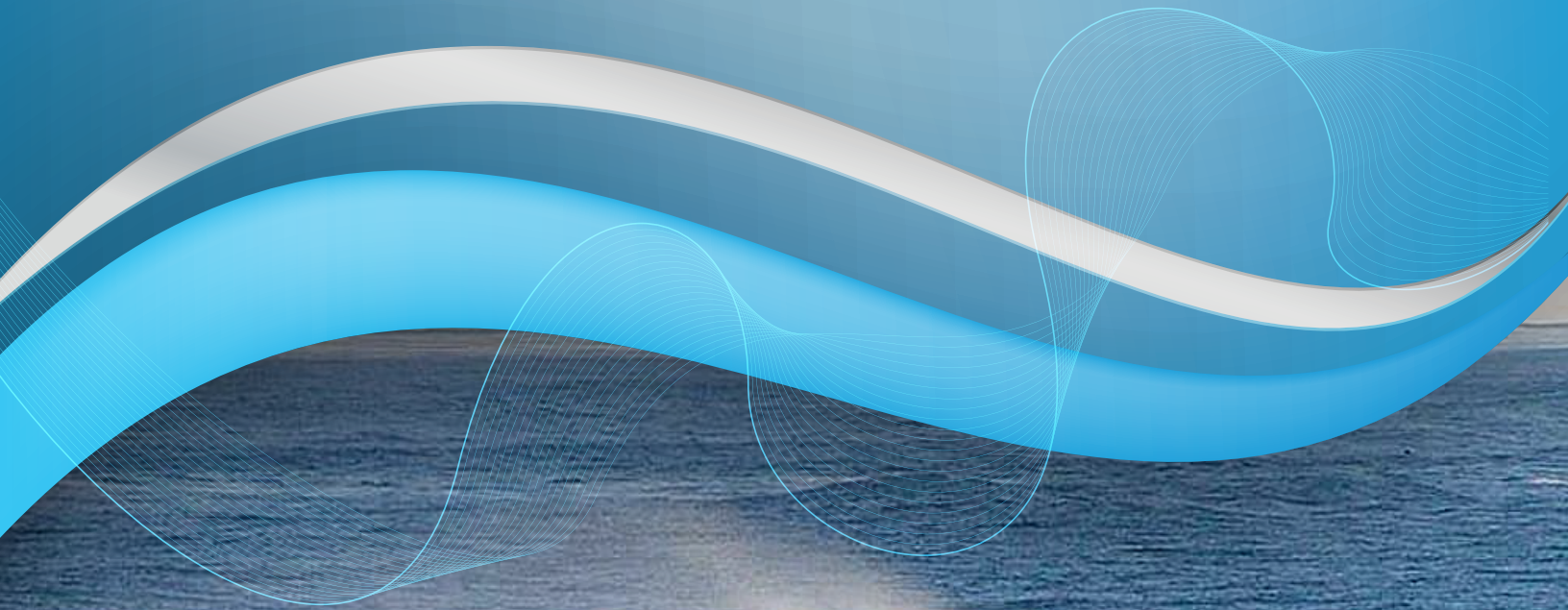


# Overview Analysis of Wind and Wave Conditions on the West Coast of Vancouver Island



Prepared for:  
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## 1.0 INTRODUCTION

The hourly wind and wave data collected from buoys located along the west coast of Vancouver Island were analyzed to support an assessment of weather related risks to navigation, principally to identify times when there would be a probability of weather related delays, for Port Alberni, on Vancouver Island in British Columbia. An assessment of data quality and gaps was also conducted.

There are six buoys located along the west coast of Vancouver Island as shown in Figure 1-1 (Red Dots). The locations of these buoys and their data periods are tabulated in Table 1. Data from only five of the buoys, was used for this analysis as the East Dellwood buoy was considered to be outside the range of the study.

The data collected from buoys operated by Environment Canada (EC) was obtained from EC, and the data collected from buoys operated by the United States National Oceanic and Atmospheric Administration (NOAA) was downloaded from NOAA's National Data Buoy Center (<http://www.ndbc.noaa.gov/>).

As the data from the NOAA buoys prior to 2005 were recorded in a different data format, only the data collected from 2005 and onwards was used in this analysis.

Figure 1: Buoy Locations along the West Coast of Vancouver Island

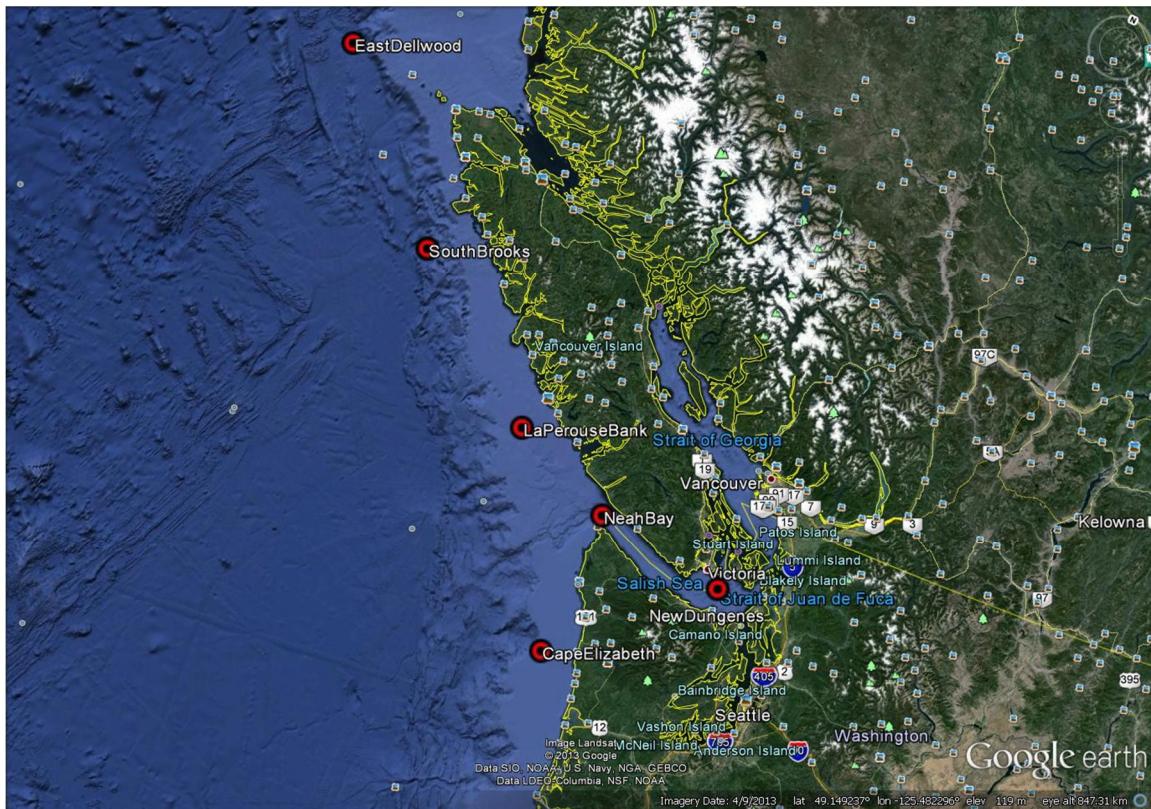


Table 1: Locations of Six Buoys

Station Name	Station ID	Latitude (°N)	Longitude (°W)	Operated by	Available Data Period	Evaluation Period
South Brooks	46132	49.738	127.931	EC	May 1994 – Dec. 2013	May 1994 – Dec. 2013
La Perouse Bank	46206	48.835	125.998	EC	Nov. 1988 – Dec. 2013	Nov. 1988 – Dec. 2013
East Dellwood	46207	50.874	129.916	EC	Oct. 1989 – Dec. 2013	Not Evaluated
Neah Bay	46087	48.494	124.728	NOAA	Jul. 2004 – Dec. 2013	Jan. 2005 – Dec. 2013
New Dungeness	46088	48.336	123.159	NOAA	Jul. 2004 – Dec. 2013	Jan. 2005 – Dec. 2013
Cape Elizabeth	46041	47.349	124.708	NOAA	Jun. 1987 – Dec. 2013	Jan. 2005 – Dec. 2013

## 2.0 APPROACH

The key meteorological variables that are related to navigation risks are wind speed, wind direction and wave height. Accordingly, the following three parameters were analyzed:

- Wind speed (knots) is the horizontal movement of the air and measured by anemometers aboard the buoys;
- Wind direction (°) is the direction from which wind blows, and expressed numerically in a range of 0° – 360°: 0° (or 360°) as north, 90° as east, 180° as south and 270° as west;
- Wave height (m) is the significant wave height that is calculated as the average of the highest one-third of all the wave heights during the sampling period.

