XLINKS' MOROCCO-UK POWER PROJECT

Environmental Statement

Volume 3, Appendix 8.2: Wave and Tidal Conditions

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Prepared for:

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Glossary

Term	Meaning
Proposed Development	The element of Xlinks' Morocco-UK Power Project within the UK. The Proposed Development covers all works required to construct and operate the offshore cables (from the UK Exclusive Economic Zone to Landfall), Landfall, onshore Direct Current and Alternating Current cables, converter stations, and highways improvements.
Significant Wave Height	Average height of the largest 1/3 of waves.
Weibull Distribution	A continuous probability distribution.

Acronyms

Acronym	Meaning
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CCO	Channel Coast Observatory
DHI	Danish Hydraulic Institute
EVA	Extreme Values Analysis
GDAS	Global Data Assimilation System
NOAA	National Oceanic and Atmospheric Administration
Hs	Significant Wave Height
ODN	Ordnance Datum Newlyn
SW	Spectral Wave
UKHO	United Kingdom Hydrographic Office

Units

Units	Meaning
m	Metres
km	Kilometre

1 WAVE AND TIDAL CONDITIONS

1.1 Introduction

1.1.1 This technical note provides a review and interpretation of available wave and tidal data required to carry out the Environmental Statement Physical Processes assessment (see Volume 3, Chapter 8: Physical Processes of the ES) for Xlinks' Morocco-UK Power Project. The purpose is to gain an understanding of the wave and tidal conditions along and around the proposed cable route.

1.1.2 Measured and modelled wave data has been compiled from a range of sources, covering the offshore and nearshore locations along the proposed cable route between Bideford Bay and the Isles of Scilly, shown in **Plate 1-1**.

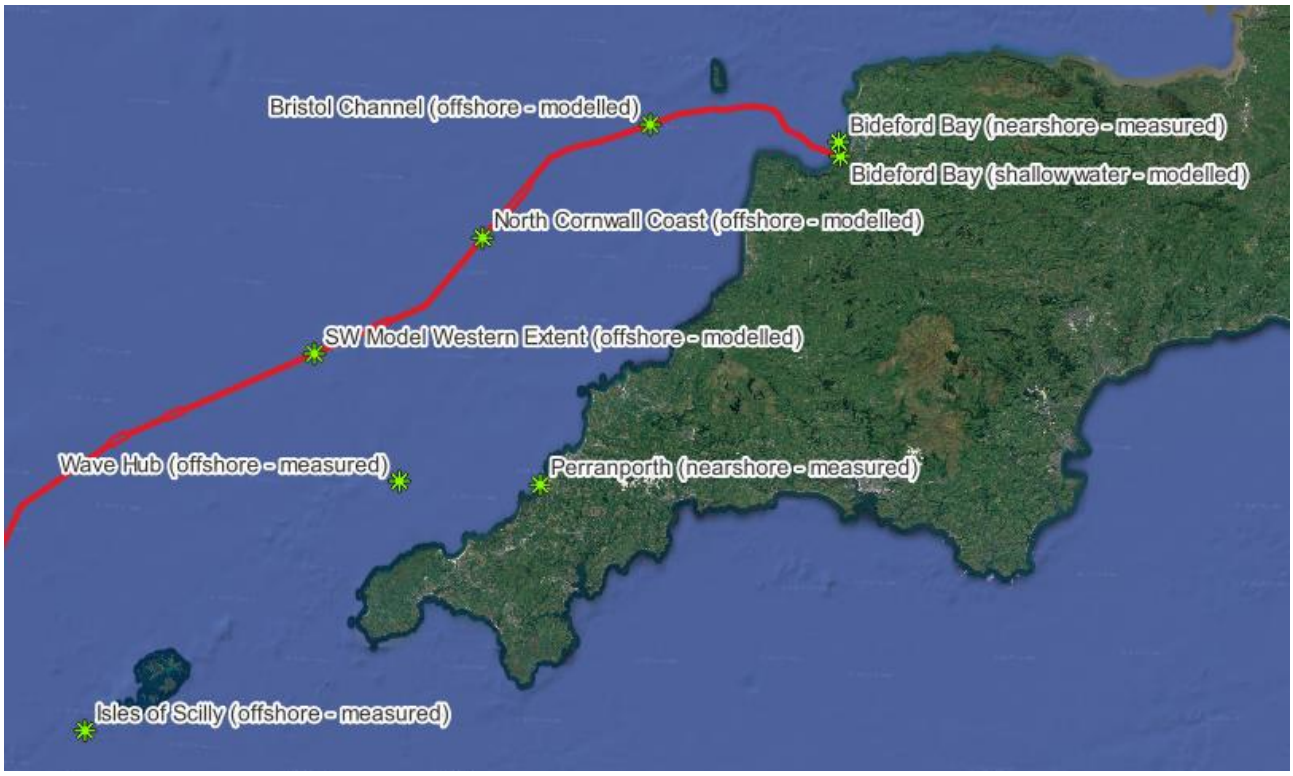

Plate 1-1 Location of Wave Data Sources

1.1.3 Measured wave data has been obtained from the Channel Coast Observatory (CCO) and Centre for Environment, Fisheries and Aquaculture Science (CEFAS) wave buoys. Modelled data has been obtained from an existing WSP regional Spectral Wave (SW) model (built in MIKE21 by Danish Hydraulic Institute (DHI)) covering the Severn Estuary and Bristol Channel, and the ABPmer Renewables Atlas model. Tidal data has been obtained from the ABPmer Renewables Atlas model, DHI Global Tide model, and United Kingdom Hydrographic Office (UKHO) Admiralty Total Tide.

1.2 WSP Regional Wave Model

1.2.1 The model domain illustrated in **Plate 1-2** covers the entire Bristol Channel and Severn Estuary and has an open 'forcing' boundary to the West. The offshore boundary is approximately between 120000E, 30000N and 130000E, 240000N.

