CENTRE FOR MARINE APPLIED RESEARCH

2020

WIND AND WAVE CONDITIONS – ST. PETER'S INLET – MARINE FINFISH LEASES 0994, 0778

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Title	**Wind and Wave Conditions – St. Peter's Inlet – Marine Finfish Leases 0994, 0778**
DSA Document	Report-DSA-CMAR-19EXM-St. Peter's Inlet Wind and Wave Conditions RevB.0.docx
Revision	B
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Prepared for	CMAR
Client reference / project	N/A
DSA project	CMAR-19EXM
Last revised	2021-01-25
Pages (incl. Grove Br)	22

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Revision history

Revision	Date last revised	Summary of changes / Comments	Revisions by	Checked by	Approved for release by	Issued to / Distribution	Engineering review status (IFI / IFR / IFC)
A	2020-12-03	Report Draft	MEK	DMS	DMS	CMAR	IFR
B	2021-01-25	Approved for public release	MEK	DMS	DMS	CMAR	IFR

List of authors / reviewers

Initials	Name
MEK	Meysam Karimi, Ph.D.
DMS	Dean M. Steinke, P.Eng.

Engineering Review Status Acronyms
IFI – Issued for information
IFR – Issued for review
IFC – Issued for construction

Executive Summary

In support of Centre for Marine Applied Research (CMAR), the following report presents wind and wave conditions at two marine finfish leases in St. Peter's Inlet, Nova Scotia, Canada.

In this report, wave and wind conditions are presented for 2 locations:

- Marine Finfish Lease - 0994: 45° 39.284'N, 60° 50.748'W.
- Marine Finfish Lease - 0778: 45° 39.702'N, 60° 50.804'W.

To determine the wave field evolution closer to shore at a specific site, and to determine more accurate 10- and 50- year return period wave data, near shore wave modelling can be used. For the St. Peter's Inlet sites, STWave was used to model the wave conditions inside the area. The STWave model results are determined using only wind boundary condition data from the MSC50 HindCast model of a point in St Peters Bay. The extreme wind-driven waves at the lease locations are determined in part by using the offshore hindcast data located outside of the site of interest.

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1 Introduction

1.1 Overview

For the finfish lease locations near the St. Peter's Inlet shown in Figure 1, wind and wave conditions have been estimated. The following presents data on the predicted 10- and 50- year wind and wave conditions at two locations.

Figure 1 Two (2) site locations at St. Peter's Inlet [4]

St. Peter's Inlet is overall very protected from offshore waves by surrounding lands as can be seen in Figure 2. Due to the nature of the region, wind-driven waves are calculated for the finfish leases 0778 and 0994. However, waves will lose energy by travelling into shallower waters. Detailed wave modelling is required to determine the amount of energy lost and wave height reduction.

Figure 2 St. Peter's Inlet, Nova Scotia, Canada

The context of this project is that extreme wind and wave conditions are needed to select engineering load cases for those wishing to install finfish or shellfish farms in the area. For example, extreme environmental conditions with minimum 10- year and 50- year return periods are required for the design of a marine fish farm site, as per guidance in the Scottish technical standard [2] and NS9415 [3]. While the locations assessed as part of this modeling exercise are actual aquaculture site locations, the data produced for these locations is useful for understanding the approximate wave climate in the region and can be used to evaluate any proposals for sites in the area. Understanding the wind and wave climates at aquaculture sites is important for mitigating risks.

1.2 Objective(s)

- Determine wave/wind conditions at two locations in St. Peter's Inlet and find the conditions with 10- and 50- year return periods.

2 Abbreviations and acronyms

DSA	Dynamic Systems Analysis Ltd.
SMS	Surface-water Modeling System
CMAR	Centre for Marine Applied Research
CHS	Canadian Hydrographic Services

3 Reference documents and drawings

[1]	V. Swail, V. Cardone, M. Ferguson, D. Gummer, E. Harris, E. Orelup, and A. Cox, "The msc50 wind and wave reanalysis," in *9th International Workshop On Wave Hindcasting and Forecasting*, 2006.
[2]	Marine Scotland. (2015). A Technical Standard for Scottish Finfish Aquaculture. Ministerial Group for Sustainable Aquaculture's Scottish Technical Standard Steering Group
[3]	Norge, S. (2009). Norwegian Standard NS 9415. E: 2009. Marine Fish Farms—Requirements for Site Survey, Risk Analyses, Design, Dimensioning, Production, Installation and Operation. *Standard Norge, Lysaker*.
[4]	CMAR approved sites -RevB.kmz

4 Wave conditions

4.1 Overview

SMS version 12.2.13 was used to setup the bathymetric and computational grid. This section provides a description of the grid size, mesh size and offshore environmental conditions. Site bathymetry is provided in Figure 3. Note that a CHS hydrographic chart is used to generate the bathymetric data for wave modeling.

