10. CLIMATE AND CLIMATE CHANGE ADAPTATION

This chapter describes the existing climate and climate extremes in the vicinity of the Arrow LNG Plant, in terms of rainfall patterns, air temperature, humidity, wind and other factors that potentially affect the management of the project. Climate change predictions describing how historic patterns may change during the life of the project are discussed, and climate change adaption strategies for the project are proposed.

A climate change assessment for the Arrow LNG Plant was undertaken by PAEHolmes (Appendix 1, Climate and Climate Change Adaptation). Katestone Environmental Pty Ltd also prepared a detailed description of the Gladstone region's existing climate as part of the air quality impact assessment for the project (Appendix 14, Air Quality Impact Assessment).

Objectives for climate change adaptation have been developed based on the relevant legislative context to protect infrastructure from the potential effects of climate change. Objectives are set out in Box 10.1.

Box 10.1 Objectives: Climate change adaptation

- To assess risks to the Arrow LNG Plant associated with changing climate patterns.
- To identify the preferred and alternative climate change adaptation strategies that will be implemented for the project.

Design considerations for the Arrow LNG Plant to protect against climate change are described in Chapter 6, Project Description: LNG Plant.

The potential impacts of climatic factors as they relate to soil erosion, surface water and effects on air quality are discussed in Chapter 11, Geology, Landform and Soils; Chapter 13, Surface Water, Hydrology and Water Quality; and Chapter 21, Air Quality, respectively.

10.1 Legislative Context and Standards

The following sections describe the national framework and state policy and actions specific to climate change adaptation, as well as Australian standards that require climatic factors to be considered in design.

10.1.1 National Framework for Climate Change Adaptation

Climate change adaptation is one pillar of the Australian Government's three pillar strategy to address climate change; the other pillars being emissions reduction (e.g., the introduction of the Australian Government's Clean Energy Plan and carbon pricing (Australian Government, 2011a; 2011b; 2011c)) and Australia's participation in developing a global response. The government is progressing a number of actions specifically focused on climate change adaptation separate to the emissions reductions initiatives described in Chapter 20, Greenhouse Gas. Key progress on climate change adaptation to date includes:

- In 2007, the Council of Australian Governments endorsed the adaption framework for national climate change (COAG, 2007). Recognising climate change adaptation as a long term agenda, the framework established targeted, medium term strategies to guide actions by governments for the period 2007 to 2014. Strategies aim to support informed decisions on adaptation and include identifying sectors and regions especially vulnerable to climate change impacts, with Australia's coast being a particular focus.

- In response to the national framework, the Department of Climate Change (now the Department of Climate Change and Energy Efficiency) reported on the risks of climate change to Australia's coast (DCC, 2009a). The scope of the report included, but was not limited to, identifying (via spatial analysis) areas at high risk to climate change impacts and helping to identify national adaptation priorities for the coastal zone. In the same year, the House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts made 47 recommendations with regard to managing the coastal zone in the context of climate change, including 14 recommendations specifically relating to adaptation (HRSCCCWEA, 2009).
- In early 2010, the Department of Climate Change released a position paper (DCC, 2010) setting out the Australian Government's vision for adapting to the impacts of climate change and expressing the government's desire to work through COAG to develop a national adaptation agenda. With coastal adaption identified as a priority area for national adaptation, a national climate change forum was held in Adelaide, South Australia in February 2010. The forum initiated dialogue on the national coastal adaptation agenda, and a report detailing the outcomes of the forum was subsequently published (DCCEE, 2010a).
- Building the capacity of local governments to identify and implement climate change adaptation actions has also been an area of Australian Government focus. In 2010, the Department of Climate Change and Energy Efficiency reissued the report, Climate Change Adaptation Actions for Local Government, first published in 2007. The report considers, along with other matters, climate change adaption in the context of local government planning and development approval functions (DCCEE, 2010b).

The Australian Government will continue to work toward establishing a national adaptation agenda and enhanced framework for climate change adaptation, while aiding local governments to build their capacity to address this issue.

