

Jersey Shoreline Management Plan

Hydraulic Modelling Report: Wave Transformation and
Overtopping Modelling (Appendix G)

Government of Jersey

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Quality information

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G. Wave Transformation and Overtopping Modelling

G.1 Joint Probability Analysis

G.1.1 Analysis Approach

Joint probability refers to the chance of two or more conditions occurring at the same time. For the assessment of flood risk, the coincidence of extreme waves and Still Water Level (SWL) is of particular interest. For a defined probability of occurrence there will be different combinations of still water level and wave height that satisfy this condition. Determining these combinations depends on the correlation of a given water level and wave height condition, which are affected by meteorological conditions, surge, tides and the degree of exposure for the specific location. A Joint Probability Analysis (JPA) of waves and sea levels was therefore undertaken for locations along the Jersey coastline as part of the Jersey SMP study. These will subsequently be used to calculate wave overtopping rates, as required for the assessment of coastal flooding.

Previous studies (HR Wallingford, 1991 & 2009) assumed that the largest waves and the highest still water level (tide and surge) occur simultaneously, which is likely to provide the worst-case assessment in terms of the intensity of overtopping. The use of this assumption means that a value of 1.0 for the correlation coefficient (ρ) was applied which relates still water level and wave height. In a more recent study (WSP, 2016) it was assumed that waves and still water levels were 'super-correlated' for coastal areas around the island of Jersey with a correlation coefficient of 0.70 assumed. More recently Prime (2018) applied the JOIN-SEA software to conduct a full JPA of waves using data from a wave buoy 12km offshore from St Aubin's Bay (Figure G-1) and sea levels at St Helier. This assessment provided four curves for return periods of 1, 10, 50 and 100 years, but the strength of the correlation between wave and sea level was not presented. This limits application of this information where other return periods are needed. Prime (2018) also concluded that the HR Wallingford report provides an over-estimate (i.e. a conservative assessment) of the frequency and intensity of predicted flooding.

The various JPA methods are described in the relevant guidance (Use of Joint Probability Methods in Flood Management: A Guide to Best Practice – R&D Technical Report FD2308/TR2, EA/Defra, 2005). For the simplified JPA approach, the report summarises dependence information for wave and still water level in UK waters (Figure G-2). However, the guidance does not provide the strength of correlation between wave and still water level specifically for Jersey. For the present study, an analytical approach has therefore been used to investigate the dependence between wave height and sea level. This approach was developed by HR Wallingford and Lancaster University and makes use of a series of algorithms within the JOIN-SEA software package.

JPA Result

The 21-year time-series of wave conditions recorded at the Jersey wave buoy and water levels measured at the St Helier tide gauge were applied to establish the correlation coefficient. The duration of the wave dataset is from 1996 to 2017 with missing data for 2008. AECOM obtained the water level measurements for the operational gauge at St Helier, Jersey. The dataset was made available by the British Oceanographic Data Centre (BODC) and covers the same period as the wave data at 15-minute intervals. The measured water levels include both tide and surge, which have been applied in the JPA analysis.

The results of the JOIN-SEA analysis indicate a maximum value for the correlation coefficient of 0.38, close to the value of 0.37 specified in the EA/Defra guidance for the south-west of England (Figure G-2). Moreover, Figure G-3 suggests that the correlation coefficient can be up to 0.48 for the wave direction sector in which dependence is highest. Therefore, a 'well-correlated' level of dependence ($0.38 \leq \rho \leq 0.53$) defined in the guidance (EA/Defra, 2005), is considered appropriate for Jersey. This result is supported by the uniform distribution of wave height over a range of sea levels, as shown in the scatter plots of Figure G-4 (omnidirectional) and Figure G-5 (directional).

However, considering that the 21-year dataset is a relatively short duration for the JPA assessment, a slightly more conservative approach is recommended that assumes a 'strong' level of correlation between waves and still water levels. Further analysis would be required to justify the use of a less conservative approach which would need to be supported by a longer record of both measured datasets.

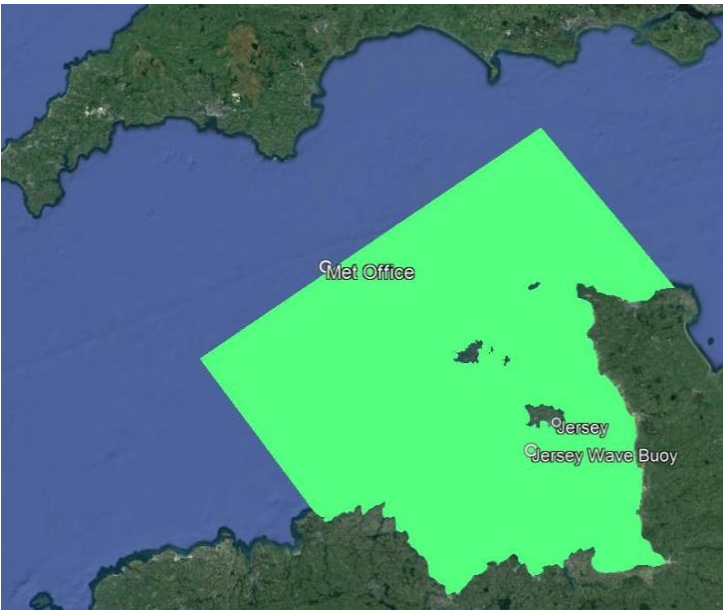


Figure G-1: Location of the Jersey Wave Buoy

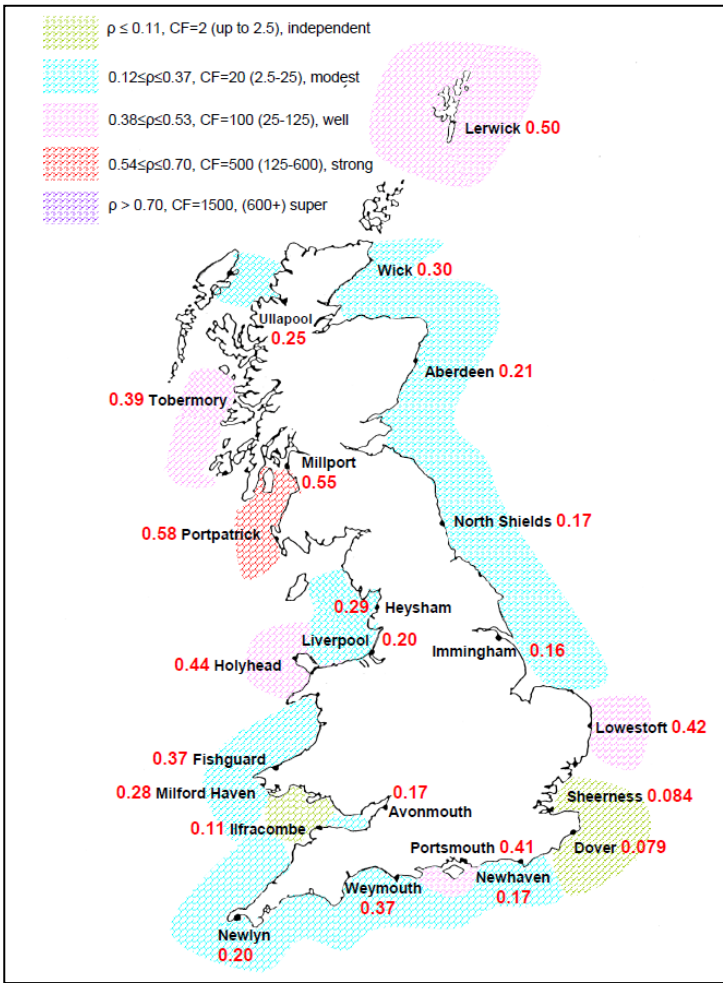


Figure G-2: Correlation coefficient (p, wave height & sea level): all wave directions

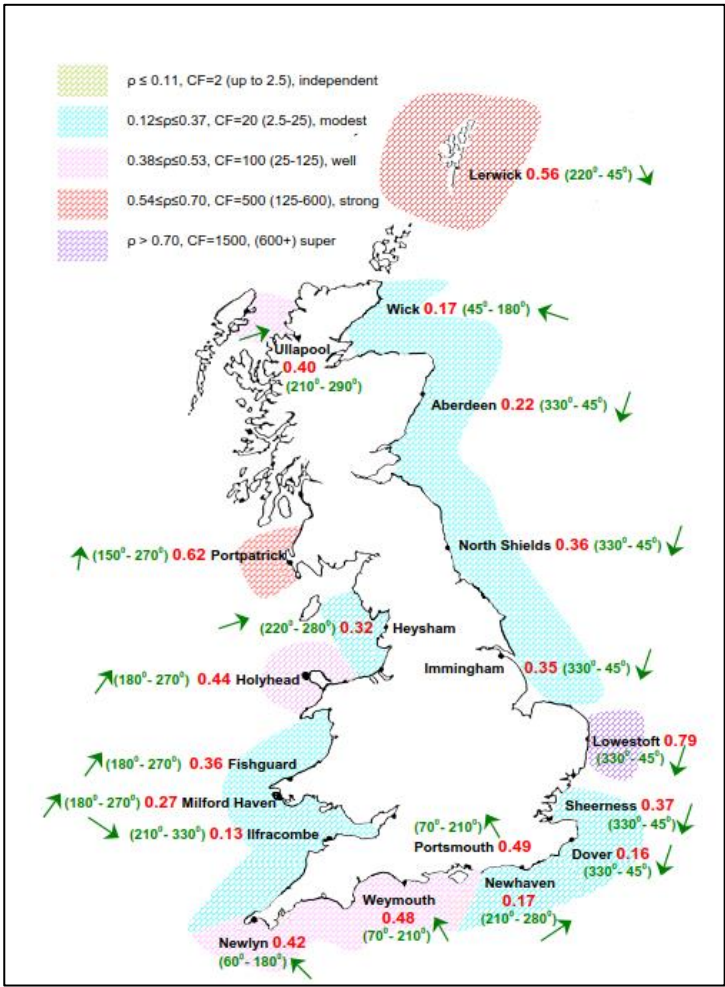


Figure G-3. Correlation Coefficient (p , Wave Height & Sea Level): Wave Direction where Dependence is Highest

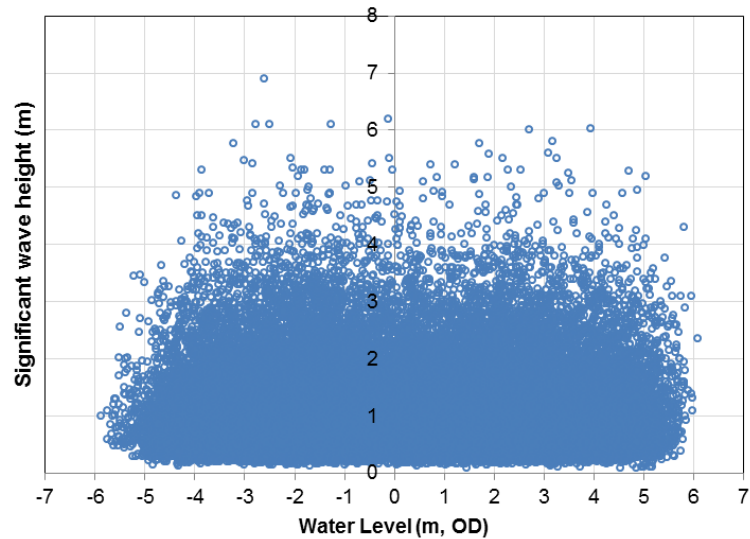


Figure G-4: Plot of Wave Height against Water Level

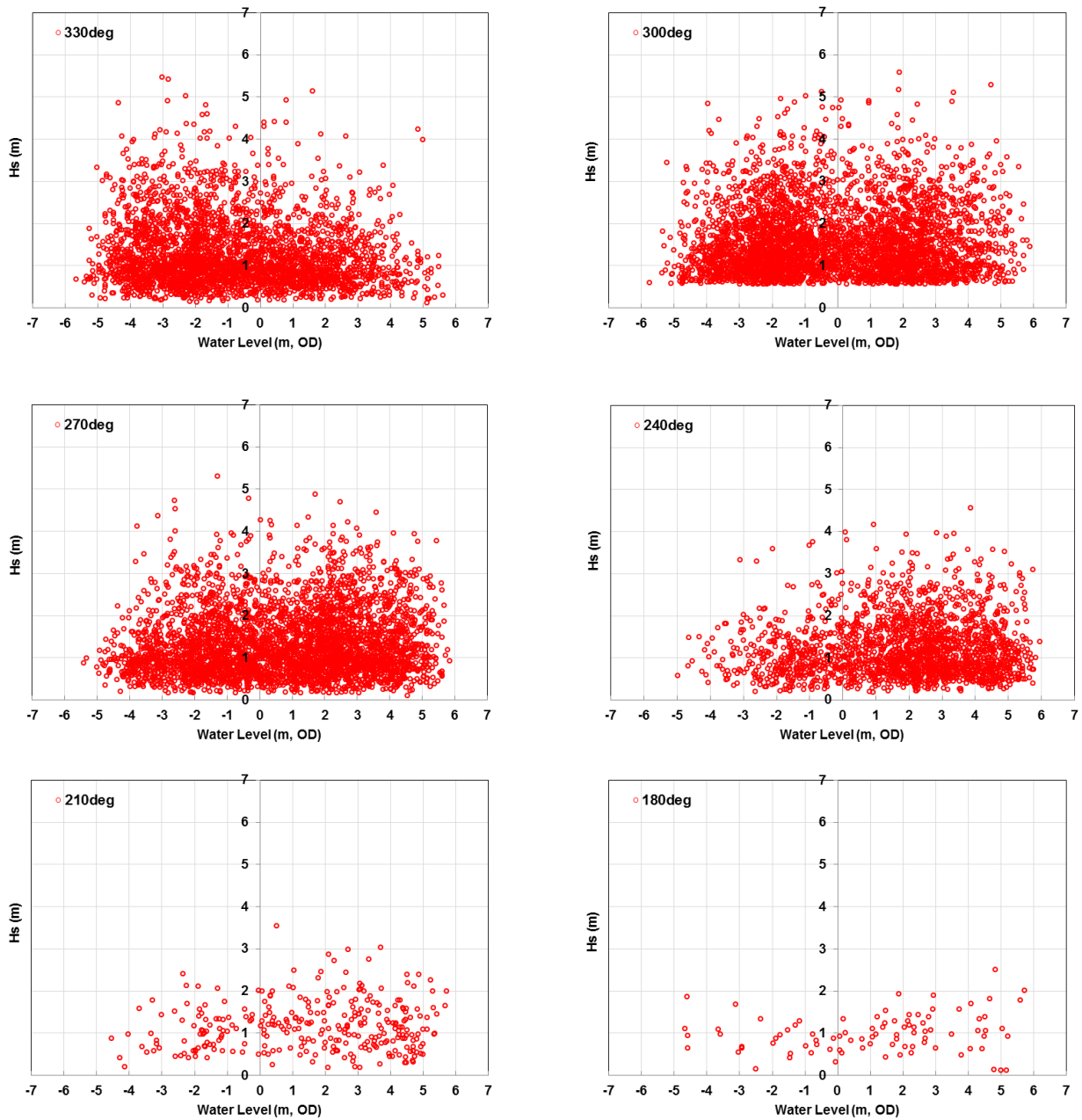


Figure G-5: Directional Scatter Plot of Wave Height against Water Level

G.2 Wave Transformation

G.2.1 Wave Model

AECOM has re-calibrated the regional wave model previously developed for the Government of Jersey (WSP, 2016) and demonstrated that the improved performance was achieved during this process (Appendix B). Further local wave transformation along the south, east and west coasts was undertaken to provide wave conditions in front of the defence structures (significant wave height, period and direction).