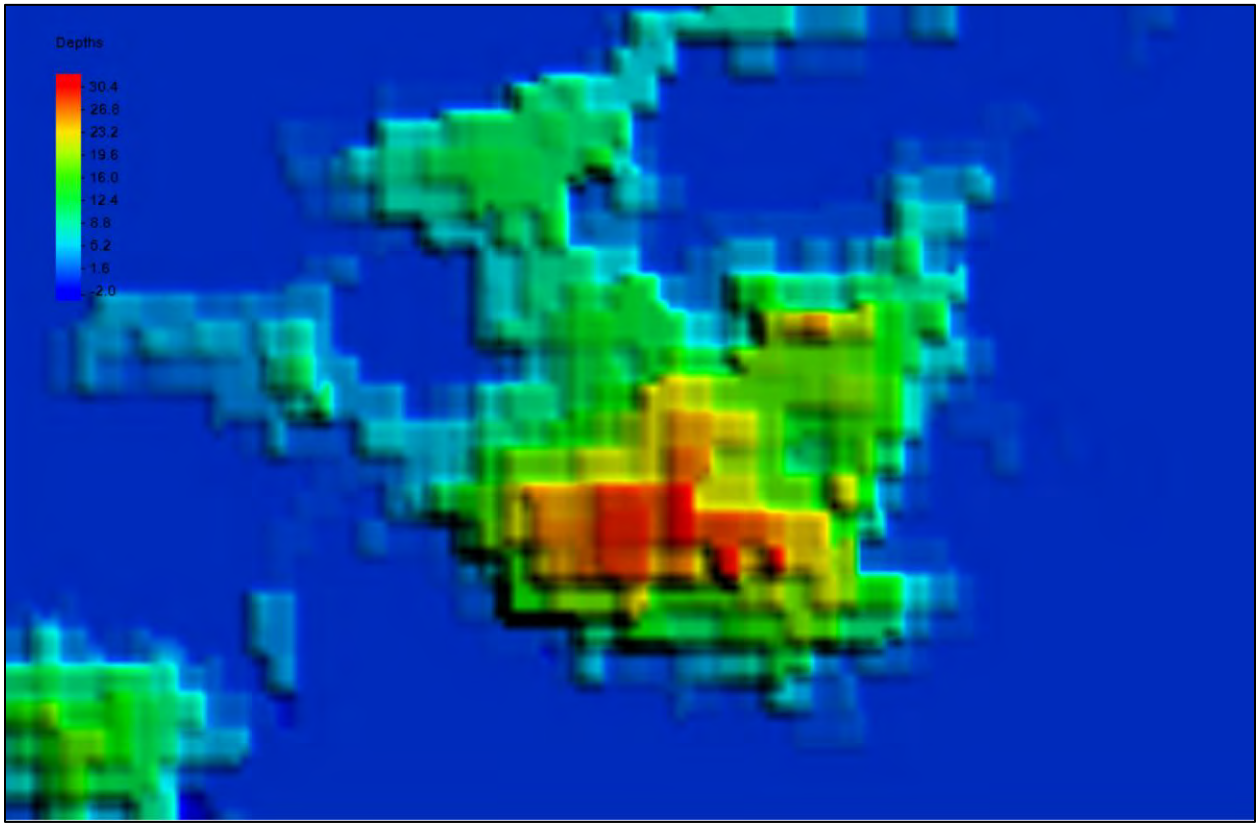


Figure 3 Bathymetry at site on hydrographic charts- Depth reported in meters

4.2 Wave Model Description

SMS, created by Aquaveo, is a modelling suite in which various water surface modelling tools, like wave and flow models, can be used. For this analysis SMS in combination with STWave is used. STWave is a nearshore spectral Hydraulics model, developed by U.S. Army Engineer Research and Development Center (ERDC) and Coastal and Hydraulics Laboratory (CHL). It is capable of modelling accurately wave transformation and propagation.

Two grids were setup, computational grid and spectral grid. The computational grid and its mesh sizes are mainly defined by the bathymetry. The bathymetry in SMS is presented in Figure 4. For this analysis the computational grid size was 3.9 km x 2.5 km. The mesh size was 5 m x 5 m, resulting in 768 x 485 = 372,480 grid cells. The spectral domain was divided into 72 directions and 50 frequencies, with a minimum frequency of 0.03 Hz and a maximum frequency of 1.01 Hz.

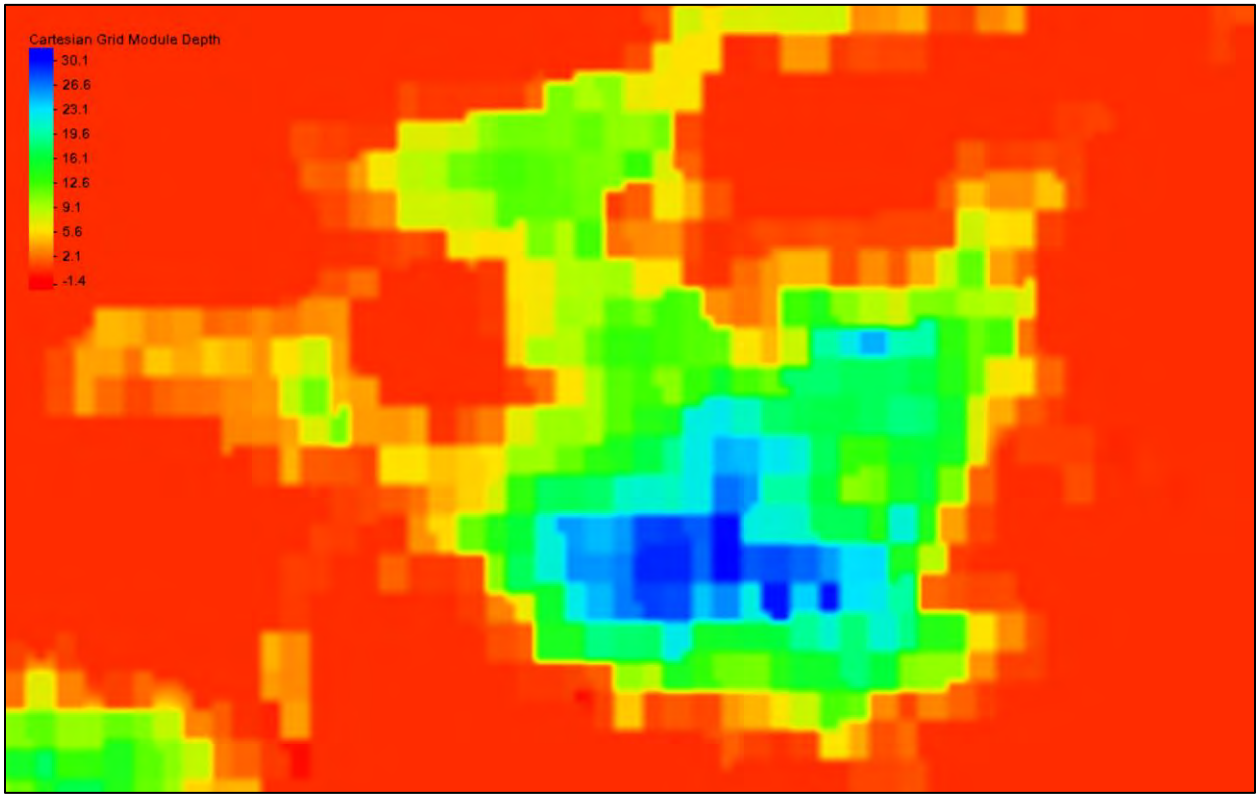


Figure 4 Bathymetry at site on STWave. Note the MSC50 HindCast model Source Point indicated at 45° 36.000'N, 60° 54.001'W Boundary conditions – offshore wind conditions

4.3 Boundary conditions – offshore wind and wave conditions

The MSC50 HindCast model [1] data from location 45° 36.000'N, 60° 54.001'W was used to determine the 10- and 50- year return periods for wind and wave of the St. Peter's Inlet fish farm sites. The scatter plot of wind speeds versus wind directions for the source point is also shown in Figure 5. Extreme winds at the source point appear to originate more frequently from the northeast and east.

