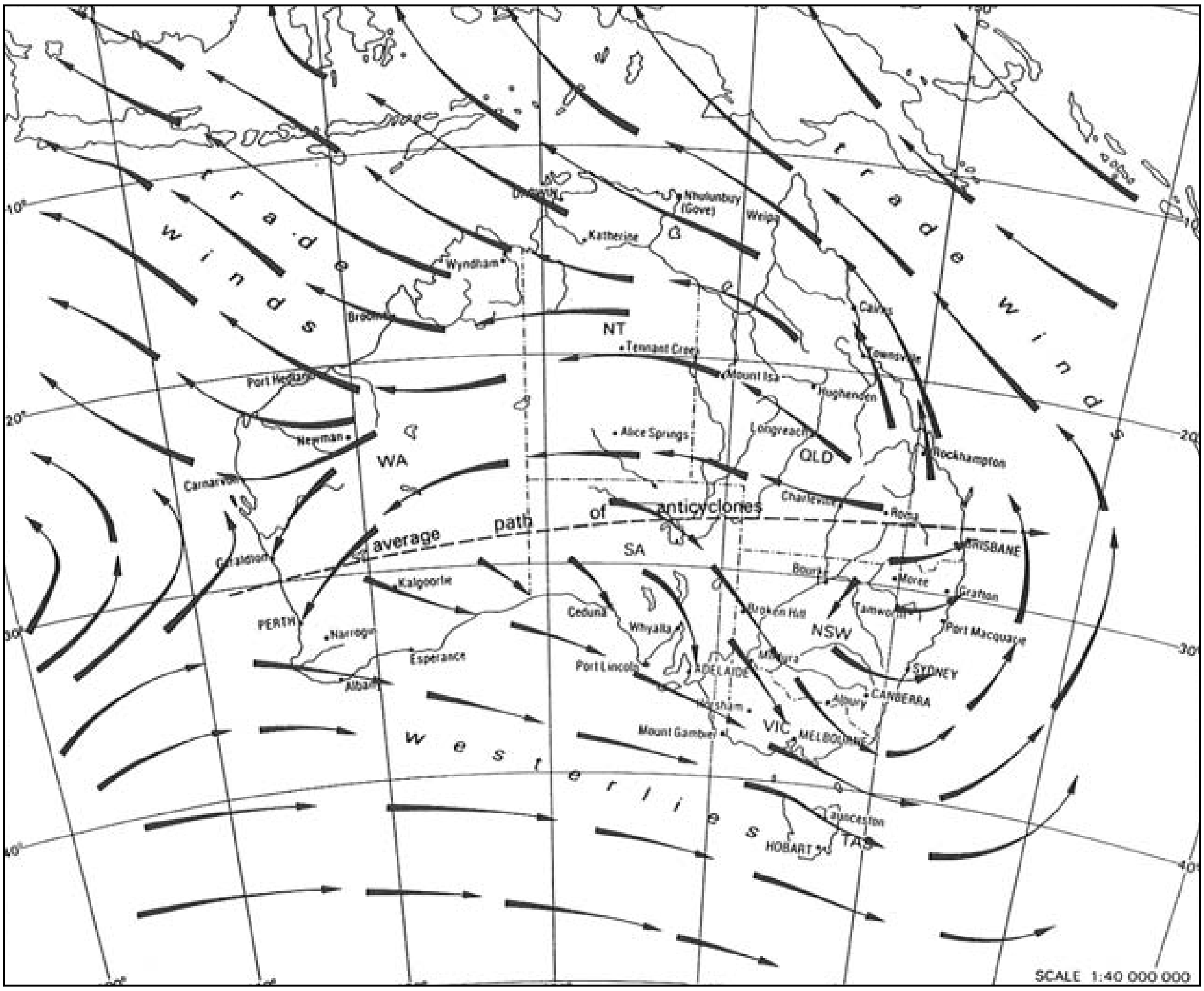
Climate

7.1 Regional Climate

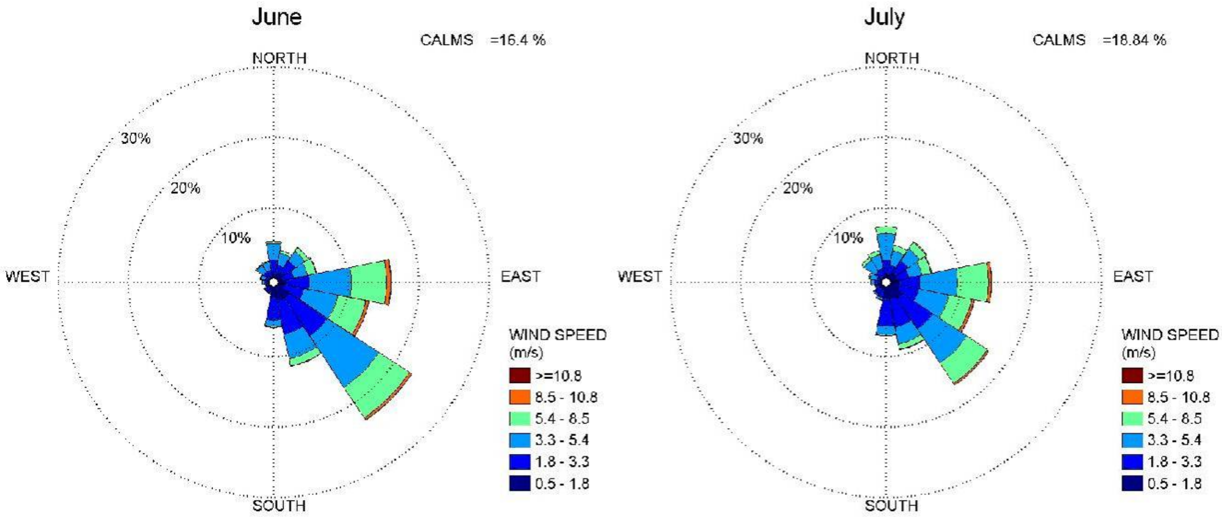
The EAW precinct lies within the monsoonal tropics of northern Australia and experiences two distinct seasons: a hot, wet season from November to March and a warm, dry season from May to September. April and October are transitional months between the Wet and Dry seasons (Parkinson, 1996). These dates are typical and may vary a little from year to year. The seasonality of rainfall is the most distinguishing feature of the regional climate (Dames & Moore, 1997; Guillaume et al., 2010).

During the dry season, dry south-easterly airstreams (refer Figure 7-1) pass over northern Australia resulting in very little rain. The climatic wind roses for the dry season months of June and July reflect the prevailing airstream direction (refer Figure 7-2). Depending on the intensity of the high pressure systems that generate the south-easterly air streams, winds can be strong, resulting in rough seas in coastal waters, and wildfire risk on land. Temperatures remain warm to hot during the day usually ranging between the high twenties and low thirties (°C), accompanied by relatively low humidity (Swan et al., 1994).



Source: Swan et al., 1994

Figure 7-1 Dry season airstreams over Australia



Source: Darwin Airport records

Figure 7-2 Climatic wind roses for June and July in Darwin

The build-up is the seasonal change from the end of the dry season to the onset of the monsoon rains. Humidity increases during this time, with November and early December generally being the hottest periods with a high level of discomfort associated with the humidity.

