8.1 Attachment 1: Ambient Weather Conditions at Jervoise Bay, Cockburn Sound

Cockburn Sound is 20km south of the Perth-Fremantle area and has two features that are unique along Perth's metropolitan coast – its degree of shelter from ocean swell and its depth. As a result it is also the most intensively used marine embayment in Western Australia. Cockburn Sound is 16km long and 9km wide with a 17-20m deep central basin. Garden Island extends along almost the entire western side of the Sound, providing shelter from ocean swells. The sheltered, deep waters of the Sound make it equally ideal as an outer harbour for the Perth-Fremantle area, a site for industries requiring port facilities, and a strategic naval base.

The Jervoise Bay shipbuilding precinct is located immediately south of Fremantle in Cockburn Sound at S32°9' E115°46'. The local time zone is -0800 Universal Time, i.e. time is 8 hours ahead of UT. There is currently no daylight savings in WA.

8.1.1 Climate

The south-west of Western Australia is characterized by hot, dry summers and cool, wet winters. The synoptic-scale weather patterns of the region are controlled by the migration of the anticyclonic belt from about 40°S in January to about 30°S in July. From October to April, the belt is south of the continent and stable anticyclonic high pressure cells produces a predominantly easterly airflow. From May to September the anticyclonic belt is located across the continent and associated high pressure cells produce predominantly westerly winds (DEP, 1996).

During summer, differential heating and cooling across the coastline results in a land-sea breeze diurnal cycle being superimposed on the regional pattern.

The following information summarises the key local climate variables, however, the Western Australian Bureau of Meteorology should be contacted if more specific climate information is required.

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8.1.2 Air Temperature

The variation in air temperature at Jervoise Bay is moderated slightly by the proximity to the sea with slightly lower maximums and higher minimums than are recorded at Perth Airport. Figure 1 shows a summary of the past air temperature records for the nearby Kwinana Refinery which is on the coast ~10km south of the Jervoise Bay precinct.

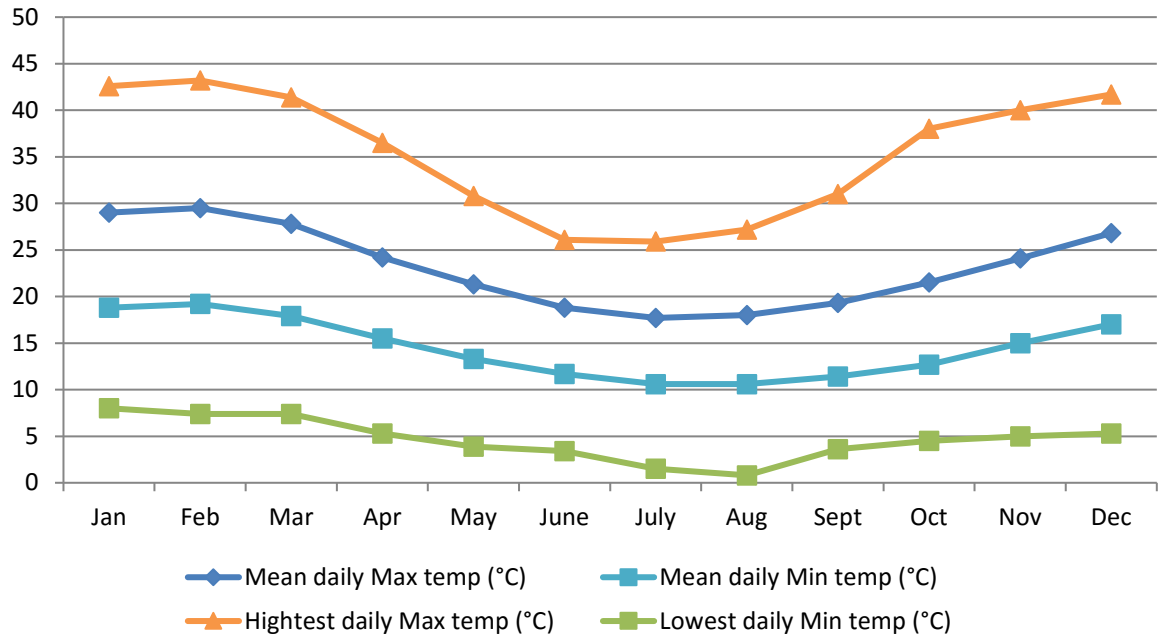

Figure 1: Air temperature characteristics at BP Refinery, Kwinana

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Rainfall

The annual average rainfall at Kwinana since 1995 is 745.5mm. The distribution of rainfall throughout the year is shown in Figure 2 below.