As these three variables affect the navigation differently, a joint frequency distribution (JFD) of these three parameters was constructed for each buoy. The JFD was calculated as:

$$f(i, j, k) = \frac{n(i, j, k)}{N} \times 100\%$$
$$\sum_{i=1}^I \sum_{j=1}^J \sum_{k=1}^K f(i, j, k) = 1$$

where I, J and K represent the number of groups of wind direction, wind speed and significant wave height;  $n(i, j, k)$  is the number of occurrence for the  $i^{\text{th}}$  wind direction group,  $j^{\text{th}}$  wind speed group and  $k^{\text{th}}$  wave height group; and N is the total number of occurrence for all the combination of occurrence when all the wind speed, wind direction and wave height were valid.

The different parameters were subdivided into smaller grouping to allow greater flexibility in analyzing the data.

Wind directions were grouped into 12 (I) sectors with each sector covering 30 degrees: the north sector being defined as wind direction from 345° to 15°, and other sectors rotate clockwise.

Wind speeds were grouped into 4 (J) classes: ≤10 knots; 10-20 knots; 20-30 knots and >30 knots.

Wave heights were grouped into 5 (K) classes: ≤3 m; 3-5 m; 5-7 m; 7-9 m and >9 m.

As recommended by navigation experts, the key statistics of these parameters including the wave heights above 7 m and 9 m, as well as the wind speed above 30 knots were also calculated.

Finally, a wind rose for each buoy was constructed for the most recent 5-year period (2009 to 2013).

## 3.0 SUMMARY OF RESULTS

Summaries of the wind and wave analyses are presented in a JFD table, a key statistics table and a windrose diagram for each buoy.

### 3.1 South Brooks

Table 3.1-A: Key Statistics at South Brooks

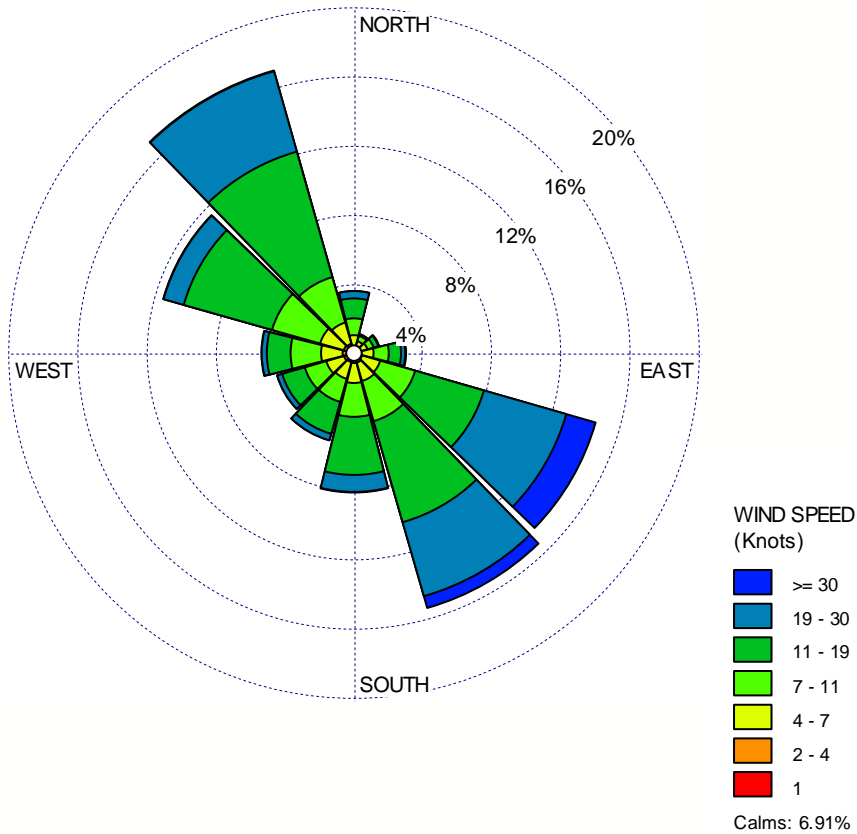
Key Indicators	Percent of Time Occurring
Wave Height > 7 m	0.704%
Wave Height > 9 m	0.090%
Wind Speed > 30 knots	2.584%



Table 3.1-B: JFD at South Brooks

Wind Direction (° from North)	Wind Speed (knot)	Wave Height (m)				
		<=3	3-5	5-7	7-9	>9
Total	<=10	29.250%	6.111%	0.725%	0.053%	0.003%
	10-20	31.284%	9.458%	1.759%	0.131%	0.008%
	20-30	10.064%	6.870%	1.440%	0.230%	0.029%
	>30	0.082%	1.274%	0.978%	0.199%	0.050%
345-15	<=10	3.360%	1.174%	0.139%	0.017%	0.000%
	10-20	1.281%	0.302%	0.020%	0.001%	0.000%
	20-30	0.321%	0.149%	0.010%	0.001%	0.000%
	>30	0.002%	0.004%	0.004%	0.000%	0.000%
16-45	<=10	0.885%	0.177%	0.021%	0.000%	0.000%
	10-20	0.239%	0.082%	0.006%	0.000%	0.000%
	20-30	0.050%	0.013%	0.005%	0.000%	0.000%
	>30	0.000%	0.002%	0.004%	0.000%	0.000%
46-75	<=10	1.078%	0.178%	0.009%	0.001%	0.000%
	10-20	0.302%	0.100%	0.011%	0.000%	0.000%
	20-30	0.018%	0.018%	0.010%	0.000%	0.000%
	>30	0.000%	0.000%	0.004%	0.000%	0.000%
76-105	<=10	1.832%	0.236%	0.021%	0.000%	0.000%
	10-20	0.799%	0.185%	0.022%	0.001%	0.000%
	20-30	0.074%	0.118%	0.018%	0.003%	0.000%
	>30	0.003%	0.020%	0.010%	0.002%	0.000%
106-135	<=10	2.916%	0.381%	0.041%	0.001%	0.000%
	10-20	4.284%	0.877%	0.078%	0.002%	0.000%
	20-30	1.898%	2.242%	0.231%	0.012%	0.001%
	>30	0.043%	0.785%	0.615%	0.090%	0.013%
136-165	<=10	3.203%	0.535%	0.058%	0.006%	0.000%
	10-20	4.869%	1.603%	0.220%	0.012%	0.001%
	20-30	1.437%	1.881%	0.356%	0.051%	0.010%
	>30	0.020%	0.350%	0.249%	0.070%	0.015%
166-195	<=10	2.818%	0.713%	0.099%	0.004%	0.000%
	10-20	1.887%	1.391%	0.332%	0.031%	0.003%
	20-30	0.188%	0.529%	0.239%	0.050%	0.006%
	>30	0.001%	0.036%	0.024%	0.008%	0.000%
196-225	<=10	1.942%	0.660%	0.103%	0.009%	0.001%
	10-20	0.927%	1.051%	0.266%	0.030%	0.001%
	20-30	0.064%	0.236%	0.120%	0.029%	0.005%
	>30	0.001%	0.020%	0.008%	0.005%	0.008%
226-255	<=10	1.939%	0.599%	0.081%	0.006%	0.000%
	10-20	0.670%	0.794%	0.300%	0.024%	0.001%
	20-30	0.025%	0.148%	0.094%	0.034%	0.004%
	>30	0.000%	0.006%	0.008%	0.001%	0.003%
256-285	<=10	2.604%	0.561%	0.062%	0.006%	0.001%
	10-20	1.096%	0.842%	0.232%	0.015%	0.001%
	20-30	0.051%	0.209%	0.123%	0.019%	0.001%
	>30	0.001%	0.006%	0.010%	0.005%	0.001%
286-315	<=10	3.541%	0.499%	0.052%	0.000%	0.000%
	10-20	5.682%	1.102%	0.178%	0.010%	0.001%
	20-30	1.128%	0.407%	0.134%	0.029%	0.003%
	>30	0.003%	0.012%	0.023%	0.017%	0.009%
316-345	<=10	3.131%	0.398%	0.038%	0.004%	0.000%
	10-20	9.248%	1.129%	0.094%	0.003%	0.000%
	20-30	4.810%	0.920%	0.100%	0.002%	0.000%
	>30	0.007%	0.034%	0.019%	0.001%	0.000%

Figure 2: Windrose at South Brooks (2009-2013)



