FUGRO

Wave Statistics off Kenyan Coast

Fugro Document No.: 162030-1-R0

06 February 2017

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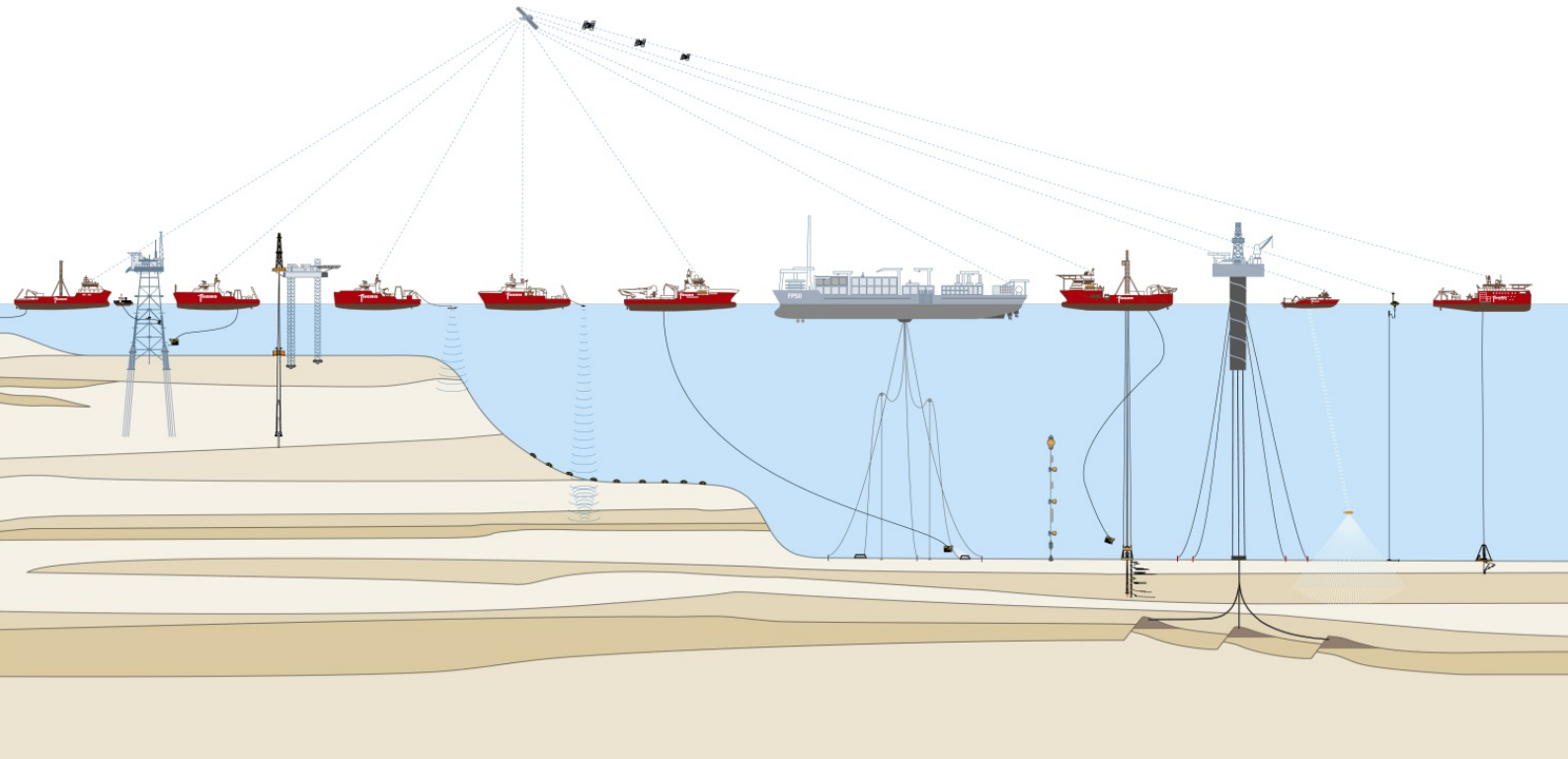
Initial Issue



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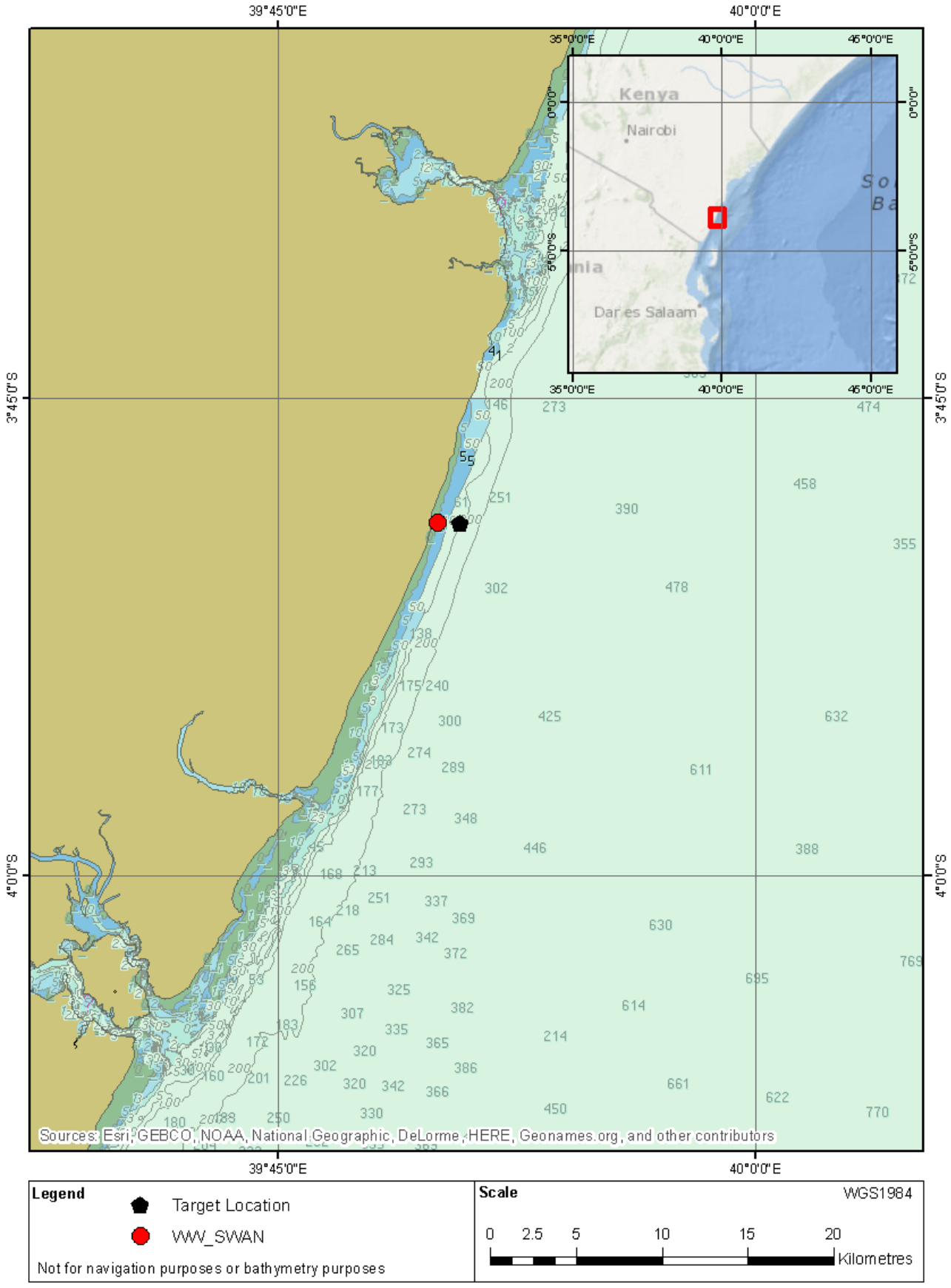
Fugro Document No.: 162030-1-R0

Prepared for: Uppsala Universitet

On behalf of: Jens Engström

UPPSALA UNIVERSITET

Issue	Document Status	Prepared	Checked	Approved	Date
R0	Initial Issue	Sophie Noon	Richard Sproson	Richard Sproson	06 February 2017



FRONTISPIECE

EXECUTIVE SUMMARY

This report has been prepared on behalf of the wave energy research group at Uppsala Universitet and provides wave criteria offshore Kenya in the Indian Ocean. The target location was 3.815° S, 39.846° E, in a water depth of approximately 34 m.

The report is based on the analysis of the WorldWaves data for the period January 1997 to December 2015. Due to the steep bathymetry near the coast offshore Kenya, the target location in WorldWaves was deeper than anticipated, therefore, wave criteria were instead derived from a nearby location of 3.815° S, 39.834° E, in a water depth of 35 m. The location of the data source is shown in the Frontispiece.

At this location, wave directions from the model data propagated predominantly from an east and south-eastward direction throughout the year. Significant wave heights typically ranged between 0.75 m and 2.00 m; with a maximum significant wave height of 3.37 m. Mean wave energy periods were between 3.28 s and 15.97 s with the most commonly occurring wave energy periods between 6 s and 8 s. The maximum peak wave period was 18.51 s; the most common occurrence was between 8 s and 9 s with a significant wave height between 1.00 m and 1.25 m.

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ABBREVIATIONS

SWAN	Simulating Waves Nearshore
UTC	Universal Coordinated Time
WGS	World Geodetic System
WW	WorldWaves

1. INTRODUCTION

1.1 Background

This report has been prepared on behalf of the wave energy research group at Uppsala Universitet and provides wave criteria offshore Kenya in the Indian Ocean. The target location was 3.815° S, 39.846° E, in a water depth of approximately 34 m.

The report is based on the analysis of the WorldWaves data for the period January 1997 to December 2015. Due to the steep bathymetry near the coast offshore Kenya, the target location in WorldWaves was deeper than anticipated, therefore, wave criteria were instead derived from a nearby location of 3.815° S, 39.834° E, in a water depth of 35 m. The location of the data source is shown in the Frontispiece.

1.2 Units and Conventions

The following list describes the units and conventions used in this report. Where possible, units have been expressed using SI convention.

- Wave height is expressed in metres [m];
- Wave period is expressed in seconds [s];
- Wave direction is expressed in compass points or degrees, measured clockwise from true north, and describes the direction from which the waves were travelling;
- Positions are quoted relative to WGS84 except where stated;
- All times are quoted in Coordinated Universal Time [UTC].

1.3 Parameter Descriptions

The following table provides summary descriptions of the primary metocean parameters.

Table 1.3.1: Parameter Descriptions

Parameter	Units	Description	Comments
Mdir	deg	Mean wave direction	
Hs	m	Significant wave height	Estimated from the wave energy spectrum, $Hs = 4\sqrt{(m_0)}$. Equivalent to the mean height (from wave crest to trough) of the highest one-third of the waves in a sea-state.
Tp	s	Peak period	The period associated with the peak in the wave energy spectrum.
Te	s	Mean wave energy period	$Te = m_{-1}/m_0$

2. DATA SOURCES

2.1 WorldWaves

The WorldWaves data used to provide wave statistics originate from the European Centre for Medium-range Weather Forecasts (ECWMF) Wave Model archive and are calibrated and corrected by Fugro Oceanor against a global buoy and multi-satellite altimeter database (Topex, Jason, Geosat, GFO and Envisat). Offshore wave data from four grid points (red dots in Figure 2.1.1) were transformed to location 3.815° S, 39.834° E (yellow circle see Figure 2.1.1), using the SWAN (Simulating Wave Nearshore) model. Data from the selected grid point is available on 6-hourly intervals from 1 January 1997 to 31 December 2015.

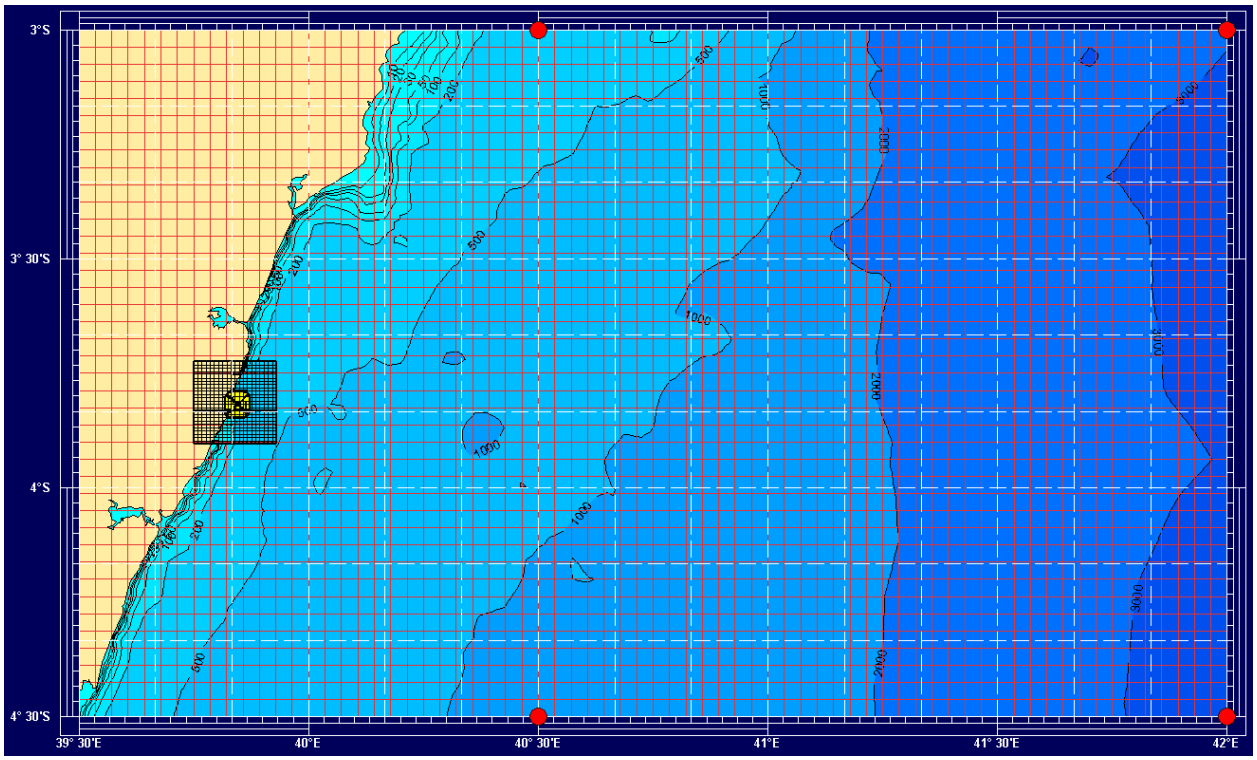


Figure 2.1.1: Offshore WorldWaves Grid Points (red dots) and Target Location (yellow circle)

3. OPERATIONAL ANALYSIS

Operational wave criteria have been derived from analysis of the SWAN output for the location 3.815° S, 39.834° E. The following operational criteria are presented:

- Monthly and all-year joint frequency distributions and rose plots of Hs and Mdir;
- Monthly and all-year joint frequency distributions of Hs and Te;
- Monthly and all-year joint frequency distributions of Hs and Tp.

3.1 Operational Wave Criteria – Hs and Mdir

The following figures are presented in this section:

Figure 3.1.1: Percentage Occurrence of Hs and Mdir – All-Year
Figure 3.1.2: Percentage Occurrence of Hs and Mdir – January
Figure 3.1.3: Percentage Occurrence of Hs and Mdir – February
Figure 3.1.4: Percentage Occurrence of Hs and Mdir – March
Figure 3.1.5: Percentage Occurrence of Hs and Mdir – April
Figure 3.1.6: Percentage Occurrence of Hs and Mdir – May
Figure 3.1.7: Percentage Occurrence of Hs and Mdir – June
Figure 3.1.8: Percentage Occurrence of Hs and Mdir – July
Figure 3.1.9: Percentage Occurrence of Hs and Mdir – August
Figure 3.1.10: Percentage Occurrence of Hs and Mdir – September
Figure 3.1.11: Percentage Occurrence of Hs and Mdir – October
Figure 3.1.12: Percentage Occurrence of Hs and Mdir – November
Figure 3.1.13: Percentage Occurrence of Hs and Mdir – December

All-Year

Significant Wave Height [m]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total		0.53	31.53	66.66	1.27				100.00	
3.25				0.01	<0.01				0.01	0.01
3.00				0.04					0.04	0.05
2.75				0.09	<0.01				0.09	0.15
2.50				0.32	<0.01				0.33	0.48
2.25				1.01	0.06				1.07	1.54
2.00			0.03	3.01	0.14				3.18	4.73
1.75		0.03	0.17	8.05	0.24				8.48	13.21
1.50		0.05	0.85	13.73	0.39				15.02	28.23
1.25		0.13	3.95	15.48	0.24				19.80	48.04
1.00		0.22	11.80	12.15	0.13				24.31	72.34
0.75		0.10	11.78	8.83	0.04				20.75	93.10
0.50		<0.01	2.77	3.51	<0.01				6.28	99.38
0.25		<0.01	0.18	0.43					0.62	100.00
0.00				<0.01					<0.01	

Mean Wave Direction [°T From]

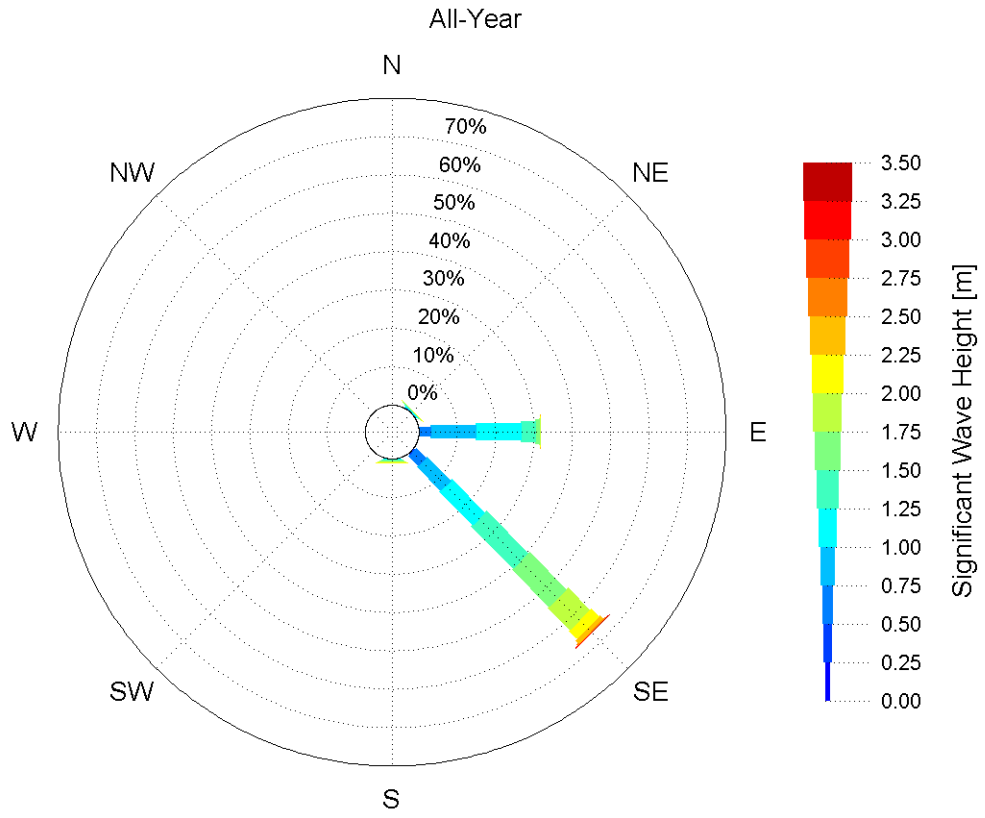
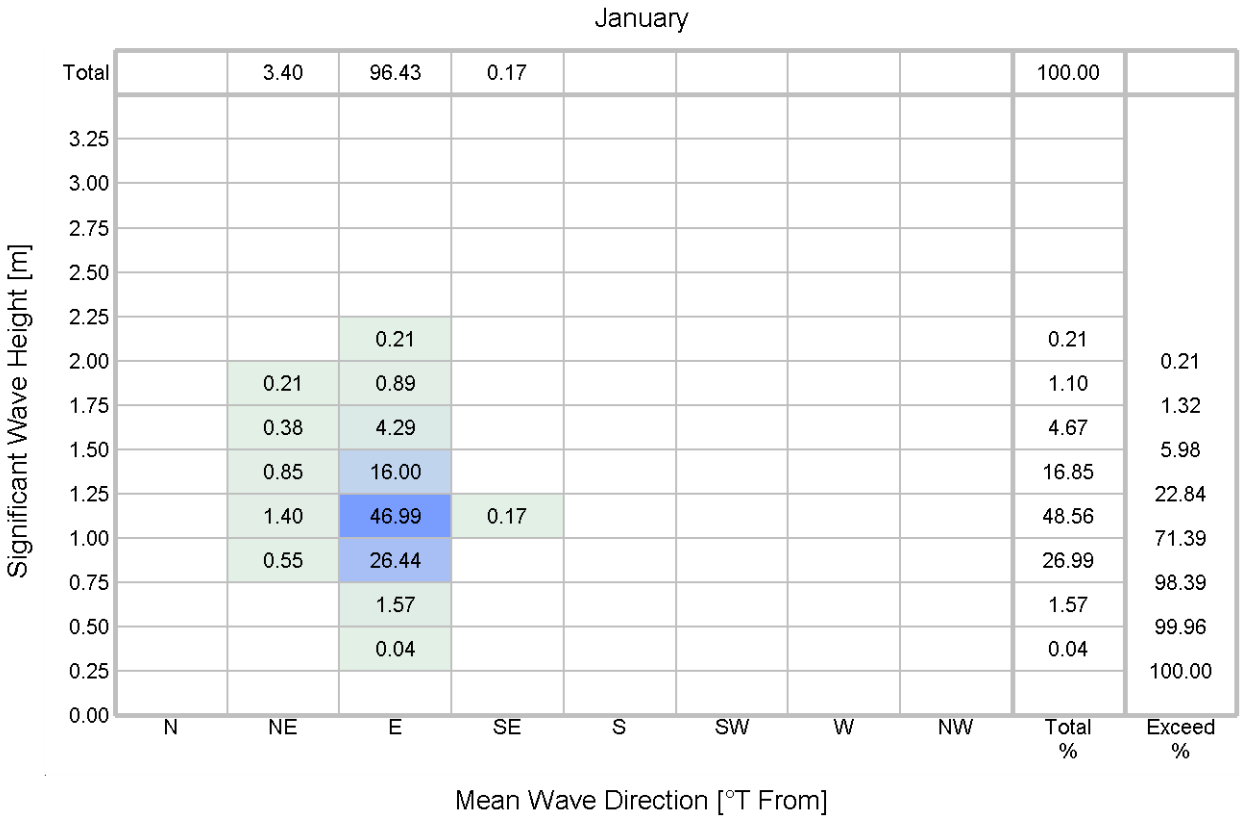


