City Pacific Limited

Townsville Ocean Terminal Review of Site Climatic Conditions

Tuesday, 11 September 2007

Report no: QL00704-CC-R001

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Report no: QL00704-CC-R001 Date: Tuesday, 11 September 2007

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Executive Summary

This report provides a review of meteorological conditions in Townsville and the region pursuant to Section 4.1 of the Terms of Reference.

The Townsville area is characterised by a tropical wet and dry climate. During the dry season, temperatures are mild and humidity is moderate. During the wet season, temperatures and humidity are high with frequent storm events including tropical cyclones. Average climate conditions are:

Table 1: Townsville Climate Averages (1940 – 2007)

Month	Mean daily Maximum Temp.(ºC)	Mean daily Minimum Temp. (ºC)	Highest maximum Temp.(ºC)	Mean 9am Relative Humidity (%)	Mean 3pm Relative Humidity (%)	Mean 9am Wind Speed (km/hr)	Mean 3pm Wind Speed (km/hr)	Mean Rainfall (mm)	Mean Daily Evaporation (mm)
Jan	31.4	24.2	44.3	71	65	10.8	19.8	265.3	8.3
Feb	31.1	24.0	42.7	75	67	9.7	18.5	292.6	7.3
Mar	30.7	22.9	37.6	72	64	10.0	19.4	183.4	7.0
Apr	29.6	20.6	35.8	68	60	10.6	20.5	68.0	6.6
May	27.6	17.6	32.2	67	57	8.6	19.2	33.9	5.5
Jun	25.6	14.6	32.2	66	52	8.1	18.0	21.1	5.0
Jul	25.1	13.6	31.6	66	51	7.7	19.7	13.1	5.3
Aug	26.0	14.7	33.3	63	52	9.7	21.8	16.5	6.2
Sep	27.7	17.3	36.5	60	53	13.6	23.5	10.2	7.7
Oct	29.4	20.7	37.1	61	55	15.4	23.3	25.3	8.8
Nov	30.7	22.9	41.0	63	58	14.9	22.9	57.1	9.2

Dec	31.4	24.0	42.1	67	61	13.4	22.1	124.7	9.0
Annual Average	28.9	19.8	44.3	66	58	11.0	20.7	1115.8	7.2

Source: Bureau of Meteorology; www.bom.gov.au

Ambient climatic conditions that may influence the construction and operation of the TOT project including seasonal and diurnal variations are:

- Heavy Rainfall;
- Tropical Cyclones
- Wind Storms and Storm Surge

Tropical cyclones can develop during monsoonal conditions from late December until early April and can cause major flooding and beach erosion within the entire Northern Australian region. The average frequency of cyclones affecting Townsville is estimated to be 1.78 events per season. Storm surges often occur during the passing of a tropical cyclone, causing flooding of low lying coastal areas and severe wave action on coastal structures.

A review of historic events in the Townsville region is provided in Section 2.3.1. Extreme events may have impacts on coastal structures within the project site. A study has been undertaken by Coastal Engineering Solutions (CES) to assess the potential impacts of extreme events on the project. These impacts may include damage to buildings and property and potential risks to human lives.

The TOT and Breakwater Cove precincts have been designed and constructed to ensure that the development minimises the potential adverse effects of extreme weather events and does not result in an unacceptable risk to people or property.

While the Proponent will not be constructing any residential buildings within the Breakwater Cove Precinct directly, it is mandatory in cyclone prone areas for all development constructed to comply with minimum engineering and construction standards to withstand such damage. These Standards must be met by all future development within the TOT Project area.

A designated evacuation route within the site will be identified to provide safe access during an emergency event. In addition, a Disaster Action Plan will be developed for the site to provide prevention and response measures in the event of a natural hazard such as a storm, flood or cyclone.

Changes in extreme events are predicted to occur as a result of climate change with possible increases in intensity of cyclones and storms. It is predicted that average temperatures will increase overall by 1-2ºC over most of Australia by 2030. In addition, a global mean sea-level rise of approximately 50cm is predicted to occur between 1990 and 2100. The TOT and Breakwater Cove precincts have been designed and constructed to ensure that the development minimises the potential adverse effects of extreme weather events and does not result in an unacceptable risk to people or property.

The floors of all dwellings within the Breakwater Cove precinct will be situated above the required design levels to provide flood immunity. All structures have been designed and constructed to withstand hydrostatic and hydrodynamic forces that may occur as a result of tidal inundation. A detailed description of these requirements is provided in the Coastal Engineering Report prepared for the project.

The climatic conditions of the project area include the risk of impacts that are applicable to the region for all development. However, the knowledge and ability to predict the impact of expected cyclonic and extreme climatic events at the design and development stage of the TOT Project allows for the mitigation of impacts on the development to be incorporated.

1 Introduction

Development of the Townsville Ocean Terminal (TOT) project will involve construction of a dedicated ocean terminal for use by cruise ships and naval vessels and a residential area providing for a range of uses including apartments, attached dwellings, detached dwellings, commercial and retail facilities services, landscaping and public open space.

The site proposed for development of the TOT Project is the area defined as the "Future Development Area" under the *Breakwater Island Casino Agreement Act 1984*. The TOT Project is to create two developed precincts:

(a) The TOT Precinct: adjoining and cut into the existing Western Breakwater of the Port of Townsville, to create both a significant cruise ship wharf and land based facilities, including a terminal building, car parking and associated facilities; and

(b) The Breakwater Cove Precinct: a residential canal estate:

Both precincts will be constructed on reclaimed land adjoining the Townsville Entertainment Centre and Hotel Casino Complex, to the north of Sir Leslie Thiess Drive and Entertainment Drive. The reclamation site is bordered by existing breakwaters that form the western boundary of the Port of Townsville.

Hyder Consulting has conducted a review of the existing climatic conditions within the project area and the potential impacts of climate matters on the construction and operation of the TOT project in accordance with the requirements of the Terms of Reference issued by the State Government in March 2007.

2 Existing Environment

The Townsville area is characterised by a tropical wet and dry climate (savanna climate)[1]. During the dry season (May to October), temperatures are mild and humidity is moderate. During the wet season (November to April), temperatures and humidity are high with frequent storm events. These events include tropical cyclones, high intensity rainfall and strong winds.

2.1 Townsville Average Climate Data

The nearest weather recording station to the TOT Project site is the Townsville Meteorological Office, located at the Townsville Aerodrome (elevation 7.5m) approximately 6km from the Port of Townsville. The Local meteoriological environment and climate history has been recorded for 67 years by the Bureau of Meteorology (BoM) between 1940 and 2007 at the Townsville Aerodrome weather station. Average climate data for Townsville is presented in Table 1.

Table 1: Townsville Climate Averages (1940 – 2007)

Month	Mean daily Maximum Temp.(ºC)	Mean daily Minimum Temp. (ºC)	Highest maximum Temp.(ºC)	Mean 9am Relative Humidity (%)	Mean 3pm Relative Humidity (%)	Mean 9am Wind Speed (km/hr)	Mean 3pm Wind Speed (km/hr)	Mean Rainfall (mm)	Mean Daily Evaporation (mm)
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Sep	27.7	17.3	36.5	60	53	13.6	23.5	10.2	7.7
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Source: Bureau of Meteorology; www.bom.gov.au

[1] These climates have a pronounced dry season, with the driest month having precipitation less than 60mm.

2.2 General Climatic Conditions

2.2.1 General Rainfall Conditions

Townsville experiences an average annual rainfall of 1115.8mm with the highest average monthly rainfall occurring during the wet season from November to April. During the wet season, the Townsville area experiences frequent heavy rainfall events. On average, the highest monthly rainfall occurs in January (265.3mm). The lowest monthly rainfall occurs between May and October (see Figure 1).

The highest annual rainfall on record at the Townsville Aerodrome weather station was 2399.8mm in 2000. In contrast, the following year recorded only 467mm.

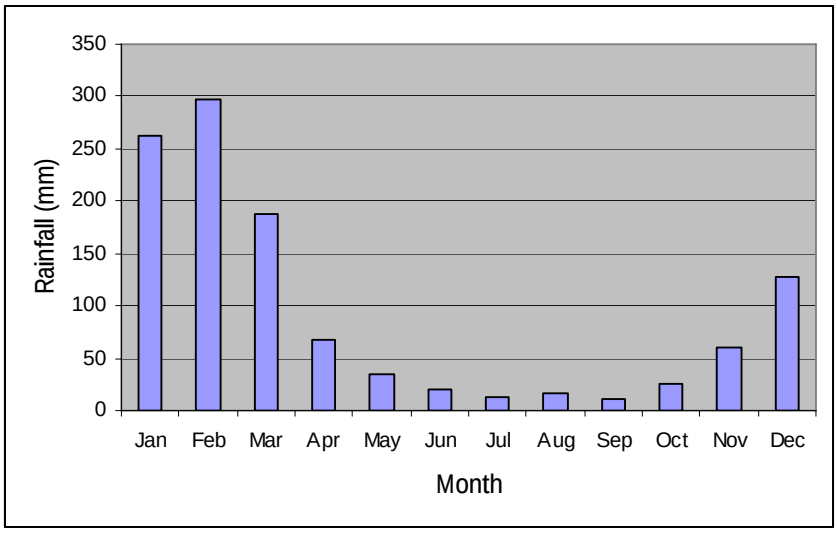


Figure 1: Average Monthly Rainfall Data. Source of data: Bureau of Meteorology; www.bom.gov.au

2.2.2 General Temperature Conditions

In the Townsville area, the highest temperatures occur between November and March and the lowest temperatures occur between April and October. The city has 142.4 mean days per year with temperature in excess of 30ºC, the mean annual maximum temperature is 28.8ºC and the mean annual minimum temperature is 19.8ºC (see Figure 2).