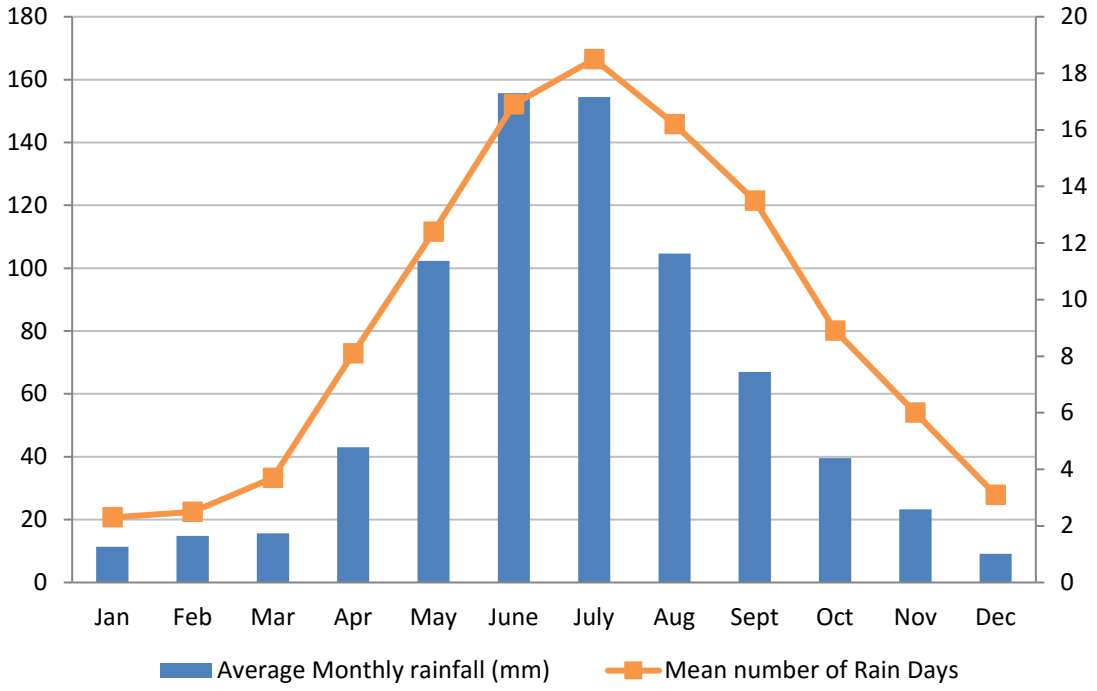

Figure 2: Rainfall characteristics at BP Refinery, Kwinana

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Humidity

Perth is characterized by hot, dry summers and cool, wet winters which are reflected in the annual humidity data shown in Figure 3, below.