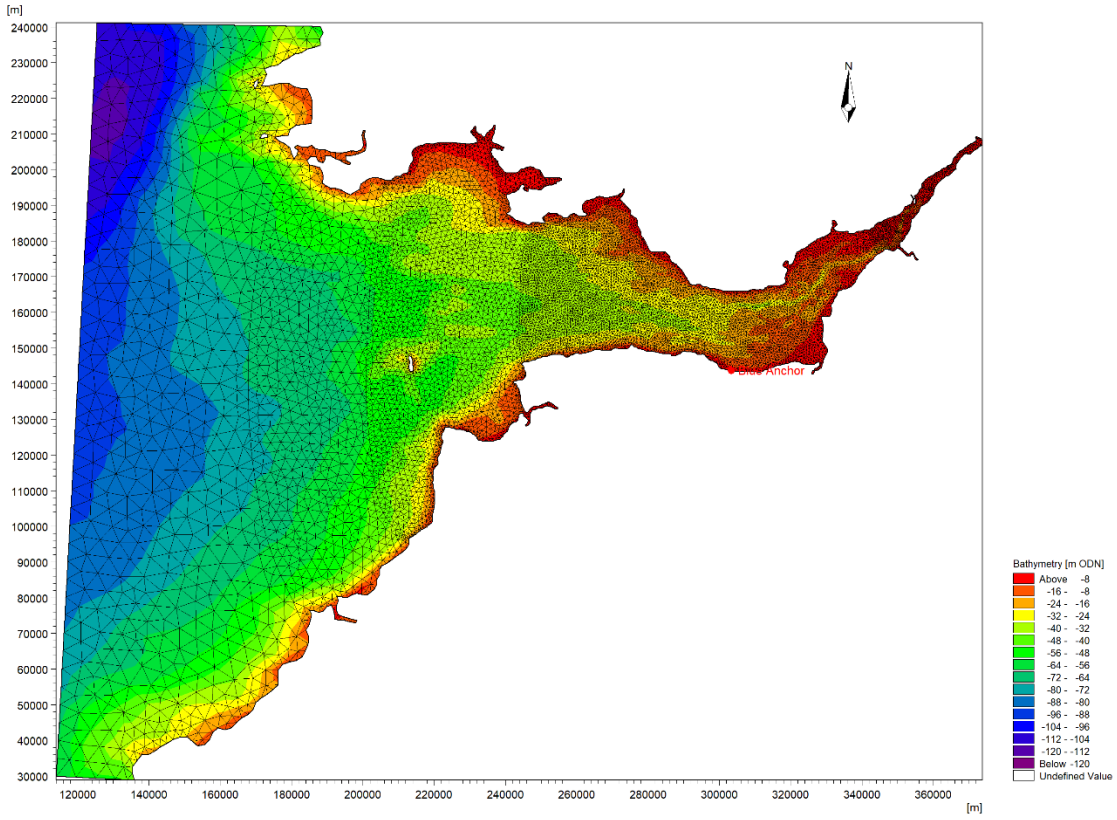

Plate 1-2 WSP Regional Bristol Channel Model Domain (Bathymetry m ODN)

1.2.2 The model boundary conditions were applied along the western edge of the model domain. Wave conditions were extracted from the from National Oceanic and Atmospheric Administration (NOAA) Global Wave Database at position 92700E,177100N. Information was available for the period 1979 to June 2019 (40.5 years).

1.2.3 The operational wave forecasting systems at NOAA are based on the WAVEWATCH III model which is a third-generation wave model and solves the random phase spectral action density balance equation for wave direction spectra. Wind data in the model was obtained from the Global Data Assimilation System (GDAS) for the Global Forecast System. The WAVEWATCH III model consists of global and regional nested grids. This system has a 0.5-degree resolution in UK waters.

1.3 Data Sources

1.3.1 **Table 1-1** details the locations, sources, bed levels, and durations of the various wave data obtained for this study (as shown on **Plate 1-1**).

Table 1-1 Details of Wave Data Sources

Name	Location (Easting, Northing)	Approximate Location (Description)	Source	Approximate Bed Level (mODN)	Duration
Bideford Bay (shallow water - modelled)	240851, 128046	350 m northwest of the proposed cable landfall location northwest of Bideford	WSP SW model	-6	January 1979 – June 2019
Bideford Bay (nearshore - measured)	240544, 131176	3 km west of Westward Ho! Beach and 3 km north of the proposed cable route	CCO directional waverider buoy	-15	June 2009 – December 2023
Bristol Channel (offshore - modelled)	198675, 135082	45 km west of Bideford, 46 km along the proposed cable route	WSP SW model	-60	January 1979 – June 2019
North Cornwall Coast (offshore - modelled)	161496, 109937	55 km north of Perranporth, 93 km along the proposed cable route	WSP SW model	-75	January 1979 – June 2019
Perranporth (nearshore - measured)	174275, 055181	1.5 km west of Perranporth Beach, 50 km southeast of the proposed cable route	CCO directional waverider buoy	-21	November 2006 – December 2023
Wave Hub (offshore - measured)	142986, 055961	32 km west of Perranporth, 33 km southeast of the proposed cable route	CCO directional waverider buoy	-55	June 2015 – May 2018
SW Model Western Extent (offshore - modelled)	124126, 084255	60 km northwest of Perranporth, 140 km along the proposed cable route	WSP SW model	-80	January 1979 – June 2019
Isles of Scilly (offshore - measured)	073220, 000623	15 km southwest of the Isles of Scilly, 35 km east of the proposed cable route	CEFAS directional waverider buoy	-95	October 2014 – January 2024

1.4 Wave Height and Direction

1.4.1 Wave data were obtained from publicly available sources and the WSP regional model of the Bristol Channel at the locations shown in **Plate 1-1**.

Bideford Bay (Shallow Water – Modelled)

1.4.2 The typical (~90% of the data available) significant wave height (Hs) extracted from the WSP spectral wave model at Bideford Bay (shallow water) ranges from 0.0 m to 2.5 m, with a maximum significant wave height of 4.1 m. The directional wave rose plot in **Plate 1-3** shows that the majority of the waves approach from the west-northwest direction, and this is also the direction that the largest waves originate from. There are also large waves (>3 m) approaching from the northwest direction less frequently.