Figure 3.1.1: Percentage Occurrence of Hs and Mdir – All-Year



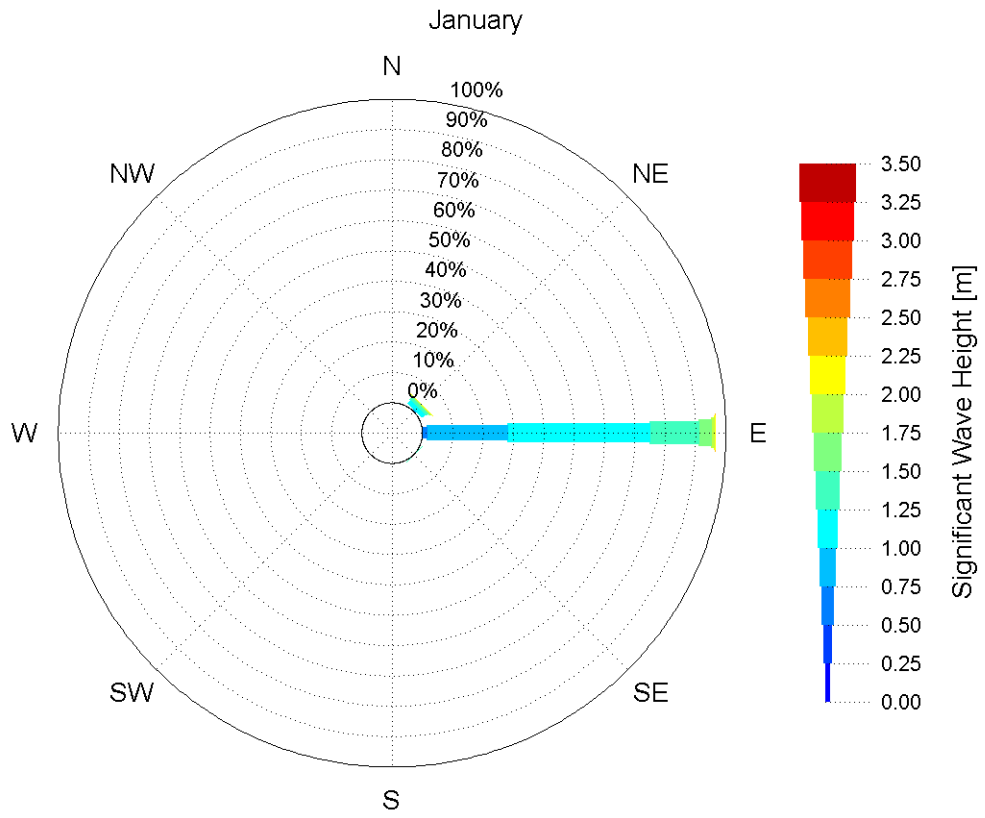
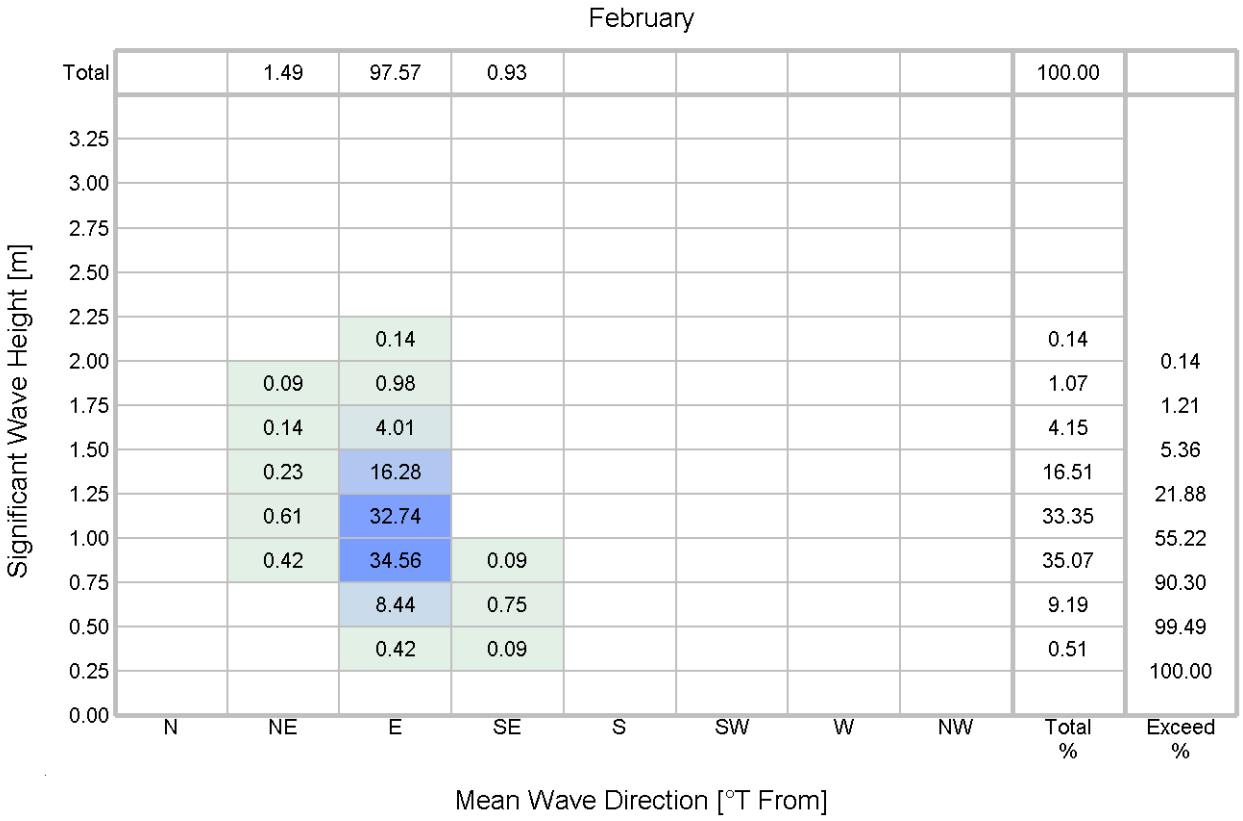


Figure 3.1.2: Percentage Occurrence of Hs and Mdir – January



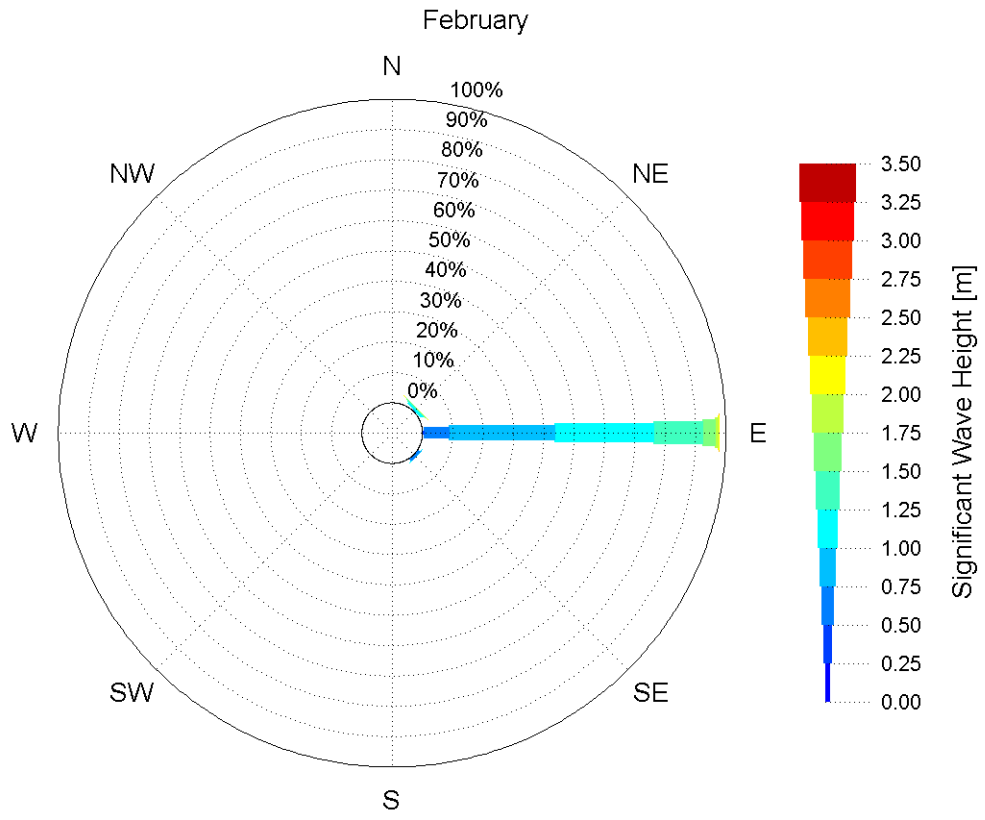


Figure 3.1.3: Percentage Occurrence of Hs and Mdir – February

March

Significant Wave Height [m]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total		0.04	58.36	41.17	0.42				100.00	
3.25 – 2.25										
2.00 – 1.75			0.04						0.04	0.04
1.75 – 1.50			0.25	0.04	0.04				0.34	0.38
1.50 – 1.25			4.07	0.98	0.21				5.26	5.65
1.25 – 1.00			18.76	6.41	0.04				25.21	30.86
1.00 – 0.75			25.17	18.76	0.08				44.02	74.87
0.75 – 0.50			9.00	13.12	0.04				22.16	97.03
0.50 – 0.25		0.04	1.06	1.83					2.93	99.96
0.25 – 0.00				0.04					0.04	

Mean Wave Direction [°T From]

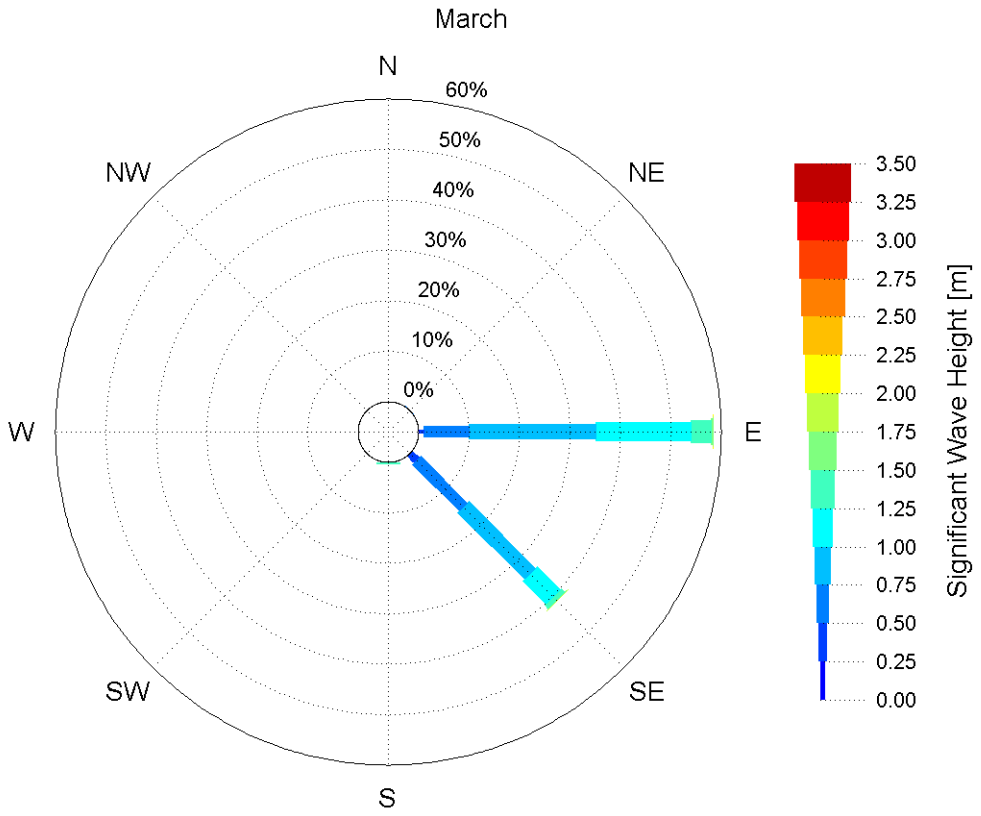
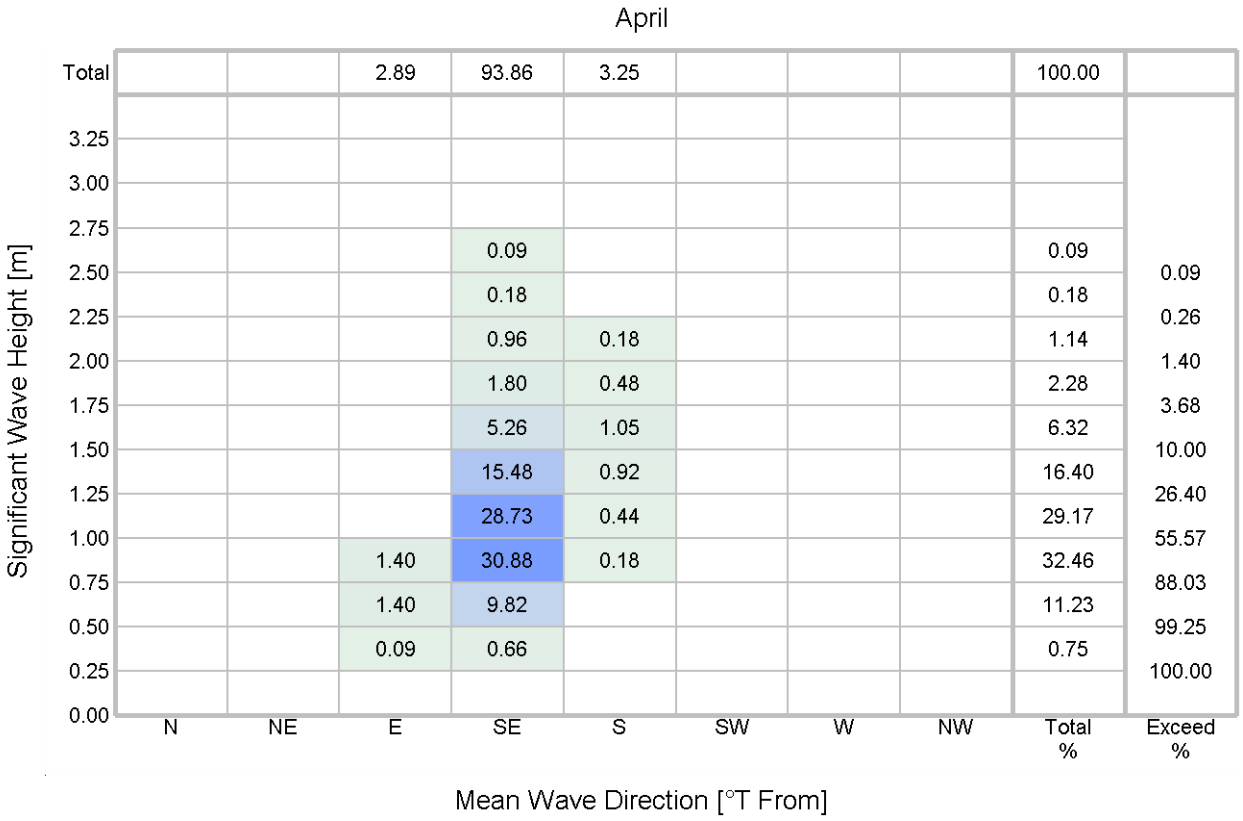


Figure 3.1.4: Percentage Occurrence of Hs and Mdir – March



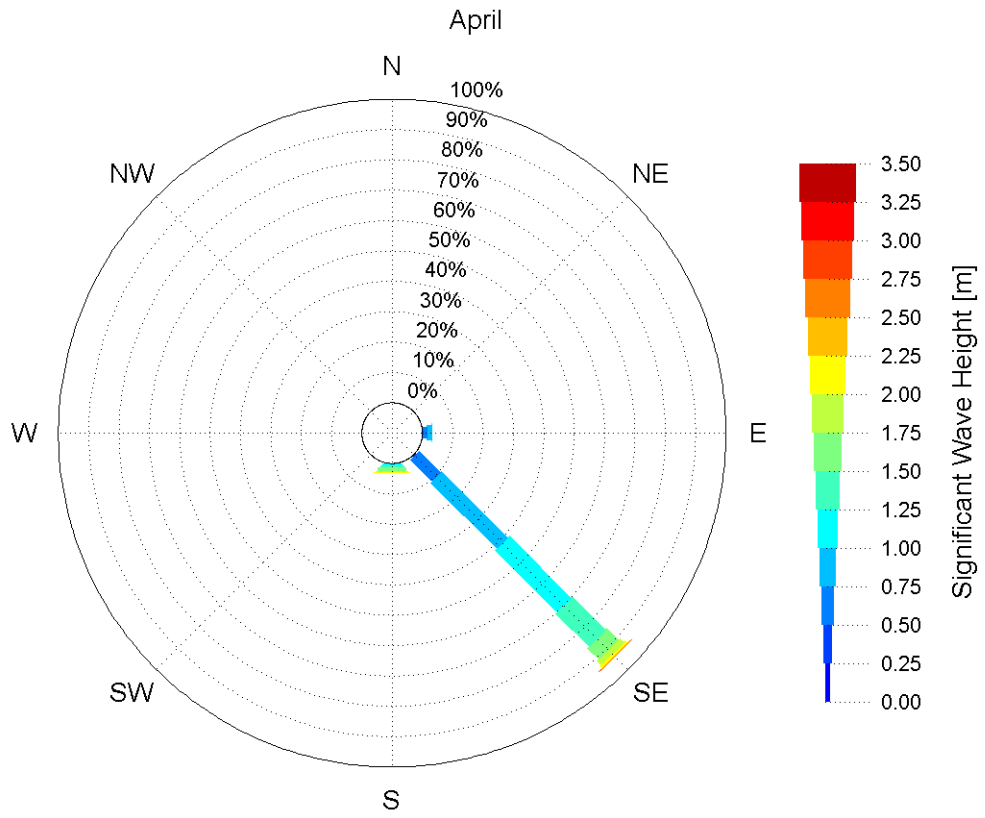


Figure 3.1.5: Percentage Occurrence of Hs and Mdir – April

May

Significant Wave Height [m]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total				93.55	6.45				100.00	
3.25										
3.00										
2.75				0.08					0.08	0.08
2.50				0.13					0.13	0.21
2.25				0.72	0.04				0.76	0.98
2.00				3.52	0.47				3.99	4.97
1.75				9.13	1.23				10.36	15.32
1.50				21.90	2.38				24.28	39.60
1.25				28.23	1.44				29.67	69.27
1.00				22.79	0.68				23.47	92.74
0.75				5.86	0.21				6.07	98.81
0.50				1.06					1.06	99.87
0.25				0.13					0.13	100.00
0.00										

Mean Wave Direction [°T From]