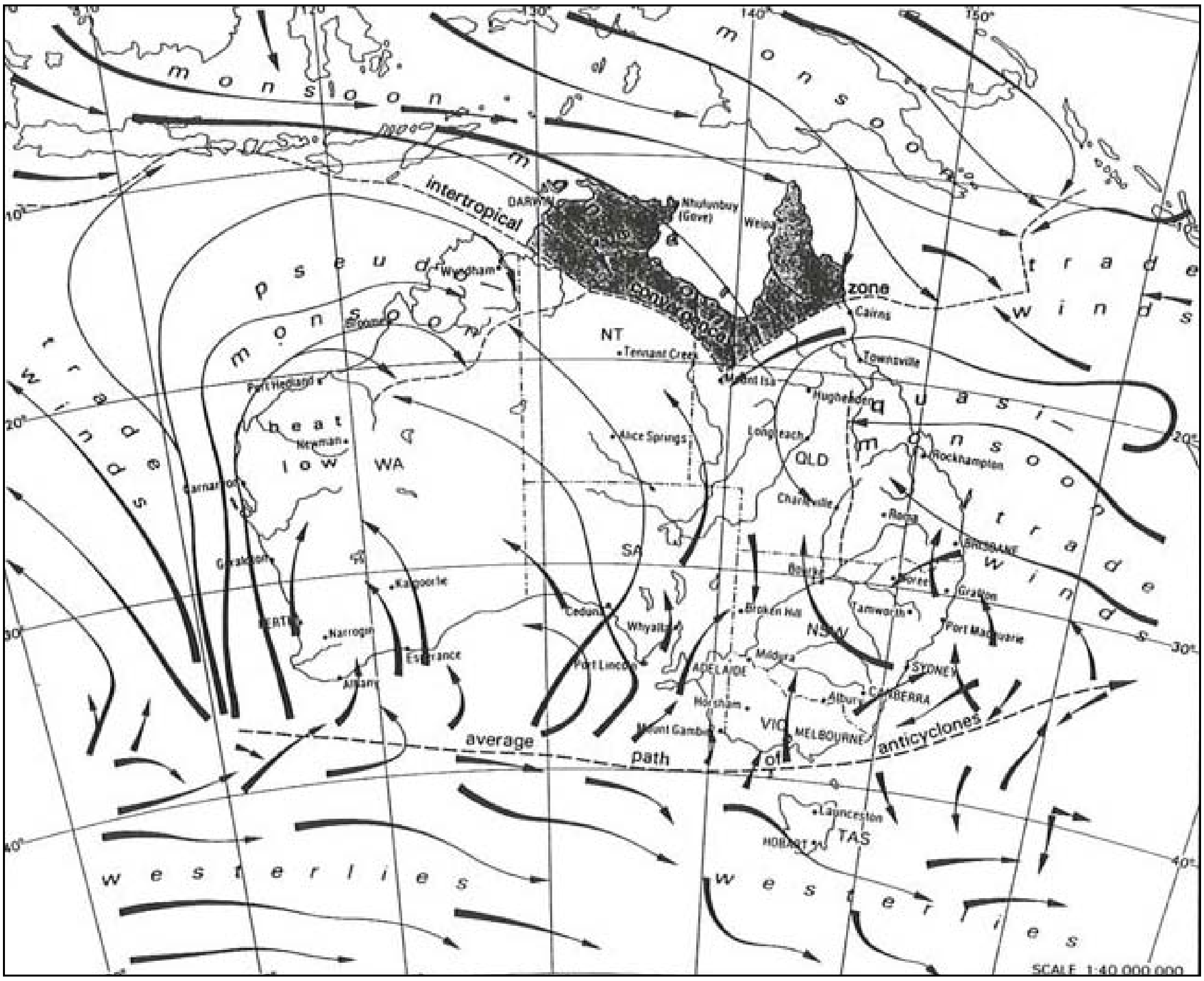
Weather conditions during the wet season are largely determined by the position and activity of the monsoon trough, which is broadly where the dry south-east trade and monsoon winds from the north-west merge (refer Figure 7-3); the prevailing winds are shown in wind roses for January and February (refer Figure 7-4). Daytime temperatures rise to the mid thirties in coastal regions and are hotter inland. Minimum temperatures are around the middle twenties (°C) at night. Winds are mainly light away from the storms, and humidity is high throughout the day.

Periods of monsoon activity over the region peak in January and February, and produce cloudy conditions and frequent rains which when persistent can produce flooding. During March the monsoon trough weakens and moves northward, leaving another transitional, humid weather period until the dry season commences (usually in late April or early May). Regional variations in climatic conditions are experienced across northern Australia.

7.2 Darwin Climate

The closest meteorological station to EAW with comprehensive climatic data is located at Darwin Airport, approximately 9 km to the north-east of the EAW. The climatic information for the project area in this DEIS is based on data collected at this station (Darwin Airport weather station 014015) by the Australian Bureau of Meteorology (BoM). Climatic statistics for the period 1941 – 2010 are summarised in Table 7-1, and presented graphically in Figure 7-5.

Darwin has a mean annual rainfall of 1,711 mm (111 rain days), most of which falls within the wet season (refer Figure 7-5). Humidity over this period averages 70–80%. In the dry season humidity is often below 35-55% and there is virtually no rainfall. Monthly mean evaporation ranges from 167 mm in February to 259 mm in October. The mean annual evaporation is 2,630 mm.