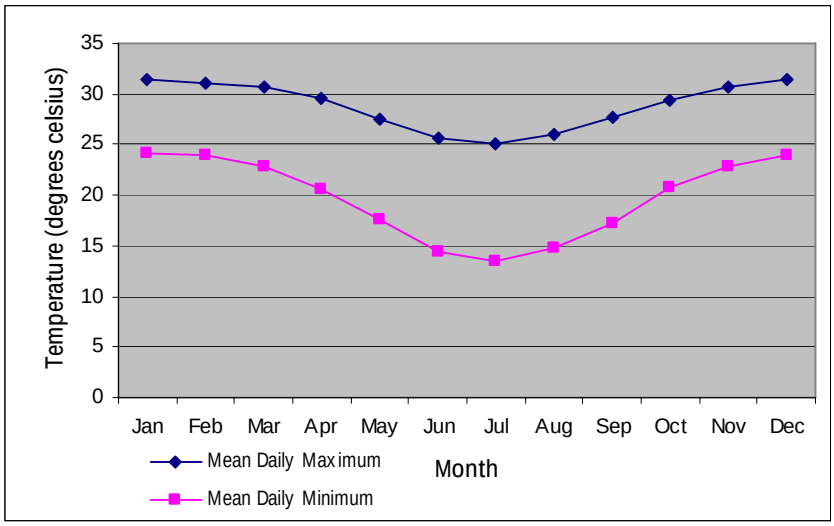


Figure 2: Average Monthly Temperature Data. Source of data: Bureau of Meteorology; www.bom.gov.au

2.2.3 General Humidity Conditions

Relative humidity is highest in the morning and monthly averages range between 60% in April to 75% in February.

2.2.4 General Wind Conditions

Wind speed is highest in the afternoon and is predominantly onshore, from the northeast during the wet season and the southeast during the dry season. Monthly wind speed averages vary between 18km/hr in June and 23.5km/hr in September. Seasonal wind roses for Townsville are presented in Appendix A.

Review of the wind roses confirms that wind conditions at the Port of Townsville are typically defined by sea breezes. Wind roses for the Townsville Airport meteorological station show that morning winds are generally off-shore with wind speeds varying between 10 – 30 km/hr. It is noted however, that during this period the occurrence of calm wind is high with a greater occurrence of calm conditions during the autumn and winter months (15 % and 33 % respectively). During summer and spring, calm conditions are less prevalent at 7 % and 15 % respectively.

During the day time, winds typically turn on-shore with the afternoon wind roses from the airport site identifying this trend. The occurrence of calm conditions is also low in the afternoons at less than 2 % for all periods of the year.

2.3 Extreme Climatic Events

2.3.1 Tropical Cyclones

Tropical cyclones can develop during monsoonal conditions from late December until early April and can cause major flooding and beach erosion within the entire Northern Australian region.

Tropical cyclone data presented in Table 2 is based on 11 years of weather data recorded by the Bureau of Meteorology. On average, the North Queensland coast faced around 3.45 cyclones a year during this period.

Table 2: Frequency of cyclones occurring in the North Queensland region 1996-2006

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Jan	2			3			1			1	1
Feb	1	3	1	2	1	2	1	1	1	1	1
Mar	1		2				1	2		1	2
Apr		1			2						1
Nov	1										
Dec	1	1									

The *Townsville-Thuringowah Storm Tide Study* (GHD 2007) provides data on the frequency of occurrence of cyclones that entered within a 500km radius of Townsville from 1959 to 2004. It was estimated that the frequency of cyclones affecting Townsville was an average of 1.78 cyclones per season during this period. For the purpose of comparison with the frequency of cyclones in North Queensland as presented in Table 2, Table 3 presents data on tropical cyclone occurrence in Townsville from the GHD Study for the period 1996 to 2004.

Table 3: Frequency of cyclones occurring within 500km of Townsville 1996-2004

	1996	1997	1998	1999	2000	2001	2002	2003	2004
Jan	2			1					
Feb		2	1		1	1			
Mar		1	2	1	1			1	1
Apr									
Nov									
Dec									

Although cyclones are a frequent occurrence in tropical northern regions, the majority cause no significant damage. The following historic weather events indicate the potential impacts that may occur in coastal areas of Townsville during extreme weather conditions.

Tropical cyclone 'Althea' caused approximately $50 million damage in the Townsville region in December 1971 including extensive damage at the Strand and Cape Pallarenda. A 2.9m storm surge was recorded in Townsville Harbour and 3.6m storm surge was recorded at Toolakea. In March 1988, cyclone 'Charlie' caused beach erosion and tidal inundation within Townsville. Although cyclone 'Justin' did not make landfall in Townsville in March 1997, it caused severe beach erosion and tidal inundation along the Townsville coast.

Cyclones 'Sid' and 'Rona' caused major flooding and extensive damage to private property and local government infrastructure (Sid caused damage in excess of $100 million) in January 1998 and February 1999 respectively. Cyclone 'Tessi', which hit the coast in March 2000, set new weather records for April in Townsville. Wind gusts of 70knots, highest daily rainfall of 271.6mm and highest monthly rainfall of 539mm were recorded by the Townsville Meteorological Office.

2.3.2 Wind Storms and Storm Surge

Townsville's coastal location means the city can be subject to strong winds caused by low pressures. Although not classified as cyclones, such wind storms can still create storm surges and may have potential impacts on coastal areas, especially when they coincide with a spring tide, in which case they are called storm tides. Spring tides occur when the tide's range is at its maximum. They result in higher than average and lower than average waters, shorter than average slack water time and stronger than average tidal currents. In Townsville, spring tides occur in January and September and are about 4m above average sea level.

2.3.3 Heavy Rainfall

Townsville is located in a sub tropical zone and receives a significant amount of rainfall, especially during the wet season and in association with cyclonic events, as discussed above. The city has experienced heavy rainfall events in the past. In January 1998, torrential rain fell in Townsville, causing the Ross and Black rivers and Bluewater Creek to overflow, flooding the city and surrounding areas. During this extreme event of almost 10 times the monthly average of rainfall, the Strand was extensively damaged and was later fully redesigned and redeveloped to more updated standards.

2.3.4 Project Requirements

Extreme events may cause flooding of low-lying areas and may have impacts on structures in coastal areas. A study has been undertaken by Coastal Engineering Solutions (CES) to assess the potential impacts of extreme events on the project. This report provides requirements for the design of project infrastructure in order to withstand potential impacts associated with storm surge and storm tides.

2.4 Climate Change Issues

The Intergovernmental Panel on Climate Change (IPCC)[2] report *Climate Change 2001: Impacts, Adaptation and Vulnerability* describes the scientific projections of potential impacts of climate change on Australia. The report states that Australia has significant vulnerability to the changes in temperature and precipitation projected for the next 50-100 years because it already has extensive arid and semi-arid areas and lies largely in the tropics and subtropics. Australia is also sensitive to possible changes toward a more El Niño-like mean state. The El Niño-Southern Oscillation (ENSO) phenomenon is known to lead to floods and prolonged droughts, especially in eastern Australia.

Changes in extreme events are predicted with possible increases in intensity of tropical cyclones, mid-latitude storms, heavy rain events and changes in the location-specific frequency of tropical cyclones. Scenarios of climate change suggest that large areas of mainland Australia will experience significant decreases in rainfall during the 21st century.

Climate modelling undertaken by CSIRO has predicted that average temperatures will increase overall by 1-2ºC over most of Australia by 2030. Annual average increases in evaporation due to increased temperatures are expected to range from 0 to 8% per degree increase in temperature resulting in decreases in the annual water balance of around 15 to 160mm by 2030 (CSIRO 2001).

A 2006 CSIRO report *Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gases Emissions* predicts that Australia's annual average temperatures are projected to increase 0.4–2.0 °C above 1990 levels by the year 2030, and 1–6 °C by 2070. Average precipitation in South-West and South-East Australia is projected to decline further in future decades, while regions such as the North-West may experience increases in precipitation.

[2] www.ipcc.ch

3 Potential Impacts

The extreme climatic events described above do and may continue to have significant impacts on the Townsville area and therefore the TOT Project. Furthermore, climate change is expected to increase the frequency and severity of such events.

Potential impacts associated with extreme climatic events are well known and can be identified for the TOT Project as all impacts generally applicable to any coastal development in the region. Impacts include damage to buildings and property and potential risks to human lives.

3.1 Tropical cyclones and storm surges

Tropical cyclones impact coastal areas through strong winds and heavy wave action. The TOT project is proposed to be built on reclaimed land within Cleveland Bay and will therefore be susceptible to such impacts.

Strong winds associated with tropical cyclones can cause extensive structural damage to buildings.

Heavy winds also trigger strong wave action that causes coastal erosion, storm surges or storm tides, that may destroy buildings and infrastructure located in susceptible coastal areas. The most recent study undertaken with regard to storm tides that may occur in the Townsville region is the *Townsville-Thuringowah Storm Tide Study* (GHD 2007). This study identifies the hazards associated with cyclones including strong winds, intense rainfall and induced ocean effects such as extreme waves, currents, storm surge and resulting storm tide.

Storm surges often occur during the passing of a tropical cyclone, causing flooding of low lying coastal areas and severe wave action on coastal structures[3]. If combined with a spring tide, a storm surge is then known as a storm tide. If the maximum surge coincides with a high spring tide, the impacts on low lying coastal areas can be even greater. The TOT Project site is located in the area affected by predicted storm surges of 4m AHD (Australian Height Datum) on the Storm Surge Map of Townsville and is therefore prone to such impacts. The Townsville Storm Surge Map is included in Appendix B.

Even when not caused by cyclones, strong winds triggered by low pressure systems can still cause damage. They also can create storm surges, which can be very destructive if combined with a spring tide. The frequency of such wind storms

[3] Coastal Engineering Studies Report (CES, 31 August 2007).

combined to the relatively high frequency of tropical cyclones makes storm surges a prime threat for the TOT project.