### 3.2 La Perouse Bank

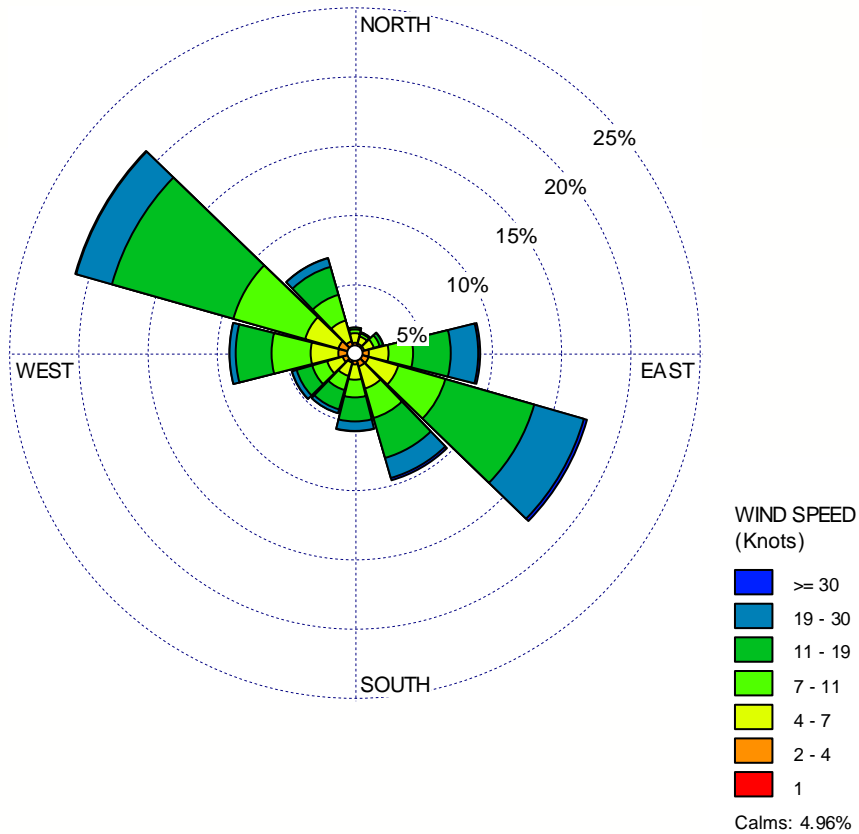
Table 3.2-A: Key Statistics at La Perouse Bank

Key Indicators	Percent of Time Occurring
Wave Height > 7 m	0.161%
Wave Height > 9 m	0.010%
Wind Speed > 30 knots	0.699%

Table 3.2-B: JFD at La Perouse Bank

Wind Direction (° from North)	Wind Speed (knot)	Wave Height (m)				
		<=3	3-5	5-7	7-9	>9
Total	<=10	43.952%	5.140%	0.350%	0.005%	0.000%
	10-20	29.753%	7.719%	0.904%	0.041%	0.002%
	20-30	5.868%	4.681%	0.814%	0.070%	0.002%
	>30	0.052%	0.413%	0.194%	0.034%	0.006%
345-15	<=10	2.727%	0.412%	0.017%	0.000%	0.000%
	10-20	0.159%	0.080%	0.002%	0.000%	0.000%
	20-30	0.010%	0.043%	0.007%	0.000%	0.000%
	>30	0.000%	0.002%	0.002%	0.000%	0.000%
16-45	<=10	1.639%	0.203%	0.003%	0.000%	0.000%
	10-20	0.137%	0.033%	0.002%	0.000%	0.000%
	20-30	0.007%	0.005%	0.000%	0.000%	0.000%
	>30	0.001%	0.000%	0.000%	0.000%	0.000%
46-75	<=10	2.118%	0.210%	0.010%	0.000%	0.000%
	10-20	0.395%	0.095%	0.003%	0.000%	0.000%
	20-30	0.070%	0.015%	0.001%	0.000%	0.000%
	>30	0.001%	0.001%	0.000%	0.000%	0.000%
76-105	<=10	4.246%	0.363%	0.016%	0.000%	0.000%
	10-20	3.457%	0.486%	0.009%	0.001%	0.001%
	20-30	1.394%	0.413%	0.020%	0.000%	0.000%
	>30	0.023%	0.099%	0.005%	0.000%	0.000%
106-135	<=10	5.768%	0.504%	0.015%	0.000%	0.000%
	10-20	7.025%	0.862%	0.037%	0.001%	0.000%
	20-30	2.170%	1.120%	0.071%	0.001%	0.001%
	>30	0.020%	0.153%	0.042%	0.003%	0.000%
136-165	<=10	3.881%	0.491%	0.036%	0.001%	0.000%
	10-20	2.543%	0.934%	0.089%	0.001%	0.000%
	20-30	0.512%	0.764%	0.169%	0.005%	0.000%
	>30	0.004%	0.076%	0.071%	0.011%	0.001%
166-195	<=10	2.973%	0.549%	0.051%	0.001%	0.000%
	10-20	1.154%	0.965%	0.141%	0.004%	0.000%
	20-30	0.125%	0.380%	0.099%	0.008%	0.001%
	>30	0.001%	0.014%	0.014%	0.005%	0.000%
196-225	<=10	2.236%	0.541%	0.059%	0.001%	0.000%
	10-20	0.643%	0.858%	0.160%	0.014%	0.001%
	20-30	0.039%	0.170%	0.080%	0.014%	0.000%
	>30	0.000%	0.004%	0.002%	0.001%	0.001%
226-255	<=10	2.603%	0.551%	0.061%	0.002%	0.000%
	10-20	0.578%	0.756%	0.165%	0.008%	0.000%
	20-30	0.032%	0.155%	0.062%	0.014%	0.001%
	>30	0.000%	0.003%	0.001%	0.005%	0.000%
256-285	<=10	4.772%	0.526%	0.038%	0.001%	0.000%
	10-20	2.394%	0.858%	0.150%	0.010%	0.001%
	20-30	0.153%	0.259%	0.098%	0.013%	0.001%
	>30	0.001%	0.010%	0.010%	0.004%	0.002%
286-315	<=10	7.045%	0.455%	0.023%	0.001%	0.000%
	10-20	9.346%	1.245%	0.117%	0.002%	0.000%
	20-30	1.177%	1.079%	0.167%	0.015%	0.000%
	>30	0.001%	0.044%	0.037%	0.005%	0.001%
316-345	<=10	3.944%	0.335%	0.021%	0.000%	0.000%
	10-20	1.922%	0.549%	0.029%	0.001%	0.000%
	20-30	0.181%	0.279%	0.040%	0.000%	0.000%
	>30	0.000%	0.009%	0.010%	0.000%	0.000%

Figure 3: Windrose at La Perouse Bank (2009-2013)



### 3.3 Neah Bay

Table 3.3-A: Key Statistics at Neah Bay

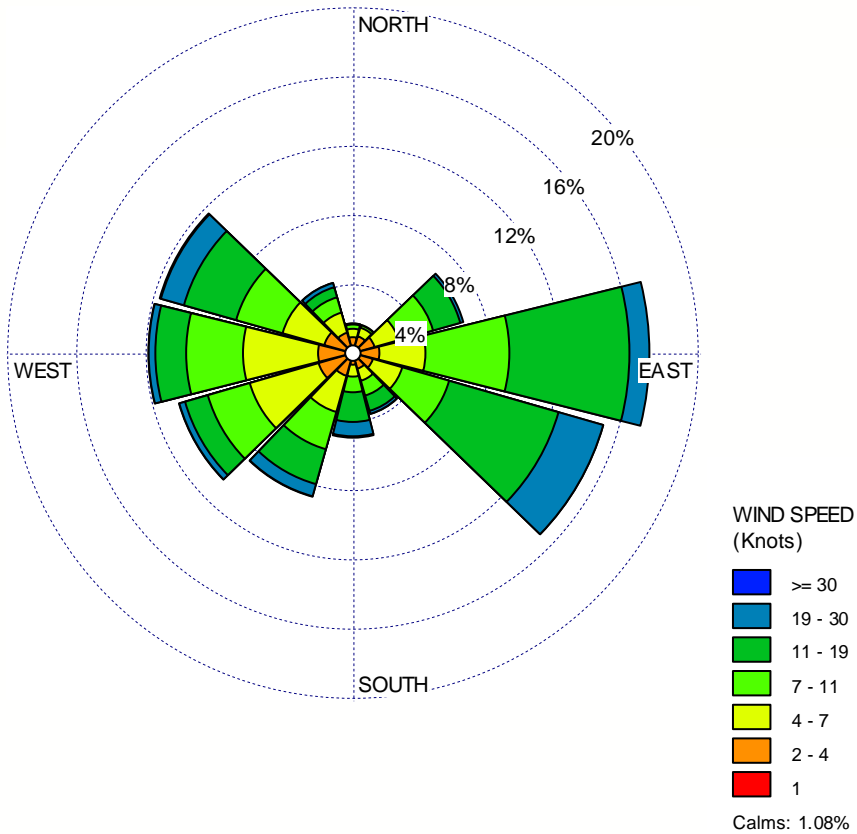
Key Indicators	Percent of Time Occurring
Wave Height > 7 m	0.055%
Wave Height > 9 m	0.008%
Wind Speed > 30 knots	0.362%



