TECHNICAL NOTE

DATE:	15 February 2024	**CONFIDENTIALITY:**	Internal
SUBJECT:	Xlinks MUPP Wave and Tidal Conditions		
PROJECT:	Xlinks Morocco UK Power Project	**AUTHOR:**	EN
CHECKED:	JG	**APPROVED:**	SB

INTRODUCTION

This technical note provides a review and interpretation of available wave and tidal data required to carry out the Environmental Statement Scoping for the 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.

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 Figure 1.

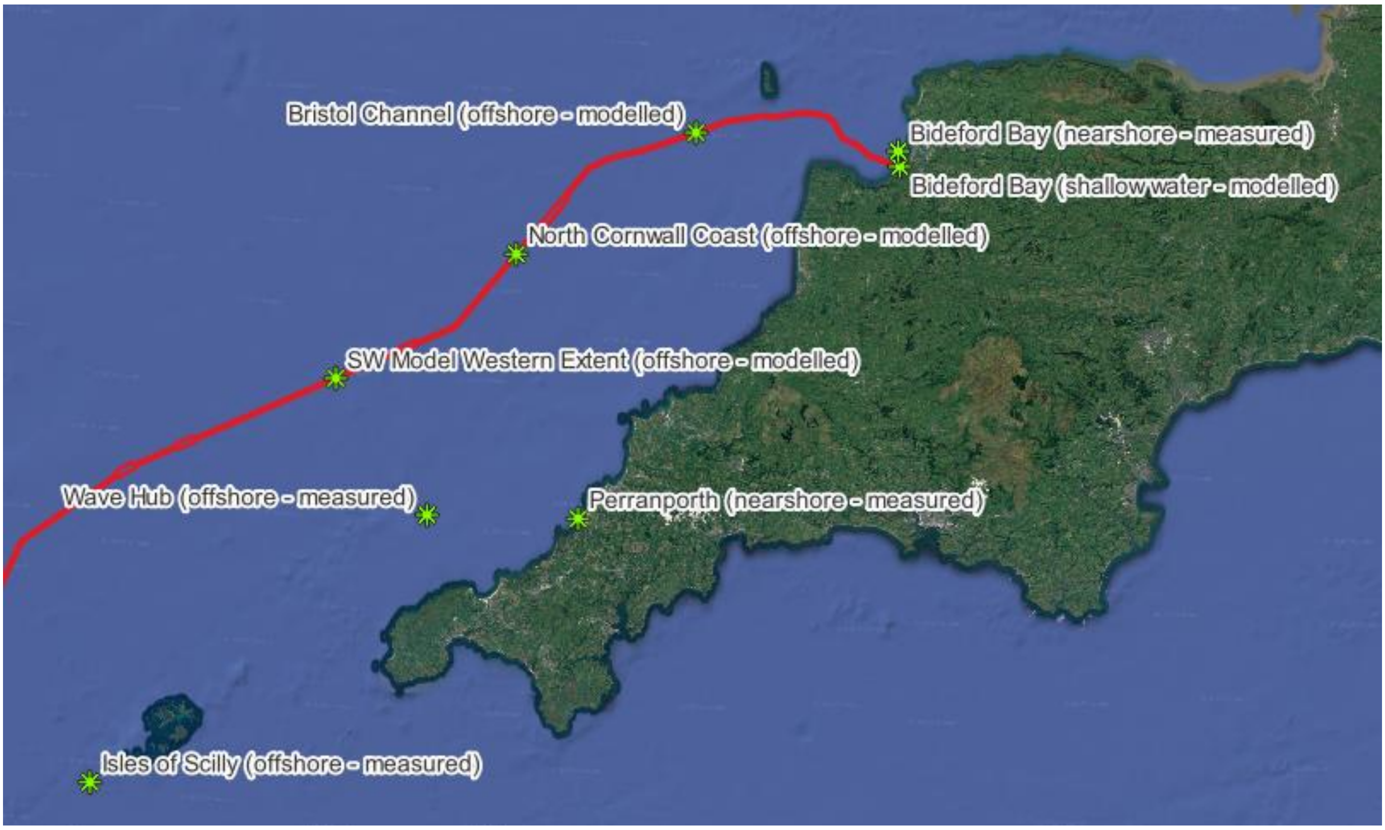

Figure 1 - Locations of Wave Data Sources

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. Tidal data has been obtained from the ABPmer Renewables Atlas model, DHI Global Tide model, and United Kingdom Hydrographic Office (UKHO) Admiralty Total Tide.

WSP REGIONAL WAVE MODEL

The model domain illustrated in Figure 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.

