Appendix O
Climate Change Impact Assessment

Townsville Marine Precinct Project

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1. Climate Change Risk and Adaptation Assessment

1.1 Background

In 2007 the Intergovernmental Panel on Climate Change (IPCC) released its fourth assessment report on climate change which stated that warming of the climate system is now unequivocal. Changes in the global climate system, as a result of this warming, are likely to result in:

- Fewer cold days and nights and an increased frequency of heat waves over most land areas;
- An increase in the proportion of total rainfall from heavy falls;
- An increase in area effected by drought; and
- Increased intensity of tropical cyclones and incidences of extreme high sea level.

Increases in global average air and ocean temperatures and rising global average sea level are already evident from observations during the late twentieth century. For example, over the period from 1961 to 2003, global average sea level rose at a rate of 1.8 (1.3 to 2.3) mm per year and during the period from 1993 to 2003, the rate was faster at approximately 3.1 (2.3 to 3.8) mm per year (IPCC 2007).

The impacts of climate change are likely to affect many infrastructure projects with a projected lifespan greater than 30 years and therefore an assessment of this project's vulnerabilities to climate change is included in this report.

1.2 Scope of Work

The following additional Terms of Reference in regards to climate change adaptation have been received from the Townsville Port Authority:

The EIS should provide an assessment of the project's vulnerabilities to climate change and describe possible adaptation strategies for the activity including:

- *The implications of climate change on the Project's environmental and commercial feasibility should be discussed with particular reference to rainfall, sea level rise and the occurrence of extreme water level and wave conditions.*
- *The preferred and alternative adaptation strategies to be implemented.*
- *Commitments to undertaking, where practicable, a cooperative approach with government, other industry and other sectors to address adaptation to climate change.*

It is noted that that predictions of climate change and its effects have inherent uncertainties, and that a balance must be found between the costs of preparing for climate change and the uncertainty of outcomes. However, the proponent should use its best efforts to incorporate adaptation to climate change in their EIS and project design.

1.3 Methodology

The Townsville Port Authority has requested a climate change response component be included as part of the EIS for the Townsville Marine Precincts Project. The QLD Government developed a methodology for *Climate Change Impact Statements* (CCIS) in July 2008 to consider climate change in decision making and to provide an assessment of the climate change impacts associated with projects. The CCIS is a mandatory requirement for all cabinet submissions.

The guidelines for a CCIS outlines a qualitative methodology for undertaking:

- (1) a greenhouse gas (GHG) emissions assessment which measures the potential contribution of the project to the State's emissions profile; and
- (2) a climate change adaptation assessment which analyses the physical risks to the project from climate change and identifies measures to reduce these risks.

This report encompasses a *Climate Change Adaptation Assessment* (CCAA) which includes an analysis of the risks to the proposal from climate change impacts and a description of adaptation measures to minimise these risks.

In order to address the above requirements, the risk assessment methodology adopted was as follows:

- Based on the expected lifespan of the project, appropriate climate change modelling scenarios were identified and projected changes in the variables of rainfall, sea level rise and the occurrence of extreme water level and wave conditions for the Townsville region were identified;
- Potential impacts of changes in each of these climate variables on the project were identified;
- A 3 hour workshop was held with relevant project staff involved in the EIS to review the potential impacts of climate change on different aspects and phases of the project, discuss and rank preferred adaptation options;
- The potential to undertake cooperative approaches with government, other industry and other sectors to implement strategies was investigated; and
- Deliver a *Climate Change Adaptation Assessment* Report for the EIS.

The following table outlines the methodology used to perform an assessment of the climate change impacts on the project and determine potential adaptation options.

Table 1 Climate Change Risk and Adaptation Assessment Methodology

Steps	Activities
1. Context setting – Climate scenarios, scope of assessment, evaluation framework	1.1 Identify appropriate climate change scenarios for the Townsville region
	1.2 Determine the projected climate changes likely for temperature; rainfall; sea-level rise; extreme events; and extreme wave conditions
	1.3 Establish the scope for the assessment and determine the evaluation framework to be used
2. Risk Assessment Workshop – Identify, evaluate and analyse risks	2.1 Conduct a multi-disciplinary risk workshop with the project's key technical consultants
	2.2 Identify and analyse the risks to the project from projected climate change impacts using determined risk management framework
3. Adaptation Assessment - Adaptation actions to minimise the identified risks	3.1 Evaluate and rank preferred adaptation actions (potential controls or risk options)
	3.2 Review the initial assessment and place risks into priority categories
	3.3 Determine potential cooperative approaches with other government and industry sectors to implement strategies
4. Climate Change Adaptation Report	4.1 Deliver the CCAA report to be incorporated into the EIS

1.3.1 Risk Assessment Workshop

The following tasks were completed in the Climate Change Risk Workshop, using a risk register (see Appendix A) to record the inputs.