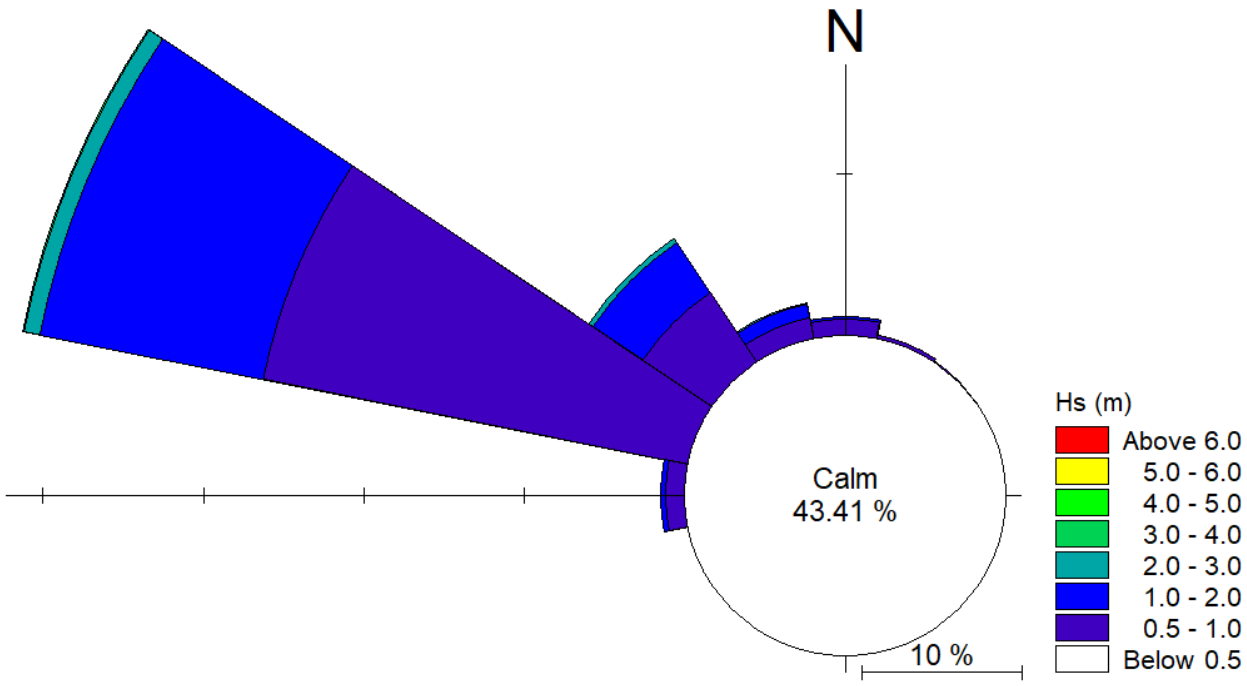

Plate 1-3 Bideford Bay (Shallow Water - Modelled) Wave Rose, January 1979 - June 2019

Bideford Bay (Nearshore - Measured)

1.4.3 The typical Hs recorded by the CCO wave buoy at Bideford Bay ranges from 0.5 m to 4.5 m, with a maximum significant wave height of 7.5 m. The directional wave rose plot in **Plate 1-4** shows that the waves mainly approach from the west and west-northwest directions, and this is also where the largest (>4 m) waves originate from. The waves measured at this location are larger than those extracted from the model closer to the shore (Bideford Bay shallow water) as they are subject to less refraction and diffraction. This location is also further north and so more exposed to larger waves from the westerly direction.

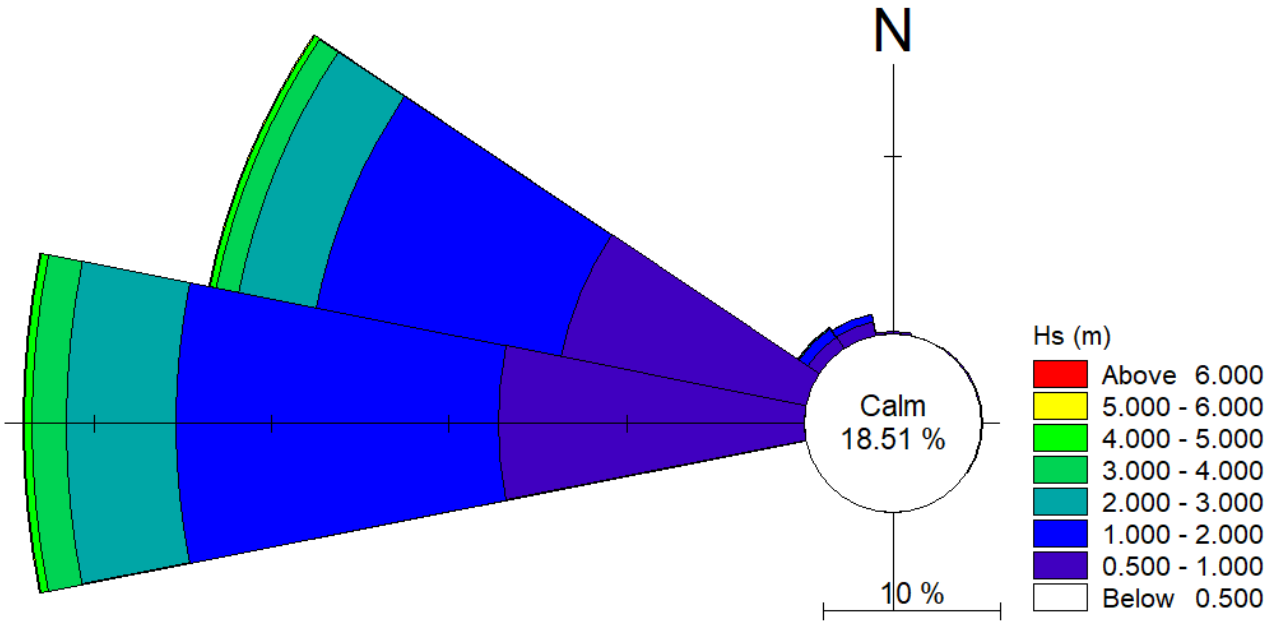

Plate 1-4 Bideford Bay (Nearshore – Measured) Wave Rose, June 2009 – December 2023

Bristol Channel (Offshore – Modelled)

1.4.4 The typical Hs extracted from the WSP spectral wave model in the Bristol Channel 45 km west of Bideford ranges from 0.0 m to 5.5 m, with a maximum Hs of 9.0 m. The directional wave rose plot in **Plate 1-5** shows that the majority of the waves approach from the west-southwest, and this is also the direction that the largest waves (>6 m) originate from. There are also large waves (>5 m) approaching from the west and southwest directions less frequently.