Table 3.3-B: JFD at Neah Bay

Wind Direction (° from North)	Wind Speed (knot)	Wave Height (m)				
		<=3	3-5	5-7	7-9	>9
Total	<=10	54.856%	3.731%	0.110%	0.000%	0.000%
	10-20	28.677%	5.175%	0.313%	0.014%	0.000%
	20-30	4.496%	1.904%	0.338%	0.022%	0.004%
	>30	0.094%	0.160%	0.092%	0.012%	0.004%
345-15	<=10	1.411%	0.186%	0.002%	0.000%	0.000%
	10-20	0.051%	0.027%	0.002%	0.000%	0.000%
	20-30	0.004%	0.000%	0.000%	0.000%	0.000%
	>30	0.000%	0.000%	0.000%	0.000%	0.000%
16-45	<=10	1.456%	0.178%	0.004%	0.000%	0.000%
	10-20	0.039%	0.010%	0.000%	0.000%	0.000%
	20-30	0.000%	0.000%	0.000%	0.000%	0.000%
	>30	0.000%	0.000%	0.000%	0.000%	0.000%
46-75	<=10	3.598%	0.313%	0.010%	0.000%	0.000%
	10-20	1.534%	0.076%	0.000%	0.000%	0.000%
	20-30	0.233%	0.002%	0.000%	0.000%	0.000%
	>30	0.000%	0.000%	0.000%	0.000%	0.000%
76-105	<=10	8.180%	0.663%	0.010%	0.000%	0.000%
	10-20	9.115%	0.624%	0.014%	0.000%	0.000%
	20-30	0.873%	0.033%	0.004%	0.000%	0.000%
	>30	0.014%	0.000%	0.000%	0.000%	0.000%
106-135	<=10	5.341%	0.382%	0.002%	0.000%	0.000%
	10-20	7.000%	0.712%	0.006%	0.000%	0.000%
	20-30	1.792%	0.160%	0.000%	0.000%	0.000%
	>30	0.025%	0.004%	0.000%	0.000%	0.000%
136-165	<=10	2.299%	0.233%	0.006%	0.000%	0.000%
	10-20	1.019%	0.335%	0.018%	0.000%	0.000%
	20-30	0.133%	0.090%	0.010%	0.000%	0.000%
	>30	0.002%	0.014%	0.002%	0.000%	0.000%
166-195	<=10	2.841%	0.233%	0.008%	0.000%	0.000%
	10-20	1.947%	0.571%	0.020%	0.000%	0.000%
	20-30	0.575%	0.389%	0.016%	0.000%	0.000%
	>30	0.039%	0.088%	0.020%	0.000%	0.000%
196-225	<=10	5.914%	0.278%	0.020%	0.000%	0.000%
	10-20	1.866%	0.538%	0.029%	0.000%	0.000%
	20-30	0.284%	0.223%	0.029%	0.000%	0.000%
	>30	0.004%	0.016%	0.008%	0.000%	0.000%
226-255	<=10	7.773%	0.280%	0.008%	0.000%	0.000%
	10-20	1.053%	0.530%	0.039%	0.008%	0.000%
	20-30	0.108%	0.121%	0.045%	0.010%	0.004%
	>30	0.002%	0.006%	0.008%	0.000%	0.002%
256-285	<=10	8.262%	0.360%	0.020%	0.000%	0.000%
	10-20	1.837%	0.698%	0.063%	0.006%	0.000%
	20-30	0.119%	0.203%	0.063%	0.004%	0.000%
	>30	0.000%	0.012%	0.020%	0.006%	0.002%
286-315	<=10	5.188%	0.348%	0.010%	0.000%	0.000%
	10-20	2.811%	0.810%	0.092%	0.000%	0.000%
	20-30	0.342%	0.573%	0.158%	0.008%	0.000%
	>30	0.008%	0.020%	0.033%	0.006%	0.000%
316-345	<=10	2.594%	0.278%	0.012%	0.000%	0.000%
	10-20	0.405%	0.243%	0.031%	0.000%	0.000%
	20-30	0.033%	0.108%	0.014%	0.000%	0.000%
	>30	0.000%	0.002%	0.002%	0.000%	0.000%

Figure 4: Windrose at Neah Bay (2009 – 2013)



### 3.4 New Dungeness

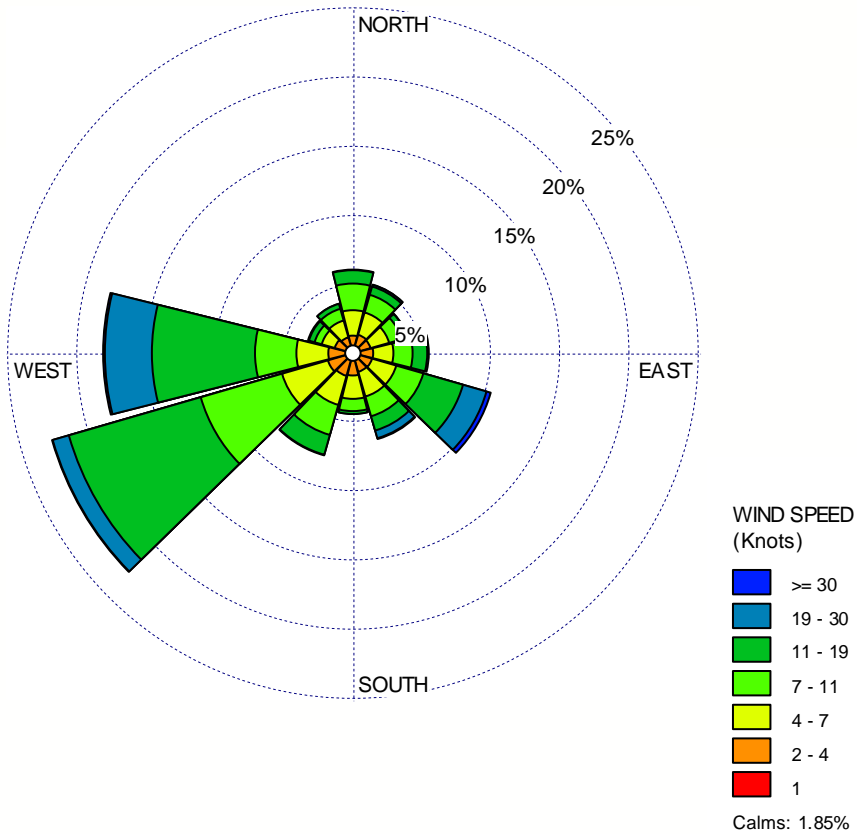
Table 3.4-A Key Statistics at New Dungeness

Key Indicators	Percent of Time Occurring
Wave Height > 7 m	0.000%
Wave Height > 9 m	0.000%
Wind Speed > 30 knots	0.567%