Identify Risks

Workshop participants brainstormed the likely impacts on the project associated with the projected changes in each of the following climate change variables until the main issues were considered to have been identified:

- Mean sea level;
- Extreme wave and wind events;
- Increased variability of rainfall; and
- Increases in average and extreme temperatures.

Analyse Risks

The following analysis was undertaken for each risk:

- Determination of any existing controls that are already in place to mitigate the risk (features of the environment, natural and man made structures and mechanisms, procedures and other factors);
- Describe the consequences the risk would have if it was to arise, given the controls, for the 100 year scenario under consideration;
- Describe the likelihood of that level of consequence, again given the controls, in the scenario under consideration; and
- Assign an initial priority based on the likelihood and consequence of the risk.

1.3.2 Adaptation Assessment

Evaluate the Risks

When all key elements had been considered, the risks were assembled into a single set and reviewed as a whole. The risk ratings were then reviewed, and adjusted to reflect the agreed priorities the participants felt were appropriate. The outcome was a list of risks with all information recorded from the identification and analysis stages.

Review Assessment

The review process placed the identified risks into the following categories:

- Risks that should be treated immediately without further analysis and for which the appropriate treatment is clear;
- Risks that can be set aside without further action for the time being; and
- Risks that will require more detailed analysis before determining whether to treat them or not, or to determine the most appropriate form of treatment.

Finally, any substantial, high or extreme risks were assessed as to the potential adaptation options available to reduce the risk, as well as the preferred control options.

2. Context Setting

2.1 Background on Climate Change

The IPCC (2007) has projected that by 2050, ongoing coastal development and population growth in some areas of Australia will exacerbate risks from sea level rise and from increases in the severity and frequency of storms and coastal flooding.

IPCC (2007) projections for the Townsville region include:

» Increase in annual average temperatures;

» Increase in the number of extreme hot days;

» Decrease in average annual rainfall and number of rain days;

» Slight increase in the intensity of rainfall;

» Increase in mean sea level;

» Increase in storm tide height (storm surge);

» Increase in number of severe cyclones (but not an increase in total cyclone days);

» Increase in extreme wind conditions (related to severe cyclones); and

» Increase in fire risks and hazards.

2.2 Impacts on Infrastructure, Transport and Settlements

The IPCC (2007) documented the possible impacts from climate change on various sectors. The projected major impacts on industry, settlements and society are highlighted below.

Table 2 Projected Major Impacts on Industry, Settlement and Society (IPCC 2007)

Climate Change	Possible Impacts
Increase in intense tropical cyclone activity	Disruption by floods and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for population migration; loss of property
Increased incidence of extreme high sea levels	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; (also see tropical cyclones above)
Heavy precipitation events	Disruptions to settlements, commerce, transport and societies due to flooding; pressures on rural and urban infrastructures; loss of property
Warmer and more frequent hot days	Decreased demand for heating; increased demand for cooling; declining air quality in cities; impacts on the elderly, very young and the poor

2.3 Possible Impacts on Coastal Infrastructure

The following published literature contains information relevant to coastal and port developments.

2.3.1 Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering

Based on the *Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering* (Engineers Australia 2004), key climatic and environmental variables relevant to a port related project are tabled below.

Table 3 Main Impacts on a Port Development from the Effects of Climate Change

Key Climatic Variable	Secondary Variables	Main Impact
Mean sea level	Local sea level	Increased astronomical tides and storm surge - Estuaries and over-land penetration
	Local currents	Wave driven, tidal stream, storm surge - Shallow water and estuaries
	Local waves	Breakers - Shallow water
	Effects on Structures	Increased maintenance, changes to standards - Design and older structures
	Groundwater	Level and quality - Saltwater intrusion
	Coastal Flooding	Level, frequency and extent - Infrastructure
	Foreshore stability	Entrance - Tidal prism changes, flow velocities and bar configuration
		Dune - Groundwater level affecting stability, wave set-up and run-up, increased wave exposure and beach fluctuations, dune overtopping
	Sediment transport	Longshore, on and off shore - Changed distribution of motive energy, breaker depth, wave refracted angle
	Beach response	Alignment - Changed wave refraction, diffraction and attenuation
		Recession - Decreased amenity and buffer zones
		Fluctuations - Changed wave refraction, diffraction and attenuation, wave setup and run-up
	Hydraulics of Estuaries	Tides - Reduced friction, increased tidal prism, increased heights and volumes
		Wave penetration - Increased
		Seawater penetration - Upstream