10.1.2 State Policies and Action Plans

The Queensland Government's focus on climate change adaptation is governed through state planning policies as well as climate, community and coastal action plans and planning schemes. Those relevant to the Arrow LNG Plant include:

- ClimateSmart Adaptation 2007–2012. An action plan for managing the impacts of climate change, prepared by the Queensland Department of Natural Resources and Water (DNRW, 2007), the five-year plan contains 62 actions across sectors including business and industry, and was developed as part of Queensland's broader ClimateSmart 2050 strategy. The Office of Climate Change now has responsibility for implementing the plan.
- State Planning Policy 1/03: Mitigating the adverse impacts of flood, bushfire and landslide 2003. The policy requires likely impacts of climate change on natural hazards to be incorporated into hazard assessment studies. Suitable data sources for climate change predictions must be used.
- Queensland Coastal Plan: The coastal zone is also a priority area of focus for the Queensland Government (DERM, 2011a). The Queensland Coastal Plan comprises two policies: the State Policy for Coastal Management, and the State Planning Policy for Coastal Protection. The former policy applies to developments not assessable under the *Sustainable Planning Act 2009* (Qld), while the latter relates to assessable developments. Both policies seek to ensure that the projected effects of climate change are taken into account in infrastructure design, and

that development is undertaken in a manner that maintains or enhances coastal values. Under the plan, coastal hazard risk assessments are to be based on:

– A planning period of over 90 years.
– A projected mean sea level rise of 0.8 m by 2100.
– A 100 year average recurrence interval (ARI) for extreme storm events or water levels.
– An increased cyclone intensity of 10% (compared to maximum potential intensity).

- Gladstone Region Community Plan. The plan was adopted by the Gladstone Regional Council on 17 May 2011 (GRC, 2011a) and includes the goal of being responsive to emerging climate change and sustainability requirements. Detailed 'sustainability checks' will ensure that world's best practice is proven before new industries and companies come to the region.

- City of Gladstone's planning scheme (SKM, 2006). The scheme requires owners of premises situated below 4 m Australian Height Datum (AHD) to improve flood and storm surge immunity.

10.1.3 Australian Standards

The Australian Standard AS 4997-2005 Guidelines for the design of maritime structures includes the requirement to incorporate a factor for sea level rise in design as appropriate to the structure's design life. Sea level rise factors are 0.1, 0.2 and 0.4 m for 25, 50 and 100 year design life respectively. Design measures that enable future modification of structures are encouraged.

Other Australian standards that address climatic factors in design (but not specifically climate change) include:

- AS/NZS 1170.2-2011 Structural design actions – Part 2: wind actions.

- AS 1170.4-2007 Structural design actions – Part 4: earthquake actions in Australia.

- AS 3959-2009 Construction of buildings in bushfire prone areas.

The application of standards to address potential impacts from earthquakes and bushfires is discussed in Chapter 29, Hazard and Risk.

10.2 Assessment Method

The objective of the study was to identify the project's vulnerability to changing climate patterns and describe climate change adaption strategies that may be adopted for the design, construction and operation of the project. The study involved:

- Reviewing emerging Australian and Queensland government frameworks that deal with climate change adaptation.

- Summarising the current climate parameters and climatic extremes experienced within the project area.

- Reviewing projections for various climate parameters reported by the Intergovernmental Panel on Climate Change (IPCC), the Australian Government and the Queensland Government.

- Assessing the risks to the project related to projected climate change.

- Recommending a climate change strategy for the project, consistent with emerging frameworks, to mitigate against climate change risks.

10.2.1 Characterising the Existing Environment

In characterising the existing climate, long-term climate data for the project area was sourced from two Australian Bureau of Meteorology (BOM) weather stations considered largely representative of the weather on Curtis Island. These were:

- Gladstone Radar (latitude 23.8553°S, longitude 151.2628°E, elevation above mean sea level (MSL) 74.5 m).
- Gladstone Airport (latitude 23.8690°S, longitude 151.2214°E, elevation above MSL 16.6 m).

The Gladstone Radar, established in 1957, has collected more than 50 years of monitoring data, while the Gladstone Airport, established in 1993, has recorded up to 17 years of data. Monitoring data up to 31 December 2010 was used for the study.

Wind patterns, atmospheric stability class and mixing height at the LNG plant site were characterised by Katestone Environmental Pty Ltd (Appendix 14, Air Quality Impact Assessment).

10.2.2 Climate Change Projections

The IPCC provides the most authoritative projections for global climate change. In its special report on emissions scenarios (IPCC, 2000), the IPCC developed the following emission scenarios:

- Low range (B1) emissions scenario that assumes a rapid shift to less fossil fuel intensive industries.
- Medium range (A1B) emissions scenario that assumes a balance of energy sources.
- High range (A1FI) emissions scenario that assumes strong economic growth based on fossil fuel dependence.

These scenarios were used to develop low, medium and high projections for climate change at 2030, 2050 and 2070. Projections are detailed in the IPCC's third assessment report (IPCC, 2001) and fourth assessment report (IPCC, 2007).

