# Australia Pacific LNG - LNG facility

## Volume 4: LNG Facility

## Chapter 4: Climate and Climate Change Adaptation

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# 4. Climate and climate change adaptation

## 4.1 Introduction

This chapter provides information on the existing climate of Gladstone and explores predictions of climate change in the region where the liquefied natural gas (LNG) facility will be located as part of the Australia Pacific LNG Project (the Project). It describes the potential impacts of climate change on the LNG facility based on current knowledge.

Greenhouse gas emissions, their impacts and mitigation strategies specific to the LNG facility are discussed in detail in Volume 4 Chapter 14.

Sections 4.2 and 4.3 of this chapter address the environmental impact statement (EIS) terms of reference (TOR) Sections 3.1.1 Climate and 3.1.2 Climate change adaptation respectively.

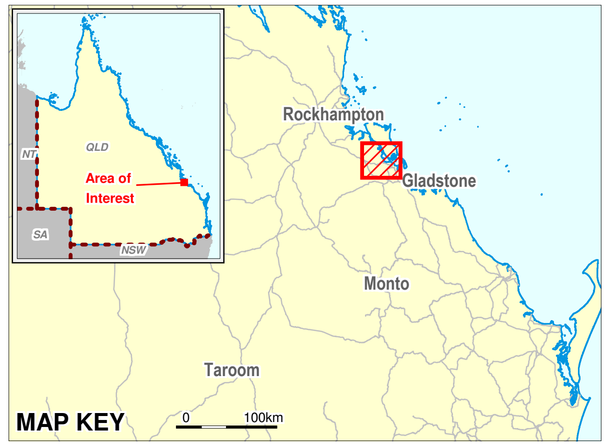
Throughout the Project life, including site preparation, construction, operation, decommissioning and rehabilitation, the Project will be influenced by the climate. Australia Pacific LNG's sustainability principles will be used to develop strategies which ensure that climate induced impacts do not adversely impact the Project's LNG facility. Of Australia Pacific LNG's 12 sustainability principles, as discussed in Volume 1 Chapter 3 the relevant sustainability principles for climate are as follows:

- Minimising adverse environmental impacts and enhancing environmental benefits associated with Australia Pacific LNG's activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the biodiversity values and water resources in its operational areas
- Identifying, assessing, managing, monitoring and reviewing risks to Australia Pacific LNG's workforce, its property, the environment and the communities affected by its activities.

Under these principles, climate and climate change values are reflected by the identification and assessment of climate change risks and the mitigation of impacts on project assets and activities through climate change adaptation strategies.

## 4.2 Climate

Information in this section is for climate in the Gladstone region and is based on long term monitoring information. Meteorological monitoring data from the Bureau of Meteorology (BOM) stations at Gladstone Airport and Radar Hill have been used to characterise long-term wind speed and direction, temperature, atmospheric pressure, rainfall and relative humidity in the Gladstone region. The location of the Gladstone Airport and Radar Hill monitoring stations are illustrated in Figure 4.1. The meteorological parameters that are measured at the Gladstone Airport and Radar Hill monitoring stations are summarised in Table 4.1. Gladstone Airport has been chosen as the most representative monitoring station for the Gladstone and Curtis Island region as it is the closest station to the LNG facility site. This station has been collecting useful parameters for thirteen continuous years (1996 to 2009). The monitoring station at Radar Hill has been used for rainfall averages as it has been operating since 1957 providing the longest record of rainfall data for the Gladstone area.


**LEGEND**

- Bureau of Meteorology monitoring station
- LNG facility development footprint

**Source Information**

Satellite Imagery
Captured by GeoEye-1 on 24 March 2009

Indicative sites dated 27/10/2009
Supplied by Bechtel.

**AUSTRALIA PACIFIC LNG PROJECT**

## Volume 4 Chapter 4
## Figure 4.1 - Location of the Bureau of Meteorology monitoring stations in the Gladstone Region

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**Table 4.1 Summary of BOM monitoring sites and parameters**

| Site | Easting AMG | Northing AMG | Record Period | Parameters |
|---|---|---|---|---|
| Gladstone Airport | 318895 | 7359053 | January 1996 to June 2009 | Half hourly measurements converted to 1 hour averages for :<br>• temperature<br>• relative humidity<br>• wind speed<br>• wind direction<br>• surface air pressure |
| Radar Hill | 323092 | 7360700 | December 1957 to June 2009 | Daily total rainfall |

### 4.2.1 Rainfall

The minimum, average and maximum monthly rainfall over the 52 year period from December 1957 to August 2009 collected at the Radar Hill monitoring station is presented in Table 4.2 (BOM 2009a) and Figure 4.2. The annual average rainfall at Radar Hill is 873.2 mm/year. The maximum and minimum annual rainfall was 1,732mm in 1971 and 432.5mm in 1965 respectively. Consistent with a sub-tropical climate, the summer months are wetter and the winter months are drier. On average, the months of December, January and February account for 47.7% of the annual rainfall while the months of June through September total only 15.0%.

**Table 4.2 Minimum, average and maximum, monthly rainfall at the Radar Hill monitoring station for the period 1957 to 2009**

| Month | Minimum (mm) | Maximum (mm) | Average (mm) | Monthly rainfall distribution (%) |
|---|---|---|---|---|
| January | 0.4 | 640.1 | 143.4 | 16.5 |
| February | 7.2 | 709.8 | 143.4 | 16.5 |
| March | 2.4 | 311.6 | 82.6 | 9.5 |
| April | 3.8 | 250.4 | 46.4 | 5.3 |
| May | 0.2 | 316.4 | 59.6 | 6.8 |
| June | 0.0 | 220.3 | 38.9 | 4.5 |
| July | 0.0 | 170.2 | 34.4 | 3.9 |
| August | 0.0 | 141.6 | 31.2 | 3.6 |
| September | 0.0 | 89.6 | 26.5 | 3.0 |
| October | 0.4 | 276.8 | 62.3 | 7.1 |
| November | 1.4 | 218.1 | 74.2 | 8.5 |
| December | 2.8 | 508.9 | 128.8 | 14.8 |

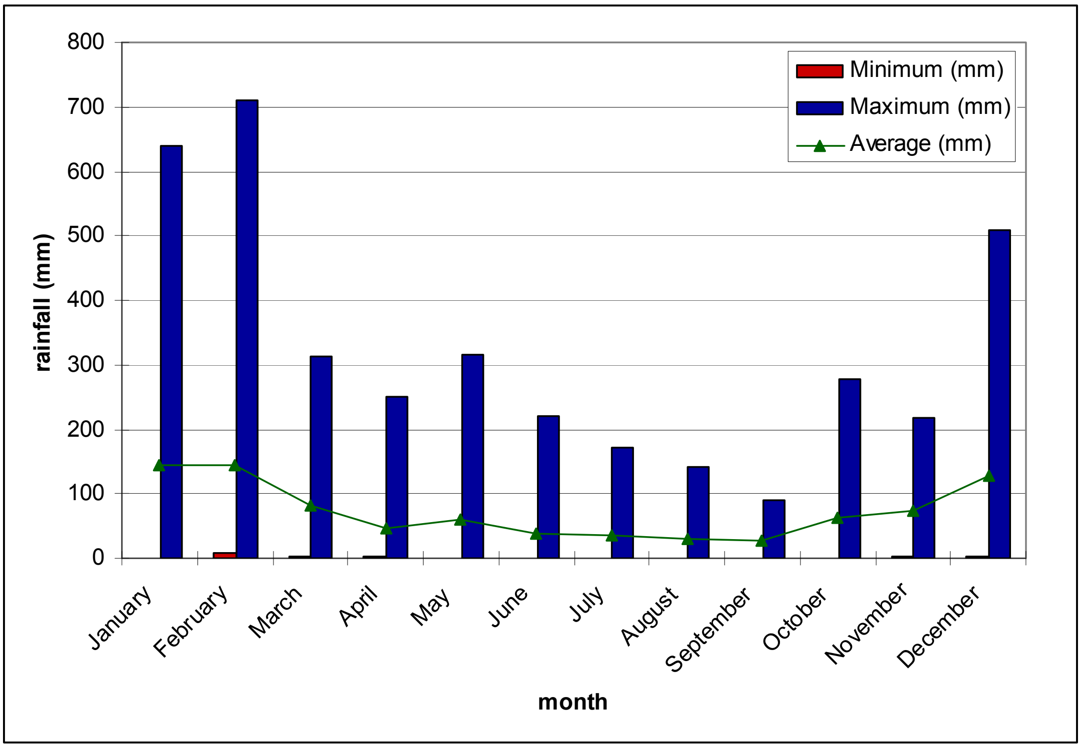



**Figure 4.2 Minimum, maximum and average monthly rainfall at the Radar Hill monitoring station for the period 1957 to 2009**

### 4.2.2 Temperature and solar radiation

The annual average maximum daily temperature recorded at Gladstone Airport for the period 1993 to 2009 is 27.2°C, with an average minimum temperature of 18.0°C. The warmest months are January and February, with average maximum daily temperatures of 30.7°C and 30.5°C, respectively and an average minimum daily temperature of 23.0°C. The coolest month is July with an average maximum daily temperature of 22.9°C and an average minimum daily temperature of 11.7°C.