Table 3.4-B: JFD at New Dungeness

Wind Direction (° from North)	Wind Speed (knot)	Wave Height (m)				
		<=3	3-5	5-7	7-9	>9
Total	<=10	60.501%	0.000%	0.000%	0.000%	0.000%
	10-20	32.268%	0.000%	0.000%	0.000%	0.000%
	20-30	6.662%	0.003%	0.000%	0.000%	0.000%
	>30	0.556%	0.011%	0.000%	0.000%	0.000%
345-15	<=10	5.304%	0.000%	0.000%	0.000%	0.000%
	10-20	1.438%	0.000%	0.000%	0.000%	0.000%
	20-30	0.036%	0.000%	0.000%	0.000%	0.000%
	>30	0.000%	0.000%	0.000%	0.000%	0.000%
16-45	<=10	4.450%	0.000%	0.000%	0.000%	0.000%
	10-20	0.879%	0.000%	0.000%	0.000%	0.000%
	20-30	0.155%	0.000%	0.000%	0.000%	0.000%
	>30	0.011%	0.000%	0.000%	0.000%	0.000%
46-75	<=10	3.633%	0.000%	0.000%	0.000%	0.000%
	10-20	0.575%	0.000%	0.000%	0.000%	0.000%
	20-30	0.022%	0.000%	0.000%	0.000%	0.000%
	>30	0.000%	0.000%	0.000%	0.000%	0.000%
76-105	<=10	3.959%	0.000%	0.000%	0.000%	0.000%
	10-20	1.230%	0.000%	0.000%	0.000%	0.000%
	20-30	0.127%	0.000%	0.000%	0.000%	0.000%
	>30	0.006%	0.000%	0.000%	0.000%	0.000%
106-135	<=10	4.974%	0.000%	0.000%	0.000%	0.000%
	10-20	3.385%	0.000%	0.000%	0.000%	0.000%
	20-30	1.430%	0.000%	0.000%	0.000%	0.000%
	>30	0.294%	0.003%	0.000%	0.000%	0.000%
136-165	<=10	4.590%	0.000%	0.000%	0.000%	0.000%
	10-20	1.313%	0.000%	0.000%	0.000%	0.000%
	20-30	0.625%	0.000%	0.000%	0.000%	0.000%
	>30	0.072%	0.000%	0.000%	0.000%	0.000%
166-195	<=10	4.523%	0.000%	0.000%	0.000%	0.000%
	10-20	0.267%	0.000%	0.000%	0.000%	0.000%
	20-30	0.004%	0.000%	0.000%	0.000%	0.000%
	>30	0.000%	0.000%	0.000%	0.000%	0.000%
196-225	<=10	5.527%	0.000%	0.000%	0.000%	0.000%
	10-20	1.727%	0.000%	0.000%	0.000%	0.000%
	20-30	0.022%	0.000%	0.000%	0.000%	0.000%
	>30	0.000%	0.000%	0.000%	0.000%	0.000%
226-255	<=10	9.604%	0.000%	0.000%	0.000%	0.000%
	10-20	10.391%	0.000%	0.000%	0.000%	0.000%
	20-30	1.039%	0.001%	0.000%	0.000%	0.000%
	>30	0.052%	0.003%	0.000%	0.000%	0.000%
256-285	<=10	7.359%	0.000%	0.000%	0.000%	0.000%
	10-20	9.763%	0.000%	0.000%	0.000%	0.000%
	20-30	3.068%	0.001%	0.000%	0.000%	0.000%
	>30	0.117%	0.006%	0.000%	0.000%	0.000%
286-315	<=10	3.219%	0.000%	0.000%	0.000%	0.000%
	10-20	0.851%	0.000%	0.000%	0.000%	0.000%
	20-30	0.123%	0.000%	0.000%	0.000%	0.000%
	>30	0.003%	0.000%	0.000%	0.000%	0.000%
316-345	<=10	3.360%	0.000%	0.000%	0.000%	0.000%
	10-20	0.450%	0.000%	0.000%	0.000%	0.000%
	20-30	0.011%	0.000%	0.000%	0.000%	0.000%
	>30	0.001%	0.000%	0.000%	0.000%	0.000%

Figure 5: Windrose at New Dungeness (2009-2013)



### 3.5 Cape Elizabeth

Table 3.5-A: Key Statistics at Cape Elizabeth

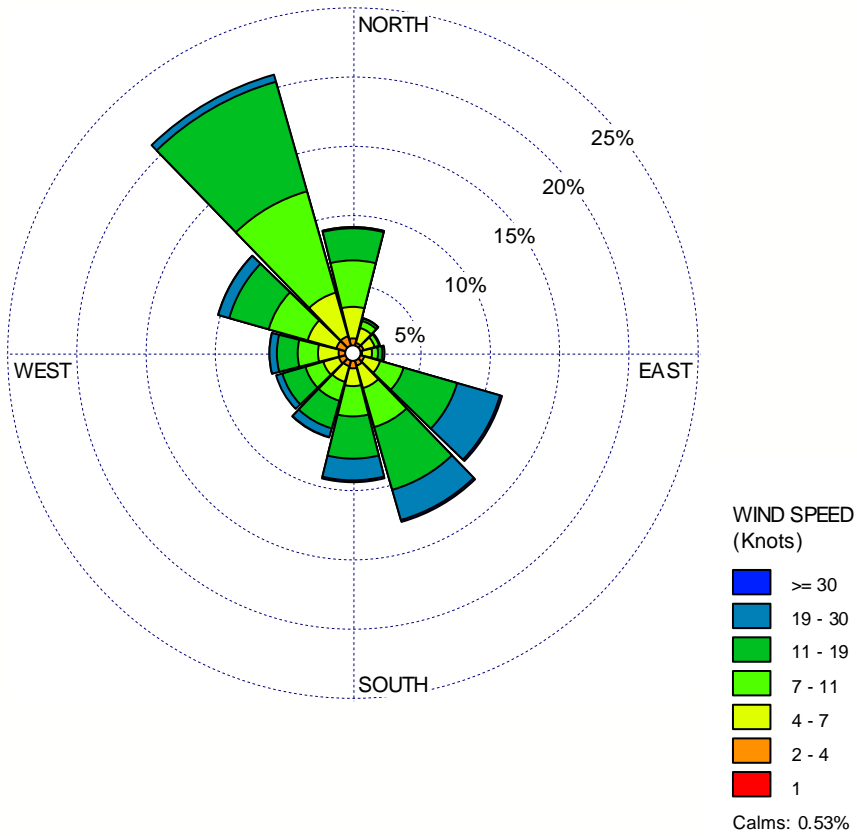
Key Indicators	Percent of Time Occurring
Wave Height > 7 m	0.312%
Wave Height > 9 m	0.043%
Wind Speed > 30 knots	0.546%



Table 3.5-B: JFD at Cape Elizabeth

Wind Direction (° from North)	Wind Speed (knot)	Wave Height (m)				
		<=3	3-5	5-7	7-9	>9
Total	<=10	46.289%	5.655%	0.366%	0.017%	0.000%
	10-20	28.495%	9.038%	1.164%	0.050%	0.000%
	20-30	3.181%	4.038%	0.978%	0.171%	0.011%
	>30	0.059%	0.252%	0.173%	0.030%	0.033%
345-15	<=10	5.044%	0.390%	0.011%	0.000%	0.000%
	10-20	1.845%	0.254%	0.004%	0.000%	0.000%
	20-30	0.024%	0.017%	0.000%	0.000%	0.000%
	>30	0.000%	0.002%	0.000%	0.000%	0.000%
16-45	<=10	1.949%	0.236%	0.007%	0.000%	0.000%
	10-20	0.184%	0.033%	0.000%	0.000%	0.000%
	20-30	0.011%	0.000%	0.000%	0.000%	0.000%
	>30	0.000%	0.002%	0.000%	0.000%	0.000%
46-75	<=10	1.815%	0.267%	0.007%	0.000%	0.000%
	10-20	0.082%	0.026%	0.000%	0.000%	0.000%
	20-30	0.000%	0.002%	0.000%	0.000%	0.000%
	>30	0.000%	0.000%	0.000%	0.000%	0.000%
76-105	<=10	1.878%	0.236%	0.013%	0.000%	0.000%
	10-20	0.544%	0.102%	0.011%	0.000%	0.000%
	20-30	0.160%	0.052%	0.004%	0.000%	0.000%
	>30	0.013%	0.002%	0.000%	0.000%	0.000%
106-135	<=10	3.335%	0.512%	0.020%	0.000%	0.000%
	10-20	3.866%	0.826%	0.056%	0.000%	0.000%
	20-30	1.605%	0.891%	0.074%	0.004%	0.000%
	>30	0.037%	0.102%	0.033%	0.002%	0.000%
136-165	<=10	4.339%	0.575%	0.037%	0.000%	0.000%
	10-20	4.426%	1.236%	0.087%	0.002%	0.000%
	20-30	0.742%	1.071%	0.152%	0.002%	0.000%
	>30	0.009%	0.087%	0.067%	0.004%	0.002%
166-195	<=10	4.708%	0.677%	0.059%	0.007%	0.000%
	10-20	2.056%	1.349%	0.130%	0.007%	0.000%
	20-30	0.247%	0.737%	0.176%	0.035%	0.002%
	>30	0.000%	0.041%	0.065%	0.015%	0.017%
196-225	<=10	2.737%	0.646%	0.054%	0.004%	0.000%
	10-20	0.956%	1.128%	0.180%	0.011%	0.000%
	20-30	0.043%	0.312%	0.126%	0.030%	0.000%
	>30	0.000%	0.007%	0.002%	0.009%	0.011%
226-255	<=10	2.400%	0.585%	0.065%	0.007%	0.000%
	10-20	0.768%	0.945%	0.191%	0.020%	0.000%
	20-30	0.030%	0.134%	0.100%	0.037%	0.007%
	>30	0.080%	0.004%	0.000%	0.000%	0.000%
256-285	<=10	3.198%	0.490%	0.046%	0.000%	0.000%
	10-20	0.852%	0.913%	0.221%	0.007%	0.000%
	20-30	0.063%	0.241%	0.152%	0.059%	0.002%
	>30	0.000%	0.004%	0.004%	0.000%	0.002%
286-315	<=10	5.313%	0.507%	0.043%	0.000%	0.000%
	10-20	3.012%	1.203%	0.232%	0.004%	0.000%
	20-30	0.126%	0.434%	0.150%	0.004%	0.000%
	>30	0.000%	0.004%	0.000%	0.000%	0.000%
316-345	<=10	9.573%	0.533%	0.007%	0.000%	0.000%
	10-20	9.903%	1.023%	0.052%	0.000%	0.000%
	20-30	0.130%	0.145%	0.046%	0.000%	0.000%
	>30	0.000%	0.000%	0.002%	0.000%	0.000%