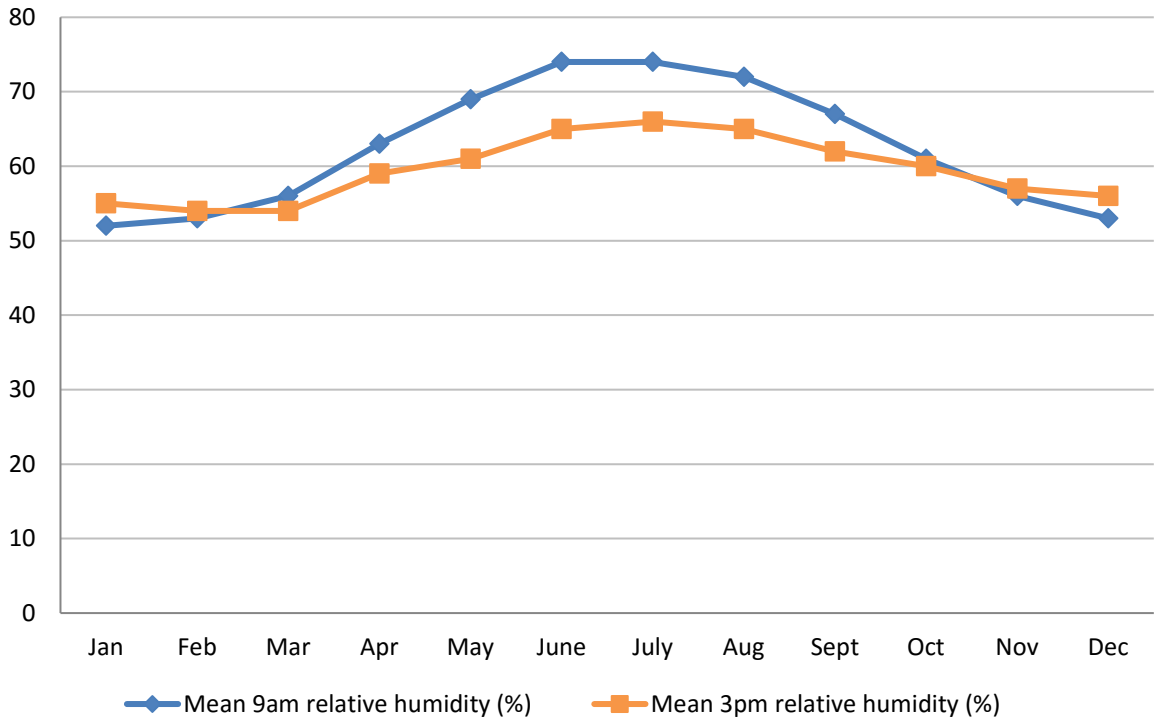

Figure 3: Humidity characteristics at BP Refinery, Kwinana

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8.1.3 Day Length

Perth is known for its sunny climate and clear skies. This is reflected in Figure 4 which shows the typical day length for each month and the mean number of sunshine hours.

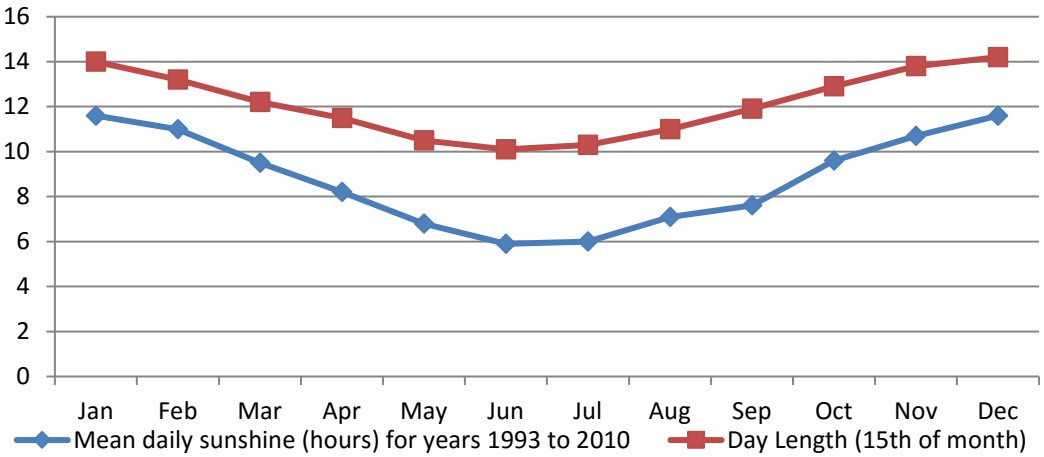

Figure 4: Day length and mean daily hours of sunshine at Perth Airport.