The Australian Government used IPCC's emissions scenario projections as the basis for its national projections (CSIRO & BOM, 2007). In 2009, the Queensland Government built on CSIRO and BOM results, using finer spatial resolution and taking into account local topography and small-scale weather behaviour to produce more accurate predictions for the different regions of Queensland (DERM, 2009a). Only low (B1) and high (A1FI) emissions scenarios were discussed for 2050 and 2070 projections, as this was sufficient to describe the range of projections. The project area lies within the Central Queensland region designation.

Climate change projections discussed in the climate change assessment have been drawn from the above reports.

Further refinement and understanding of projections is ongoing through climate research at international, national and state level. DERM (2011b) details national and state research activities currently underway.

The design life of the LNG plant is 25 years, the concrete personnel jetty and materials offloading facility (MOF) have a design life of 40 years. Emissions projections for 2030 and 2050 were considered most relevant. Projections to 2070 were included in the study for completeness. The Queensland Coastal Plan encourages a planning life for development in excess of 90 years (DERM, 2011a).

There are inherent uncertainties associated with climate change projections produced by climate models. Further details of these uncertainties are provided in Appendix 1, Climate and Climate Change Adaptation.

10.3 Existing Environment and Environmental Values

The following section describes rainfall patterns (including magnitude and seasonal variability), air temperatures, humidity, wind (direction and speed), tidal characteristics, and historic weather patterns pertaining to thunderstorms, lightening, tropical cyclones and drought.

10.3.1 Rainfall and Evaporation

The Gladstone region has a subtropical climate with wet, hot and humid summers, and dry, mild winters. Average annual rainfall at the Gladstone Radar is 879 mm, most of which occurs during summer when monthly rainfall averages between 100 to 190 mm. January and February are typically the wettest months. Comparatively, during winter, average monthly rainfall ranges between 20 to 45 mm.

The Gladstone Radar has nevertheless recorded a significant difference between maximum and minimum rainfall across different years. The region experiences long term climate variability including the effects of the El Niño Southern Oscillation cycle that repeats every 2 to 8 years, and the Pacific Decadal Oscillation, an inter decadal system that demonstrates oscillating ‘warm’ and ‘cool’ regimes that, during the twentieth century, persisted for 20 to 30 years. During El Niño years, rainfall tends to be less than average while during La Niña years, above average rainfall or floods are often observed. Higher than average rainfall is also influenced by intense, short duration weather systems such as tropical cyclones.

Evaporation rates, measured using evaporation pans, are highest in summer (approximately 190 mm for the month of January) and lowest in winter (approximately 90 mm for the month of June). For both peaks, mean evaporation exceeds mean rainfall on a monthly basis.

10.3.2 Air Temperature

Long term monthly average temperatures display typical ranges for a subtropical region. In summer, mean monthly minimum temperatures range between 21°C and 23°C, with mean maximum temperatures of 30°C to 32°C. Temperatures equal to or above 35°C occur on average 4.4 days per year, with the highest temperature of 42°C recorded at Gladstone Airport in March 2007.

In winter, mean monthly minimum temperatures range between 12°C and 14°C, with mean maximum temperatures of 22°C to 23°C. Coolest temperatures are typically experienced in July. Gladstone Airport recorded the lowest temperature of 3.5°C in August 2003.

The warmest period of the day is between midday and 2.00 p.m., while the coolest period is just before sunrise, between 4.00 a.m. and 6.00 a.m.

Table 10.1 shows the percentage distribution of different classes of atmospheric stability at the LNG plant site. The high percentage of Class D stability is indicative of a coastal setting where the high heat capacity of water dampens the development of a strong convective boundary layer. A similar effect occurs at night, where the warmth of the water prevents the development of strong temperature inversions.

Table 10.1 Atmospheric stability at the LNG plant site

Atmospheric Stability Class	Frequency (%)
A – Extremely unstable	2
B – Unstable	12
C – Slightly unstable	15
D – Neutral	59
E – Slightly stable	5
F – Stable	7

The height above ground within which a plume can mix with ambient air is described as the mixing height and can vary over the course of a day. The growth of the mixing height is subject to how well the air can mix with the cooler upper levels of air and, therefore, depends on meteorological factors such as the intensity of solar radiation and wind speed. Computer modelling for the site shows that between the hours of 6.00 p.m. and 5.00 a.m., average mixing heights sit 350 m above ground level without much fluctuation. During the day, average mixing heights increase from 350 m above ground level to peak at 1.00 p.m. with average mixing heights of 1,000 m above ground level and maximum mixing heights of 2,000 m above the ground.