Figure 6: Windrose at Cape Elizabeth



## 4.0 DISCUSSION OF DATA QUALITY AND GAPS AND RECOMMENDATIONS

The wind and wave data collected from five buoys placed along the west coast of Vancouver Island can be used to support the identification of navigation risks associated with meteorological variables. Based on this data, high wind (> 30 knots) and wave conditions (> 7 m and 9 m) occurred infrequently. The high waves typically occurred in non-summer months, as shown in Figure 7, during the evaluation periods.

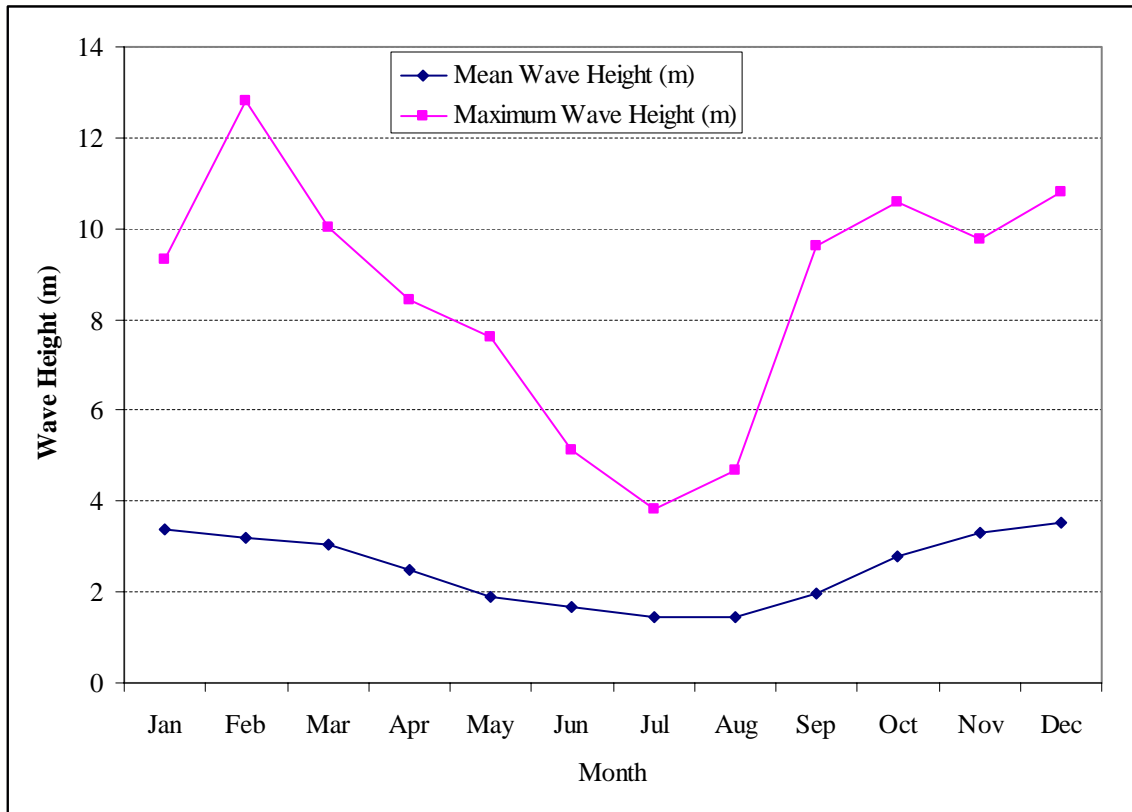
However, it should be noted that the buoys, as shown in Figure 1, are very sparsely placed. Therefore, the wind and wave characteristics of the general area (west coast) might not be representative of the conditions along the actual navigation routes.

Additionally, as shown in Appendix A, the data recovery rates during the evaluation periods were not consistently good, particularly for the winter months during which the high wave conditions could occur. This data gap could result in underestimation of the frequency in the high wind and wave conditions.

Besides the wind and wave data collected from buoys, the wave hindcast data is also available for the Northeast Pacific. This data set consists of data that is archived for 3-hour periods from 1980-2011, on a 35-km resolution and can be accessed at: (<http://www.oceanweather.com/metocean/nepac/index.html>). The wave hindcast predicts past wave conditions using a computer model and observed wind and wave fields, and therefore is often representative of observed wave conditions. This data set does not have missing data and can be accessed through EC.

It is recommended that the hindcast data set be used to supplement the buoy data for a refined analysis to reduce the uncertainty associated with the identified data gaps. .

Figure 7 Monthly Variations in Wave Heights at South Brooks





APPENDIX A:  
DATA RECOVERY RATE



The data recovery rate is defined as the number of valid data records collected versus the maximum possible number of records over the entire reporting period. A recovery rate was determined for each month and was calculated as follows:

$$\text{Data Recovery Rate(\%)} = \frac{\text{Data Records Collected}}{\text{Data Records Possible}} (100)$$

where,

Data Records Collected = Data Records Possible – Number of Missing Records

It should also be noted that the data recovery rate listed here assumes that all wind speed, wind direction and wave height data are valid.

Month	South Brooks	La Perouse Bank	Neah Bay	New Dungeness	Cape Elizabeth
Nov-88	-	22.4%	-	-	-
Dec-88	-	92.5%	-	-	-
Jan-89	-	88.3%	-	-	-
Feb-89	-	91.2%	-	-	-
Mar-89	-	96.8%	-	-	-
Apr-89	-	90.7%	-	-	-
May-89	-	12.6%	-	-	-
Jun-89	-	3.9%	-	-	-
Jul-89	-	-	-	-	-
Aug-89	-	-	-	-	-
Sep-89	-	89.4%	-	-	-
Oct-89	-	93.1%	-	-	-
Nov-89	-	42.5%	-	-	-
Dec-89	-	4.4%	-	-	-
Jan-90	-	58.1%	-	-	-
Feb-90	-	96.3%	-	-	-
Mar-90	-	96.9%	-	-	-
Apr-90	-	95.3%	-	-	-
May-90	-	91.9%	-	-	-
Jun-90	-	85.6%	-	-	-
Jul-90	-	26.2%	-	-	-
Aug-90	-	20.6%	-	-	-
Sep-90	-	64.7%	-	-	-

**Overview Analysis of Wind and Wave  
Conditions on the West Coast of  
Vancouver Island**

Month	South Brooks	La Perouse Bank	Neah Bay	New Dungeness	Cape Elizabeth
Oct-90	-	99.3%	-	-	-
Nov-90	-	98.2%	-	-	-
Dec-90	-	92.5%	-	-	-
Jan-91	-	89.8%	-	-	-
Feb-91	-	92.7%	-	-	-
Mar-91	-	83.1%	-	-	-
Apr-91	-	57.4%	-	-	-
May-91	-	78.8%	-	-	-
Jun-91	-	90.3%	-	-	-
Jul-91	-	89.5%	-	-	-
Aug-91	-	88.4%	-	-	-
Sep-91	-	58.6%	-	-	-
Oct-91	-	95.6%	-	-	-
Nov-91	-	96.1%	-	-	-
Dec-91	-	99.5%	-	-	-
Jan-92	-	84.9%	-	-	-
Feb-92	-	95.7%	-	-	-
Mar-92	-	95.8%	-	-	-
Apr-92	-	57.6%	-	-	-
May-92	-	95.2%	-	-	-
Jun-92	-	91.0%	-	-	-
Jul-92	-	96.4%	-	-	-
Aug-92	-	94.9%	-	-	-
Sep-92	-	95.8%	-	-	-
Oct-92	-	94.0%	-	-	-
Nov-92	-	90.0%	-	-	-
Dec-92	-	94.9%	-	-	-
Jan-93	-	79.4%	-	-	-
Feb-93	-	92.7%	-	-	-
Mar-93	-	97.3%	-	-	-
Apr-93	-	97.2%	-	-	-
May-93	-	93.0%	-	-	-
Jun-93	-	96.5%	-	-	-
Jul-93	-	94.0%	-	-	-