The range of daily average maximum and minimum temperatures and the highest and lowest daily temperatures by season are presented in Table 4.3 for the period 1993 to 2009 (BOM 2009). The average daily solar exposure is presented in Figure 4.3.

**Table 4.3 Summary of the range in daily temperatures by season as observed at Gladstone Airport for the period 1993 to 2009**

| Season | Average daily temperature (°C) | | Highest temperature (°C) | Lowest temperature (°C) |
|---|---|---|---|---|
| | Maximum | Minimum | | |
| Summer | 30.4 | 22.7 | 39.3 | 16.7 |
| Autumn | 27.8 | 18.7 | 41.0 | 4.9 |
| Winter | 23.3 | 12.5 | 30.8 | 3.5 |
| Spring | 27.3 | 18.3 | 36.7 | 7.2 |

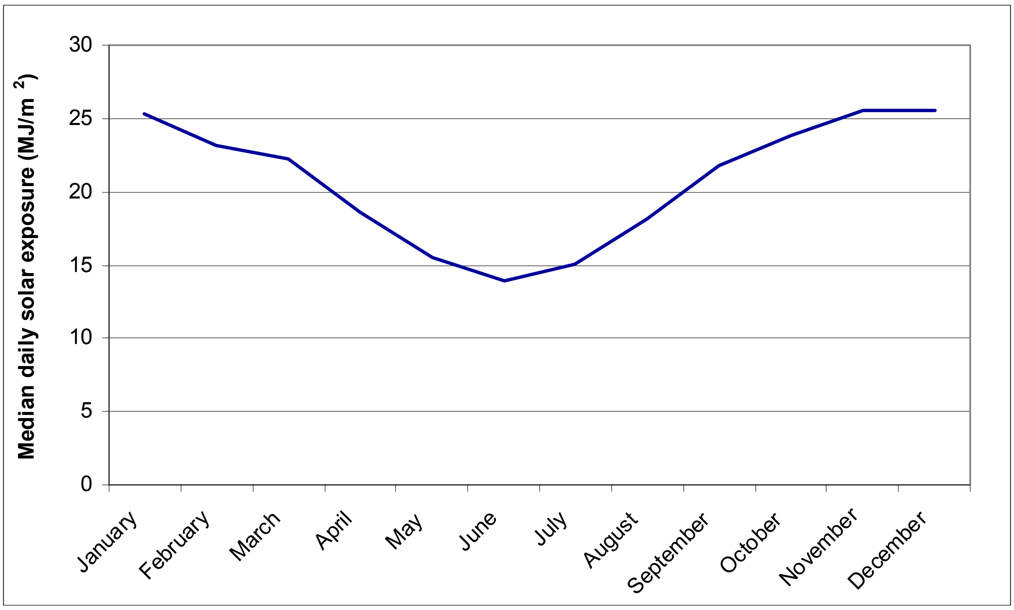



**Figure 4.3 Average daily solar exposure for Gladstone**

### 4.2.3 Relative humidity

The seasonal availability of moisture is another important factor in influencing the climate, by affecting the transfer of heat in the atmosphere through the balance between sensible and latent heat fluxes, and the occurrence of precipitation. Relative humidity is one of several measures used to describe the amount of moisture in the atmosphere, and is the ratio of the actual amount of moisture in the atmosphere to the maximum amount that could be held, at a given temperature.

The monthly averaged relative humidity at 9am and 3pm at Gladstone Airport for the period from 1993 to 2009 is presented in Figure 4.4.

The relative humidity at 3pm has greater seasonal variance than at 9am, with a 16% difference between the lowest and highest months, July and February. The monthly averaged relative humidity at 3pm indicates slightly drier afternoon conditions during the winter months.

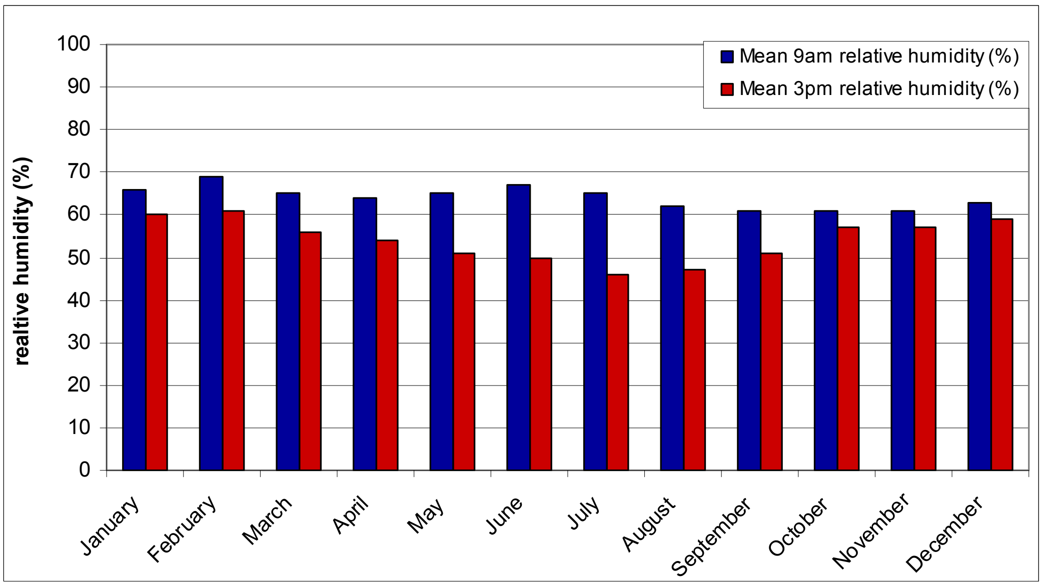



**Figure 4.4 Relative humidity at 9am and 3pm by month for Gladstone between 1993 and 2009**

### 4.2.4 Wind speed and direction

Gladstone's coastal proximity, large deep water harbour and elevated terrain around Mt Larcom provide a number of complexities in the flow of winds across the region.

The annual distribution of wind speed and direction at Gladstone Airport for the period 1 January 1996 to 30 June 2009 is presented as a wind rose diagram in Figure 4.5. The seasonal and diurnal distributions of wind speed and direction at Gladstone Airport for the same period are presented in Figure 4.6 and Figure 4.7. The predominant annual wind flows at Gladstone are from the sector between the northeast and south-southeast with 62% of winds blowing from this direction. These winds tend to dominate the daytime flows and early evening winds, particularly during spring, summer and autumn months. During the cooler late autumn and winter months there is a more pronounced nocturnal (midnight to 6am) drainage flow, with winds blowing from the southern and western sectors between the south-southeast and the west for 50% of the time (autumn and winter only). Variations in seasonal wind patterns are largely influenced at a synoptic scale by the southeast trade winds.

Diurnal variations in wind flows across the Gladstone region are strongly influenced by sea breezes, resulting in a high percentage of easterly daytime winds. The sea breeze generally develops around 10 to 11am each day and is often preceded by a significant shift in wind direction from the more southerly and westerly night time drainage flows.

The distribution of wind speeds at Gladstone Airport for the period January 1996 to June 2009 is summarised in Table 4.4. Wind speeds are summarised for all directions as well as the dominant easterly sea breeze (east-northeast, east and east-southeast). The analysis indicates the sea breezes recorded in the region are predominantly greater than five metres per second. The daily and seasonal variability are further illustrated in the wind roses presented in Figure 4.6 and Figure 4.7.