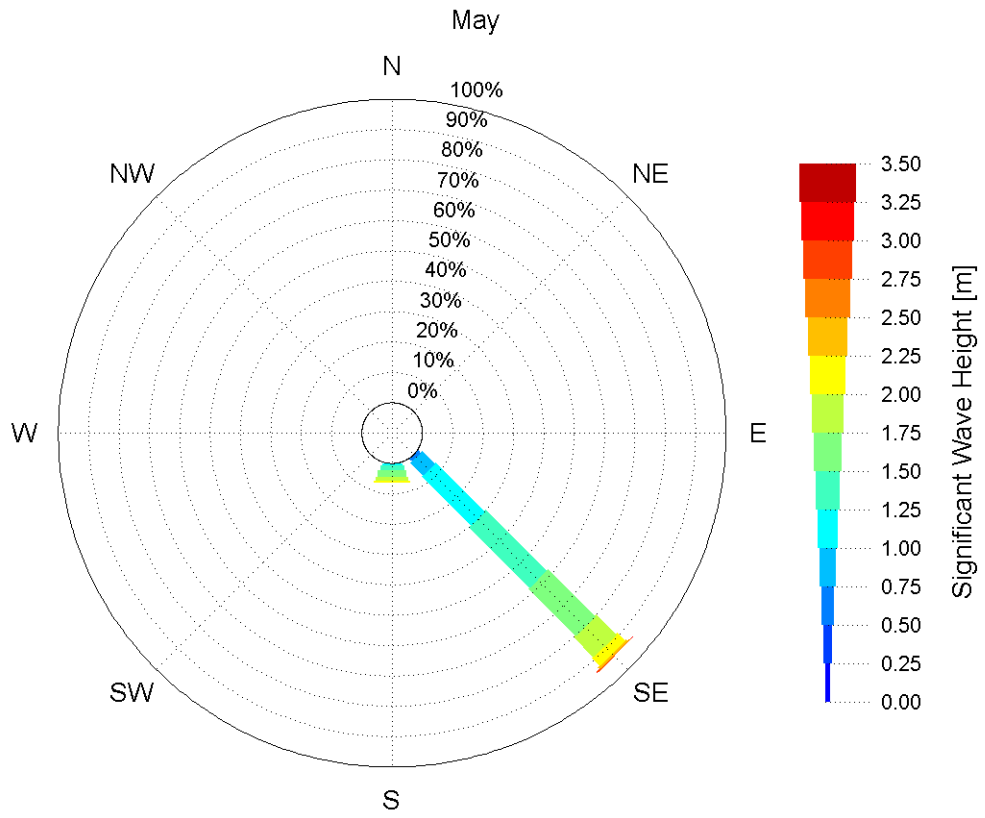
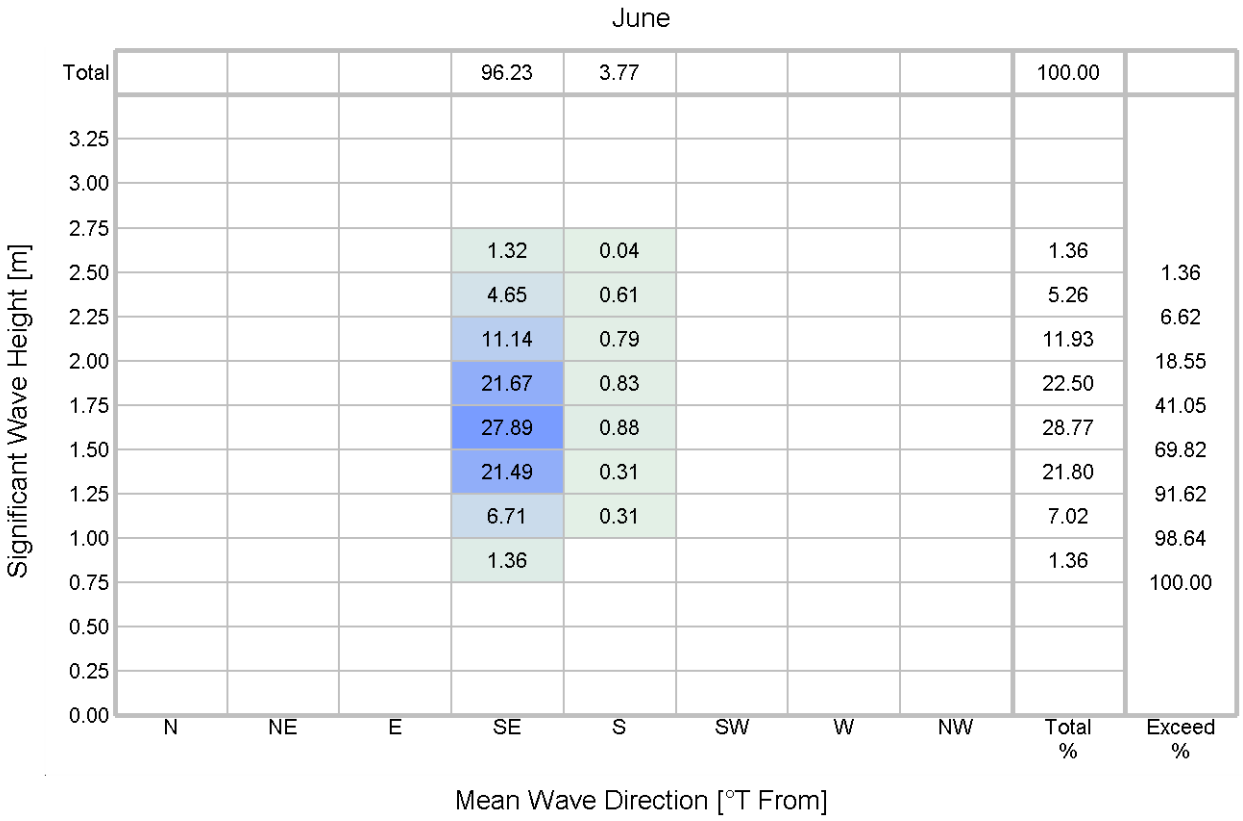


Figure 3.1.6: Percentage Occurrence of Hs and Mdir – May



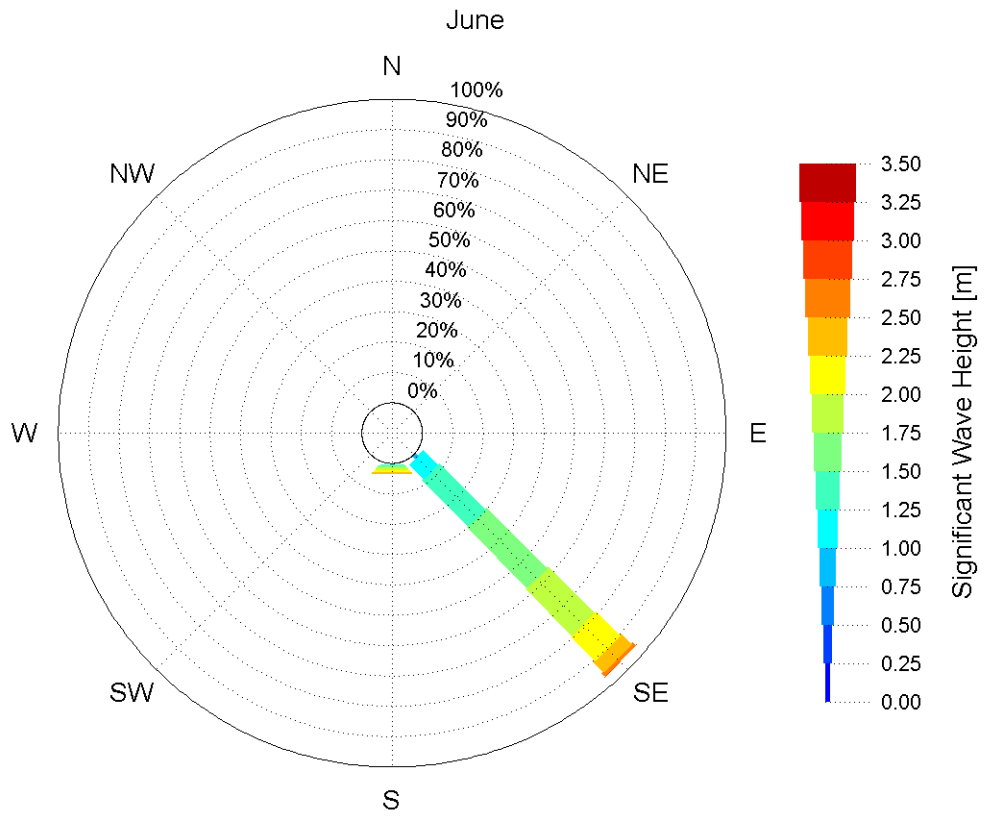


Figure 3.1.7: Percentage Occurrence of Hs and Mdir – June

July

Significant Wave Height [m]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total				98.90	1.10				100.00	
3.25				0.08	0.04				0.13	0.13
3.00				0.34					0.34	0.47
2.75				0.76	0.08				0.85	1.32
2.50				1.91	0.04				1.95	3.27
2.25				4.84	0.08				4.92	8.19
2.00				12.52	0.30				12.82	21.01
1.75				25.25	0.25				25.51	46.52
1.50				29.20	0.21				29.41	75.93
1.25				19.35	0.04				19.40	95.33
1.00				4.46	0.04				4.50	99.83
0.75				0.17					0.17	100.00
0.50										
0.25										
0.00										

Mean Wave Direction [°T From]

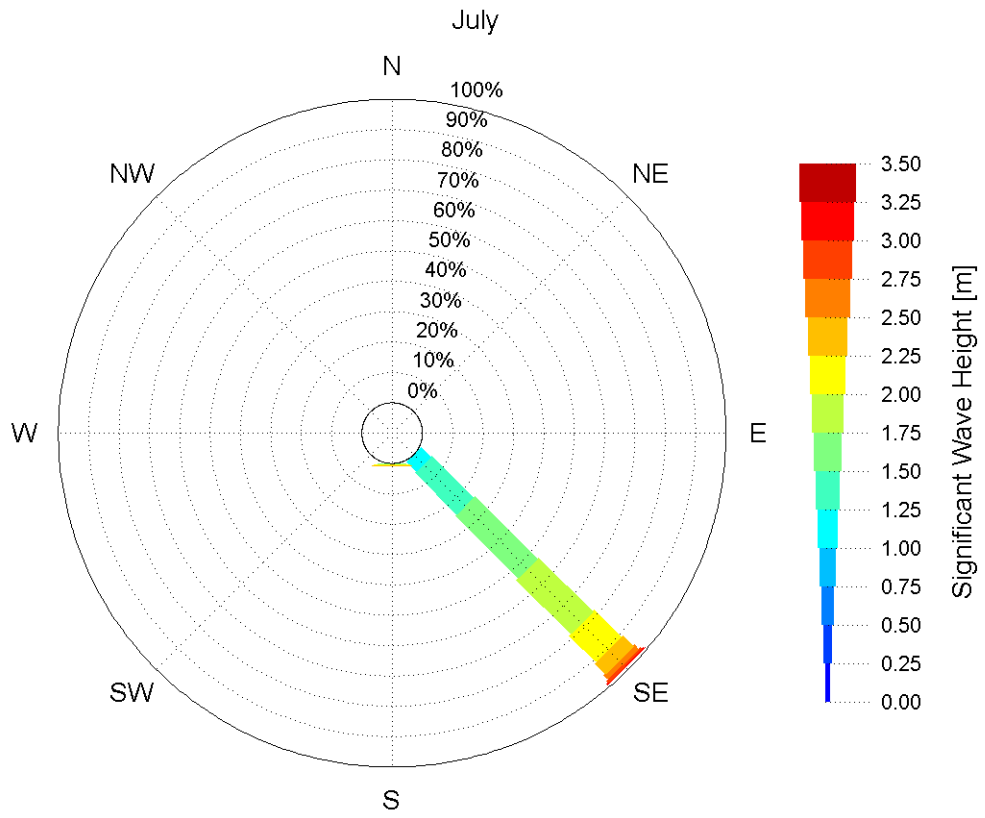
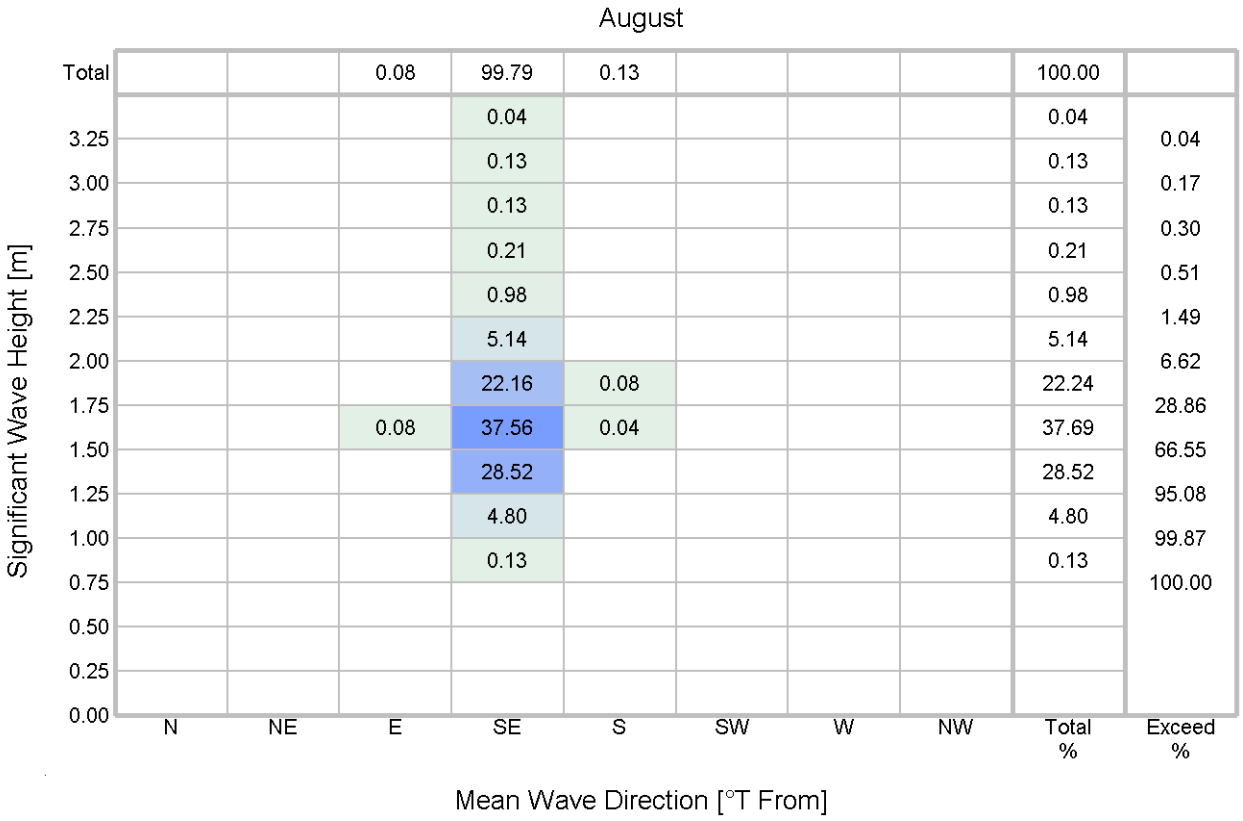


Figure 3.1.8: Percentage Occurrence of Hs and Mdir – July



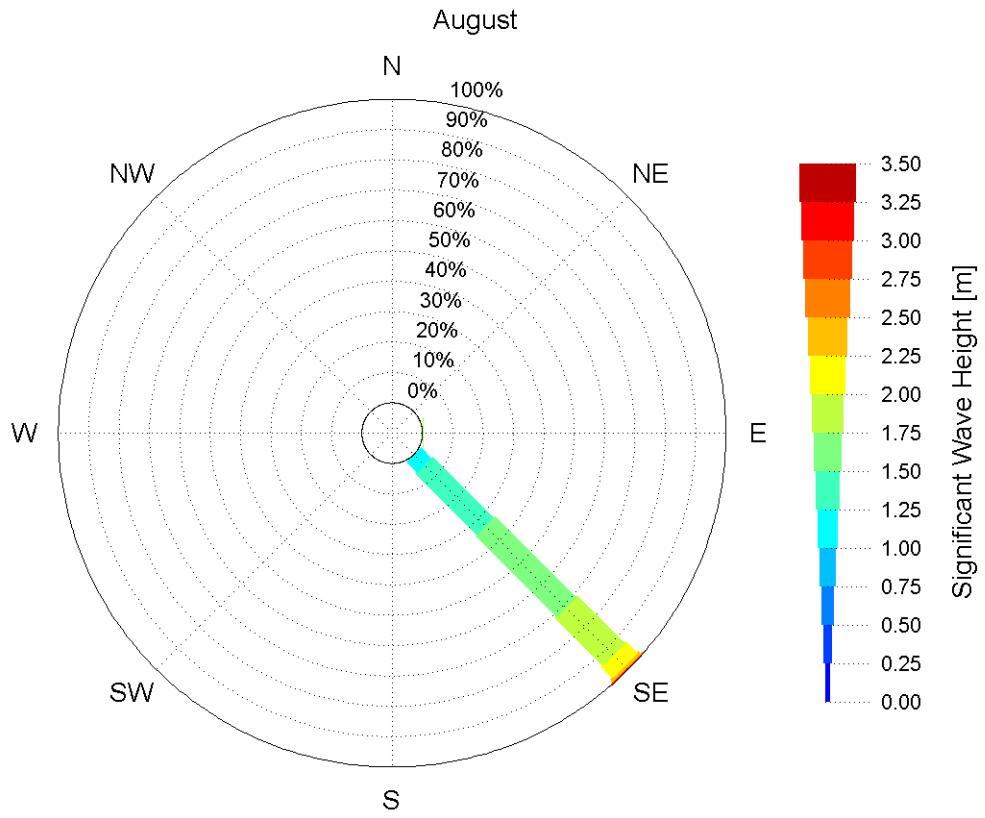
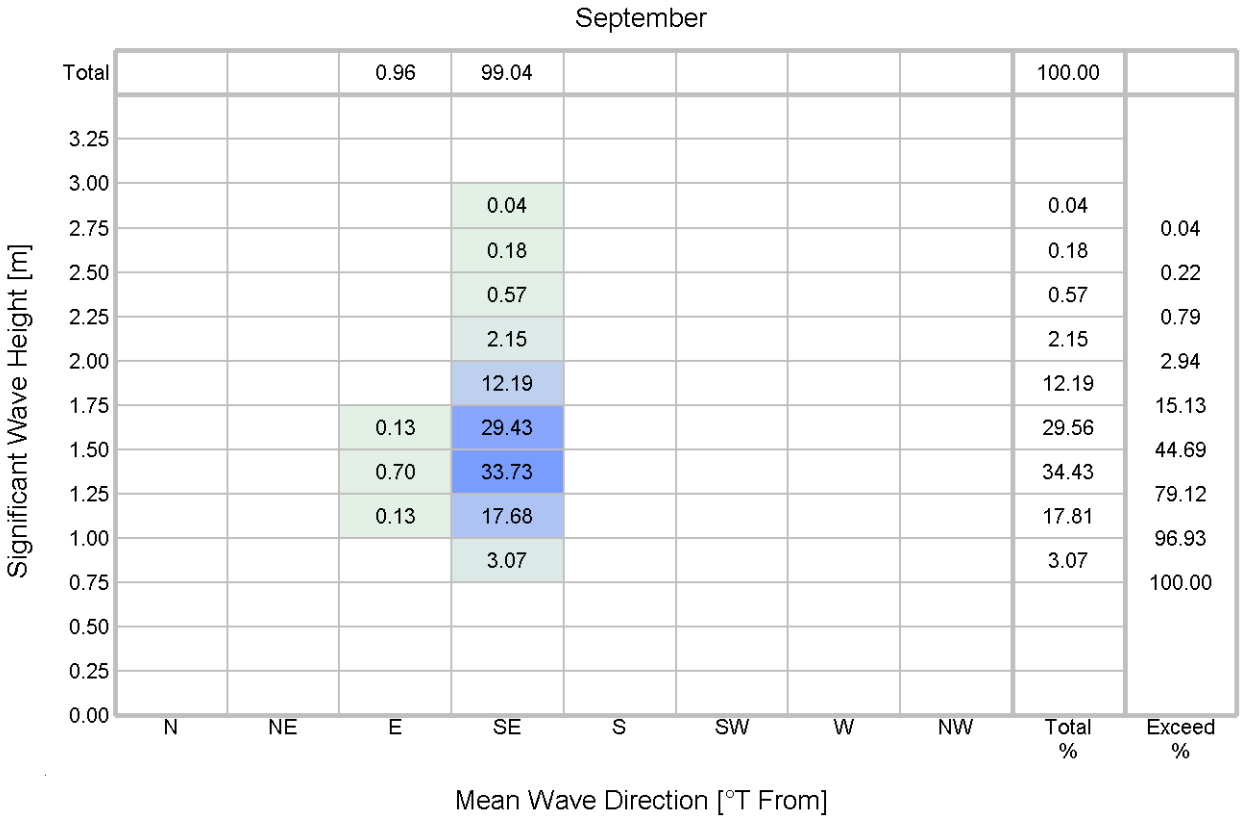