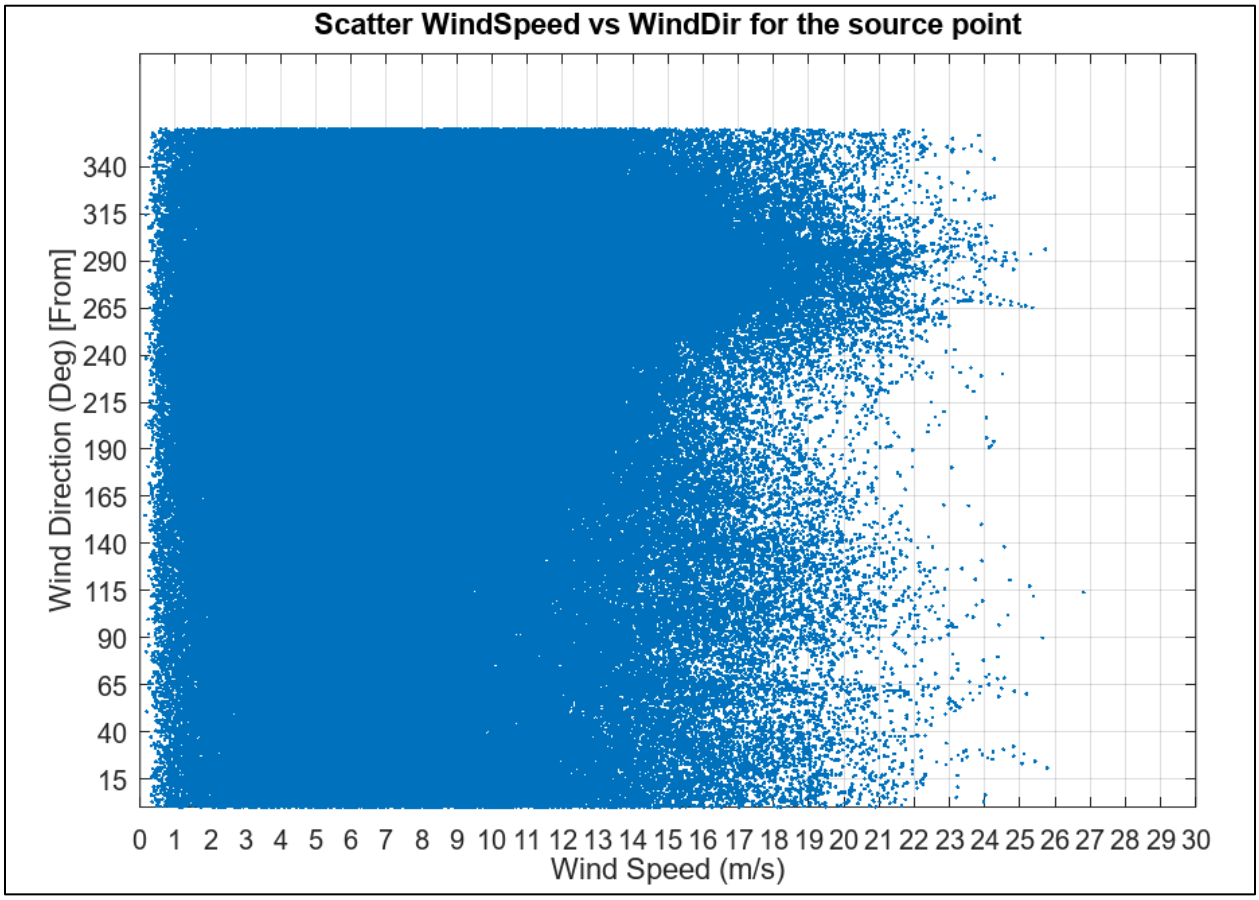
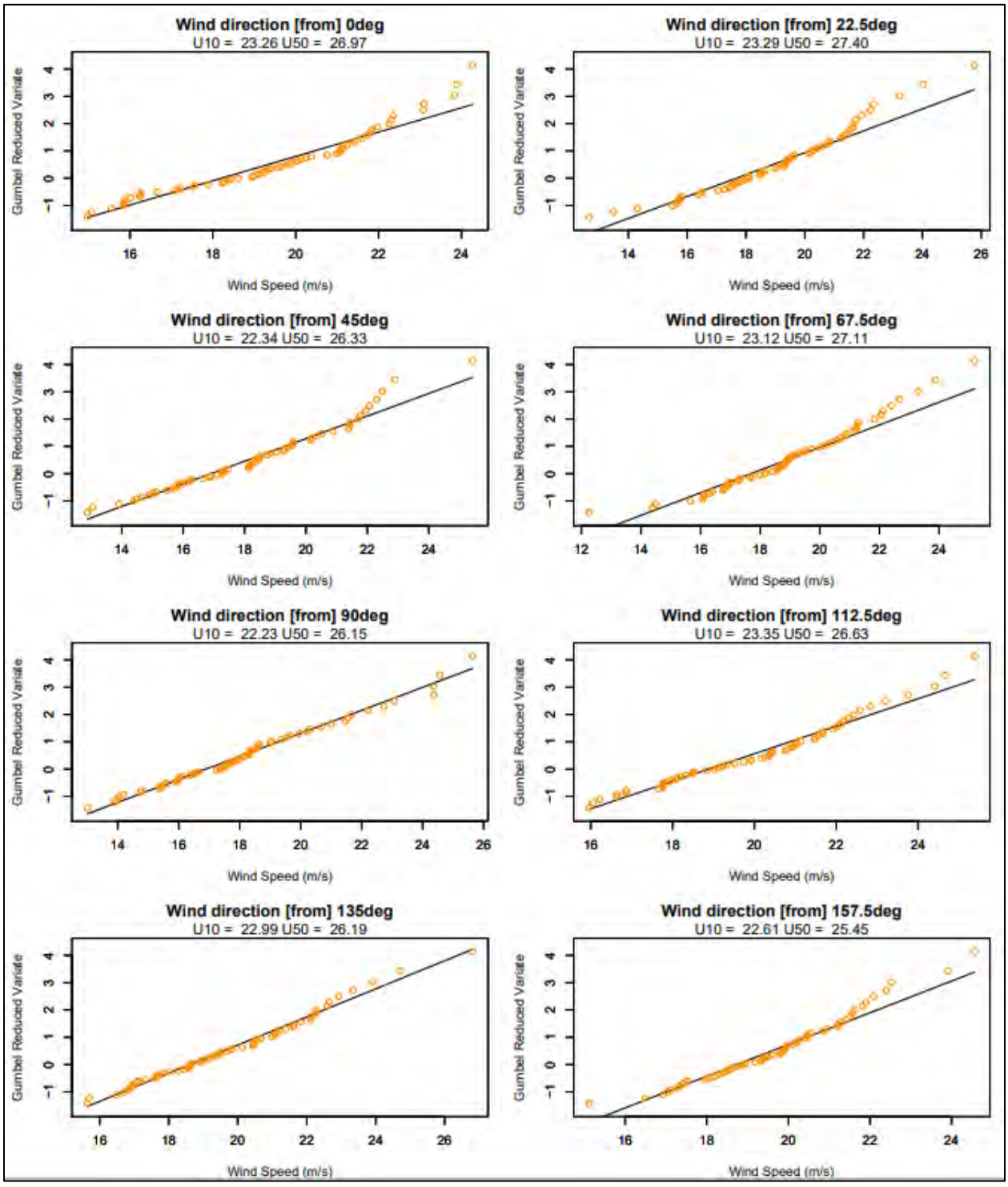


