1. AMBIENT CONDITIONS AT JERVOISE BAY, COCKBURN SOUND

Cockburn Sound is 20 km 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 of these features it is also the most intensively used marine embayment in Western Australia. Cockburn Sound is 16 km long and 9 km wide, with a 17–20 m 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^{o}9' E115^{o}46'. The local time zone is - 0800 Universal Time, e.g. time is 8 hours in advance of UT. There is currently no daylight saving in WA.

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^{o}S in January to about 30^{o}S in July. From October to April, the belt is south of the continent and stable anticyclonic high pressure cells produce 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 this regional pattern.

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

1.1.1 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 46 years of air temperature records for the nearby Kwinana refinery (which is on the coast ~10 km south of the Jervoise Bay precinct).

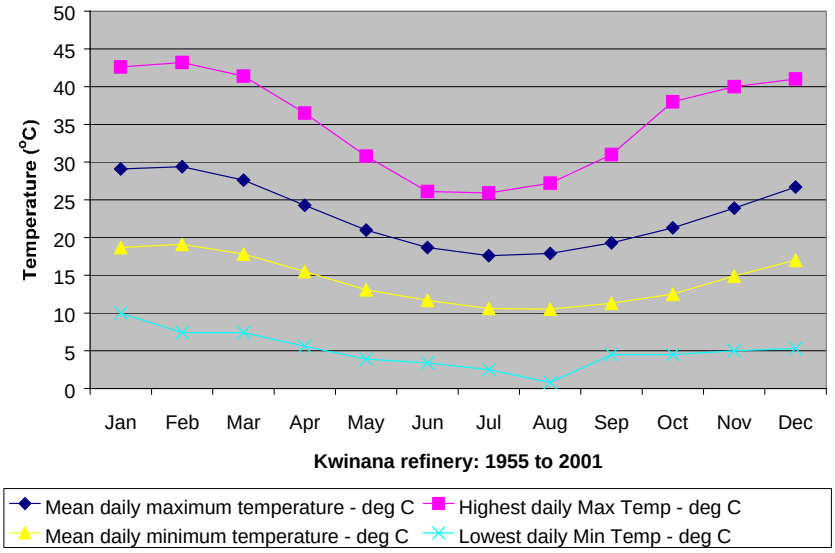

Figure 1 Air temperature characteristics at BP Refinery, Kwinana 1955 to 2002

1.1.2 Rainfall

The annual average rainfall at Kwinana since 1955 is 767 mm. The distribution of rainfall throughout the year is shown in Figure 2 below.