Overview Analysis of Wind and Wave  
Conditions on the West Coast of  
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Month	South Brooks	La Perouse Bank	Neah Bay	New Dungeness	Cape Elizabeth
Aug-93	-	96.2%	-	-	-
Sep-93	-	96.5%	-	-	-
Oct-93	-	96.4%	-	-	-
Nov-93	-	89.4%	-	-	-
Dec-93	-	95.4%	-	-	-
Jan-94	-	72.7%	-	-	-
Feb-94	-	70.8%	-	-	-
Mar-94	-	89.5%	-	-	-
Apr-94	-	96.0%	-	-	-
May-94	0.7%	22.0%	-	-	-
Jun-94	0.8%	0.4%	-	-	-
Jul-94	0.4%	0.7%	-	-	-
Aug-94	1.1%	0.5%	-	-	-
Sep-94	66.8%	61.3%	-	-	-
Oct-94	84.4%	78.6%	-	-	-
Nov-94	77.6%	85.6%	-	-	-
Dec-94	74.6%	78.5%	-	-	-
Jan-95	68.1%	66.1%	-	-	-
Feb-95	87.1%	73.2%	-	-	-
Mar-95	94.0%	90.3%	-	-	-
Apr-95	98.8%	96.3%	-	-	-
May-95	89.0%	75.4%	-	-	-
Jun-95	95.0%	87.1%	-	-	-
Jul-95	93.4%	92.2%	-	-	-
Aug-95	98.7%	90.6%	-	-	-
Sep-95	91.8%	86.8%	-	-	-
Oct-95	70.0%	72.8%	-	-	-
Nov-95	61.5%	70.8%	-	-	-
Dec-95	57.1%	96.1%	-	-	-
Jan-96	72.0%	68.5%	-	-	-
Feb-96	70.1%	9.5%	-	-	-
Mar-96	74.5%	20.3%	-	-	-
Apr-96	93.8%	84.6%	-	-	-
May-96	87.9%	83.9%	-	-	-

Overview Analysis of Wind and Wave  
Conditions on the West Coast of  
Vancouver Island

Month	South Brooks	La Perouse Bank	Neah Bay	New Dungeness	Cape Elizabeth
Jun-96	34.4%	84.3%	-	-	-
Jul-96	93.3%	96.0%	-	-	-
Aug-96	94.8%	100.0%	-	-	-
Sep-96	93.3%	95.3%	-	-	-
Oct-96	91.9%	96.8%	-	-	-
Nov-96	94.6%	94.0%	-	-	-
Dec-96	88.2%	99.9%	-	-	-
Jan-97	85.6%	97.7%	-	-	-
Feb-97	92.4%	99.1%	-	-	-
Mar-97	82.8%	89.7%	-	-	-
Apr-97	86.8%	95.6%	-	-	-
May-97	93.4%	91.9%	-	-	-
Jun-97	95.7%	91.7%	-	-	-
Jul-97	96.2%	98.7%	-	-	-
Aug-97	90.3%	79.0%	-	-	-
Sep-97	95.8%	58.9%	-	-	-
Oct-97	98.0%	82.0%	-	-	-
Nov-97	97.8%	99.9%	-	-	-
Dec-97	90.1%	91.3%	-	-	-
Jan-98	96.6%	99.6%	-	-	-
Feb-98	97.8%	98.7%	-	-	-
Mar-98	96.2%	96.6%	-	-	-
Apr-98	89.7%	94.6%	-	-	-
May-98	95.4%	93.8%	-	-	-
Jun-98	93.5%	60.6%	-	-	-
Jul-98	13.3%	2.7%	-	-	-
Aug-98	-	-	-	-	-
Sep-98	72.1%	0.4%	-	-	-
Oct-98	98.7%	0.4%	-	-	-
Nov-98	84.4%	1.1%	-	-	-
Dec-98	-	1.9%	-	-	-
Jan-99	29.8%	-	-	-	-
Feb-99	99.1%	-	-	-	-
Mar-99	96.0%	53.8%	-	-	-



Overview Analysis of Wind and Wave  
Conditions on the West Coast of  
Vancouver Island

Month	South Brooks	La Perouse Bank	Neah Bay	New Dungeness	Cape Elizabeth
Apr-99	92.2%	92.6%	-	-	-
May-99	86.6%	87.1%	-	-	-
Jun-99	99.7%	99.2%	-	-	-
Jul-99	98.5%	99.3%	-	-	-
Aug-99	95.4%	96.2%	-	-	-
Sep-99	96.4%	96.5%	-	-	-
Oct-99	99.6%	98.4%	-	-	-
Nov-99	93.5%	91.8%	-	-	-
Dec-99	99.9%	97.7%	-	-	-
Jan-00	98.9%	98.1%	-	-	-
Feb-00	99.4%	97.7%	-	-	-
Mar-00	96.0%	93.3%	-	-	-
Apr-00	92.2%	79.6%	-	-	-
May-00	91.9%	96.6%	-	-	-
Jun-00	64.4%	97.9%	-	-	-
Jul-00	31.6%	97.7%	-	-	-
Aug-00	99.6%	99.1%	-	-	-
Sep-00	99.3%	98.9%	-	-	-
Oct-00	98.4%	97.7%	-	-	-
Nov-00	89.0%	95.7%	-	-	-
Dec-00	68.4%	99.9%	-	-	-
Jan-01	60.9%	96.4%	-	-	-
Feb-01	45.1%	99.7%	-	-	-
Mar-01	81.3%	94.1%	-	-	-
Apr-01	86.1%	92.5%	-	-	-
May-01	96.1%	96.8%	-	-	-
Jun-01	97.1%	96.0%	-	-	-
Jul-01	95.6%	96.4%	-	-	-
Aug-01	95.2%	93.5%	-	-	-
Sep-01	92.2%	43.2%	-	-	-
Oct-01	99.2%	-	-	-	-
Nov-01	96.0%	-	-	-	-
Dec-01	94.5%	-	-	-	-
Jan-02	97.0%	-	-	-	-

Overview Analysis of Wind and Wave  
Conditions on the West Coast of  
Vancouver Island

Month	South Brooks	La Perouse Bank	Neah Bay	New Dungeness	Cape Elizabeth
Feb-02	97.9%	76.8%	-	-	-
Mar-02	99.5%	98.8%	-	-	-
Apr-02	95.6%	91.1%	-	-	-
May-02	59.5%	55.5%	-	-	-
Jun-02	89.3%	80.8%	-	-	-
Jul-02	99.2%	96.4%	-	-	-
Aug-02	93.7%	84.9%	-	-	-
Sep-02	91.9%	89.9%	-	-	-
Oct-02	91.0%	80.8%	-	-	-
Nov-02	99.6%	91.7%	-	-	-
Dec-02	86.7%	76.9%	-	-	-
Jan-03	99.2%	96.9%	-	-	-
Feb-03	92.9%	78.7%	-	-	-
Mar-03	99.6%	92.6%	-	-	-
Apr-03	99.6%	95.8%	-	-	-
May-03	99.5%	93.1%	-	-	-
Jun-03	96.8%	95.7%	-	-	-
Jul-03	98.7%	95.8%	-	-	-
Aug-03	99.3%	90.9%	-	-	-
Sep-03	97.5%	57.6%	-	-	-
Oct-03	87.0%	61.8%	-	-	-
Nov-03	94.4%	86.7%	-	-	-
Dec-03	98.3%	75.0%	-	-	-
Jan-04	42.1%	85.8%	-	-	-
Feb-04	97.7%	98.9%	-	-	-
Mar-04	99.6%	99.5%	-	-	-
Apr-04	99.4%	92.6%	-	-	-
May-04	99.5%	96.6%	-	-	-
Jun-04	99.7%	86.8%	-	-	-
Jul-04	98.4%	76.9%	-	-	-
Aug-04	100.0%	91.0%	-	-	-
Sep-04	97.2%	77.5%	-	-	-
Oct-04	99.7%	75.8%	-	-	-
Nov-04	99.3%	61.7%	-	-	-

