



Gladstone Ports Corporation

Growth, Prosperity, Community.

Chapter 4 – Climate and Climate Change





Gladstone Ports Corporation
Growth. Prosperity. Community.

Western Basin Dredging and Disposal Project

4. Climate and Climate Change

Overview

This chapter provides an assessment of the Project's vulnerabilities to climate change and addresses Section 3.1 Climate and Climate Change of the ToR (Appendix A) for the Project. The impacts of rainfall on soil erosion are addressed in Section 3.2 (Land). The impacts of storm events on the capacity of waste containment systems are addressed in Section 3.6 (Infrastructure). The impacts of climate on air quality are addressed in Section 3.6 (Air Quality, Noise and Vibration).

This assessment of climate change vulnerability was focused on the construction of the Western Basin Reclamation Area, adjacent to the proposed Fisherman's Landing Northern Expansion and the existing port facility at Fisherman's Landing. The detailed Climate and Climate Change Assessment report can be found in Appendix H.

Requirements to assess potential risks associated with climate change on development projects and to implement adaptation strategies are included in a number of planning instruments and guidelines:

- ▶ State Planning Policy 1/03 *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide*;
- ▶ *State Coastal Management Plan* and the *Curtis Coast Regional Coastal Management Plan*;
- ▶ QLD EPA - *ECOaccess Guidelines Operational Policy – Coastal Development - Building and engineering standards for tidal works*;
- ▶ Australian Standard 4997-2005 *Guidelines for the design of maritime structures*; and
- ▶ QLD Office of Climate Change - *EPA Guidelines for Preparing a Climate Change Impact Statement (CCIS)*.

4.1 Description of Environmental Values

4.1.1 Current and Historical Climate for the Gladstone Region

Meteorological data is available from the Bureau of Meteorology (BoM) website for three monitoring stations in the Project vicinity (Table 4-1). The old Gladstone Post Office monitoring site has been closed since 1958 and provides historical data only. The Gladstone Airport monitoring site has only been in existence since 1993 and provides the least amount of data. The Gladstone Radar monitoring site has been in existence since 1957 and provides a substantial amount of relevant data, thus most of the climate figures used below have been sourced from this monitoring site (BoM 2009a). It is situated approximately 12 km from the Project Area.

The Gladstone Airport site data was used for relative humidity and wind as this monitoring site is at a lower elevation than the Gladstone Radar site. Some parameters may be affected by elevation (i.e. wind, humidity) and this data is therefore more likely to be representative of the conditions at the Project Area.



Table 4-1 Location of BoM Monitoring Stations in the Project Vicinity

Location	Stn #	Latitude	Longitude	Elevation	Data Period	Status
Gladstone Post Office	039041	23.83 °S	151.25 °E	15 m	1872 – Dec 1958	Closed
Gladstone Airport	039326	23.87 °S	151.22 °E	17 m	1993 – Aug 2009	Open
Gladstone Radar	039123	23.86°S	151.26°E	75 m	1957 – Aug 2009	Open

Rainfall

Using rainfall data from the Gladstone Radar site, the average annual rainfall for Gladstone over a period from December 1957 to July 2009 is 880 mm, with the majority of rainfall occurring during the summer months. The highest monthly rainfall recorded was 709.8 mm in 1971 and the highest daily rainfall recorded was 284 mm on 5 February 2005. Mean monthly and annual rainfall as well as highest (denoted by red text) and lowest rainfall (denoted by blue text) are summarised in Table 4-2.

Table 4-2 Rainfall Summary – BoM Gladstone Radar (1957 – July 2009)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean rainfall (mm)	143.4	143.4	82.6	46.2	60.5	39.4	35.2	32.4	26.5	62.3	74.2	128.8	880
Highest rainfall (mm)	640.1	709.8	311.6	250.4	316.4	220.3	170.2	141.6	89.6	276.8	218.1	508.9	1731.6
Lowest rainfall (mm)	0.4	7.2	2.4	3.8	0.2	0	0	0	0	0.4	1.4	2.8	432.5

Rainfall patterns throughout the year demonstrate distinct seasonal differences. The wet season occurs during the summer months of December, January and February, accounting for nearly half of the annual average rainfall, with the dry season occurring during the winter months.

Temperature

Average minimum and maximum temperatures in Gladstone range from 13.3 to 22.8°C in July and 22.5 to 31.2°C in January. Monthly mean maximum and minimum and highest and lowest recorded temperatures are shown in Table 4-3. The highest figures are denoted by red text and the lowest by blue.

On average, Gladstone experiences 4.5 days per year with a temperature equal or greater than 35°C, and 111.6 days per year with a temperature equal or greater than 30°C (BoM 2009a).



Table 4-3 Temperature Summary BoM Gladstone Radar (1957 – Jul 2009)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean maximum temp (°C)	31.2	30.9	30.2	28.4	25.7	23.2	22.8	24	26.4	28.4	29.9	31	27.7
Mean Min Temp (°C)	22.5	22.4	21.5	19.6	17	14.3	13.3	14.2	16.4	18.7	20.5	21.9	18.5
Highest temp (°C)	38.3	40.1	42	34.1	31.3	29.7	28.7	30.9	33.8	40	40.1	39.8	42
Lowest temperature (°C)	12.8	17.2	16.2	11	8.5	6.1	4.4	4.7	9.6	10.9	14.7	12.4	4.4

Relative Humidity

Relative humidity is an indicator of the moisture content in air and is typically presented as a percentage of the total moisture that the air could contain at that temperature. The monthly average relative humidity, as measured at 9 am and 3 pm at Gladstone Airport between 1993 and 2008, is shown in Figure 4-1. There is a greater seasonal variability for relative humidity measured at 3 pm compared to the 9 am measurements. For the 3 pm measurements, there is a difference of 16 % between the lowest month, July, and the highest, February. This is due to the drier afternoons during the winter months. Relative humidity at 9 am displayed very little variation throughout the year. Annually, the 9 am and 3 pm relative humidity averages were 64 % and 54 % respectively.