Figure 5 Wind speed versus wind direction plot for the source point

10- and 50- year return period conditions are in general achieved by:

- Obtaining measured or hindcast data for parameter in question
- For each parameter, bin data by direction
- Perform extreme value analysis.
    - Extract annual maxima
    - Fit Gumbel or Weibull distribution to this data
    - Use fitted distribution to calculate values corresponding to 10- and 50- year return period

The extreme value analysis of the wind velocities is presented in Figure 6. U10 and U50 represent the 10- and 50- year return period wind velocities, respectively.


Wind direction [from] 0deg
U10 = 23.26 U50 = 26.97
Wind direction [from] 22.5deg
U10 = 23.29 U50 = 27.40
Wind direction [from] 45deg
U10 = 22.34 U50 = 26.33
Wind direction [from] 67.5deg
U10 = 23.12 U50 = 27.11
Wind direction [from] 90deg
U10 = 22.23 U50 = 26.15
Wind direction [from] 112.5deg
U10 = 23.35 U50 = 26.63
Wind direction [from] 135deg
U10 = 22.99 U50 = 26.19
Wind direction [from] 157.5deg
U10 = 22.61 U50 = 25.45
Gumbel Reduced Variate
Wind Speed (m/s)

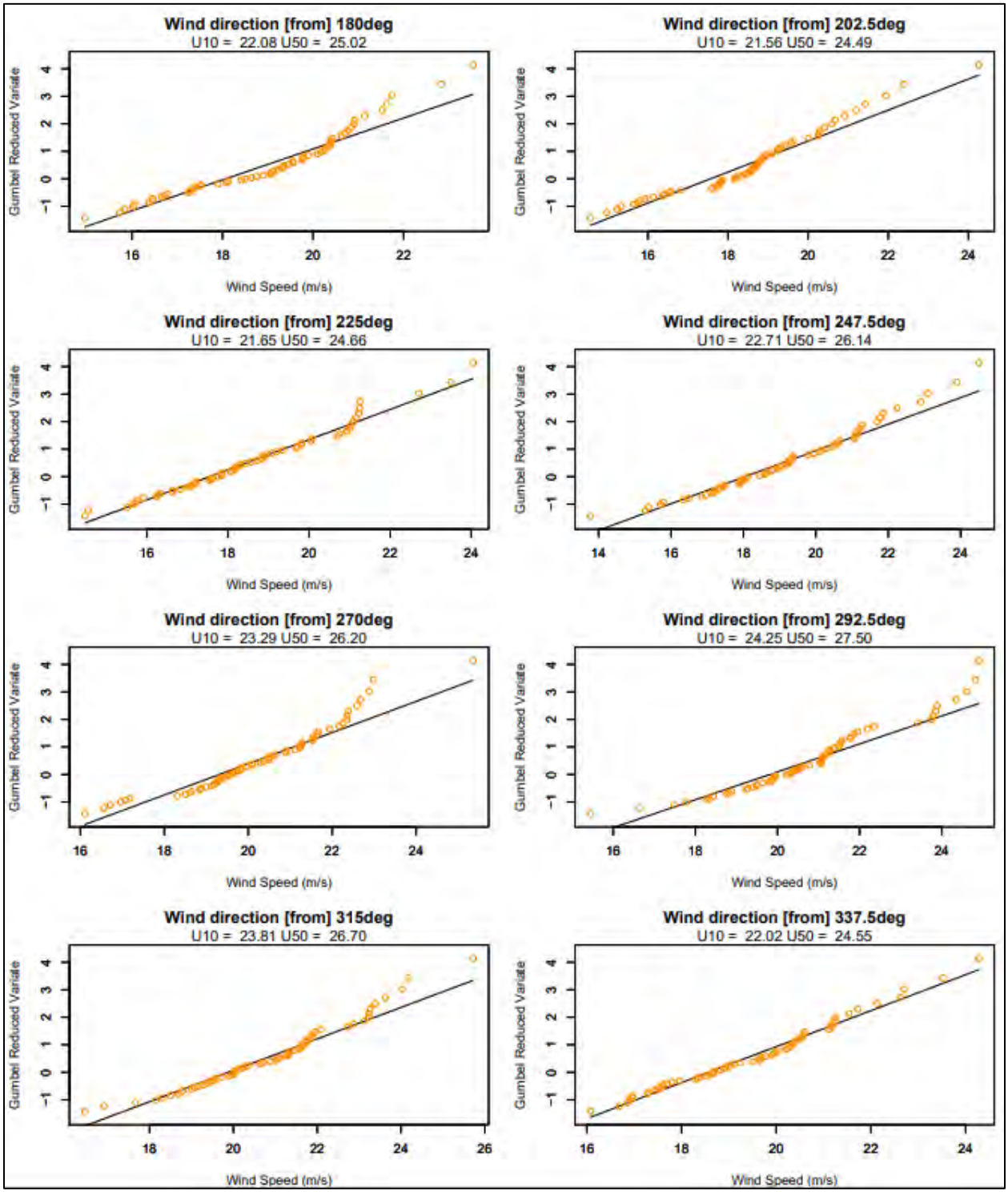


Figure 6: Extreme value analysis on wind data – for Source Point offshore location [1]