Source: Swan et al., 1994

Figure 7-3 Wet season airstreams over Australia

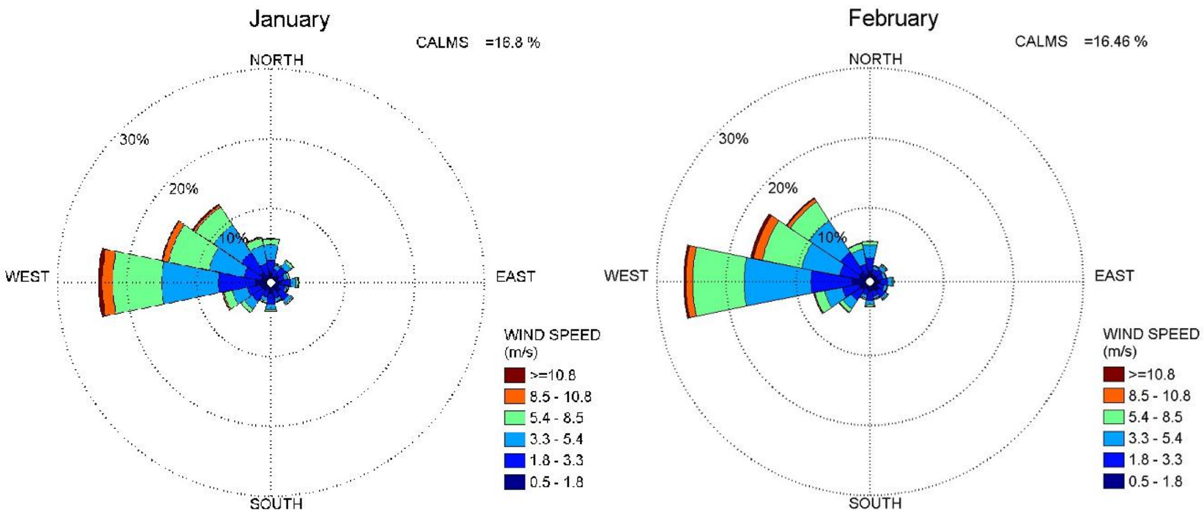
While the maximum temperatures are defined as hot all year round, November is the hottest month with a range of 25°C (mean minimum) to 33°C (mean maximum). June and July normally experience the lowest monthly minima with a range of 20°C (mean minimum) to 30°C (mean maximum). Darwin has a yearly average of 8.5 sunshine hours per day, with August experiencing the highest monthly average of 10.3 hours per day.

7.3 Cyclone Activity

The strongest winds and heaviest rainfall are associated with the passage of tropical cyclones, which can occur in the region at any time during the period November to April, and occur on average once every two years. Typically, cyclones form south of the equator in the Timor or Arafura Seas when sea temperatures are greater than 26.5°C. Cyclones may move in any direction; however, the majority of past cyclones have moved over the Timor Sea to the north of the project area.

Tropical cyclones cause most damage within a distance of 50 km from the coast; once a cyclone has passed onto land it weakens rapidly, but resultant storm surge can be of concern to coastal developments and flood damage can result from associated squally rains (BoM, 2011a).

7 Climate



Source: Darwin Airport records

Figure 7-4 Climatic wind roses for January and February in Darwin

Table 7-1 Climate Statistics from Darwin Airport Weather Station 014015 for the period 1941-2010

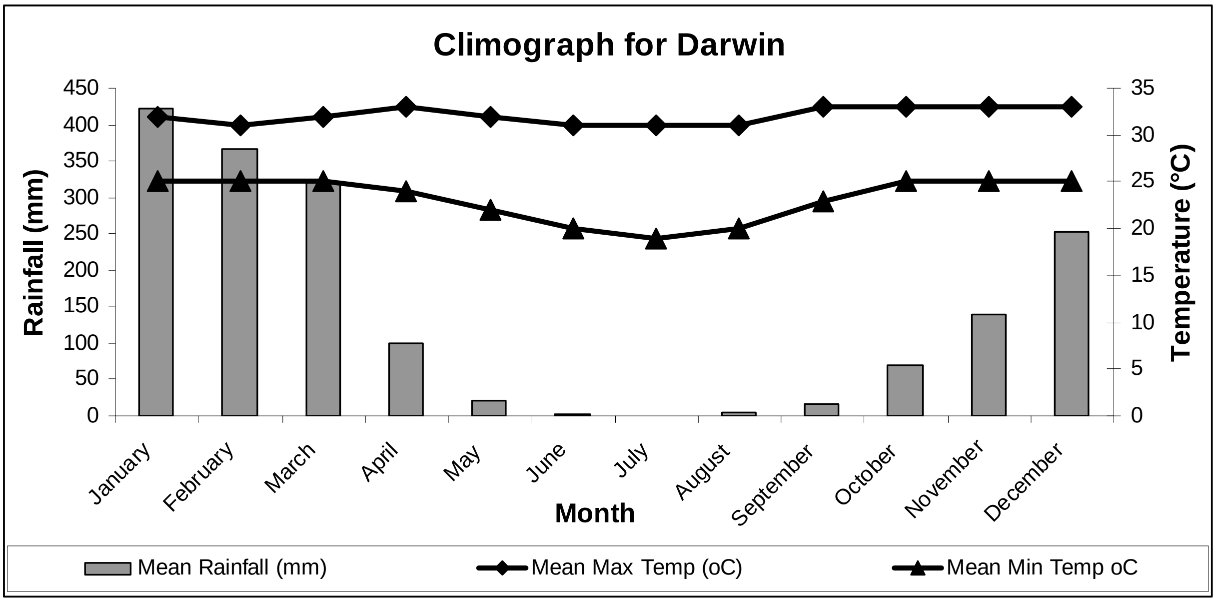
Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	A
Mean Max Temp (^oC)	32	31	32	33	32	31	31	31	33	33	33	33	385
Mean Min Temp ^oC	25	25	25	24	22	20	19	20	23	25	25	25	278
Mean Rainfall (mm)	423	366	319	100	21	2	1	5	16	70	140	252	171 5
Highest Rainfall (mm)	940	815	1014	396	299	51	27	84	130	339	371	665	512 9
Lowest Rainfall (mm)	136	103	88	1	0	0	0	0	0	0	17	19	364
Mean daily evaporation (mm)	6	6	6	6	7	7	7	7	8	8	7	7	81