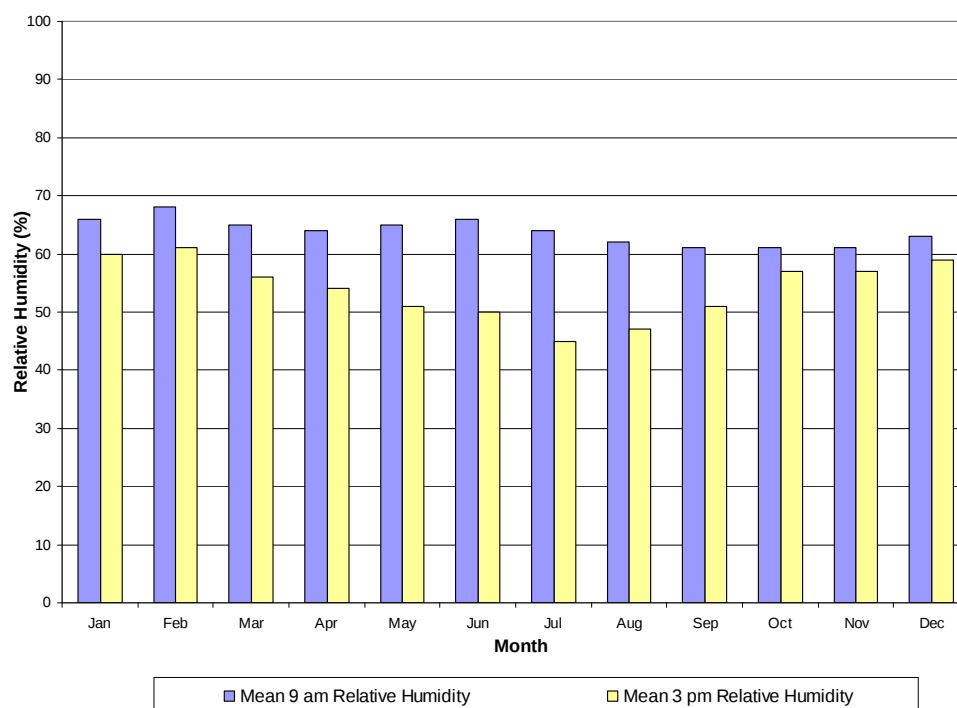


Figure 4-1 Monthly Averaged Relative Humidity (%) at Gladstone Airport (1993 - 2008)

Wind

Wind speed is usually measured at 10 m above the ground surface and data is averaged over the ten minutes prior to the time of observation. Observation times for the BoM are 9 am and 3 pm, and these are averaged over the period of record for monthly and annual data presented (Figure 4-2). Average monthly wind speeds at 9 am and 3 pm show that wind speed is variable with seasons and during the day. Wind speed is lower in the winter months and a greater wind speed is experienced at 3 pm compared to 9 am in all months. Average wind speeds experienced at Gladstone range from 11.4 to 16.5 km/h at 9 am and from 15.6 to 23.3 km/h at 3 pm.

A summary of maximum monthly wind gust speeds recorded in Gladstone, along with the maximum wind gust speeds recorded so far in 2009, is shown in Figure 4-3. The maximum wind gust speed recorded at Gladstone was 156 km/h on 19 January 1976.