Figure 3.1.9: Percentage Occurrence of Hs and Mdir – August



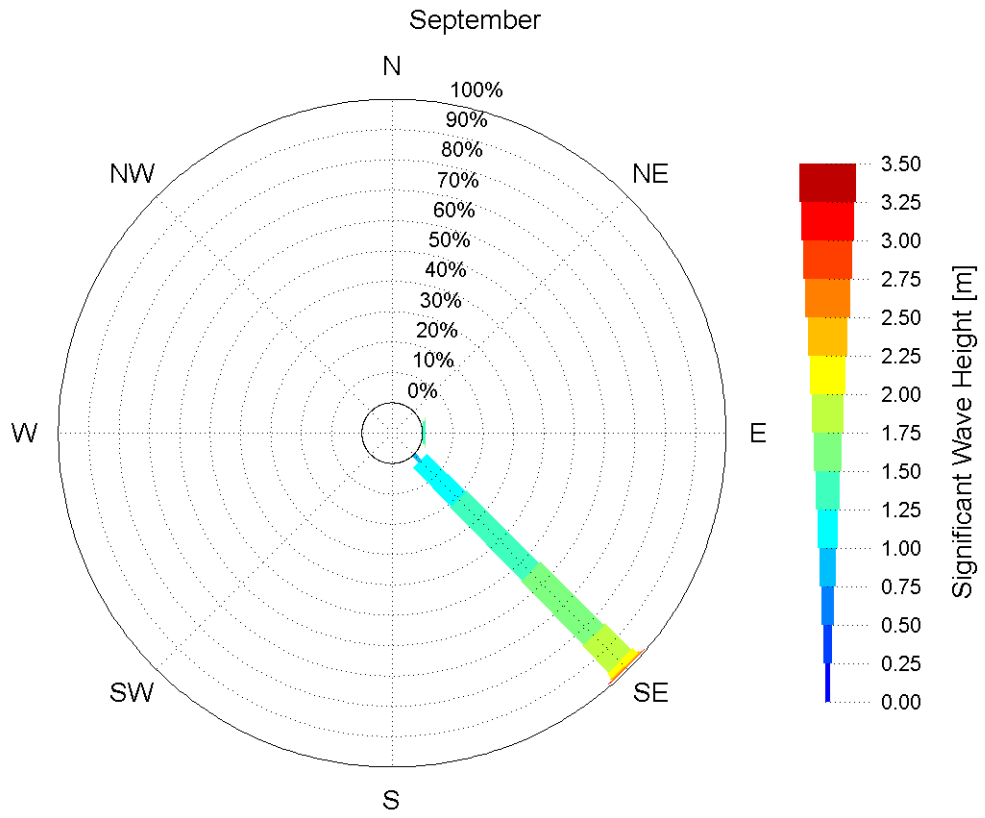
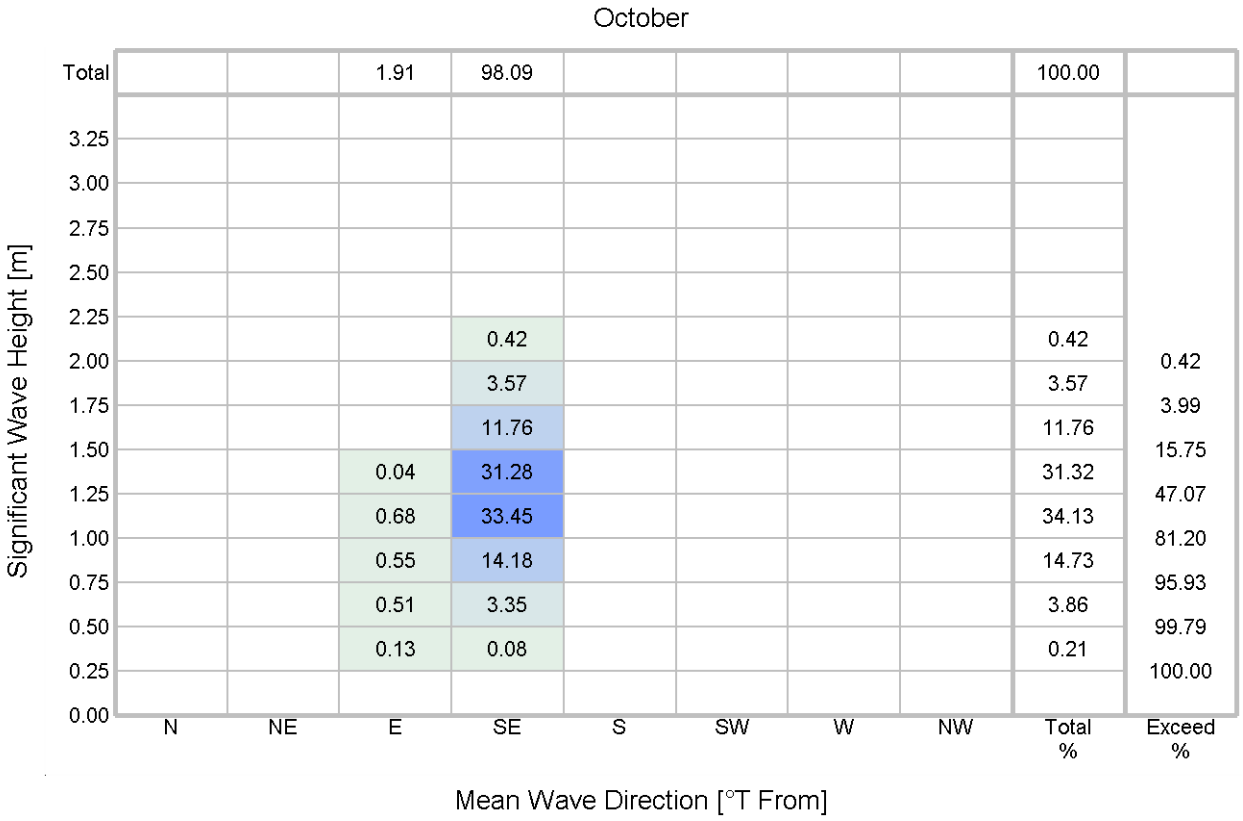


Figure 3.1.10: Percentage Occurrence of Hs and Mdir – September



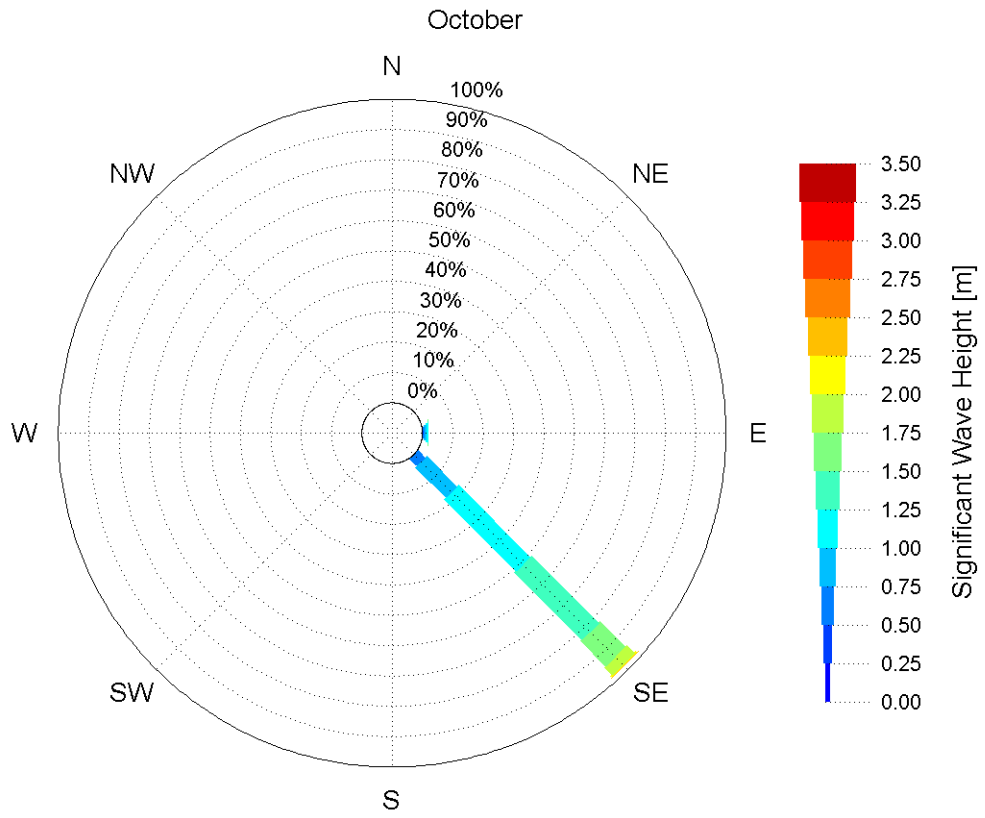
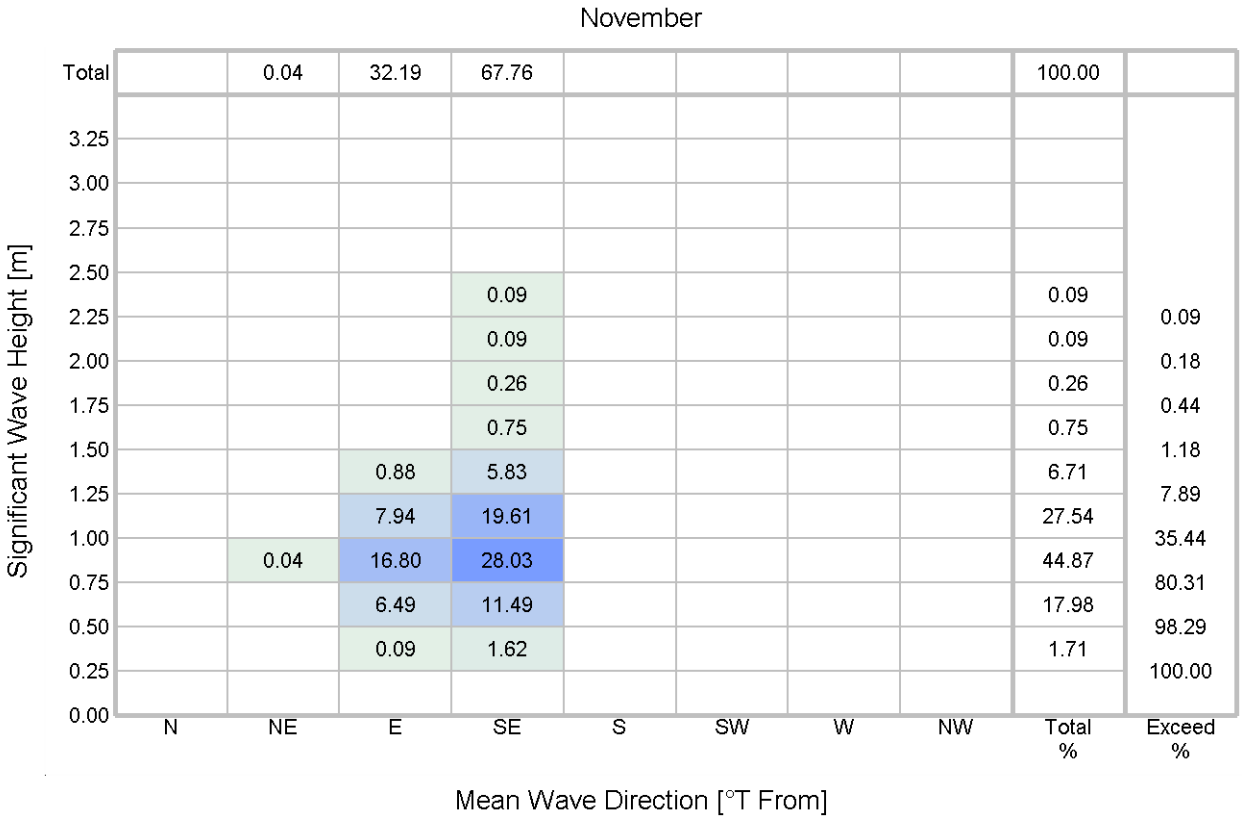


Figure 3.1.11: Percentage Occurrence of Hs and Mdir – October



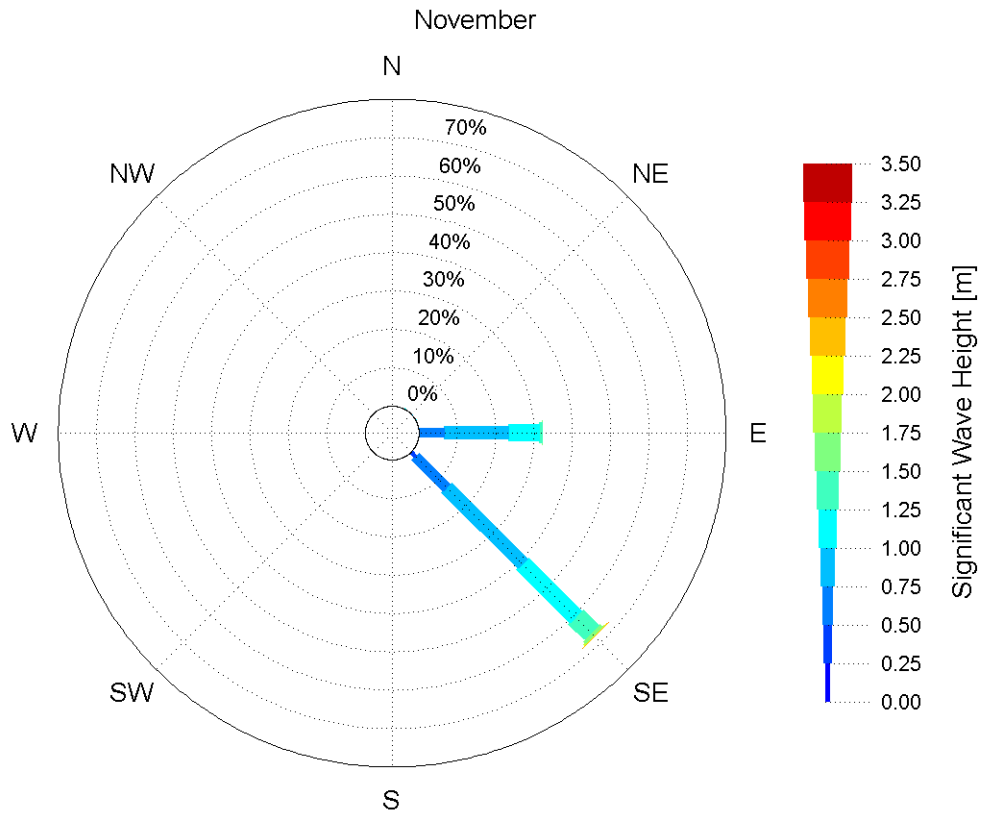


Figure 3.1.12: Percentage Occurrence of Hs and Mdir – November

December

Significant Wave Height [m]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total		1.44	91.00	7.47	0.08				100.00	
3.25 – 2.25										
2.00 – 1.75			0.13						0.13	0.13
1.75 – 1.50		0.08	1.66						1.74	1.87
1.50 – 1.25		0.47	10.02						10.48	12.35
1.25 – 1.00		0.64	35.02	0.72	0.08				36.46	48.81
1.00 – 0.75		0.17	37.61	3.57					41.34	90.15
0.75 – 0.50		0.08	6.20	2.46					8.74	98.90
0.50 – 0.25			0.38	0.72					1.10	100.00
0.25 – 0.00										

Mean Wave Direction [°T From]

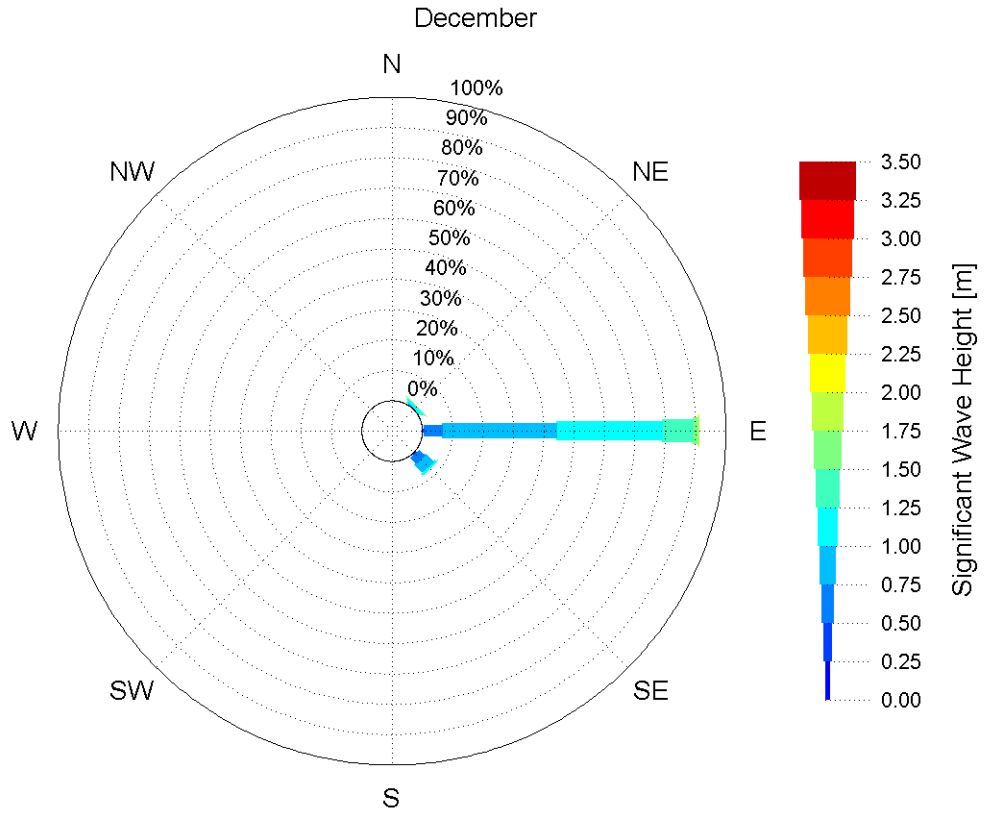


Figure 3.1.13: Percentage Occurrence of Hs and Mdir – December

3.2 Operational Wave Criteria – Hs and Te

The following figures are presented in this section:

Figure 3.2.1: Percentage Occurrence of Hs and Te – All-Year
Figure 3.2.2: Percentage Occurrence of Hs and Te – January
Figure 3.2.3: Percentage Occurrence of Hs and Te – February
Figure 3.2.4: Percentage Occurrence of Hs and Te – March
Figure 3.2.5: Percentage Occurrence of Hs and Te – April
Figure 3.2.6: Percentage Occurrence of Hs and Te – May
Figure 3.2.7: Percentage Occurrence of Hs and Te – June
Figure 3.2.8: Percentage Occurrence of Hs and Te – July
Figure 3.2.9: Percentage Occurrence of Hs and Te – August
Figure 3.2.10: Percentage Occurrence of Hs and Te – September
Figure 3.2.11: Percentage Occurrence of Hs and Te – October
Figure 3.2.12: Percentage Occurrence of Hs and Te – November
Figure 3.2.13: Percentage Occurrence of Hs and Te – December