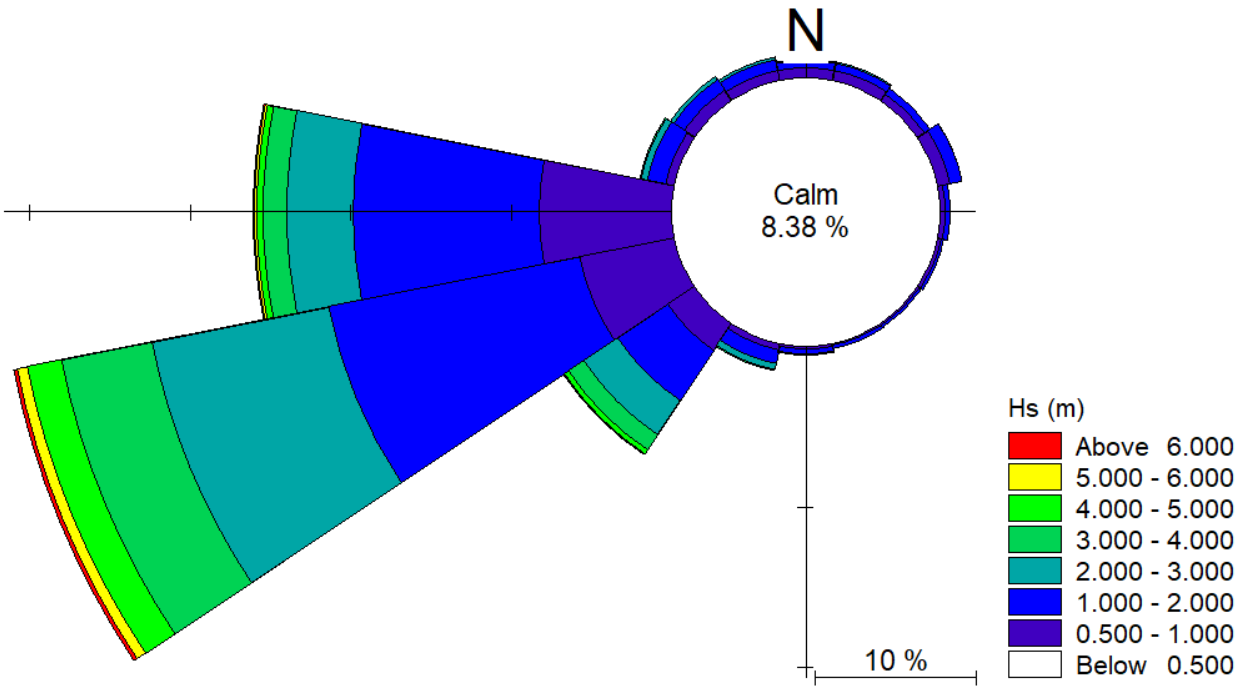

Plate 1-5 Bristol Channel (Offshore - Modelled) Wave Rose, January 1979 - June 2019

North Cornwall Coast (Offshore – Modelled)

1.4.5 The typical H_s extracted from the WSP spectral wave model 55 km north of Perranporth ranges from 0.0 m to 6.0 m, with a maximum H_s of 9.9 m. The wave rose plot in **Plate 1-6** shows that the majority of the waves approach from the west-southwest, and this is also the direction that the largest (>6 m) waves originate from. There are also large waves (>5 m) approaching from the west and southwest directions less frequently.

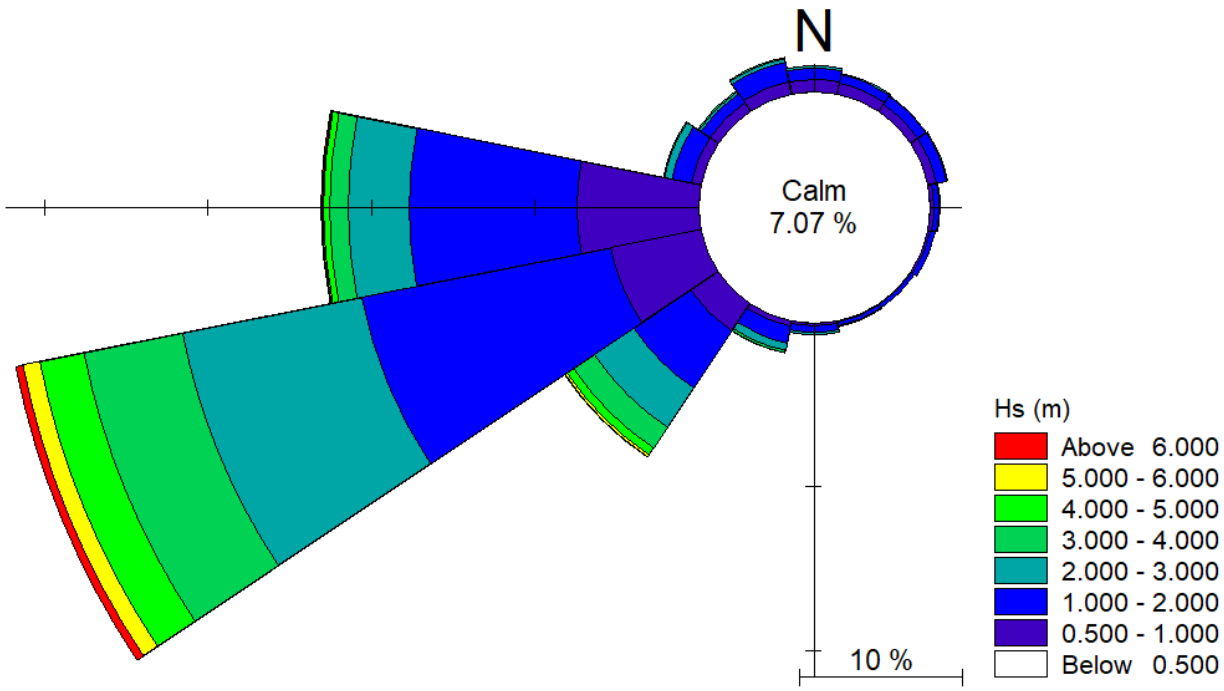

Plate 1-6 North Cornwall Coast (Offshore - Modelled) Wave Rose, January 1979 – June 2019

Perranporth (Nearshore – Measured)

1.4.6 The typical Hs recorded by the CCO wave buoy at Perranporth ranges from 0.5 m to 5.0 m, with a maximum Hs of 7.8 m. The directional wave rose plot in **Plate 1-7** shows that the majority of the waves approach from the west and west-northwest directions, and this is also where the largest waves (>5 m) originate from.