10.3.3 Relative Humidity

Gladstone Airport and Gladstone Radar record relative humidity at 9.00 a.m. and 3.00 p.m. daily. Mean monthly relative humidity is fairly consistent throughout the year, with slightly higher relative humidity from October through to March. Relative humidity at 9.00 a.m. at Gladstone Radar ranges from 63% in the spring months of September, October and November, to 72% in February. Relative humidity at 3.00 p.m. ranges from 53% in July to 64% in February.

Gladstone Radar observations record higher mean relative humidity than Gladstone Airport. This is most likely because the Gladstone Radar is closer to the coast, leading to greater moisture content in the air and, hence, greater relative humidity.

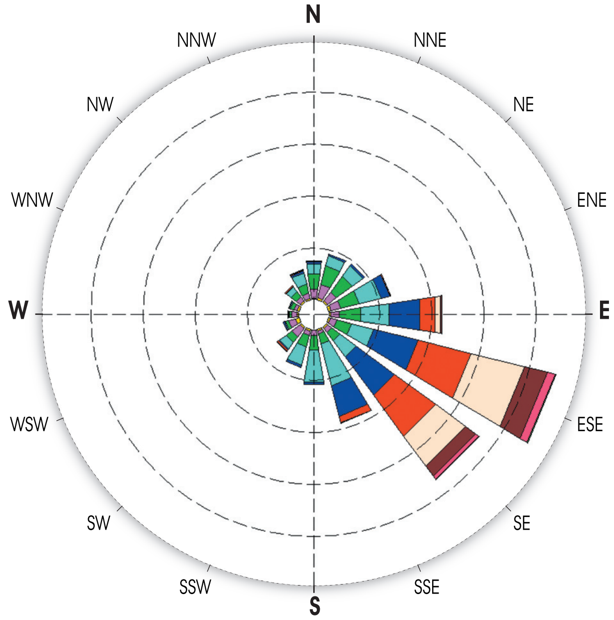
10.3.4 Wind Speed and Direction

Wind roses show the frequency of occurrence of winds by direction and strength. The bars correspond to the 16 compass points (north, north northeast, northeast, etc.) and represent wind blowing from that direction. Each bar is broken into discrete frequency categories that show the percentage of time wind blows from that particular direction, and at what speed.

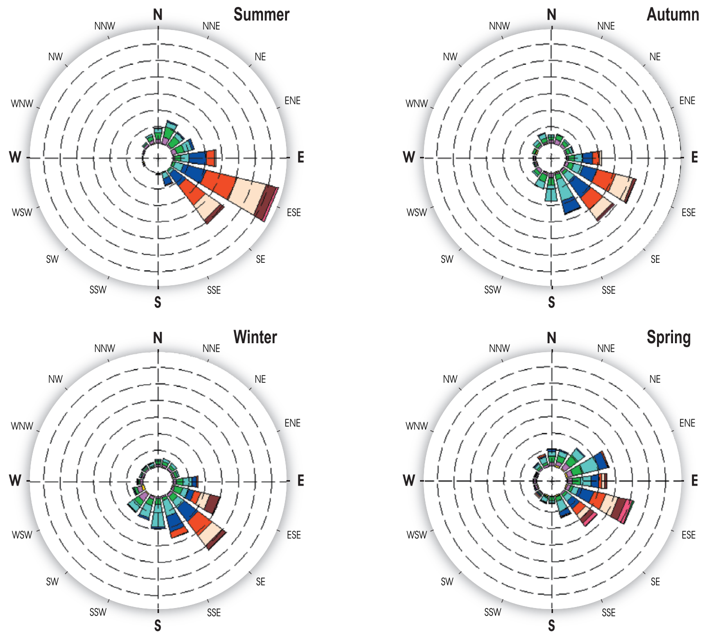
The annual distribution of wind patterns at the LNG plant site is shown in the wind rose in Figure 10.1. The southeast trade winds dominate, with winds from this direction accounting for 66% of the annual winds. Winds are strongest during the summer, when dominated by southeasterly and, to a lesser extent, northeasterly breezes. Winds are lighter during spring and blow from the same direction as summer winds. Autumn and winter winds are dominated by southeasterly and southwesterly winds.

Wind patterns change over the course of a day and are strongest between the hours of 12.00 p.m. and 6.00 p.m. A small ridge to the north of the LNG plant site can generate light winds that flow down the ridge to the coast during the evening.