Five MIKE21 Spectral Wave (SW) models have been configured to include details of the nearshore bathymetry. Table G-1 describes the coverage of each model domain, cross-sections selected for overtopping estimation and figures showing their mesh design. Three of them (Models A, B and C) are the local wave models to consider wave diffraction processes in St Aubin's Bay, St Brelade's Bay, and the areas of La Collete, La Greve D'Azette and La Mare. Extreme wave conditions at the local model boundary were extracted from the regional model along the 20-25m depth contour. At this location it is assumed that the water is sufficiently deep so that depth-limited wave breaking will not occur.

The flexible mesh was generated using the MIKE-Zero Mesh Generator. Resolution across the model domain is variable with the highest resolution along the coastal defence structures. For the offshore area the mesh resolution is 200m gradually increasing to 10m for the main areas of interest.

Table G-1: Description of Wave Transformation Model

Model	Area	Cross Section	Figure
A	St Aubin's Bay	07-03; 07-05; 07-06; 07-08; 07-11; 07-12; 07-13; 07-14; 07-16; 07-17	Figure G-6 Figure G-9 Figure G-10
B	La Collete La Greve D'Azette La Mare	08-01; 08-03; 11-03; 11-03; 12-02; 12-03	Figure G-6 Figure G-11 Figure G-12
C	St Brelade's Bay Ouaisné Bay	03-05 03-07	Figure G-7 Figure G-13 Figure G-14
D	East Coast (La Nez Point; La Rocque; Royal Bay of Grouville; Archirondel (north))	14-01; 14-04; 19-03; 19-05; 19-06; 20-01; 20-06; 20-07; 24-02	Figure G-8 Figure G-15 Figure G-16
E	West Coast (St Quen's Bay)	35-11; 35-12; 35-14; 35-15; 35-16	Figure G-8 Figure G-17 Figure G-18

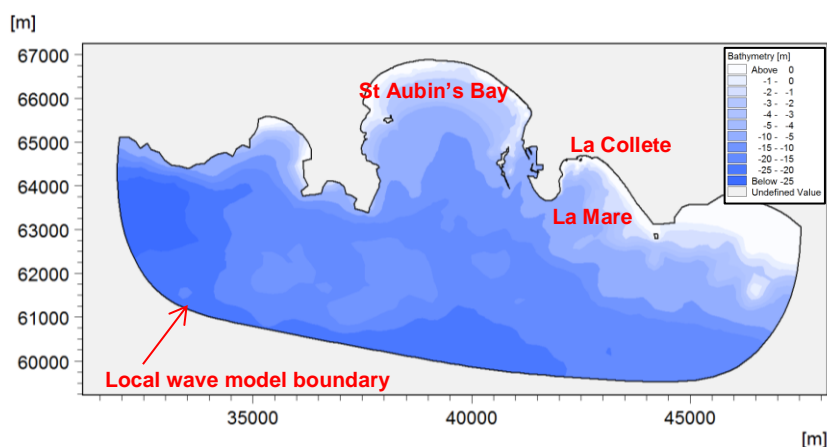


Figure G-6: Local Wave Model Domain (Model A and Model B)

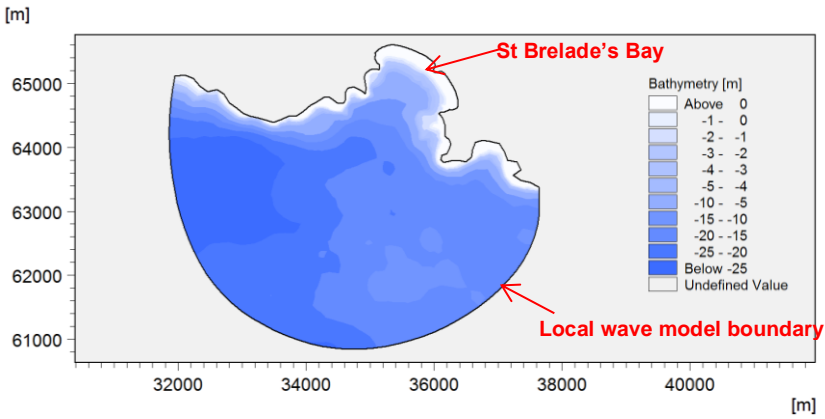


Figure G-7: Local Wave Model Domain (Model C)

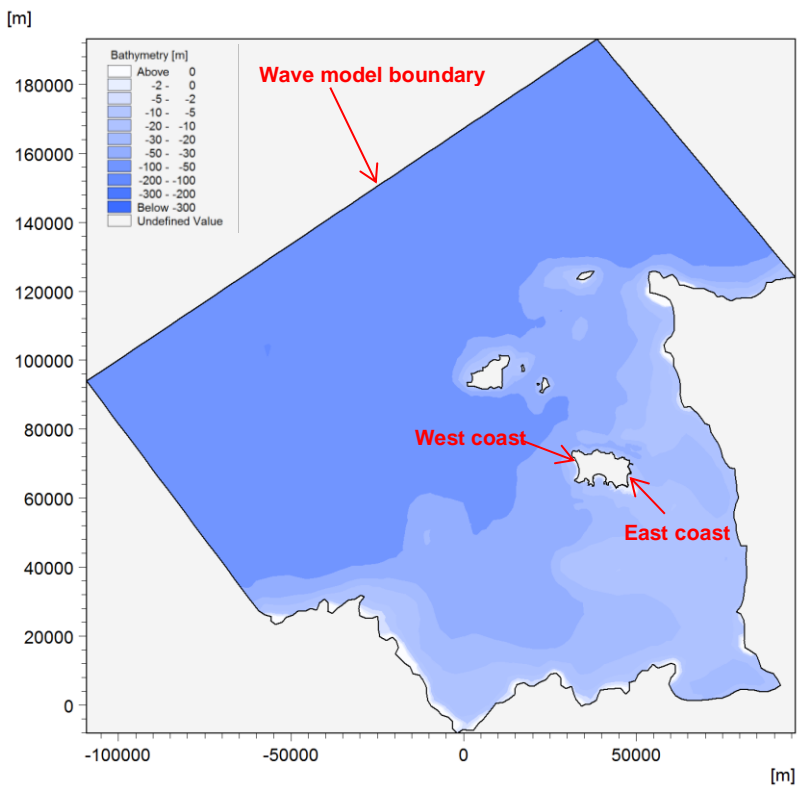


Figure G-8: Wave Model Domain (Model D and Model E)



Figure G-9: Local Wave Model Mesh (Model A)



Figure G-10: View of Enhanced Nearshore Mesh Resolution (Model A)



Figure G-11: Local Wave Model Mesh (Model B)



Figure G-12: View of Enhanced Nearshore Mesh Resolution (Model B)



Figure G-13: Local Wave Model Mesh (Model C)



Figure G-14: View of Enhanced Nearshore Mesh Resolution (Model C)

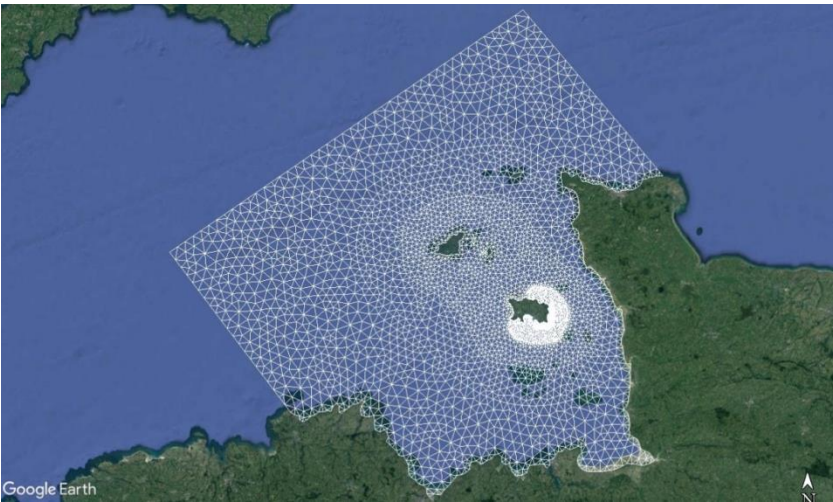


Figure G-15: Wave Model Mesh (Model D)

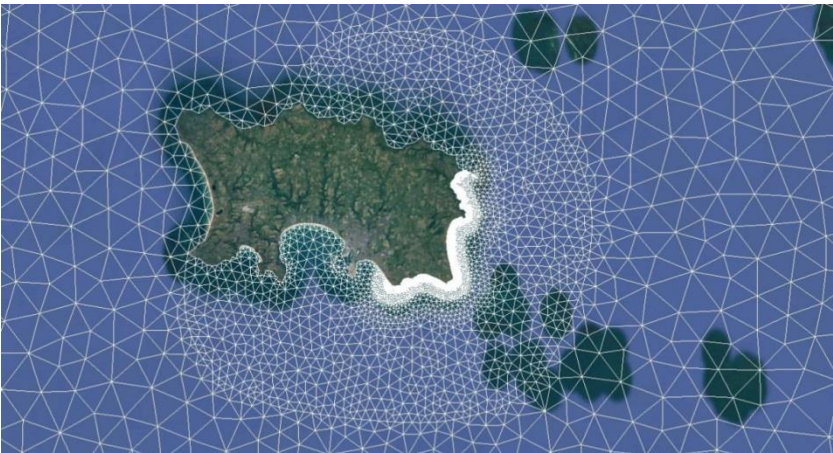


Figure G-16: View of Enhanced Nearshore Mesh Resolution along the East Coast (Model D)

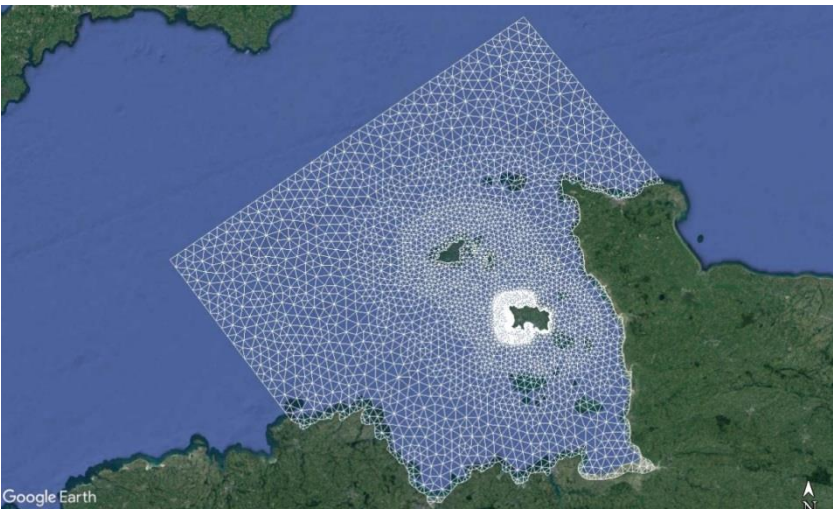


Figure G-17: Wave Model Mesh (Model E)

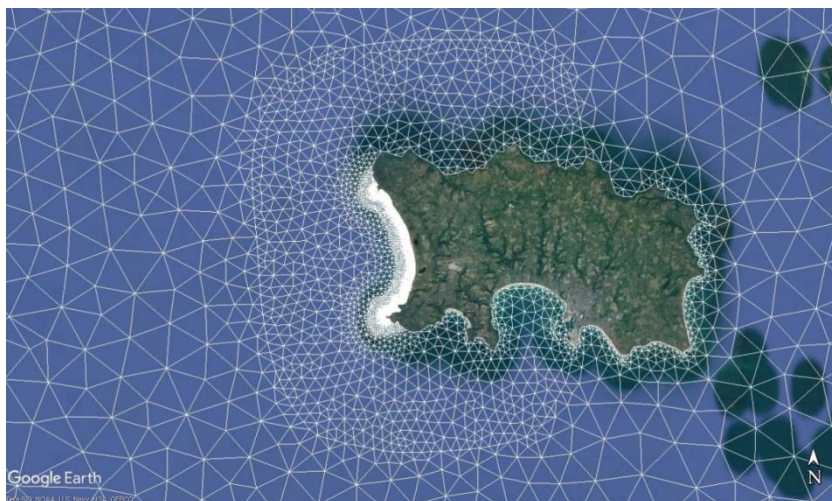


Figure G-18: View of Enhanced Mesh Resolution along the West Coast (Model E)

G.2.2 Boundary Condition

For the purpose of model calibration, AECOM purchased hindcast offshore wave data and wind conditions from the UK Met Office (UKMO). The time-series data is available at hourly intervals for the years 2008, 2016 and 2017. Figure G-19 shows wave and wind roses based on the UKMO dataset for the grid point identified in Figure 1-1. The directional resolution in each rose plot is 30°. The wave rose indicates that prevailing waves come from south-west and west. The wind rose shows wind coming from all directions although the strongest winds are from the sector between south-west and north-west. In this study wave and wind conditions have been investigated for in all sectors with directional resolution of 30°, i.e. 0°, 30°, 60°, 90°, 120°, 150°, 180°, 210°, 240°, 270°, 300° and 330°. Following the intensive sensitivity tests, the dominant wave and wind conditions generating the largest wave overtopping were established at each site.