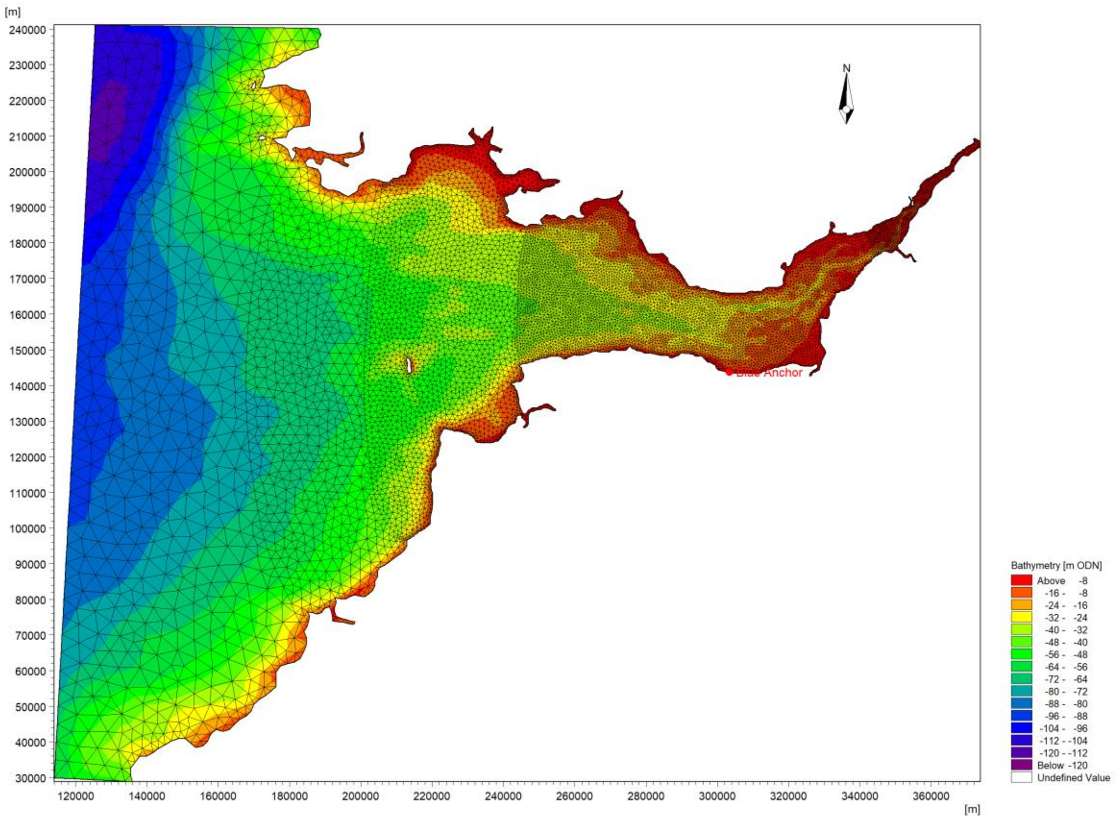

Figure 2 - WSP Regional Bristol Channel Model Domain (Bathymetry m ODN)

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).

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.

DATA SOURCES

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

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

WAVE HEIGHT AND DIRECTION

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

Bideford Bay (Shallow Water – Modelled)

The typical (~90% of the data available) significant wave height (H_s) extracted from the WSP spectral wave model at Bideford Bay (shallow water) ranges from 0.0m to 2.5m, with a maximum significant wave height of 4.1m. The directional wave rose plot in Figure 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 (>3m) approaching from the northwest direction less frequently.