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8.1.4 Wind

The synoptic wind climate of Perth is controlled by the annual variation in the location of the mid-latitude anticyclonic belt. The influence of local-scale effects is also of considerable importance, in particular the diurnal sea breeze cycle that occurs during summer. At this time the winds are typically persistent and half occur in the 5-9m/s range. In winter, winds are more variable with occasional calms and strong storm winds, with half having a velocity of 2-7m/s.

During summer the dominant wind direction is south to south-west, whereas in winter the dominant wind direction is westerly, though northerly winds frequently occur.

The most relevant local wind stations are located at Hope Valley, Kwinana (maintained by the Environmental Protection Authority) and Swanbourne, a coastal site approximately 20km north or Jervoise Bay. The monthly 9am and 3pm wind roses for these stations are attached as Appendix A.

8.1.5 Tides

The tides at Jervoise Bay are predominantly diurnal, with the major diurnal constituents (K1 and O1) having 2-3 times the amplitude of the semi-diurnal M2 and S2 constituents. Sea level can also be significantly influenced by the passage of anticyclonic pressure systems, storm fronts and other long period forcings. For example seiching within Cockburn Sound can contribute ~0.1m variation in sea level.

The key characteristics of the astronomic tides at Jervoise Bay can be assumed to be the same as those for the Port of Fremantle and are summarised in Table 1.

Parameter	Highest Astronomical Tide	MHHW	MLHW	MSL	MHLW	MLLW	LAT
Height above LAT (m)	1.2	1.1	1.0	0.7	0.5	0.4	0.1

Table 1: 2005 Australian National Tide Tables - Fremantle

8.1.6 Waves

The wave climate of Perth's coastal waters consists of oceanic swell and wind-generated waves. The swell generally develops in the Southern and south Indian Oceans and approaches WA from the southwest. Records collected south-southwest of Rottnest Island have indicated that the swell waves have a mean significant period of about 12s and significant wave heights of between 0.5m and 5m with a mean annual value of about 1.8m. The largest swells are recorded in winter and spring and the smallest swells are recorded in summer and early autumn. Occasionally, winter or late summer storms will form to the north-west and on these rare occasions, significant swells may be generated from this quarter.
Wind waves have a mean significant period of less than 8s and significant wave heights of between 0.3 and 3.3m with a mean annual value of approximately 1.3m.

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Swell waves are substantially attenuated by banks and sills offshore between Fremantle and Warnbro Sound and Garden Island provides a barrier to incident swell waves from the south-west, and as little as 5% of the swell energy penetrates to southern Cockburn Sound (DEP, 1996a). As such, the wave climate in Cockburn Sound is dominated by short period (less than 8s), wind generated waves. However, the degree of shelter is dependent on the incident wave direction and location within Cockburn Sound. The gap between Carnac Island and Garden Island allows west and north-west swell attenuated to about 10-30% of its offshore height to reach Jervoise Bay, this swell is then blocked from the Jervoise Bay precinct by the breakwaters. A review by Tremarfon (1996) found that there was evidence of long period wave energy with periods of greater than 30s in Cockburn Sound. This is attributed to seiching and very long period waves moving up the WA coastline.

Shipping waiting to berth at Fremantle Inner Harbour or to access Cockburn Sound may lay-up in Gage Roads. The Gage Roads area is reasonably protected from the predominately south-westerly swell but will be affected by westerly and north-westerly storms.

The Fremantle Port Authority and/or the Marine Division of the Western Australian Department of Transport should be contacted if more specific information is required on local wave conditions.

8.1.7 Currents

The currents in Cockburn Sound are predominantly a result of the prevailing wind direction. In between Woodman Point and James Point, the net drift is northward during summer in response to the prevailing south to south-westerly winds. Current velocities range from up to 0.2m/s during average conditions. During winter and periods of calm the current velocities drop to below 0.1m/s.

8.1.8 Extreme Events

Cockburn Sound is occasionally subject to severe weather events. These will generally be strong winter storms, however on rare occasions late-summer cyclones have been known to track down the WA coast. A total of 14 tropical cyclones passed within 180 nautical miles of Fremantle during the 38-year period 1968 - 1998. All of these occurred within the period January - April.