In summary, the following data was obtained from the extreme value analysis:

Table 1 Results extreme value analysis for wind at the offshore Source Point locations in Figure 4

Direction [from] [°]		$U_{wind,10year}$ [m/s]	$U_{wind,50year}$ [m/s]
0	N	23.26	26.97
23	NNE	23.29	27.4
45	NE	22.34	26.33
68	ENE	13.12	27.11
90	E	22.23	26.15
113	ESE	13.35	26.63
135	SE	22.99	26.19
158	SSE	22.61	25.45
180	S	22.08	25.02
203	SSW	21.56	24.49
225	SW	21.65	24.66
248	WSW	22.71	26.14
270	W	23.29	26.2
293	WNW	24.25	27.5
315	NW	23.81	26.7
338	NNW	22.02	24.55

Polar plots for maximum wind speeds at 10- year and 50- year return periods are shown in Figure 7 and Figure 8, respectively.

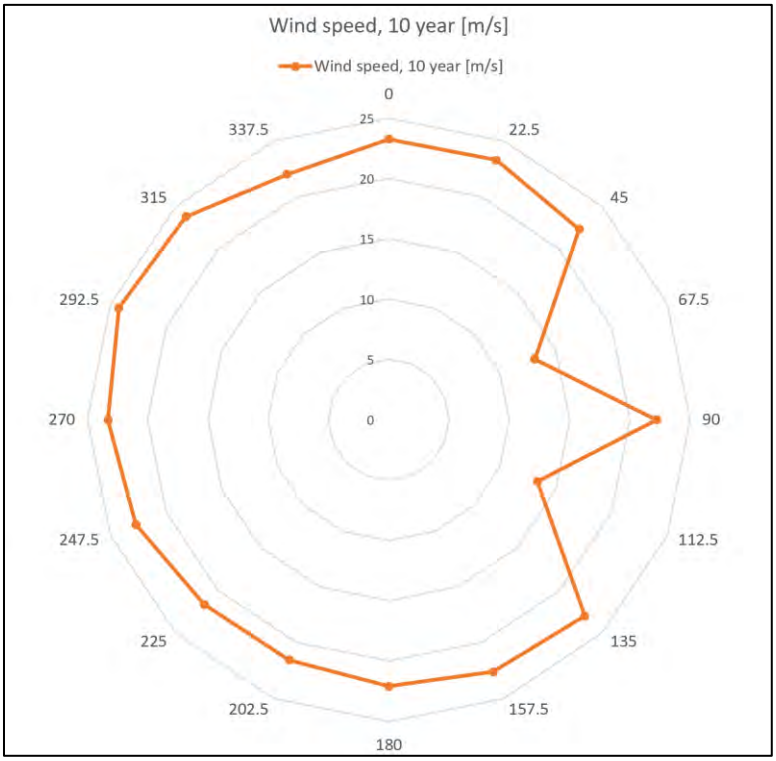


Figure 7 Maximum wind speed at 10- year return period and direction [from]- for Source Point offshore location [1]

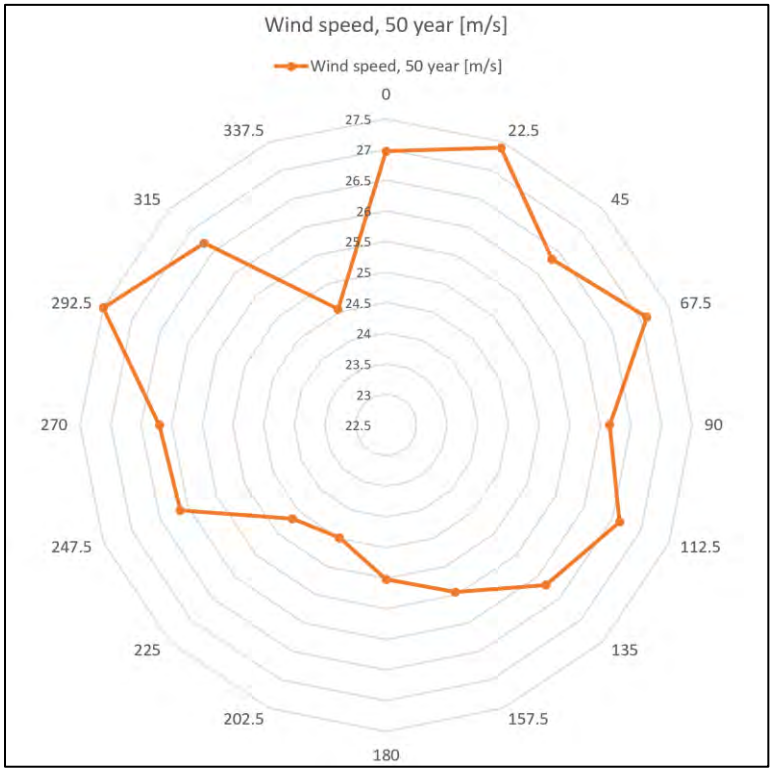


Figure 8 Maximum wind speed at 50- year return period and direction [from]- for Source Point offshore location [1]

Only wind-driven waves considered for the wave modeling. Current-wave interaction was not included because local flow velocities are very small.

16 headings were used, the wind direction was kept constant within its directional bin.

In this method, wave design conditions for the project location are based on 10- and 50- year return period winds for an offshore location, which have subsequently been transferred to the project location. This will provide reasonable design conditions; however, they cannot be linked directly to a return period at the site.