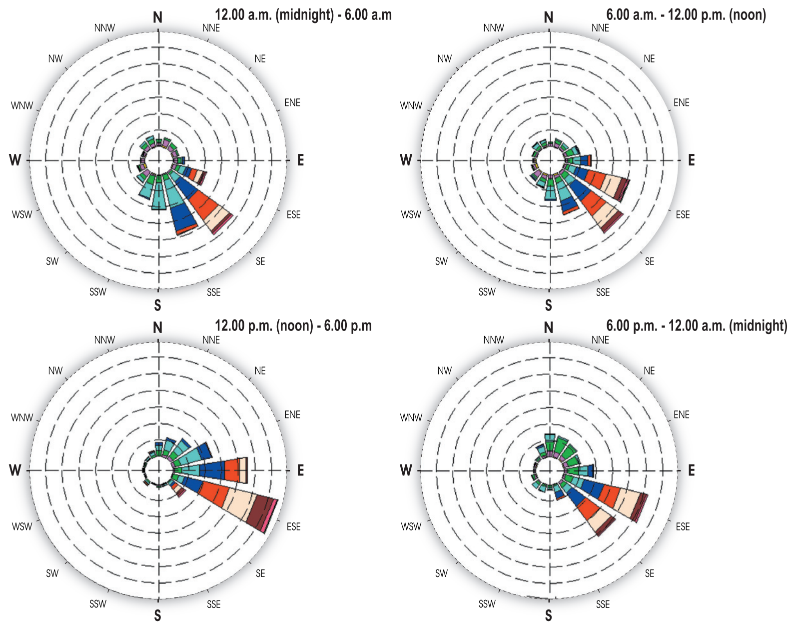
Annual distribution

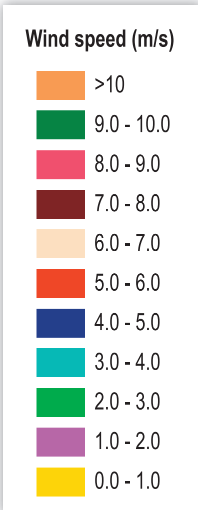


Seasonal variation



Daily variation





Source:
Appendix 14
(Air Quality Impact Assessment)

coffey environments	Job No: 7033	Arrow Energy	arrow energy go further	Annual wind speed and direction at the LNG plant site	Figure No: 10.1
	File Name: 7033_07_F10.01_GL	Arrow LNG Plant			

10.3.5 Tidal Characteristics

There are no tidal charts specific to Curtis Island. Tidal characteristics for Gladstone (the standard port) and Fishermans Landing (10 km west of Gladstone) are presented in Table 10.2. Mean sea level at Gladstone is 2.34 m.

Table 10.2 Tidal conditions for Gladstone and Fishermans' Landing

Tidal Condition	Gladstone (Standard Port)		Fishermans Landing	
	Height above Lowest Astronomical Tide (m)	Level AHD (-2.268m)	Height above Lowest Astronomical Tide (m)	Level AHD (-2.43 m)
Highest astronomical tide	4.83	2.562	5.12	2.69
Mean high water spring tide	3.96	1.692	4.20	1.77
Mean high water neap tide	3.11	0.842	3.30	0.87
Mean sea level	2.34	0.072	2.41	-0.02
Mean low water neap tide	1.57	-0.698	1.66	-0.77
Mean low water spring tide	0.72	-1.548	0.76	-1.67
Lowest astronomical tide	0	-2.268	0	-2.43

Source: MSQ (2011a).

10.3.6 Extreme Weather Events

Thunder frequency maps available from the Australian Government BOM indicate Gladstone experiences 20 to 25 thunder days per year (BOM, 2011).

Lightning flash density analysis shows Gladstone receives on average approximately five total flashes per km^2 per year (including intra cloud flashes), and two cloud to ground flashes per km^2 per year (BOM, 2011).

Gladstone lies to the south of Queensland's main area of tropical cyclone occurrence. Cyclones nevertheless impact the area; on some occasions this can be due to strong easterly winds and heavy rain that accompany cyclones to the north, and on other occasions because cyclones track further southward. Between 1906 and 2006, 34 tropical cyclones passed within 200 km of Gladstone, 6 of which passed within 50 km of the project area. Historic weather patterns have shown that cyclone activity in Australia decreases during an El Niño pattern and increases during La Niña. Cyclones also show greater tendency to track south during La Niña decades (DERM, 2009a).

