.25	0.42	1.92	283
	4.18	4.41	4.35	0.37	1.84	283
	4.28	4.50	4.45	0.33	1.75	283
2%	3.74	3.96	3.91	0.67	2.27	282
	3.94	4.17	4.11	0.58	2.17	283
	4.08	4.31	4.25	0.52	2.10	283
	4.18	4.41	4.35	0.47	2.01	283
	4.28	4.50	4.45	0.43	1.94	283
	4.41	4.63	4.58	0.36	1.84	283
1%	3.74	3.96	3.91	0.76	2.42	280
	3.94	4.17	4.11	0.67	2.31	281
	4.18	4.41	4.35	0.56	2.16	282
	4.28	4.50	4.45	0.51	2.07	282
	4.41	4.63	4.58	0.44	1.97	283
	4.51	4.73	4.67	0.39	1.90	282
0.5%	3.84	4.07	4.01	0.78	2.41	281
	4.08	4.31	4.25	0.67	2.29	282
	4.28	4.50	4.45	0.58	2.18	283
	4.41	4.63	4.58	0.51	2.09	283
	4.51	4.73	4.67	0.47	2.01	283
	4.60	4.83	4.77	0.42	1.95	283
0.1%	3.94	4.17	4.11	0.92	2.56	281
	4.18	4.41	4.35	0.81	2.46	282
	4.28	4.50	4.45	0.76	2.41	282
	4.41	4.63	4.58	0.70	2.34	283
	4.51	4.73	4.67	0.65	2.27	283
	4.60	4.83	4.77	0.60	2.21	283

High End Future Scenario (HEFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.90	4.12	4.07	0.50	2.04	283
	4.00	4.22	4.16	0.46	1.97	283
	4.10	4.33	4.27	0.41	1.90	283
	4.24	4.46	4.41	0.35	1.79	283
	4.34	4.57	4.51	0.30	1.70	283
	4.44	4.67	4.61	0.27	1.70	283
20%	4.00	4.22	4.16	0.56	2.14	283
	4.10	4.33	4.27	0.51	2.07	283
	4.24	4.46	4.41	0.45	1.97	283
	4.34	4.57	4.51	0.40	1.89	283
	4.44	4.67	4.61	0.35	1.83	283
	4.58	4.81	4.75	0.29	1.72	283
10%	4.10	4.33	4.27	0.58	2.17	283
	4.24	4.46	4.41	0.52	2.09	283
	4.34	4.57	4.51	0.48	2.01	283
	4.44	4.67	4.61	0.43	1.95	283
	4.58	4.81	4.75	0.36	1.85	283
	4.68	4.91	4.85	0.32	1.78	283
5%	4.10	4.33	4.27	0.66	2.27	282
	4.34	4.57	4.51	0.55	2.14	283
	4.44	4.67	4.61	0.50	2.07	283
	4.58	4.81	4.75	0.44	1.97	283
	4.68	4.91	4.85	0.39	1.90	283
	4.78	5.00	4.95	0.34	1.82	283
2%	4.24	4.46	4.41	0.70	2.33	282
	4.44	4.67	4.61	0.60	2.21	283
	4.58	4.81	4.75	0.54	2.14	283
	4.68	4.91	4.85	0.49	2.06	283
	4.78	5.00	4.95	0.44	1.98	283
	4.91	5.13	5.08	0.37	1.87	283
1%	4.24	4.46	4.41	0.79	2.43	282
	4.44	4.67	4.61	0.69	2.32	283
	4.68	4.91	4.85	0.57	2.18	283
	4.78	5.00	4.95	0.52	2.11	283
	4.91	5.13	5.08	0.45	2.00	283
	5.01	5.23	5.17	0.40	1.92	283
0.5%	4.34	4.57	4.51	0.82	2.47	282
	4.58	4.81	4.75	0.70	2.35	283
	4.78	5.00	4.95	0.60	2.22	283
	4.91	5.13	5.08	0.53	2.13	283
	5.01	5.23	5.17	0.48	2.05	283
	5.10	5.33	5.27	0.43	1.97	283
0.1%	4.44	4.67	4.61	0.97	2.63	282
	4.68	4.91	4.85	0.85	2.51	282
	4.78	5.00	4.95	0.79	2.46	283
	4.91	5.13	5.08	0.72	2.39	283
	5.01	5.23	5.17	0.67	2.32	283
	5.10	5.33	5.27	0.62	2.25	283

AEP	High+ End Future Scenario (H+EFS)					
	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	4.40	4.62	4.57	0.52	2.11	283
	4.50	4.72	4.66	0.48	2.04	283
	4.60	4.83	4.77	0.43	1.96	283
	4.74	4.96	4.91	0.36	1.85	283
	4.84	5.07	5.01	0.32	1.79	283
	4.94	5.17	5.11	0.27	1.68	283
20%	4.50	4.72	4.66	0.58	2.18	283
	4.60	4.83	4.77	0.53	2.12	283
	4.74	4.96	4.91	0.46	2.02	283
	4.84	5.07	5.01	0.41	1.94	283
	4.94	5.17	5.11	0.36	1.85	283
	5.08	5.31	5.25	0.30	1.72	283
10%	4.60	4.83	4.77	0.61	2.23	283
	4.74	4.96	4.91	0.54	2.14	283
	4.84	5.07	5.01	0.49	2.07	283
	4.94	5.17	5.11	0.44	1.98	283
	5.08	5.31	5.25	0.37	1.86	283
	5.18	5.41	5.35	0.32	1.78	283
5%	4.60	4.83	4.77	0.69	2.35	283
	4.84	5.07	5.01	0.57	2.19	283
	4.94	5.17	5.11	0.52	2.12	283
	5.08	5.31	5.25	0.45	2.00	283
	5.18	5.41	5.35	0.40	1.92	283
	5.28	5.50	5.45	0.35	1.82	283
2%	4.74	4.96	4.91	0.73	2.39	283
	4.94	5.17	5.11	0.63	2.26	283
	5.08	5.31	5.25	0.56	2.17	283
	5.18	5.41	5.35	0.50	2.09	283
	5.28	5.50	5.45	0.45	2.01	283
	5.41	5.63	5.58	0.38	1.87	283
1%	4.74	4.96	4.91	0.82	2.48	283
	4.94	5.17	5.11	0.71	2.38	283
	5.18	5.41	5.35	0.59	2.21	283
	5.28	5.50	5.45	0.53	2.14	283
	5.41	5.63	5.58	0.46	2.02	283
	5.51	5.73	5.67	0.40	1.93	283
0.5%	4.84	5.07	5.01	0.85	2.52	283
	5.08	5.31	5.25	0.72	2.40	283
	5.28	5.50	5.45	0.62	2.26	283
	5.41	5.63	5.58	0.54	2.16	283
	5.51	5.73	5.67	0.49	2.07	283
	5.60	5.83	5.77	0.43	1.97	283
0.1%	4.94	5.17	5.11	1.01	2.69	282
	5.18	5.41	5.35	0.88	2.57	283
	5.28	5.50	5.45	0.82	2.50	283
	5.41	5.63	5.58	0.74	2.42	283
	5.51	5.73	5.67	0.68	2.36	283
	5.60	5.83	5.77	0.63	2.28	283

Table 9-5: Shoreline Wave Climate and Water Level Combinations – Location D

Irish Coastal Wave & Water Level Modelling Study (ICWWS) 2018	
Coastal Areas Potentially Vulnerable to Wave Overtopping (CAPO)	
Output: Shoreline Wave Climate and Water Level Combinations	
Location: Bunratty_Location D	
Bed Level: 1.63m MSL	
Bed Level (OD Malin OSGM02): 1.854m	
Bed Level (OD Malin OSGM15): 1.796m	
Dated: October 2020	
Joint Probability Event (AEP): Varies from 50% to 0.1%	
Prepared By: CN	Checked By: MB
Table Reference: ICWWS_CAPO_Shn_Bunratty	