3.2 Heavy rainfall

Heavy rains may trigger overflowing of rivers and creeks and flooding of infrastructure within the TOT precinct and dwellings within the Breakwater Cove precinct. However, as shown on the Townsville 1990 flood map, included in Appendix C due to its proximity to the ocean, the TOT project site is relatively unlikely to be impacted by flooding of rivers and creeks caused by heavy rains.

3.3 Climate change

The increasing concentration of greenhouse gases in the atmosphere is expected to result in changes in climatic conditions. If climate changes develop as predicted, the foreshores of the Townsville region will be subjected to potentially greater storm and cyclone activity, higher waves, stronger winds and increased water levels.[4]

The IPCC Climate Change 2001 report identifies potential impacts of Climate Change and sea-level rise on coastal systems. These impacts include:

- increased coastal erosion,
- more extensive coastal inundation,
- higher storm-surge flooding,
- landward intrusion of seawater in estuaries and aquifers increased loss of property and coastal habitats,
- increased flood risk and potential loss of life,
- damage to coastal protection works and other infrastructure,
- loss of tourism, recreation, and transportation functions.

The recent *Queensland Climate Change and Community Vulnerability to Tropical Cyclones* study (Dept. Natural Resources & Mines, 2004) addresses the effect of enhanced Greenhouse conditions on sea level rise and tropical cyclone occurrences.

Predictions of the impact of climate change on sea level rise vary greatly. However, the best available data indicates that a global mean sea-level rise of approximately 50cm is expected between 1990 and 2100[5]. The IPCC Climate Change 2001 report indicates that port facilities are likely to be affected by sea-level rise because higher sea level will

[4] Ibid.

[5] Ibid.

probably decrease the effectiveness of breakwaters against wave forces, and wharves may have to be raised to avoid inundation. When such effects are anticipated, countermeasures can be implemented to maintain function and stability.

Although it is unsure what effects these projected changes will have on the Townsville area and the TOT Project, the potential risks must be taken into account in the development of management strategies to maintain public safety and to protect property and assets.

3.4 Hazard Management

3.4.1 Response to impacts from tropical cyclones, storm surges and heavy rainfall

The TOT and Breakwater Cove precincts have been designed and constructed to ensure that the development minimises the potential adverse effects of extreme weather events and does not result in an unacceptable risk to people or property.

While the Proponent will not be constructing any residential buildings within the Breakwater Cove Precinct directly, it is mandatory in cyclone prone areas for all development constructed to comply with minimum engineering and construction standards to withstand such damage. These Standards must be met by all future development within the TOT Project area.

The floors of all dwellings within the Breakwater Cove precinct will be situated above the required design levels to provide flood immunity. All structures have been designed and constructed to withstand hydrostatic and hydrodynamic forces that may occur as a result of tidal inundation. A detailed description of these requirements is provided in the Coastal Engineering Report prepared for the project.

The terminal building and other infrastructure within the TOT Precinct must also be built to these contemporary engineering standards. A designated evacuation route within the site will be identified above the flood and storm surge planning level to provide safe access during an emergency event. The Body Corporate will be responsible for advising residents of evacuation routes and emergency procedures.

It is intended that a Disaster Action Plan will be developed for the site to provide prevention and response measures for preservation of life and property in the event of a natural hazard such as a storm, flood or cyclone. The Disaster Action Plan will be based upon the intent of the main objects of the *Queensland Disaster Management Act 2003*.

The primary purpose of the Disaster Action Plan will be to inform residents of the characteristics of the site and its environs and the evacuation processes in case of an emergency. The Body Corporate will review this document with Council to ensure its

currency, accuracy and compatibility with the Townsville-Thuringowa State Emergency Services (SES) Unit. The Body Corporate Manager will be responsible for educating the residents in relation to being aware of emergency agency warnings and monitoring the Bureau of Meteorology and SES reports in relation to possible events and provide timely and adequate advice of such reports to all residents and occupants of the site.

3.4.2 Response to Impacts from Climate Change

The Queensland Government currently requires that all design water levels for works within coastal areas include an allowance of 0.3 metres for the predicted rise in sea level due to climate change. This design level has been allowed for by Coastal Engineering Solutions in the design of the rock armoured breakwaters for the project and in the finished land levels for the building platforms within the TOT Precinct and the Breakwater Cove Precinct.

3.5 Water Management

Rainfall in Townsville is highly variable with more than 75% of average annual rainfall occurring between January and March and 275 days a year on average being rain free. In addition, daily evaporation rates can exceed daily rainfall for most of the year (Bureau of Meteorology 2006). The municipal water supply within Townsville is adequate to meet projected water demands for the TOT project. However, management of water within the site can assist in reducing demand on high quality potable water supplies.

The management of stormwater within the project site is specifically addressed in Water Resources sections of the EIS.

Reduction of household potable water use will be encouraged by provision of information on water saving measures within the Breakwater Cove EMP to be provided to future landowners by the Body Corporate. The Water element of the EMP provides measures to maximise water efficiency through installation of water efficient fixtures and equipment, water efficient landscaping and rainwater re-use.

4 Conclusion

The existing and regional meteorological environment is a significant reason for the location of the TOT Project in this area, providing an enjoyable tropical environment for the use of the terminal for visiting cruise ships and recreational activities for military ships and a high quality coastal location for the Breakwater Cove residential development. The environment also includes inherent risk of impacts that are and have been applicable to the region for all development. The TOT Project will be no exception.

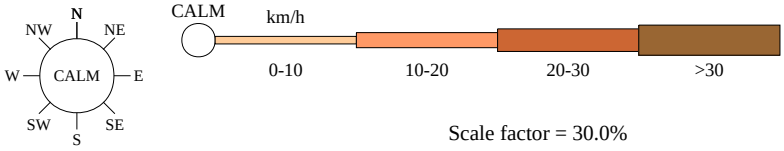
However, the knowledge and ability to predict the impact of expected cyclonic and extreme climatic events at the design and development stage of the TOT Project allows for the mitigation of impacts on the development to be incorporated.

APPENDIX A
SEASONAL WIND ROSES

WIND FREQUENCY ANALYSIS (in km/h)

TOWNSVILLE AERO STATION NUMBER 032040

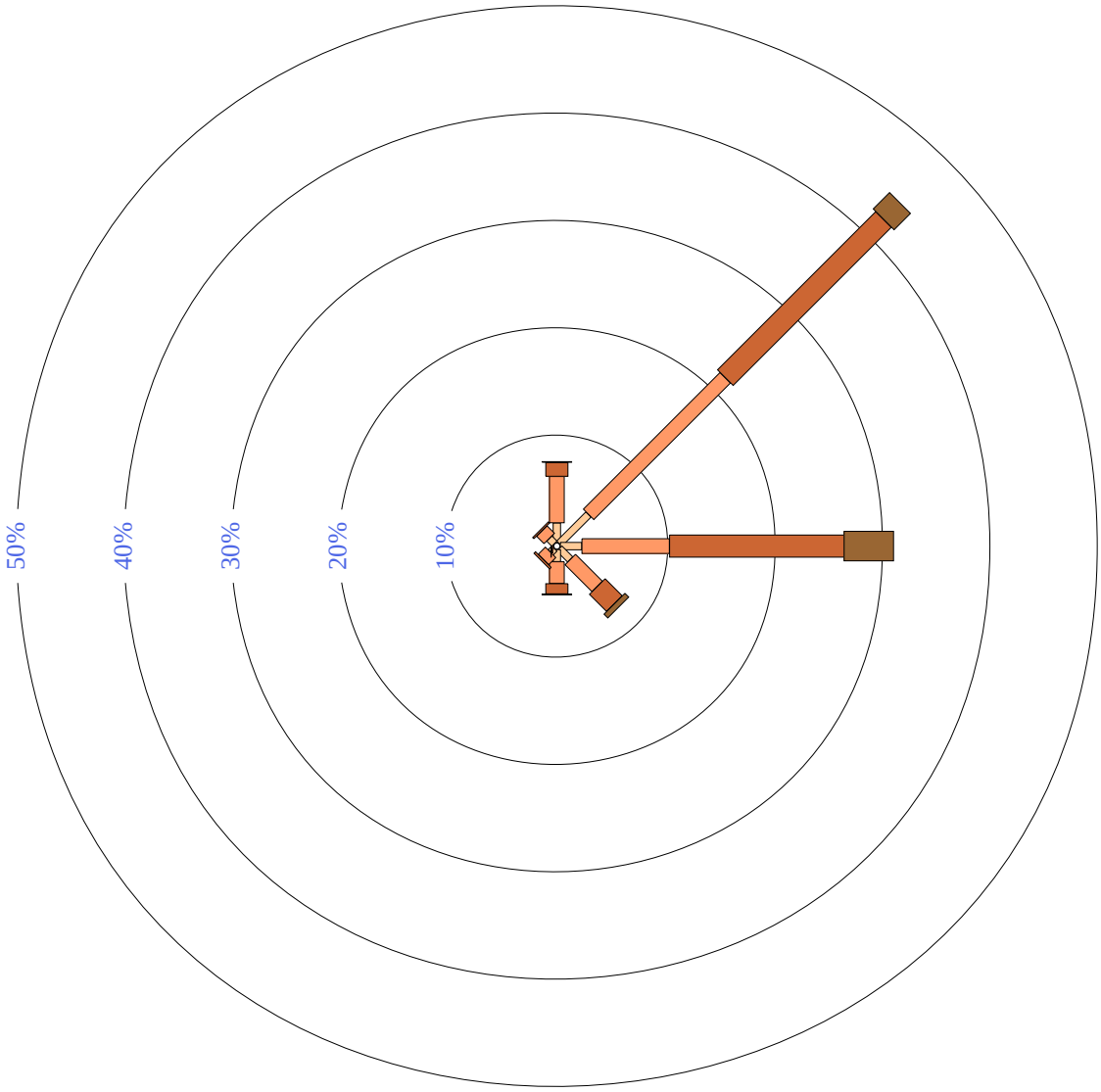
Latitude: -19.25 ° Longitude: 146.77 °



3 pm Autumn
5829 Total Observations (1940 to 2004)

Scale factor = 30.0%

Calm 1%

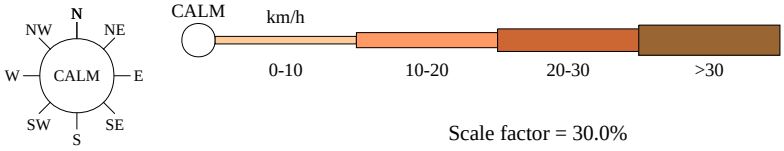


Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
An observed wind speed which falls precisely on the boundary between two divisions (eg 10km/h) will be included in the lower range (eg 1-10 km/h). Only quality controlled data have been used.