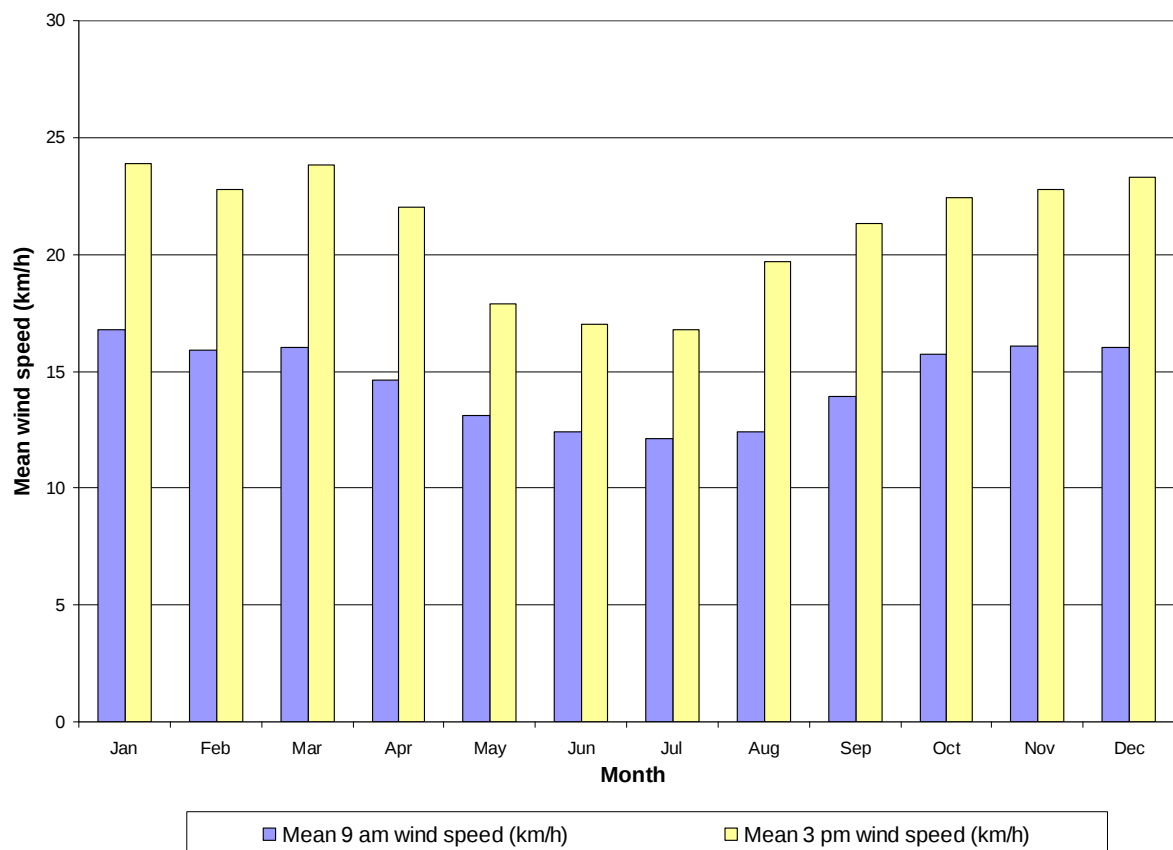


Figure 4-2 Average Monthly Wind Speed Recorded at Gladstone Airport at 9 am and 3 pm

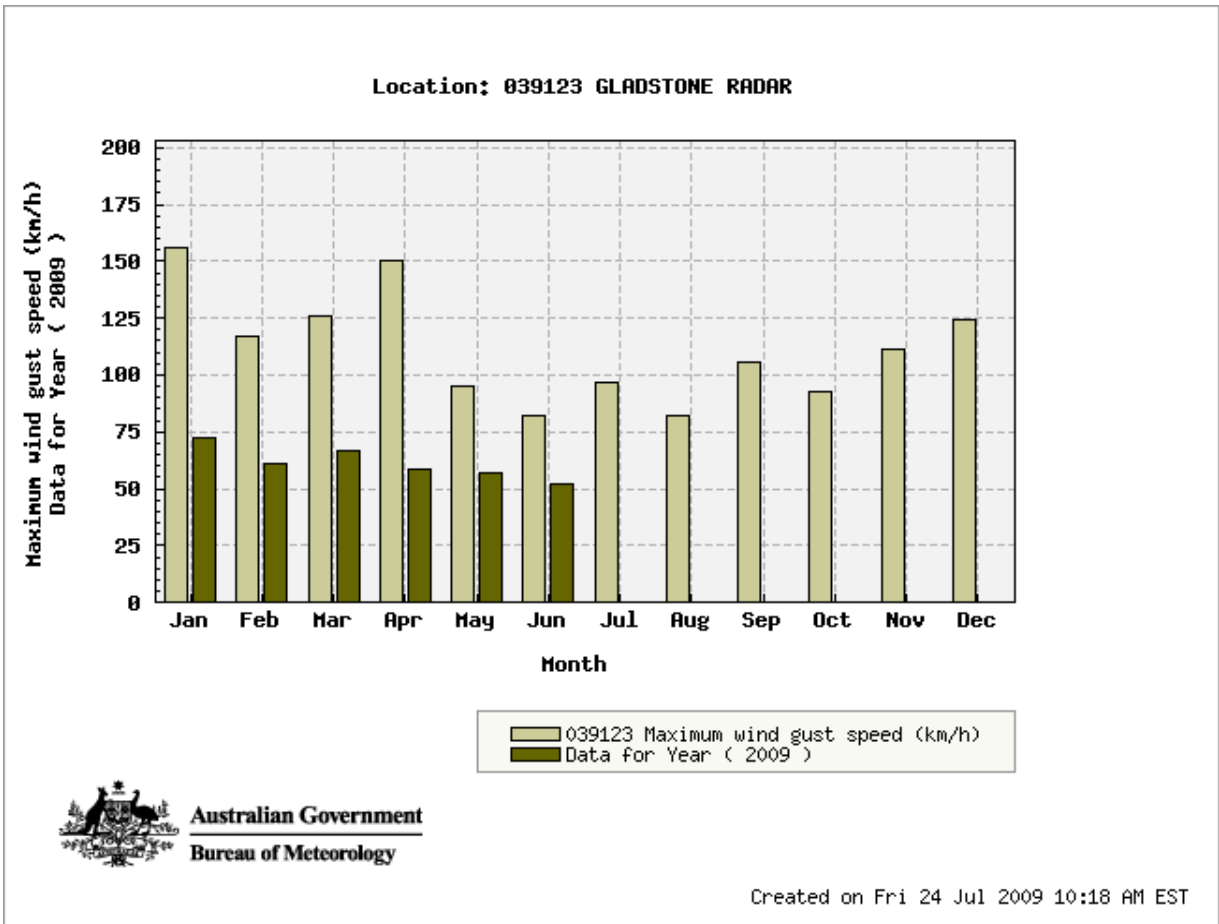


Figure 4-3 Gladstone Maximum Recorded Wind Gust Speeds (BoM 2009)

Annual wind roses for 9 am and 3 pm averaged data from the BoM website (Gladstone Airport) are shown in Figure 4-4 and Figure 4-5 respectively. From these wind roses it can be concluded that:

- ▶ At 9 am, wind speeds between 20 and 30 km/h were recorded from the south-easterly direction for most of the time; and
- ▶ At 3 pm, wind speeds between 20 and 30 km/h were mostly from the east and north-easterly direction and between 30 and 40 km/h winds were mostly from the easterly direction.