**Overview Analysis of Wind and Wave  
Conditions on the West Coast of  
Vancouver Island**

Month	South Brooks	La Perouse Bank	Neah Bay	New Dungeness	Cape Elizabeth
Dec-04	98.8%	78.6%	-	-	-
Jan-05	99.5%	71.9%	99.5%	99.2%	99.6%
Feb-05	99.4%	77.2%	99.9%	98.7%	99.6%
Mar-05	99.9%	72.0%	99.9%	99.5%	99.6%
Apr-05	98.8%	61.1%	99.0%	99.3%	99.9%
May-05	100.0%	-	99.3%	98.7%	99.7%
Jun-05	90.4%	6.1%	99.0%	99.3%	99.4%
Jul-05	26.9%	-	100.0%	99.3%	99.9%
Aug-05	100.0%	-	100.0%	99.1%	99.6%
Sep-05	99.7%	-	98.5%	99.2%	98.3%
Oct-05	98.5%	-	99.9%	99.2%	99.7%
Nov-05	98.3%	-	40.0%	99.3%	98.9%
Dec-05	98.0%	21.2%	-	-	93.4%
Jan-06	98.7%	1.5%	-	-	-
Feb-06	97.0%	27.4%	-	-	-
Mar-06	98.8%	25.1%	-	97.4%	-
Apr-06	96.7%	62.6%	65.6%	38.6%	-
May-06	84.1%	52.8%	98.9%	98.5%	-
Jun-06	87.9%	13.2%	99.7%	99.6%	30.6%
Jul-06	81.9%	18.5%	99.9%	99.3%	99.7%
Aug-06	78.9%	-	98.5%	96.9%	99.7%
Sep-06	67.4%	37.2%	95.1%	90.0%	99.6%
Oct-06	80.9%	94.4%	96.6%	98.8%	99.1%
Nov-06	81.9%	81.3%	91.9%	99.2%	49.6%
Dec-06	72.0%	69.5%	98.8%	99.6%	-
Jan-07	42.6%	83.6%	100.0%	99.1%	-
Feb-07	62.6%	82.9%	99.3%	97.9%	-
Mar-07	78.5%	89.0%	80.1%	97.6%	-
Apr-07	32.8%	93.8%	99.0%	97.2%	-
May-07	8.6%	32.3%	100.0%	98.7%	-
Jun-07	56.5%	52.6%	97.6%	98.9%	-
Jul-07	99.3%	98.5%	99.2%	98.7%	-
Aug-07	98.3%	98.1%	99.1%	99.1%	-
Sep-07	96.1%	94.2%	99.3%	98.5%	-

**Overview Analysis of Wind and Wave  
Conditions on the West Coast of  
Vancouver Island**

Month	South Brooks	La Perouse Bank	Neah Bay	New Dungeness	Cape Elizabeth
Oct-07	68.8%	90.7%	99.5%	98.9%	64.0%
Nov-07	67.9%	83.5%	99.2%	90.1%	98.6%
Dec-07	75.5%	79.6%	99.6%	99.7%	96.2%
Jan-08	65.3%	79.3%	99.6%	99.7%	99.3%
Feb-08	21.1%	85.6%	97.6%	99.4%	97.1%
Mar-08	-	89.1%	98.4%	98.1%	99.5%
Apr-08	1.1%	95.8%	96.3%	98.8%	100.0%
May-08	99.3%	72.3%	52.0%	98.9%	99.7%
Jun-08	100.0%	-	13.9%	99.0%	100.0%
Jul-08	99.6%	81.5%	7.8%	99.5%	99.9%
Aug-08	98.9%	100.0%	12.2%	97.3%	99.7%
Sep-08	99.4%	100.0%	47.8%	98.3%	100.0%
Oct-08	99.5%	100.0%	98.7%	99.2%	100.0%
Nov-08	96.8%	100.0%	98.3%	98.9%	99.9%
Dec-08	98.1%	99.7%	98.5%	99.3%	37.9%
Jan-09	95.0%	98.3%	97.0%	29.4%	-
Feb-09	93.5%	99.6%	99.1%	99.0%	-
Mar-09	98.7%	98.8%	98.3%	99.2%	-
Apr-09	94.3%	69.0%	98.5%	98.9%	-
May-09	92.5%	82.4%	97.7%	99.3%	-
Jun-09	95.4%	89.0%	97.5%	99.6%	46.7%
Jul-09	67.1%	95.4%	97.7%	99.2%	99.6%
Aug-09	82.7%	95.6%	95.7%	99.3%	96.1%
Sep-09	98.1%	92.8%	95.8%	98.8%	97.2%
Oct-09	97.6%	90.9%	94.8%	98.4%	94.0%
Nov-09	70.1%	83.9%	57.2%	16.0%	-
Dec-09	74.3%	87.4%	-	15.2%	-
Jan-10	97.2%	84.1%	-	79.8%	-
Feb-10	99.7%	90.3%	-	97.9%	-
Mar-10	99.2%	87.2%	-	98.4%	-
Apr-10	95.4%	61.3%	-	98.9%	-
May-10	80.4%	94.8%	-	98.4%	-
Jun-10	83.1%	97.8%	-	98.5%	23.8%
Jul-10	51.5%	96.9%	-	99.3%	100.0%

**Overview Analysis of Wind and Wave  
Conditions on the West Coast of  
Vancouver Island**

Month	South Brooks	La Perouse Bank	Neah Bay	New Dungeness	Cape Elizabeth
Aug-10	76.9%	98.9%	-	99.5%	100.0%
Sep-10	87.2%	93.1%	-	99.6%	100.0%
Oct-10	84.7%	93.1%	-	99.9%	95.3%
Nov-10	74.6%	91.8%	-	97.9%	86.5%
Dec-10	84.3%	85.3%	-	99.1%	86.3%
Jan-11	82.9%	80.4%	-	98.5%	96.4%
Feb-11	69.5%	7.0%	-	97.3%	88.2%
Mar-11	82.5%	89.4%	-	97.4%	97.8%
Apr-11	76.7%	93.6%	53.2%	98.5%	98.2%
May-11	81.9%	97.8%	91.9%	98.0%	99.7%
Jun-11	75.8%	98.6%	95.8%	99.9%	100.0%
Jul-11	76.5%	98.3%	96.9%	99.9%	100.0%
Aug-11	64.1%	93.7%	98.3%	99.5%	100.0%
Sep-11	76.4%	93.8%	89.0%	100.0%	99.7%
Oct-11	61.3%	94.4%	74.7%	99.7%	65.5%
Nov-11	55.0%	86.4%	67.5%	98.5%	99.2%
Dec-11	56.0%	96.8%	66.7%	99.7%	99.5%
Jan-12	55.9%	89.2%	64.9%	98.7%	97.4%
Feb-12	59.6%	90.1%	62.8%	99.1%	99.7%
Mar-12	58.3%	92.1%	37.6%	99.5%	99.3%
Apr-12	64.9%	93.3%	-	98.8%	99.6%
May-12	64.4%	92.1%	-	98.4%	99.6%
Jun-12	83.5%	94.4%	-	98.3%	99.7%
Jul-12	84.5%	99.1%	99.2%	97.7%	99.7%
Aug-12	87.2%	81.9%	99.9%	98.3%	98.5%
Sep-12	86.8%	10.4%	97.4%	99.3%	97.5%
Oct-12	88.0%	72.3%	95.3%	98.3%	95.8%
Nov-12	88.8%	70.4%	90.0%	45.6%	80.6%
Dec-12	85.1%	35.8%	95.4%	83.9%	5.6%
Jan-13	86.6%	81.6%	99.7%	96.6%	-
Feb-13	87.8%	93.0%	88.7%	96.3%	-
Mar-13	91.0%	94.5%	75.5%	92.7%	-
Apr-13	87.2%	93.3%	59.4%	46.0%	-
May-13	37.5%	96.2%	3.1%	99.9%	-

Overview Analysis of Wind and Wave  
Conditions on the West Coast of  
Vancouver Island

Month	South Brooks	La Perouse Bank	Neah Bay	New Dungeness	Cape Elizabeth
Jun-13	28.6%	93.3%	-	99.7%	-
Jul-13	45.8%	92.1%	-	99.7%	-
Aug-13	77.7%	94.0%	-	99.3%	-
Sep-13	88.8%	97.1%	-	57.9%	-
Oct-13	88.7%	96.2%	90.3%	51.5%	-
Nov-13	88.6%	93.8%	98.6%	98.9%	-
Dec-13	86.3%	95.7%	99.2%	97.3%	-