4.4 Wave modeling results

The results of the wave modeling are presented in Figure 9 and Figure 10 for directions from Southwest and West, respectively for two key wave headings with the highest wave heights. As stated in the previous section, the wind conditions are assumed to stay constant for the region. The results from STWave represent the maximum significant wave height value at the region including its spectral peak period and wave direction.

The location of sites at the St. Peter's Inlet are presented in Figure 1. The estimated wave and wind conditions for each site based on the STWave modeling are presented in the following sections.

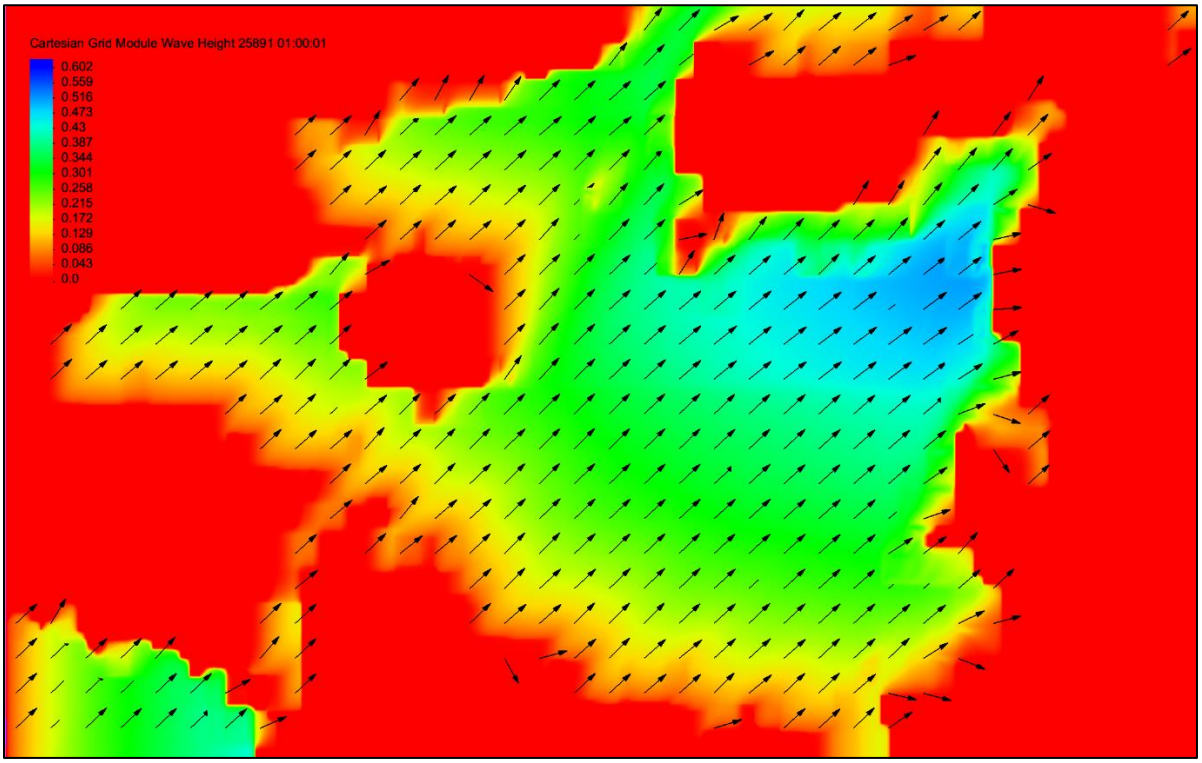


Figure 9 Wave modeling results for direction [From] 225 deg- SW

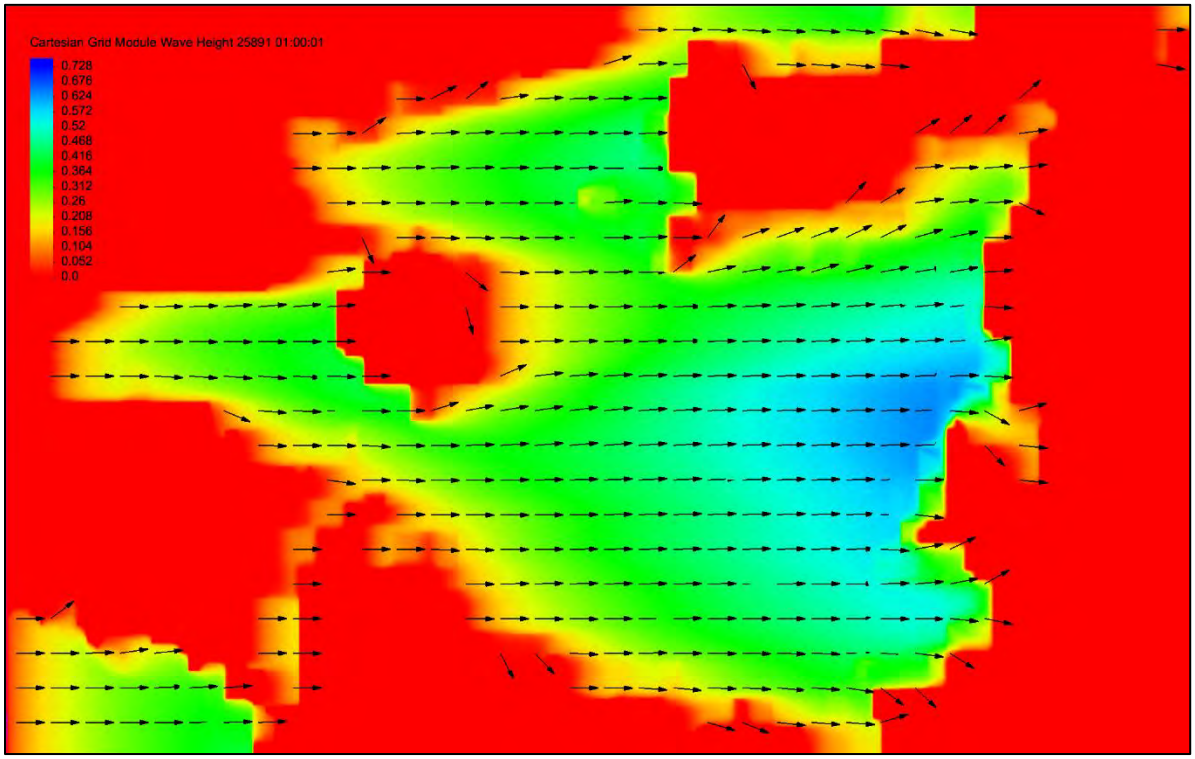


Figure 10 Wave modeling results for direction [From] 270 deg- W

4.4.1 Wave/wind conditions for St. Peter's Inlet - Marine Finfish Lease - 0994

The wave and wind results from the STWave model, for the Marine Finfish Lease – 0994 near the St. Peter's Inlet, are summarized in Table 2. Note that the results in Table 2 indicate significant wave height (Hs) and peak period (T_P) for the selected site. These represent the extreme wave conditions at this coordinate: 45° 39.284'N, 60° 50.748'W.