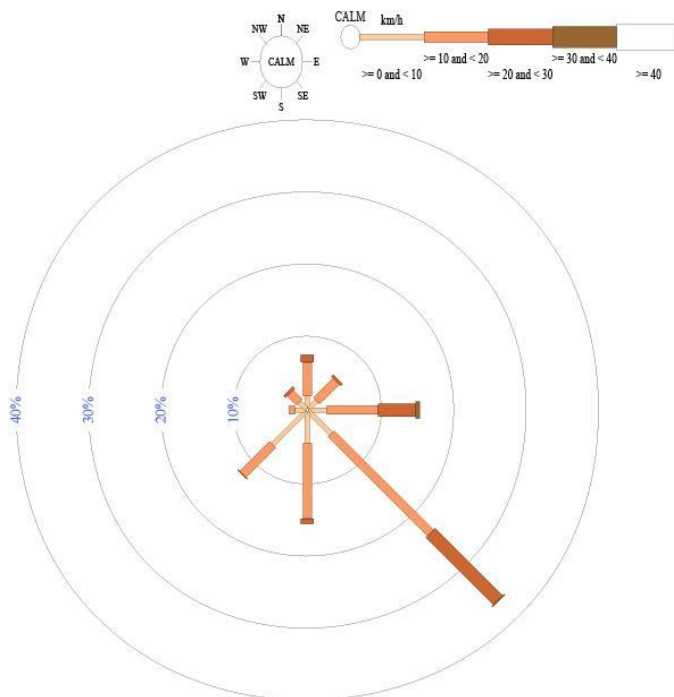


Figure 4-4 Annual Wind Rose for 9 am at Gladstone Airport (1993 – 2008)

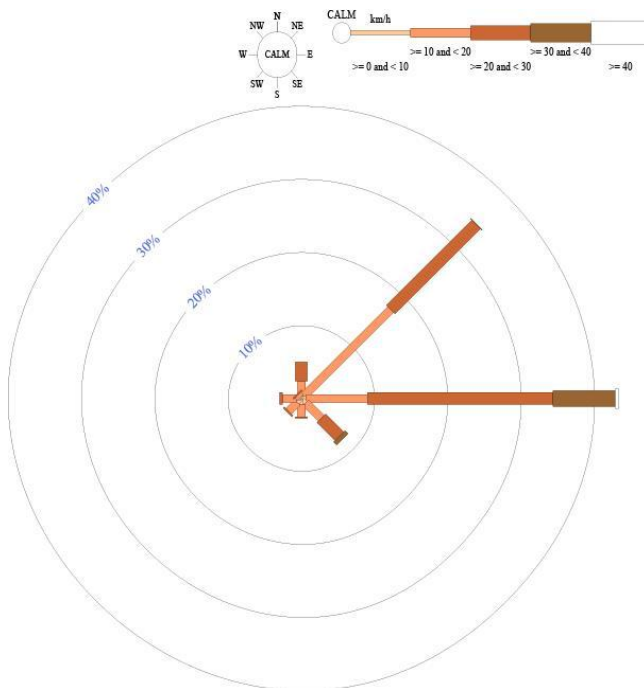


Figure 4-5 Annual Wind Rose for 3 pm at Gladstone Airport (1993 – 2008)



Temperature Inversions

Temperature normally decreases with increasing height, however, sometimes this is reversed and temperature increases with increasing height in an occurrence called temperature inversion. A temperature inversion can occur when cold air becomes trapped below air of higher temperatures and with it, pollutants become trapped as the warmer air or fog provides a 'lid' and prevents the colder air from dissipating. Temperature inversions usually occur during winter nights 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.

No information or data is available on temperature inversions for the Gladstone area on either the BoM or DERM websites. Temperature inversions can occur in any season but are more common in the cooler winter months and therefore, pollutants are more likely to be trapped by an inversion layer during winter. Inversions are typically visible in the winter months where a distinct layer can be seen above the various industrial plants in Gladstone.

Sea Levels for the Gladstone Region

The Lowest Astronomical Tide (LAT) values shown in Table 4-4 are the LAT design criteria that form the basis for the preliminary design for the Western Basin Reclamation Area. The figures have also been shown in relation to the Australian Height Datum (AHD). The sea level acronyms used in Table 4-4 are described in Section 2.2.4 of the technical report (Appendix H).

Table 4-4 Current Tidal Range Figures for the Western Basin Reclamation Site

	(m, LAT)	(m, AHD)
HAT	4.97	2.54
MHWS	4.14	1.71
MHWN	3.24	0.81
MSL	2.44	0.01
AHD	2.43	0
MLWN	1.61	-0.82
MLWS	0.71	-1.72
LAT	0	-2.43

4.1.2 Extreme Weather Events

Extreme Wind and Tropical Cyclones

The maximum wind gust speed recorded at Gladstone was associated with winds generated from Tropical Cyclone David (BoM 2009b). According to the BoM website, an average of two to four cyclones affect Queensland every year and due to great length of coastline, may not affect a particular area for many years. Cyclones affecting Queensland tend to develop over the seas to the north and east of the state, though on occasions small cyclones develop close to the coast. The magnitude of the damage caused by cyclones is dependent on the severity and intensity of the cyclone as well as the proximity to areas that could be potentially damaged.