Notes:	
1	Users of this information should refer to the ICWWS 2018 Phase 3 Bunratty Technical Report for a detailed description of the derivation of the data and it's applicability
2	Bed Level taken at approximately half the shallow water wavelength from structure / shoreline
3	Bed level source: OPW LiDAR data (2012)
4	AEP denotes the combined wave and water level joint Annual Exceedance Probability
5	Wind Wave Component refers to waves generated by the immediate local wind
6	Hm0 denotes the spectral significant wave height in metres
7	Tp denotes the spectral peak wave period in seconds
8	MWD denotes the mean wave direction in degrees north

Present Day Scenario Water Level						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	2.90	3.12	3.07	0.52	2.43	228
	3.00	3.22	3.16	0.52	2.44	229
	3.10	3.33	3.27	0.49	2.31	230
	3.24	3.46	3.41	0.43	2.44	232
	3.34	3.57	3.51	0.38	1.90	234
	3.44	3.67	3.61	0.33	1.84	235
20%	3.00	3.22	3.16	0.57	2.48	230
	3.10	3.33	3.27	0.57	2.47	230
	3.24	3.46	3.41	0.54	2.32	230
	3.34	3.57	3.51	0.50	2.22	232
	3.44	3.67	3.61	0.44	1.97	234
	3.58	3.81	3.75	0.37	1.81	235
10%	3.10	3.33	3.27	0.61	2.53	231
	3.24	3.46	3.41	0.61	2.48	231
	3.34	3.57	3.51	0.58	2.35	231
	3.44	3.67	3.61	0.53	2.18	233
	3.58	3.81	3.75	0.45	1.99	235
	3.68	3.91	3.85	0.41	2.60	234
5%	3.10	3.33	3.27	0.64	2.53	233
	3.34	3.57	3.51	0.65	2.51	231
	3.44	3.67	3.61	0.62	2.41	232
	3.58	3.81	3.75	0.55	2.19	234
	3.68	3.91	3.85	0.49	2.04	235
	3.78	4.00	3.95	0.43	1.96	235
2%	3.24	3.46	3.41	0.70	2.60	233
	3.44	3.67	3.61	0.71	2.60	231
	3.58	3.81	3.75	0.67	2.45	233
	3.68	3.91	3.85	0.61	2.29	234
	3.78	4.00	3.95	0.55	2.17	235
	3.91	4.13	4.08	0.47	2.01	236
1%	3.24	3.46	3.41	0.72	2.56	236
	3.44	3.67	3.61	0.75	2.69	232
	3.68	3.91	3.85	0.70	2.49	233
	3.78	4.00	3.95	0.65	2.35	234
	3.91	4.13	4.08	0.57	2.20	235
	4.01	4.23	4.17	0.51	2.08	235
0.5%	3.34	3.57	3.51	0.77	2.61	236
	3.58	3.81	3.75	0.80	2.73	233
	3.78	4.00	3.95	0.74	2.53	233
	3.91	4.13	4.08	0.67	2.36	235
	4.01	4.23	4.17	0.60	2.24	235
	4.10	4.33	4.27	0.54	2.14	236
0.1%	3.44	3.67	3.61	0.85	2.62	239
	3.68	3.91	3.85	0.89	2.78	235
	3.78	4.00	3.95	0.89	2.81	234
	3.91	4.13	4.08	0.88	2.76	234
	4.01	4.23	4.17	0.83	2.65	234
	4.10	4.33	4.27	0.77	2.51	235

Mid-Range Future Scenario (MRFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.40	3.62	3.57	0.64	2.45	232
	3.50	3.72	3.66	0.59	2.29	233
	3.60	3.83	3.77	0.53	2.16	234
	3.74	3.96	3.91	0.45	1.98	235
	3.84	4.07	4.01	0.39	1.88	236
	3.94	4.17	4.11	0.34	1.77	237
20%	3.50	3.72	3.66	0.69	2.54	232
	3.60	3.83	3.77	0.65	2.41	233
	3.74	3.96	3.91	0.58	2.22	235
	3.84	4.07	4.01	0.52	2.13	235
	3.94	4.17	4.11	0.46	2.00	235
	4.08	4.31	4.25	0.37	1.84	237
10%	3.60	3.83	3.77	0.73	2.59	232
	3.74	3.96	3.91	0.67	2.41	234
	3.84	4.07	4.01	0.61	2.27	235
	3.94	4.17	4.11	0.56	2.18	235
	4.08	4.31	4.25	0.47	2.00	237
	4.18	4.41	4.35	0.41	1.92	237
5%	3.60	3.83	3.77	0.79	2.72	233
	3.84	4.07	4.01	0.71	2.45	234
	3.94	4.17	4.11	0.65	2.32	235
	4.08	4.31	4.25	0.57	2.18	236
	4.18	4.41	4.35	0.50	2.06	236
	4.28	4.50	4.45	0.43	1.97	237
2%	3.74	3.96	3.91	0.85	2.77	233
	3.94	4.17	4.11	0.78	2.56	234
	4.08	4.31	4.25	0.70	2.40	235
	4.18	4.41	4.35	0.64	2.28	236
	4.28	4.50	4.45	0.57	2.19	237
	4.41	4.63	4.58	0.48	2.04	237
1%	3.74	3.96	3.91	0.90	2.80	234
	3.94	4.17	4.11	0.87	2.74	234
	4.18	4.41	4.35	0.73	2.45	235
	4.28	4.50	4.45	0.67	2.33	236
	4.41	4.63	4.58	0.58	2.21	237
	4.51	4.73	4.67	0.51	2.11	237
0.5%	3.84	4.07	4.01	0.94	2.84	235
	4.08	4.31	4.25	0.90	2.74	234
	4.28	4.50	4.45	0.77	2.50	236
	4.41	4.63	4.58	0.68	2.35	236
	4.51	4.73	4.67	0.62	2.25	237
	4.60	4.83	4.77	0.55	2.17	237
0.1%	3.94	4.17	4.11	1.03	2.88	237
	4.18	4.41	4.35	1.03	2.92	235
	4.28	4.50	4.45	1.00	2.86	235
	4.41	4.63	4.58	0.93	2.73	235
	4.51	4.73	4.67	0.86	2.60	236
	4.60	4.83	4.77	0.79	2.50	236

High End Future Scenario (HEFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.90	4.12	4.07	0.68	2.38	235
	4.00	4.22	4.16	0.62	2.26	235
	4.10	4.33	4.27	0.55	2.17	236
	4.24	4.46	4.41	0.46	2.00	237
	4.34	4.57	4.51	0.40	1.91	237
	4.44	4.67	4.61	0.35	1.91	237
20%	4.00	4.22	4.16	0.75	2.49	235
	4.10	4.33	4.27	0.68	2.36	236
	4.24	4.46	4.41	0.60	2.23	236
	4.34	4.57	4.51	0.53	2.13	237
	4.44	4.67	4.61	0.46	2.02	237
	4.58	4.81	4.75	0.38	1.90	237
10%	4.10	4.33	4.27	0.78	2.54	235
	4.24	4.46	4.41	0.70	2.38	236
	4.34	4.57	4.51	0.63	2.27	236
	4.44	4.67	4.61	0.56	2.18	237
	4.58	4.81	4.75	0.47	2.03	238
	4.68	4.91	4.85	0.41	1.96	237
5%	4.10	4.33	4.27	0.88	2.72	235
	4.34	4.57	4.51	0.73	2.44	236
	4.44	4.67	4.61	0.67	2.32	237
	4.58	4.81	4.75	0.58	2.20	237
	4.68	4.91	4.85	0.51	2.11	237
	4.78	5.00	4.95	0.44	2.00	238
2%	4.24	4.46	4.41	0.94	2.77	235
	4.44	4.67	4.61	0.81	2.53	236
	4.58	4.81	4.75	0.71	2.40	237
	4.68	4.91	4.85	0.65	2.29	237
	4.78	5.00	4.95	0.58	2.21	237
	4.91	5.13	5.08	0.48	2.06	238
1%	4.24	4.46	4.41	1.02	2.89	235
	4.44	4.67	4.61	0.92	2.70	236
	4.68	4.91	4.85	0.75	2.45	237
	4.78	5.00	4.95	0.68	2.35	237
	4.91	5.13	5.08	0.59	2.23	238
	5.01	5.23	5.17	0.51	2.13	238
0.5%	4.34	4.57	4.51	1.06	2.94	235
	4.58	4.81	4.75	0.93	2.71	236
	4.78	5.00	4.95	0.79	2.49	237
	4.91	5.13	5.08	0.69	2.38	237
	5.01	5.23	5.17	0.62	2.27	238
	5.10	5.33	5.27	0.55	2.19	238
0.1%	4.44	4.67	4.61	1.19	3.07	236
	4.68	4.91	4.85	1.12	2.95	236
	4.78	5.00	4.95	1.05	2.85	236
	4.91	5.13	5.08	0.95	2.72	237
	5.01	5.23	5.17	0.88	2.60	237
	5.10	5.33	5.27	0.80	2.51	237