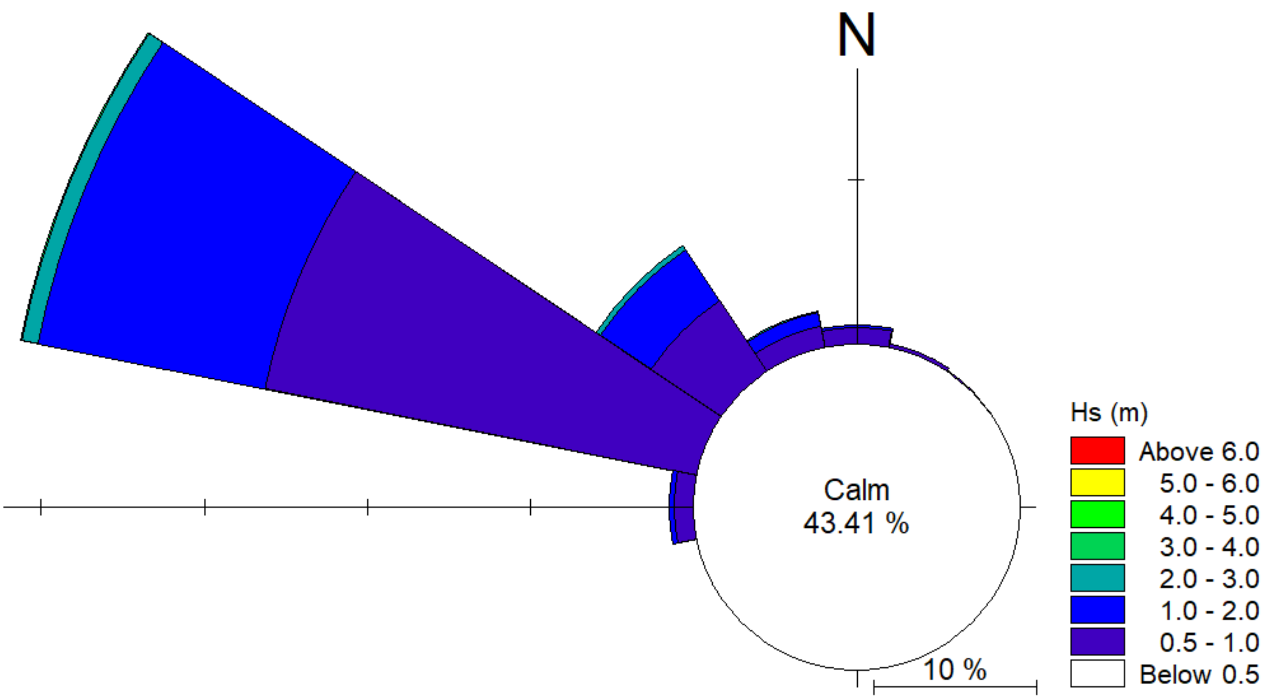

Figure 3 - Bideford Bay (Shallow Water - Modelled) Wave Rose, January 1979 – June 2019

Bideford Bay (Nearshore – Measured)

The typical H_s recorded by the CCO wave buoy at Bideford Bay ranges from 0.5m to 4.5m, with a maximum significant wave height of 6.9m. The directional wave rose plot in Figure 4 shows that the waves mainly approach from the west and west-northwest directions, and this is also where the largest (>4m) 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.

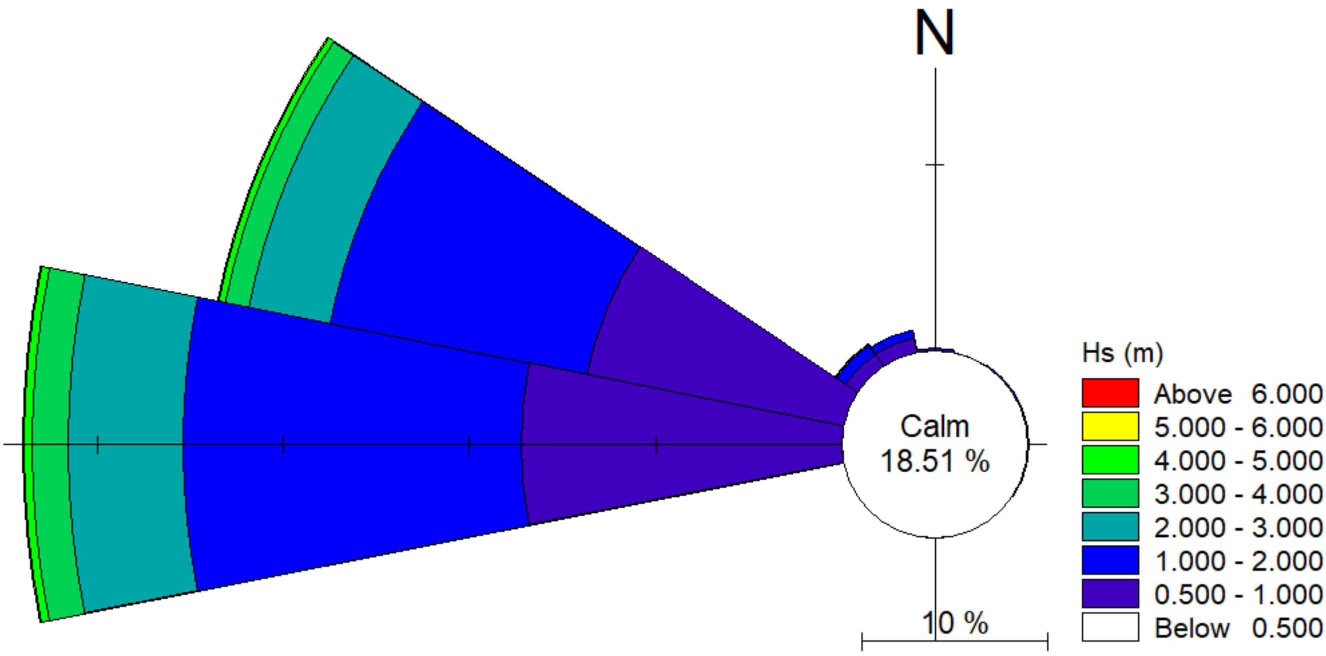

Figure 4 - Bideford Bay (Nearshore - Measured) Wave Rose, June 2009 – December 2023