Tsunami hazard, which results from seismic activity in the earth's crust under the ocean, is generally considered low along the east coast of Queensland (Geoscience Australia, 2011).

While the portion of the project area located on Curtis Island is not impacted by river floods, the proposed mainland launch site 1 is located at the mouth of the Calliope River, which has experienced numerous floods. The largest flood was recorded in 1947 and the fifth largest flood in 2003. The Calliope River also flooded in December 2010, though the magnitude of the flood event was unknown at the time of writing the EIS. Portions of the temporary workers' accommodation facility (TWAF) 7 site, located in a meander of Auckland Creek, are also subject to inundation. The stormwater impact assessment presents further details of flood modelling at these sites (see Appendix 6, Stormwater Quality Impact Assessment).

Awoonga Dam on the Boyne River (22.7 km upstream from the river mouth) serves as the major water supply for the city of Gladstone. The Gladstone region has experienced 'short term' droughts, with limited rainfall over periods of up to 12 months, including months during which the Boyne River experienced zero or very low flows. The most significant short term droughts occurred in 1941 and 1969 (GAWB, 2009a).

There have also been ‘long term’ droughts, sometimes coinciding with short term droughts. Many droughts in northern and eastern Australia are associated with the El Niño Southern Oscillation cycle. Long term droughts occurred during 1965 to 1967, 1969 to 1970, 1984 to 1985, 1993 to 1995, 1997 to 2003 and 2004 to 2008 (GAWB, 2009a).

Drought leads to drier conditions, hence increased chance and severity of bushfires. The LNG plant site on Curtis Island is considered to have medium bushfire hazard according to the Calliope Shire Council Planning Scheme Bushfire Management Overlay (CCC, 2007a).

10.4 Issues and Potential Impacts

The following section summarises IPCC, Australian Government and Queensland Government climate change predictions, including the Queensland Government observed climate change trends for key climate change parameters; and discusses the potential impacts of these changes on the design, construction and operation of the Arrow LNG Plant.

10.4.1 Rainfall, Evaporation and Drought

The Central Queensland region experienced a 13% decline in average annual rainfall for the decade 1998 to 2007 compared to the period 1969 to 1990. Declines in summer (14%) and autumn (38%) were the greatest contributors to this decline. Historical records suggest this decline falls within the normal ranges for natural climate variation, as similar periods of decline in autumn rainfall were observed for the Central Queensland region in the 1920s and 1960s (DERM, 2009).

The influence of multiple variables, including local terrain and small scale through to large scale weather systems, makes rainfall one of the hardest variables for climate models to predict. Best estimates (i.e., median) for the Central Queensland region identify a decrease in average annual rainfall (DERM, 2009a) as follows:

- 3% by 2030.
- 4% to 7% by 2050 (for low to high emissions scenario).
- 6% to 10% by 2070 (for low to high emissions scenario).

Overall average annual rainfall is expected to decrease and severe, short term, high rainfall events, i.e., associated with cyclone activity, are expected to increase.

Evaporation is dependent on a number of climate variables, including temperature, relative humidity, and cloud cover. Best estimates (i.e., median) for the Central Queensland region show evaporation increasing by 3% by 2030, 4% to 7% by 2050, and 5% to 10% by 2070 (dependent on the emissions scenario) (DERM, 2009a).

Decreased rainfall coupled with increased evaporation depletes soil moisture. The Gladstone region is susceptible to drought and, with decreased rainfall, increased evaporation and the ongoing influence of the El Niño Southern Oscillation cycle, periods of short term and long term drought are likely to continue to occur.

Potential impacts on the LNG plant arising from the climate variables discussed above include:

- Increased bushfire risk arising from drier conditions caused by decreased rainfall, increased evaporation and higher temperatures.

- Decreased availability of fresh water. This impact is expected to be minor during the operational life of the plant as LNG facilities will be designed to incorporate reverse osmosis seawater desalination facilities. Water will be required in the short term for construction activities and the construction camp, until such time that the reverse osmosis plant is built.

10.4.2 Air Temperature

Across the Central Queensland region, the average annual temperature increased by 0.5°C in the period 1997 to 2007 (DERM, 2009a). Looking forward, average annual temperatures are expected to increase by:

- 0.7°C to 1.4°C by 2030 (dependent on the emissions scenario).
- 0.8°C to 2.8°C by 2050 (dependent on the emissions scenario).
- 1.1°C to 2.3°C by 2070 for the low emissions (B1) scenario.
- 2.2°C to 4.5°C by 2070 for the high emissions (A1FI) scenario.