A recent study (Prime, 2018) investigated the impact of climate change on wind and wave conditions at Jersey. It was found that both wind and waves are unlikely to be affected by climate change for this region. This conclusion was adopted in the Jersey SMP study allowing future changes in wind and wave conditions to be discounted. Increases in sea level as a result of climate change are considered due to the influence of local water depths on wave breaking at the toe of sea defence structures. Table G-2 to Table G-49 provide the marginal extreme distributions of wave height and sea level for the baseline year (2020) and future epoch (2040) at the boundary of each model accompanied by the corresponding JPA results.

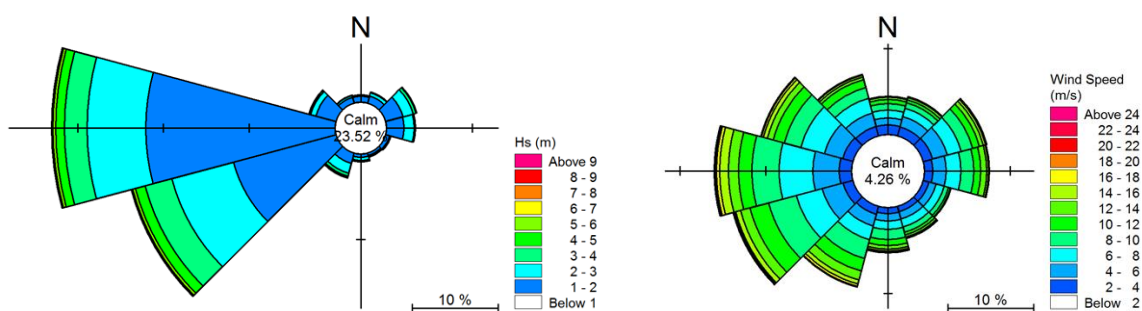


Figure G-19: Wave and Wind Roses for UKMO Model Data

Tables of joint exceedance extreme values and JPA curves have been derived using available information on marginal (single variable) extreme values and an estimate of the dependence between the two variables. Inputs required for the analysis include:

- Marginal extremes of wave height and water level (Table G-2);
- Dependence parameter (i.e. 'strong' in this case);

- Number of records per year; and,
- Required joint exceedance return periods.

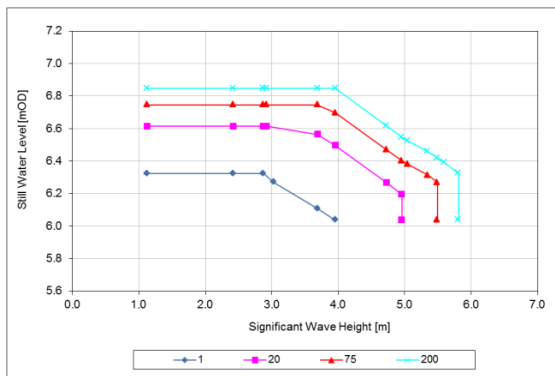
The JPA results are presented in the following plots and tables showing the joint exceedance return periods for a combination of extreme wave heights and Still Water Levels for 2020 and 2040 epochs.

G.2.3 Model A & Model B

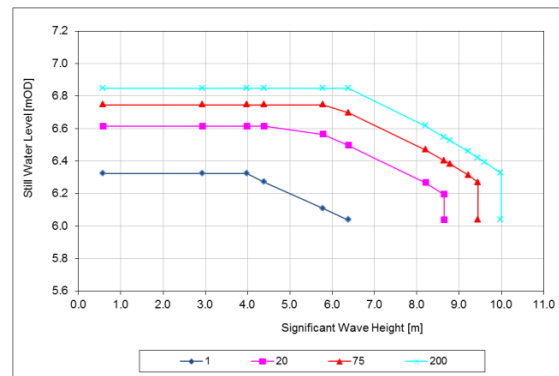
Table G-2: Marginal Extreme Combinations of Hs and SWL (Model A & Model B)

RP (yrs)	Significant Wave Height Hs (m)							Still Water Level (m AOD)	
	300°	270°	240°	210°	180°	150°	120°	2020	2040
1	3.96	6.39	5.17	2.86	2.15	1.97	1.63	6.32	6.45
10	4.73	8.21	6.63	3.38	2.58	2.45	2.01	6.54	6.67
20	4.96	8.65	6.96	3.49	2.67	2.56	2.09	6.61	6.74
25	5.04	8.79	7.09	3.53	2.70	2.60	2.13	6.63	6.76
50	5.35	9.23	7.44	3.68	2.83	2.73	2.23	6.71	6.83
75	5.49	9.45	7.64	3.75	2.88	2.79	2.28	6.75	6.87
100	5.60	9.62	7.79	3.81	2.93	2.84	2.32	6.78	6.90
200	5.81	10.00	8.13	3.93	3.04	2.96	2.40	6.85	6.98
1000	6.37	10.85	8.92	4.29	3.35	3.35	2.63	7.02	7.15

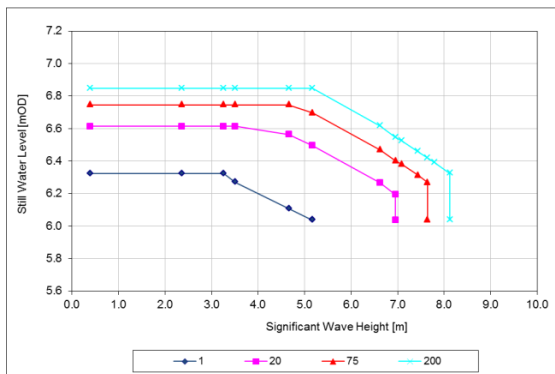
Epoch 2020



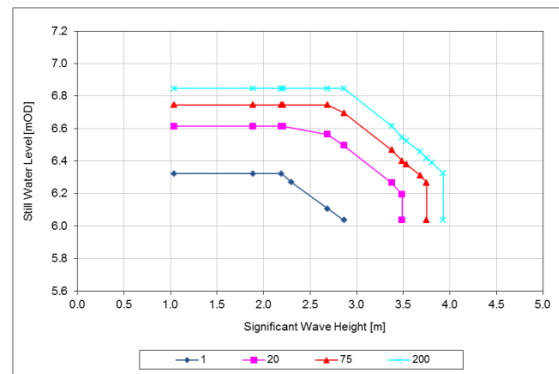
(a) 300°



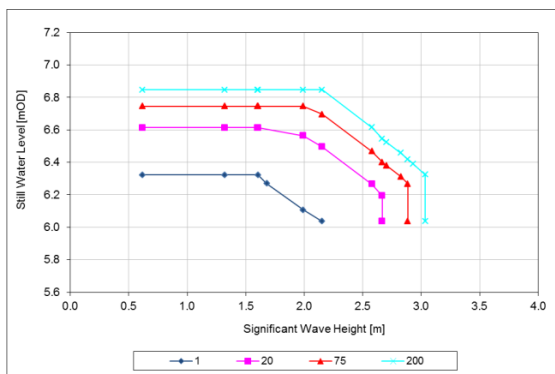
(b) 270°



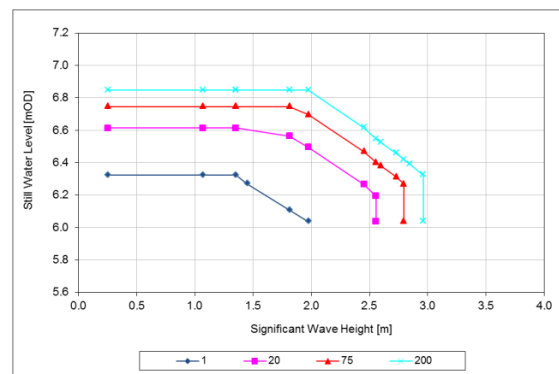
(c) 240°



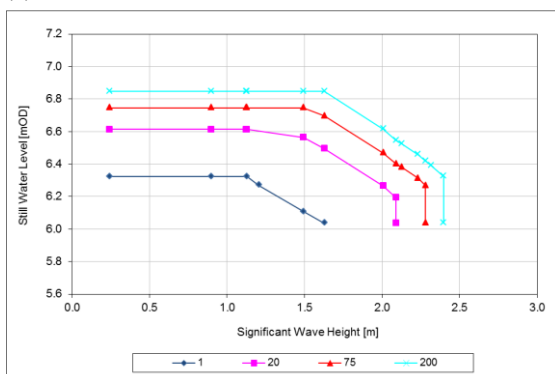
(d) 210°



(e) 180°



(f) 150°



(g) 120°

Figure G-20: Joint Probability Combinations of H_s and SWL (2020)

Table G-3: Joint Probability Combinations of Hs and SWL in Sector 300° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
1.12	6.32	6.61	6.75	6.85
2.42	6.32	6.61	6.75	6.85
2.88	6.32	6.61	6.75	6.85
3.03	6.27	6.61	6.75	6.85
3.69	6.11	6.56	6.75	6.85
3.96	6.04	6.50	6.70	6.85
4.73		6.27	6.47	6.62
4.96		6.19	6.40	6.55
4.96		6.04	6.40	6.55
5.04			6.38	6.52
5.35			6.31	6.46
5.49			6.27	6.42
5.49			6.04	6.42
5.60				6.39
5.81				6.32
5.81				6.04

Table G-4: Joint Probability Combinations of Hs and SWL in Sector 270° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
0.59	6.32	6.61	6.75	6.85
2.93	6.32	6.61	6.75	6.85
3.99	6.32	6.61	6.75	6.85
4.43	6.27	6.61	6.75	6.85
5.79	6.11	6.56	6.75	6.85
6.39	6.04	6.50	6.70	6.85
8.21		6.27	6.47	6.62
8.65		6.19	6.40	6.55
8.65		6.04	6.40	6.55
8.79			6.38	6.52
9.23			6.31	6.46
9.45			6.27	6.42
9.45			6.04	6.42
9.62				6.39
10.00				6.32
10.00				6.04

Table G-5: Joint Probability Combinations of Hs and SWL in Sector 240° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.39	6.32	6.61	6.75	6.85
2.36	6.32	6.61	6.75	6.85
3.26	6.32	6.61	6.75	6.85
3.51	6.27	6.61	6.75	6.85
4.66	6.11	6.56	6.75	6.85
5.17	6.04	6.50	6.70	6.85
6.63		6.27	6.47	6.62
6.96		6.19	6.40	6.55
6.96		6.04	6.40	6.55
7.09			6.38	6.52
7.44			6.31	6.46
7.64			6.27	6.42
8.13			6.04	6.42
7.79				6.39
8.13				6.32
8.13				6.04

Table G-6: Joint Probability Combinations of Hs and SWL in Sector 210° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
1.04	6.32	6.61	6.75	6.85
1.89	6.32	6.61	6.75	6.85
2.19	6.32	6.61	6.75	6.85
2.30	6.27	6.61	6.75	6.85
2.69	6.11	6.56	6.75	6.85
2.86	6.04	6.50	6.70	6.85
3.38		6.27	6.47	6.62
3.49		6.19	6.40	6.55
3.49		6.04	6.40	6.55
3.53			6.38	6.52
3.68			6.31	6.46
3.75			6.27	6.42
3.75			6.04	6.42
3.81				6.39
3.93				6.32
3.93				6.04

Table G-7: Joint Probability Combinations of Hs and SWL in Sector 180° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.62	6.32	6.61	6.75	6.85
1.32	6.32	6.61	6.75	6.85
1.60	6.32	6.61	6.75	6.85
1.70	6.27	6.61	6.75	6.85
1.99	6.11	6.56	6.75	6.85
2.15	6.04	6.50	6.70	6.85
2.58		6.27	6.47	6.62
2.67		6.19	6.40	6.55
2.67		6.04	6.40	6.55
2.70			6.38	6.52
2.83			6.31	6.46
2.88			6.27	6.42
2.88			6.04	6.42
2.93				6.39
3.04				6.32
3.04				6.04

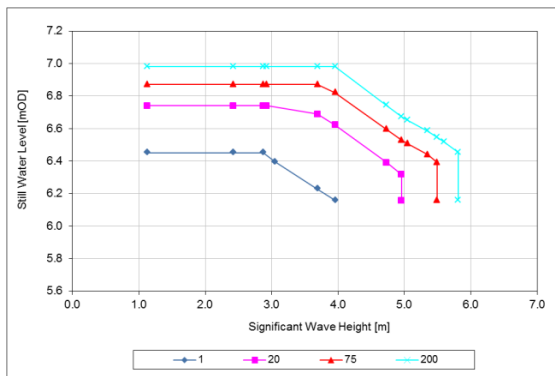
Table G-8: Joint Probability Combinations of Hs and SWL in Sector 150° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.25	6.32	6.61	6.75	6.85
1.07	6.32	6.61	6.75	6.85
1.35	6.32	6.61	6.75	6.85
1.45	6.27	6.61	6.75	6.85
1.81	6.11	6.56	6.75	6.85
1.97	6.04	6.50	6.70	6.85
2.45		6.27	6.47	6.62
2.56		6.19	6.40	6.55
2.56		6.04	6.40	6.55
2.60			6.38	6.52
2.73			6.31	6.46
2.79			6.27	6.42
2.79			6.04	6.42
2.84				6.39
2.96				6.32
2.96				6.04