Bristol Channel (Offshore – Modelled)

The typical H_s extracted from the WSP spectral wave model in the Bristol Channel 45km west of Bideford ranges from 0.0m to 5.5m, with a maximum H_s of 9.0m. The directional wave rose plot in Figure 5**Error! Reference source not found.** shows that the majority of the waves approach from the west-southwest, and this is also the direction that the largest waves (>6m) originate from. There are also large waves (>5m) approaching from the west and southwest directions less frequently.

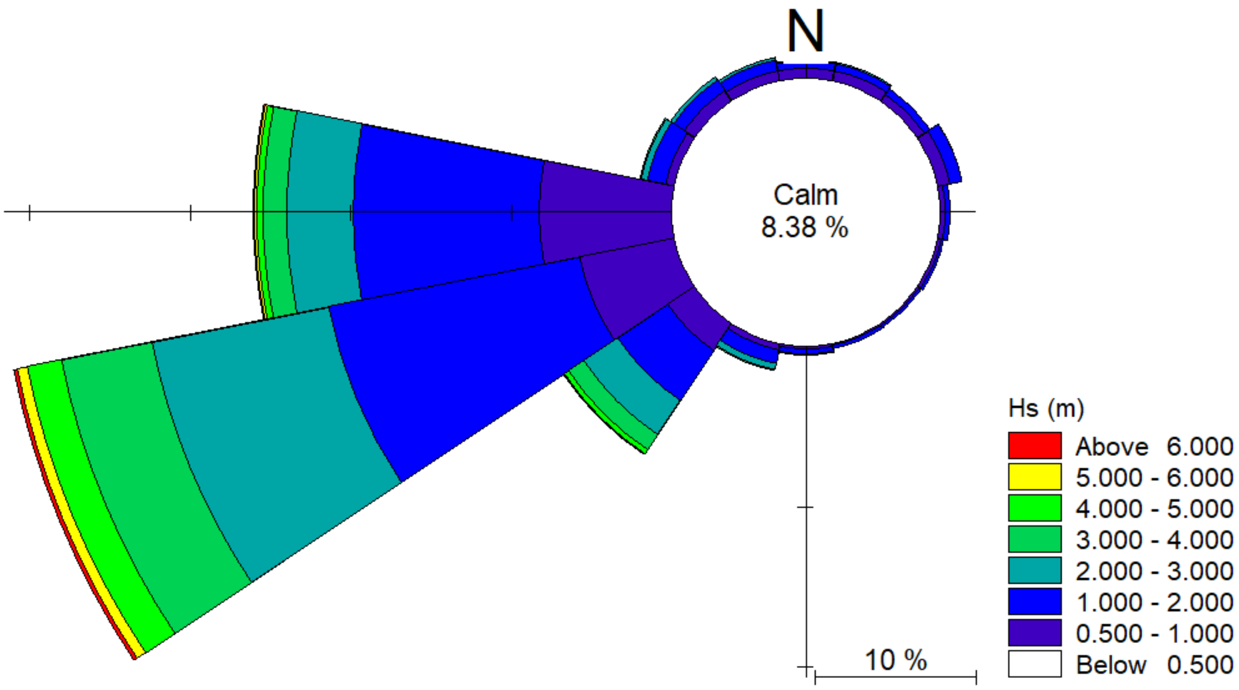

Figure 5 - Bristol Channel (Offshore - Modelled) Wave Rose, January 1979 – June 2019

North Cornwall Coast (Offshore – Modelled)