WIND FREQUENCY ANALYSIS (in km/h)

TOWNSVILLE AERO STATION NUMBER 032040

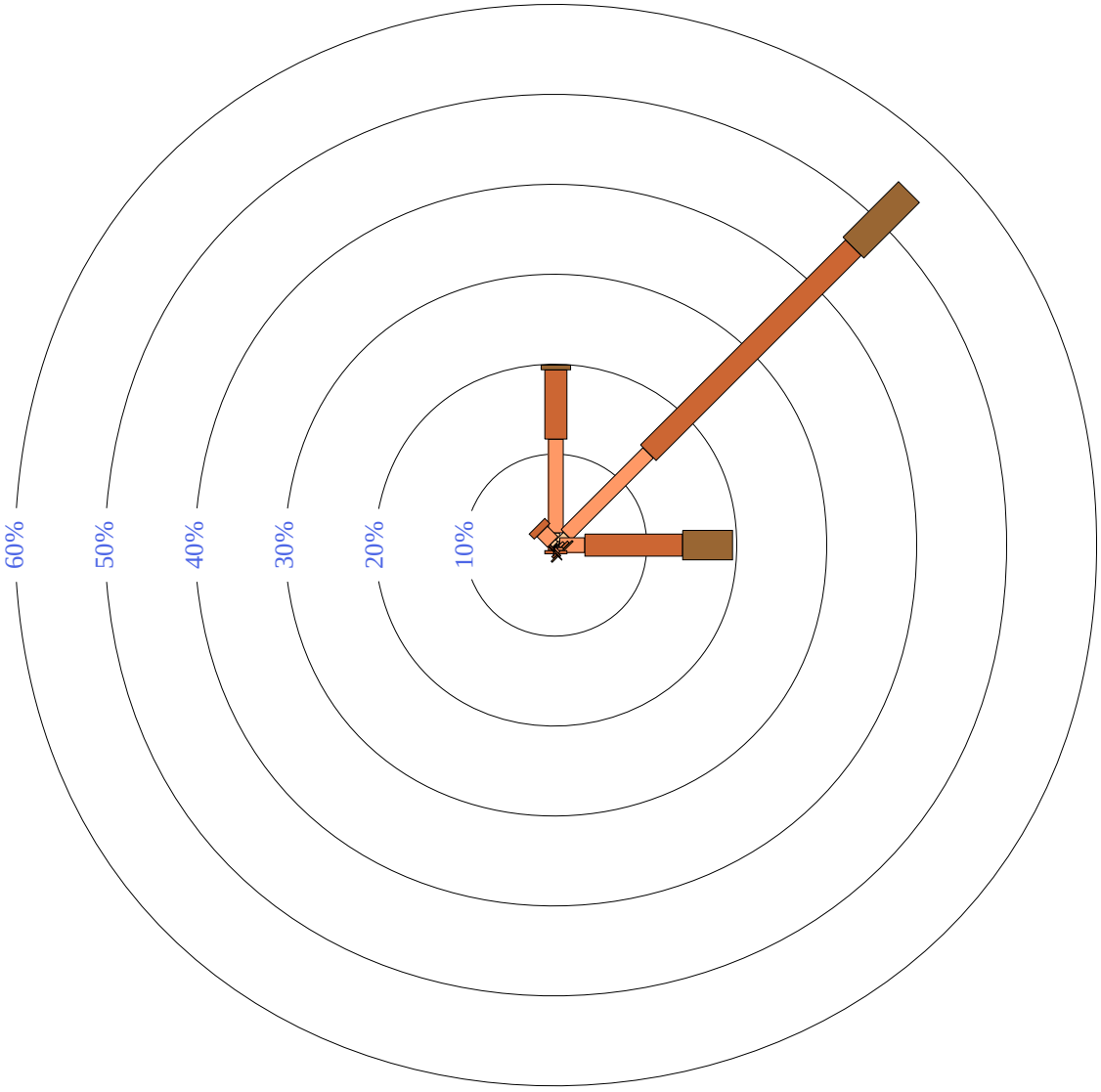
Latitude: -19.25 ° Longitude: 146.77 °



3 pm Spring
5756 Total Observations (1940 to 2004)

Scale factor = 30.0%

Calm *

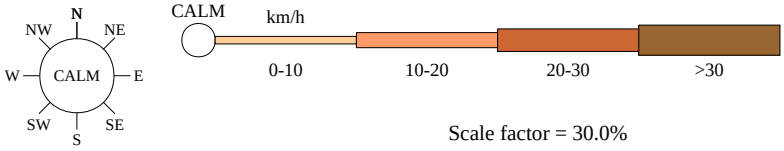


Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
An observed wind speed which falls precisely on the boundary between two divisions (eg 10km/h) will be included in the lower range (eg 1-10 km/h). Only quality controlled data have been used.

WIND FREQUENCY ANALYSIS (in km/h)

TOWNSVILLE AERO STATION NUMBER 032040

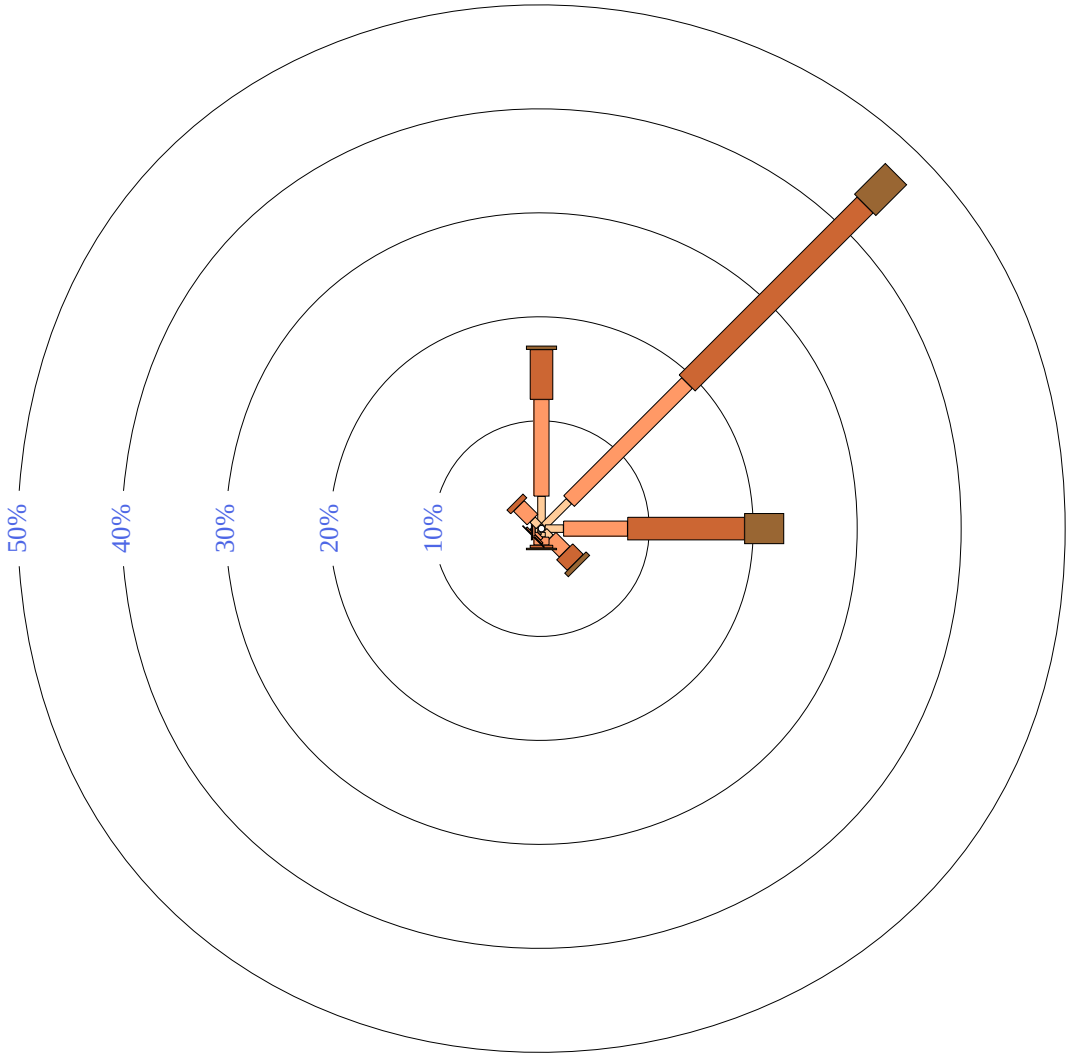
Latitude: -19.25 ° Longitude: 146.77 °



Scale factor = 30.0%

3 pm Summer
5711 Total Observations (1940 to 2004)

Calm 2%

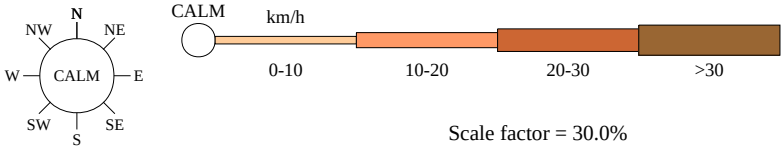


Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
An observed wind speed which falls precisely on the boundary between two divisions (eg 10km/h) will be included in the lower range (eg 1-10 km/h). Only quality controlled data have been used.