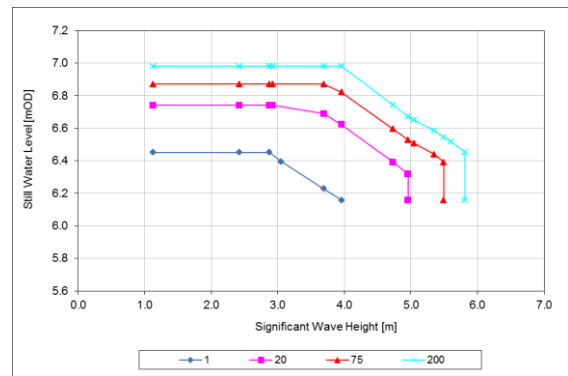
Table G-9: Joint Probability Combinations of Hs and SWL in Sector 120° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.24	6.32	6.61	6.75	6.85
0.90	6.32	6.61	6.75	6.85
1.13	6.32	6.61	6.75	6.85
1.21	6.27	6.61	6.75	6.85
1.49	6.11	6.56	6.75	6.85
1.63	6.04	6.50	6.70	6.85
2.01		6.27	6.47	6.62
2.09		6.19	6.40	6.55
2.09		6.04	6.40	6.55
2.13			6.38	6.52
2.23			6.31	6.46
2.28			6.27	6.42
2.28			6.04	6.42
2.32				6.39
2.40				6.32
2.40				6.04

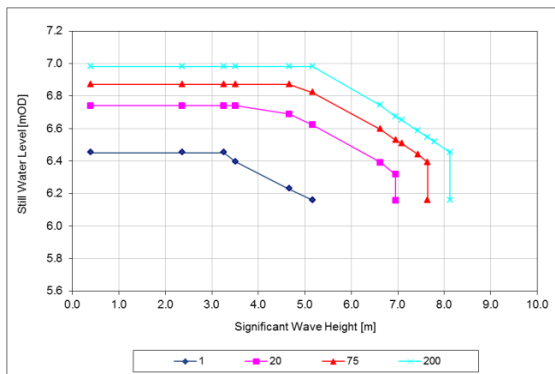
Epoch 2040



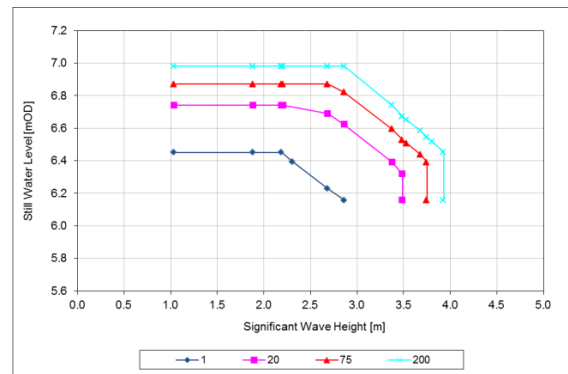
(a) 300°



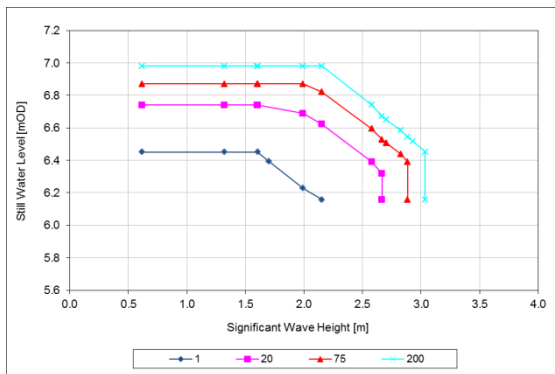
(b) 270°



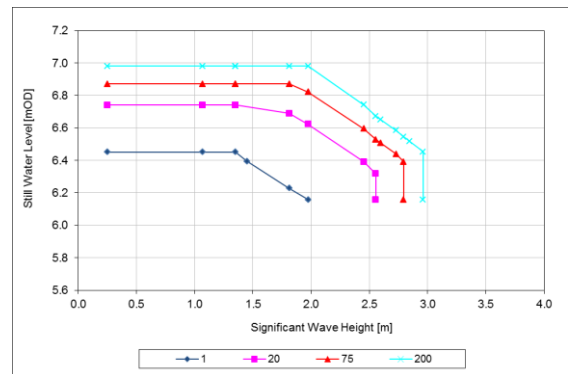
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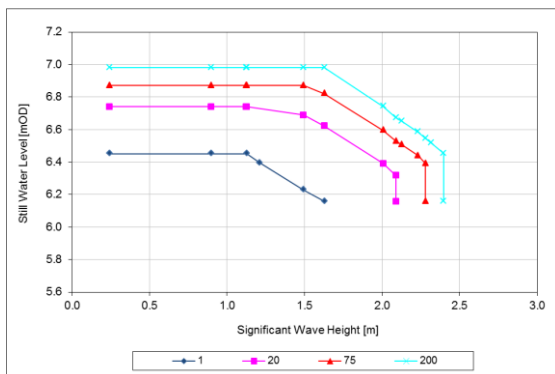
(d) 210°



(e) 180°



(f) 150°



(g) 120°

Figure G-21: Joint Probability Combinations of H_s and SWL (2040)

Table G-10: Joint Probability Combinations of Hs and SWL in Sector 300° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
1.12	6.45	6.74	6.87	6.98
2.42	6.45	6.74	6.87	6.98
2.88	6.45	6.74	6.87	6.98
3.05	6.39	6.74	6.87	6.98
3.69	6.23	6.69	6.87	6.98
3.96	6.16	6.62	6.82	6.98
4.73		6.39	6.59	6.74
4.96		6.32	6.53	6.67
4.96		6.16	6.53	6.67
5.04			6.51	6.65
5.35			6.44	6.58
5.49			6.39	6.55
5.49			6.16	6.55
5.60				6.52
5.81				6.45
5.81				6.16

Table G-11: Joint Probability Combinations of Hs and SWL in Sector 270° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
0.59	6.45	6.74	6.87	6.98
2.93	6.45	6.74	6.87	6.98
3.99	6.45	6.74	6.87	6.98
4.40	6.39	6.74	6.87	6.98
5.79	6.23	6.69	6.87	6.98
6.39	6.16	6.62	6.82	6.98
8.21		6.39	6.59	6.74
8.65		6.32	6.53	6.67
8.65		6.16	6.53	6.67
8.79			6.51	6.65
9.23			6.44	6.58
9.45			6.39	6.55
9.45			6.16	6.55
9.62				6.52
10.00				6.45
10.00				6.16

Table G-12: Joint Probability Combinations of Hs and SWL in Sector 240° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.39	6.45	6.74	6.87	6.98
2.36	6.45	6.74	6.87	6.98
3.26	6.45	6.74	6.87	6.98
3.51	6.39	6.74	6.87	6.98
4.66	6.23	6.69	6.87	6.98
5.17	6.16	6.62	6.82	6.98
6.63		6.39	6.59	6.74
6.96		6.32	6.53	6.67
6.96		6.16	6.53	6.67
7.09			6.51	6.65
7.44			6.44	6.58
7.64			6.39	6.55
7.64			6.16	6.55
7.79				6.52
8.13				6.45
8.13				6.16

Table G-13: Joint Probability Combinations of Hs and SWL in Sector 210° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
1.04	6.45	6.74	6.87	6.98
1.89	6.45	6.74	6.87	6.98
2.19	6.45	6.74	6.87	6.98
2.21	6.39	6.74	6.87	6.98
2.69	6.23	6.69	6.87	6.98
2.86	6.16	6.62	6.82	6.98
3.38		6.39	6.59	6.74
3.49		6.32	6.53	6.67
3.49		6.16	6.53	6.67
3.53			6.51	6.65
3.68			6.44	6.58
3.75			6.39	6.55
3.75			6.16	6.55
3.81				6.52
3.93				6.45
3.93				6.16

Table G-14: Joint Probability Combinations of Hs and SWL in Sector 180° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.62	6.45	6.74	6.87	6.98
1.32	6.45	6.74	6.87	6.98
1.60	6.45	6.74	6.87	6.98
1.70	6.39	6.74	6.87	6.98
1.99	6.23	6.69	6.87	6.98
2.15	6.16	6.62	6.82	6.98
2.58		6.39	6.59	6.74
2.67		6.32	6.53	6.67
2.67		6.16	6.53	6.67
2.70			6.51	6.65
2.83			6.44	6.58
2.88			6.39	6.55
2.88			6.16	6.55
2.93				6.52
3.04				6.45
3.04				6.16

Table G-15: Joint Probability Combinations of Hs and SWL in Sector 150° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.25	6.45	6.74	6.87	6.98
1.07	6.45	6.74	6.87	6.98
1.35	6.45	6.74	6.87	6.98
1.40	6.39	6.74	6.87	6.98
1.81	6.23	6.69	6.87	6.98
1.97	6.16	6.62	6.82	6.98
2.45		6.39	6.59	6.74
2.56		6.32	6.53	6.67
2.56		6.16	6.53	6.67
2.60			6.51	6.65
2.73			6.44	6.58
2.79			6.39	6.55
2.79			6.16	6.55
2.84				6.52
2.96				6.45
2.96				6.16

Table G-16: Joint Probability Combinations of Hs and SWL in Sector 120° (2040)

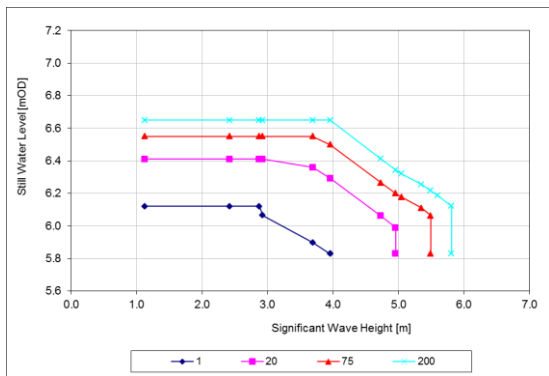
Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.24	6.45	6.74	6.87	6.98
0.90	6.45	6.74	6.87	6.98
1.13	6.45	6.74	6.87	6.98
1.17	6.39	6.74	6.87	6.98
1.49	6.23	6.69	6.87	6.98
1.63	6.16	6.62	6.82	6.98
2.01		6.39	6.59	6.74
2.09		6.32	6.53	6.67
2.09		6.16	6.53	6.67
2.13			6.51	6.65
2.23			6.44	6.58
2.28			6.39	6.55
2.28			6.16	6.55
2.32				6.52
2.40				6.45
2.40				6.16

G.2.4 Model C

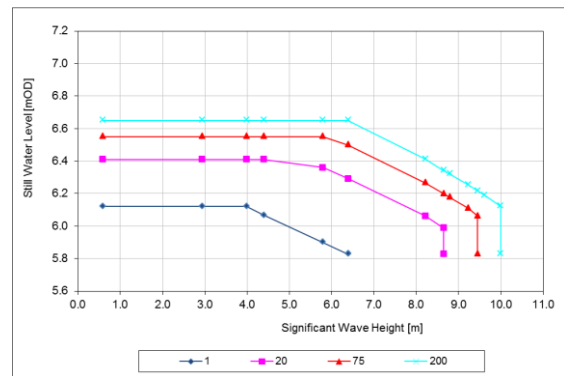
Table G-17: Marginal Extreme Combinations of Hs and SWL (Model C)

RP (yrs)	Significant Wave Height Hs (m)							Still Water Level (m AOD)	
	300°	270°	240°	210°	180°	150°	120°	2020	2040
1	3.96	6.39	5.17	2.86	2.15	1.97	1.63	6.12	6.25
10	4.73	8.21	6.63	3.38	2.58	2.45	2.01	6.34	6.47
20	4.96	8.65	6.96	3.49	2.67	2.56	2.09	6.41	6.54
25	5.04	8.79	7.09	3.53	2.70	2.60	2.13	6.43	6.56
50	5.35	9.23	7.44	3.68	2.83	2.73	2.23	6.51	6.63
75	5.49	9.45	7.64	3.75	2.88	2.79	2.28	6.55	6.67
100	5.60	9.62	7.79	3.81	2.93	2.84	2.32	6.58	6.70
200	5.81	10.00	8.13	3.93	3.04	2.96	2.40	6.65	6.78
1000	6.37	10.85	8.92	4.29	3.35	3.35	2.63	6.82	6.95

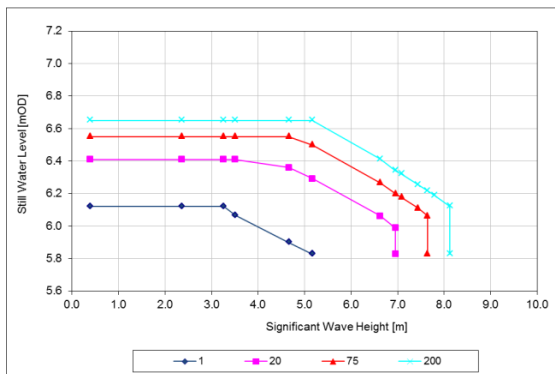
Epoch 2020



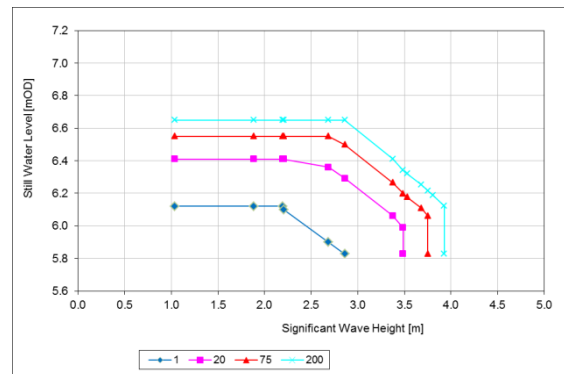
(a) 300°



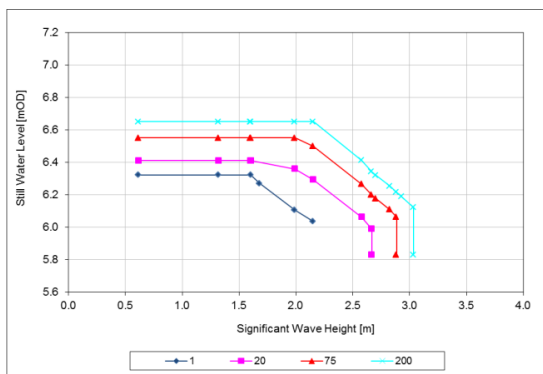
(b) 270°



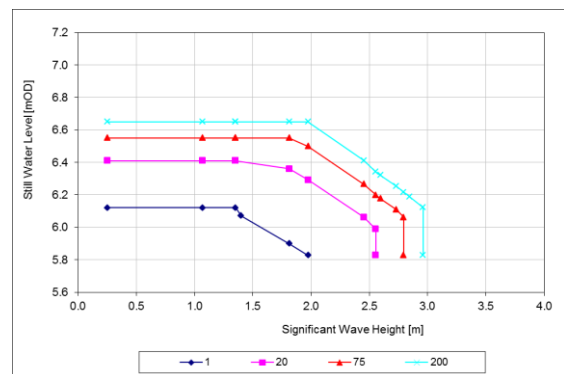
(c) 240°



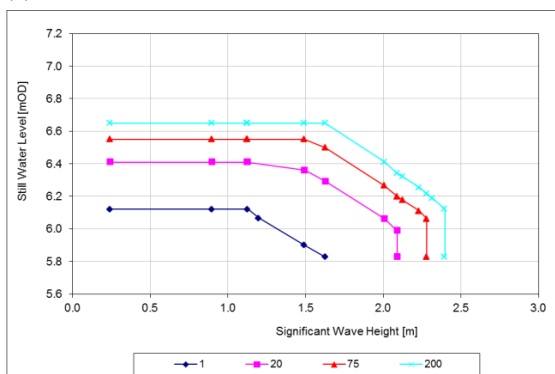
(d) 210°



(e) 180°



(f) 150°



(g) 120°

Figure G-22: Joint Probability Combinations of H_s and SWL (2020)