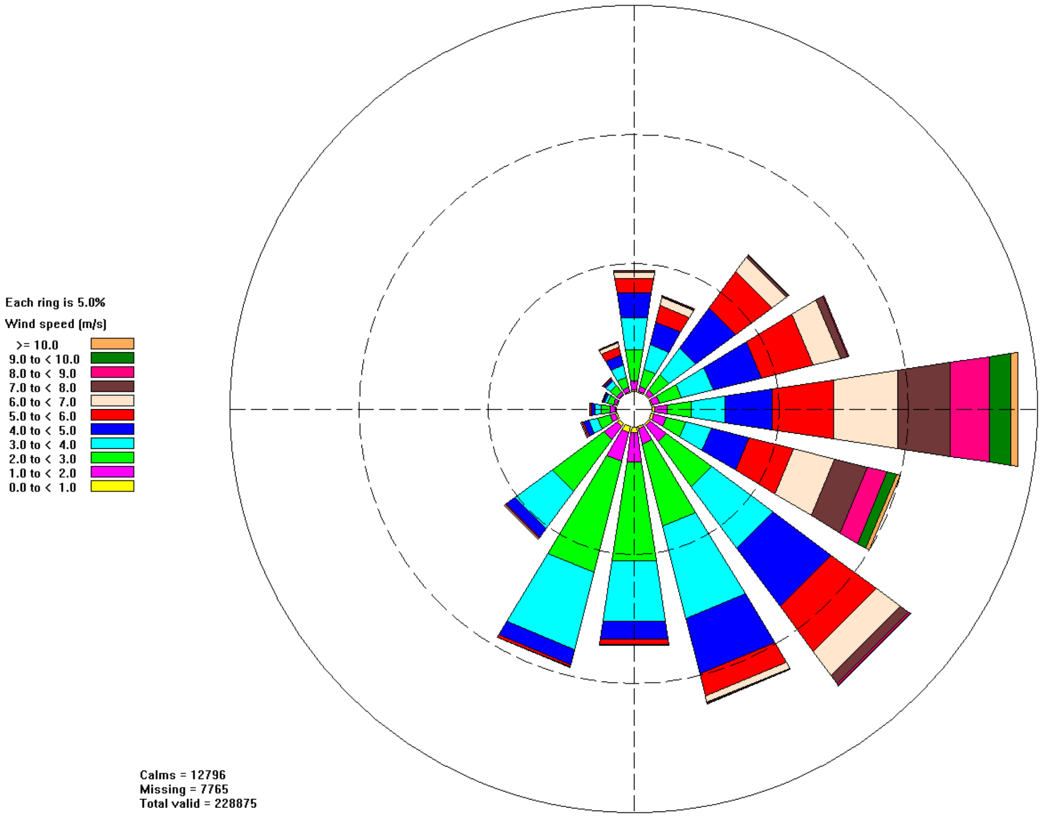



**Figure 4.5 Annual distribution of wind speed and direction for Gladstone (January 1996 to June 2009)**

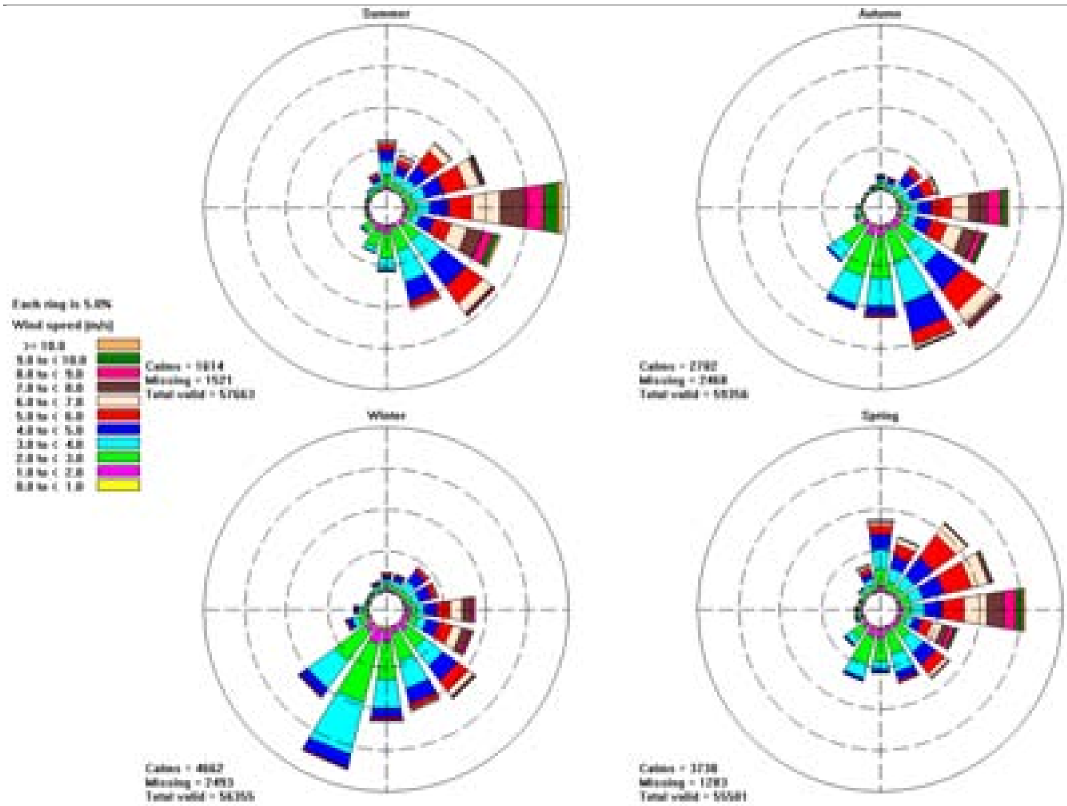



**Figure 4.6 Seasonal distribution of wind speed and direction for Gladstone (January 1996 to June 2009)**

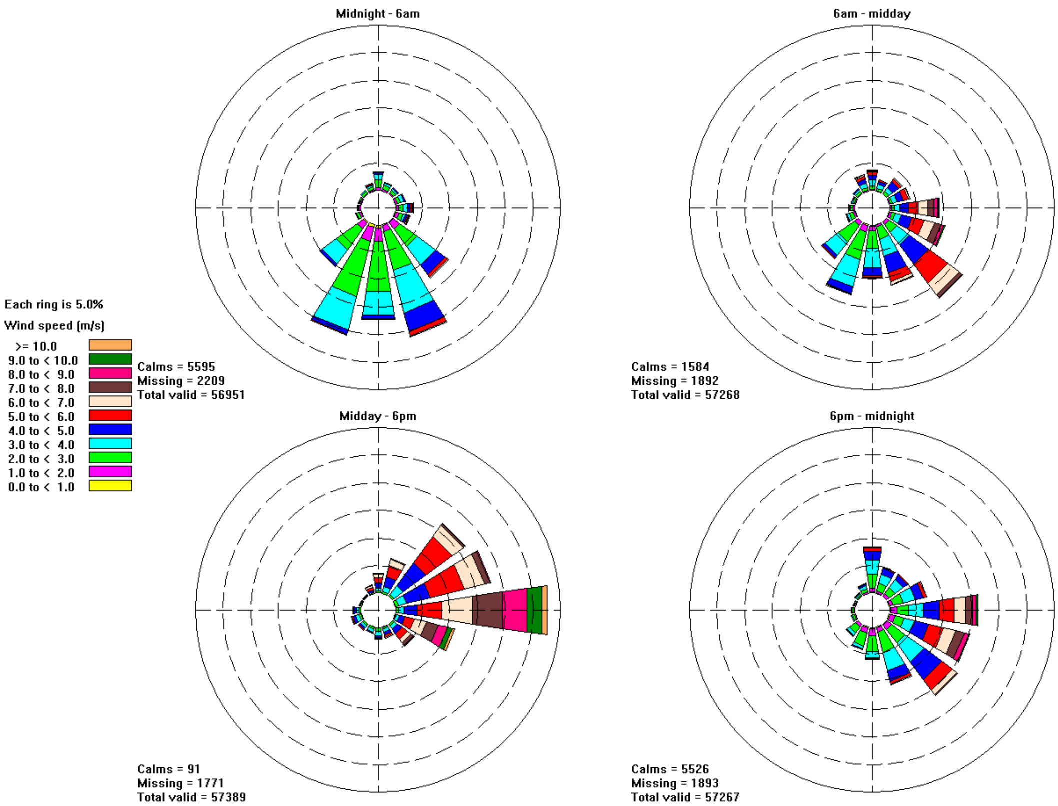



**Figure 4.7 Diurnal distribution of wind speed and direction for Gladstone (January 1996 to June 2009)**

**Table 4.4 Summary of the distribution of wind speeds at Gladstone Airport for all directions and the dominant easterly sea breeze sector (January 1996 to June 2009)**

| Direction | Wind speed | Wind speed range (m/s) | Percent (%) |
|---|---|---|---|
| All | Calm to light | 0 – 1.99 | 8.5 |
| | Moderate | 2.0 – 4.99 | 61.8 |
| | Strong | > 5.00 | 29.6 |
| Easterly sector | Calm to light | 0 – 1.99 | 4.8 |
| | Moderate | 2.0 – 4.99 | 35.8 |
| | Strong | > 5.00 | 59.4 |

Note: Easterly sector refers to the directional zone between east-northeast and east-southeast

### 4.2.5 Surface pressure

The monthly average surface pressure at Gladstone Airport is presented in Figure 4.8. The biannual patterns of peaks and troughs in the monthly averaged surface pressure indicate the months of January and July are generally dominated by low pressure features that are typically associated with either wetter (summer) and/or colder (winter) conditions. The magnitude of change is much less in January than July. The months of April and October are generally dominated by high pressure features typically associated with clear, drier and warmer conditions.