The Bureau of Meteorology identified ten tropical cyclones that passed within 100 km of Gladstone between 1940 and 2006 (BoM 2009b) (Figure 4-6). Additionally, in March 2009, Tropical Cyclone Hamish passed along the coastline near Gladstone. Although the cyclone did not cross the coastline, the event caused the temporary closure of the Gladstone Port (GPC 2009). Refer to Section 17.1.4 for additional detail on cyclones and flooding within the region.

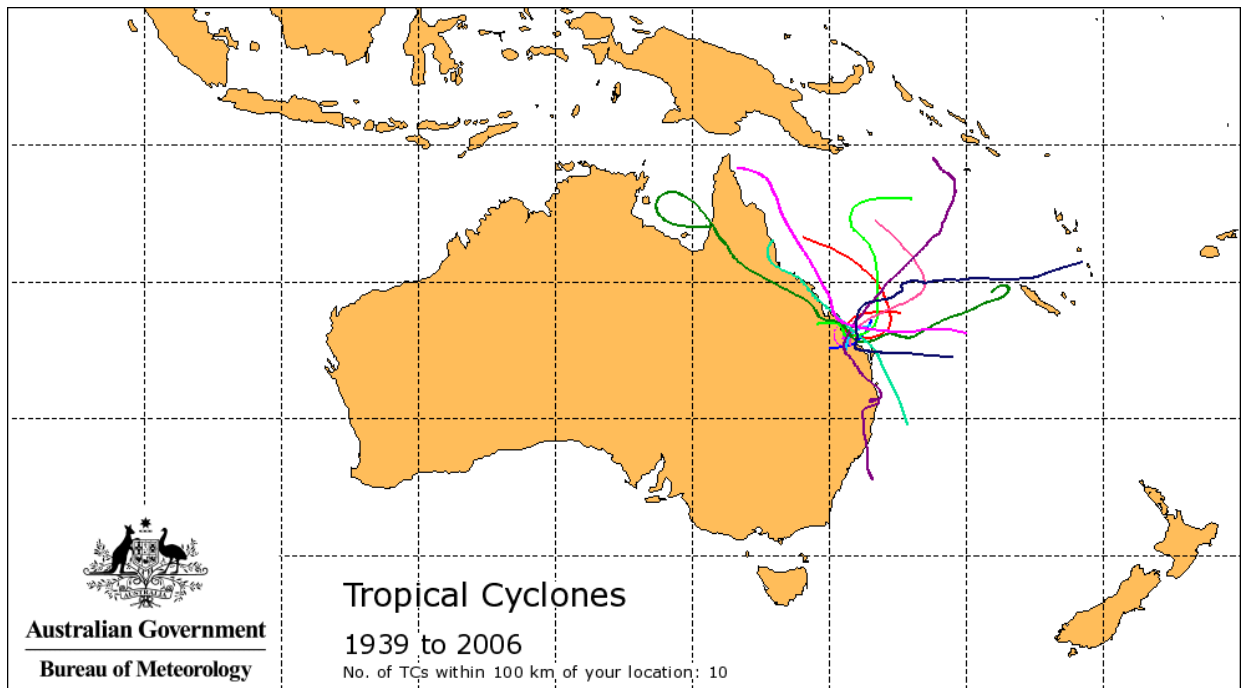


Figure 4-6 Tropical Cyclones Tracks within 100 km of Gladstone (1940 – 2006)

Floods

The closest river to the Project area is the Calliope River, located approximately six kilometres south east of the proposed Western Basin Reclamation. The DERM gauging station on the Calliope River indicates that numerous flood events have occurred since the installation of the gauge in 1938 (Connell Hatch 2006). The BoM website indicated that the flood events were associated with cyclones or associated rain depressions (Connell Hatch 2006).

There are a couple of minor overland flowpaths and unnamed creeks that flow into the Project area. The catchment upstream of these flowpaths is small and does not result in a large inflow of water to the tidal area during rainfall events. The main adjacent creek catchment is Boat Creek, located to the south east of the Project area. The mangrove fringe around the Fisherman's Landing embayment would serve to dissipate any overland flow.