Source: Based on data from Darwin Airport, Bureau of Meteorology

Cyclones in the areas near Darwin have the following frequency: the Gulf of Carpentaria averages two cyclones a year; the Arafura and Timor Seas average one cyclone a year. Cyclones in the Gulf of Carpentaria move very erratically, whereas those in the Arafura and Timor Seas tend to follow more regular tracks to the southwest. The cyclones generated in northern Australia move either southwest or southeast into adjoining regions; Figure 7-6 shows the tracking of cyclones for the period 1970 to 2006 (BoM, 2011b).

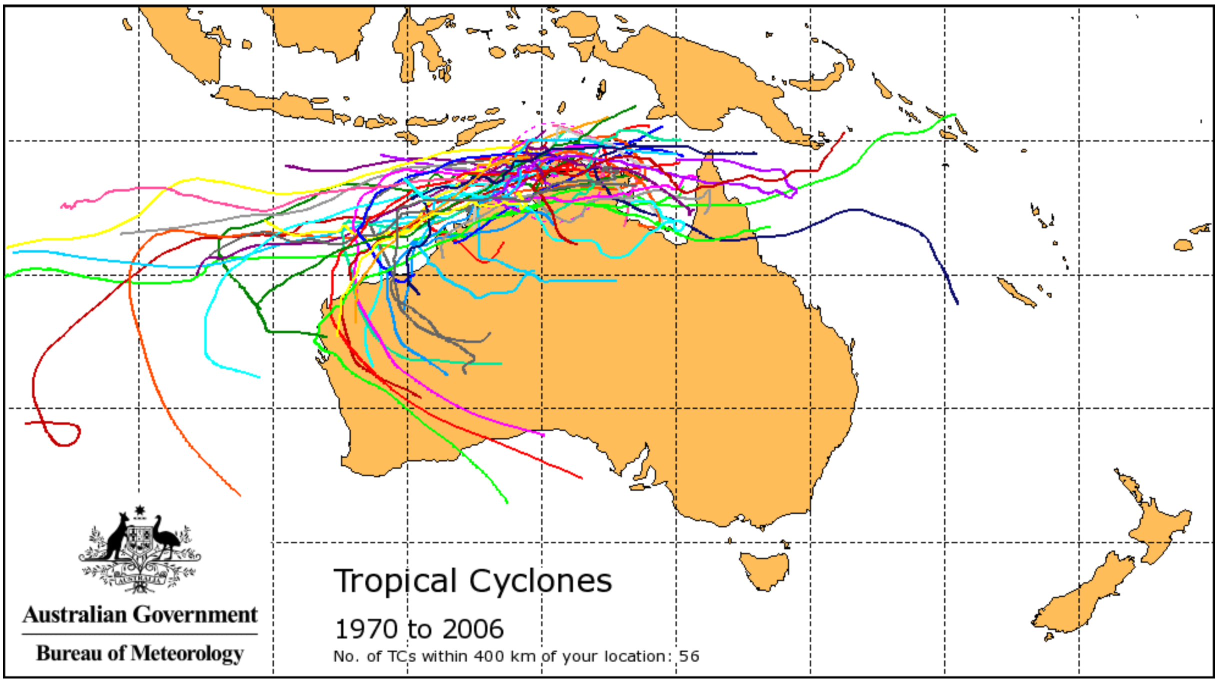
The number and category of cyclones in the Northern Region per month during the cyclone season, and the number of cyclones of each category, are shown graphically in Figure 7-7 and Figure 7-8, respectively. Tropical cyclone intensity is classified as in Table 7-1.

Australian Standard AS 1170 Part 2-1989 specifies likely maximum gusts during cyclonic events in Darwin for purposes of structural designs. The standard indicates likely maximum gusts of 122, 163, 180, 205 and 252 km/h for cyclones having mean return periods of 2, 10, 20, 100 and 1,000 years, respectively.