The number of days Gladstone experiences temperatures of greater than 35°C are also likely to increase from the current average of 4.4 days per year. Queensland Government projections for Rockhampton (located approximately 90 km northwest of Gladstone near the coast) and Barcaldine (located approximately 600 km inland from Gladstone) demonstrate that changes to temperature extremes will vary depending on location specific data (regional topography, prevailing winds, etc.). Rockhampton's current average of 16 days per year average is projected to increase by a factor of 4 to 64 days per year under the high range (A1FI) scenario at 2070, whereas Barcaldine's number of 35°C and above days is projected to double from 87 days to 163 days under the same scenario (DERM, 2009a).

An increase in ambient temperature has potential to impact the LNG plant by:

- Increasing the operational temperature range of equipment and construction materials. This impact is expected to be minor given the large temperature variation the plant must be designed to accommodate in the liquefaction process.

- Decreasing the efficiency of power generation. Estimates suggest an ambient inlet temperature rise of 3.5°C could decrease power output of gas turbines by 0.6 MW to 1 MW. This will increase the amount of gas required for power generation and reduce the output of LNG product.

- Increasing risks to the health of workers and, in particular, incidence of heat stress and insect borne diseases. Tropical diseases such as Ross River virus and dengue fever, for which temperature is a key determinant, are expected to increase under climate change (DERM, 2009a).

10.4.3 Sea Level Rise and Severe Weather Events

Global sea level rose at a rate of 1.8 mm per year from 1961 to 2003, rising to 3 mm per year from 1993 to 2003. Around Australia, mean sea level rose about 1.2 mm per year during the twentieth century. These rates are an order of magnitude larger than average rates over the previous several thousand years (CSIRO & BOM, 2007).

Mean sea level rise results from two main processes: increases to heat content of the ocean otherwise known as thermal expansion, which increases the volume and therefore the height of the ocean; and the melting of land based ice. The IPCC projects the global average mean sea level will rise by 18 to 59 cm by 2100, with melting ice sheets potentially contributing an additional 100 to 200 mm (IPCC, 2007).

CSIRO and BOM note that the effect of rising sea levels will be felt most profoundly, and potentially have the greatest impacts, during extreme weather events when falling atmospheric pressure and strong winds produce localised increases in sea levels, known as storm surge (CSIRO & BOM, 2007). Coupled with a rise in mean sea levels, storm surges will penetrate further inland, therefore increasing the risk of erosion and damage to ecosystems and infrastructure (DERM, 2009a).

Although recent studies project the overall frequency of cyclones off the east coast of Australia to decrease slightly by 2070, the number of long-lived and severe cyclones (Category 3 to 5) is projected to increase, potentially by up to 140%. Cyclone development is also projected to shift southward in the coming century, exposing the Central Queensland region to greater cyclone impacts (DERM, 2009a).

Hardy et al. (2004a) have predicted a 0.51 m increase to the 1 in 100 year storm tide event (also known as the 100 year ARI) at Gladstone should the following conditions eventuate simultaneously: mean sea level rises by 0.3 cm, cyclone intensity and frequency increase by 10% and cyclone tracks shift 130 km southward. This would lead to a storm surge tide rise from 2.82 m AHD to 3.33 m AHD. Projected values for the 500 and 1,000 year ARI events are also presented in Table 10.3, along with data for Emu Park (approximately 80 km northeast of Gladstone) and Tannum Sands (approximately 16 km southeast of Gladstone).

Table 10.3 Present and projected storm tide

Location	Storm Tide Level (m AHD)					
	100-year ARI		500-year ARI		1,000-year ARI	
	2003	Greenhouse	2003	Greenhouse	2003	Greenhouse
Emu Park (Rosslyn Bay)	2.87	3.28	3.30	3.95	3.54	4.30
Gladstone (Auckland Point)	2.82	3.33	3.51	4.18	3.80	4.51
Tannum Sands (Gatcombe Head)	2.50	2.95	3.05	3.64	3.31	3.94

Source: Hardy et al. (2004a). Note: 'Greenhouse' corresponds to a storm tide level caused by the combination of three greenhouse induced climate change scenarios that would occur simultaneously at a given time. It should be noted that, for the scenarios selected for this particular study, no specific date is associated with storm tide level predictions.