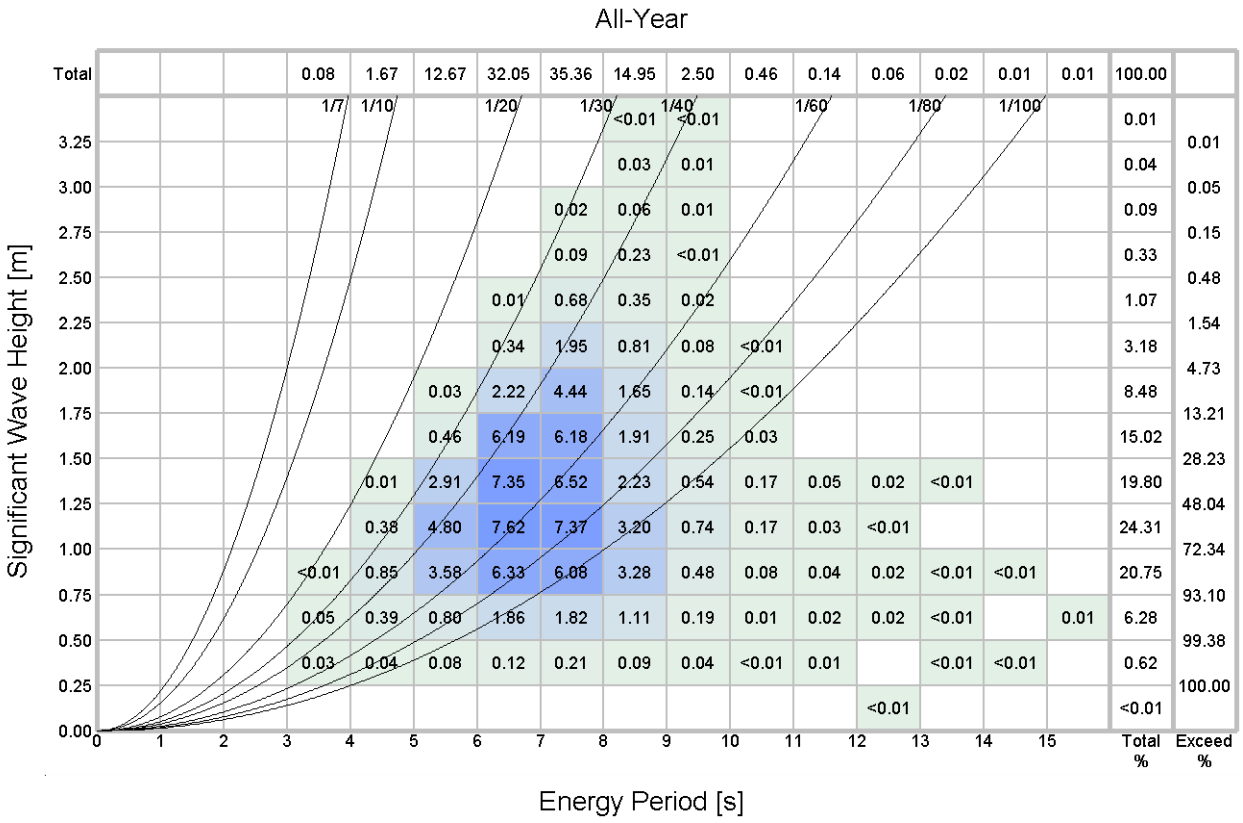


Figure 3.2.1: Percentage Occurrence of Hs and Te – All-Year

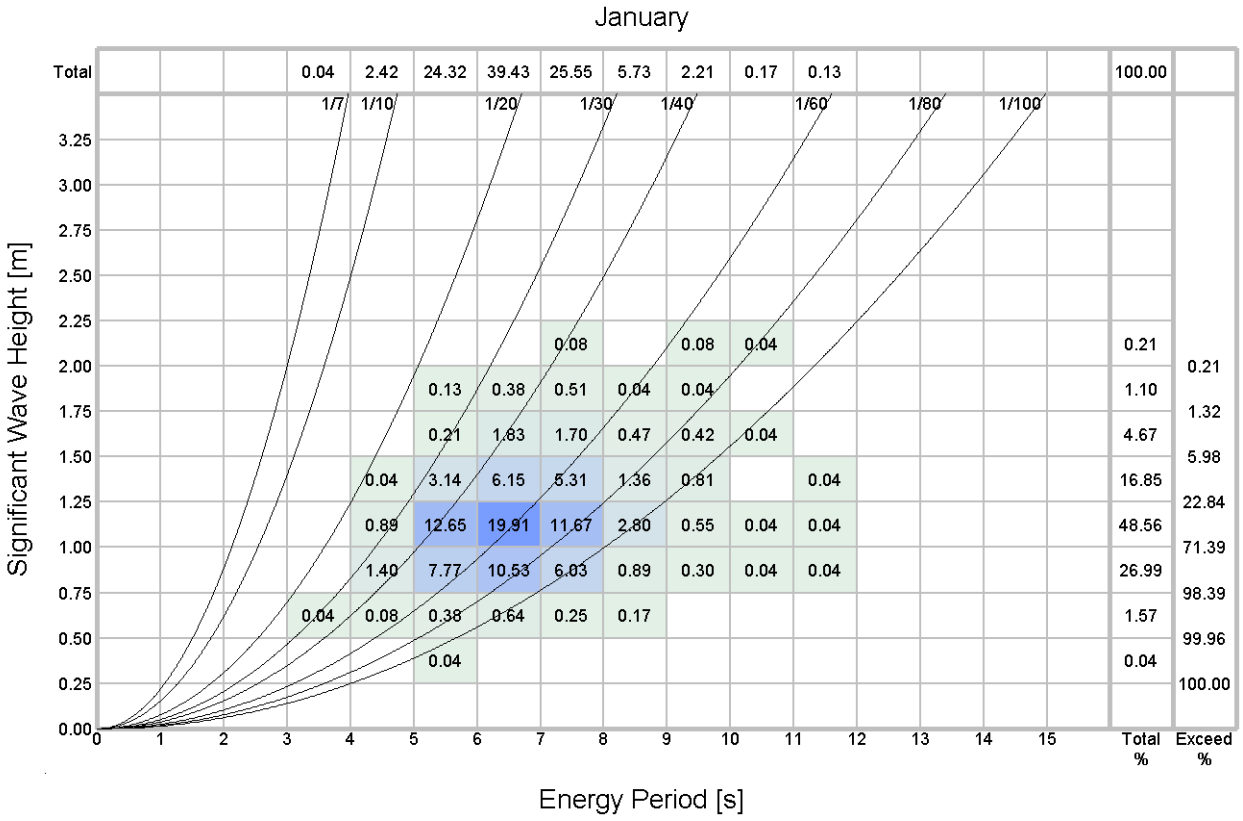


Figure 3.2.2: Percentage Occurrence of Hs and Te – January

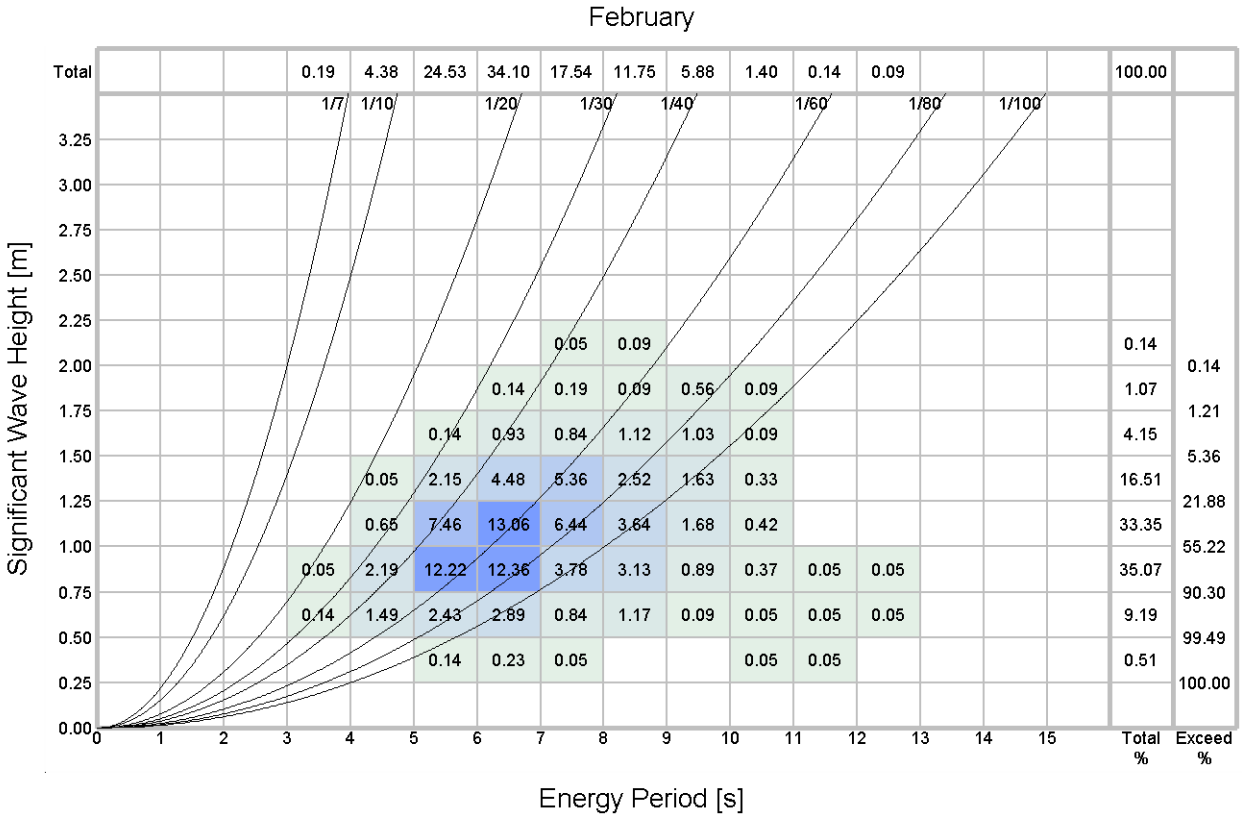


Figure 3.2.3: Percentage Occurrence of Hs and Te – February

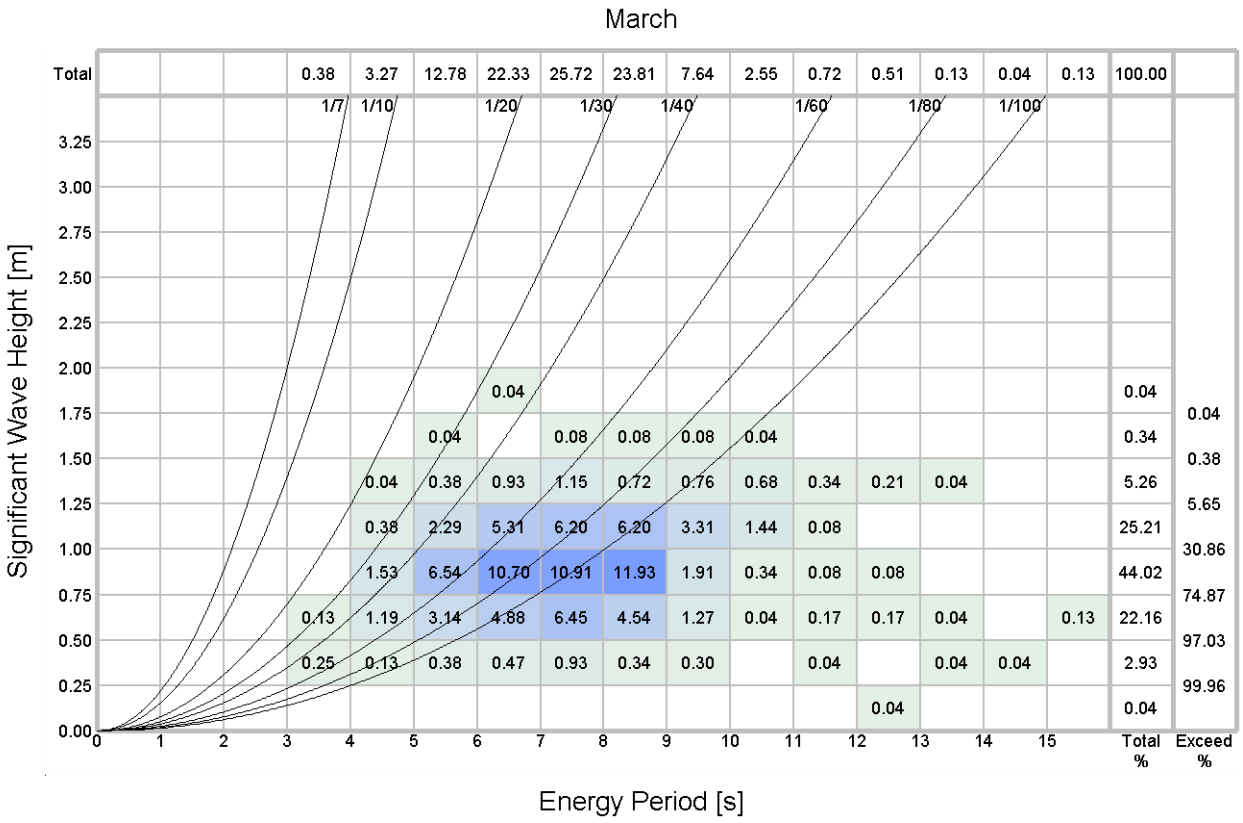


Figure 3.2.4: Percentage Occurrence of Hs and Te – March

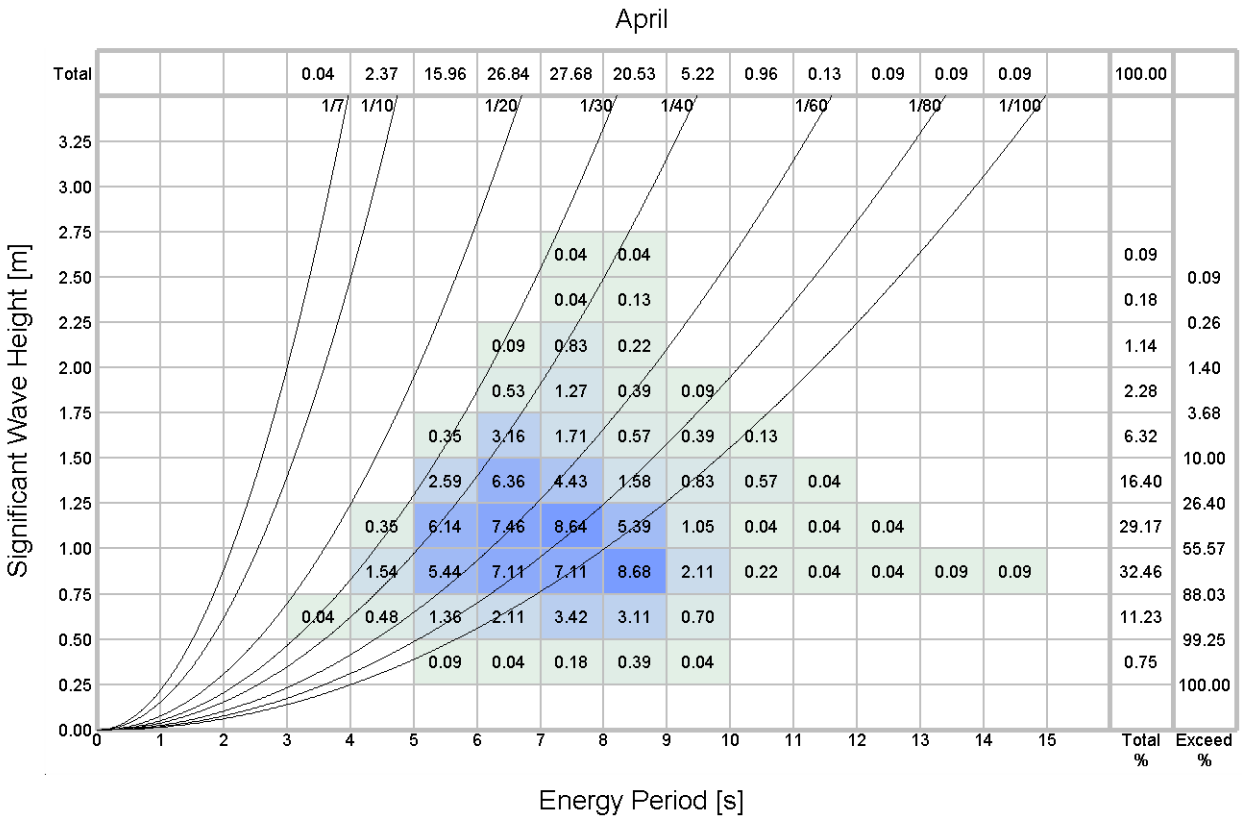


Figure 3.2.5: Percentage Occurrence of Hs and Te – April

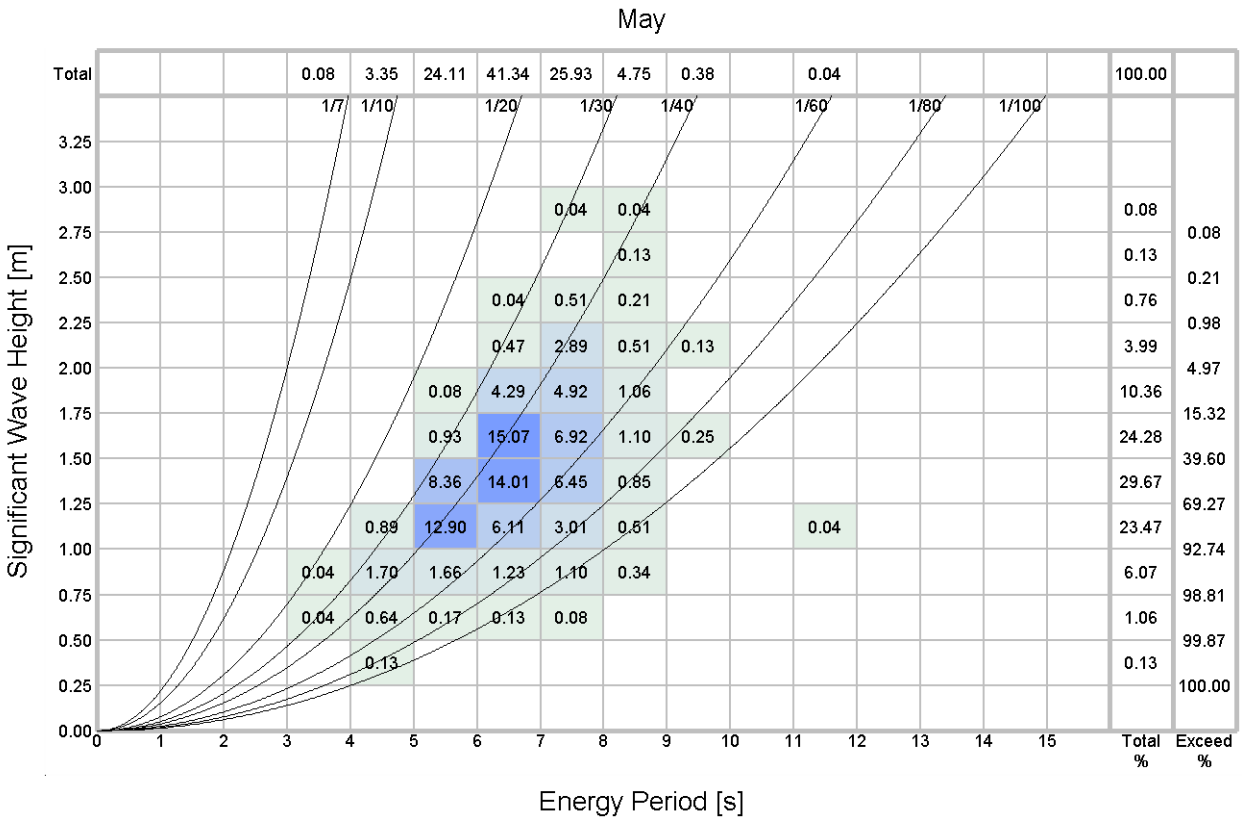


Figure 3.2.6: Percentage Occurrence of Hs and Te – May

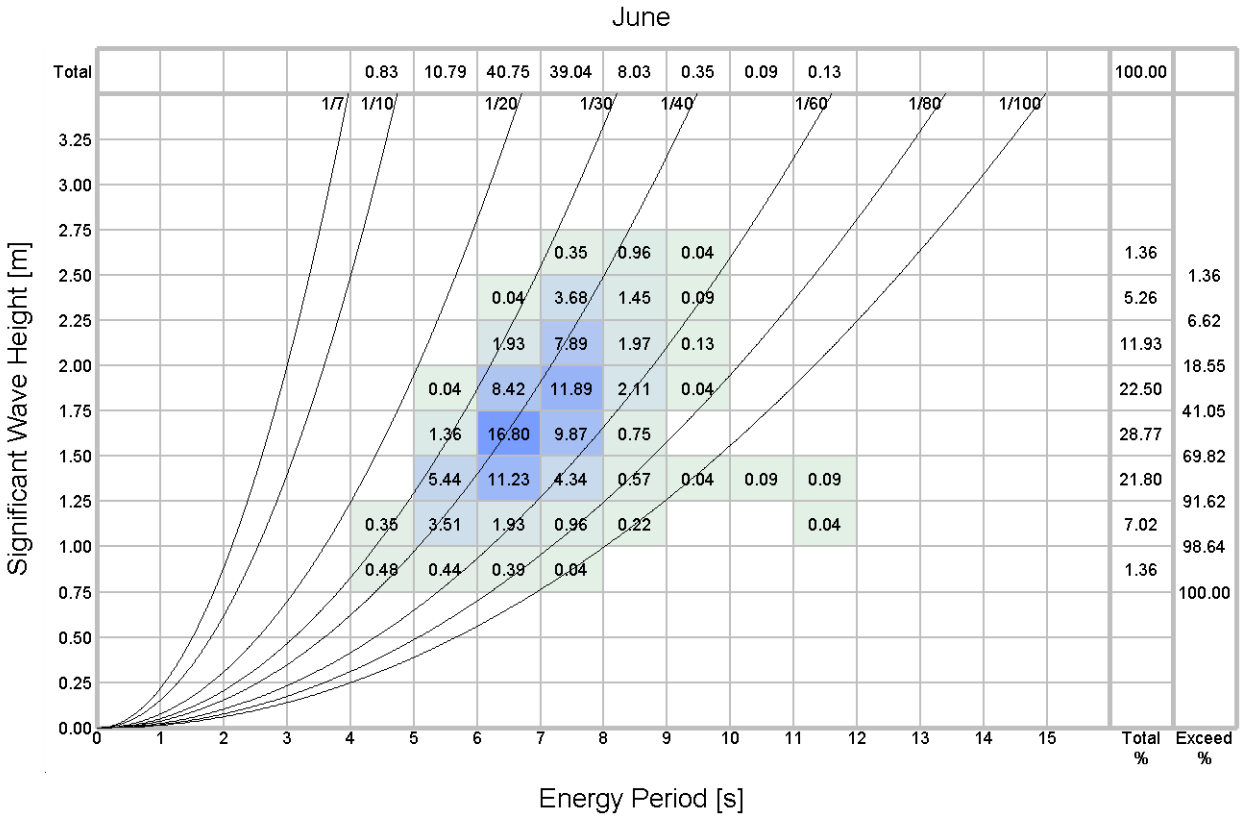


Figure 3.2.7: Percentage Occurrence of Hs and Te – June

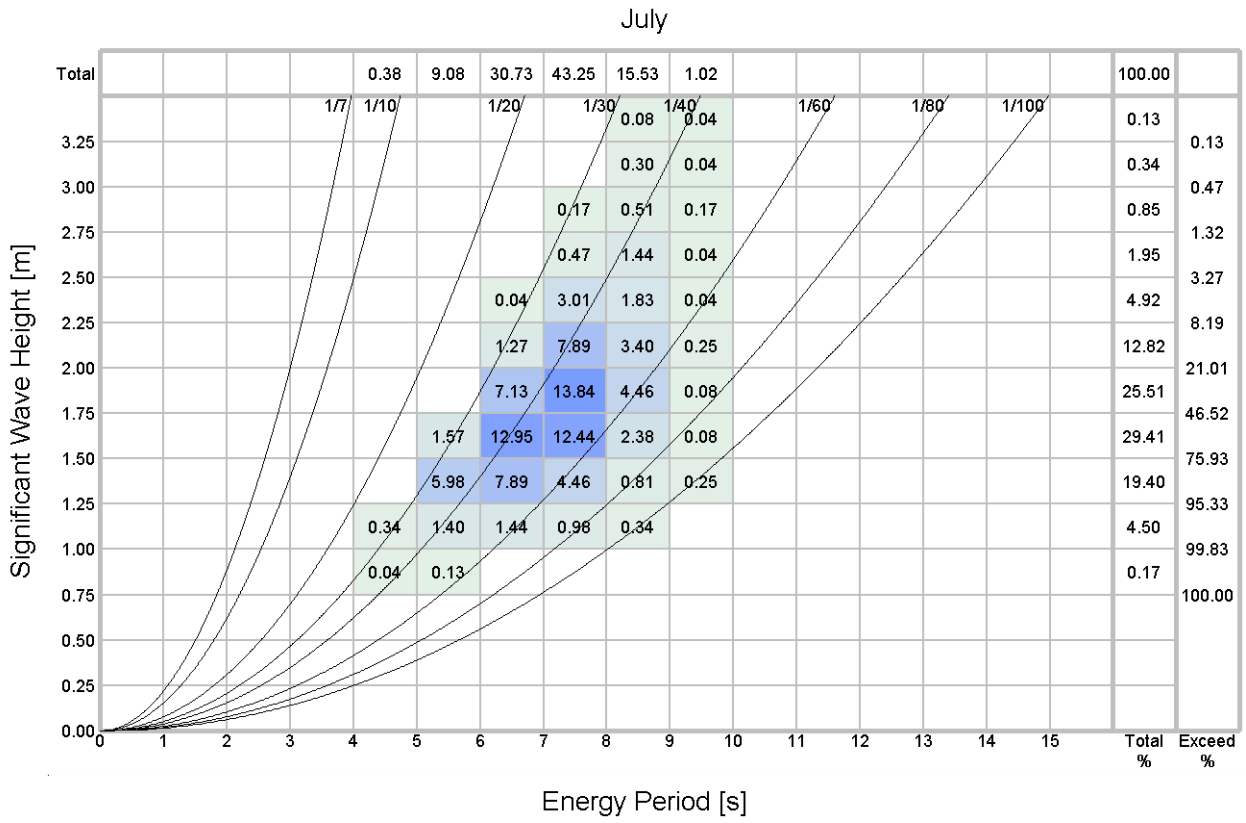


Figure 3.2.8: Percentage Occurrence of Hs and Te – July

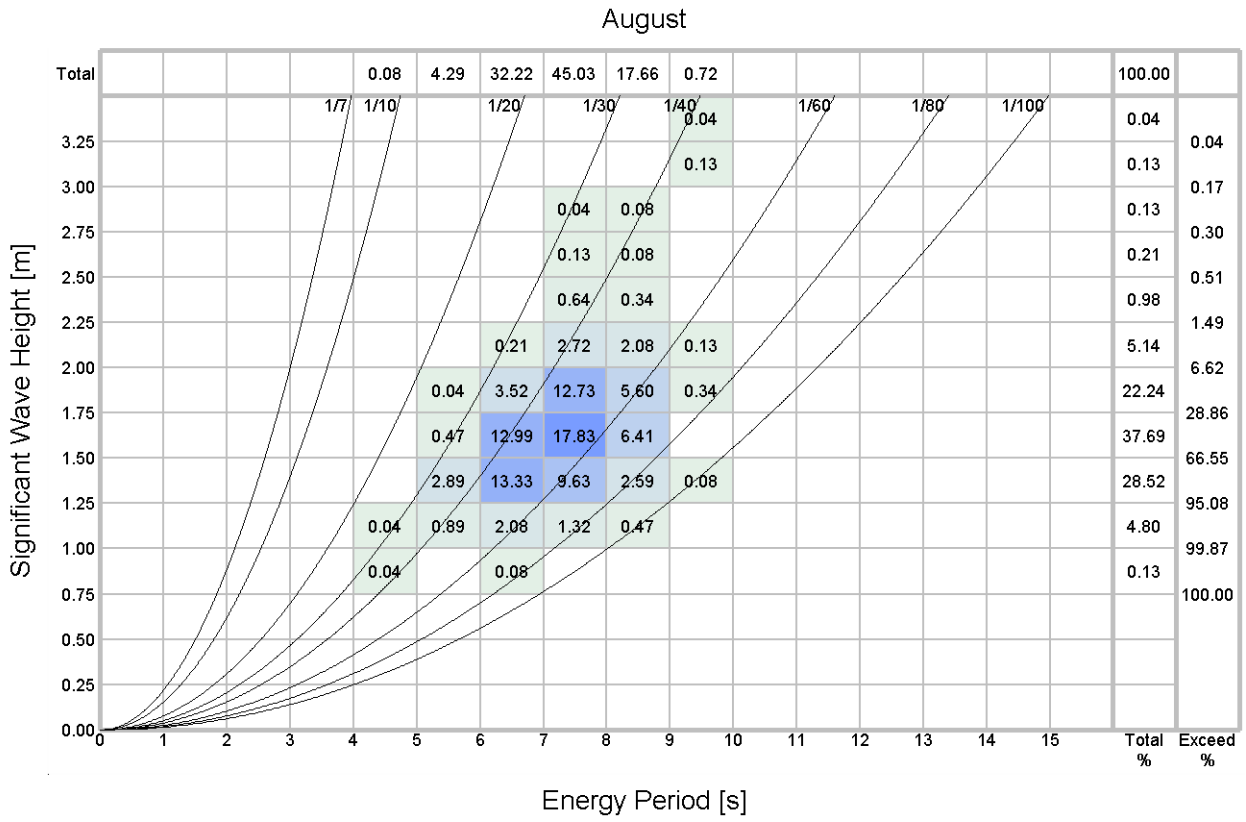


Figure 3.2.9: Percentage Occurrence of Hs and Te – August

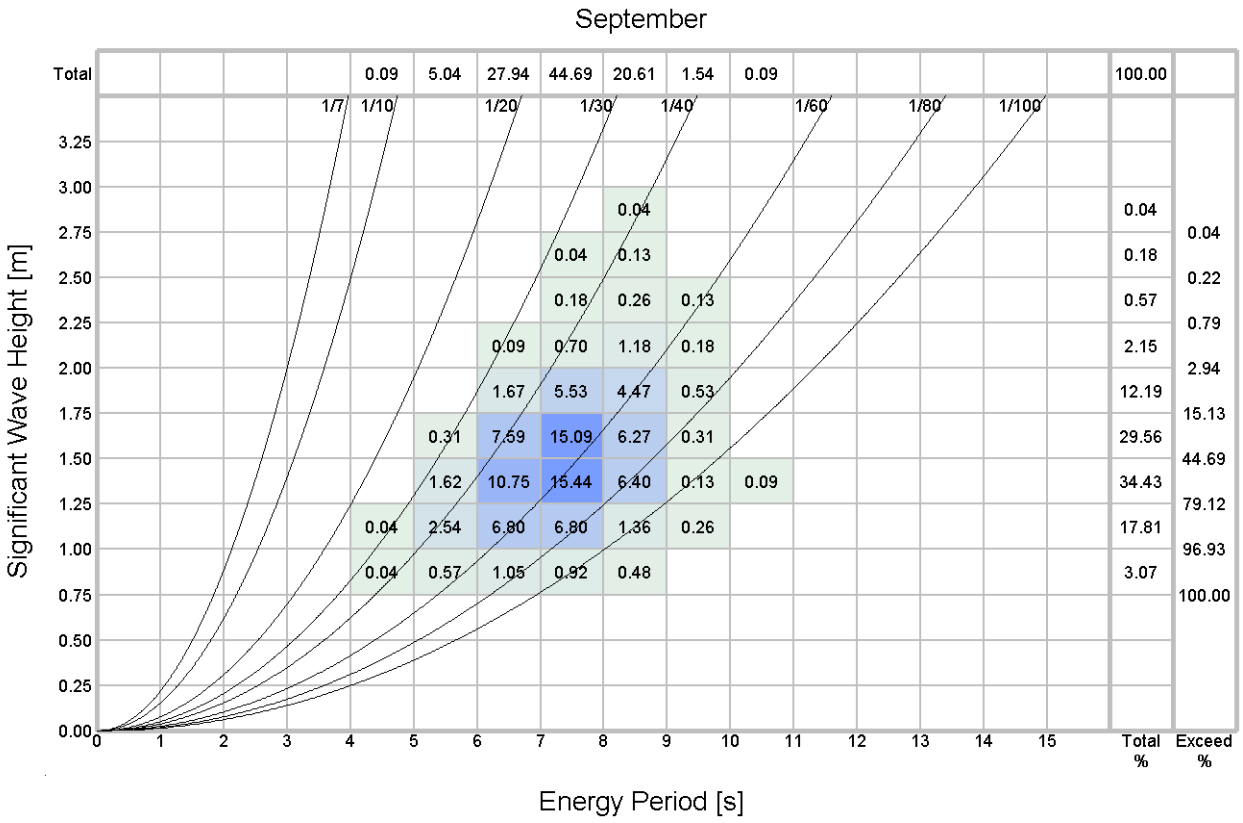


Figure 3.2.10: Percentage Occurrence of Hs and Te – September

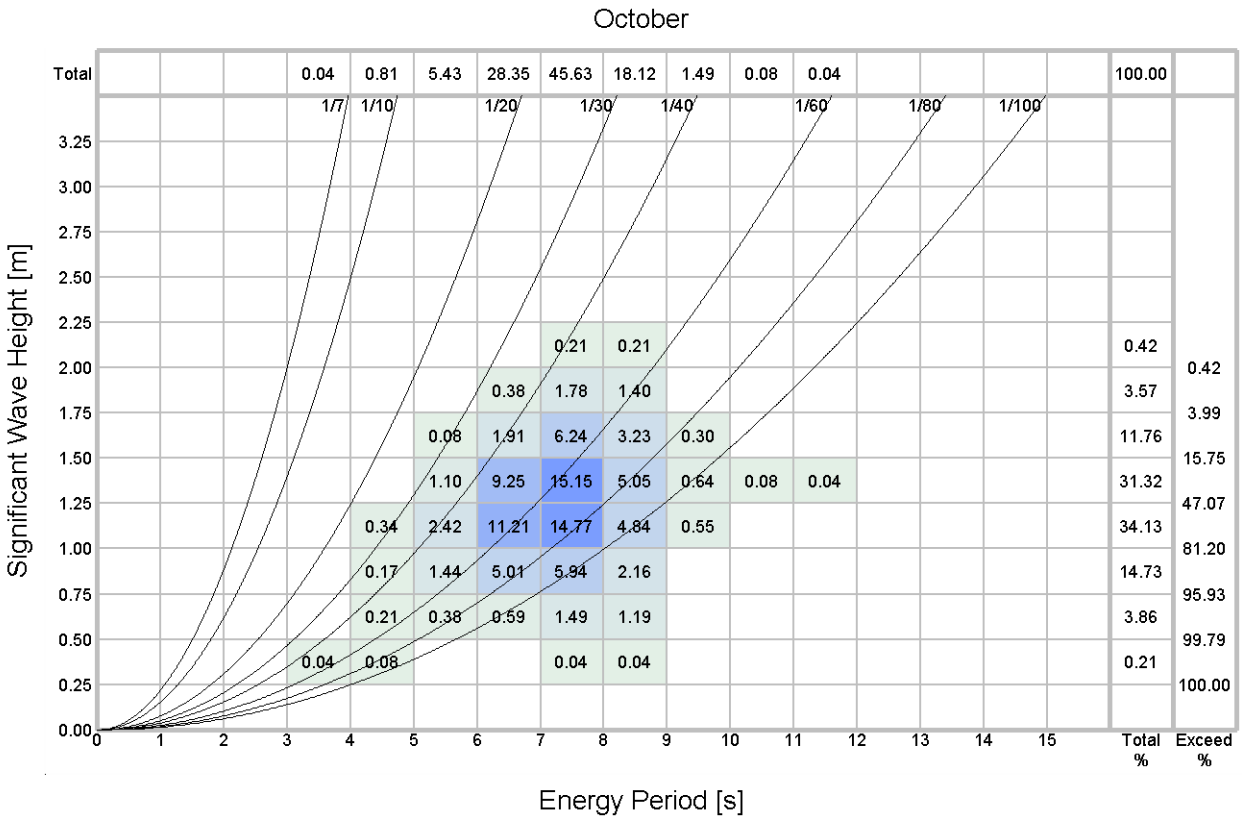


Figure 3.2.11: Percentage Occurrence of Hs and Te – October