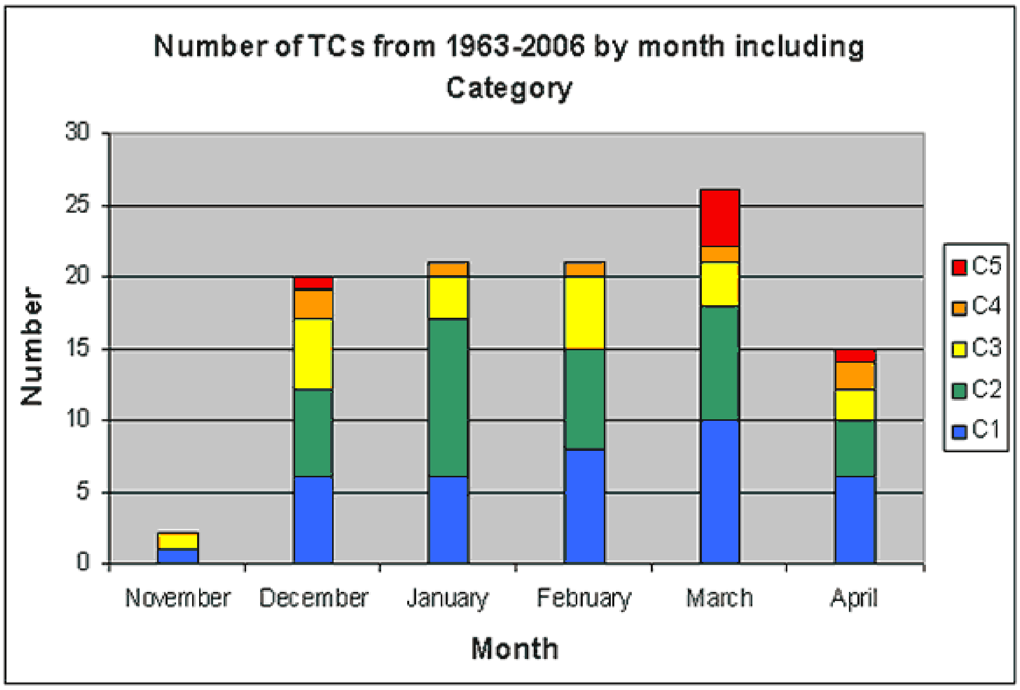
Source: Based on data from Darwin Airport, Bureau of Meteorology

Figure 7-5 Monthly-averaged air temperature and precipitation



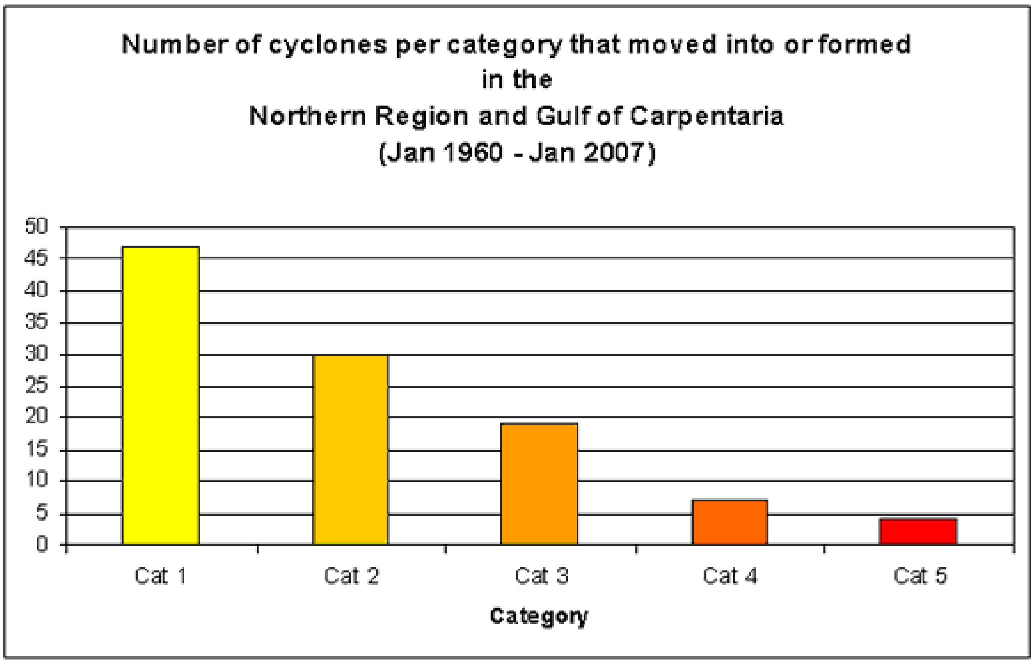
Source: BOM, 2011b

Figure 7-6 Tropical Cyclone tracks in the Northern Region



Source: Bureau of Meteorology, 2011a

Figure 7-7 Number of tropical cyclones in the Northern region per month



Source: Bureau of Meteorology, 2011a

Figure 7-8 Number of tropical cyclones in the Northern region per category and per month