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

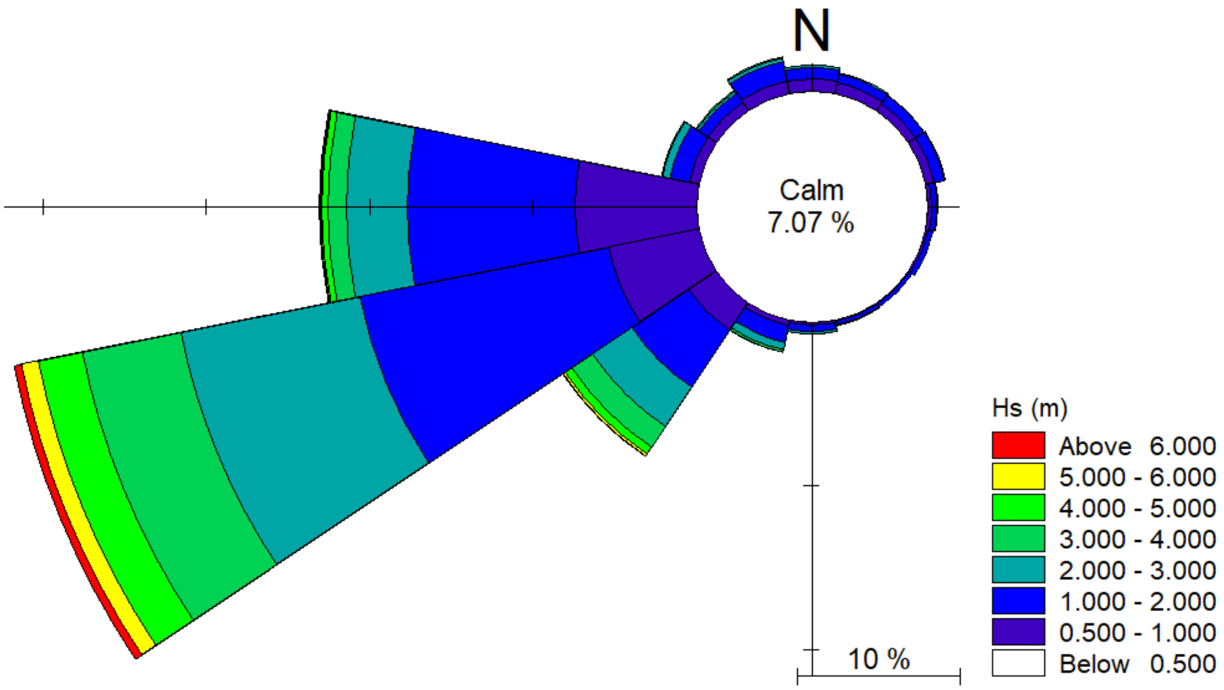

Figure 6 - North Cornwall Coast (Offshore - Modelled) Wave Rose, January 1979 – June 2019

Perranporth (Nearshore – Measured)

The typical H_s recorded by the CCO wave buoy at Perranporth ranges from 0.5m to 5.0m, with a maximum H_s of 7.7m. The directional wave rose plot in Figure 7 shows that the majority of the waves approach from the west and west-northwest directions, and this is also where the largest waves (>5m) originate from.

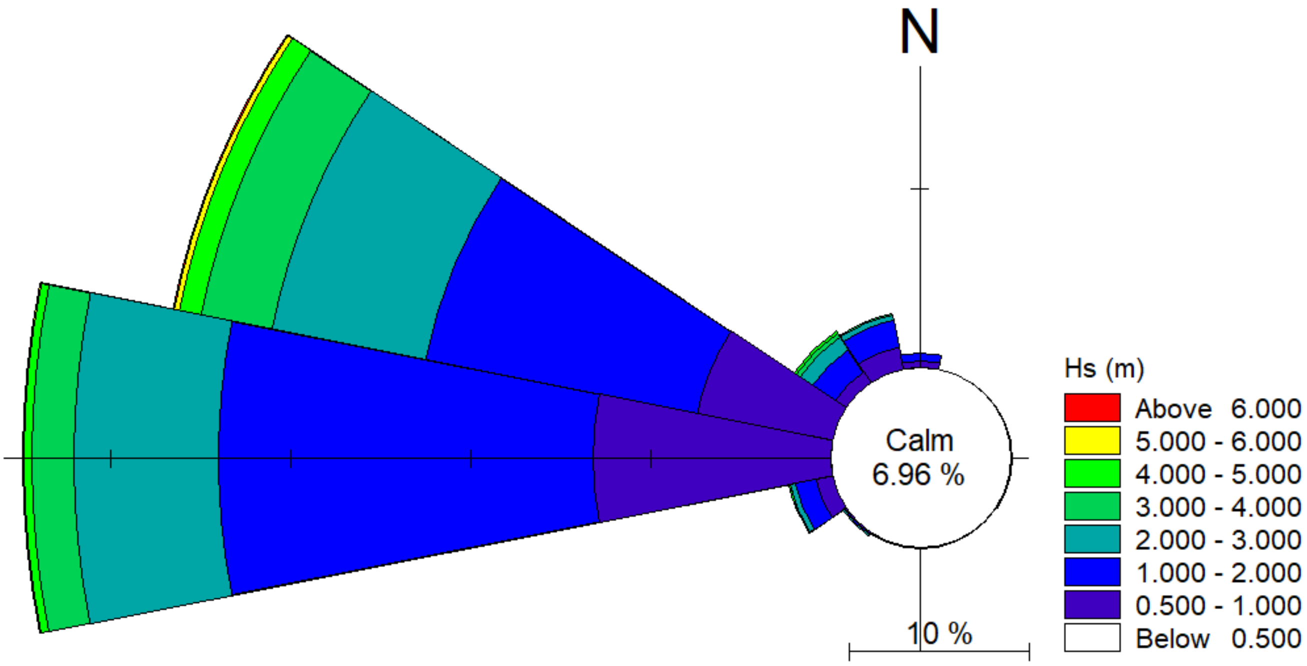

Figure 7 - Perranporth (Nearshore - Measured) Wave Rose, November 2006 – December 2023