The planning scheme for the City of Gladstone requires owners of premises situated below 4 m AHD to employ mitigation to improve flood and storm surge immunity (SKM, 2006). The surface water and stormwater impact assessment for the Arrow LNG Plant (Appendix 5, Surface Water Impact Assessment) recommends that a design storm tide maximum level of 4.06 AHD be adopted for detailed design of the project and future planning. This figure was based on a 100 year planning period with a 6% allowance for tide amplification (see Appendix 8, Coastal Processes, Marine Water Quality, Hydrodynamics and Legislation Assessment).

These requirements will be considered during design of the mainland launch site 1 (at the mouth of the Calliope River) and TWAF 7 (near Auckland Creek) should these options be progressed. The Gladstone State Development Area Development Scheme, which applies to the LNG plant site, does not specifically address storm surge (DIP, 2010c).

Potential impacts to the LNG plant arising from sea level rise and severe weather include:

- Stronger winds arising from more frequent and severe weather events, which could increase wind shear stresses on LNG plant infrastructure.
- Storm surge associated with increased mean sea level and severe weather events could lead to inundation of low lying areas of the LNG plant site. The tidal flats to the immediate south of

the site experience inundation during mean high water neap tides (i.e., 0.842 m AHD and 0.87 m AHD) and above. A 0.51 m increase to the 1-in-100-year storm tide event would increase salt water encroachment a further 50 m into the site. Proposed earthworks to in-fill the south of the site to 11 m AHD will modify the area to sit 8 m above the highest astronomical tide. Therefore, storm surge is not expected to pose a threat to the site for 100 year, 500 year or 1,000 year ARI events once the LNG plant is constructed.

- Heavy rainfall associated with more frequent and severe weather events could place greater strain on stormwater drainage systems. Hydraulic modelling conducted as part of the surface water and stormwater impact assessment indicates that, due to the steepness of slope, any flash flooding caused by storm events will rapidly dissipate. Consequently, flood hazard is considered low to moderate (see Chapter 13, Surface Water, Hydrology and Water Quality).

10.5 Avoidance, Mitigation and Management Measures

A preventative approach to the design and construction of various project components will for the most part ensure the Arrow LNG Plant is well prepared for the potential effects of climate change. The Arrow LNG Plant climate change adaptation strategy will include the following actions.

Design considerations that will be implemented include:

- Design the plant in accordance with the most current Australian standards addressing climatic factors including wind, bushfires, and sea level rise for maritime structures. [C10.01]
- Consider climate change induced increases in ambient air temperature when specifying the design operating conditions for plant and equipment. [C10.02]
- Consider changes to natural tidal inundation and storm surge levels due to climate change when siting permanent facilities. [C10.03]
- Seek ways to lower water consumption through water efficient technologies and practices or by installation of water efficient devices. [C10.04]
- Deploy preventive and responsive measures for bushfire management. [C10.05]
- Incorporate climate change induced health risks into workplace health, safety and environmental management plans. [C10.06]
- Engage in government or industry climate change programs. [C10.07]
- Estimate and include climate change costs in business cost projection and, at the same time, take advantage of emerging business opportunities that climate change may generate. [C10.08]

10.6 Residual Impacts

There is significant uncertainty associated with climate change projections. Assessment of residual risks, should the climate adaptation strategy fail, is therefore considered premature.

A fundamental first step to reducing the project's vulnerability to potential climate change impacts is to design the Arrow LNG Plant to take into account high emissions (A1FI) projections for the Central Queensland region and, where possible, projections for the Port of Gladstone specifically. Arrow Energy will keep informed of ongoing refinement of climate change projections within government and scientific communities, and will consider future adaptation requirements should additional or revised risks be identified.

10.7 Commitments

The measures (commitments) that Arrow Energy will implement to manage impacts on climate and climate change are set out in Table 10.4.

Table 10.4 Commitments: Climate and climate change

No.	Commitment
C10.01	Design the plant in accordance with the most current Australian standards addressing climatic factors including wind, bushfires, and sea level rise for maritime structures.
C10.02	Consider climate change induced increases in ambient air temperature when specifying the design operating conditions for plant and equipment.
C10.03	Consider changes to natural tidal inundation and storm surge levels due to climate change when siting permanent facilities.
C10.04	Seek ways to lower water consumption through water-efficient technologies and practices or by installation of water efficient devices.
C10.05	Deploy preventative and responsive measures for bushfire management.
C10.06	Incorporate climate change induced health risks into workplace health, safety and environmental management plans.
C10.07	Engage in government or industry climate change programs.
C10.08	Estimate and include climate change costs in business cost projection and, at the same time, take advantage of emerging business opportunities that climate change may generate.