Table 7-2 Classification of tropical cyclone intensity (Bureau of Meteorology, 2011)

Category	Sustained winds (km/h)	Maximum Wind Gust (km/h)	Typical effects
1	63 - 88	<125	Damaging winds
2	89 - 117	125-<170	Destructive winds
3	118 - 159	170-<225	Very destructive winds
4	160 - 199	225-<280	
5	Over 200	>280	

Source: Bureau of Meteorology, 2011b

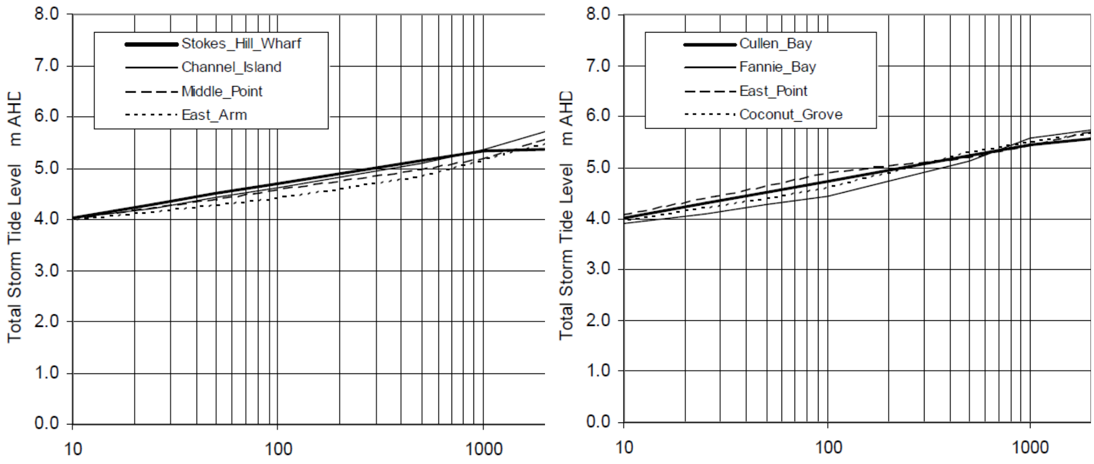
It is noted that the return period concept does not mean that the nominated event's return period number of years will elapse before such an event occurs again. In fact, the probability of experiencing the "n" year return period event within any consecutive period of "n" years is approximately 64%, i.e. more likely than not (Systems Engineering Australia (SEA), 2006).

7.4 Storm Surge

Storm surge is a raised mass of water, generally 2–5 m higher than normal tide levels, which results from strong onshore winds and reduced atmospheric pressure (BoM, 2011c). An individual storm surge is measured relative to the tide level at the time. Storm surge is often associated with cyclones and can cause flooding and damage through raised tides and waves. The height of storm surge is influenced by many factors, including the intensity and speed of an associated cyclone, the angle at which the cyclone crosses the coast and the topography of the affected area.

Cyclonic tidal surges are associated with the passage of intense tropical cyclones on particularly critical paths, combined with a high state of the astronomical tide. Surge levels significantly above the predicted levels are possible. Cyclonic storm surge within the Greater Darwin area has been evaluated by VIPAC (1994). The study indicated that peak combined sea level predictions at East Arm Port of 10, 100, 1,000 and 10,000 year return periods were 3.7, 4.9, 6.0 and 7.0 m AHD, respectively.

More recently, estimates of total storm tide levels (relative to AHD) for several locations within Darwin Harbour were produced by SEA (2006) (refer Figure 7-9).



Source: SEA, 2006

Figure 7-9 Total Storm Tide Levels at Selected Sites within Darwin Harbour

Total storm tide levels for the same locations are also summarised in Table 7-3. The estimates are based on the assumption of an unchanged future climate.