Wave Hub (Offshore – Measured)

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

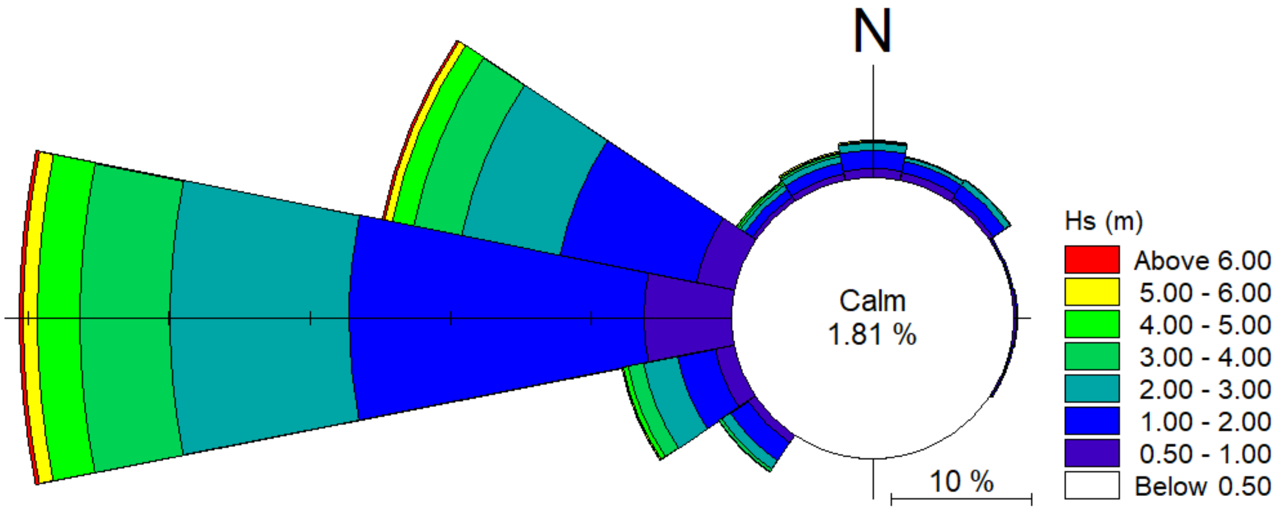

Figure 8 - Wave Hub (Offshore - Measured) Wave Rose, June 2015 – May 2018

SW Model Western Extent (Offshore – Modelled)