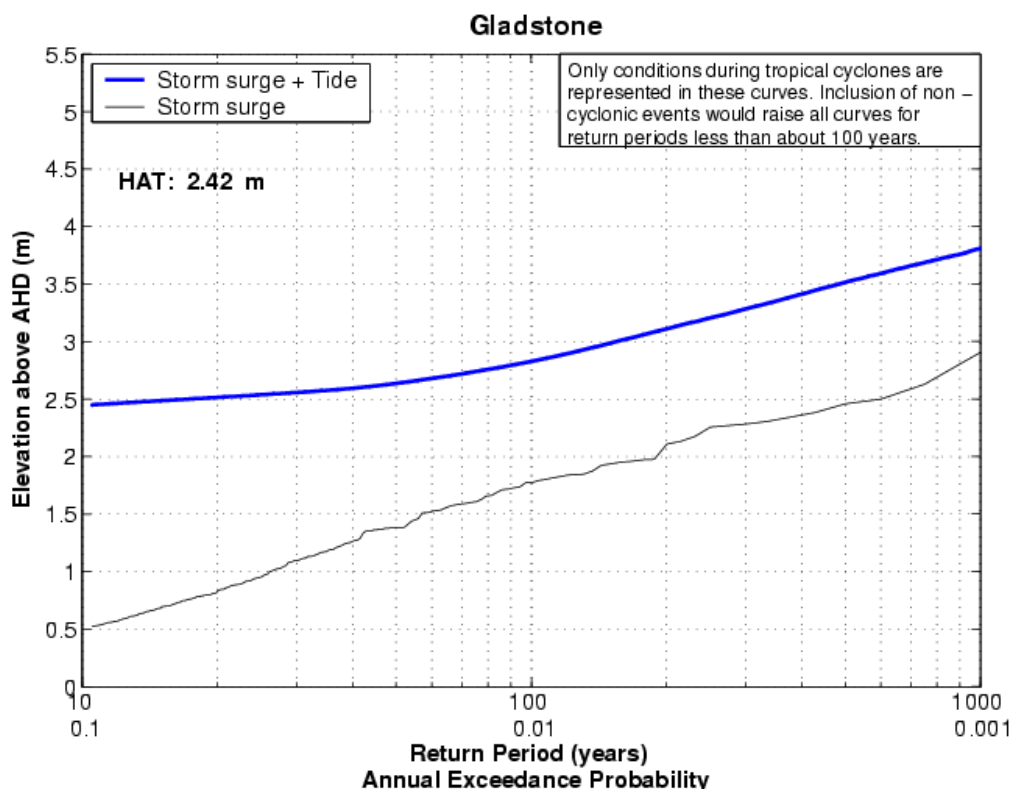
Storm Tides

Storm tides are caused by severe meteorological events such as tropical cyclones, which are often accompanied by a temporary local rise in sea level known as storm surge. This surge is usually caused by strong onshore winds exerting a stress on the sea surface, which causes water to accumulate against the coast. Additionally, the low atmospheric pressure within a cyclone can allow a small rise in water

level. Storm tides can have devastating consequences on coastal communities and the environment, causing dangerous levels of flooding in low-lying coastal areas. The greatest potential for loss of life related to a cyclone is from the associated storm tide. The effects of storm tides are beach erosion, inundation of low-lying coastal areas and increase in flood levels.

The first storm tide in Queensland was recorded in 1884 at Bowen with 3.1 m surge. There have been 70 known instances affecting 150 locations in Queensland. In the Gladstone region, two storm tides were recorded, these occurred in 1974 and 1980 with 0.4 m surge.

Figure 4-7 outlines modelled storm surge plus tide levels for various return periods for Gladstone at Auckland Point (Hardy *et al.* 2004). It should also be noted that this study did not take wave setup into account.



Marine Modelling Unit, School of Engineering, James Cook University

Figure 4-7 Gladstone (Auckland Point) Predicted Storm Surge and Tide Levels (Hardy *et al.* 2004)

Based on the information in the Hardy *et al.* (2004) report, and the Coastal Processes Report (see Appendix M of the main EIS - Coastal Processes), the elevations above AHD for selected Annual Exceedance Probabilities (AEPs) for the Study Area were calculated as shown in Table 4-5.



Table 4-5 Storm Surge plus Tide for Study Area

Annual Exceedance Probability	0.02 (2%)	0.01 (1%)	0.002 (0.2%)	0.001 (0.1%)
Western Basin study area (m, AHD)	2.91	3.04	3.72	4.03

These figures include adjustments to take into account:

- ▶ An approximate increase of 6% in tidal range for the study area, compared to Auckland Point (see Appendix M - Coastal Processes Assessment); and
- ▶ An increase due to non-cyclonic events, expected to be about 0.2 m for an event with a 10% AEP, reducing to 0 m for an event with about a 0.5% AEP (Hardy *et al.* 2004).

For a further explanation of calculations see detailed report (Appendix H).

4.2 Potential Impacts and Mitigation Measures

The potential impacts of climatic factors on the construction and operation of the proposed Western Basin Reclamation Area and mitigation measures are presented in this section, along with an assessment of the potential impacts of climate change and adaptation measures that have been adopted or recommended to address these impacts in the future.

It is noted that the potential vulnerability of any specific facilities to be built on the Western Basin Reclamation Area in the future is not assessed in this EIS. It is expected that the potential impacts of climatic factors, extreme climatic events, natural or induced hazards and climate change on the construction and operation of these facilities will be considered by the future proponents through separate assessment requirements.

4.2.1 Vulnerability of Area to Natural or Induced Hazards

This section assesses the Project against the *State Planning Policy 1/03 Mitigating the impacts of flood, bushfire and landslide* and *Section 2.2.4 Coastal Hazards* in the State Coastal Management Plan.

Floods

As the proposed Reclamation Area is not adjacent to any major river or creek, it is not expected that flooding following large rainfall events will result in inundation or scouring of the Reclamation Area. Turbid flood plumes from the Calliope River may reach the Reclamation Area during a flooding spring tide, but flooding is not expected to impact on water levels at the Reclamation Area.

Floods - Storm Surge

The 1% and 0.1% AEP events modelled in the storm surge plus tide study (Hardy *et al.* 2004) are below the level of the bund walls for the Project Reclamation Area.

It should also be noted that the highest storm surges modelled in a Hardy *et al.* (2004) study, are not the highest possible. The probable maximum water level at a given location would be caused by a tropical cyclone and tide with characteristics including a very severe central pressure, and an astronomical tide



level, at the time of maximum surge that is close to Highest Astronomical Tide (HAT). The combination of these characteristics would be very rare, but not impossible (Hardy *et al.* 2004).

Potential impacts of storm surge plus tide levels, taking into account climate change scenarios are discussed in Section 3.6.2 of Appendix H for the Western Basin Reclamation Area.