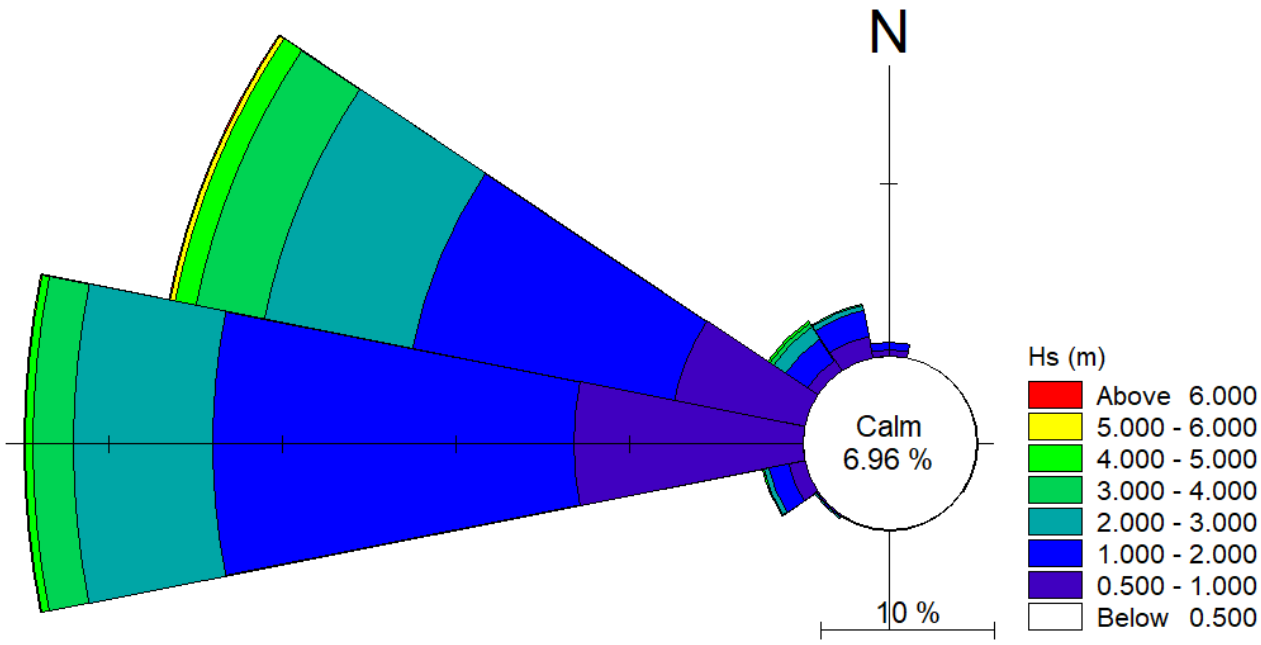

Plate 1-7 Perranporth (Nearshore - Measured) Wave Rose, November 2006 – December 2023

Wave Hub (Offshore – Measured)

1.4.7 The typical Hs recorded by the CCO wave buoy 32 km west of Perranporth ranges from 0.5 m to 4.5 m, with a maximum Hs of 10.1 m. The wave rose plot in **Plate 1-8** shows that the majority of the waves approach from the west, and this is also the direction that the largest waves (>6 m) originate from. The west-northwest direction also shows some large waves less frequently, with occasional waves from the west-southwest direction.

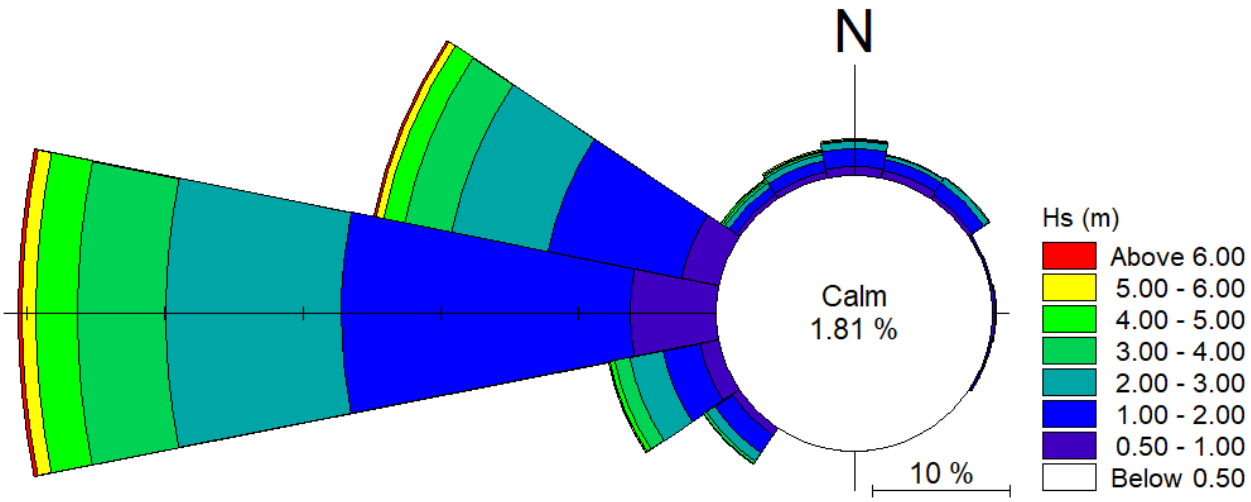

Plate 1-8 Wave Hub (Offshore - Measured) Wave Rose, June 2015 – May 2018

SW Model Western Extent (Offshore – Modelled)

1.4.8 The typical Hs extracted from the WSP spectral wave model at its western extent 60 km northwest of Perranporth ranges from 0.0 m to 6.5 m, with a maximum Hs of 11.0 m. The directional wave rose plot in **Plate 1-9** shows that the majority of the waves approach from the west-southwest, and this is also the direction that the largest waves (>6 m) originate from. There are also large waves approaching from the west and southwest directions less frequently.

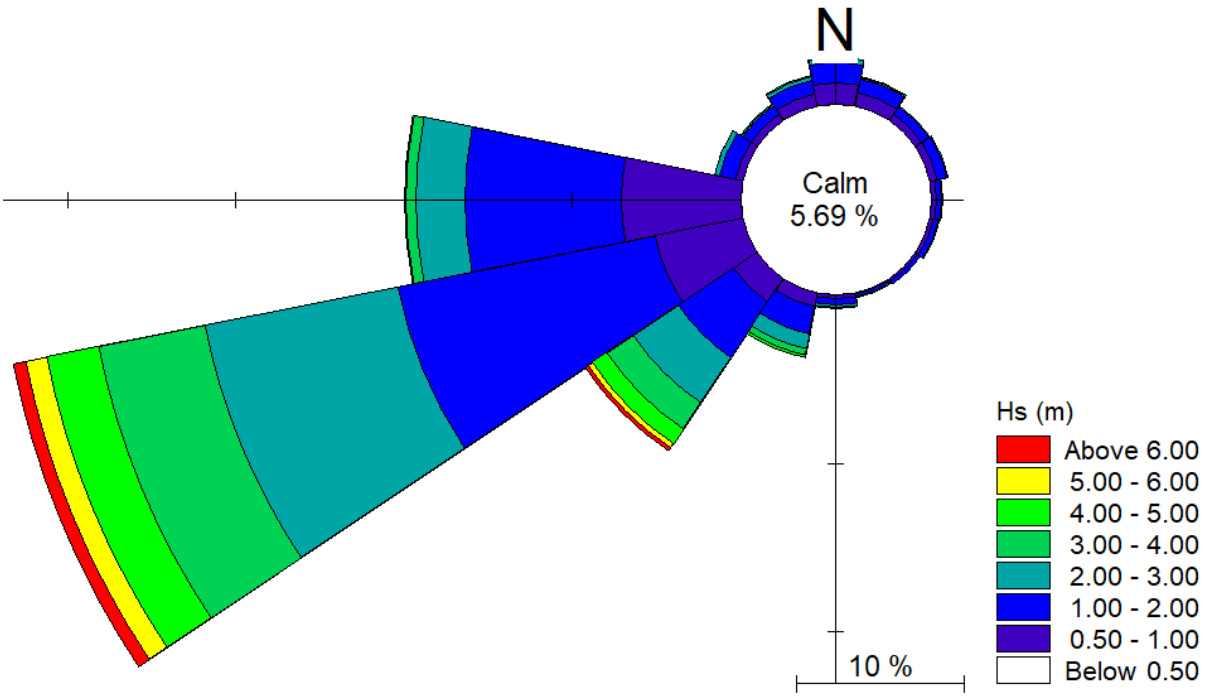

Plate 1-9 SW Model Western Extent (Offshore - Modelled) Wave Rose, January 1979 – June 2019