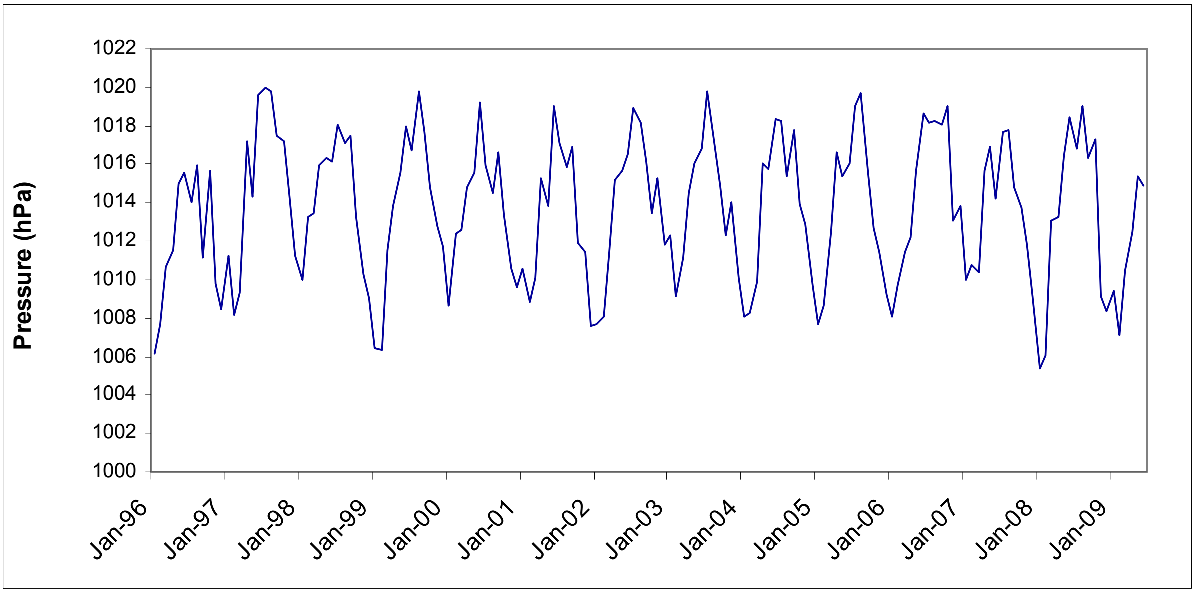



**Figure 4.8 Surface atmospheric pressure for Gladstone**

### 4.2.6 Temperature inversions

Temperature inversions can occur when cold air becomes trapped below air of higher temperatures and with it, pollutants become trapped as the warmer air (commonly referred to as fog) provides a cap and prevents the colder air from dissipating. Inversions usually occur during winter, especially at night, when conditions are conducive for cold air to flow along the ground under otherwise relatively stable and calm conditions without vertical mixing of the air layers.

Information in regards to the prevalence of temperature inversions within the Gladstone region is not available from either the BOM or any Queensland Government website. However, inversions typically occur in Gladstone during winter months, where a distinct layer can be seen over many of the major industrial plants.

### 4.2.7 Climate extremes

#### *Droughts*

The Gladstone area has experienced long-term droughts, defined by a series of very weak wet seasons coupled by low annual flow in the Boyne River, during 1964 to 1967, 1969 to 1970, 1984 to 1985, 1993 to 1995, and 1997 to 2003. The most significant of these droughts between 1997 and 2003 resulted in the implementation of water restrictions for the first time in 2002 to both municipal and industrial customers. Presently, there are no water restrictions in place for consumers within the Lake Awoonga catchment, which includes the city of Gladstone.

As at 30 September 2009, the northern part of the Gladstone local government district is “drought declared” (Department of Primary Industries and Fisheries 2009). This was first declared on 10 January 2007.

#### *Floods*

Most of the region’s recorded flood events are typically due to tropical cyclones activity occurring within the summer months. Tropical Cyclone Beni, which occurred in February 2003 within the Boyne River catchment, brought small-scale flooding to the greater Gladstone area.

#### *Tropical cyclones*

Gladstone is subject to tropical cyclone activity originating from the Coral Sea or the Gulf of Carpentaria.

Tropical cyclones that have crossed the coast in this region can be identified from the database maintained by the BOM.

In the summer months from January to March, tropical cyclones and tropical lows have an influence on Central Queensland weather patterns. These systems often interact with regions of high pressure over southern Australia to produce strong pressure gradients over the whole of eastern Australia.

Figure 4.9 shows all tropical cyclones since 1960 that have tracked within a radius of 250km of Gladstone (shown as the circle in Figure 4.9). The number of tropical cyclones in Figure 4.9 totals 26 and includes tracks of intense cyclones such as tropical cyclone David (1975) resulting in wind gust speeds of 83 knots in Gladstone and caused failure of a breakwater at Rosslyn Bay, 90km north of Gladstone.

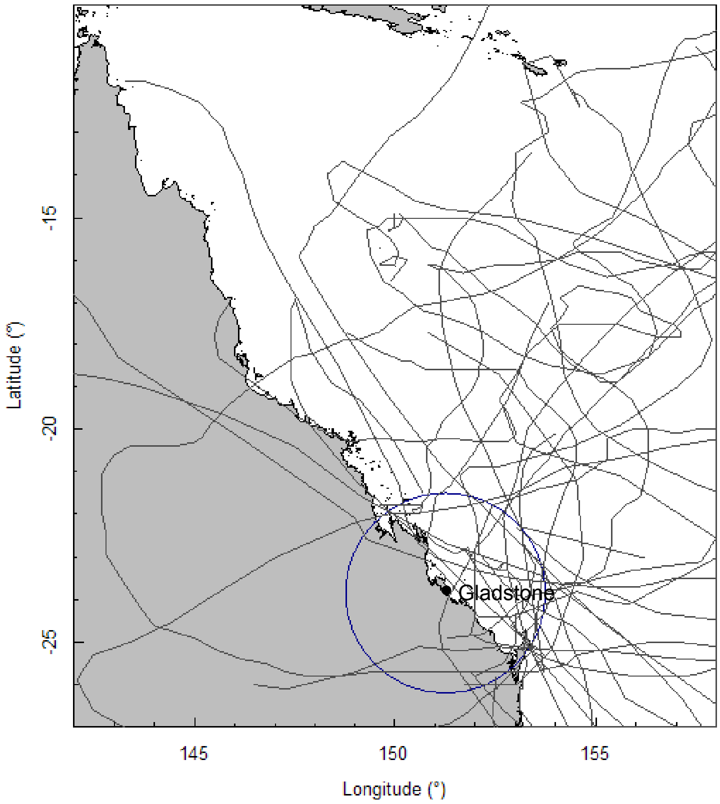



**Figure 4.9 Tropical cyclones (1960 to present) tracking within a radius of 250km of Gladstone**

The tropical cyclones shown in Figure 4.9 are listed in Table 4.5 along with the season and central pressure at the time the tropical cyclone crossed the coast or the minimum central pressure in the track if the system did not reach land. Table 4.5 includes notable events such as tropical cyclones Fiona, Dinah, Emily, and Fran that all passed relatively close to Gladstone and were intense category four or five systems. These storms provide an indication of the vulnerability of the Gladstone region to severe weather systems. However, historically, Gladstone has not been subjected to an intense tropical cyclone landfall.

**Table 4.5 Tropical cyclones within 250km of Gladstone**

| Tropical cyclone name | Season | Landfall or minimum central pressure – Po (hPa) |
|---|---|---|
| | 1962 | 978 |
| Off primary | 1962 | |
| | 1962 | 1002 |
| | 1962 | 996 |
| | 1962 | 1009 |
| Dinah | 1966 | 945 |
| (Unnamed) | 1969 | 1004 |
| Dora | 1970 | 993 |
| Fiona | 1970 | 965 |
| Althea | 1971 | 952 |

| Tropical cyclone name | Season | Landfall or minimum central pressure – Po (hPa) |
|---|---|---|
| Daisy | 1971 | 959 |
| Emily | 1971 | 985 |
| Wanda | 1973 | 998 |
| David | 1975 | 969 |
| Beth | 1975 | 996 |
| Dawn (secondary) | 1975 | 988 |
| Watorea | 1975 | 970 |
| Kerry | 1978 | 995 |
| Paul | 1979 | 992 |
| Simon | 1979 | 950 |
| Cliff | 1980 | 990 |
| Elinor | 1982 | 935 |
| Lance | 1983 | 992 |
| Pierre | 1984 | 998 |
| Fran | 1991 | 985 |
| Rewa | 1993 | 920 |

Source: (BOM tropical cyclone database (BOM 2009b)

### *Storm surge and storm tide*

When tropical cyclones track over the ocean their extreme winds and low pressure result in an elevated dome of water that travels as a long period wave. As this surge approaches the coastline it can be affected by the seabed slope and coastline shape causing it to amplify in height. When this surge is combined with the normal tide on the day at the landfall location it becomes a storm tide.