Table G-18: Joint Probability Combinations of Hs and SWL in Sector 300° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
1.12	6.12	6.41	6.55	6.65
2.42	6.12	6.41	6.55	6.65
2.88	6.12	6.41	6.55	6.65
2.93	6.07	6.41	6.55	6.65
3.69	5.90	6.36	6.55	6.65
3.96	5.83	6.29	6.50	6.65
4.73		6.06	6.26	6.41
4.96		5.99	6.20	6.34
4.96		5.83	6.20	6.34
5.04			6.18	6.32
5.35			6.11	6.25
5.49			6.06	6.22
5.49			5.83	6.22
5.60				6.19
5.81				6.12
5.81				5.83

Table G-19: Joint Probability Combinations of Hs and SWL in Sector 270° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
0.59	6.12	6.41	6.55	6.65
2.93	6.12	6.41	6.55	6.65
3.99	6.12	6.41	6.55	6.65
4.40	6.07	6.41	6.55	6.65
5.79	5.90	6.36	6.55	6.65
6.39	5.83	6.29	6.50	6.65
8.21		6.06	6.26	6.41
8.65		5.99	6.20	6.34
8.65		5.83	6.20	6.34
8.79			6.18	6.32
9.23			6.11	6.25
9.45			6.06	6.22
9.45			5.83	6.22
9.62				6.19
10.00				6.12
10.00				5.83

Table G-20: Joint Probability Combinations of Hs and SWL in Sector 240° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.39	6.12	6.41	6.55	6.65
2.36	6.12	6.41	6.55	6.65
3.26	6.12	6.41	6.55	6.65
3.51	6.07	6.41	6.55	6.65
4.66	5.90	6.36	6.55	6.65
5.17	5.83	6.29	6.50	6.65
6.63		6.06	6.26	6.41
6.96		5.99	6.20	6.34
6.96		5.83	6.20	6.34
7.09			6.18	6.32
7.44			6.11	6.25
7.64			6.06	6.22
7.64			5.83	6.22
7.79				6.19
8.13				6.12
8.13				5.83

Table G-21: Joint Probability Combinations of Hs and SWL in Sector 210° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
1.04	6.12	6.41	6.55	6.65
1.89	6.12	6.41	6.55	6.65
2.19	6.12	6.41	6.55	6.65
2.21	6.10	6.41	6.55	6.65
2.69	5.90	6.36	6.55	6.65
2.86	5.83	6.29	6.50	6.65
3.38		6.06	6.26	6.41
3.49		5.99	6.20	6.34
3.49		5.83	6.20	6.34
3.53			6.18	6.32
3.68			6.11	6.25
3.75			6.06	6.22
3.75			5.83	6.22
3.81				6.19
3.93				6.12
3.93				5.83

Table G-22: Joint Probability Combinations of Hs and SWL in Sector 180° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.62	6.12	6.41	6.55	6.65
1.32	6.12	6.41	6.55	6.65
1.60	6.12	6.41	6.55	6.65
1.65	6.07	6.41	6.55	6.65
1.99	5.90	6.36	6.55	6.65
2.15	5.83	6.29	6.50	6.65
2.58		6.06	6.26	6.41
2.67		5.99	6.20	6.34
2.67		5.83	6.20	6.34
2.70			6.18	6.32
2.83			6.11	6.25
2.88			6.06	6.22
2.88			5.83	6.22
2.93				6.19
3.04				6.12
3.04				5.83

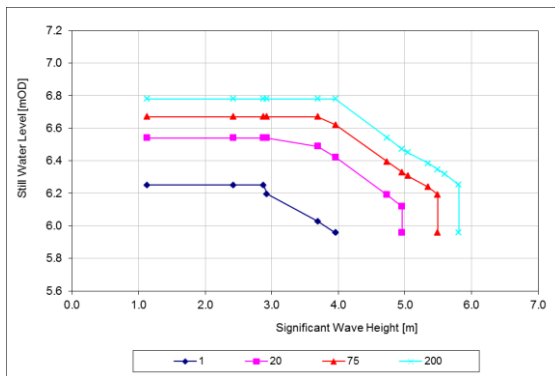
Table G-23: Joint Probability Combinations of Hs and SWL in Sector 150° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.25	6.12	6.41	6.55	6.65
1.07	6.12	6.41	6.55	6.65
1.35	6.12	6.41	6.55	6.65
1.40	6.07	6.41	6.55	6.65
1.81	5.90	6.36	6.55	6.65
1.97	5.83	6.29	6.50	6.65
2.45		6.06	6.26	6.41
2.56		5.99	6.20	6.34
2.56		5.83	6.20	6.34
2.60			6.18	6.32
2.73			6.11	6.25
2.79			6.06	6.22
2.79			5.83	6.22
2.84				6.19
2.96				6.12
2.96				5.83

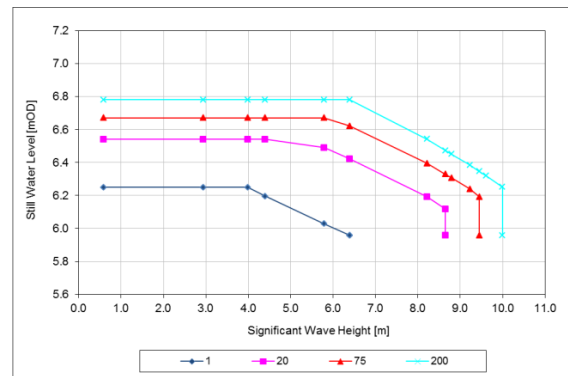
Table G-24: Joint Probability Combinations of Hs and SWL in Sector 120° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.24	6.12	6.41	6.55	6.65
0.90	6.12	6.41	6.55	6.65
1.13	6.12	6.41	6.55	6.65
1.13	6.07	6.41	6.55	6.65
1.49	5.90	6.36	6.55	6.65
1.63	5.83	6.29	6.50	6.65
2.01		6.06	6.26	6.41
2.09		5.99	6.20	6.34
2.09		5.83	6.20	6.34
2.13			6.18	6.32
2.23			6.11	6.25
2.28			6.06	6.22
2.28			5.83	6.22
2.32				6.19
2.40				6.12
2.40				5.83

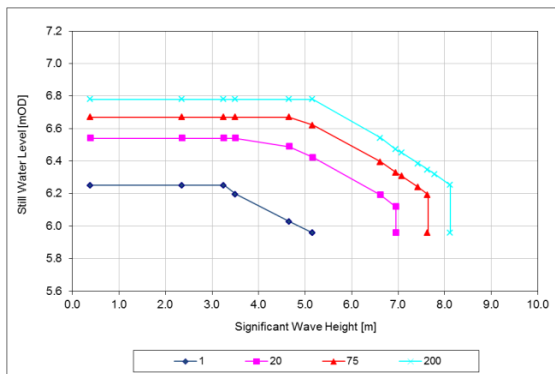
Epoch 2040



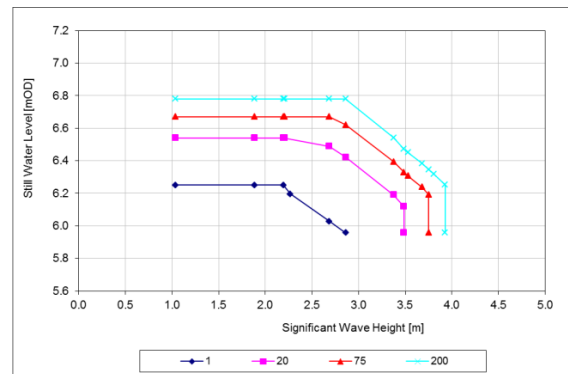
(a) 300°



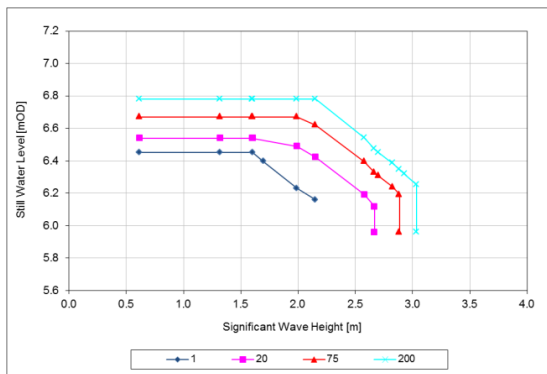
(b) 270°



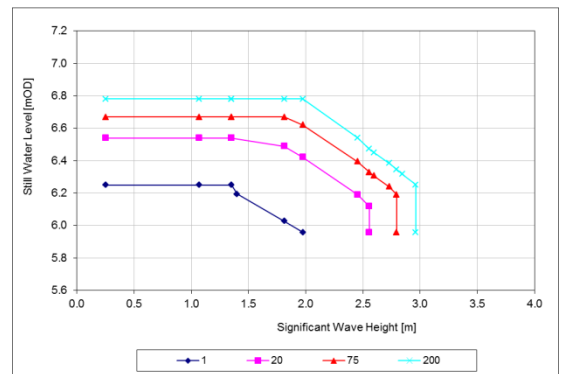
(c) 240°



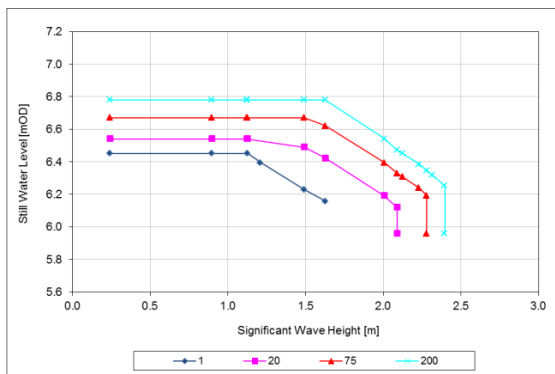
(d) 210°



(e) 180°



(f) 150°



(g) 120°

Figure G-23: Joint Probability Combinations of H_s and SWL (2040)

Table G-25: Joint Probability Combinations of Hs and SWL in Sector 300° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
1.12	6.25	6.54	6.67	6.78
2.42	6.25	6.54	6.67	6.78
2.88	6.25	6.54	6.67	6.78
2.93	6.19	6.54	6.67	6.78
3.69	6.03	6.49	6.67	6.78
3.96	5.96	6.42	6.62	6.78
4.73		6.19	6.39	6.54
4.96		6.12	6.33	6.47
4.96		5.96	6.33	6.47
5.04			6.31	6.45
5.35			6.24	6.38
5.49			6.19	6.35
5.49			5.96	6.35
5.60				6.32
5.81				6.25
5.81				5.96

Table G-26: Joint Probability Combinations of Hs and SWL in Sector 270° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
0.59	6.25	6.54	6.67	6.78
2.93	6.25	6.54	6.67	6.78
3.99	6.25	6.54	6.67	6.78
4.40	6.19	6.54	6.67	6.78
5.79	6.03	6.49	6.67	6.78
6.39	5.96	6.42	6.62	6.78
8.21		6.19	6.39	6.54
8.65		6.12	6.33	6.47
8.65		5.96	6.33	6.47
8.79			6.31	6.45
9.23			6.24	6.38
9.45			6.19	6.35
9.45			5.96	6.35
9.62				6.32
10.00				6.25
10.00				5.96

Table G-27: Joint Probability Combinations of Hs and SWL in Sector 240° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.39	6.25	6.54	6.67	6.78
2.36	6.25	6.54	6.67	6.78
3.26	6.25	6.54	6.67	6.78
3.51	6.19	6.54	6.67	6.78
4.66	6.03	6.49	6.67	6.78
5.17	5.96	6.42	6.62	6.78
6.63		6.19	6.39	6.54
6.96		6.12	6.33	6.47
7.09			6.31	6.45
7.44			6.24	6.38
7.64			6.19	6.35
7.79				6.32
8.13				6.25

Table G-28: Joint Probability Combinations of Hs and SWL in Sector 210° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
1.04	6.25	6.54	6.67	6.78
1.89	6.25	6.54	6.67	6.78
2.19	6.25	6.54	6.67	6.78
2.21	6.19	6.54	6.67	6.78
2.69	6.03	6.49	6.67	6.78
2.86	5.96	6.42	6.62	6.78
3.38		6.19	6.39	6.54
3.49		6.12	6.33	6.47
3.49		5.96	6.33	6.47
3.53			6.31	6.45
3.68			6.24	6.38
3.75			6.19	6.35
3.75			5.96	6.35
3.81				6.32
3.93				6.25
3.93				5.96