AEP	High+ End Future Scenario (H+EFS)					
	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	4.40	4.62	4.57	0.69	2.37	236
	4.50	4.72	4.66	0.63	2.26	237
	4.60	4.83	4.77	0.56	2.19	237
	4.74	4.96	4.91	0.47	2.03	238
	4.84	5.07	5.01	0.40	1.94	238
	4.94	5.17	5.11	0.35	1.83	238
20%	4.50	4.72	4.66	0.76	2.47	236
	4.60	4.83	4.77	0.70	2.37	237
	4.74	4.96	4.91	0.60	2.24	237
	4.84	5.07	5.01	0.53	2.16	237
	4.94	5.17	5.11	0.47	2.05	238
	5.08	5.31	5.25	0.38	1.91	238
10%	4.60	4.83	4.77	0.80	2.52	236
	4.74	4.96	4.91	0.71	2.40	237
	4.84	5.07	5.01	0.64	2.29	238
	4.94	5.17	5.11	0.57	2.21	238
	5.08	5.31	5.25	0.48	2.06	238
	5.18	5.41	5.35	0.42	1.98	238
5%	4.60	4.83	4.77	0.92	2.68	236
	4.84	5.07	5.01	0.74	2.45	237
	4.94	5.17	5.11	0.67	2.35	238
	5.08	5.31	5.25	0.58	2.23	238
	5.18	5.41	5.35	0.51	2.14	238
	5.28	5.50	5.45	0.45	2.03	238
2%	4.74	4.96	4.91	0.97	2.75	236
	4.94	5.17	5.11	0.82	2.53	237
	5.08	5.31	5.25	0.72	2.42	238
	5.18	5.41	5.35	0.65	2.32	238
	5.28	5.50	5.45	0.58	2.23	238
	5.41	5.63	5.58	0.49	2.11	238
1%	4.74	4.96	4.91	1.08	2.89	236
	4.94	5.17	5.11	0.93	2.69	237
	5.18	5.41	5.35	0.76	2.47	238
	5.28	5.50	5.45	0.69	2.38	238
	5.41	5.63	5.58	0.59	2.25	238
	5.51	5.73	5.67	0.52	2.17	238
0.5%	4.84	5.07	5.01	1.13	2.94	236
	5.08	5.31	5.25	0.95	2.71	237
	5.28	5.50	5.45	0.80	2.51	238
	5.41	5.63	5.58	0.70	2.41	238
	5.51	5.73	5.67	0.63	2.30	238
	5.60	5.83	5.77	0.56	2.22	238
0.1%	4.94	5.17	5.11	1.30	3.14	237
	5.18	5.41	5.35	1.16	2.95	237
	5.28	5.50	5.45	1.07	2.84	237
	5.41	5.63	5.58	0.97	2.73	238
	5.51	5.73	5.67	0.89	2.63	238
	5.60	5.83	5.77	0.81	2.53	238

Table 9-6: Shoreline Wave Climate and Water Level Combinations – Location E

Irish Coastal Wave & Water Level Modelling Study (ICWWS) 2018	
Coastal Areas Potentially Vulnerable to Wave Overtopping (CAPO)	
Output: Shoreline Wave Climate and Water Level Combinations	
Location: Bunratty_Location E	
Bed Level: 1.92m MSL	
Bed Level (OD Malin OSGM02): 2.144m	
Bed Level (OD Malin OSGM15): 2.086m	
Dated: October 2020	
Joint Probability Event (AEP): Varies from 50% to 0.1%	
Prepared By: CN	Checked By: MB
Table Reference: ICWWS_CAPO_Shn_Bunratty	

Notes:	
1	Users of this information should refer to the ICWWS 2018 Phase 3 Bunratty Technical Report for a detailed description of the derivation of the data and it's applicability
2	Bed Level taken at approximately half the shallow water wavelength from structure / shoreline
3	Bed level source: OPW LiDAR data (2012)
4	AEP denotes the combined wave and water level joint Annual Exceedance Probability
5	Wind Wave Component refers to waves generated by the immediate local wind
6	Hm0 denotes the spectral significant wave height in metres
7	Tp denotes the spectral peak wave period in seconds
8	MWD denotes the mean wave direction in degrees north

Present Day Scenario Water Level						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	2.90	3.12	3.07	0.42	1.93	257
	3.00	3.22	3.16	0.42	1.93	255
	3.10	3.33	3.27	0.40	1.90	254
	3.24	3.46	3.41	0.35	1.80	253
	3.34	3.57	3.51	0.31	1.74	253
	3.44	3.67	3.61	0.27	1.68	252
20%	3.00	3.22	3.16	0.47	2.01	257
	3.10	3.33	3.27	0.47	2.02	256
	3.24	3.46	3.41	0.44	1.97	254
	3.34	3.57	3.51	0.40	1.92	253
	3.44	3.67	3.61	0.35	1.84	253
	3.58	3.81	3.75	0.30	1.74	253
10%	3.10	3.33	3.27	0.51	2.08	257
	3.24	3.46	3.41	0.50	2.08	255
	3.34	3.57	3.51	0.47	2.03	254
	3.44	3.67	3.61	0.43	1.96	254
	3.58	3.81	3.75	0.37	1.89	253
	3.68	3.91	3.85	0.33	1.86	253
5%	3.10	3.33	3.27	0.54	2.12	258
	3.34	3.57	3.51	0.53	2.13	255
	3.44	3.67	3.61	0.50	2.09	254
	3.58	3.81	3.75	0.44	1.99	253
	3.68	3.91	3.85	0.39	1.93	253
	3.78	4.00	3.95	0.35	1.88	253
2%	3.24	3.46	3.41	0.59	2.19	258
	3.44	3.67	3.61	0.58	2.20	255
	3.58	3.81	3.75	0.54	2.15	254
	3.68	3.91	3.85	0.49	2.09	254
	3.78	4.00	3.95	0.45	2.02	253
	3.91	4.13	4.08	0.39	1.93	253
1%	3.24	3.46	3.41	0.62	2.22	259
	3.44	3.67	3.61	0.63	2.27	256
	3.68	3.91	3.85	0.57	2.19	254
	3.78	4.00	3.95	0.52	2.14	254
	3.91	4.13	4.08	0.46	2.05	253
	4.01	4.23	4.17	0.41	1.98	253
0.5%	3.34	3.57	3.51	0.66	2.30	258
	3.58	3.81	3.75	0.66	2.33	255
	3.78	4.00	3.95	0.60	2.24	254
	3.91	4.13	4.08	0.54	2.16	254
	4.01	4.23	4.17	0.49	2.11	253
	4.10	4.33	4.27	0.44	2.03	253
0.1%	3.44	3.67	3.61	0.74	2.38	259
	3.68	3.91	3.85	0.76	2.44	257
	3.78	4.00	3.95	0.75	2.44	256
	3.91	4.13	4.08	0.72	2.41	255
	4.01	4.23	4.17	0.67	2.36	254
	4.10	4.33	4.27	0.62	2.30	254