Tropical cyclone tracks are erratic and difficult to predict in advance, although research and technology are leading to improvements in this capability and so severe weather warnings are also improved and consequently mitigation measures are more reliable.

Less intense tropical cyclone activity and extra tropical low pressure systems produce surges that would most likely go unnoticed when combined with the lower tide ranges. Nevertheless, these can alter the normal currents and water levels from their predicted or forecast values. The occurrence of a major storm tide in Gladstone is primarily dependent on tropical cyclone track direction, forward speed, the radius to maximum winds and the wind strength due to the cyclone central pressure, coupled with the state of the tide at the time the cyclone makes landfall.

Storm tide statistics studies have been undertaken for most of the Queensland coastline. Figure 4.10 summarises storm tide heights above the highest astronomical tide (HAT) for selected locations along the east coast and Gladstone is highlighted (orange border). Each coloured vertical bar corresponds to a nominated average return period. Gladstone is one that has a higher storm tide risk profile and the vulnerability of the LNG facility to inundation will depend on the design level of the LNG facility and reclamation areas.

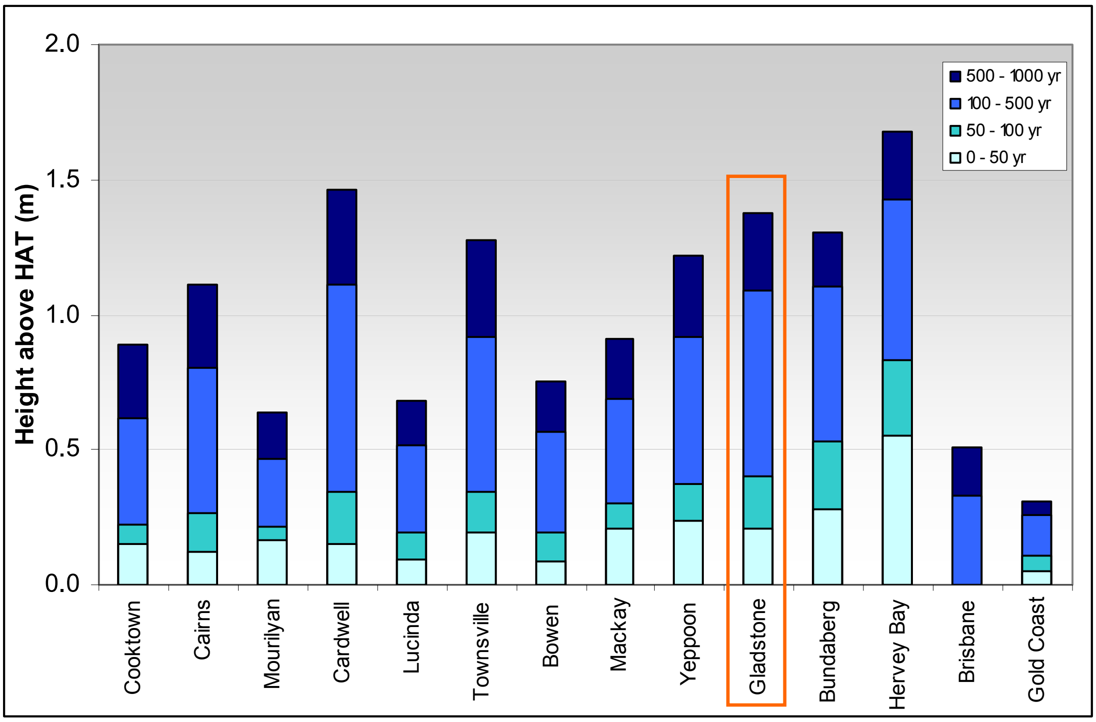



**Figure 4.10 Storm tide height above HAT for Queensland east coast locations**

### 4.2.8 Impacts of weather patterns and extremes of climate on project

When designing and constructing the LNG facility particular regard has to be given to the historical weather patterns and climate extremes.

The Gladstone region has a sub-tropical climate, which is characterised by a moderately distinctive wet and dry season, high temperatures and humidity.

Historical weather patterns show that the chance of rainfall, thunderstorms and cyclones are more prevalent through the summer months. Construction methods and scheduling will be implemented in a way that ensures personnel and the environment are protected. Methods and timing of construction include ensuring erosion and sediment control measures and stormwater management measures are appropriately constructed and sized to deal with the anticipated amount of rainfall and appropriate shelter is available for the workforce in instances of severe weather. Appropriate protection will be given to personnel to protect them from the weather.

Overall, Gladstone does not experience a typical weather pattern that will restrict construction or operation. The inclusion of appropriate measures, such as site stormwater management systems, and waste containment systems will ensure personnel and the environment are protected.

## 4.3 Climate change

Although Australia Pacific LNG recognises there are inherent uncertainties surrounding predicted impacts, this section describes the LNG facility's vulnerabilities to climate change and possible adaptation.

### 4.3.1 Methodology

A climate change adaptation risk assessment was conducted to assess how alterations to weather patterns and rising sea level has the potential to impact the LNG facility. The climate change predictions from Commonwealth Scientific and Industrial Research Organisation (CSIRO), which has published the most comprehensive data to date, was compiled ahead of a climate change adaptation risk assessment workshop. Attendees at the workshop included key decision makers on the Project, engineers and environmental specialists. Risks identified were analysed and assessed using the Australia Pacific LNG risk matrix (refer Volume 1 Chapter 4) and then screened for identification of mitigation measures. Existing measures were explored during the risk assessment process and further mitigation actions were brought forward to be included into the design criteria and operating strategies.

The climate change risk assessment process was conducted, as required by the EIS TOR Section 3.1.2 Climate change adaptation, to assess the project's vulnerabilities to climate change and describe possible and preferred adaptation strategies. The climate projections used in the risk assessment are provided in Section 4.3.2. Section 4.3.3 provides the risk mitigation measures which treat the identified risks and have been incorporated into the design criteria and operating strategies.

Effective climate change adaptation requires an awareness of the risks posed by climate change, and an understanding of the relative significance of those risks. Project vulnerabilities have been assessed through a risk assessment process in line with the risk management standard AS/NZS 31000 and the Australian government publication Climate Change Impacts & Risk Management – A Guide for Business and Government (Australian Greenhouse Office 2006).

Australia Pacific LNG's cooperative approach to adaptation to climate change is described in Section 4.3.4.

### 4.3.2 Climate projections

To assess the LNG facility's vulnerability to climate change, predictions have been gathered from the CSIRO, and the Queensland Government.

CSIRO projections are available for years 2030, 2050 and 2070. As the Project is estimated to operate for 30 years, starting in 2014 for Train 1, making projections for 2050 are the most appropriate scenario to use. Where available 2050 projections have been used but where predictions are published only for the 2030 and 2070 time horizons, both have been reported and utilised in the assessment process.

Changes in the climate of Australia by 2030 do not vary greatly from one emission scenario to another. However changes by 2070 are heavily dependent on the emission scenario because the scenarios are highly divergent beyond 2030. The best projections for the region have been sought, however, the models have not all been based upon the same emissions scenarios. The emissions scenarios discussed in this chapter are A1B, B1 and A1FI (CSIRO 2008) where scenario:

- B1 refers to a global agreement bringing about dramatic reductions in global emissions
- A1B refers to mid range levels of global emission
- A1FI refers to high levels of emissions, in line with recent global emissions.

#### *Temperature change*

The information in Table 4.6 summarises the predicted mean temperature change for Rockhampton (in the Gladstone region). The $50^{th}$ percentile temperature is the most likely outcome on a probability distribution, while the range describes the confidence interval. By 2050 the predicted increase in average temperature is 1.4°C which has been chosen as the basis for determining climate change impacts in the risk assessment. In order to predict the average temperature in 2050 the predicted mean temperature change of 1.4°C is added to the historical range of temperatures.

**Table 4.6 Mean degrees temperature change (A1B predictions, 50th percentile and range) (CSIRO 2009)**

| | 2030 | | | 2050 | | |
|---|---|---|---|---|---|---|
| | °C | Range | | °C | Range | |
| Annual | 0.8 | 0.6 | 1.2 | 1.4 | 1.0 | 2.0 |
| Dec-Feb | 0.8 | 0.5 | 1.2 | 1.4 | 0.9 | 2.0 |
| Mar-May | 0.8 | 0.6 | 1.2 | 1.4 | 1.0 | 2.0 |
| Jun-Aug | 0.8 | 0.6 | 1.2 | 1.4 | 1.0 | 2.0 |
| Sep-Nov | 0.8 | 0.6 | 1.2 | 1.4 | 1.0 | 2.0 |

### *Precipitation change*

The information in Table 4.7 summarises the predicted percentage of rainfall change for Rockhampton, (in the Gladstone region). The 50th percentile temperature is the most likely outcome on a probability distribution, while the range describes the confidence interval. By 2050 the predicted decrease in rainfall is 5.4% annually, which has been chosen as the basis for determining climate change impacts in the risk assessment. In order to predict the average precipitation in 2050 the predicted mean precipitation change of 5.4% is subtracted from the historical range of precipitation (CSIRO 2009).