Table G-29: Joint Probability Combinations of Hs and SWL in Sector 180° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.62	6.25	6.54	6.67	6.78
1.32	6.25	6.54	6.67	6.78
1.60	6.25	6.54	6.67	6.78
1.65	6.19	6.54	6.67	6.78
1.99	6.03	6.49	6.67	6.78
2.15	5.96	6.42	6.62	6.78
2.58		6.19	6.39	6.54
2.67		6.12	6.33	6.47
2.67		5.96	6.33	6.47
2.70			6.31	6.45
2.83			6.24	6.38
2.88			6.19	6.35
2.88			5.96	6.35
2.93				6.32
3.04				6.25
3.04				5.96

Table G-30: Joint Probability Combinations of Hs and SWL in Sector 150° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.25	6.25	6.54	6.67	6.78
1.07	6.25	6.54	6.67	6.78
1.35	6.25	6.54	6.67	6.78
1.40	6.19	6.54	6.67	6.78
1.81	6.03	6.49	6.67	6.78
1.97	5.96	6.42	6.62	6.78
2.45		6.19	6.39	6.54
2.56		6.12	6.33	6.47
2.56		5.96	6.33	6.47
2.60			6.31	6.45
2.73			6.24	6.38
2.79			6.19	6.35
2.79			5.96	6.35
2.84				6.32
2.96				6.25
2.96				5.96

Table G-31: Joint Probability Combinations of Hs and SWL in Sector 120° (2040)

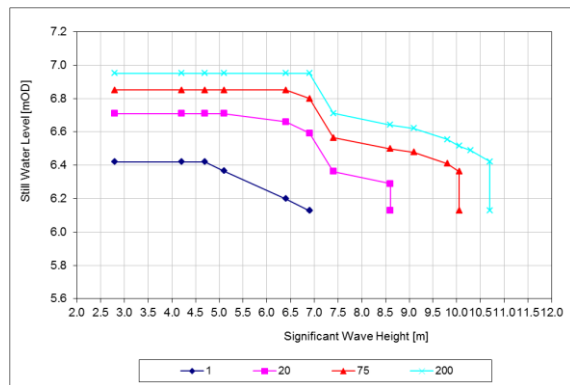
Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
0.24	6.45	6.74	6.87	6.98
0.90	6.45	6.74	6.87	6.98
1.13	6.45	6.74	6.87	6.98
1.21	6.39	6.74	6.87	6.98
1.49	6.23	6.69	6.87	6.98
1.63	6.16	6.62	6.82	6.98
2.01		6.39	6.59	6.74
2.09		6.32	6.53	6.67
2.09		6.16	6.53	6.67
2.13			6.51	6.65
2.23			6.44	6.58
2.28			6.39	6.55
2.28			6.16	6.55
2.32				6.52
2.40				6.45
2.28				6.16

G.2.5 Model D

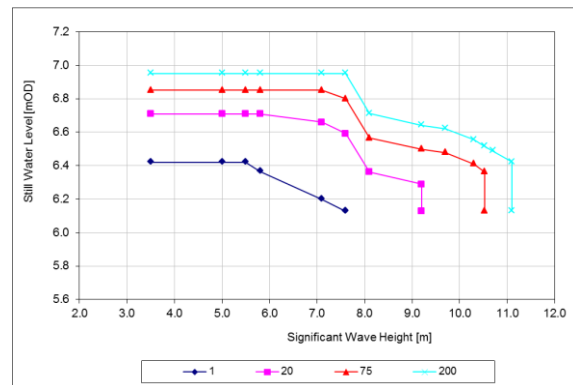
Table G-32: Marginal Extreme Combinations of Hs/wind speed and SWL (Model D)

RP (yrs)	Significant Wave Height Hs (m)		Wind Speed (m/s)		Still Water Level (m AOD)	
	270°	240°	150°	90°	2020	2040
1	6.90	7.60	16.70	16.50	6.42	6.55
10	7.40	8.10	17.80	17.30	6.64	6.77
20	8.60	9.20	20.20	19.00	6.71	6.84
25	9.10	9.70	21.20	19.70	6.73	6.86
50	9.80	10.30	22.30	20.60	6.81	6.93
75	10.06	10.52	22.81	20.94	6.85	6.97
100	10.30	10.70	23.10	21.20	6.88	7.00
200	10.70	11.10	24.00	21.80	6.95	7.08
1000	11.94	12.24	26.35	23.53	7.12	7.25

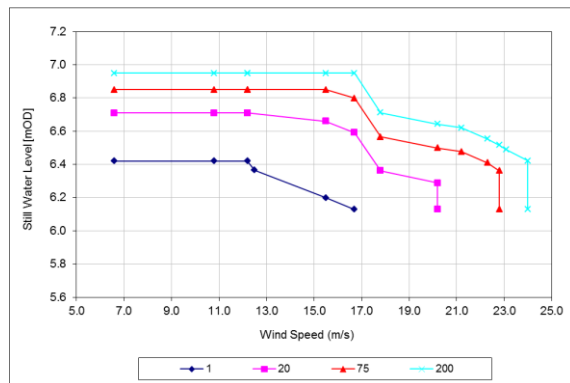
Epoch 2020



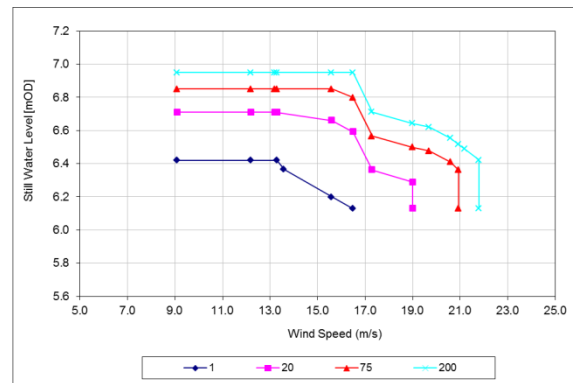
(a) 270°



(b) 240°



(c) 150°



(d) 90°

Figure G-24: Joint Probability Combinations of Hs/Wind Speed and SWL (2020)

Table G-33: Joint Probability Combinations of Hs and SWL in Sector 270° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
2.80	6.42	6.71	6.85	6.95
4.20	6.42	6.71	6.85	6.95
4.70	6.42	6.71	6.85	6.95
5.10	6.37	6.71	6.85	6.95
6.40	6.20	6.66	6.85	6.95
6.90	6.13	6.59	6.80	6.95
7.40		6.36	6.56	6.71
8.60		6.29	6.50	6.64
8.60		6.13	6.50	6.64
9.10			6.48	6.62
9.80			6.41	6.55
10.06			6.36	6.52
10.06			6.13	6.52
10.30				6.49
10.70				6.42
10.70				6.13

Table G-34: Joint Probability Combinations of Hs and SWL in Sector 240° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
3.50	6.42	6.71	6.85	6.95
5.00	6.42	6.71	6.85	6.95
5.50	6.42	6.71	6.85	6.95
5.80	6.37	6.71	6.85	6.95
7.10	6.20	6.66	6.85	6.95
7.60	6.13	6.59	6.80	6.95
8.10		6.36	6.56	6.71
9.20		6.29	6.50	6.64
9.70			6.48	6.62
10.30			6.41	6.55
10.52			6.36	6.52
10.70				6.49
11.10				6.42

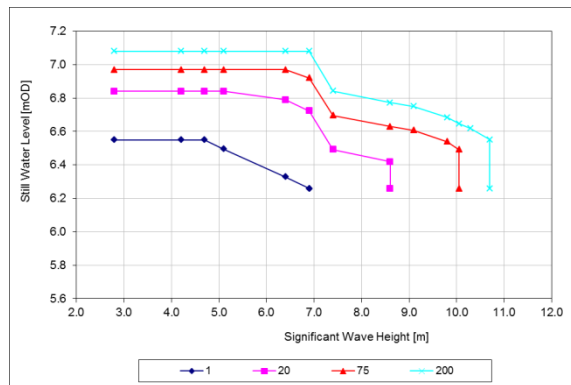
Table G-35: Joint Probability Combinations of wind speed and SWL in Sector 150° (2020)

Wind Speed (m/s)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
6.60	6.42	6.71	6.85	6.95
10.80	6.42	6.71	6.85	6.95
12.20	6.42	6.71	6.85	6.95
12.50	6.37	6.71	6.85	6.95
15.50	6.20	6.66	6.85	6.95
16.70	6.13	6.59	6.80	6.95
17.80		6.36	6.56	6.71
20.20		6.29	6.50	6.64
20.20		6.13	6.50	6.64
21.20			6.48	6.62
22.30			6.41	6.55
22.81			6.36	6.52
22.81			6.13	6.52
23.10				6.49
24.00				6.42
24.00				6.13

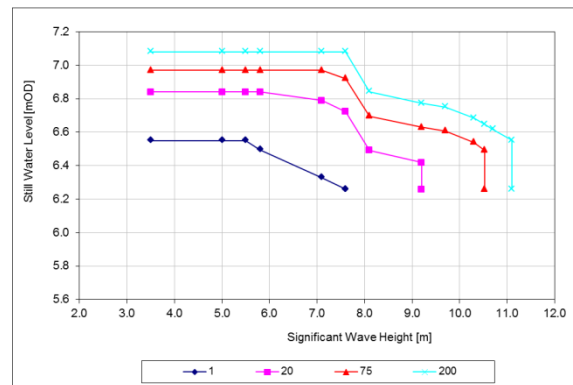
Table G-36: Joint Probability Combinations of wind speed and SWL in Sector 90° (2020)

Wind Speed (m/s)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
9.10	6.42	6.71	6.85	6.95
12.20	6.42	6.71	6.85	6.95
13.30	6.42	6.71	6.85	6.95
13.60	6.37	6.71	6.85	6.95
15.60	6.20	6.66	6.85	6.95
16.50	6.13	6.59	6.80	6.95
17.30		6.36	6.56	6.71
19.00		6.29	6.50	6.64
19.00		6.13	6.50	6.64
19.70			6.48	6.62
20.60			6.41	6.55
20.94			6.36	6.52
20.94			6.13	6.52
21.20				6.49
21.80				6.42
21.80				6.13

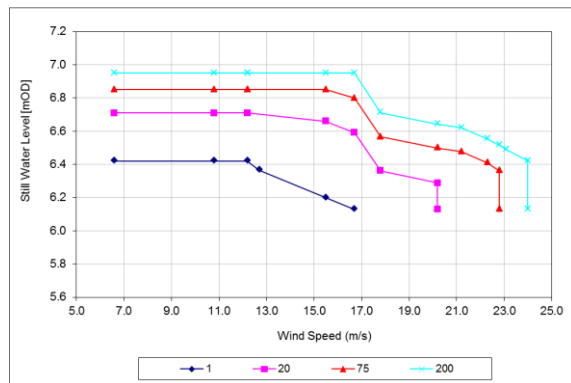
Epoch 2040



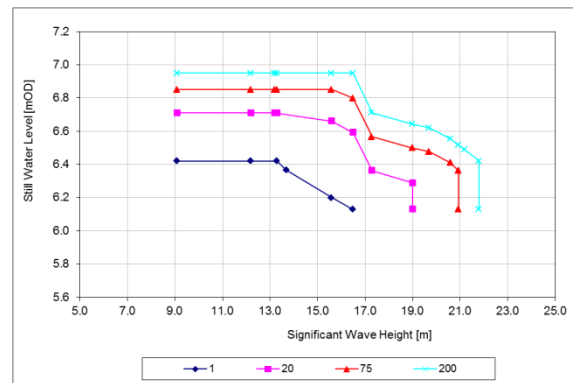
(a) 270°



(b) 240°



(c) 150°



(d) 90°

Figure G-25: Joint Probability Combinations of Hs/wind speed and SWL (2040)

Table G-37: Joint Probability Combinations of Hs and SWL in Sector 270° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
2.80	6.55	6.84	6.97	7.08
4.20	6.55	6.84	6.97	7.08
4.70	6.55	6.84	6.97	7.08
5.10	6.49	6.84	6.97	7.08
6.40	6.33	6.79	6.97	7.08
6.90	6.26	6.72	6.92	7.08
7.40		6.49	6.69	6.84
8.60		6.42	6.63	6.77
8.60		6.26	6.63	6.77
9.10			6.61	6.75
9.80			6.54	6.68
10.06			6.49	6.65
10.06			6.26	6.65
10.30				6.62
10.70				6.55
10.70				6.26

Table G-38: Joint Probability Combinations of Hs and SWL in Sector 240° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
3.50	6.55	6.84	6.97	7.08
5.00	6.55	6.84	6.97	7.08
5.50	6.55	6.84	6.97	7.08
5.80	6.49	6.84	6.97	7.08
7.10	6.33	6.79	6.97	7.08
7.60	6.26	6.72	6.92	7.08
8.10		6.49	6.69	6.84
9.20		6.42	6.63	6.77
9.70			6.61	6.75
10.30			6.54	6.68
10.52			6.49	6.65
10.70				6.62
11.10				6.55

Table G-39: Joint Probability Combinations of Wind Speed and SWL in Sector 150° (2040)

Wind Speed (m/s)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
6.60	6.42	6.71	6.85	6.95
10.80	6.42	6.71	6.85	6.95
12.20	6.42	6.71	6.85	6.95
12.70	6.37	6.71	6.85	6.95
15.50	6.20	6.66	6.85	6.95
16.70	6.13	6.59	6.80	6.95
17.80		6.36	6.56	6.71
20.20		6.29	6.50	6.64
20.20		6.13	6.50	6.64
21.20			6.48	6.62
22.30			6.41	6.55
22.81			6.36	6.52
22.81			6.13	6.52
23.10				6.49
24.00				6.42
24.00				6.13

Table G-40: Joint Probability Combinations of Wind Speed and SWL in Sector 90° (2040)

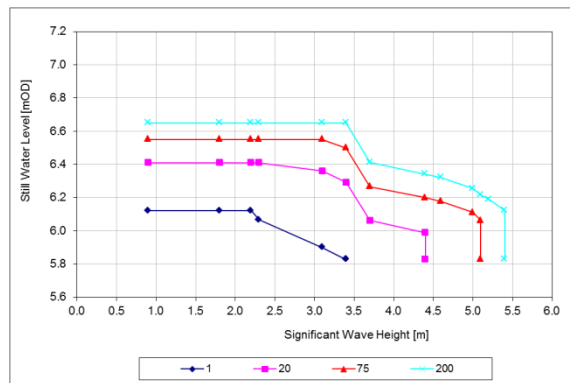
Wind Speed (m/s)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
9.10	6.42	6.71	6.85	6.95
12.20	6.42	6.71	6.85	6.95
13.30	6.42	6.71	6.85	6.95
13.70	6.37	6.71	6.85	6.95
15.60	6.20	6.66	6.85	6.95
16.50	6.13	6.59	6.80	6.95
17.30		6.36	6.56	6.71
19.00		6.29	6.50	6.64
19.00		6.13	6.50	6.64
19.70			6.48	6.62
20.60			6.41	6.55
20.94			6.36	6.52
20.94			6.13	6.52
21.20				6.49
21.80				6.42
21.80				6.13