Mid-Range Future Scenario (MRFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.40	3.62	3.57	0.51	2.11	254
	3.50	3.72	3.66	0.47	2.05	254
	3.60	3.83	3.77	0.43	1.98	253
	3.74	3.96	3.91	0.37	1.90	253
	3.84	4.07	4.01	0.33	1.81	252
	3.94	4.17	4.11	0.28	1.73	252
20%	3.50	3.72	3.66	0.56	2.18	255
	3.60	3.83	3.77	0.53	2.14	254
	3.74	3.96	3.91	0.47	2.06	253
	3.84	4.07	4.01	0.42	1.99	253
	3.94	4.17	4.11	0.37	1.92	253
	4.08	4.31	4.25	0.32	1.80	252
10%	3.60	3.83	3.77	0.60	2.23	255
	3.74	3.96	3.91	0.54	2.17	254
	3.84	4.07	4.01	0.50	2.11	254
	3.94	4.17	4.11	0.45	2.04	253
	4.08	4.31	4.25	0.39	1.94	253
	4.18	4.41	4.35	0.34	1.86	252
5%	3.60	3.83	3.77	0.66	2.32	255
	3.84	4.07	4.01	0.57	2.20	254
	3.94	4.17	4.11	0.53	2.15	254
	4.08	4.31	4.25	0.46	2.06	253
	4.18	4.41	4.35	0.41	1.98	253
	4.28	4.50	4.45	0.37	1.92	252
2%	3.74	3.96	3.91	0.71	2.39	255
	3.94	4.17	4.11	0.63	2.29	254
	4.08	4.31	4.25	0.57	2.21	254
	4.18	4.41	4.35	0.52	2.15	253
	4.28	4.50	4.45	0.47	2.10	253
	4.41	4.63	4.58	0.40	1.97	252
1%	3.74	3.96	3.91	0.76	2.44	256
	3.94	4.17	4.11	0.71	2.40	254
	4.18	4.41	4.35	0.60	2.25	254
	4.28	4.50	4.45	0.55	2.19	253
	4.41	4.63	4.58	0.48	2.12	253
	4.51	4.73	4.67	0.43	2.02	252
0.5%	3.84	4.07	4.01	0.80	2.49	256
	4.08	4.31	4.25	0.73	2.42	254
	4.28	4.50	4.45	0.63	2.31	254
	4.41	4.63	4.58	0.56	2.21	253
	4.51	4.73	4.67	0.51	2.16	253
	4.60	4.83	4.77	0.46	2.09	253
0.1%	3.94	4.17	4.11	0.90	2.61	257
	4.18	4.41	4.35	0.86	2.59	255
	4.28	4.50	4.45	0.82	2.54	254
	4.41	4.63	4.58	0.76	2.46	254
	4.51	4.73	4.67	0.70	2.41	254
	4.60	4.83	4.77	0.65	2.36	253

High End Future Scenario (HEFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.90	4.12	4.07	0.55	2.18	254
	4.00	4.22	4.16	0.50	2.12	253
	4.10	4.33	4.27	0.45	2.05	253
	4.24	4.46	4.41	0.39	1.95	252
	4.34	4.57	4.51	0.34	1.87	252
	4.44	4.67	4.61	0.30	1.88	252
20%	4.00	4.22	4.16	0.60	2.25	254
	4.10	4.33	4.27	0.55	2.19	254
	4.24	4.46	4.41	0.49	2.12	253
	4.34	4.57	4.51	0.44	2.03	253
	4.44	4.67	4.61	0.39	1.96	252
	4.58	4.81	4.75	0.33	1.84	252
10%	4.10	4.33	4.27	0.63	2.31	254
	4.24	4.46	4.41	0.57	2.22	253
	4.34	4.57	4.51	0.52	2.16	253
	4.44	4.67	4.61	0.47	2.10	253
	4.58	4.81	4.75	0.40	1.98	252
	4.68	4.91	4.85	0.35	1.91	252
5%	4.10	4.33	4.27	0.71	2.41	254
	4.34	4.57	4.51	0.60	2.27	253
	4.44	4.67	4.61	0.55	2.20	253
	4.58	4.81	4.75	0.48	2.12	253
	4.68	4.91	4.85	0.43	2.03	252
	4.78	5.00	4.95	0.38	1.95	252
2%	4.24	4.46	4.41	0.76	2.46	254
	4.44	4.67	4.61	0.66	2.36	254
	4.58	4.81	4.75	0.59	2.26	253
	4.68	4.91	4.85	0.54	2.20	253
	4.78	5.00	4.95	0.48	2.14	252
	4.91	5.13	5.08	0.41	2.01	252
1%	4.24	4.46	4.41	0.84	2.56	255
	4.44	4.67	4.61	0.74	2.45	254
	4.68	4.91	4.85	0.62	2.32	253
	4.78	5.00	4.95	0.57	2.24	253
	4.91	5.13	5.08	0.50	2.16	252
	5.01	5.23	5.17	0.44	2.07	252
0.5%	4.34	4.57	4.51	0.88	2.61	255
	4.58	4.81	4.75	0.76	2.47	254
	4.78	5.00	4.95	0.65	2.37	253
	4.91	5.13	5.08	0.58	2.26	253
	5.01	5.23	5.17	0.53	2.20	252
	5.10	5.33	5.27	0.47	2.13	252
0.1%	4.44	4.67	4.61	1.01	2.74	255
	4.68	4.91	4.85	0.92	2.67	254
	4.78	5.00	4.95	0.86	2.61	254
	4.91	5.13	5.08	0.78	2.51	254
	5.01	5.23	5.17	0.72	2.46	253
	5.10	5.33	5.27	0.67	2.40	253

High+ End Future Scenario (H+EFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	4.40	4.62	4.57	0.57	2.23	253
	4.50	4.72	4.66	0.52	2.17	253
	4.60	4.83	4.77	0.47	2.11	253
	4.74	4.96	4.91	0.40	1.98	252
	4.84	5.07	5.01	0.35	1.90	252
	4.94	5.17	5.11	0.30	1.81	251
20%	4.50	4.72	4.66	0.63	2.32	253
	4.60	4.83	4.77	0.58	2.25	253
	4.74	4.96	4.91	0.51	2.17	253
	4.84	5.07	5.01	0.45	2.09	252
	4.94	5.17	5.11	0.40	2.00	252
	5.08	5.31	5.25	0.34	1.87	251
10%	4.60	4.83	4.77	0.66	2.37	254
	4.74	4.96	4.91	0.59	2.27	253
	4.84	5.07	5.01	0.54	2.20	253
	4.94	5.17	5.11	0.48	2.14	252
	5.08	5.31	5.25	0.41	2.01	252
	5.18	5.41	5.35	0.36	1.94	252
5%	4.60	4.83	4.77	0.75	2.46	254
	4.84	5.07	5.01	0.62	2.33	253
	4.94	5.17	5.11	0.57	2.25	253
	5.08	5.31	5.25	0.50	2.16	252
	5.18	5.41	5.35	0.44	2.07	252
	5.28	5.50	5.45	0.39	1.99	252
2%	4.74	4.96	4.91	0.79	2.52	254
	4.94	5.17	5.11	0.68	2.41	253
	5.08	5.31	5.25	0.61	2.33	253
	5.18	5.41	5.35	0.55	2.24	252
	5.28	5.50	5.45	0.50	2.17	252
	5.41	5.63	5.58	0.42	2.04	252
1%	4.74	4.96	4.91	0.88	2.64	254
	4.94	5.17	5.11	0.77	2.50	254
	5.18	5.41	5.35	0.64	2.37	253
	5.28	5.50	5.45	0.58	2.29	252
	5.41	5.63	5.58	0.51	2.19	252
	5.51	5.73	5.67	0.45	2.11	252
0.5%	4.84	5.07	5.01	0.92	2.68	254
	5.08	5.31	5.25	0.79	2.53	253
	5.28	5.50	5.45	0.67	2.41	253
	5.41	5.63	5.58	0.59	2.32	252
	5.51	5.73	5.67	0.54	2.23	252
	5.60	5.83	5.77	0.48	2.16	252
0.1%	4.94	5.17	5.11	1.08	2.83	255
	5.18	5.41	5.35	0.95	2.72	254
	5.28	5.50	5.45	0.89	2.67	254
	5.41	5.63	5.58	0.81	2.57	253
	5.51	5.73	5.67	0.75	2.50	253
	5.60	5.83	5.77	0.69	2.44	253