WIND FREQUENCY ANALYSIS (in km/h)

TOWNSVILLE AERO STATION NUMBER 032040

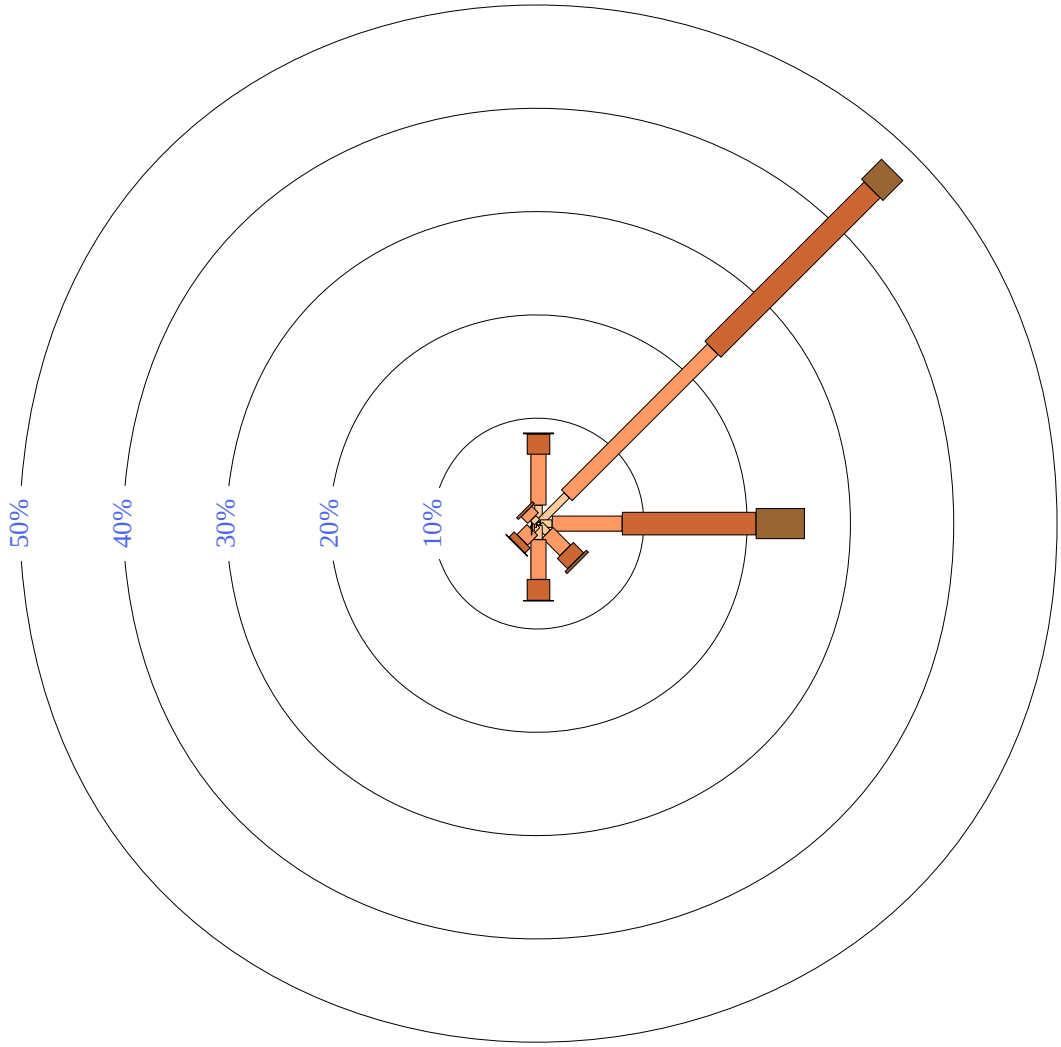
Latitude: -19.25 ° Longitude: 146.77 °



Scale factor = 30.0%

3 pm Winter
5775 Total Observations (1940 to 2004)

Calm 1%

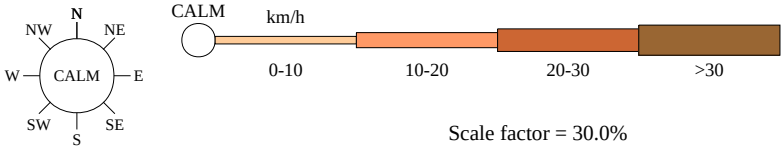


Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
An observed wind speed which falls precisely on the boundary between two divisions (eg 10km/h) will be included in the lower range (eg 1-10 km/h). Only quality controlled data have been used.

WIND FREQUENCY ANALYSIS (in km/h)

TOWNSVILLE AERO STATION NUMBER 032040

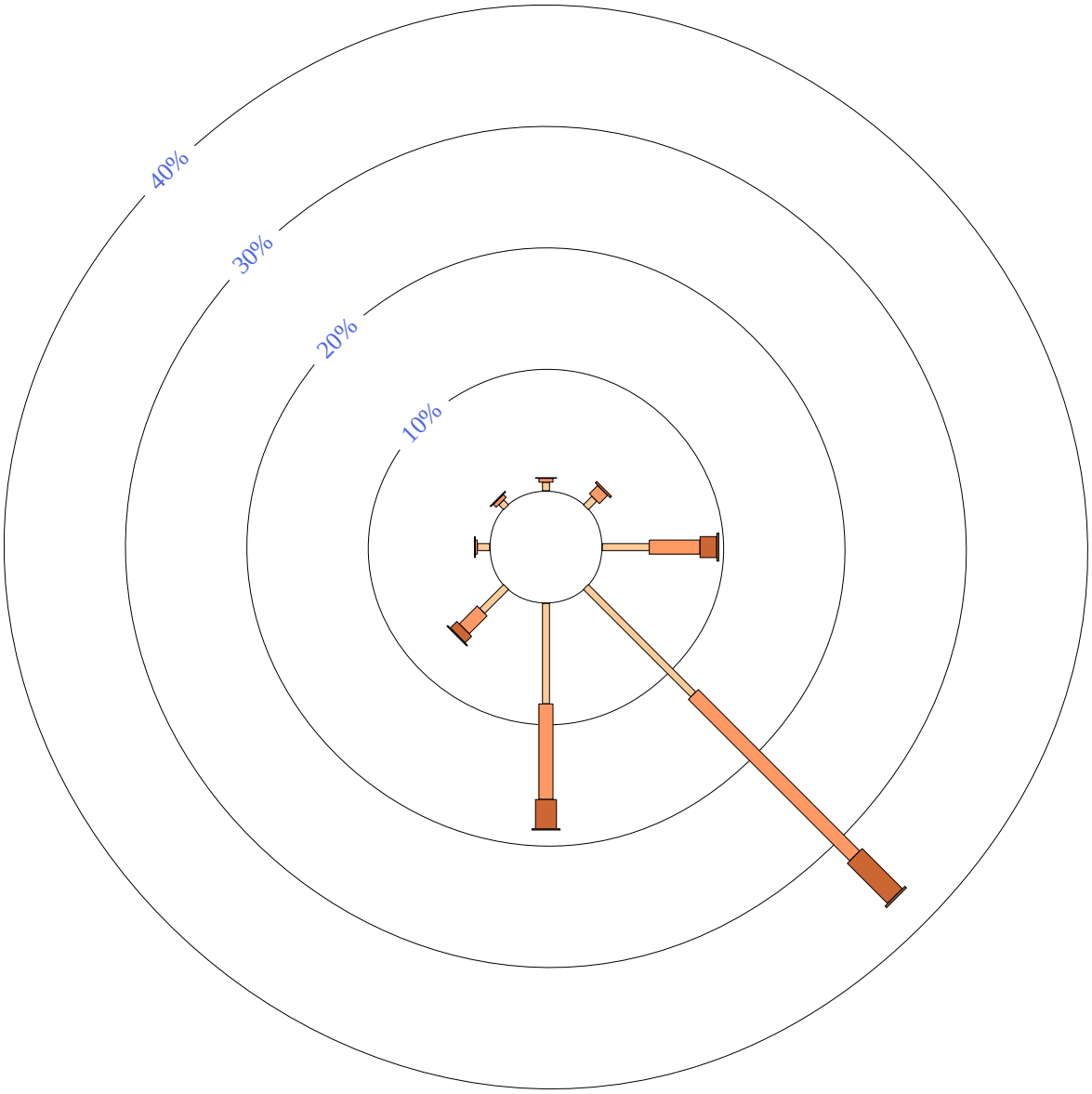
Latitude: -19.25 ° Longitude: 146.77 °



9 am Autumn
5821 Total Observations (1940 to 2004)

Scale factor = 30.0%

Calm 23%



Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
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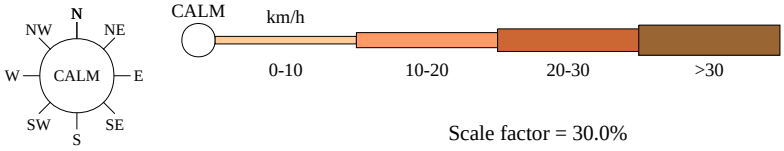
WIND FREQUENCY ANALYSIS (in km/h)