An increase in daily precipitation intensity (rain per rain day) and the number of dry days is likely. The future precipitation regime will have longer dry spells interrupted by heavier precipitation events. Changes to extreme events would have the potential to increase erosion and flood frequency, with implications for agriculture, forestry, river flow, water quality, and the design standards of infrastructure. Drought occurrence is projected to increase over most of Australia (CSIRO 2007).

**Table 4.7 Mean percentage rainfall change (A1B predictions, 50th percentile and range) (CSIRO 2009)**

| | 2030 | | | 2050 | | |
|---|---|---|---|---|---|---|
| | % | Range % | | % | Range % | |
| Annual | -3.2 | -10.1 | 4.2 | -5.4 | -17.2 | 7.1 |
| Dec-Feb | -1.8 | -9.9 | 7.0 | -3.1 | -16.8 | 12.0 |
| Mar-May | -4.9 | -14.9 | 7.2 | -8.4 | -25.3 | 12.2 |
| Jun-Aug | -1.7 | -10.8 | 8.8 | -2.9 | -18.3 | 15.0 |
| Sep-Nov | -5.3 | -13.0 | 4.1 | -9.0 | -22.2 | 7.0 |

### *Sea level rise*

The information in Table 4.8 summarises the predicted rise in global sea levels. Global climate models indicate mean sea level rise on the east coast of Australia may be greater than the global mean sea level rise. The high-end risk shown in the table includes some new evidence on icesheet dynamics published since 2006 (Department of Climate Change 2009).

The mid-level sea level rise of 0.47m by 2070 has been chosen as the basis for determining climate change impacts in the risk assessment, representing conservative estimate for the project lifespan 2050. In order to predict the global mean sea level in 2070 the predicted global mean sea level change of 0.47m is added to the historical global mean sea level.

Scenario 3 (high end) was developed considering the possible high end risk identified in the Intergovernmental Panel on Climate Change's (IPCC's) fourth assessment report for 2020 and 2050 and includes some new evidence on icesheet dynamics (Department of Climate Change 2009).

**Table 4.8 Global average sea rise scenarios (Department of Climate Change, Nov 2009)**

| Year | Scenario 1 (m) | Scenario 2 (m) | Scenario 3 (m) |
|---|---|---|---|
| | **B1** | **A1FI** | **High end** |
| 2030 | 0.132 | 0.146 | 0.200 |
| 2070 | 0.333 | 0.471 | 0.700 |

As shown in Figure 4.11 an increase in sea level causes a non-linear increase in frequency of high sea-level events (Department of Climate Change 2009). For the Gladstone region, at a 0.1m sea level rise, the frequency of high sea-level events increases two fold. At a 0.5m sea level rise the frequency of high sea-level events increases by 1,000 times.

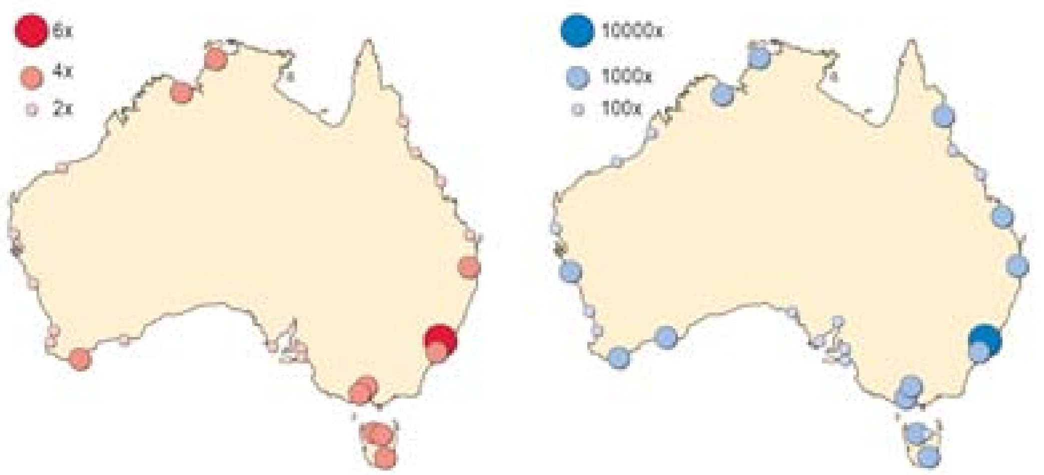



Figure 2.17 Estimated increases in the frequency of high sea-level events (indicated by the diameters of the circles), caused by sea-level rises of 0.1 metres (left) and 0.5 metres (right) showing the increasing frequency of events for rising sea levels is not linear.
Source: ACE CRC 2008

**Figure 4.11 Estimated increases in high sea-level events (0.1m and 0.5m) (Department of Climate Change 2009)**

A discussion on the potential impacts associated with storm tide at the proposed LNG facility site is provided in Section 3.3.

### *Storm surge and storm tides*

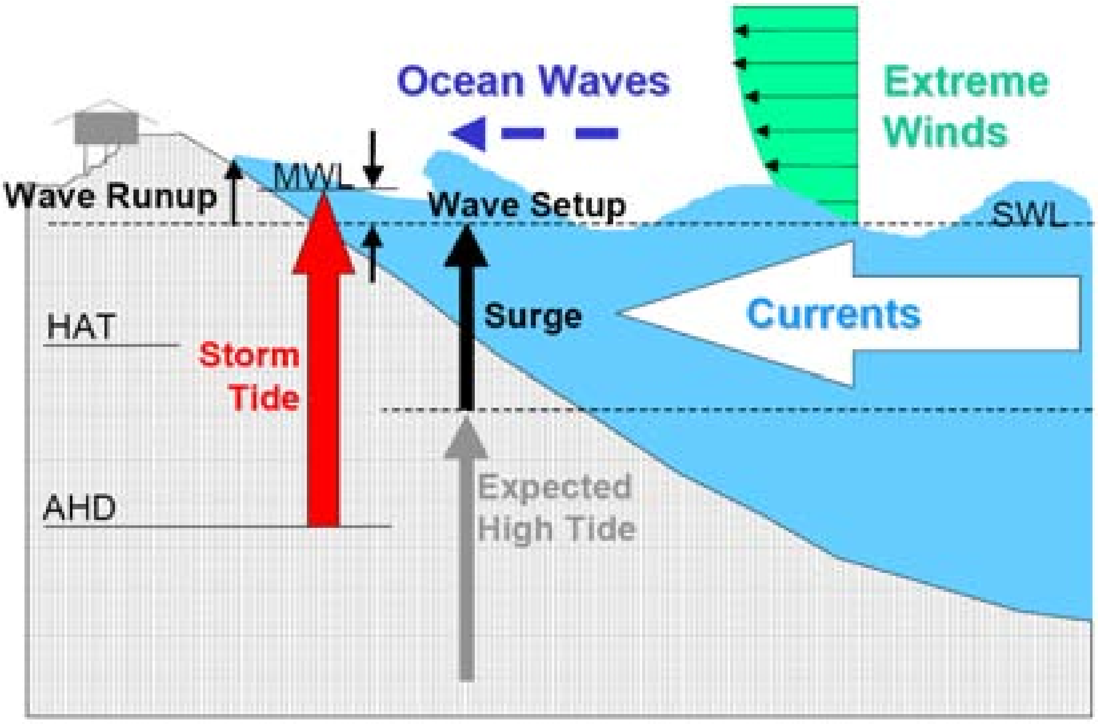
A study conducted by the Queensland government to determine the frequency of occurrence of storm tides for open waters in Queensland, including Gladstone, predicted elevated water levels for both present conditions and those where the implications of climate change are represented (Department of Natural Resources and Mines (DNRM) 2004). Storm surge levels are not total water levels – total water levels consist of other components such as wave setup and run up associated with a wave zone, as shown in Figure 4.12.

For open waters in Gladstone (Auckland Point) the 2004 study predicted storm tide levels as provided in Table 4.9. This study assumed the climate change scenarios based on a 50 year planning period.

The report provides results based on the combination of three scenarios, being a mean sea level rise of 300mm by 2050, an increase of 10% in frequency of tropical cyclones, and a pole ward shift of 1.3° and increase of 10% in maximum intensity.