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

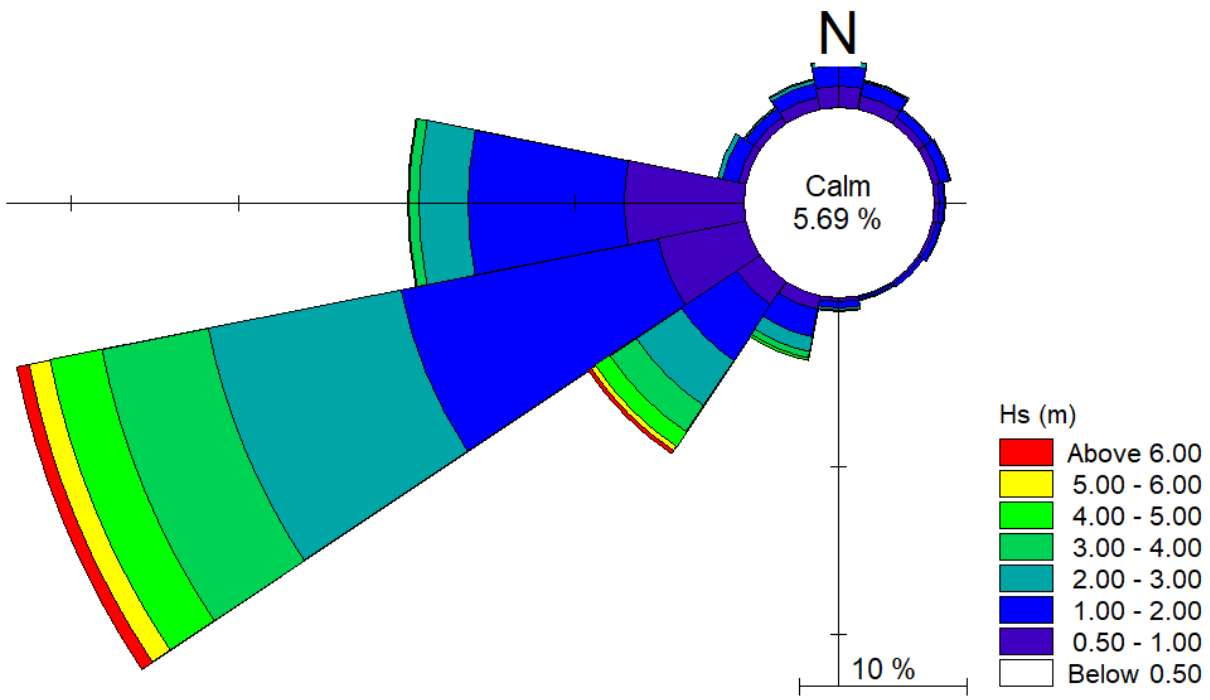

Figure 9 - SW Model Western Extent (Offshore - Modelled) Wave Rose, January 1979 – June 2019

Isles of Scilly (Offshore – Measured)

The typical H_s recorded by the CEFAS wave buoy at the Isles of Scilly ranges from 1.0m to 6.0m, with a maximum H_s of 13.5m. The directional wave rose plot in Figure 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 (>8m) approaching from the northwest and southwest directions less frequently.

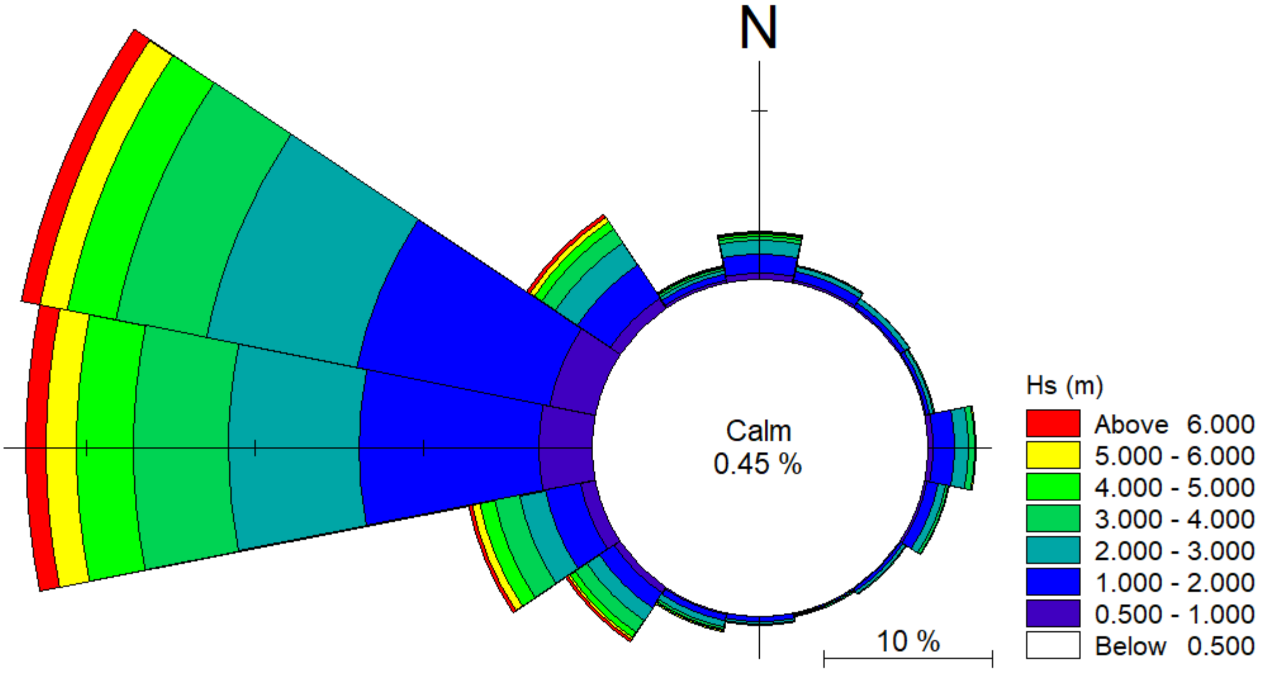

Figure 10 - Isles of Scilly (Offshore - Measured) Wave Rose, October 2014 – January 2024

Summary

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

Table 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

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.

EXTREME VALUES ANALYSIS

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 3.

Table 3 - 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

TIDAL CURRENTS

Table 4 summarises the tidal current data extracted from the ABPmer Renewables Atlas model at each wave data location.

Table 4 - 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

Table 5 summarises the tidal current data extracted from the DHI Global Tide model along the proposed cable route.