Bushfires and Landslides

The vegetated areas surrounding Gladstone are vulnerable to bushfire during the right combination of conditions. As the Project involves the construction of a bund and eventual reclamation of an area which is currently under the high tide water mark, bushfires will not have any impact on the Project and the Project will not have any impact on bushfire potential in the surrounding area. There is no risk of landslide to this Project and this Project will not result in a landslide risk to surrounding areas.

4.2.2 Summary of Climate Change Projections for the Gladstone Region

Sections 3.1 - 3.6 in the Climate and Climate Change Assessment (Appendix H) outlines climate change projections for the Gladstone region for rainfall, temperature and average wind for 2030 and 2070, sea level up to 2100 and extreme weather.

Generally, projections for 2030 show little variation between greenhouse gas emissions scenarios, as these changes in climate are mostly affected by greenhouse gases that have already been emitted. Due to this, the projections below for 2030 are shown for the mid-range Special Report on Emissions Scenarios (SRES) emissions scenario. Projections for later in the 21st century are much more dependent on the scenario used for future emissions and for this reason, projections using both low and high emissions scenarios are shown for 2070. It should be noted however, that research presented by Rahmstorf *et al.* (2007) shows that observed carbon dioxide concentration, global mean temperatures and sea level rise have been tracking at the upper end of Intergovernmental Panel on Climate Change (IPCC) scenario range from 1990 to 2006. Therefore, projections based on the mid and low IPCC scenarios for later in the 21st century may be less likely than those based on the high emissions scenarios (CSIRO 2007).

Table 4-6 summarises the climate change projections identified in Sections 3.1 - 3.6 of the detailed report (Appendix H), compared with the historical/current averages for the region. Projections based on the 'upper level' scenarios have been included in this table, where available, due to evidence that suggests that current sea level rise and temperature increases are already tracking above rates noted in the 'high emissions' scenarios used by the IPCC (Rahmstorf *et al.* 2007).



Table 4-6 Summary of Climate Change Projections for the Gladstone Region

Climate Variable	Current/ Historical Conditions	Source	Climate Change Projection	Scenario / Info	Source
Rainfall/ Runoff	Annual average rainfall: 880 mm	(BoM)	-70%	2070 A1FI emission scenario GFDL-CM2.1 Global Climate Model with high climate sensitivity (IPCC 2007 global warming values)	(CSIRO - OzClim 2009 <i>Build Number</i> 3.1.05, 26 Jun 2009)
Air Temp	Annual mean max temp: 27.7°C	(BoM)	Average temp increase: 3.0°C	2070 High emissions (A1FI) scenario Mid range model result (with high and low range) (Data for Rockhampton,)	(QOCC 2008a)
	Annual mean min temp: 21.9°C				
	Annual average number of hot days (over 35°C): 4.5	(BoM)	Increase in number of days over 35°C : +65 days	2070 High emissions (A1FI) scenario Mid range model result (with high and low range) (Data for Rockhampton,)	(CSIRO cited in QOCC 2008a)
Wind (daily wind climate)	Average 9 am wind speed: 14.2km/h Average 3 pm wind speed: 20.7km/h	(BoM)	Annual 10m wind speed variations: (-2 to +15%)	2070 High emissions (A1FI) scenario model output range	(CSIRO 2007)
Sea Level	HAT for Western Basin: 2.54 m, AHD	GHD Design Criteria	Global mean sea level rise: +0.278 m	2050 Estimate of maximum global sea level rise relative to 1980 – 1999 using high emissions (A1FI) emissions scenario	(Hunter 2008, after IPCC 2007)
			Global mean sea level rise: +0.471 m	2070 Estimate of maximum global sea level rise relative to 1980 – 1999 using high emissions (A1FI) emissions scenario	(Hunter 2008, after IPCC 2007)
			Local projected departure from global mean sea level rise: +0.02m	2070 Mid emissions scenario (A1B)	(CMAR 2008)
Tropical Cyclones	Tropical cyclones in the Gladstone region have caused local wind extremes up to 156 km/h (19 Jan 1976)	(BoM)	- likely <i>increase</i> in the proportion of cyclones in the more intense categories -possible	Based on projections produced by 3 studies in the Australian region.	(CSIRO 2007)



Climate Variable	Current/ Historical Conditions	Source	Climate Change Projection	Scenario / Info	Source
			decrease in the total number		
Storm Surge + Tide	2% AEP: approx 2.91 m, AHD	(Hardy <i>et al.</i> 2004, p.44 – adjusted for Western Basin site and additional non-cyclonic events)	3.40 m AHD 3.52 m AHD	2% AEP storm surge plus tide 2070 SLR only 2070 SLR + 10%increase in cyclone MPI	(Calculated from Hardy <i>et al.</i> (2004, p.54), and Hunter (2008), after IPCC (2007))
	1% AEP: approx 3.04 m, AHD		3.53 m AHD 3.78 m AHD	1% AEP storm surge plus tide 2070 SLR only 2070 SLR + 10%increase in cyclone MPI	
	0.2% AEP: approx 3.72 m, AHD		4.21 m AHD 4.62 m AHD	0.2% AEP storm surge plus tide 2070 SLR only 2070 SLR + 10%increase in cyclone MPI	
	0.1% AEP: approx 4.03 m, AHD		4.52 m AHD 4.97 m AHD	0.1% AEP storm surge plus tide 2070 SLR only 2070 SLR + 10%increase in cyclone MPI	

4.2.3 Potential Climate Change Impacts on the Project

Based on the *Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering* (Engineers Australia 2004), impacts associated with effects of climate change on the Project are summarised in Table 4-7. The potential impacts suggested in the Engineers Australia Guideline were assessed and modified in relation to this Project. This summary outlines potential areas where adaptation may be required in relation to the investigation, design, construction, operation and maintenance of the Project. Potential impact for structures and facilities that may be located on or adjacent to the Western Basin Reclamation in the future should be taken into account by future proponents.