Table 7-3 Total storm tide levels for selected locations within Darwin Harbour (SEA, 2006)

Site	Return period, years				
	2	10	20	100	1,000
Stokes Hill Wharf	3.9 m	4.0 m	4.4 m	4.7 m	5.3 m
Channel Island	3.9 m	4.0 m	4.3 m	4.6 m	5.4 m
Middle Point	3.9 m	4.0 m	4.3 m	4.6 m	5.2 m
East Arm	3.9 m	4.0 m	4.2 m	4.4 m	5.2 m
Cullen Bay	3.9 m	4.0 m	4.4 m	4.7 m	5.4 m
Fannie Bay	3.7 m	3.8 m	4.1 m	4.4 m	5.6 m
East Point	3.9 m	4.0 m	4.5 m	4.9 m	5.4 m
Coconut Grove	3.8 m	3.9 m	4.3 m	4.6 m	5.5 m

Source: SEA, 2006

It should be noted that a comparison of the long term wind measurements with the model winds from the former study exhibited good results, while the SEA (2006) study also used more modern parametric storm surge methods as well as wave models, both of which were extensively developed during the period 1994-2005. The VIPAC (1994) storm surge study is currently under review, and the proposed development will be designed in accordance with the findings of this review (Ken Gardner pers. comm., 25 March 2011).

7.5 Projected Trends in Climate Variability for Darwin Region

The study of climate change in Australia conducted by Commonwealth Scientific and Industrial Research Organisation (CSIRO) and BOM (2007) indicated that the likely changes in climate variables for Darwin Region appear to be consistent with the observed trends over the last half century; the project trends are summarised in Table 7-4.

Table 7-4 Projected Climate Change

Climate variable	Projected trend
Daily maximum temperature	Increase – more very hot days, with daytime temperatures in the dry season possibly increasing more than daytime temperatures in the wet season.
Daily minimum temperature	Increase – more warm nights, with night-time temperatures in the wet season possibly increasing more than night-time temperatures in the dry season.
Humidity	Increase - relative humidity and dew point likely to increase in the wet season with increasing rainfall.
Potential evaporation	Dry season potential evaporation likely to increase. Possible decrease in the wet season with increasing rainfall.
Rainfall frequency and intensity	Dry season rainfall likely to decrease. Wet season rainfall frequency and intensity may increase.
Tropical cyclone frequency and intensity	Frequency may remain relatively stable, maximum intensity likely to increase.
Sea-level	Sea-level rise may accelerate.

7 Climate

Climate variable	Projected trend
Storm surge frequency and intensity	Likely to increase in the wet season with possible increase in intensity of rainfall and cyclones and rising sea-level.

Source: CSIRO & BoM, 2007

The “Climate Change in Australia” website (Department of Climate Change and Energy Efficiency, 2011), indicate global sea-levels rose 17 cm over the past century, and from 1993 to 2003, global sea level rose by about 3.1 mm a year. Model projections from the IPCC 2001 Assessment Report (Church et al. 2001) indicate global averaged sea-level rise by 2100 is less than 0.9 m.

References

BoM, 2011a, Storm Surge, accessed 18 March 2011 at (http://reg.bom.gov.au/cyclone/about/stormsurge.shtml#introduce)

BoM, 2011b, Tropical Cyclones, accessed 18 March 2011 at (http://reg.bom.gov.au/cyclone/index.shtml)

BoM, 2011c, Tropical Cyclone Information for the Australian Region 1970 - 2006, accessed 18 March 2011 at (http://reg.bom.gov.au/cgi-bin/silo/cyclones.cgi?region=aus&syear=1970&eyear=2006&loc=1&txtloc=&radius=400&ulat=12.42&ulon=130.89)

CSIRO and BoM, 2007, *Climate Change in Australia. Technical Report*. Accessed 24 March at (http://www.climatechangeinaustralia.gov.au)

Dames & Moore, 1997, *Darwin LNG Plant, Draft Environmental Impact Statement,* Report prepared for Phillips Oil Company.

Guillaume, J., Li, G. M., Hutchinson, M.F., Proust, K. and Dovers, S., 2010, *The Integrated Assessment of Climate Change Impacts on Urban Settlements (IACCIUS) Project: A Differential Vulnerability Assessment of Climate Change Impacts on Darwin*, Fenner School of Environment and Society, Canberra.

Parkinson, G., 1996, *Atlas of Australian resources, Third Series, Volume 4*, Climate Division of National Mapping, Canberra.

SEA, 2006, Darwin Storm Tide Mapping Study, study for NT Emergency Services.

Swan, J.M. Neff, J.M. and Young, P.C., 1994, *Environmental Implications of Offshore Oil and Gas Development in Australia – The Findings of an Independent Scientific Review*, Australian Petroleum Exploration Association, Canberra.

VIPAC, 1994, *Tropical cyclone storm surge risk for the Greater Darwin Region (Volumes 1 & 2)*, prepared for NT Dept Lands, Housing and Local Government.