Lemm (1996) characterised a storm as an event generating a peak wave height of >4m offshore. They also investigated wind and wave data from 1994 to 1996 to generate the characteristics shown in Table 2.

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Month	Mean Number of Storms 1994-1996	Mean Duration (Hours)
January	0	0
February	0	0
March	0.67	39
April	1	61
May	3.67	62
June	4.33	75
July	6	70
August	5.3	65
September	2	74
October	1.33	42
November	0.67	56
December	0.67	38
TOTAL	25.6	58.2

Table 2: Frequency of Storms (Lemm 1996)

Lemm found about 25 'storms' each year reached the coast and that these lasted for just over two days. There are significantly more storms in the period of May to August and there is a distinct periodicity to these storm fronts, with a five day period the most frequently observed.

8.1.9 References

In addition to the publications below the above information has been obtained from the Bureau of meteorology and the Australian National 2005 Tide Tables.

Department of Environmental Protection 1996. Southern metropolitan Coastal Waters Study (1991 to 1995). DEP Report 17. November 1996.

Lemm A, 1996. Offshore Wave Climate, Perth Western Australia. Honours Thesis, University of Western Australia, October 1996.

Themarfon Pty Ltd 1996. An analysis of Wave Data Recorded at Stirling Channel in the Port of Fremantle. Report to Halpern Glick Maunsell for the Jervoise Bay Infrastructure Planning Study, October 1996.

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8.2 Attachment 2: Wind Frequency Analyses and Wind Roses Cover Sheet

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Wind Frequency Analyses and Wind Roses

The included set of wind frequency analysis tables or wind roses show the frequency with which winds of various strengths have been observed coming from various directions. These notes should help you to use the information.

Data

Wind speed and direction are measured by a number of means. In some cases, they are only estimated. To find out exactly which method has been used, a search of the appropriate station history file would be required.
Wind measurement is particularly sensitive to changes in site, exposure and instrumentation. Observations from a site may differ significantly from the conditions in the surrounding area, and past records are not always directly comparable with current measurements.
The data are collected by the National Climate Centre in the Bureau of Meteorology's Melbourne head office. They are stored in ADAM (the Australian Data Archive for Meteorology), an extensive computer database of meteorological observations. As the observations are stored, basic checks are performed. Any observations that fail these tests (specifically, any whose quality flag is poorer than "4 - estimated, medium certainty") are excluded from the frequency analyses that follow.

Analysis

The data are collated in a number of ways, depending on the nature of your request.
To group by hour, the observations are assigned to the closest standard three-hour reporting time. For example, all observations between 7:30 am and 10:30 am local standard time are labeled "9 am". If a seasonal grouping has been requested, then "autumn" is March, April and May, "winter" is June, July and August, "spring" is September, October and November, and "summer" is December, January and February.
The observations are then grouped by speed. The exact number of speed ranges and their size depends on your request. When the speed ranges are labelled, "1 - 10" is used for all speeds greater than 0 but less than or equal to 10. "11 - 20" means greater than 10 but less than or equal to 20.
The data are then grouped by direction; into 8 or 16 bins as requested. When doing this, observations that fall on bin boundaries are split equally between the two bins. For example, when grouping into 8 bins, a direction of "NE" covers all observations with directions strictly between NNE and ENE; "E" covers from ENE to ESE. If the direction is exactly ENE (67.5°), then it will be placed half in the "NE" bin and half in the "E" one.

Tables

If you have requested wind frequency tables, you will get a separate table for each time group. Each table shows the time to which it applies, and the total number of observations used at that time. The percentage frequency with which calm conditions (that is, no wind) are observed are displayed at the top left of the table.
The rest of the table is laid out with directions across and speeds down. To find the frequency with which winds of a given speed and direction occur, follow down the appropriate direction column and across the speed row until they intersect. The value printed there is the frequency you require. For example, a value of "14" indicates that this speed/direction group occur about 14% of the time. "*" indicates the range has occurred but less than 0.5% of the time.
The last column, labeled "All", gives the frequency of each speed range regardless of direction. Similarly, the last row gives the frequency of each direction, regardless of speed.