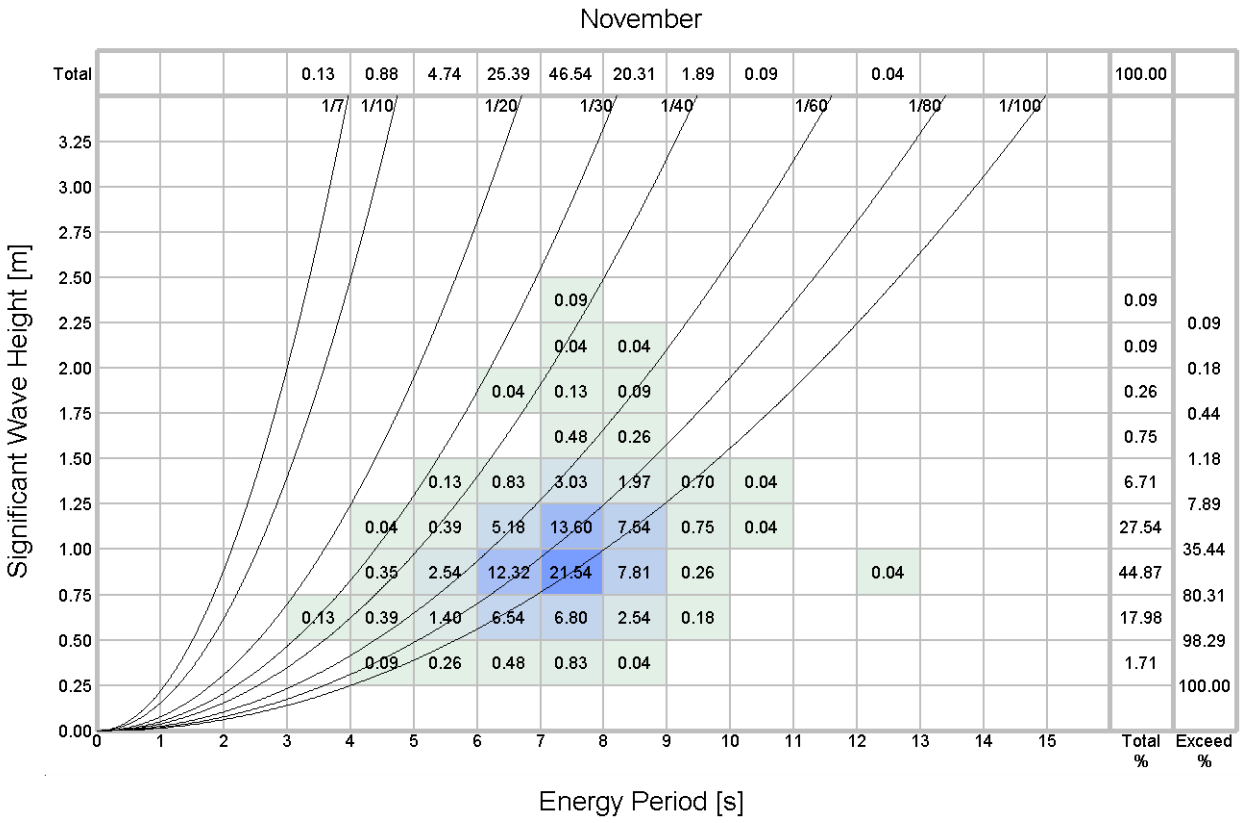


Figure 3.2.12: Percentage Occurrence of Hs and Te – November

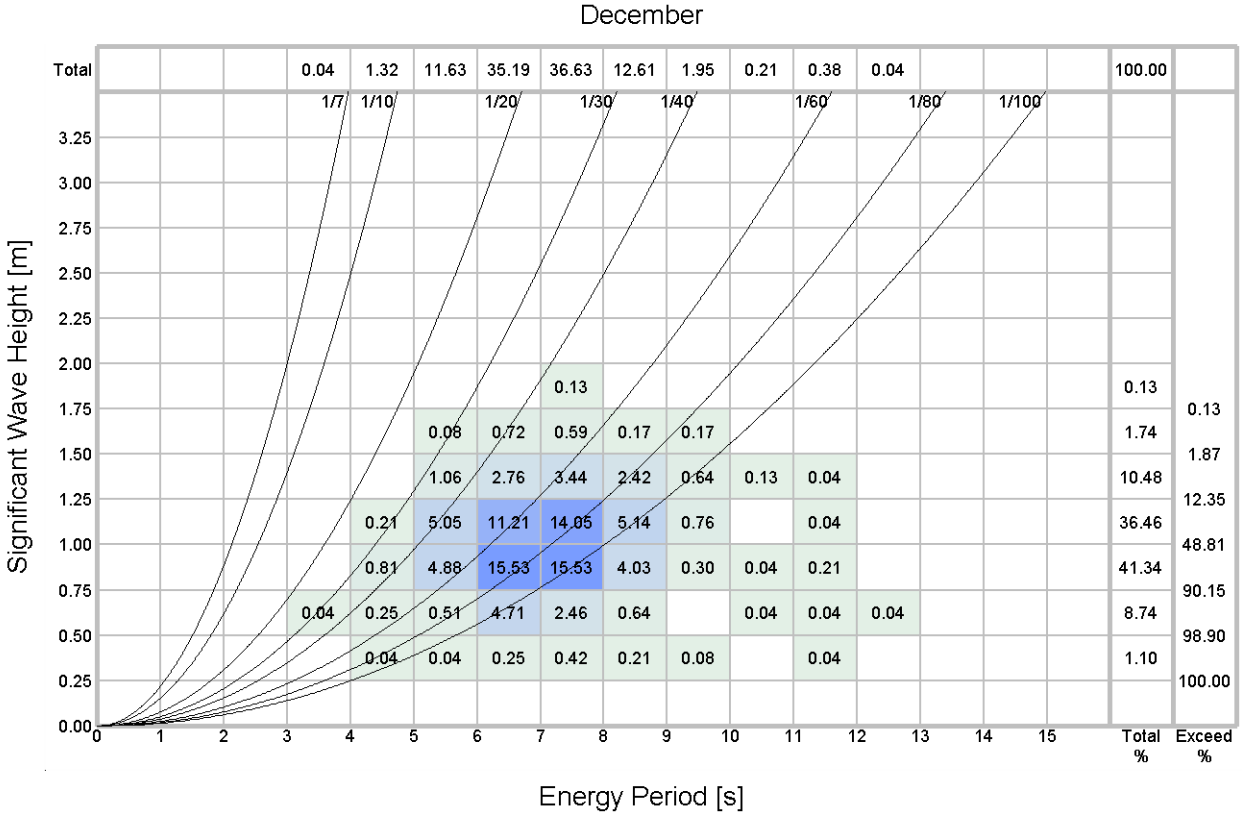


Figure 3.2.13: Percentage Occurrence of Hs and Te – December

3.3 Operational Wave Criteria – Hs and Tp

The following figures are presented in this section:

Figure 3.3.1: Percentage Occurrence of Hs and Tp - All-Year
Figure 3.3.2: Percentage Occurrence of Hs and Tp – January
Figure 3.3.3: Percentage Occurrence of Hs and Tp – February
Figure 3.3.4: Percentage Occurrence of Hs and Tp – March
Figure 3.3.5: Percentage Occurrence of Hs and Tp – April
Figure 3.3.6: Percentage Occurrence of Hs and Tp – May
Figure 3.3.7: Percentage Occurrence of Hs and Tp – June
Figure 3.3.8: Percentage Occurrence of Hs and Tp – July
Figure 3.3.9: Percentage Occurrence of Hs and Tp – August
Figure 3.3.10: Percentage Occurrence of Hs and Tp – September
Figure 3.3.11: Percentage Occurrence of Hs and Tp – October
Figure 3.3.12: Percentage Occurrence of Hs and Tp – November
Figure 3.3.13: Percentage Occurrence of Hs and Tp – December