Table 4-7 Potential Climate Change Impacts on the Project

Climate Variable	Effects on Project	Potential Impacts
Rainfall/ Runoff	Investigation	Minor/No effect
	Design	Minor/No effect
	Construction	Minor/No effect
	Operation	Minor/No effect
	Maintenance	Minor/No effect
Air Temp	Investigation	No effect
	Design	Minor/No effect
	Construction	Minor/No effect



Gladstone Ports Corporation
Growth. Prosperity. Community.

Western Basin Dredging and Disposal Project

Climate Variable	Effects on Project	Potential Impacts
	Operation	Minor/No effect
	Maintenance	Minor/Possible increased corrosion rates of construction materials
Wind (daily wind climate)	Investigation	Minor/No effect
	Design	Minor/No effect
	Construction	Minor/No effect
	Operation	Minor/No effect
	Maintenance	Minor/No effect
Sea Level	Investigation	Changing statistics will affect determination of design criteria
	Design	Possible effect
	Construction	Minor/No effect
	Operation	Structures that don't take into account the potential effects of climate change may be less efficient during operation phase
	Maintenance	Minor effect
Tropical Cyclone/ Storm Surge (Wind and Wave Climate)	Investigation	Changing statistics will affect determination of design criteria
	Design	Possible changes to marginal probability of failure for structures
	Construction	May effect down time during future construction periods
	Operation	May impact depending on function
	Maintenance	Structures that don't take into account the potential effects of climate change may need retrofitting or upgrade

4.2.4 Assessing the Level of Risk from Potential Impacts

The main impacts for the Project have been identified as those associated with potential sea level rise and associated increase in storm surge.

If the Reclamation Area was to be overtopped by storm surge, the consequence level would largely depend on the type of activity, if any that was taking place on, or adjacent to the Reclamation Area, this risk level should be assessed by future proponents, but could potentially be a major consequence based on the GPC consequence rating criteria (Section 3.2). In terms of assessing the likelihood of this event actually occurring, the GPC likelihood criteria defines an event that may occur only in exceptional circumstances or not in the next 25 years as rare, and in the next 20 to 25 years as unlikely.

The design height of the bund wall for the Western Basin Reclamation Area has been set at 7 m LAT. This is equivalent to 4.57 m AHD. Taking storm surge and tide into account, with increasing sea levels and even a 10% increase in tropical cyclone maximum potential intensity (MPI), this level is exceeded only by the 0.1% AEP event in 2050 and by the 0.2% AEP event in 2070.

These levels of consequence and likelihood would equate to a low risk level using the Gladstone Port Corporation risk matrix, but would need to be re-evaluated in the future as more detailed information becomes available.



4.2.5 Adaptation Measures

For each of the potential impacts of climate change that may affect the Western Basin Dredging and Disposal Project that have been identified, appropriate adaptation measures are highlighted in Table 4.8. This table summarises the adaptation measures that are being implemented in the design of the rock armour for the revetments for the Western Basin Reclamation Area, as well as suggesting some measures that may need to be taken into account for future structures that may be built on the reclaimed area. The individual acceptable level of risk will vary depending on the type of facilities that are to be constructed on the Reclamation Area and these will need to be assessed on a case by case basis by the future proponents.

Table 4-8 Potential Adaptation Measures for the Western Basin Dredging & Disposal Project

Climate Variable	Potential Adaptation Measures
Rainfall/ Runoff	Only minor effects expected. Therefore, no adaptation measures have been proposed.
Air Temp	- Any road surfacing used on the bunds may need to take into account higher future temperatures to reduce any ongoing maintenance costs associated with increases in ambient temperatures on the concrete and/or bitumen. - Concrete - Adequate allowance for predicted thermal movements during the design stage. This could be the inclusion of more joints in the pavement to relieve stresses and reduce the risk of damage - Bitumen - Evaluate different bitumen formulation to suit projected climate conditions. This might include higher penetration grade bitumen, alternate mix designs or the use of polymer modified bitumen.
Wind (daily wind climate)	Only minor effects expected. Therefore, no adaptation measures have been proposed.
Sea Level	Sea level rise has been included to determine the design wave heights in the design of the rock armour. The sea level rise adopted for the design of the rock armour is as recommended by the EPA Building and Engineering Standards for Tidal Works and corresponds with the approximate 'high level' mean sea level rise projections for 2050.
Tropical Cyclone/ Storm Surge (Wind and Wave Climate)	- The rock armour protection that is likely to be adopted at the Reclamation Area is based on a dynamic design. The rock armour, therefore, will move to create a stable profile over its lifetime. It is recognised that during the lifetime of the structure a design event or even bigger may occur. These events will not lead to catastrophic failure but may require some maintenance and possibly replenishment of the rock armour in places. GPC recognise this and is committed to carrying out this maintenance to allow the structure to be operationally stable for the design life of the Reclamation Area. - The rock armour has been designed for cyclonic winds associated with an average return interval (ARI) of 50 years. This is equivalent to a 2% annual exceedance probability (AEP). This AEP is based on historic data for the Gladstone region. Due to the dynamic design of the rock armour that is proposed, the maintenance regime in place would potentially be able to adapt the overall volume of the rock armour to maintain a 2% AEP design specifications if required.