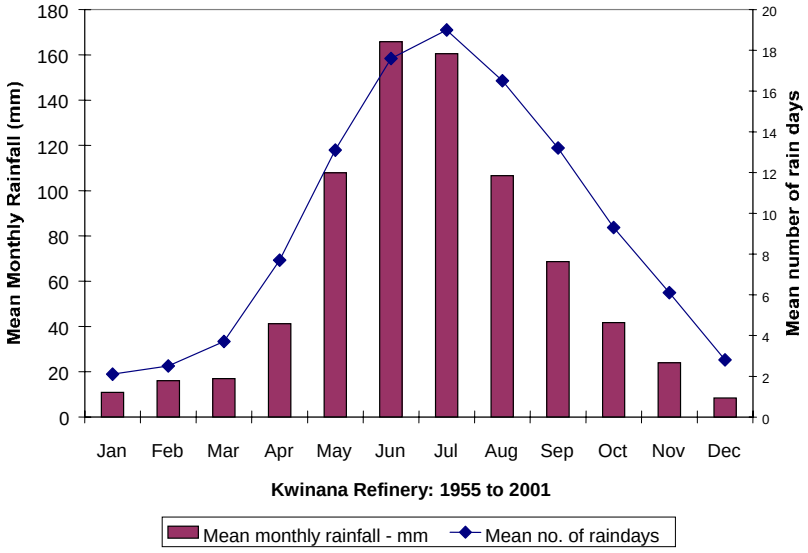

Figure 2 Rainfall characteristics at BP Refinery Kwinana: 1955 to 2002

1.1.3 Humidity

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

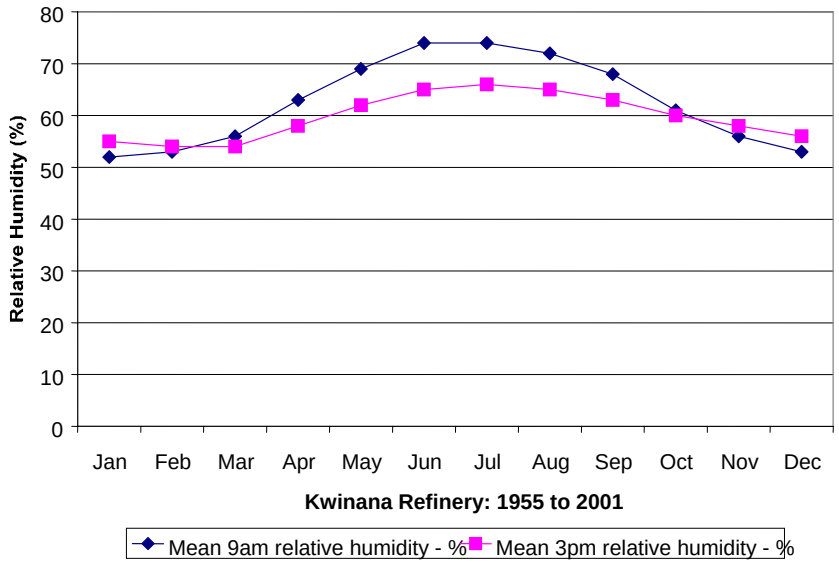

Figure 3 Humidity characteristics at BP Refinery Kwinana: 1955 to 2002

1.1.4 Day length

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

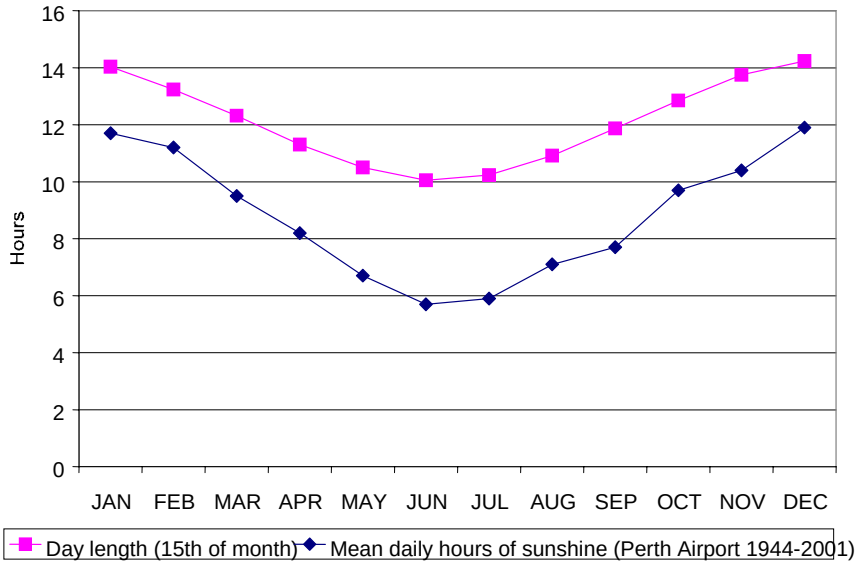

Figure 4 Day length and mean daily hours of sunshine at Perth Airport: 1944 to 2001

1.1.5 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. During summer the winds are typically quite persistent and 50% of winds occur in the 5–9 m/s range. In winter, winds are more variable with occasional calms and strong storm winds, and 50% of winds have a velocity of 2–7 m/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 20 km north of Jervoise Bay). The monthly 9:00 am and 3:00 pm wind roses for these stations are attached as Appendix A.

1.2 OCEAN CONDITIONS

1.2.1 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 summarized in Table 1.

Table 1 2002 Australian National Tide Tables: Fremantle

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

1.2.2 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 12 seconds and significant waves heights of between 0.5 m and 5 m with a mean annual value of about 1.8 m. 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 8 seconds and significant waves heights of between about 0.3 and 3.3 m, with a mean annual value of approximately 1.3 m.

Swell waves are substantially attenuated by banks and sills offshore between Fremantle and Warnboro and 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 30 seconds 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 will lay-up in Gage Roads. The Gage Roads area is reasonable protected from the predominant 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 Planning and Infrastructure should be contacted if more specific information is required on local wave conditions.

1.2.3 Currents

The currents in Cockburn Sound are predominantly a result of 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 up to 0.2 m/s during average conditions. During winter, and periods of calm the current velocities drop to below 0.1 m/s.

1.2.4 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 to April.

Lemm (1996) characterised a storm as an event generating a peak wave height of >4m offshore. Lemm (1996) investigated wind and wave data from 1994 to end 1996 to generate the characteristics shown in Table 1.2.

Table 1.2 Frequency of storms 1994-1996 (Lemm 1996)

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

Lemm (1996) 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.

1.3 REFERENCES

In addition to the publications below, the above information has been obtained from the Bureau of Meteorology and the Australian National 2002 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.

Tremarfon 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.