G.2.6 Model E

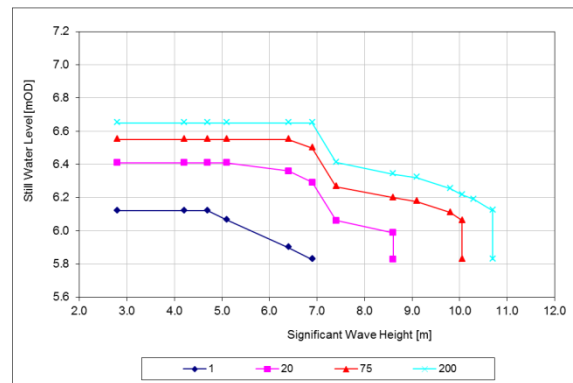
Table G-41: Marginal Extreme Combinations of Hs and SWL (Model E)

RP (yrs)	Significant Wave Height Hs (m)				Still Water Level (m AOD)	
	300°	270°	240°	210°	2020	2040
1	3.40	6.90	7.60	4.60	6.12	6.25
10	3.70	7.40	8.10	5.00	6.34	6.47
20	4.40	8.60	9.20	5.70	6.41	6.54
25	4.60	9.10	9.70	6.00	6.43	6.56
50	5.00	9.80	10.30	6.30	6.51	6.63
75	5.10	10.06	10.52	6.47	6.55	6.67
100	5.20	10.30	10.70	6.60	6.58	6.70
200	5.40	10.70	11.10	6.80	6.65	6.78
1000	6.08	11.94	12.24	7.54	6.82	6.95

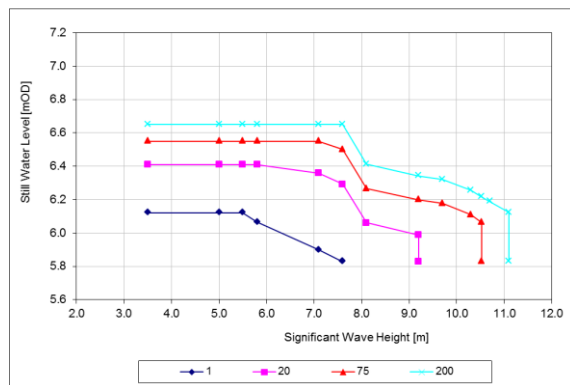
Epoch 2020



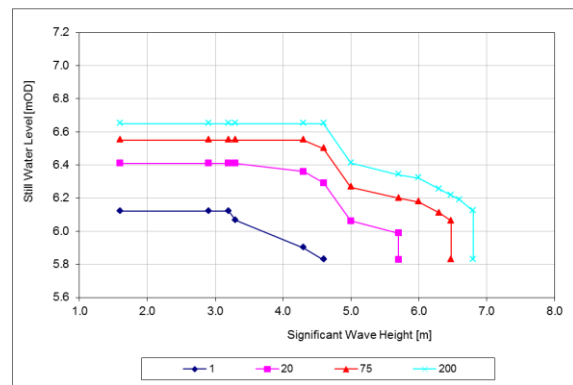
(a) 300°



(b) 270°



(c) 240°



(d) 210°

Figure G-26: Joint Probability Combinations of Hs and SWL (2020)

Table G-42: Joint Probability Combinations of Hs and SWL in Sector 300° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
0.90	6.12	6.41	6.55	6.65
1.80	6.12	6.41	6.55	6.65
2.20	6.12	6.41	6.55	6.65
2.30	6.07	6.41	6.55	6.65
3.10	5.90	6.36	6.55	6.65
3.40	5.83	6.29	6.50	6.65
3.70		6.06	6.26	6.41
4.40		5.99	6.20	6.34
4.40		5.83	6.20	6.34
4.60			6.18	6.32
5.00			6.11	6.25
5.10			6.06	6.22
5.10			5.83	6.22
5.20				6.19
5.40				6.12
5.40				5.83

Table G-43: Joint Probability Combinations of Hs and SWL in Sector 270° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
2.80	6.12	6.41	6.55	6.65
4.20	6.12	6.41	6.55	6.65
4.70	6.12	6.41	6.55	6.65
5.10	6.07	6.41	6.55	6.65
6.40	5.90	6.36	6.55	6.65
6.90	5.83	6.29	6.50	6.65
7.40		6.06	6.26	6.41
8.60		5.99	6.20	6.34
8.60		5.83	6.20	6.34
9.10			6.18	6.32
9.80			6.11	6.25
10.06			6.06	6.22
10.06			5.83	6.22
10.30				6.19
10.70				6.12
10.70				5.83

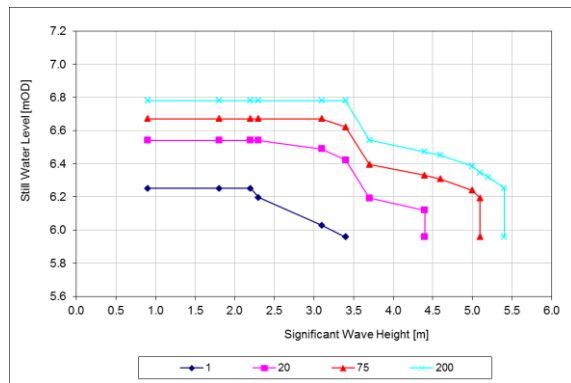
Table G-44: Joint Probability Combinations of Hs and SWL in Sector 240° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
3.50	6.12	6.41	6.55	6.65
5.00	6.12	6.41	6.55	6.65
5.50	6.12	6.41	6.55	6.65
5.80	6.07	6.41	6.55	6.65
7.10	5.90	6.36	6.55	6.65
7.60	5.83	6.29	6.50	6.65
8.10		6.06	6.26	6.41
9.20		5.99	6.20	6.34
9.20		5.83	6.20	6.34
9.70			6.18	6.32
10.30			6.11	6.25
10.52			6.06	6.22
10.52			5.83	6.22
10.70				6.19
11.10				6.12
11.10				5.83

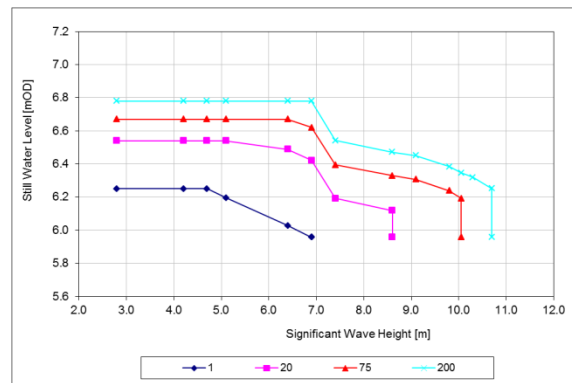
Table G-45: Joint Probability Combinations of Hs and SWL in Sector 210° (2020)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
1.60	6.12	6.41	6.55	6.65
2.90	6.12	6.41	6.55	6.65
3.20	6.12	6.41	6.55	6.65
3.30	6.07	6.41	6.55	6.65
4.30	5.90	6.36	6.55	6.65
4.60	5.83	6.29	6.50	6.65
5.00		6.06	6.26	6.41
5.70		5.99	6.20	6.34
5.70		5.83	6.20	6.34
6.00			6.18	6.32
6.30			6.11	6.25
6.47			6.06	6.22
6.47			5.83	6.22
6.60				6.19
6.80				6.12
6.80				5.83

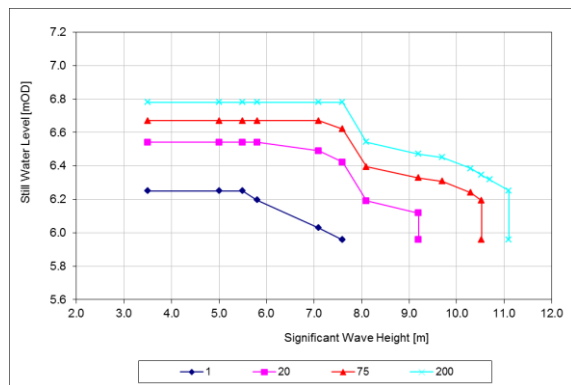
Epoch 2040



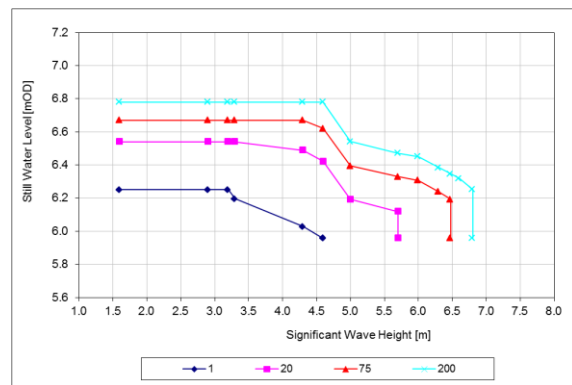
(a) 300°



(b) 270°



(c) 240°



(d) 210°

Figure G-27: Joint Probability Combinations of Hs and SWL (2040)

Table G-46: Joint Probability Combinations of Hs and SWL in Sector 300° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
0.90	6.25	6.54	6.67	6.78
1.80	6.25	6.54	6.67	6.78
2.20	6.25	6.54	6.67	6.78
2.30	6.19	6.54	6.67	6.78
3.10	6.03	6.49	6.67	6.78
3.40	5.96	6.42	6.62	6.78
3.70		6.19	6.39	6.54
4.40		6.12	6.33	6.47
4.40		5.96	6.33	6.47
4.60			6.31	6.45
5.00			6.24	6.38
5.10			6.19	6.35
5.10			5.96	6.35
5.20				6.32
5.40				6.25
5.40				5.96

Table G-47: Joint Probability Combinations of Hs and SWL in Sector 270° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (mOD)			
2.80	6.25	6.54	6.67	6.78
4.20	6.25	6.54	6.67	6.78
4.70	6.25	6.54	6.67	6.78
5.10	6.19	6.54	6.67	6.78
6.40	6.03	6.49	6.67	6.78
6.90	5.96	6.42	6.62	6.78
7.40		6.19	6.39	6.54
8.60		6.12	6.33	6.47
8.60		5.96	6.33	6.47
9.10			6.31	6.45
9.80			6.24	6.38
10.06			6.19	6.35
10.06			5.96	6.35
10.30				6.32
10.70				6.25
10.70				5.96

Table G-48: Joint Probability Combinations of Hs and SWL in Sector 240° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
3.50	6.25	6.54	6.67	6.78
5.00	6.25	6.54	6.67	6.78
5.50	6.25	6.54	6.67	6.78
5.80	6.19	6.54	6.67	6.78
7.10	6.03	6.49	6.67	6.78
7.60	5.96	6.42	6.62	6.78
8.10		6.19	6.39	6.54
9.20		6.12	6.33	6.47
9.20		5.96	6.33	6.47
9.70			6.31	6.45
10.30			6.24	6.38
10.52			6.19	6.35
10.52			5.96	6.35
10.70				6.32
11.13				6.25
11.13				5.96

Table G-49: Joint Probability Combinations of Hs and SWL in Sector 210° (2040)

Hs (m)	Joint Exceedance Return Period (years)			
	1	20	75	200
	Still Water Level (m AOD)			
1.60	6.25	6.54	6.67	6.78
2.90	6.25	6.54	6.67	6.78
3.20	6.25	6.54	6.67	6.78
3.30	6.19	6.54	6.67	6.78
4.30	6.03	6.49	6.67	6.78
4.60	5.96	6.42	6.62	6.78
5.00		6.19	6.39	6.54
5.70		6.12	6.33	6.47
5.70		5.96	6.33	6.47
6.00			6.31	6.45
6.30			6.24	6.38
6.47			6.19	6.35
6.47			5.96	6.35
6.60				6.32
6.80				6.25
6.80				5.96

G.3 Wave Overtopping Assessment

G.3.1 Overtopping Rate

Wave overtopping calculations for the coastal defence structures were undertaken to identify the level of risk from coastal flooding for a range of return periods. The calculations have been carried out using EurOtop (2018) 'Manual on wave overtopping of Sea Defences and Related Structures' to determine the overtopping discharge (l/s/m) along the Jersey coastal frontages.

At present, the EurOtop guidance (2018) is regarded as best practice within the industry. The required inputs to the calculation vary according to structure type. For the vertical wall and the revetments, the inputs typically consist of:

- significant wave height (m);
- mean wave period (s);
- wave direction;
- structure freeboard (m);
- water depth at the structure toe (m);
- revetment slope.

For the cross-section identified in Figure G-28, the typical geometry of the defence structure (crest height, bed level, slope etc.) was established using the detailed topographical survey information. The estimated wave overtopping rates based on EurOtop (2018) are presented in Table G-50 to Table G-55 for a range of Annual Exceedance Probabilities (AEP).