**Table 4.9 Storm tide average recurrence interval (ARI) for Gladstone (DNRM 2004)**

| Location | Storm tide ARI (m Australian height datum) | | | | | |
|---|---|---|---|---|---|---|
| | 100 year | | 500 year | | 1000 year | |
| | 2004 | Climate change | 2004 | Climate change | 2004 | Climate change |
| Gladstone | 2.82 | 3.33 | 3.51 | 4.18 | 3.80 | 4.41 |




Storm tide = astronomical tide + storm surge + wave setup + waves
(Queensland climate change and community vulnerability to tropical cyclones ocean hazard assessment – Stage 1, 2001)

**Figure 4.12 Storm tide, wave setup, wave run up (Queensland Government 2001)**

To estimate total water levels in Gladstone for a 100 year ARI storm tide event, the 2004 study was used as a starting point. Wave heights are dependent on water depth, fetch, and wind duration, but if it is assumed water depths are similar to sections of the Western Basin then significant wave heights can be estimated for a 1 in 50 year wind speed and combined with the storm tide. Table 4.10 summarises components of the indicative total water level.

Storm tide, an allowance for wave setup and crest level combine to give the total water level of 5.6m above Australian height datum (AHD). Wave crest level is derived from the significant wave height and contains some profile asymmetry associated with the highest waves.

**Table 4.10 Total storm tide water level estimate**

| Significant wave height | 1 in 100 year | |
|---|---|---|
| Storm tide (incl. climate change)(Qld. Govt 2004) | 3.33 | m AHD |
| Wave setup allowance | 0.4 | m |
| Wave crest (1 in 50 year AEP) | 1.8 | m |
| Total water level | 5.6 | m AHD |

### Humidity

The information in Table 4.11 summarises the predicted percent of relative humidity change for Brisbane (which is the closest coastal location to the Gladstone region for which this information is available). The $50^{th}$ percentile humidity change is the most likely outcome on a probability distribution, while the range describes the confidence interval. By 2070 the predicted change in average humidity is -0.2% which has been chosen as the basis for determining climate change impacts in the risk assessment. In order to predict the average humidity in 2070 the predicted percent of relative humidity change of -0.2% is added to the historical range of relative humidity.

**Table 4.11 Percent relative humidity change for Brisbane (CSIRO 2009)**

| | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|
| | % | Range (A1B) | | % | Range (A1F1) | |
| Annual | -0.1 | -1.1 | 0.9 | -0.2 | -3.6 | 3 |

### Cyclones

There are three hazardous features of tropical cyclones – strong winds, intense rainfall and induced ocean effects including extreme waves. Climate change may affect the frequency, severity, unpredictability and position of cyclones. There is some indication that precipitation rates may increase by 20% to 30% during tropical cyclones. Changes to precipitation and extreme waves have been discussed in Section 4.3.2

Projections of tropical cyclones in the Australian region are limited however the available studies suggest there maybe an increase in the number of tropical cyclones in the more intensive categories (categories 3-5) but a possible decrease in the total number of cyclones.

A preliminary study on cyclonic and non-cyclonic wind estimated the wind hazard related with climate change. For cyclonic winds, the northwest coast around Port Hedland, the northern part of the Northern Territory, and the northeast coast between Cairns and Townsville are the most sensitive regions to changes in intensity and frequency of cyclonic winds. (Department of Climate Change 2009)

### Bushfires

Projections of fire risk have been conducted in the vicinity of the Gladstone region (Rockhampton) for 2020 and 2050. Fire risk is a rating calculated from observations of temperature, relative humidity and wind speed combined with an estimate of the fuel state to predict the fire behaviour (Lucas et al. 2007). Changes in the risk of fire are summarised as percentile differences from 1974 to 2007 levels in Table 4.12. Projections for 2050 indicate that when the global warming scenario is low, the fire risk raises by 5% on 1974 to 2007 levels. When the global warming scenario is high, the fire risk increases by 140% on 1974 to 2007 levels. These percentage changes are relative to very small baseline frequencies, where at present (1974 to 2007) the annual average number of extreme fire danger days at Rockhampton is 0.6 days and in a high global warming scenario the prediction is 1.5 days.

One simulation, denoted " CCAM Mark2", was driven by boundary conditions from the CSIRO Mark2 coupled ocean-atmosphere model, while the other simulation, denoted " CCAM Mark3", was driven by boundary conditions from the CSIRO Mark3.0 model. Data from these simulations were then used to generate changes in the relevant meteorological variables per °C of global warming, including changes in daily weather variability. These changes were multiplied by global warming values consistent with the IPCC's fourth assessment report for 2020 and 2050 and then applied to the daily weather records for the 1974 to 2007 period for 26 sites in southern and eastern Australia (CSIRO 2008).

**Table 4.12 Percent change in fire risk from average 1974 to 2007 levels (CSIRO 2008)**

| Global Warming Scenario | 2020 (%) | 2050 (%) |
|---|---|---|
| Low (Mark2) | 5 | 5 |
| High (Mark3) | 30 | 140 |

### 4.3.3 Climate change adaptation

The following sections describe the climate change risk mitigation measures that have been incorporated into the design criteria and operating strategies. Alternative and further adaptation measures have been considered and documented in the risk assessment process and will be taken forward into the design phases of the Project. Climate change risk will continue to be reviewed during project implementation.

#### *Elevated temperatures*

Design for flexibility in operating temperatures is included in the design basis for the LNG facility. It is proposed that:

- Inlet air cooling be used for the gas turbines
- Shading and air-conditioning of work areas, critical plant and equipment, ferries and waiting areas be included in the design of the LNG facility
- Work procedures for hot conditions be included in the operating strategy to protect personnel and equipment from exposure to elevated temperatures.

These measures, which are to be included in the design of the facility, assist in adapting to climate change. Further alternative adaptation measures to be considered include higher temperature conditions when designing equipment, such as air coolers.

The residual risk to the LNG facility was determined to be low. This relates to the potential for higher temperatures to affect LNG production efficiencies.

#### *Precipitation change*

The change in precipitation intensity and frequency is not expected to significantly impact operations of the LNG facility due to allowance for flooding in the existing design. Risk of flooding as a result of change in precipitation is considered to be relatively minor. Similarly, all water for the operations, including potable water and process water, will be sourced from the desalination of sea water, from stormwater collected on the site, and from the inlet air chilling process. As rainwater recovery is not essential for water supply the change in precipitation is not considered to have a large impact on operations.

These measures, which are included in the design of the facility, assist in adapting to climate change.

The residual risk to the LNG facility was determined to be negligible.

### Humidity

The impacts of humidity change are considered to be low because the decrease is still well within the design range of the LNG facility equipment.

The residual risk to the LNG facility was determined to be negligible.

### Sea level change

The LNG facility has been designed with sufficient elevation above the sea level rise estimates.

Additionally, the LNG plant design level (6m AHD) is greater than the calculated predicted extreme water level (5.6m AHD). The jetty design level is approximately 7m AHD, with the loading arm for the facilities at higher elevation still.

Contingency plans for continuing operation when access from the mainland is interrupted will be implemented similar to offshore facilities.

These measures, which will be included in the design of the LNG facility assist in adapting to climate change.

The residual risk to the LNG facility was determined to be low.

### Coastal erosion

Increased coastal erosion may arise from a combination of more high intensity weather events, storm surge, extreme waves, more intense rainfall, wind action and higher sea level.

The LNG facility is protected from coastal erosion by the natural rocky coastline. Within the foreshore area at the site are mud flats which have the potential to be impacted by coastal erosion. Sufficient distance from the shoreline and elevation of foundations has been allowed in the design to protect from the risk of coastal erosion. Potential erosion will be monitored during the operational period.

These measures, which are included in the design of the facility, assist in adapting to climate change.

The residual risk to the LNG facility remains as medium as determined within Volume 4 Chapter 5.

### Cyclones

ConocoPhillips has experience with operating an LNG facility in Darwin in northern Australia which is prone to cyclones on a regular basis. Interruptions to normal business operation may occur during cyclone events if ships are unable to berth or if it is determined to be unsafe to transport personnel, to and from the site. Tank level management, where extra tank space is reserved, for such situations is normal business practice for ConocoPhillips based on their Darwin operations. Procedures from Darwin LNG will be modified to suit local circumstances and protocols. Contingency plans for continuing operation when access from the mainland is interrupted will be implemented similar to offshore facilities.

For vessels, the existing Gladstone Port advanced warning systems for cyclones and port management of shipping traffic mitigates the impacts of a high intensity weather event.

The appropriate designed cyclonic regional wind speeds applicable to Gladstone, with adjustment for more intense and frequent cyclones will be taken into consideration.

These measures, which will be included in the design of the facility, assist in adapting to climate change.

The residual risk to the LNG facility was determined to be medium. This is due to the potential for more frequent cyclones to interrupt shipping of LNG potentially causing a loss of production or sales (financial risk) and not based on any perceived safety risk.