Isles of Scilly (Offshore – Measured)

1.4.9 The typical Hs recorded by the CEFAS wave buoy at the Isles of Scilly ranges from 1.0 m to 6.0 m, with a maximum Hs of 13.5 m. The directional wave rose plot in **Plate 1-10** shows that the majority of the waves approach from the west-northwest and west directions, and this is also where the largest waves originate from. There are also large waves (>8 m) approaching from the northwest and southwest directions less frequently.

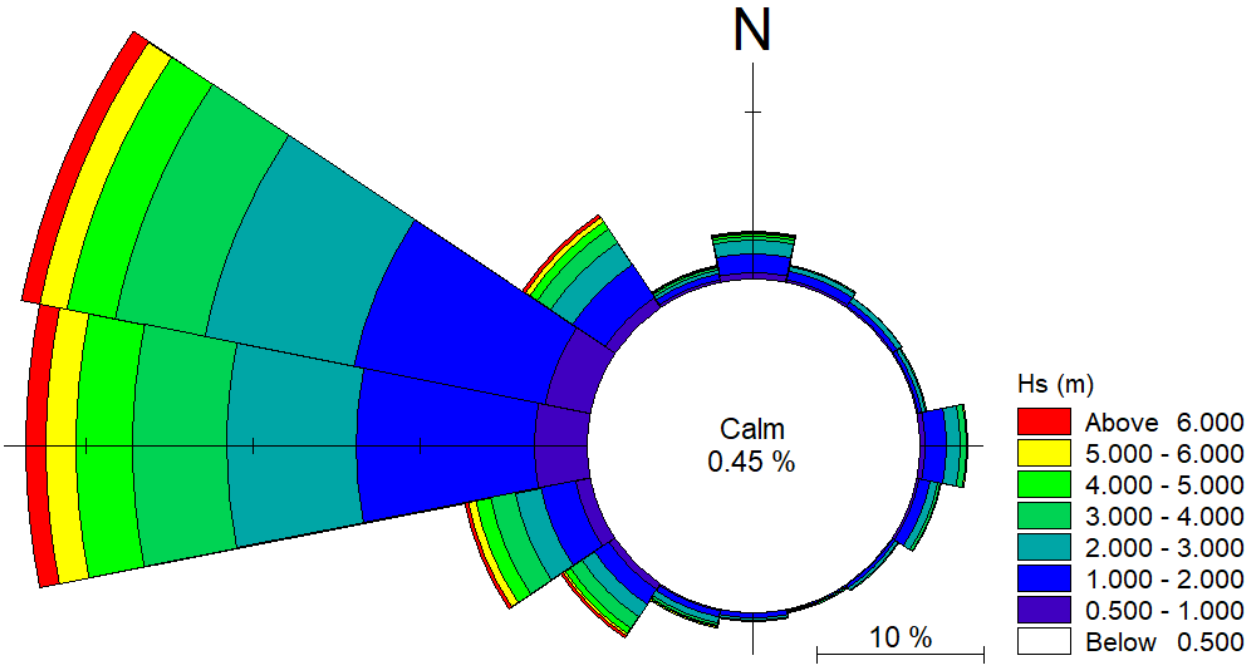

Plate 1-10 Isles of Scilly (Offshore - Measured) Wave Rose, October 2014 – January 2024

Summary

Table 1-2 summarises the wave heights and directions of the eight locations analysed.

Table 1-2 Summary of Wave Heights and Directions

Name	Measured/ Modelled	Typical Sig. Wave Heights (m)	Largest Significant Wave Height (m)	Dominant Wave Direction
Bideford Bay (shallow water)	Modelled	0.0 - 2.5	4.1	West-northwest
Bideford Bay (nearshore)	Measured	0.5 - 4.5	6.9	West
Bristol Channel (offshore)	Modelled	0.0 - 5.5	9.0	West-southwest
North Cornwall Coast (offshore)	Modelled	0.0 - 6.0	9.9	West-southwest
Perranporth (nearshore)	Measured	0.5 - 5.0	7.7	West
Wave Hub (offshore)	Measured	0.5 - 4.5	10.1	West
SW Model Western Extent (offshore)	Modelled	0.0 - 6.5	11.0	West-southwest
Isles of Scilly (offshore)	Measured	1.0 - 6.0	13.5	West-northwest

1.4.10 Overall, the largest waves at each of the measured/ modelled locations predominantly originate from west/ west-south-westerly directions. The largest modelled/ recorded significant wave heights increase as the distance offshore from Bideford Bay increases. This is to be expected since the offshore locations are more exposed to Atlantic swells.

1.5 ABPmer Renewables Atlas Model

1.5.1 Summer, winter and annual average significant wave heights were extracted from the ABPmer Renewables Atlas model at the grid cells corresponding to the locations in **Plate 1-1** (see **Table 1-3** below for wave heights). This dataset is derived from seven years (2000 - 2007) of modelled data from the Met Office UK Waters Wave model which has a 12km resolution (ABPmer, 2008). The model is forced using wind data from a Met Office atmospheric model and includes the effects of time-varying currents.

Table 1-3 ABPmer Renewables Atlas Seasonal Mean Significant Wave Height

Name	ABPmer Grid ID	Summer Mean Significant Wave Height (m)	Winter Mean Significant Wave Height (m)
Bideford Bay (shallow water)	853*	1.04	1.85
Bideford Bay (nearshore)	853*	1.04	1.85
Bristol Channel (offshore)	850	1.26	2.42
North Cornwall Coast (offshore)	792	1.34	2.64
Perranporth (nearshore)	603	1.14	1.99
Wave Hub (offshore)	601	1.32	2.5
SW Model Western Extent (offshore)	699	1.42	2.83
Isles of Scilly (offshore)	375	1.51	3.14

* Note: This grid cell is approximately 9.5 km West (offshore) of the Bideford Bay location (shown in **Plate 1-1**) as the model resolution does not cover Bideford Bay. This means that the ABPmer wave heights are larger than the measured/ modelled data.