Table 9-7: Shoreline Wave Climate and Water Level Combinations – Location F

Irish Coastal Wave & Water Level Modelling Study (ICWWS) 2018 Coastal Areas Potentially Vulnerable to Wave Overtopping (CAPO)						
Output: Shoreline Wave Climate and Water Level Combinations						
Location: Bunratty_Location F						
Bed Level: 1.76m MSL						
Bed Level (OD Malin OSGM02): 1.984m						
Bed Level (OD Malin OSGM15): 1.926m						
Dated: October 2020						
Joint Probability Event (AEP): Varies from 50% to 0.1%						
Prepared By: CN				Checked By: MB		
Table Reference: ICWWS_CAPO_Shn_Bunratty						

Notes:						
1	Users of this information should refer to the ICWWS 2018 Phase 3 Bunratty Technical Report for a detailed description of the derivation of the data and it's applicability					
2	Bed Level taken at approximately half the shallow water wavelength from structure / shoreline					
3	Bed level source: OPW LIDAR data (2012)					
4	AEP denotes the combined wave and water level joint Annual Exceedance Probability					
5	Wind Wave Component refers to waves generated by the immediate local wind					
6	Hm0 denotes the spectral significant wave height in metres					
7	Tp denotes the spectral peak wave period in seconds					
8	MWD denotes the mean wave direction in degrees north					

Present Day Scenario Water Level						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	2.90	3.12	3.07	0.50	1.90	246
	3.00	3.22	3.16	0.52	1.97	243
	3.10	3.33	3.27	0.52	2.02	241
	3.24	3.46	3.41	0.48	2.00	240
	3.34	3.57	3.51	0.42	1.84	242
20%	3.44	3.67	3.61	0.37	1.78	243
	3.00	3.22	3.16	0.55	1.98	246
	3.10	3.33	3.27	0.57	2.04	243
	3.24	3.46	3.41	0.58	2.16	241
	3.34	3.57	3.51	0.55	2.10	240
10%	3.44	3.67	3.61	0.49	2.00	242
	3.58	3.81	3.75	0.41	1.84	243
	3.10	3.33	3.27	0.60	2.05	246
	3.24	3.46	3.41	0.62	2.19	243
	3.34	3.57	3.51	0.62	2.24	242
5%	3.44	3.67	3.61	0.59	2.18	242
	3.58	3.81	3.75	0.50	2.01	243
	3.68	3.91	3.85	0.45	1.99	242
	3.78	4.00	3.95	0.49	2.01	242
	3.10	3.33	3.27	0.62	2.06	248
2%	3.34	3.57	3.51	0.67	2.24	244
	3.44	3.67	3.61	0.66	2.28	242
	3.58	3.81	3.75	0.61	2.23	242
	3.68	3.91	3.85	0.54	2.07	242
	3.78	4.00	3.95	0.49	2.01	242
1%	3.24	3.46	3.41	0.68	2.18	248
	3.44	3.67	3.61	0.72	2.30	244
	3.58	3.81	3.75	0.72	2.36	243
	3.68	3.91	3.85	0.68	2.29	242
	3.78	4.00	3.95	0.62	2.22	243
0.50%	3.91	4.13	4.08	0.52	2.04	244
	3.24	3.46	3.41	0.70	2.18	250
	3.44	3.67	3.61	0.75	2.31	246
	3.68	3.91	3.85	0.76	2.46	243
	3.78	4.00	3.95	0.72	2.35	243
0.10%	3.91	4.13	4.08	0.64	2.25	243
	4.01	4.23	4.17	0.57	2.14	243
	3.34	3.57	3.51	0.75	2.23	250
	3.58	3.81	3.75	0.80	2.45	246
	3.78	4.00	3.95	0.80	2.52	244
0.050%	3.91	4.13	4.08	0.74	2.40	243
	4.01	4.23	4.17	0.68	2.29	243
	4.10	4.33	4.27	0.60	2.20	244
	3.44	3.67	3.61	0.82	2.31	253
	3.68	3.91	3.85	0.88	2.48	248
0.010%	3.78	4.00	3.95	0.90	2.54	247
	3.91	4.13	4.08	0.91	2.60	245
	4.01	4.23	4.17	0.90	2.59	244
	4.10	4.33	4.27	0.86	2.55	244

Mid-Range Future Scenario (MRF5)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.40	3.62	3.57	0.67	2.26	243
	3.50	3.72	3.66	0.64	2.26	242
	3.60	3.83	3.77	0.60	2.20	242
	3.74	3.96	3.91	0.50	2.02	244
	3.84	4.07	4.01	0.44	1.91	245
20%	3.94	4.17	4.11	0.37	1.79	245
	3.50	3.72	3.66	0.72	2.33	244
	3.60	3.83	3.77	0.71	2.33	243
	3.74	3.96	3.91	0.64	2.25	243
	3.84	4.07	4.01	0.59	2.19	242
10%	3.94	4.17	4.11	0.51	2.04	243
	4.08	4.31	4.25	0.41	1.87	245
	3.60	3.83	3.77	0.77	2.46	244
	3.74	3.96	3.91	0.74	2.40	243
	3.84	4.07	4.01	0.69	2.29	243
5%	3.94	4.17	4.11	0.62	2.23	243
	4.08	4.31	4.25	0.64	2.24	244
	4.18	4.41	4.35	0.56	2.11	244
	4.28	4.50	4.45	0.48	2.00	246
	3.60	3.83	3.77	0.80	2.46	246
2%	3.84	4.07	4.01	0.78	2.49	243
	3.94	4.17	4.11	0.73	2.35	243
	4.08	4.31	4.25	0.78	2.47	243
	4.18	4.41	4.35	0.64	2.24	244
	4.28	4.50	4.45	0.56	2.11	244
1%	4.41	4.63	4.58	0.48	2.00	246
	3.74	3.96	3.91	0.87	2.52	246
	3.94	4.17	4.11	0.85	2.55	244
	4.08	4.31	4.25	0.78	2.47	243
	4.18	4.41	4.35	0.71	2.32	244
0.50%	4.28	4.50	4.45	0.63	2.23	245
	4.41	4.63	4.58	0.53	2.07	245
	3.84	4.07	4.01	0.94	2.57	248
	4.08	4.31	4.25	0.96	2.71	245
	4.28	4.50	4.45	0.86	2.55	244
0.10%	4.41	4.63	4.58	0.77	2.42	244
	4.51	4.73	4.67	0.69	2.29	245
	4.60	4.83	4.77	0.61	2.22	245
	3.94	4.17	4.11	1.03	2.65	250
	4.18	4.41	4.35	1.07	2.81	247
0.050%	4.28	4.50	4.45	1.06	2.84	246
	4.41	4.63	4.58	1.03	2.80	245
	4.51	4.73	4.67	0.96	2.66	244
	4.60	4.83	4.77	0.89	2.56	245