Roses

Wind Roses seek to make the data in a wind frequency table easier to digest. Although not ideal for quantitative work, they are good for providing a quick visual impression of the wind regime.
Like the tables, there is one wind rose for each time group that you requested. Each rose consist of a central circle, surrounded by branches, each made up of a number of petals.
The circle represents the frequency of calm conditions. The size of the circle is proportional to the number of calms; a scale is given in the legend at the top of the page.
Each branch represents the wind coming from that direction. North is to the top, and the other directions are shown in the legend. In each case, the wind is blowing from that direction toward the calms circle. Each petal corresponds to a speed range from that direction. The length of the petal is proportional to the frequency of that wind; the scale is shown in the legend. The thickness of the petal is used to indicate which speed range it represents.

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More Information

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8.3 Attachment 3: Wind Frequency Analysis for Garden Island HSF

Wind Frequency analysis using available data between Nov 2001 and Nov 2010 for Garden Island HSF

Site Number 009256 • Locality: Garden Island • Opened Nov 2001 • Still Open • Latitude 32°14'36"S • Longitude 115°41'02"E • Elevation 6m

Values are percentage frequencies; * indicates the range has occurred but with a frequency of less than 0.5%.

3 pm January

Calm *	A total of 274 observations analysed								
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10									
11–20			1	1	1	4	1	1	10
21–30			*	1	1	28	3	*	34
>30				1	2	52		1	56
All			1	4	4	84	4	3	100

3 pm February

Calm *	A total of 252 observations analysed								
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10		*		1	*		*		2
11–20		2	2	2	1	7	4	2	20
21–30		*	5	4	2	26	3	1	41
>30					1	35	*		36
All		3	6	8	4	68	8	3	100

3 pm March

Calm	A total of 278 observations analysed								
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10				1		1	1		3
11–20		1	4	3	2	13	8	3	33
21–30		*	1	1	3	29	2	1	38
>30					1	23	1		26
All		1	5	5	6	67	12	3	100

3 pm April

Calm *	A total of 269 observations analysed								
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10			*	1		3	2	*	7
11–20	1	2	3	4	3	17	7	4	40
21–30	1		1	2	3	23	3	3	36
>30					3	11	1	2	17
All	2	2	4	7	10	53	12	9	100

3 pm May

Calm 1	A total of 276 observations analysed								
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10		1	1	3	2	1	3	3	13
11–20	5	4	4	3	4	11	5	6	42
21–30	5	1		2	10	7	4	3	30
>30	1				4	4	3	2	13
All	12	5	5	8	20	22	14	13	100

3 pm June

Calm 2	A total of 267 observations analysed								
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10	*	2	1	2	2	2	3	1	15
11–20	5	6	5	7	4	3	2	5	37
21–30	9	1	1	3	5	4	1	2	27
>30	2	*			1	4	8	3	19
All	17	10	7	11	13	13	15	12	100

3 pm July

Calm 1	A total of 274 observations analysed								
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10	2	2	*	1	3	4	2	1	16
11–20	6	3	3	3	6	3	4	8	34
21–30	8	1	*	1	5	3	5	4	27
>30	1				2	3	10	6	21
All	17	6	3	5	16	12	20	20	100

3 pm August

Calm *	A total of 278 observations analysed								
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10	1	*			1	3	3	3	10
11–20	3	2	2	1	3	10	7	9	37
21–30	6	*	2	1	6	7	5	5	33
>30	1			*	3	4	6	4	19
All	11	3	4	2	13	25	21	21	100

3 pm September

Calm	A total of 269 observations analysed								
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10			*		*	1	1	1	4
11–20	2	1	1	1	2	14	9	8	38
21–30	1		1	1	2	14	6	5	30
>30	1				4	9	9	6	28
All	4	1	3	2	8	39	23	19	100