1.5.2 Analysis was carried out on the measured/ modelled datasets described previously to determine exceedance thresholds representative of summer and winter conditions. Generally, summer conditions are represented by a wave height which is exceeded by 60% of the waves in the dataset and winter conditions are represented by a wave height which is exceeded by 20% of the waves in the dataset (**Plate 2-1**).

1.5.3 The ABPmer model describes offshore conditions (e.g. North Cornwall Coast) better than the nearshore conditions (e.g. Bideford Bay) due to the model resolution and its representation of processes such as nearshore wave transformation (ABPmer, 2008). Overall, there is good correlation between the ABPmer and measured/ modelled data, with an average difference between the 60% exceedance and summer mean values of 0.04 m and an average difference between the 20% exceedance and winter mean values of 0.05 m.

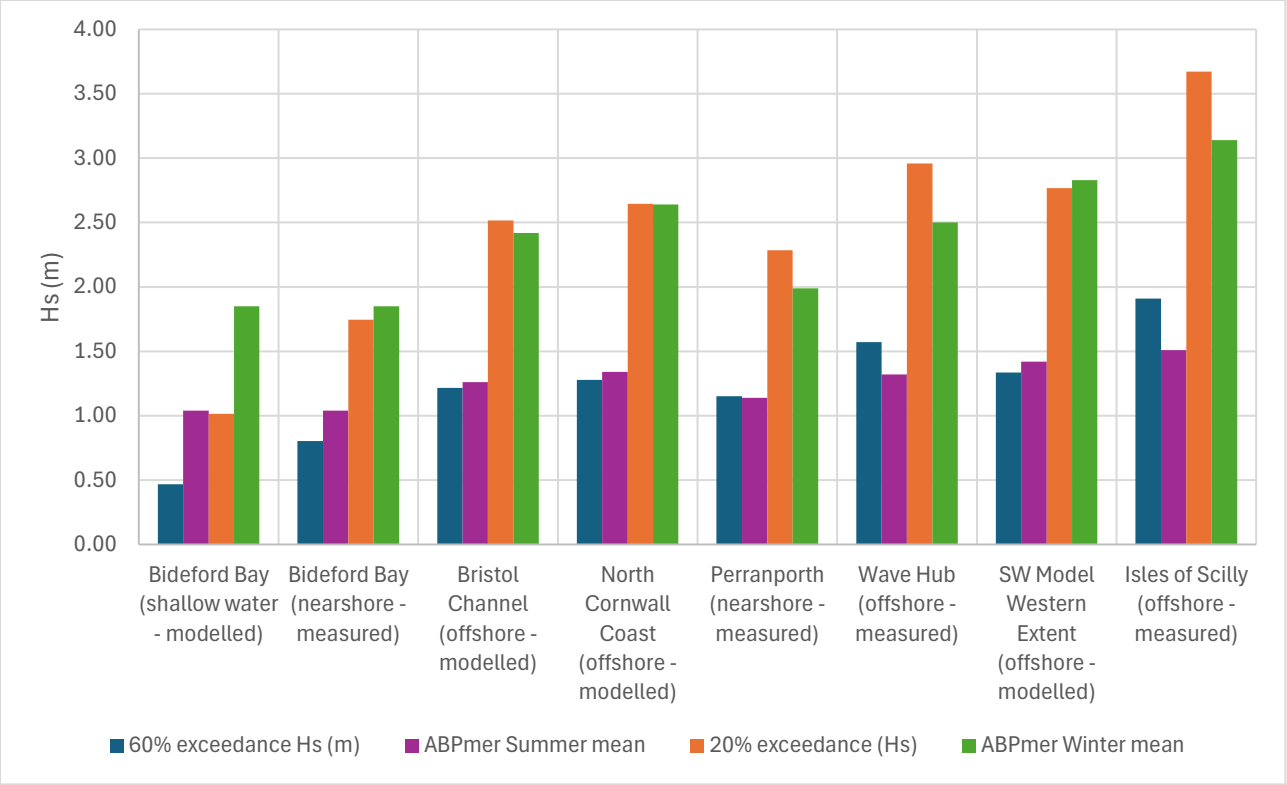

Plate 1-11 ABPmer Seasonal Mean Significant Wave Heights Compared to Exceedance Threshold Analysis of Measured/ Modelled Datasets

1.6 Extreme Values Analysis

1.6.1 An Extreme Values Analysis (EVA) has been carried out using the EVA Editor function within MIKE by DHI to estimate wave heights associated with specific return periods. A Weibull distribution was fitted to the extreme values of each wave height timeseries, with sensitivity testing used to determine the threshold giving a suitable fit for each location (assessed using the probability plot correlation coefficient). The results are shown in **Table 1-4**.

Table 1-4 Wave Height Extreme Values Analysis

Name	Measured/ Modelled	Sig. Wave Height (m) for Return Period (years)					
		1	5	10	50	100	200
Bideford Bay (shallow water)	Modelled	3.20	3.65	3.83	4.25	4.42	4.60
Bideford Bay (nearshore)	Measured	6.12	7.23	7.69	8.73	9.17	9.60
Bristol Channel (offshore)	Modelled	6.78	7.93	8.41	9.49	9.94	10.39
North Cornwall Coast (offshore)	Modelled	7.35	8.63	9.16	10.35	10.86	11.36
Perranporth (nearshore)	Measured	6.65	7.50	7.82	8.52	8.81	9.08
Wave Hub (offshore)	Measured	8.10	9.64	10.29	11.77	12.40	13.03
SW Model Western Extent (offshore)	Modelled	7.94	9.36	9.96	11.35	11.94	12.52
Isles of Scilly (offshore)	Measured	10.42	12.60	13.53	15.68	16.61	17.53

1.7 Tidal Currents

1.7.1 **Table 1-5** summarises the tidal current data extracted from the ABPmer Renewables Atlas model at each wave data location.

Table 1-5 Tidal Current Data from ABPmer Renewables Atlas Model

Name	ABPmer ID	Distance from Nearest Land (km)	Average Depth (m relative to MSL)	Depth-averaged Spring Peak Velocity (m/s)	Depth-averaged Neap Peak Velocity (m/s)	Mean Spring Tidal Range (m)	Mean Neap Tidal Range (m)
Bideford Bay (shallow water)	58975	1.20	13	0.16	0.08	7.78	3.81
Bideford Bay (nearshore)	58977	1.94	16	0.46	0.23	7.80	3.82
Bristol Channel (offshore)	51099	16.40	63	0.76	0.36	6.69	3.28
North Cornwall Coast (offshore)	42782	39.92	74	0.62	0.28	5.95	2.93
Perranporth (nearshore)	46751	1.20	30	0.25	0.12	6.21	3.06
Wave Hub (offshore)	39131	13.99	49	0.90	0.41	5.72	2.84
SW Model Western Extent (offshore)	34895	47.70	83	0.64	0.29	5.39	2.68
Isles of Scilly (offshore)	26154	13.61	86	0.62	0.28	4.54	2.29

1.7.2 **Table 1-6** summarises the tidal current data extracted from the DHI Global Tide model along the proposed cable route.