High End Future Scenario (HEFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	3.90	4.12	4.07	0.75	2.41	243
	4.00	4.22	4.16	0.69	2.29	243
	4.10	4.33	4.27	0.62	2.23	243
	4.24	4.46	4.41	0.51	2.03	245
	4.34	4.57	4.51	0.44	1.94	246
20%	4.44	4.67	4.61	0.38	1.93	245
	4.00	4.22	4.16	0.83	2.53	244
	4.10	4.33	4.27	0.76	2.42	244
	4.24	4.46	4.41	0.67	2.27	244
	4.34	4.57	4.51	0.59	2.18	245
10%	4.44	4.67	4.61	0.52	2.06	245
	4.58	4.81	4.75	0.42	1.93	245
	4.10	4.33	4.27	0.87	2.56	244
	4.24	4.46	4.41	0.78	2.45	244
	4.34	4.57	4.51	0.71	2.31	244
5%	4.44	4.67	4.61	0.63	2.23	245
	4.58	4.81	4.75	0.52	2.06	246
	4.68	4.91	4.85	0.45	1.98	245
	4.10	4.33	4.27	0.95	2.69	245
	4.34	4.57	4.51	0.82	2.50	244
2%	4.44	4.67	4.61	0.75	2.38	245
	4.58	4.81	4.75	0.64	2.25	245
	4.68	4.91	4.85	0.56	2.15	245
	4.78	5.00	4.95	0.49	2.03	245
	4.24	4.46	4.41	1.01	2.79	245
1%	4.44	4.67	4.61	0.90	2.57	244
	4.58	4.81	4.75	0.80	2.47	245
	4.68	4.91	4.85	0.72	2.34	245
	4.78	5.00	4.95	0.64	2.25	245
	4.91	5.13	5.08	0.53	2.09	246
0.50%	4.24	4.46	4.41	1.07	2.83	246
	4.44	4.67	4.61	1.01	2.77	245
	4.68	4.91	4.85	0.84	2.51	245
	4.78	5.00	4.95	0.76	2.41	246
	4.91	5.13	5.08	0.65	2.26	246
0.10%	5.01	5.23	5.17	0.57	2.16	246
	4.34	4.57	4.51	1.12	2.85	247
	4.58	4.81	4.75	1.04	2.79	245
	4.78	5.00	4.95	0.88	2.54	245
	4.91	5.13	5.08	0.77	2.43	246
0.050%	5.01	5.23	5.17	0.69	2.31	246
	5.10	5.33	5.27	0.61	2.22	246
	4.44	4.67	4.61	1.22	2.92	249
	4.68	4.91	4.85	1.21	2.95	246
	4.78	5.00	4.95	1.17	2.89	245
0.010%	4.91	5.13	5.08	1.07	2.80	245
	5.01	5.23	5.17	0.98	2.67	245
	5.10	5.33	5.27	0.90	2.56	246

High+ End Future Scenario (H+EFS)						
AEP	Water Level (m)			Wind Wave Component		
	MSL	OD Malin OSGM02	OD Malin OSGM15	Hm0 (m)	Tp (s)	MWD (°)
50%	4.40	4.62	4.57	0.78	2.44	245
	4.50	4.72	4.66	0.70	2.31	245
	4.60	4.83	4.77	0.63	2.24	245
	4.74	4.96	4.91	0.51	2.05	246
	4.84	5.07	5.01	0.44	1.96	246
20%	4.94	5.17	5.11	0.38	1.85	246
	4.50	4.72	4.66	0.86	2.53	245
	4.60	4.83	4.77	0.78	2.43	245
	4.74	4.96	4.91	0.67	2.28	246
	4.84	5.07	5.01	0.59	2.20	246
10%	4.94	5.17	5.11	0.52	2.08	245
	5.08	5.31	5.25	0.42	1.91	247
	4.60	4.83	4.77	0.90	2.57	245
	4.74	4.96	4.91	0.79	2.45	245
	4.84	5.07	5.01	0.71	2.33	246
5%	4.94	5.17	5.11	0.63	2.25	246
	5.08	5.31	5.25	0.52	2.08</	

REFERENCES

Reference 1: RPS, November 2013 “Irish Coastal Wave and Water Level Modelling Study – Coastal Areas Potentially Vulnerable to Wave Overtopping”

Reference 2: RPS, December 2020, “Irish Coastal Wave and Water Level Modelling Study 2018 – Phase 2 – Coastal Areas Potentially Vulnerable to Wave Overtopping”

Reference 3: RPS, October 2020, “Irish Coastal Wave and Water Level Modelling Study 2018 – Phase 1 – Extreme Water Levels”

Reference 4: Eurocode, BS EN 1991-1-4:2005+A1:2010, “Actions on structures – Part 1-4: General actions – Wind actions”

Reference 5: DEFRA / Environment Agency, March 2005, R&D Technical Report FD2308/TR2, “Use of Joint Probability Methods in Flood Management: A Guide to Best Practice”

Reference 6: RPS, November 2020, “Irish Coastal Wave and Water Level Modelling Study 2018 – Phase 4 – Review of Mean Sea Level and OD Malin Head Relationship at Irish Gauge Locations”

Appendix A

Extreme Value Analysis of Offshore Wind data

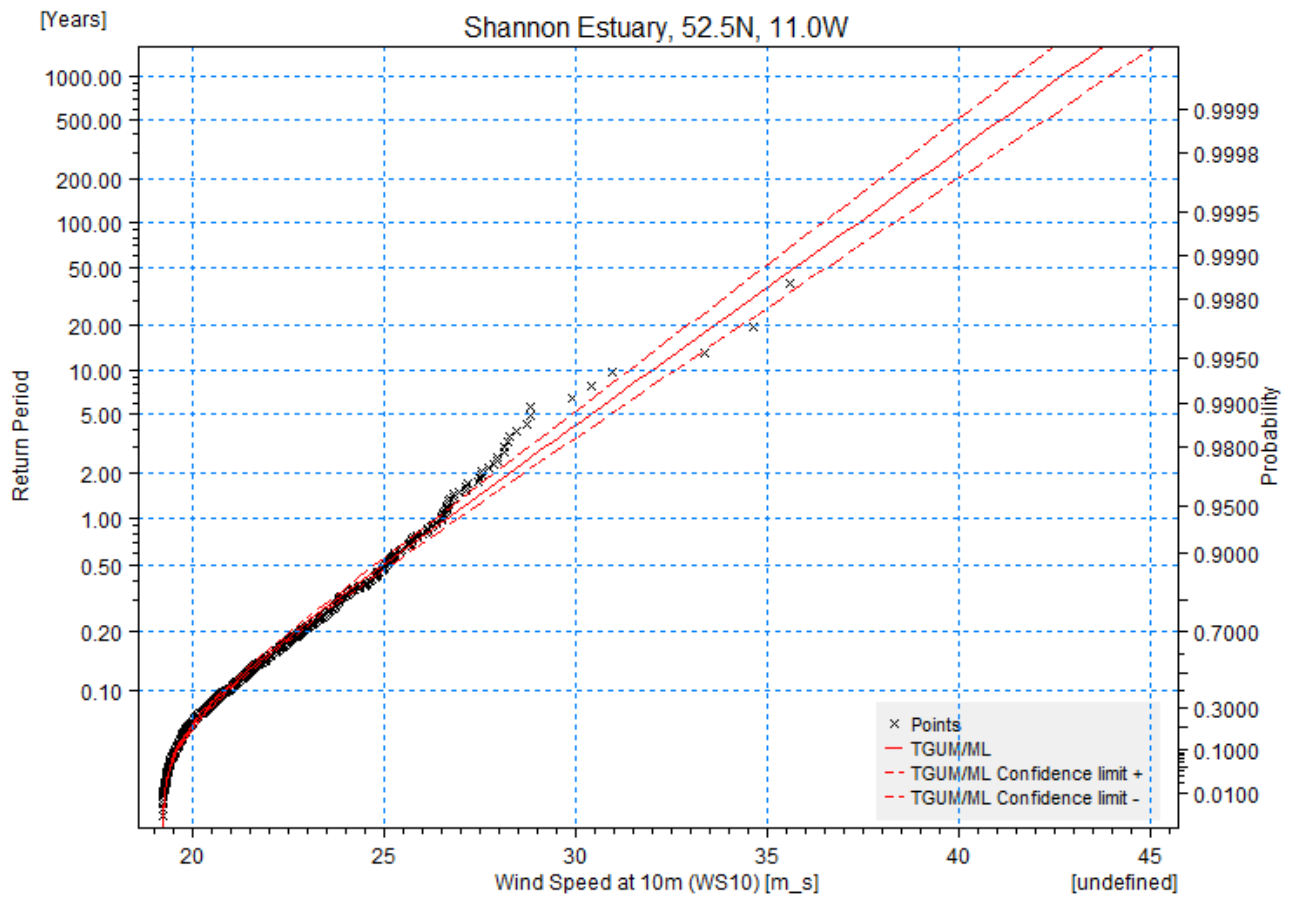


Figure A1: Omnidirectional EVA results for wind speed at 52.5N, 11.0W

Table A1: Met Office Method Factorisation and Extreme Values for Relevant Direction