3 pm October

Calm	A total of 277 observations analysed								
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10					*	1	1	1	3
11–20		*	1	2	1	9	6	3	24
21–30	1		*	1	1	27	5	3	39
>30	*		*		4	25	4	1	35
All	2	*	2	4	7	62	15	8	100

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Wind Frequency analysis using available data between Nov 2001 and Nov 2010 for Garden Island HSF

Site Number 009256 • Locality: Garden Island • Opened Nov 2001 • Still Open • Latitude 32°14'36"S • Longitude 115°41'02"E • Elevation 6m

Values are percentage frequencies; * indicates the range has occurred but with a frequency of less than 0.5%.

3 pm November

Calm		A total of 284 observations analysed							
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10				*			*		1
11–20	1	*	2	1	1	7	5	2	20
21–30		*	2	2	2	26	3	3	38
>30					1	37	2	1	41
All	1	1	4	3	4	70	11	6	100

3 pm December

Calm		A total of 277 observations analysed							
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10								*	*
11–20	*	*	1	2	1	11	1	*	17
21–30			3	1	2	22	4	1	32
>30				1	*	47	1	1	50
All	*	*	4	3	3	79	7	3	100

6 pm January

Calm *		A total of 275 observations analysed							
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10						*			*
11–20			1	1	1	3	1	*	8
21–30				3	6	12	2	*	23
>30				1	17	49	*	*	68
All			1	4	25	65	3	1	100

6 pm February

Calm		A total of 254 observations analysed							
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10	*				*	*	*		2
11–20	*	*	2	1	2	4	1	1	12
21–30			4	3	7	20	2	1	38
>30				2	14	31	1		48
All	1	*	6	7	24	56	4	2	100

6 pm March

Calm *		A total of 279 observations analysed							
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10	*	*	*	1	1	*	*		4
11–20		*	3	*	3	6	3		16
21–30	*	*	3	4	13	21	1		42
>30				1	18	19	*		38
All	1	1	6	6	34	47	5		100

6 pm April

Calm 2		A total of 267 observations analysed							
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10	1	*		*	1	1	1		5
11–20	2	1	6	2	7	9	3	1	32
21–30	1		1	2	22	8	2	2	37
>30			*	1	14	7	1	1	24
All	3	2	7	6	44	24	7	4	100

6 pm May

Calm 2		A total of 275 observations analysed							
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10	4	3	1	1	4	1	1	1	15
11–20	3	2	4	6	10	6	3	3	36
21–30	3		*	2	19	1	3	4	33
>30	*				6	3	3	2	13
All	11	4	5	10	38	11	9	9	100

6 pm June

Calm 2		A total of 265 observations analysed							
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10	2	2	1	3	2	2	*	1	14
11–20	5	4	8	11	8	2	2	2	41
21–30	3	2	1	1	6	4	3	4	25
>30	2				3	5	5	4	18
All	13	8	10	14	19	13	10	11	100

6 pm July

Calm 5		A total of 276 observations analysed							
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10	4	*	3	2	2	1	2	3	17
11–20	6	3	3	5	9	2	3	2	33
21–30	2	*	1	1	7	4	4	7	25
>30	2			*	2	4	8	4	20
All	14	3	7	9	19	12	17	15	100

6 pm August

Calm 1		A total of 277 observations analysed							
km/h	N	NE	E	SE	S	SW	W	NW	All
1–10	1	1	*	1	2	3	1	1	10
11–20	2	1	4	3	9	10	3	4	36
21–30	4	*	1	1	14	3	6	4	32
>30	*			*	4	4	5	6	20
All	7	3	5	5	29	19	16	15	100

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8.4 Attachment 4: Wind Roses for Garden Island HSF

Wind Roses using data between Nov 2001 and Nov 2010 for Garden Island HSF

Site Number 009256 • Locality: Garden Island • Opened Nov 2001 • Still Open
Latitude 32°14'36"S • Longitude 115°41'02"E • Elevation 6m