TOWNSVILLE AERO STATION NUMBER 032040

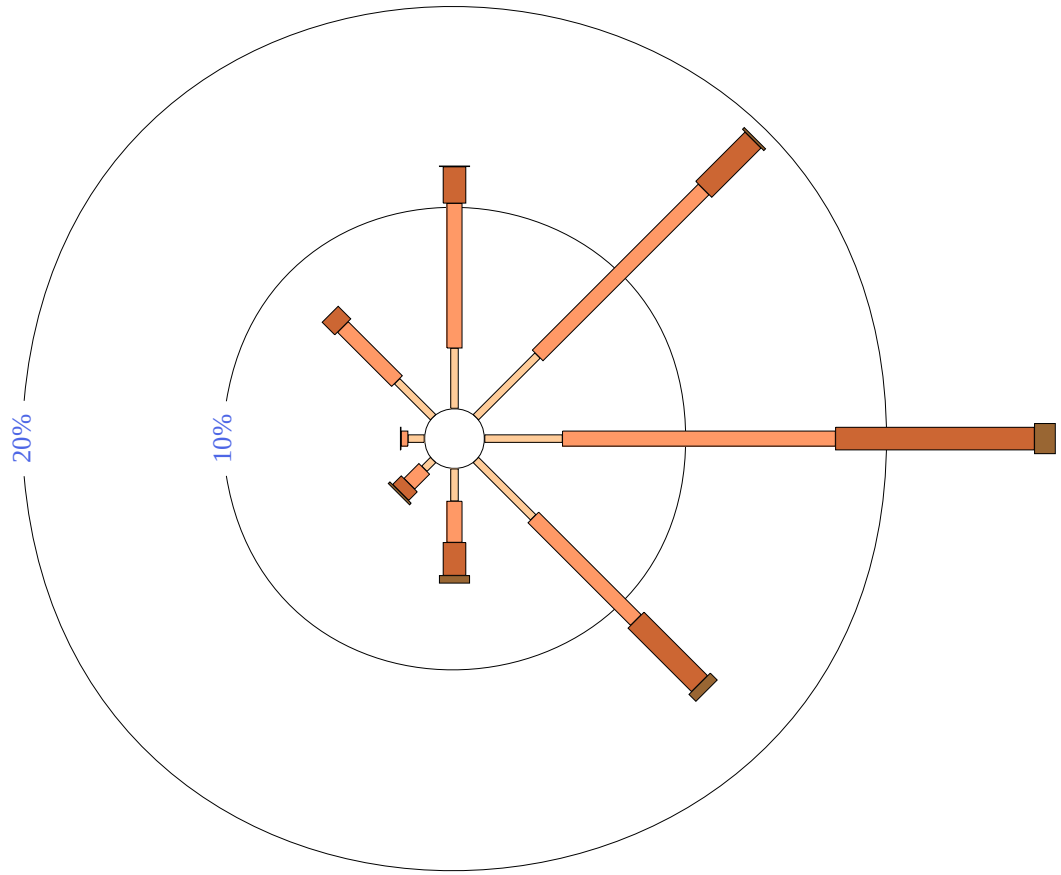
Latitude: -19.25 ° Longitude: 146.77 °



Scale factor = 30.0%

9 am Spring
5757 Total Observations (1940 to 2004)

Calm 7%



Wind directions are divided into eight compass directions. Calm has no direction.
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An observed wind speed which falls precisely on the boundary between two divisions (eg 10km/h) will be included in the lower range (eg 1-10 km/h). Only quality controlled data have been used.

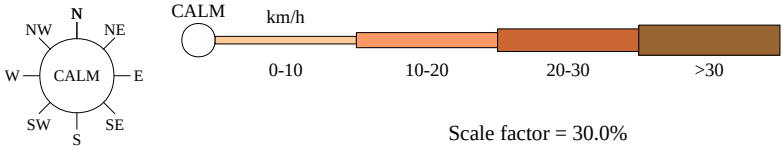
Australian Government
Bureau of Meteorology

Prepared by the National Climate Centre of the Bureau of Meteorology.
Contact us by phone on (03) 9669 4082, by fax on (03) 9669 4515, or by email at webclim@bom.gov.au . We have taken all due care but cannot provide any warranty nor accept any liability for this information.

WIND FREQUENCY ANALYSIS (in km/h)

TOWNSVILLE AERO STATION NUMBER 032040

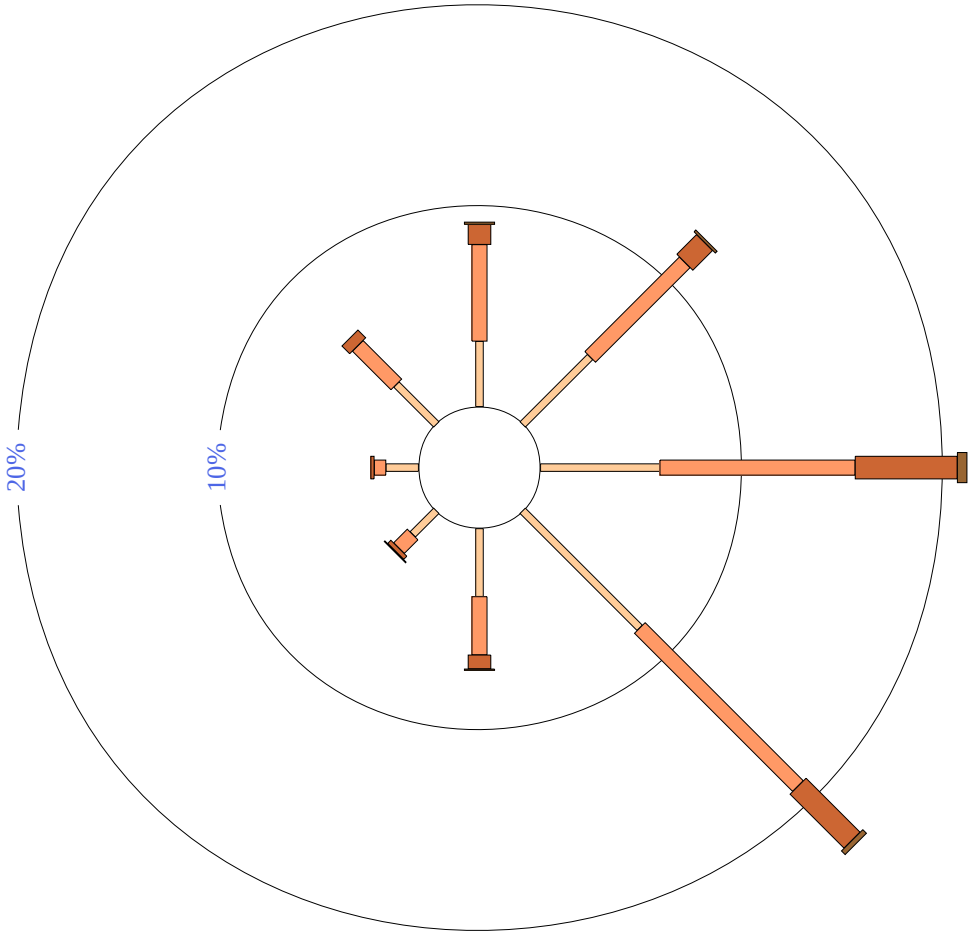
Latitude: -19.25 ° Longitude: 146.77 °



Scale factor = 30.0%

9 am Summer
5706 Total Observations (1940 to 2004)

Calm 15%



Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
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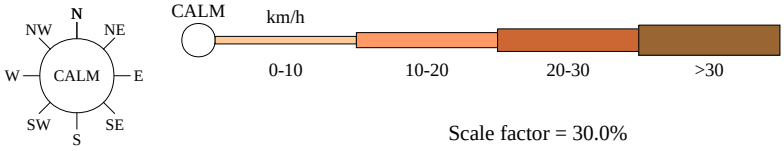
WIND FREQUENCY ANALYSIS (in km/h)

TOWNSVILLE AERO STATION NUMBER 032040

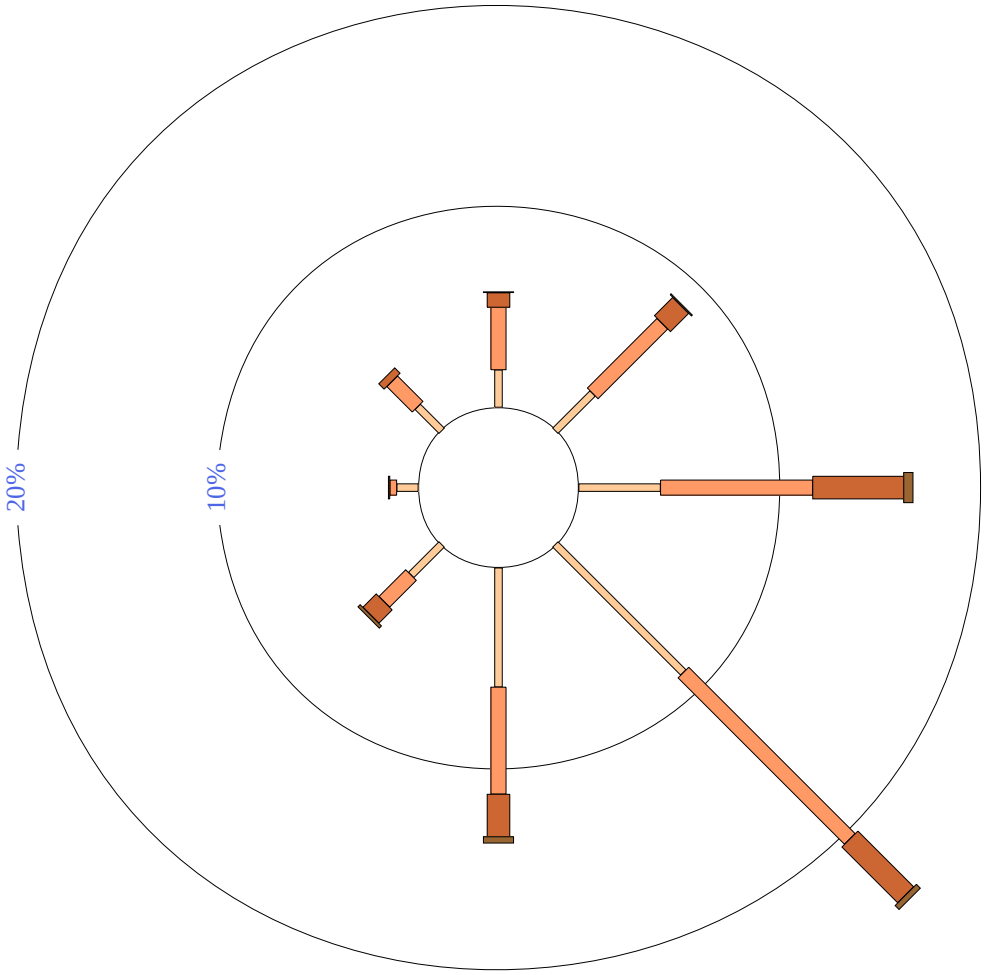
Latitude: -19.25 ° Longitude: 146.77 °



Scale factor = 30.0%

9 am
23064 Total Observations (1940 to 2004)