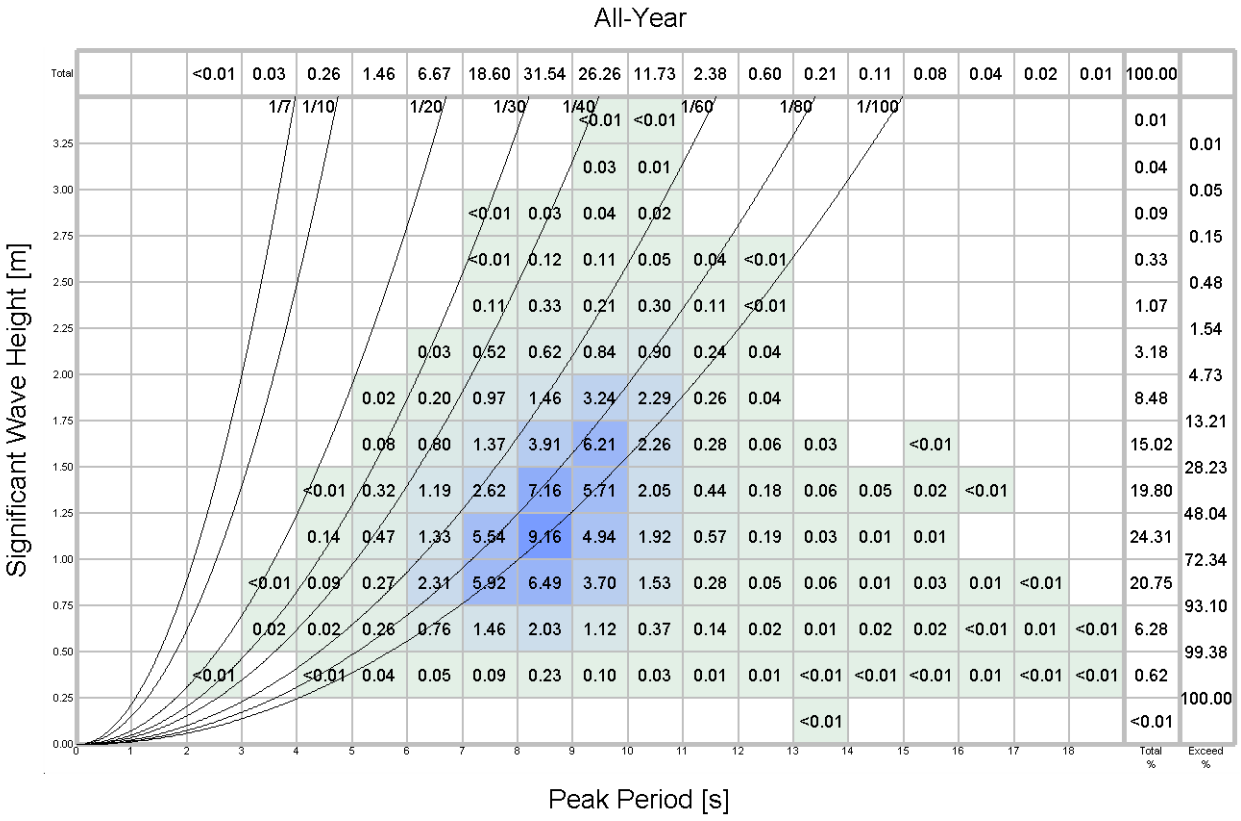


Figure 3.3.1: Percentage Occurrence of Hs and Tp - All-Year

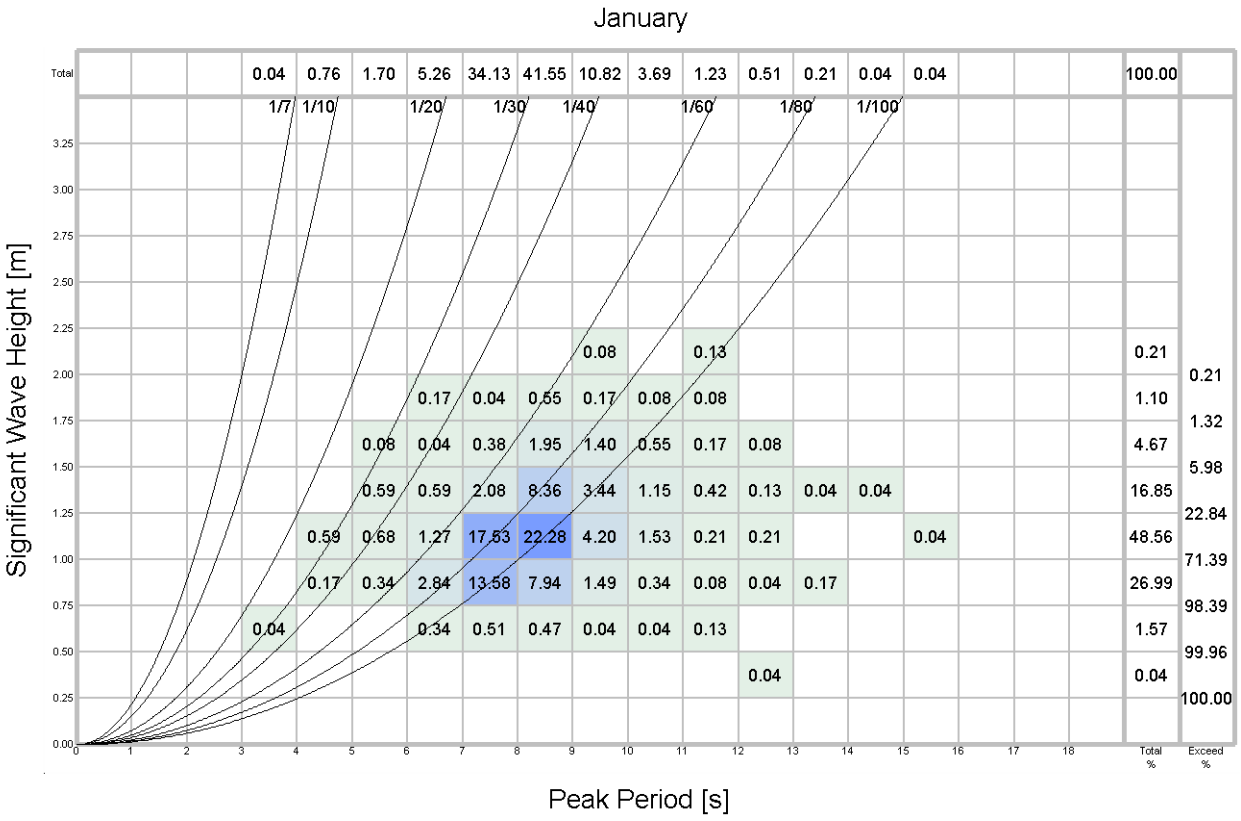


Figure 3.3.2: Percentage Occurrence of Hs and Tp – January

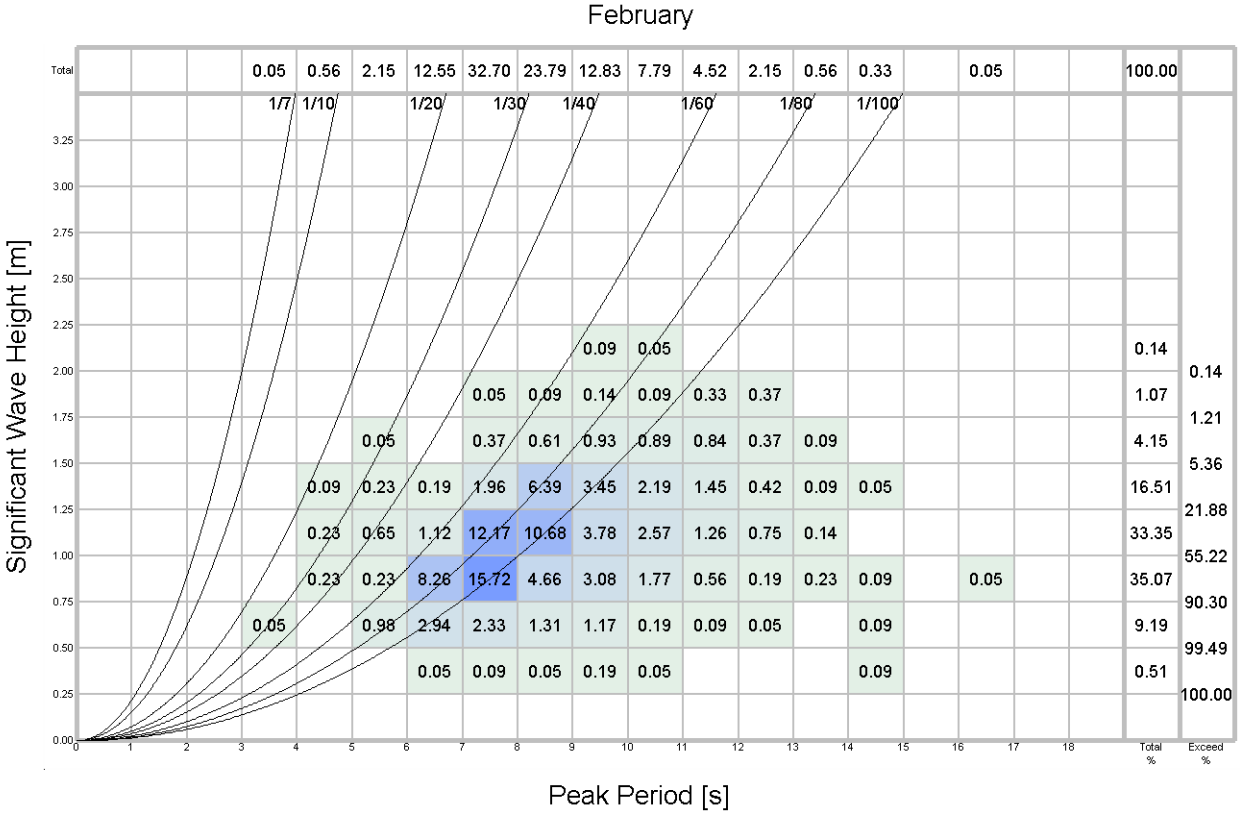


Figure 3.3.3: Percentage Occurrence of Hs and Tp – February

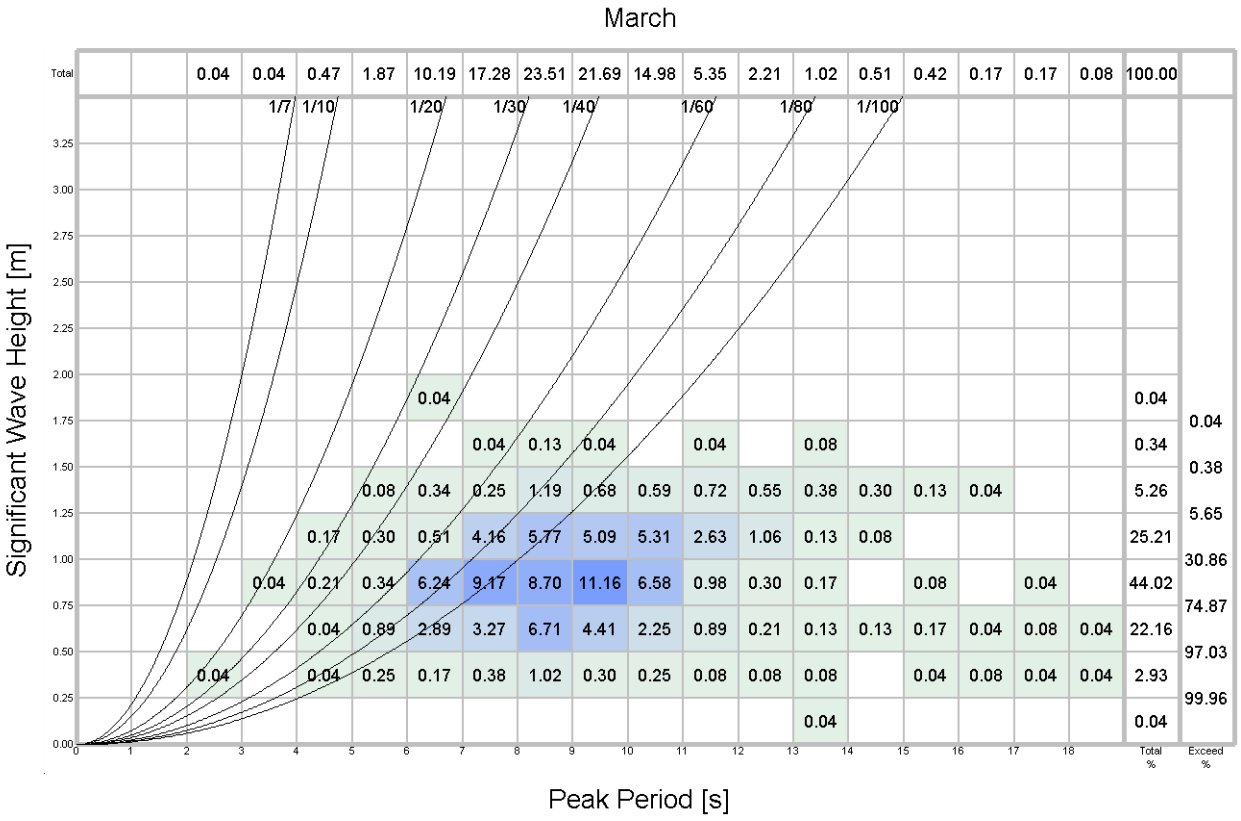


Figure 3.3.4: Percentage Occurrence of Hs and Tp – March

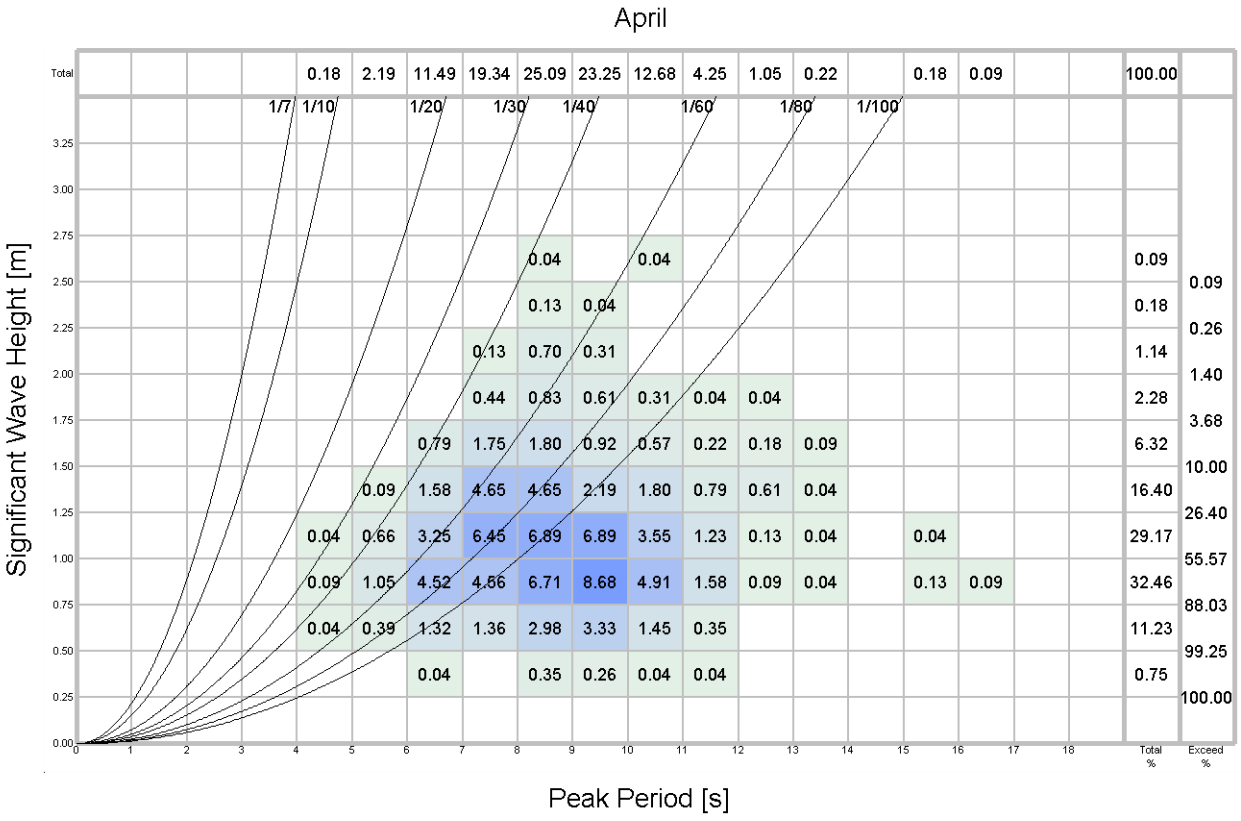


Figure 3.3.5: Percentage Occurrence of Hs and Tp – April

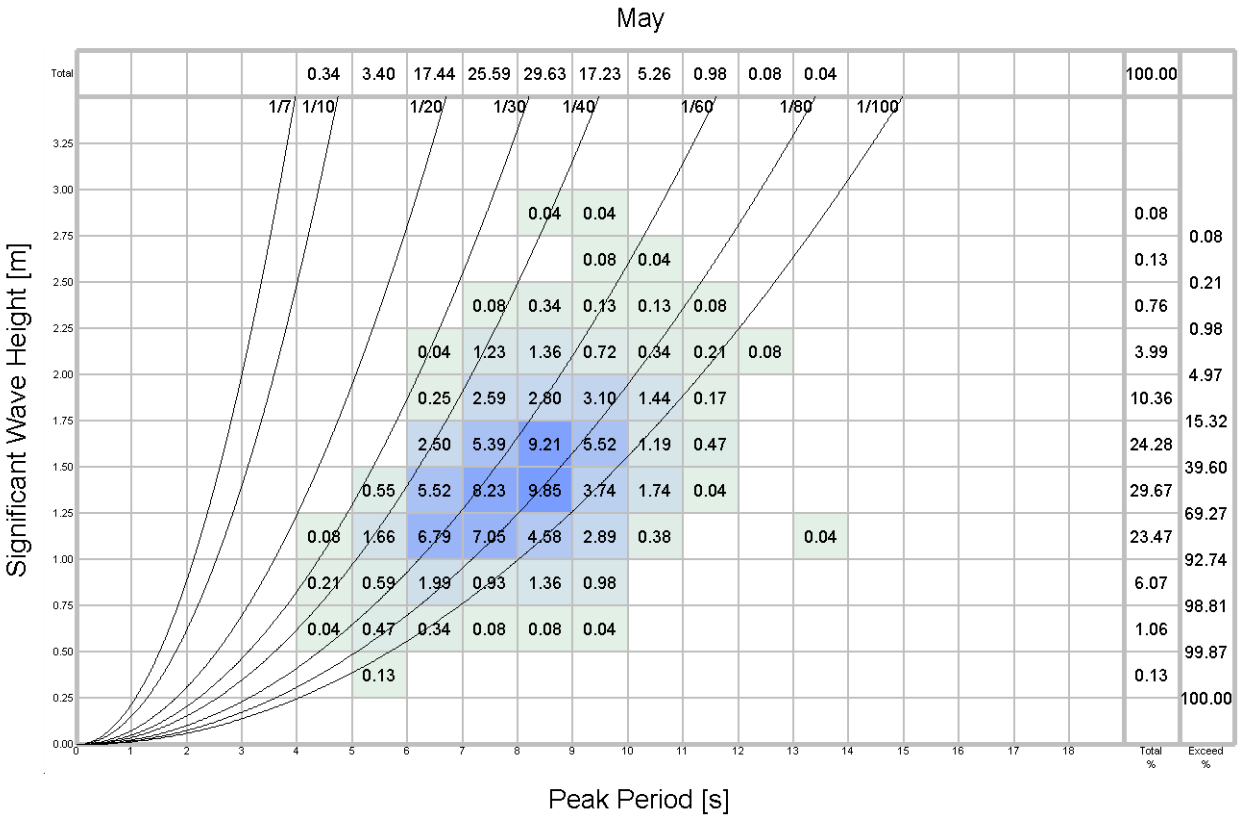


Figure 3.3.6: Percentage Occurrence of Hs and Tp – May

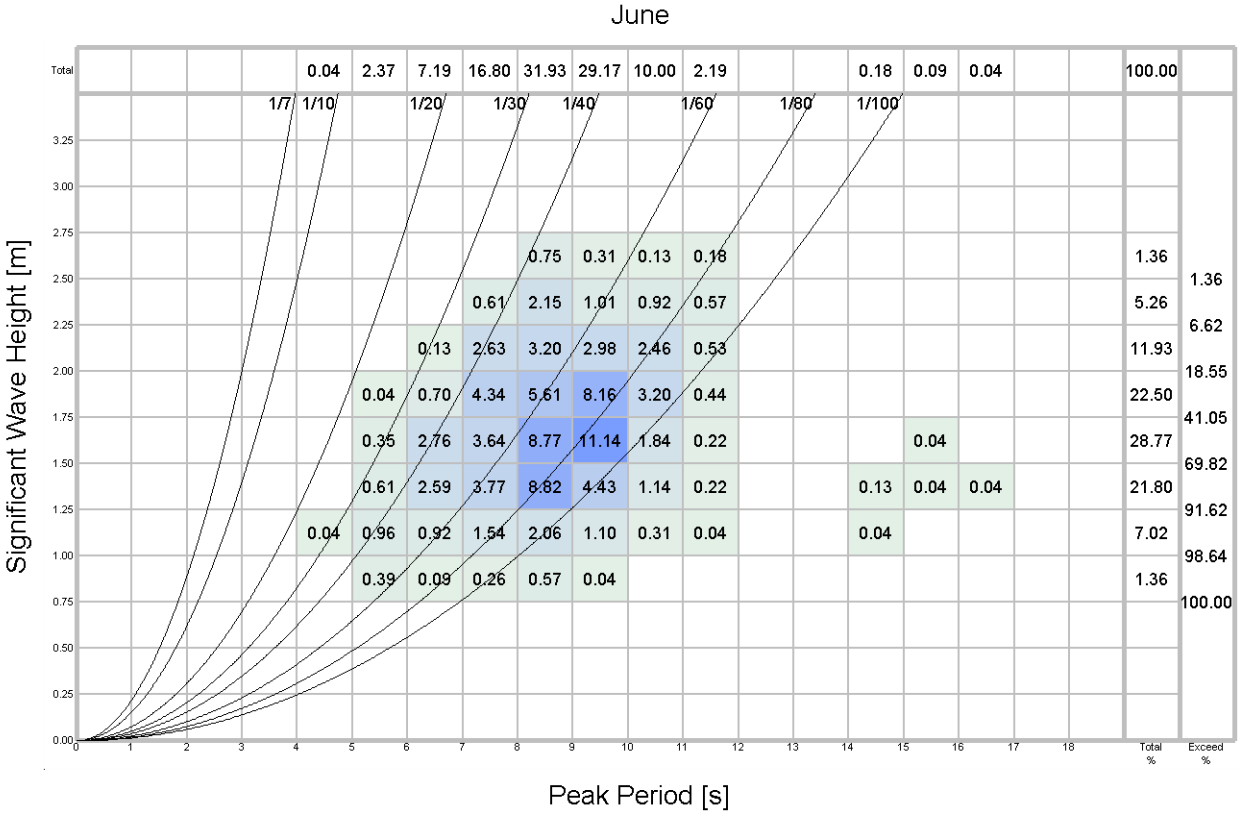