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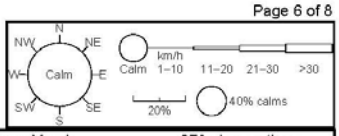

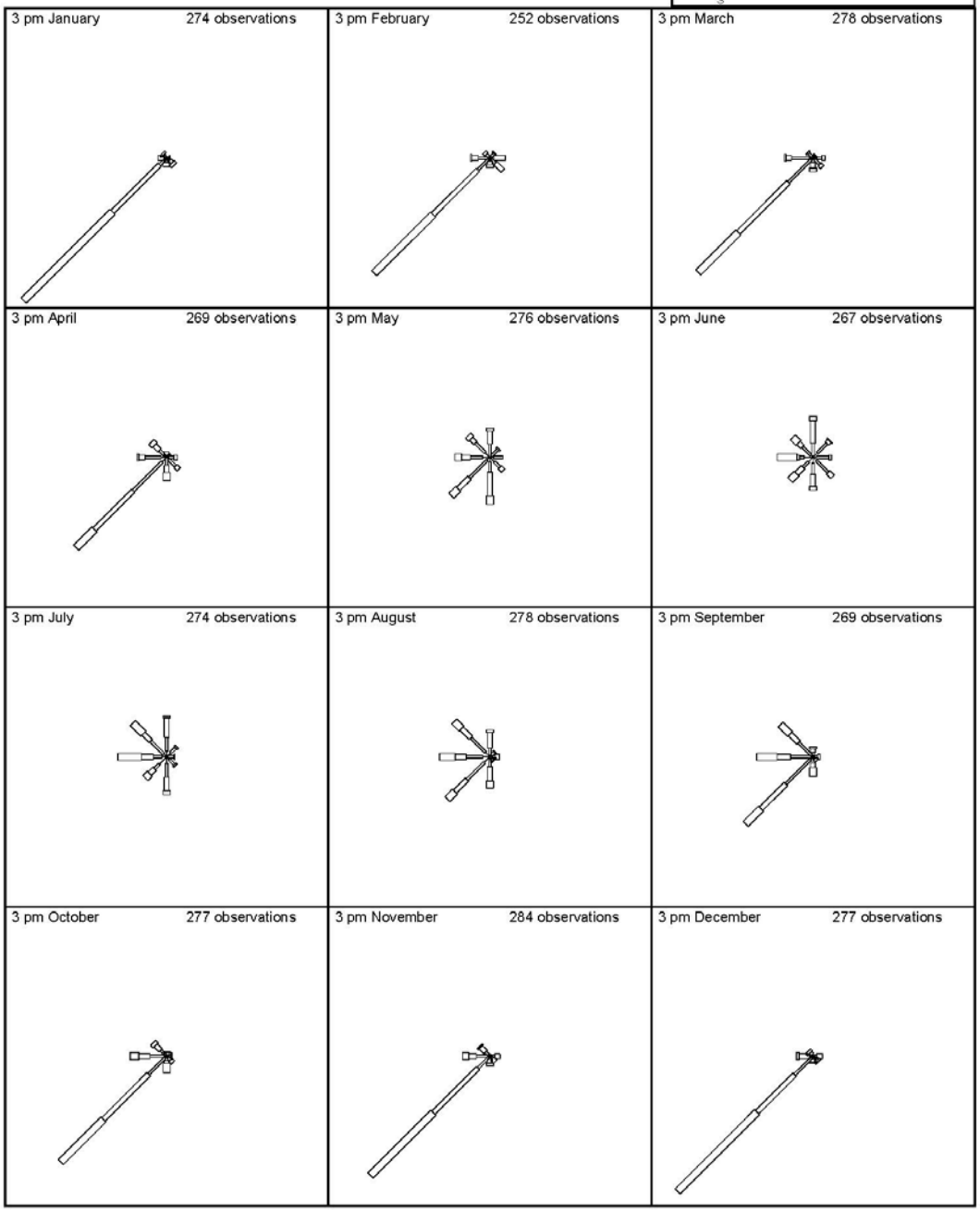

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