Table 2 Estimated wave and wind design conditions for St. Peter's Inlet - Marine Finfish Lease - 0994

Wave/Wind conditions	Direction [from] [°]		Wind (m/s)	Hs (m)	Tp (s)
10yr wave/wind	*0*	N	23.26	0.5	2
	23	NNE	23.29	0.38	1.9
	45	NE	22.34	0.29	1.62
	68	ENE	13.12	0.12	1.3
	90	E	22.23	0.28	1.6
	113	ESE	13.35	0.08	1.13
	135	SE	22.99	0.25	1.85
	158	SSE	22.61	0.28	1.78

	180	S	22.08	0.32	1.73
	203	SSW	21.56	0.18	1.46
	225	SW	21.65	0.28	2.32
	248	WSW	22.71	0.4	2.11
	270	W	23.29	0.52	2.1
	293	WNW	24.25	0.41	2.1
	315	NW	23.81	0.55	2.2
	338	NNW	22.02	0.49	2
50yr wave/wind	*0*	N	26.97	0.59	2.13
	23	NNE	27.4	0.46	2
	45	NE	26.33	0.35	1.73
	68	ENE	27.11	0.31	1.75
	90	E	26.15	0.34	1.7
	113	ESE	26.63	0.25	1.64
	135	SE	26.19	0.3	1.94
	158	SSE	25.45	0.33	1.84
	180	S	25.02	0.37	1.79
	203	SSW	24.49	0.22	1.59
	225	SW	24.66	0.33	2.47
	248	WSW	26.14	0.41	2.13
	270	W	26.2	0.59	2.17
	293	WNW	27.5	0.48	2.2
	315	NW	26.7	0.62	2.31
	338	NNW	24.55	0.56	2.1

It should be noted that the return periods indicated for each wave parameter in Table 2 are representative of the boundary condition used to derive that value, not the value itself. Polar plots for maximum wave heights are presented in Figure 11 and Figure 12.

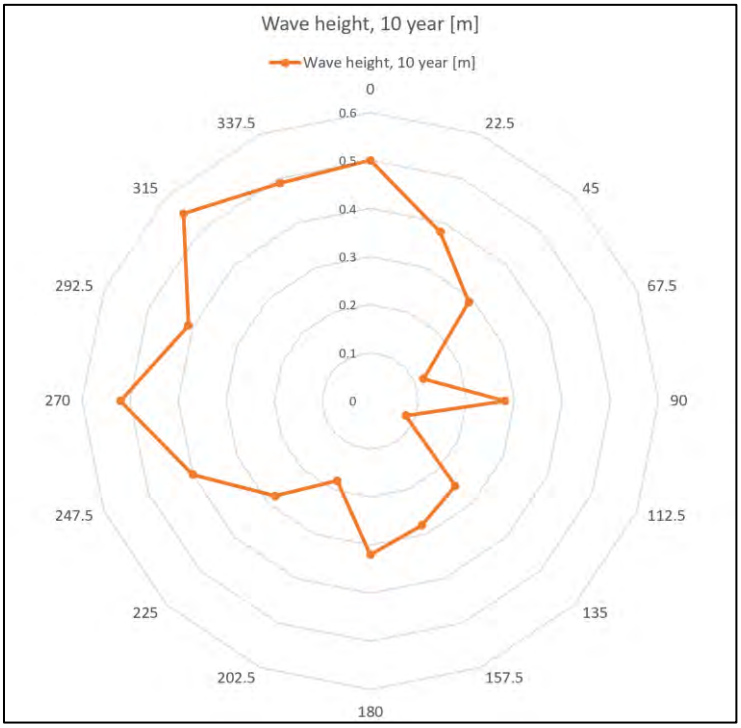


Figure 11 Maximum wave height at 10- year return period and direction [from]- St. Peter's Inlet - Marine Finfish Lease - 0994

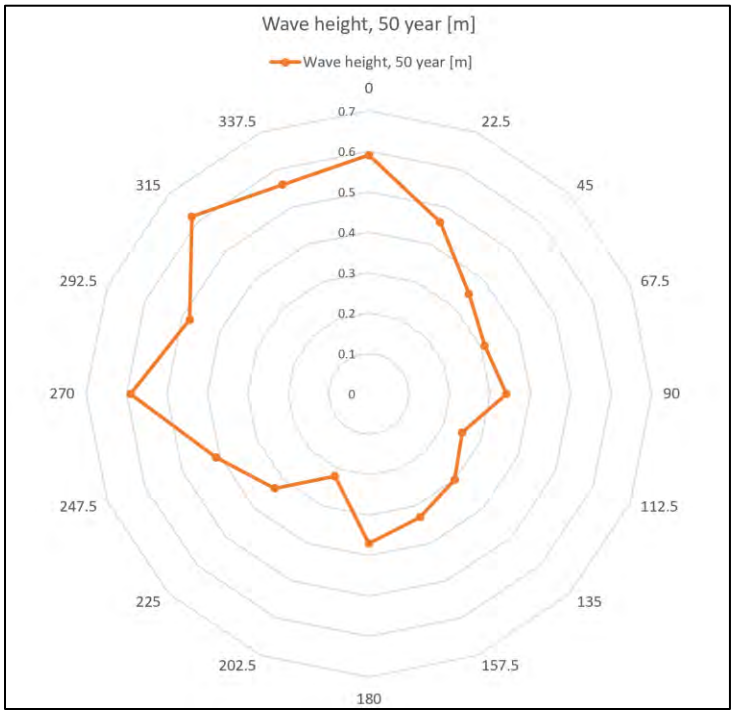


Figure 12 Maximum wave height at 50- year return period and direction [from]- St. Peter's Inlet - Marine Finfish Lease - 0994

4.4.2 Wave/wind conditions for St. Peter's Inlet - Marine Finfish Lease - 0778

The wave and wind results from the STWave model, for the St. Peter's Inlet - Marine Finfish Lease - 0778, are summarized in Table 3. Note that the results in Table 3 indicate significant wave height (Hs) and peak period (T_P) for the selected site. These represent the extreme wave conditions at this coordinate: 45° 39.702'N, 60° 50.804'W.