Figure 3.3.7: Percentage Occurrence of Hs and Tp – June

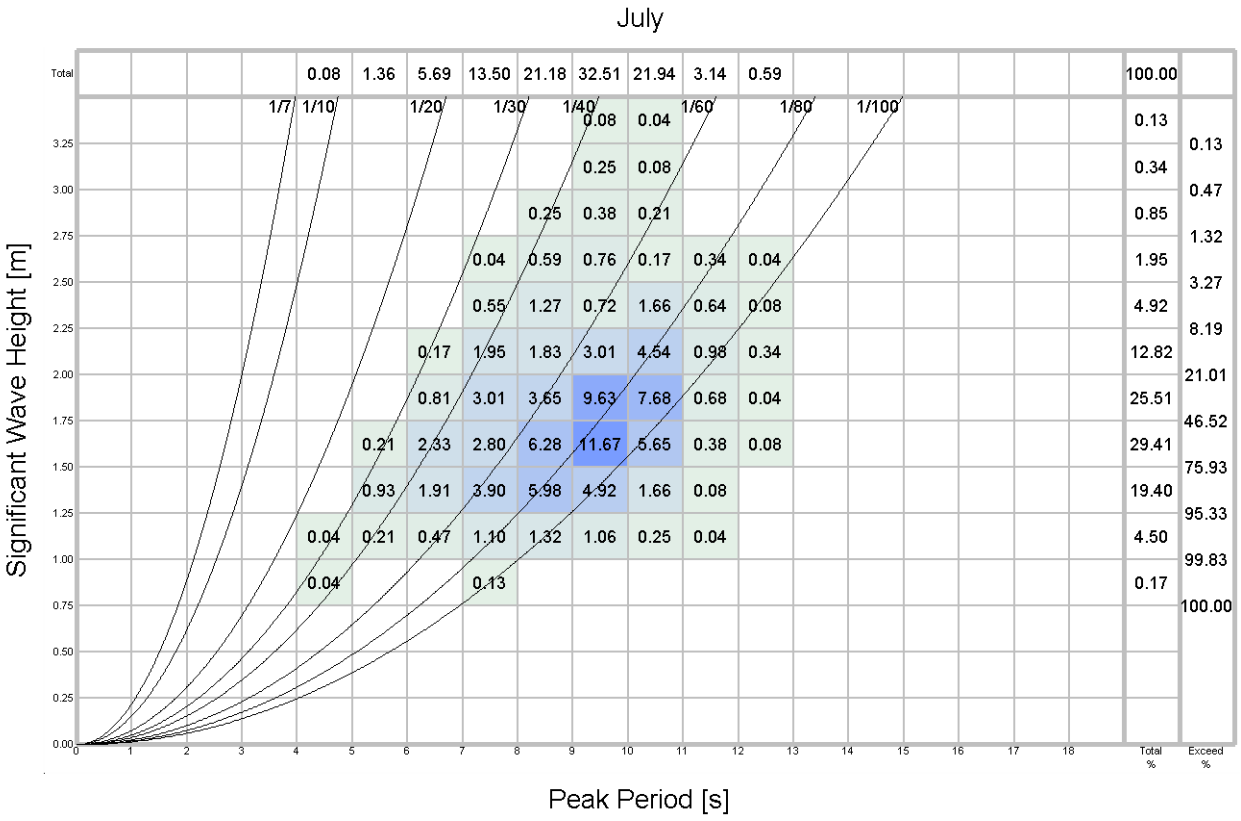


Figure 3.3.8: Percentage Occurrence of Hs and Tp – July

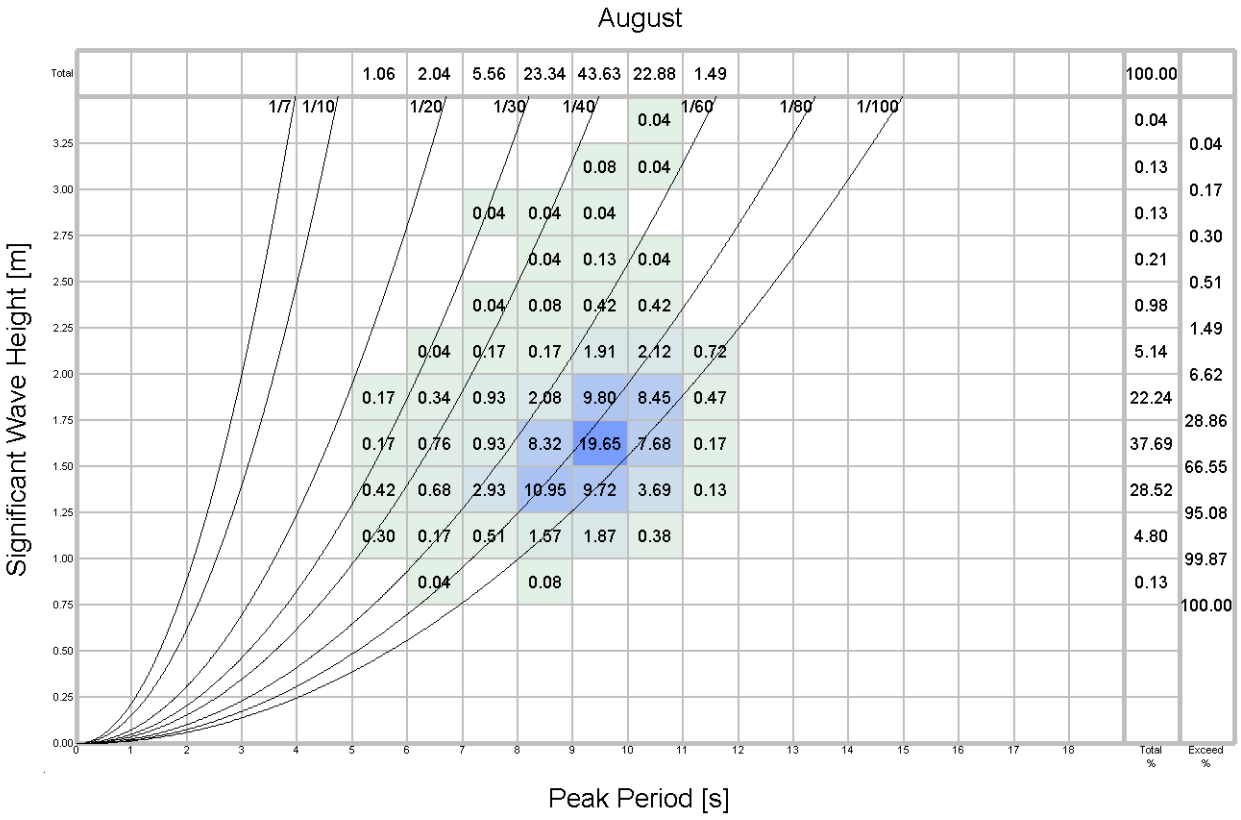


Figure 3.3.9: Percentage Occurrence of Hs and Tp – August

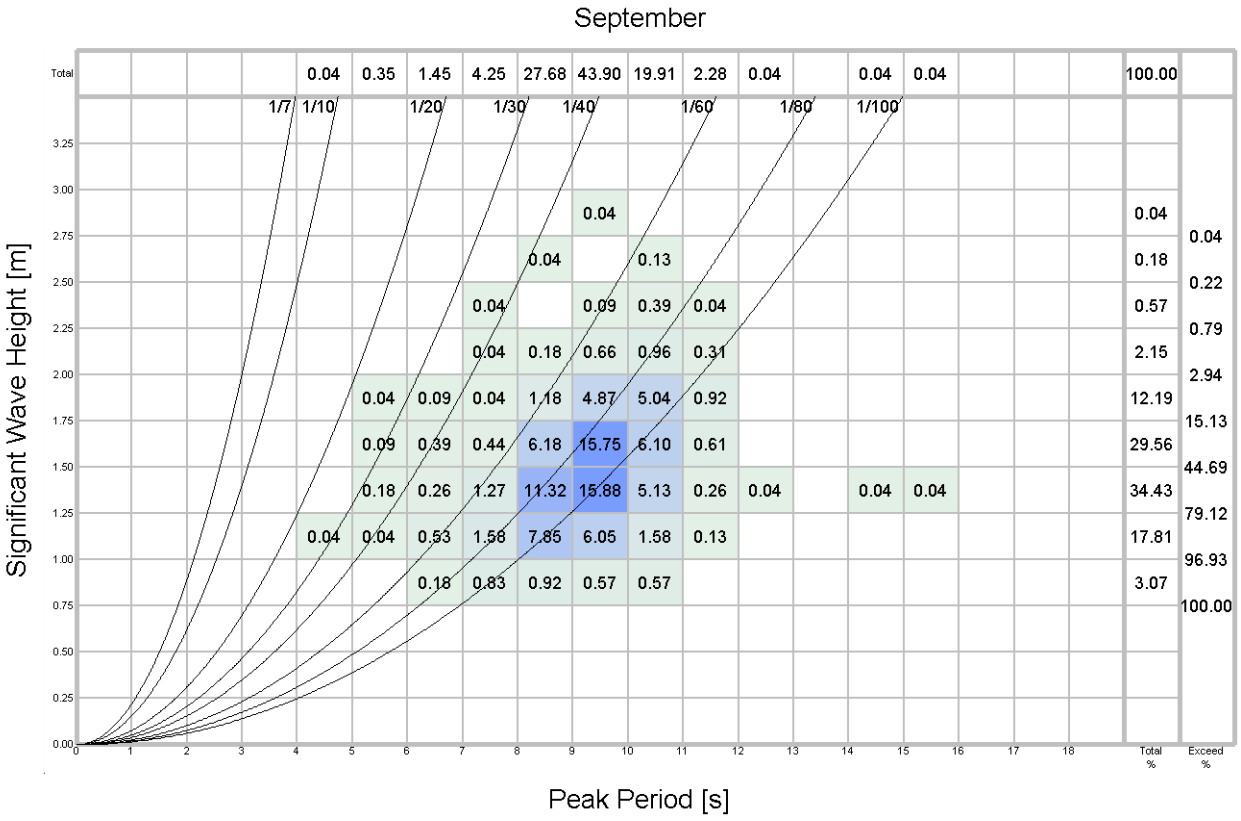


Figure 3.3.10: Percentage Occurrence of Hs and Tp – September

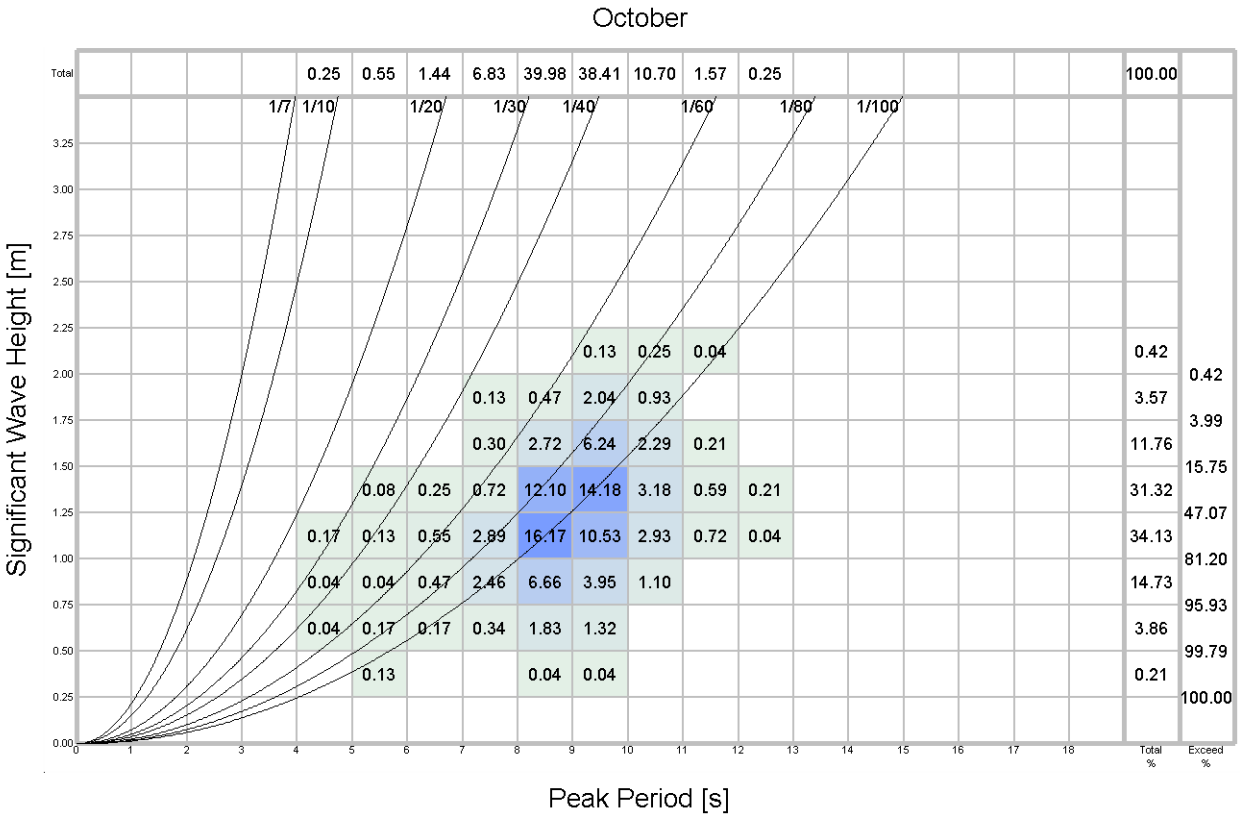


Figure 3.3.11: Percentage Occurrence of Hs and Tp – October

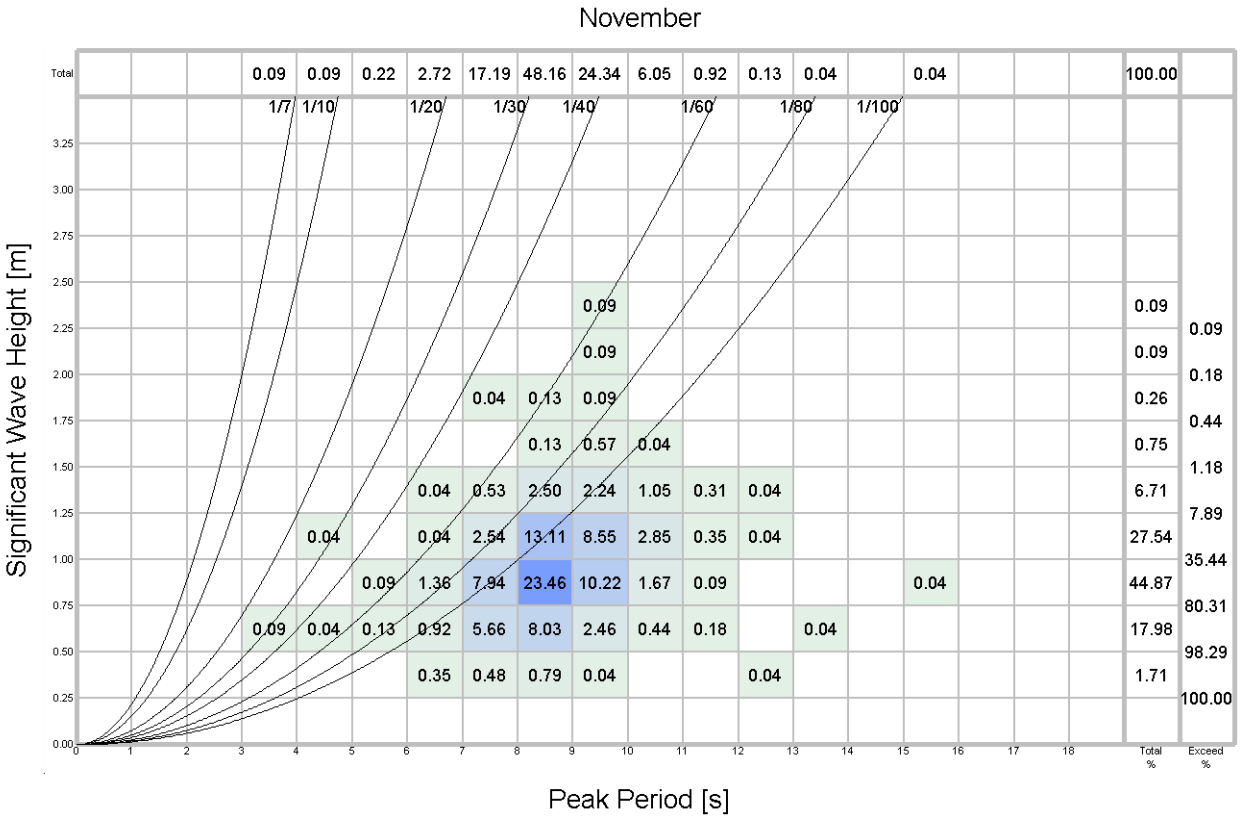


Figure 3.3.12: Percentage Occurrence of Hs and Tp – November

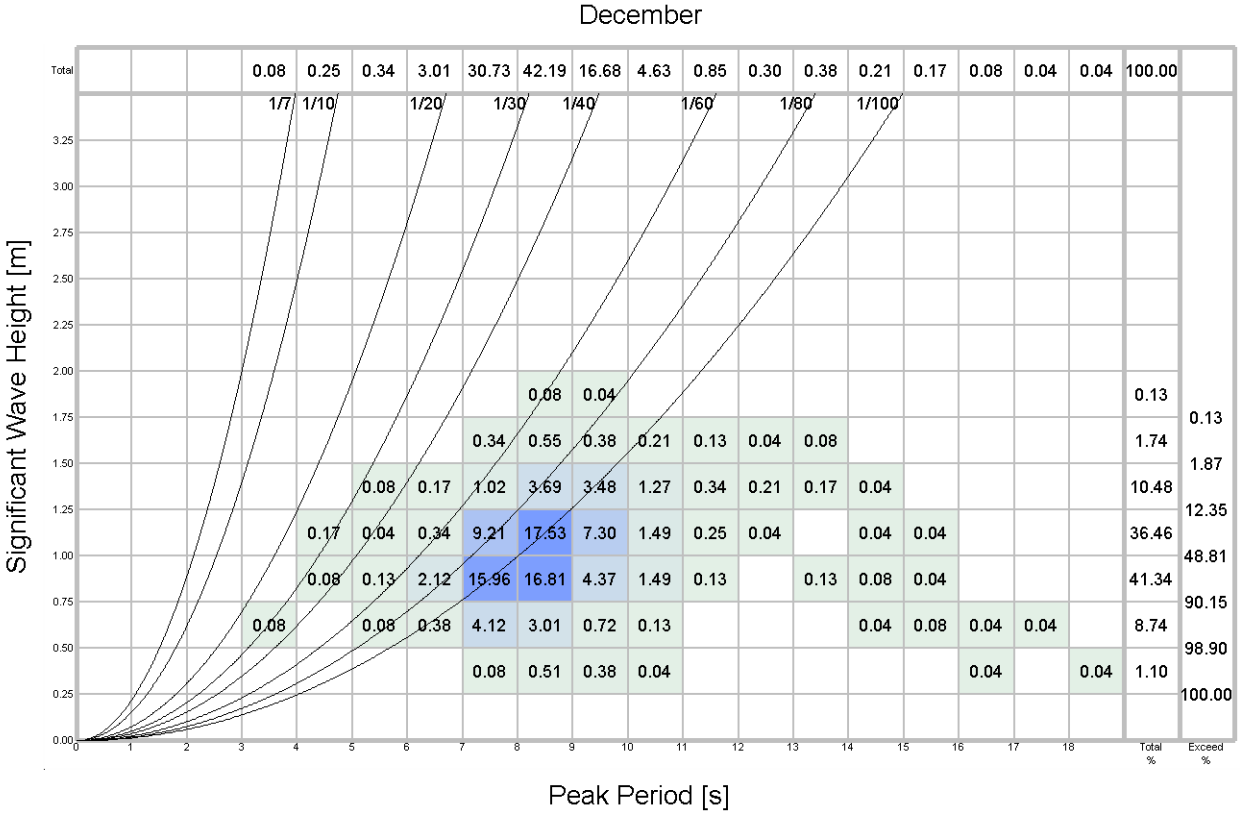


Figure 3.3.13: Percentage Occurrence of Hs and Tp – December