Calm 20%

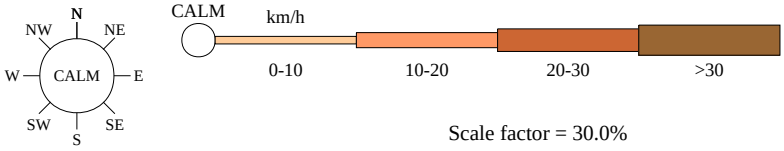


Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
An observed wind speed which falls precisely on the boundary between two divisions (eg 10km/h) will be included in the lower range (eg 1-10 km/h). Only quality controlled data have been used.

WIND FREQUENCY ANALYSIS (in km/h)

TOWNSVILLE AERO STATION NUMBER 032040

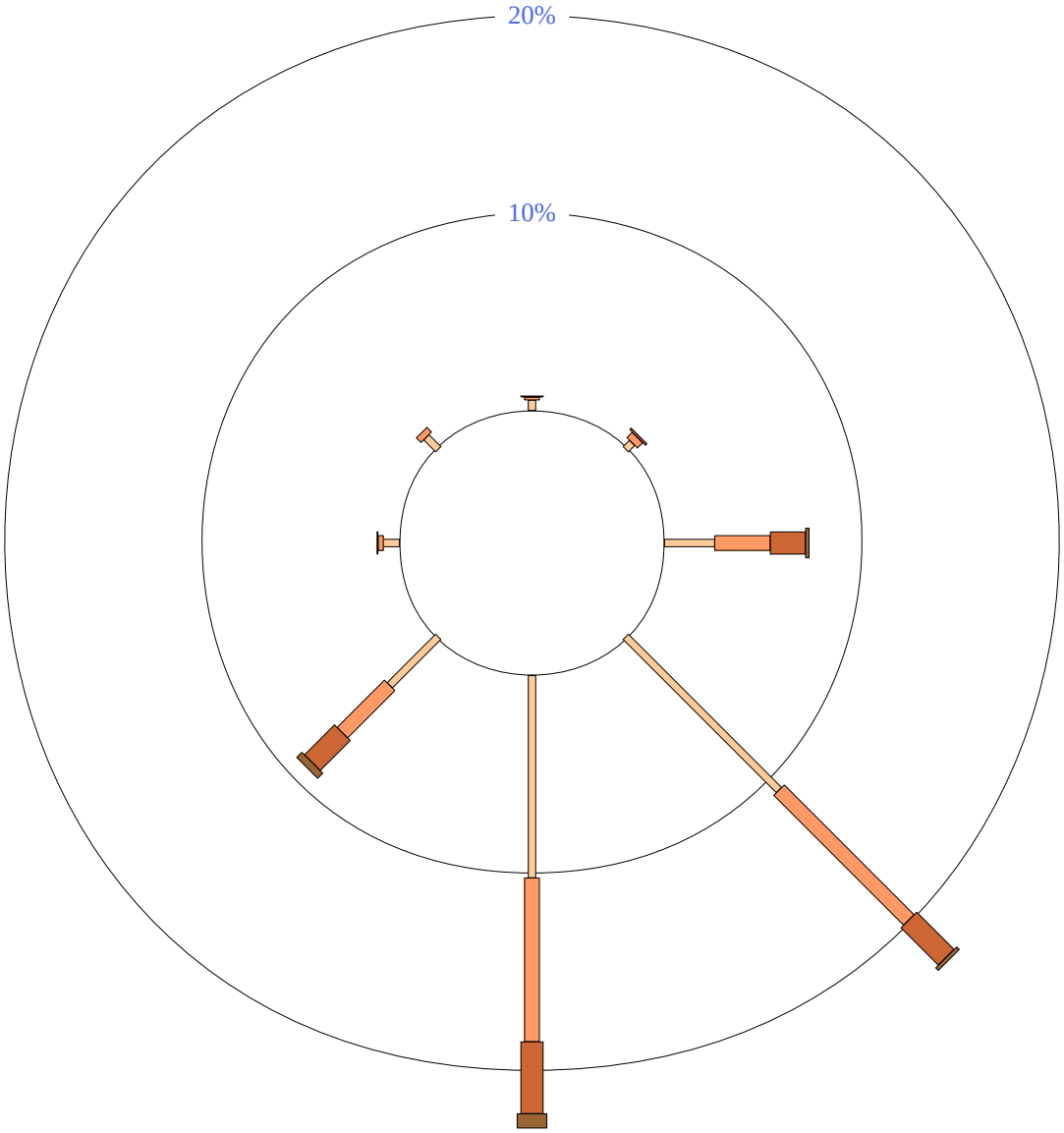
Latitude: -19.25 ° Longitude: 146.77 °



9 am Winter
5780 Total Observations (1940 to 2004)

Scale factor = 30.0%

Calm 33%

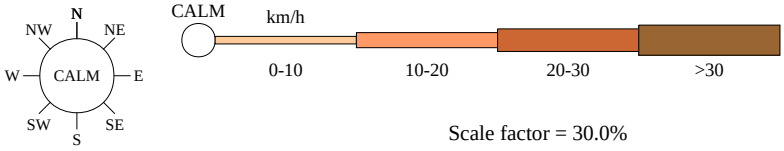


Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
An observed wind speed which falls precisely on the boundary between two divisions (eg 10km/h) will be included in the lower range (eg 1-10 km/h). Only quality controlled data have been used.

WIND FREQUENCY ANALYSIS (in km/h)

TOWNSVILLE AERO STATION NUMBER 032040

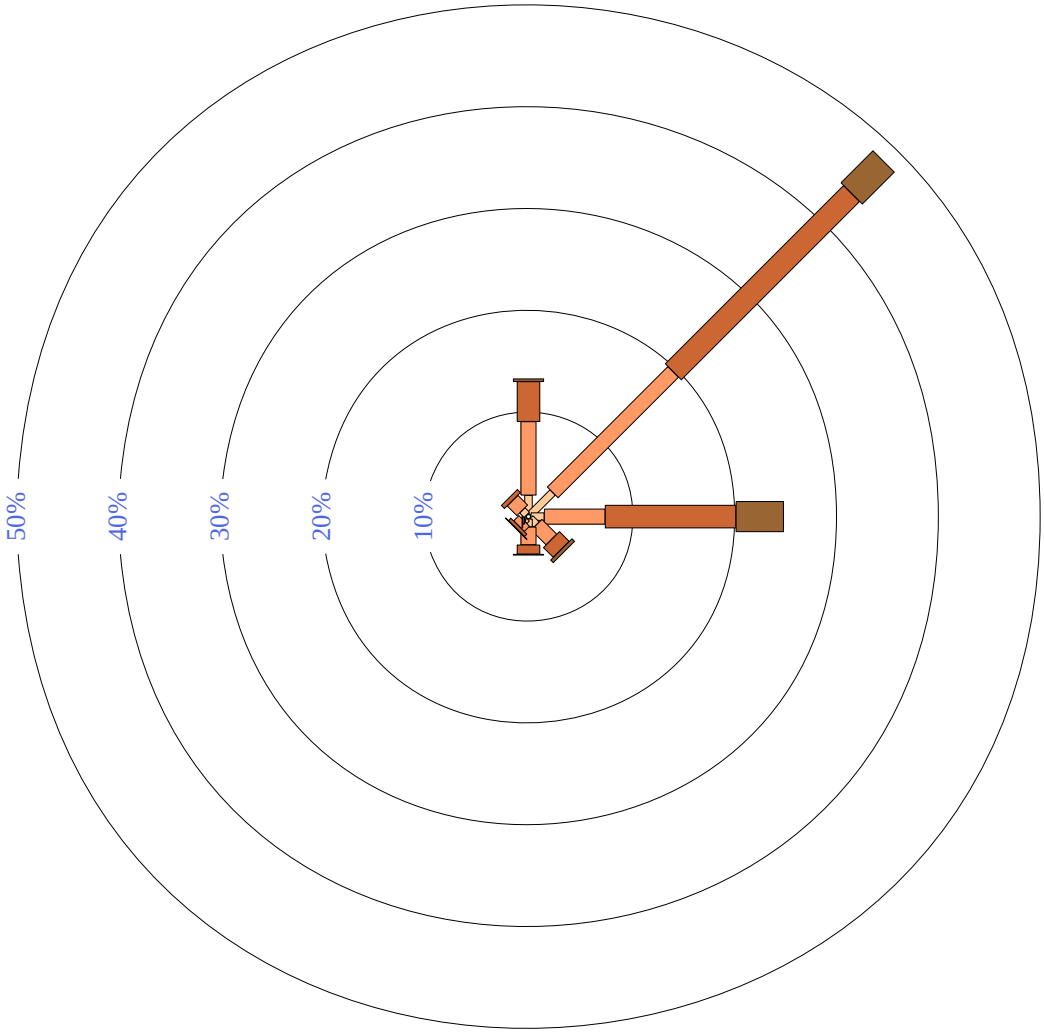
Latitude: -19.25 ° Longitude: 146.77 °



Scale factor = 30.0%

3 pm
23071 Total Observations (1940 to 2004)