Table 1-6 Tidal Current Data from DHI Global Tide Model

Name	Depth-averaged Spring Peak Velocity (m/s)	Depth-averaged Neap Peak Velocity (m/s)	Depth-averaged Spring Mean Velocity (m/s)	Depth-averaged Neap Mean Velocity (m/s)
Bideford Bay (nearshore)	1.14	0.57	0.93	0.57
Bristol Channel (offshore)	0.97	0.47	0.75	0.47
North Cornwall Coast (offshore)	0.79	0.35	0.60	0.35
SW Model Western Extent (offshore)	0.74	0.31	0.59	0.31
Isles of Scilly (offshore)	0.64	0.26	0.54	0.26

1.7.3 **Plate 4-1** shows the locations of the nearest UKHO Admiralty Total Tide Stations relative to the wave data locations. The predicted tidal diamonds for these stations are given in **Table 1-7**.

1.7.4 The ABPmer, DHI, and UKHO current data are generally similar (within ±20% where locations and data are comparable, except for Bideford Bay where the DHI model predicts higher peak spring velocities), noting that the UKHO Total Tide velocities are at the surface while the DHI and ABPmer velocities are depth-

Plate 1-12 Locations of UKHO Admiralty Total Tide Stations (red) Relative to Wave Data Locations (green)

averaged. The agreement between each data source provides confidence in the values and a likely range of spring and neap current speeds within the study area.

Table 1-7 UKHO Admiralty Total Tide Tidal Diamonds

Name	Time (hr)	Direction (°)	Surface Spring Tide Current Velocity		Surface Neap Tide Current Velocity	
			kn	m/s	kn	m/s
SN051K	-06	326	0.7	0.36	0.3	0.15
	-05	359	0.6	0.31	0.3	0.15
	-04	38	0.3	0.15	0.1	0.05
	-03	60	0.7	0.36	0.3	0.15
	-02	60	1	0.51	0.5	0.26
	-01	65	0.8	0.41	0.4	0.21
	HW	83	0.4	0.21	0.2	0.10
	+01	184	0.8	0.41	0.4	0.21
	+02	198	0.9	0.46	0.4	0.21
	+03	212	0.9	0.46	0.4	0.21
	+04	225	0.8	0.41	0.4	0.21
	+05	290	0.6	0.31	0.3	0.15
	+06	313	0.7	0.36	0.3	0.15
SN051L	-06	355	0.8	0.41	0.4	0.21
	-05	66	1.6	0.82	0.7	0.36
	-04	59	2.6	1.34	1.2	0.62
	-03	60	2.6	1.34	1.2	0.62
	-02	57	2.5	1.29	1.2	0.62

Name	Time (hr)	Direction (°)	Surface Spring Tide Current Velocity		Surface Neap Tide Current Velocity	
			kn	m/s	kn	m/s
	-01	61	1.7	0.87	0.8	0.41
	HW	50	0.6	0.31	0.3	0.15
	+01	257	1.4	0.72	0.7	0.36
	+02	240	2.8	1.44	1.3	0.67
	+03	228	3	1.54	1.4	0.72
	+04	233	2.7	1.39	1.3	0.67
	+05	239	1.8	0.93	0.8	0.41
	+06	264	0.6	0.31	0.3	0.15
SN054A	-06	195	0.3	0.15	0.1	0.05
	-05	90	0.3	0.15	0.1	0.05
	-04	67	0.8	0.41	0.4	0.21
	-03	65	1.1	0.57	0.5	0.26
	-02	59	1.2	0.62	0.6	0.31
	-01	50	1	0.51	0.5	0.26
	HW	23	0.6	0.31	0.3	0.15
	+01	279	0.3	0.15	0.1	0.05
	+02	239	0.7	0.36	0.3	0.15
	+03	235	1	0.51	0.5	0.26
	+04	235	1.2	0.62	0.6	0.31
	+05	235	1	0.51	0.5	0.26

Name	Time (hr)	Direction (°)	Surface Spring Tide Current Velocity		Surface Neap Tide Current Velocity	
			kn	m/s	kn	m/s
	+06	235	0.5	0.26	0.2	0.10
SN055B	-06	148	0.1	0.05	0.1	0.05
	-05	82	0.3	0.15	0.1	0.05
	-04	42	0.7	0.36	0.3	0.15
	-03	36	0.9	0.46	0.4	0.21
	-02	32	0.9	0.46	0.4	0.21
	-01	29	0.6	0.31	0.3	0.15
	HW	102	0.3	0.15	0.2	0.10
	+01	213	0.3	0.15	0.1	0.05
	+02	228	0.6	0.31	0.3	0.15
	+03	229	0.8	0.41	0.4	0.21
	+04	222	0.9	0.46	0.4	0.21
	+05	207	0.6	0.31	0.3	0.15
	+06	175	0.3	0.15	0.2	0.10
SN055D	-06	242	0.7	0.36	0.3	0.15
	-05	320	0.2	0.10	0.1	0.05
	-04	34	0.7	0.36	0.3	0.15
	-03	42	1.2	0.62	0.5	0.26
	-02	45	1.4	0.72	0.6	0.31
	-01	48	1.3	0.67	0.5	0.26

Name	Time (hr)	Direction (°)	Surface Spring Tide Current Velocity		Surface Neap Tide Current Velocity	
			kn	m/s	kn	m/s
	HW	51	0.8	0.41	0.3	0.15
	+01	61	0.3	0.15	0.1	0.05
	+02	220	0.4	0.21	0.2	0.10
	+03	226	1	0.51	0.4	0.21
	+04	228	1.3	0.67	0.5	0.26
	+05	232	1.2	0.62	0.5	0.26
	+06	237	0.9	0.46	0.4	0.21
SN000I	-06	268	0.9	0.46	0.4	0.21
	-05	319	0.9	0.46	0.5	0.26
	-04	347	1.4	0.72	0.7	0.36
	-03	2	1.6	0.82	0.8	0.41
	-02	18	1.4	0.72	0.7	0.36
	-01	43	1.2	0.62	0.6	0.31
	HW	70	1	0.51	0.5	0.26
	+01	142	0.9	0.46	0.4	0.21
	+02	172	1.2	0.62	0.6	0.31
	+03	188	1.4	0.72	0.7	0.36
	+04	201	1.5	0.77	0.7	0.36
	+05	217	1.3	0.67	0.6	0.31
	+06	250	0.9	0.46	0.5	0.26

1.8 References

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