52.5N, 11.0W

Omnidirectional EVA

RP	Wind Speed m/s	Dir Sector	Max Values			Av. Max	Factor
0.1	20.86	45	28.27	27.21	23.71	26.40	0.76
0.2	22.71	90	28.23	23.51	23.57	25.10	0.73
0.5	24.97	135	28.48	27.97	27.54	28.00	0.81
1	26.63	180	26.85	26.81	26.71	26.79	0.78
2	28.25	225	32.97	30.68	30.44	31.36	0.91
5	30.39	270	35.62	34.63	33.39	34.55	1.00
10	32.01	315	28.84	28.13	27.55	28.17	0.82
20	33.61	360	26.63	26.06	25.07	25.92	0.75
50	35.74					max 34.55	
100	37.36						
200	38.96						
500	41.09						
1000	42.70						

	Factor	0.76	0.73	0.81	0.78	0.91	1.00	0.82	0.75
	Direction	45	90	135	180	225	270	315	360
Return Period	0.1	15.94	15.16	16.90	16.18	18.94	20.86	17.01	15.65
	0.2	17.35	16.50	18.40	17.61	20.61	22.71	18.52	17.04
	0.5	19.08	18.14	20.23	19.36	22.67	24.97	20.36	18.73
	1	20.34	19.35	21.58	20.65	24.17	26.63	21.71	19.98
	2	21.58	20.52	22.89	21.90	25.64	28.25	23.04	21.19
	5	23.22	22.08	24.62	23.56	27.59	30.39	24.78	22.80
	10	24.46	23.26	25.94	24.82	29.06	32.01	26.10	24.02
	20	25.68	24.42	27.24	26.07	30.52	33.61	27.41	25.22
	50	27.31	25.97	28.96	27.71	32.45	35.74	29.15	26.81
	100	28.54	27.14	30.27	28.97	33.91	37.36	30.46	28.03
	200	29.77	28.31	31.58	30.21	35.37	38.96	31.77	29.23
	500	31.39	29.86	33.30	31.86	37.30	41.09	33.51	30.83
	1000	32.63	31.03	34.60	33.11	38.77	42.70	34.82	32.04

Overland adjustments Bunratty

	Direction	230	260	280	50
Return Period	0.1	18.94	20.86	20.86	13.05
	0.2	20.61	22.71	22.71	14.21
	0.5	22.67	24.97	24.97	15.62
	1	24.17	26.63	26.63	16.66
	2	25.64	28.25	28.25	17.68
	5	27.59	30.39	30.39	19.02
	10	29.06	32.01	32.01	20.03
	20	30.52	33.61	33.61	21.03
	50	32.45	35.74	35.74	22.37
	100	33.91	37.36	37.36	23.38
	200	35.37	38.96	38.96	24.38
	500	37.30	41.09	41.09	25.71
	1000	38.77	42.70	42.70	26.72

Appendix B

Joint Probability Analysis of Offshore Wind data and Inshore Water Level

Table B1: Joint probability table showing probability of wind speed with water level (260deg sector)

		Joint exceedance return period (years)							
		2	5	10	20	50	100	200	1000
		Marginal return period (years) for				Wind Speed 260°MWD (m/s)			
Marginal return period (years) for	0.01	2.000	5.000	10.000	20.000	50.000	100.000	200.000	1000.000
	0.02	1.695	5.000	10.000	20.000	50.000	100.000	200.000	1000.000
	0.05	0.678	2.619	7.277	20.000	50.000	100.000	200.000	1000.000
	0.1	0.339	1.309	3.638	10.111	39.044	100.000	200.000	1000.000
	0.2	0.170	0.655	1.819	5.055	19.522	54.251	150.760	1000.000
Extreme Sea Level (m to MSL)	0.5	0.068	0.262	0.728	2.022	7.809	21.700	60.304	647.144
	1	0.034	0.131	0.364	1.011	3.904	10.850	30.152	323.572
	2	0.017	0.065	0.182	0.506	1.952	5.425	15.076	161.786
	5	#N/A	0.026	0.073	0.202	0.781	2.170	6.030	64.714
	10	#N/A	#N/A	0.036	0.101	0.390	1.085	3.015	32.357
	20	#N/A	#N/A	#N/A	0.051	0.195	0.543	1.508	16.179
	50	#N/A	#N/A	#N/A	#N/A	0.078	0.217	0.603	6.471
	100	#N/A	#N/A	#N/A	#N/A	#N/A	0.109	0.302	3.236
	200	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.151	1.618
	1000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.324

Table B2: Joint probability table showing water level and wind speed (260deg sector)

		Joint exceedance return period (years)							
Value of first variable:		2	5	10	20	50	100	200	1000
Extreme Sea Level (m to MSL)	Value of second variable:	Wind Speed 260°MWD (m/s)							
	2.65	28.25	30.39	32.01	33.61	35.74	37.36	38.96	42.69
	2.76	27.86	30.39	32.01	33.61	35.74	37.36	38.96	42.69
	2.90	25.70	28.88	31.26	33.61	35.74	37.36	38.96	42.69
	3.00	24.01	27.26	29.64	32.03	35.17	37.36	38.96	42.69
	3.10	22.26	25.61	28.02	30.41	33.56	35.93	38.31	42.69
	3.24	19.82	23.37	25.87	28.27	31.43	33.80	36.18	41.69
	3.34	17.98	21.58	24.18	26.65	29.81	32.20	34.57	40.08
	3.44	16.13	19.73	22.45	24.99	28.19	30.58	32.96	38.47
	3.58	#N/A	17.29	20.01	22.73	26.03	28.44	30.82	36.34
	3.68	#N/A	#N/A	18.17	20.89	24.36	26.82	29.20	34.73
	3.78	#N/A	#N/A	#N/A	19.04	22.64	25.16	27.59	33.12
	3.91	#N/A	#N/A	#N/A	#N/A	20.20	22.91	25.42	30.99
	4.01	#N/A	#N/A	#N/A	#N/A	#N/A	21.08	23.72	29.37
	4.10	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	21.95	27.75
	4.33	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.00