Table 3 Estimated wave and wind design conditions for St. Peter's Inlet - Marine Finfish Lease - 0778

Wave/Wind conditions	Direction [from] [°]		Wind (m/s)	Hs (m)	Tp (s)
10yr wave/wind	*0*	N	23.26	0.29	1.6
	23	NNE	23.29	0.19	1.57
	45	NE	22.34	0.32	1.79
	68	ENE	13.12	0.17	1.4
	90	E	22.23	0.34	1.72
	113	ESE	13.35	0.11	1.24
	135	SE	22.99	0.33	2.41
	158	SSE	22.61	0.44	2.11
	180	S	22.08	0.49	2.1
	203	SSW	21.56	0.31	1.91
	225	SW	21.65	0.46	2.2
	248	WSW	22.71	0.54	2.1
	270	W	23.29	0.49	1.98
	293	WNW	24.25	0.33	2.26
	315	NW	23.81	0.3	1.76
	338	NNW	22.02	0.28	1.59
50yr wave/wind	*0*	N	26.97	0.35	1.7
	23	NNE	27.4	0.24	1.72
	45	NE	26.33	0.39	1.88
	68	ENE	27.11	0.42	1.83
	90	E	26.15	0.41	1.8
	113	ESE	26.63	0.32	1.85
	135	SE	26.19	0.38	2.55
	158	SSE	25.45	0.5	2.21
	180	S	25.02	0.57	2.13
	203	SSW	24.49	0.38	2
	225	SW	24.66	0.54	2.32
	248	WSW	26.14	0.55	2.1

	270	W	26.2	0.56	2.1
	293	WNW	27.5	0.38	2.4
	315	NW	26.7	0.35	1.82
	338	NNW	24.55	0.32	1.66

It should be noted that the return periods indicated for each wave parameter in Table 3 are representative of the boundary condition used to derive that value, not the value itself. Polar plots for maximum wave heights are presented in Figure 13 and Figure 14.

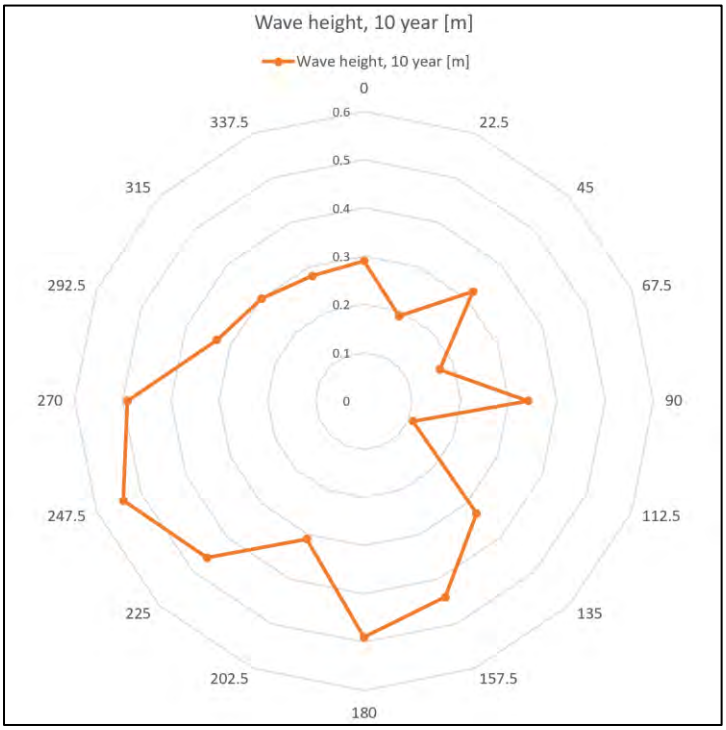


Figure 13 Maximum wave height at 10- year return period and direction [from]- St. Peter's Inlet - Marine Finfish Lease – 0778

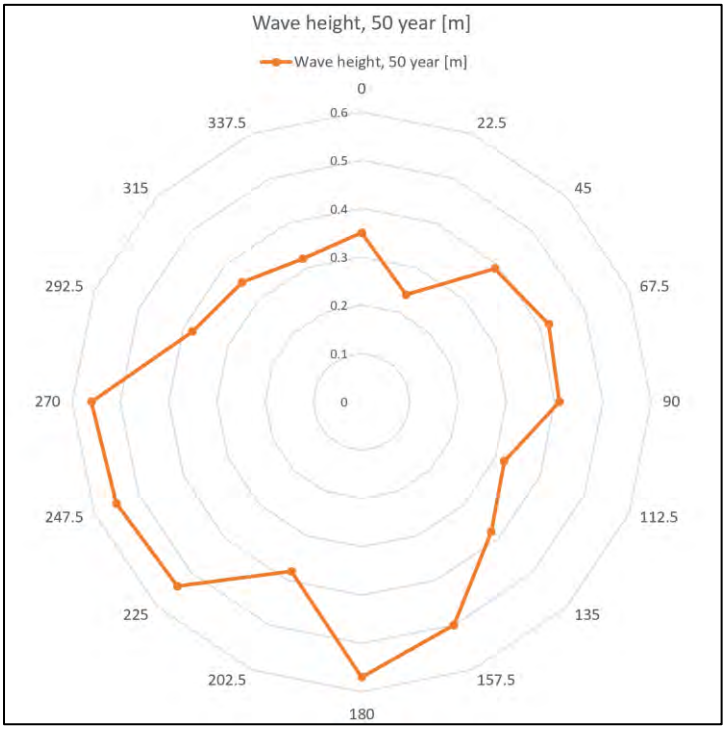


Figure 14 Maximum wave height at 50- year return period and direction [from]- St. Peter's Inlet - Marine Finfish Lease – 0778