#### *Flooding*

The change in precipitation is not expected to significantly change the amount of flooding at the LNG facility site due to the site topography. The natural landscape is contoured to drain away from the LNG facility and the site drainage is designed with contingency, for adequate overland flow paths. Electrical and mechanical equipment is designed to be elevated above the ground level (freeboard of approximately 300mm).

These measures, which are included in the design of the facility, assist in adapting to climate change.

The residual risk to the LNG facility was determined to be negligible.

#### *Drought*

Any drought which affects the Gladstone area is not expected to significantly affect the operation of the LNG facility. Technologies have been incorporated into the design, so the facility will be self-sufficient for all potable water and process water needs. Water will be sourced from the desalination of sea water, from stormwater collected on the site, and from the inlet air chilling process.

The residual risk to the LNG facility was determined to be negligible.

#### *Bushfires*

Proposed measures to address existing threats are anticipated to be sufficient to mitigate any increased likelihood of bushfires as a result of climate change. Proposed measures include bushfire buffer areas, fire management plan (controlled burning), water supply for fire fighting as per Australian guidelines, fire fighting and emergency shutdown systems. Australia Pacific LNG proposes to work cooperatively with the rural fire service and Gladstone emergency services to share information and receive advice. The facility will have fire fighting equipment which will be used in the event of a bushfire.

These measures, which are included in the design of the facility, assist in adapting to climate change.

The residual risk to the LNG facility was determined to be negligible.

### 4.3.4 Cooperative approach to climate change adaptation

Australia Pacific LNG, through its joint venture owners, Origin and ConocoPhillips, work through the Australian Petroleum Production & Exploration Association (APPEA) as an industry body. APPEA aims to work with governments to achieve credible industry actions and governmental greenhouse policies that address climate change concerns in an economically and commercially viable way. APPEA and its member companies are committed to taking action on climate change, including the promotion of natural gas as a part of the Asia-Pacific Economic Cooperation energy work.

APPEA member companies are also committed to reviewing and if necessary adapting their risk management strategies (encompassing engineering design, safety and environmental assessments) to reflect new learning's on the likely impacts of climate variability, to complement Government action. These strategies also give the community greater confidence about how the climate change issue is being addressed.

Australia Pacific LNG is involved in regular engagement with key governmental agencies. The aim of meeting with these stakeholders is to share project information as it comes to hand, seek guidance about regulator's requirements and expectations for the EIS and approvals process and to achieve the proposed project assessment and approval schedule. As part of this dialogue the Project has met with the Gladstone Ports Corporation and Maritime Safety Queensland. A cooperative relationship has been established and will continue with these organisations and, where relevant, will discuss climate change adaptation.

Australia Pacific LNG is actively engaged with the Department of Infrastructure and Planning and the Department of Employment, Economic Development and Innovation.

## 4.4 Conclusion

### 4.4.1 Assessment outcomes

Potential changes in climate have the ability to affect the implementation of the Project. Predicted changes in temperature, precipitation, humidity, sea level, storm surge and tides, cyclones and bushfires have been considered, and the vulnerabilities of the Project have been assessed using the Australia Pacific LNG risk assessment process.

Potential consequences of climate change that have been considered include:

- Exposure to higher temperatures
- Flooding from intense rainfall
- Reduction in stormwater availability
- Wave inundation
- Erosion
- Damage from cyclonic conditions
- Damage from bushfires.

Design features for wind action, flooding and bushfires have been incorporated into the design criteria and will continue to be considered during the detailed design phase. Strategies to mitigate climate change impacts during the construction and operation phases of the Project have been identified.

It was concluded from the risk assessment discussed above that there is currently adequate design controls and strategies in place or planned for to adequately mitigate climate change risk. Climate change risk will continue to be assessed during further stages of project implementation.

A summary of the environmental values, sustainability principles, potential impacts and mitigation measures in relation to climate and climate change associated with the LNG facility is presented in Table 4.13.

In addition, Table 4.13 includes the residual risk levels for climate and climate change. A risk assessment has been undertaken to identify the potential risks, causes and consequences from the climate and climate change. Mitigation measures to reduce the risk have been nominated and the residual risk has been calculated. Further details on the risk assessment methodology are provided in Volume 1 Chapter 4.

**Table 4.13 Summary of environmental values, sustainability principles, potential impacts and mitigation measures**

| Environmental values | Sustainability principles | Potential impacts | Possible causes | Mitigation and management measures | Residual risk level |
|---|---|---|---|---|---|
| Life, health and wellbeing of people<br><br>Diversity of ecological processes and associated ecosystems<br><br>Interruption to business construction, operation or decommissioning phases | Minimising adverse environmental impacts and enhancing environmental benefits associated with Australia Pacific LNG's activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the biodiversity values and water resources in its operational areas<br><br>Identifying, assessing, managing, monitoring and reviewing risks to Australia Pacific LNG's workforce, its property, the environment and the communities affected by its activities | Operational inefficiencies<br><br>Extended range of some pest and disease vectors<br><br>Increased health and safety risk to personnel | Elevated temperatures | Ensure design allows for flexibility in operating temperatures<br><br>Use inlet air cooling for the gas turbines<br><br>Implement shading and air-conditioning of work areas, critical plant and equipment, ferries and waiting areas<br><br>Implement safe work procedures for hot conditions | Negligible |
| | | Drought<br><br>Decreased water quality<br><br>Impacts on rivers and wetlands<br><br>Dust due to dry windy conditions<br><br>Erosion<br><br>Increased overland flow runoff | Precipitation change | Design to incorporate mitigation against potential flood events based on the climate change scenarios<br><br>Ensure all water for the operations, including potable water and process water, will be sourced from the desalination of sea water, from stormwater collected on the site, and from the inlet air chilling process | Negligible |
| | | Impact on corrosion rates<br><br>Increase risk of heat | Humidity | Implement and carry out facility inspection and maintenance program<br><br>Use corrosion inhibitors | Negligible |

| Environmental values | Sustainability principles | Potential impacts | Possible causes | Mitigation and management measures | Residual risk level |
|---|---|---|---|---|---|
| | | stress and dehydration<br>Incremental decrease in facility performance | | Avoid the reliance of on evaporative cooling | |
| | | Sea water intrusion over mainland supply base, ferry terminal, LNG facility, jetty and material offloading facility<br>Tidal flows and currents affecting the steering and control of vessels | Sea level change | Ensure the LNG facility and marine facilities including, the material offloading facility (MOF), jetties and ferry terminals have been designed with sufficient elevation above the current CSIRO sea level rise estimates<br>The LNG facility design level (6m AHD) is greater than the calculated predicted extreme water level (5.6m AHD)<br>Ensure the jetty design level is approximately 7m AHD | Low |
| | | Damage of coastal structures for loading and unloading<br>Stability of pipeline and equipment | Coastal erosion | Ensure the design allows for sufficient distance from the shoreline and elevation of foundations | Negligible (solely based on climate change impacts) |
| | | Potential for more frequent cyclones to interrupt shipping of LNG.<br>Storm surge and | Cyclones | Existing Gladstone Port advanced warning systems for cyclones and port management of shipping traffic mitigates the impacts of a high intensity weather event<br>Ensure structural elements for the LNG facility will be designed and constructed in accordance with AS/NZS | Medium |

| Environmental values | Sustainability principles | Potential impacts | Possible causes | Mitigation and management measures | Residual risk level |
|---|---|---|---|---|---|
| | | currents affecting the steering and control of vessels | | 1170.2: Structural design actions - Wind actions. The appropriate designed cyclonic regional wind speeds applicable to Gladstone, with adjustment for more intense and frequent cyclones will be taken into consideration<br><br>Management of LNG storage tank inventories | |
| | | Minor increase in depth of water over site<br><br>Electrical and mechanical equipment susceptible to water damage | Flooding | Ensure storm water design includes for diversion of water from the LNG facility and the site drainage is designed with contingency, for adequate overland flow paths<br><br>Ensure electrical and mechanical equipment is designed to be elevated above the ground level (freeboard of approximately 300mm) | Negligible |
| | | Bushfire encroaching on the LNG facility | Bushfires | Establish and maintain bushfire buffer areas around the facility<br><br>Implement a fire management plan (controlled burning)<br><br>Construct a water supply for fire fighting as per Australian guidelines<br><br>Facility will have emergency shutdown systems and on-site fire response equipment | Negligible |

### 4.4.2 Commitments

In order to manage potential impacts of climate change associated with the LNG facility, Australia Pacific LNG will:

- Incorporate adaptive management approach to climate change throughout the life of the Project
- Incorporate the agreed preferred climate change strategies which resulted from the risk assessment into the design process
- Cooperate with government, other industry and other sectors to address adaptation to climate change.

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