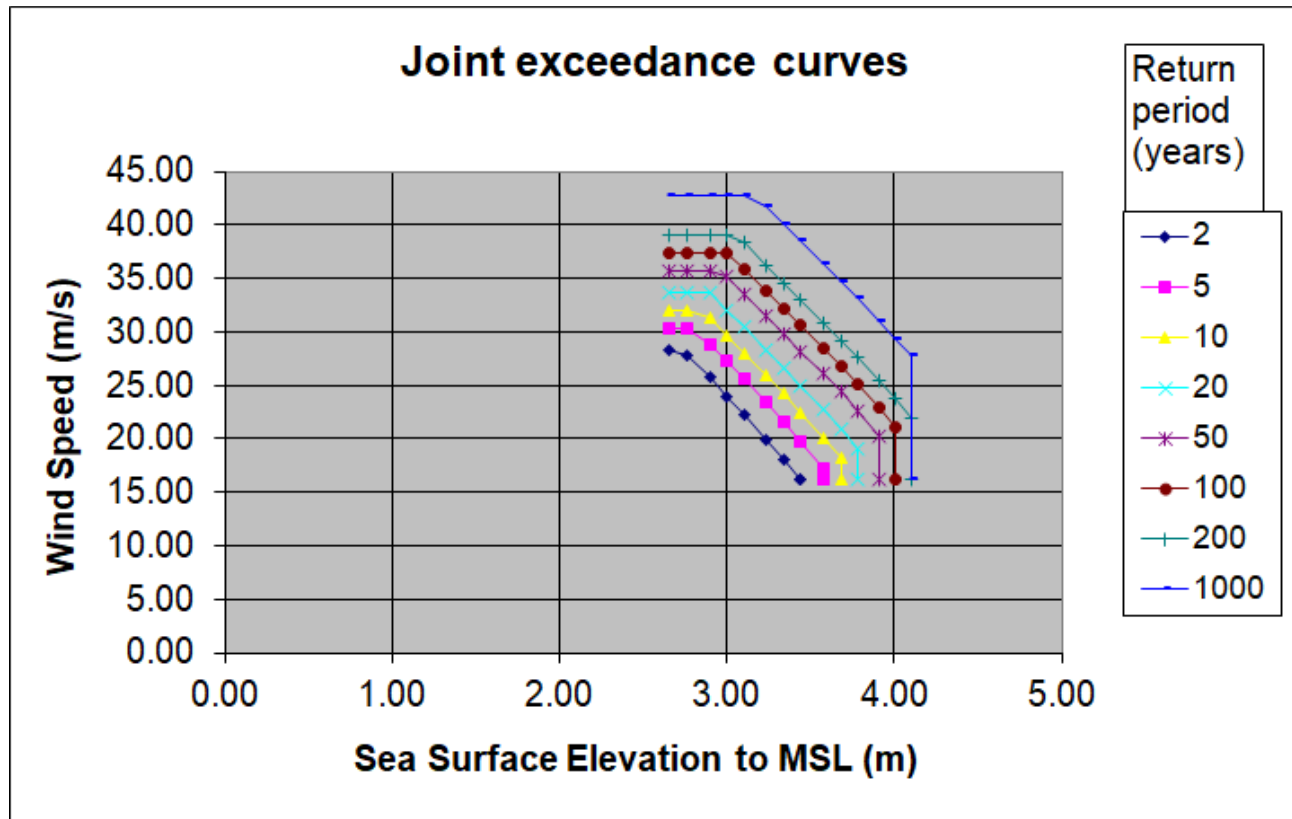


Figure B1: Offshore joint wind and water level exceedance curve (260deg sector)

Table B3: Joint probability table showing probability of wind speed with water level (280deg sector)

		Joint exceedance return period (years)							
		2	5	10	20	50	100	200	1000
Marginal return period (years) for		Wind Speed 280°MWD (m/s)							
Marginal return period (years) for	0.01	2.000	5.000	10.000	20.000	50.000	100.000	200.000	1000.000
	0.02	1.695	5.000	10.000	20.000	50.000	100.000	200.000	1000.000
	0.05	0.678	2.619	7.277	20.000	50.000	100.000	200.000	1000.000
	0.1	0.339	1.309	3.638	10.111	39.044	100.000	200.000	1000.000
	0.2	0.170	0.655	1.819	5.055	19.522	54.251	150.760	1000.000
	0.5	0.068	0.262	0.728	2.022	7.809	21.700	60.304	647.144
	1	0.034	0.131	0.364	1.011	3.904	10.850	30.152	323.572
	2	0.017	0.065	0.182	0.506	1.952	5.425	15.076	161.786
	5	#N/A	0.026	0.073	0.202	0.781	2.170	6.030	64.714
	10	#N/A	#N/A	0.036	0.101	0.390	1.085	3.015	32.357
Extreme Sea Level (m to MSL)	20	#N/A	#N/A	#N/A	0.051	0.195	0.543	1.508	16.179
	50	#N/A	#N/A	#N/A	#N/A	0.078	0.217	0.603	6.471
	100	#N/A	#N/A	#N/A	#N/A	#N/A	0.109	0.302	3.236
	200	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.151	1.618
	1000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.324

Table B4: Joint probability table showing water level and wind speed (280deg sector)

Value of first variable:	Joint exceedance return period (years)							
	2	5	10	20	50	100	200	1000
Extreme Sea Level (m to MSL)	Value of second variable: Wind Speed 280°MWD (m/s)							
2.65	28.25	30.39	32.01	33.61	35.74	37.36	38.96	42.69
2.76	27.86	30.39	32.01	33.61	35.74	37.36	38.96	42.69
2.90	25.70	28.88	31.26	33.61	35.74	37.36	38.96	42.69
3.00	24.01	27.26	29.64	32.03	35.17	37.36	38.96	42.69
3.10	22.26	25.61	28.02	30.41	33.56	35.93	38.31	42.69
3.24	19.82	23.37	25.87	28.27	31.43	33.80	36.18	41.69
3.34	17.98	21.58	24.18	26.65	29.81	32.20	34.57	40.08
3.44	16.13	19.73	22.45	24.99	28.19	30.58	32.96	38.47
3.58	#N/A	17.29	20.01	22.73	26.03	28.44	30.82	36.34
3.68	#N/A	#N/A	18.17	20.89	24.36	26.82	29.20	34.73
3.78	#N/A	#N/A	#N/A	19.04	22.64	25.16	27.59	33.12
3.91	#N/A	#N/A	#N/A	#N/A	20.20	22.91	25.42	30.99
4.01	#N/A	#N/A	#N/A	#N/A	#N/A	21.08	23.72	29.37
4.10	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	21.95	27.75
4.33	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.00

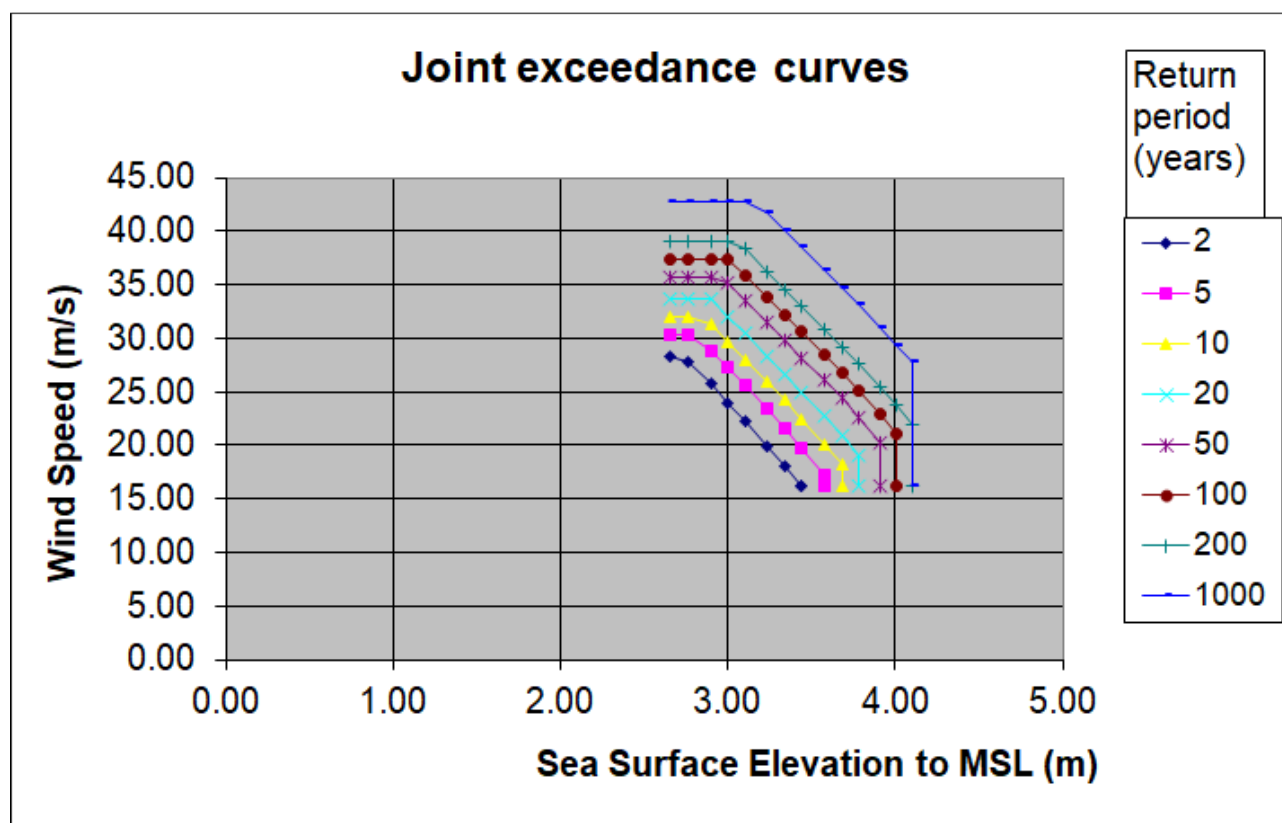


Figure B2: Offshore joint wind and water level exceedance curve (280deg sector)