Table 5 - 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

Figure 11 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 6.

The ABPmer, DHI, and UKHO current data are generally similar (within $\pm$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-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.

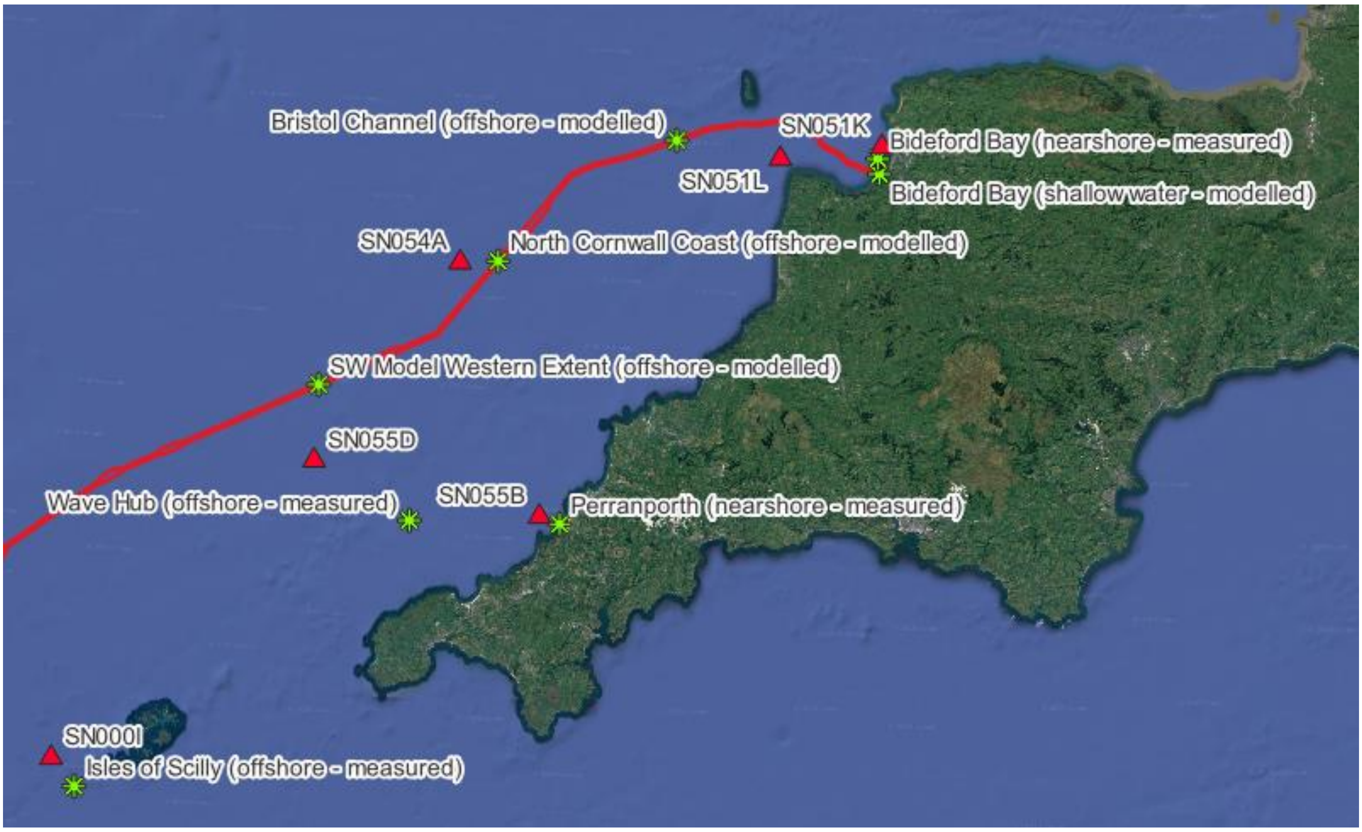

Figure 11 - Locations of UKHO Admiralty Total Tide Stations (red) Relative to Wave Data Locations (green)

Table 6 - 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

Name	Time (hr)	Direction (°)	Surface Spring Tide Current Velocity		Surface Neap Tide Current Velocity	
			kn	m/s	kn	m/s
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
	-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
	+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

Name	Time (hr)	Direction (°)	Surface Spring Tide Current Velocity		Surface Neap Tide Current Velocity	
			kn	m/s	kn	m/s
	-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
	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

Name	Time (hr)	Direction (°)	Surface Spring Tide Current Velocity		Surface Neap Tide Current Velocity	
			kn	m/s	kn	m/s
	+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

REFERENCES

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CEFAS (Centre for Environment, Fisheries and Aquaculture Science). (2024). *WaveNet*. Retrieved from https://wavenet.cefas.co.uk/map