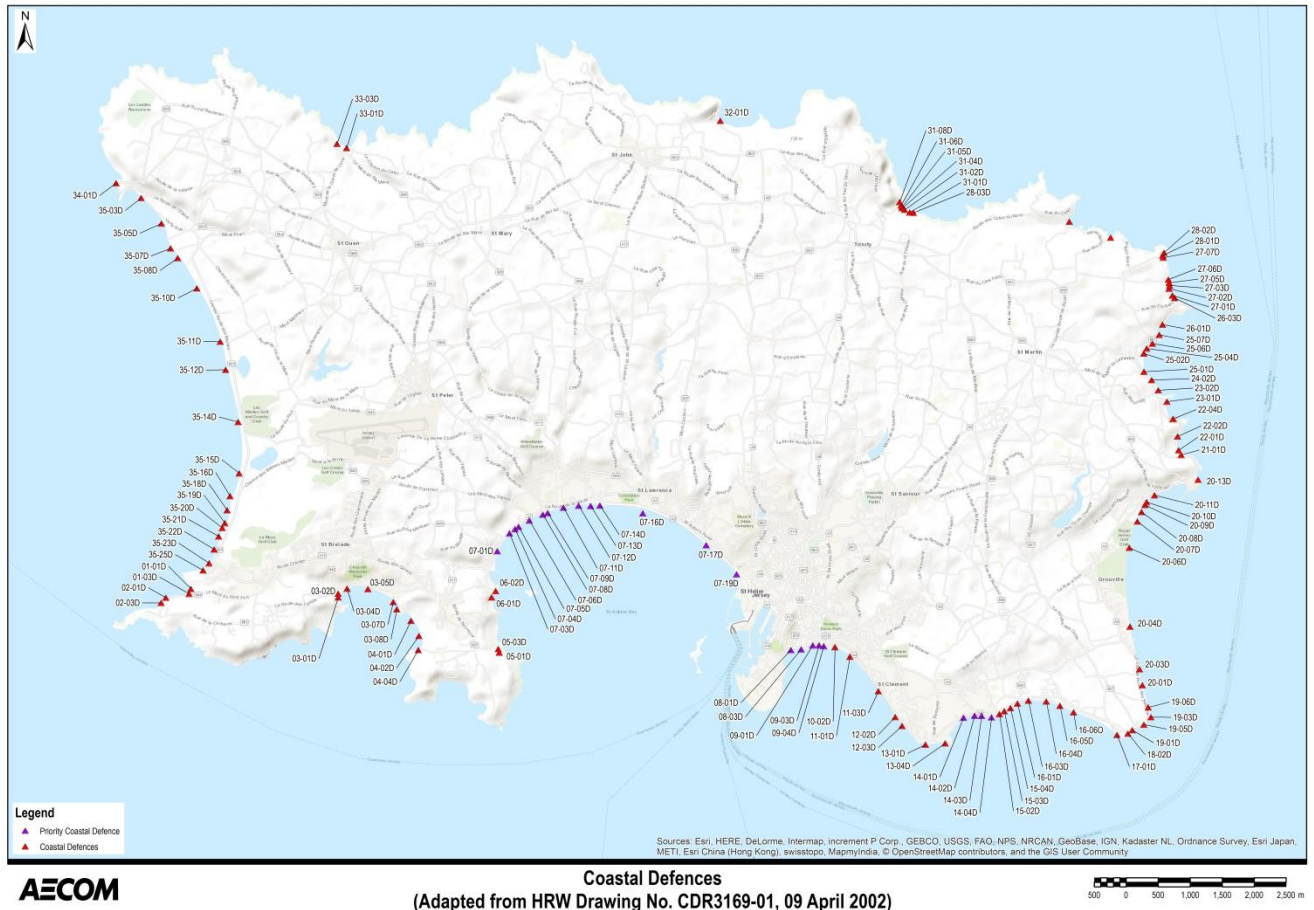


Figure G-28: Cross Sections

Table G-50: Maximum Overtopping Rates (l/s/m) at Area 07 (2020)

AEP	07-01	07-03	07-05	07-06	07-08	07-11a	07-11b	07-12	07-13	07-14	07-16	07-17
100%	0.9	12.3	6.1	7.1	13.9	6.8	0.2	0.3	24.0	3.5	36.3	133.4
5%	13.7	41.3	17.8	17.0	36.0	38.4	1.8	0.8	94.9	11.7	94.1	318.0
1.33%	28.8	59.5	37.3	34.4	63.6	69.5	2.8	0.9	142.3	18.7	124.9	388.4
0.50%	42.2	92.1	49.9	57.7	84.3	116.4	3.4	1.3	169.4	23.0	158.0	462.3

Table G-51: Maximum Overtopping Rates (l/s/m) at Area 07 (2040)

AEP	07-01	07-03	07-05	07-06	07-08	07-11a	07-11b	07-12	07-13	07-14	07-16	07-17
100%	1.3	19.1	8.5	9.3	17.1	10.3	0.4	0.4	36.9	5.0	41.8	153.1
5%	17.7	49.9	28.1	25.9	53.6	54.3	3.1	0.8	132.1	15.3	111.5	374.4
1.33%	35.5	84.9	47.8	52.0	81.2	106.5	4.7	1.2	165.3	22.4	152.2	449.1
0.50%	52.3	117.1	61.7	71.3	104.6	141.6	5.5	1.7	214.3	25.7	198.1	519.9

Table G-52: Maximum overtopping rates (l/s/m) at Area 08, 11, 12 and 35 (2020)

AEP	08-01	08-03	11-01	11-03	12-02	12-03	35-11	35-12	35-14	35-15	35-16
100%	25.4	95.6	7.7	0.0	1.0	0.5	24.5	17.8	56.9	11.6	0.3
5%	112.2	242.2	22.5	0.5	5.7	3.2	66.1	53.6	108.9	25.7	2.0
1.33%	169.8	317.4	39.7	1.1	10.7	7.0	109.8	85.3	153.7	41.1	4.4
0.50%	215.8	391.7	57.7	1.7	16.3	12.0	96.3	117.9	192.4	56.1	7.7

Table G-53: Maximum overtopping rates (l/s/m) at Area 08, 11, 12 and 35 (2040)

AEP	08-01	08-03	11-01	11-03	12-02	12-03	35-11	35-12	35-14	35-15	35-16
100%	34.6	102.3	10.9	0.1	1.7	1.1	36.4	30.3	74.4	16.3	0.6
5%	141.5	273.7	31.6	0.8	8.5	5.5	93.9	80.3	138.4	35.5	3.5
1.33%	209.1	365.3	53.5	1.6	15.0	10.8	141.4	117.6	188.1	55.0	7.0
0.50%	261.2	442.9	75.8	2.6	22.7	18.4	135.0	161.4	237.2	76.2	11.9

Table G-54: Maximum overtopping rates (l/s/m) at Area 03, 14 19, 20 and 24 (2020)

AEP	03-05	03-07	14-01	14-04	19-03	19-05	19-06	20-01	20-06	20-07	24-02
100%	2.3	2.6	210.4	386.0	6.7	19.9	42.4	179.1	61.5	1.8	78.2
5%	9.5	7.7	512.7	832.3	15.2	82.0	177.4	464.3	145.6	4.9	274.6
1.33%	21.3	14.3	719.9	1148.9	23.2	163.0	299.9	636.9	189.5	7.5	481.5
0.50%	35.1	21.0	902.3	1434.9	27.4	203.1	430.6	792.8	260.4	11.3	630.8

Table G-55: Maximum overtopping rates (l/s/m) at Area 03, 14 19, 20 and 24 (2040)

AEP	03-05	03-07	14-01	14-04	19-03	19-05	19-06	20-01	20-06	20-07	24-02
100%	4.4	4.2	279.5	509.7	7.5	23.8	54.4	240.7	83.2	2.7	74.3
5%	16.6	11.9	635.0	1044.6	17.3	96.2	263.2	565.8	171.5	6.1	292.6
1.33%	35.4	21.1	861.4	1379.3	26.4	188.7	399.0	768.2	254.3	11.0	509.1
0.50%	58.7	31.8	1082.9	1718.9	30.9	234.6	534.3	1030.8	342.3	21.1	693.8

G.3.2 Water Level Profile

Water level profiles are required to provide an estimate of the duration of a flood inundation event occurring along the coastal frontage. In this study, the water level profiles at Jersey were derived by averaging the water level measurements of the top 5 of storm events at St Helier tide gauge. Figure G-29 and Figure G-30 show typical high water level variations with time over a tidal cycle for the present day (2020) and climate change scenario (2040) including appropriate adjustments for sea level rise.

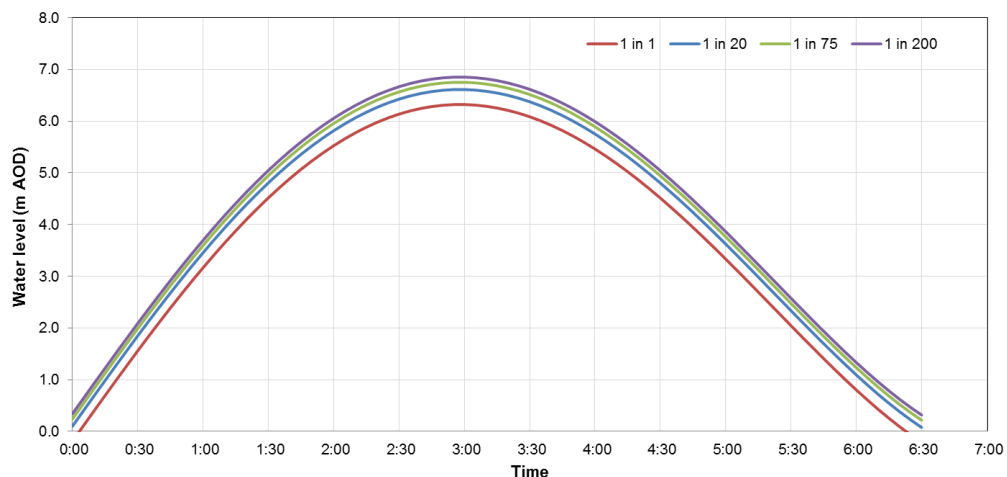


Figure G-29: Water Level Profiles (2020)

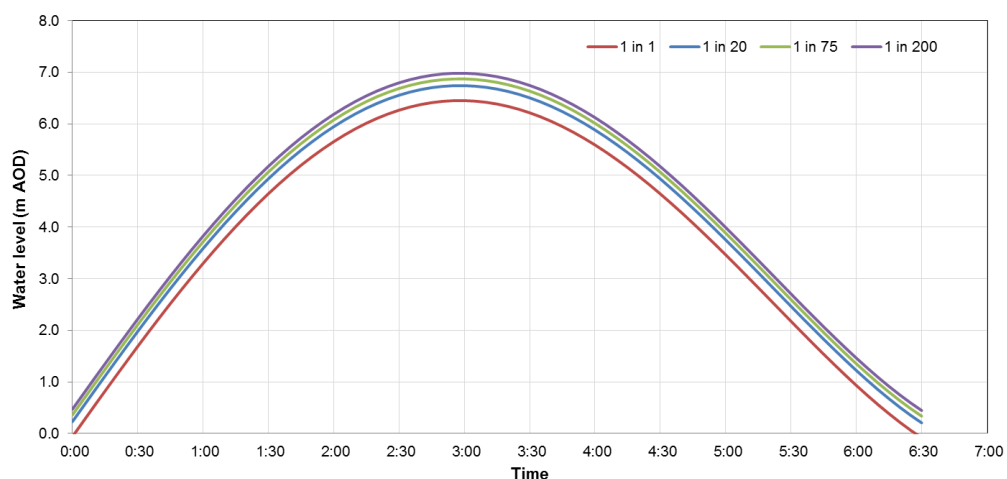


Figure G-30: Water Level Profiles (2040)

G.3.3 Wave overtopping rates after beach erosion

Extrapolation of the historic extreme lowering rate for the 2040 epoch results in beach lowering within three priority regions (Figure G-31) as follows:

- Priority Region 2 (St Aubin's – "Le St Aubin's Bay, First Tower to West Park"): -0.15 m
- Priority Region 3 (St Aubin's – "St Aubin's Bay, St Aubin's Harbour to Gunsite Slip"): -0.30 m
- Priority Region 4 (St Clement – "Bay of Fountains, Le Nez Point to Le Hocq Point"): -0.15 m

The wave models have been re-built and re-run using the proposed lower bed levels along the coastline in St Aubin's Bay and St Clement. Wave conditions (significant wave height, period and direction) in 2040 were extracted to provide inputs for the calculation of wave overtopping. The maximum overtopping rates are given in Table G-56. The wave overtopping rates are shown to increase by approximately 10% in Region 2 and Region 3, whilst increasing to 5% in Region 4 on average.

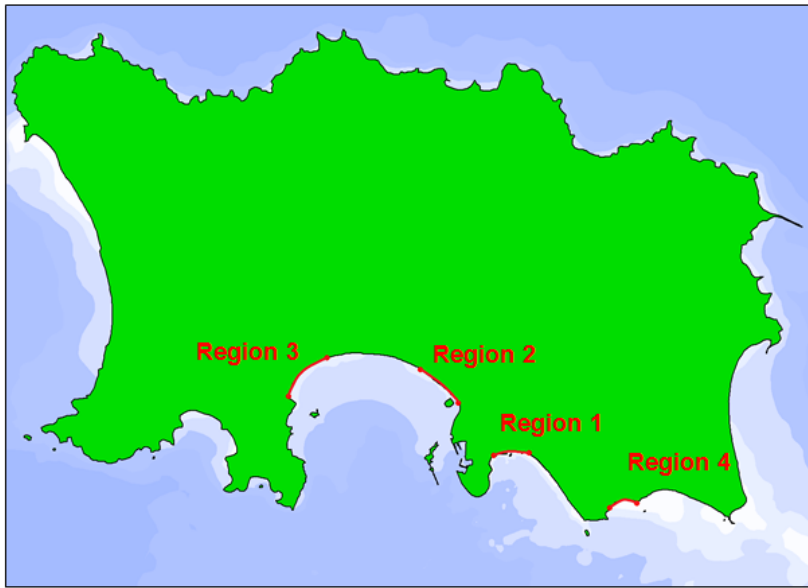


Figure G-31: High Priority Regions

Table G-56: Maximum Overtopping Rates (l/s/m) (lowered beach, 2040)

AEP	07-01	07-03	07-05	07-06	07-08	07-12	07-13	07-14	07-16	07-17	14-01	14-04
100%	1.3	22.1	9.1	13.2	17.5	0.5	50.0	7.5	43.5	172.5	295.4	557.6
5%	17.8	66.2	35.8	35.8	61.7	1.0	135.6	20.3	129.6	387.1	662.0	1107.2
1.33%	35.7	94.2	52.0	59.3	88.6	1.6	178.6	23.2	179.6	460.9	886.1	1439.9
0.50%	52.6	117.7	73.7	81.7	124.7	2.2	255.8	33.1	230.5	520.3	1102.9	1780.1

G.4 References

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