Calm 1%



Wind directions are divided into eight compass directions. Calm has no direction.
An asterisk (*) indicates that calm is less than 1% .
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APPENDIX B
STORM SURGE MAP

Storm Surge Map

Townsville

1:70 000

Areas Affected By
Predicted Storm Surge
4 Metres AHD

SHELLEY BEACH
PALLARENDA
TOWN COMMON
BOHLE
ROWES BAY
NORTH WARD
MOUNT ST JOHN
CASTLE HILL
CITY
SOUTH TOWNSVILLE
GARBUTT
WEST END
RAILWAY ESTATE
CURRAJONG
HYDE PARK
HERMIT PARK
MOUNT LOUISA
VINCENT
GULLIVER
MYSTERTON
PIMLICO
HEATLEY
OONOONBA
MUNDINGBURRA
ROSSLEA
AITKENVALE
IDALIA
CRANBROOK
ANNANDALE
CLUDEN
DOUGLAS

N
W
E
S

BALANCE OF MAGNETIC ISLAND
FLORENCE BAY
HORSESHOE BAY
ARCADIA
NELLY BAY
PICNIC BAY

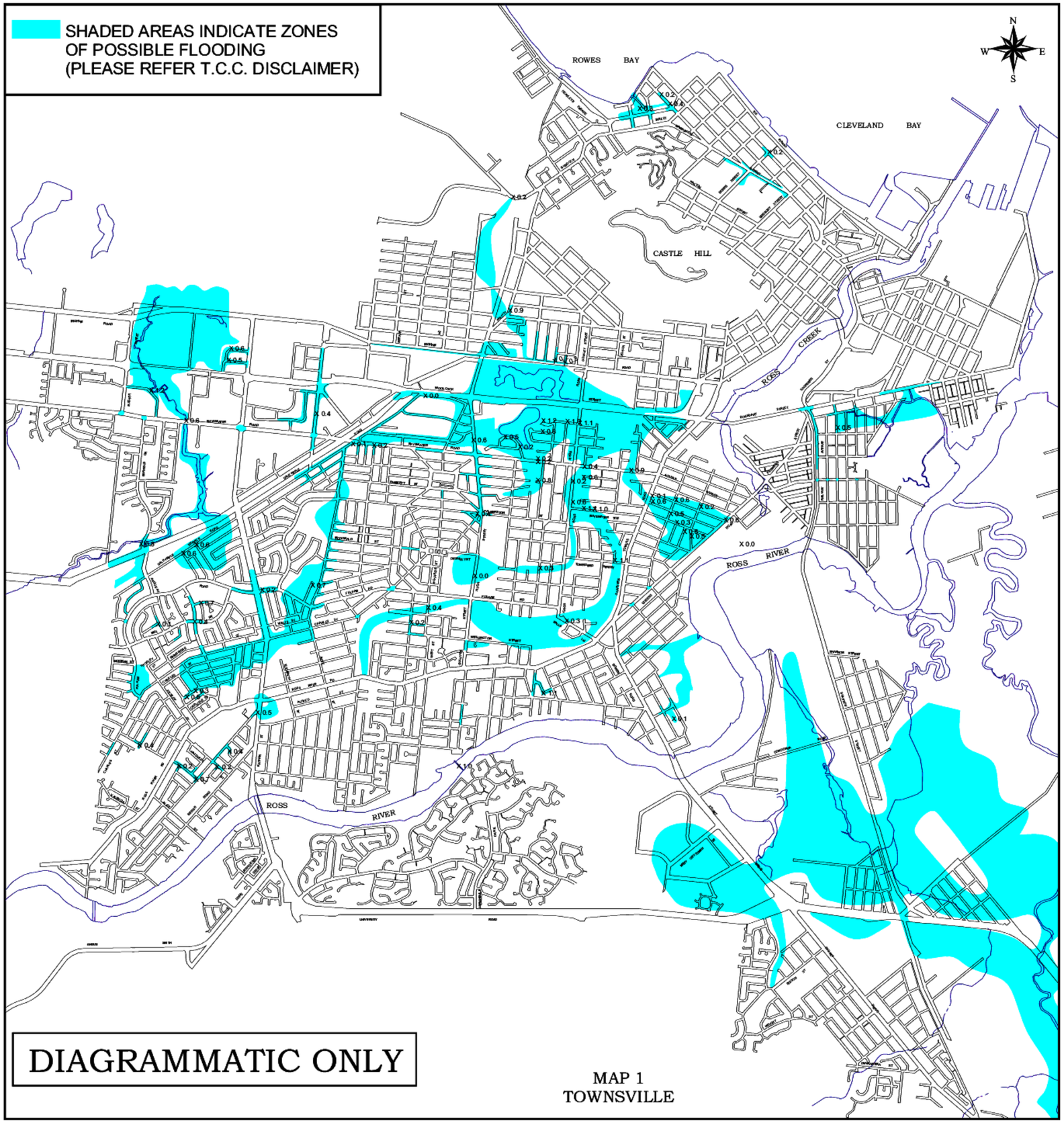
Magnetic Island
1:150 000

CUNGULLA

Cungulla
1:60 000

APPENDIX C
FLOOD MAP

SHADED AREAS INDICATE ZONES OF POSSIBLE FLOODING (PLEASE REFER T.C.C. DISCLAIMER)



MAP 1
TOWNSVILLE

DIAGRAMMATIC ONLY

INFORMATION TO ACCOMPANY FLOOD MAPS

- The information contained on the attached flood maps is gathered from records held by Council.
- Whilst every care has been taken in collecting this information, it should only be used as a guide, it is not complete and should not be used to draw conclusions about flooding on individual properties. You should seek advice from adjoining local residents.
- This warning is given because the collection of the information is often done up to one week after the event and is taken from scum lines and debris buildup on fences together with anecdotal advice from affected residents.
- Council is not confident of the completeness of the maps because:-
  - ☆ No two storms are of the same duration or intensity.
  - ☆ Many short intense storms are relatively local in nature and do not effect a large area.
  - ☆ Tidal influences can effect the efficiency of drains at certain times in some parts of the city e.g. Railway Estate, Hyde Park and Pimlico.
  - ☆ Despite ongoing maintenance, side inlet pits and grates, can become blocked with debris and fail to function properly.
  - ☆ Improvements to the drainage network are continually being undertaken by Council.
- Council endeavours to provide a drainage network comprising 2 components:-
  - ☆ An underground system to accommodate flows up to a 1 in 2 year event in residential areas.
  - ☆ An above ground system for events greater than this e.g. roads, parks, natural watercourse, etc. This means that many of the streets are meant to channel overground water in heavy rain.
- Very severe storms will produce flooding in areas other than those marked.

STORM SURGE

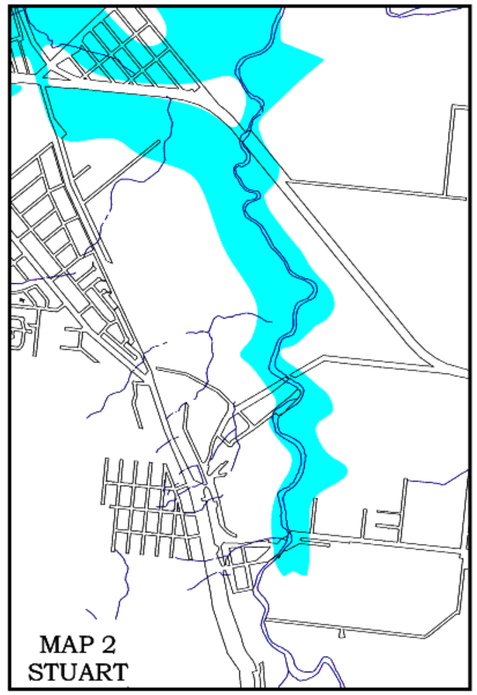
- Storm surge is a rising of the sea level associated with cyclone activity.
- Very limited information is available to enable accurate predictions to be made regarding the extent of storm surge in this city.

Council has produced contour maps, which indicate lower lying areas, which could be subject to storm surge.

Estimates from available information indicate a storm surge to the 4.00m AHD contour equates to about a 1 in 250-year-event.

Council has records of a 3m surge associated with Althea in 1971, however this coincided with a low tide, so it's affect on low-lying areas was limited.

Storm surges associates with Cyclone Justin & Cyclone Sid were of the order of 600mm.



MAP 2
STUART

TOWNSVILLE CITY COUNCIL DISCLAIMER

The ground contours on this drawing have been plotted from a range of maps prepared and collected over many years, the original accuracy of which cannot be verified. Significant changes in surface levels have occurred in various locations since the original surveys were completed.

The information shown on this plan was derived from observations and photographic evidence from the flood event and is not guaranteed as accurate or complete, but has been compiled from the best information available at the time.

This plan does not include information derived from the flood event in Townsville in 1998, because the severity of that event caused a very significant level of unreliabliity in the collected data.

The variability of rainfall and the unreliability of the core data mean that the information on this plan is no more than a guide.

For more particular flooding details, the Council recommends that you discuss the matter with long standing residents of the particular area you are interested in.

SCALE 1:30000

500 0 500 1000 1500 2000 2500 Meters

City of Townsville

TOWNSVILLE CITY AREAS FLOODED MARCH 1990

Date: 10/10/2001
Produced by
Land Information Unit

DRAWING NO: 45095