Key Climatic Variable	Secondary Variables	Main Impact
		Mixing - Increased exchange
	Quality of Coastal Waters	Estuarine - Altered depths, greater exchange, sea water penetration
Ocean currents and temperature	Local Currents	Prevailing - Changes
	Effects on Structures	Investigation - Changing statistics will affect determination of design criteria
	Sediment Transport	Longshore - Magnitude and duration of storm currents
		Deepwater - Transport
Wind Climate	Local SLR	Storm surge - Increased
	Local Current	Prevailing, Storm Surge
	Local Winds	Prevailing, Storm
	Effects on Structures	Investigation - Changing statistics will affect determination of design criteria
		Design - Forcing – possible changes to marginal probability of failure
		Maintenance - Older structures may need retrofitting or upgrade
	Coastal Flooding	Level, Frequency, Extent
	Beach Response	Fluctuations - Changed timescales for beach recovery
	Foreshore Stability	Entrance - Changed near shore currents affecting sediment transport, Aeolian transport
	Sediment Transport	Longshore wind generated currents
		Aeolian - Dune mobility and direction
	Quality of Coastal Waters	Near shore, Estuarine - Changed mixing and turbidity
Wave Climate	Local SLR	Wave Setup
	Local Currents	Wave Driven
	Local Waves	Wind driven
		Prevailing swell - Especially direction and possibly period
		Extreme
	Effects on Structures	Investigation - Changing statistics will affect determination of design criteria
		Design - Forcing – possible changes to marginal probability of failure

Key Climatic Variable	Secondary Variables	Main Impact
		Maintenance - Older structures may need retrofitting or upgrade
	Coastal Flooding	Level, Frequency, Extent - Via wave setup at open sites
	Beach Response	Alignment, Recession or Progradation - Wave direction energy changes
		Fluctuations - Wave direction energy changes, Changed timescales for beach recovery
	Foreshore Stability	Entrance - Changed littoral drift environment
		Dune - Changed scarp toe erosion, wave run-up and overtopping, break through
	Sediment Transport	Longshore, Onshore, Offshore - Wave directional energy changes, magnitude and duration of storms
		Deepwater - Major effect on mobilisation
	Quality of Coastal Waters	Offshore, near shore, estuarine - Changed mixing and turbidity
Rainfall/Runoff	Effects on Structures	Investigation - Changing statistics will affect determination of design criteria
		Design - Depends on location or purpose
	Foreshore Stability	Entrance - Frequency of Breakout, Baseline flows

2.3.2 Infrastructure and Climate Change – Report to the Victorian Government

The CSIRO (2007b) has highlighted possible major risks associated with future climate change for transport and building infrastructure in *Infrastructure and Climate Change – Report to the Victorian Government 2007*. Major risks to be considered are:

Transport

- Increased intensity of extreme rainfall events may cause significant flood damage to road, rail, bridge, airport, port and especially tunnel infrastructure.
- Rail, bridges, airports and ports are susceptible to extreme wind events; ports and coastal infrastructure are particularly at risk when storm surges combine with sea level rise.
- Accelerated degradation of materials, structures and foundations of transport infrastructure may occur through increased ground movement and changes in groundwater.
- Increased temperature and solar radiation could reduce the life of asphalt on road surfaces and airport tarmacs.
- Increased temperature stresses the steel in bridges and rail tracks through expansion and increased movement.

– Increased temperature causes expansion of concrete joints, protective cladding, coatings and sealants on bridges and airport infrastructure.

Buildings

– Increased intensity of extreme rainfall, wind and lightning events is likely to cause significant damage to buildings and urban facilities.

– Buildings and facilities close to the coast are particularly at risk when storm surges are combined with sea level rise.

– Accelerated degradation of materials, structures and foundations of buildings and facilities may occur through increased ground movement and changes in groundwater.

– Increased temperature and solar radiation could reduce the life of building and facility elements due to temperature expansion and materials breakdown of concrete joints, steel, asphalt, protective cladding, coatings, sealants, timber and masonry.

– Accelerated degradation of materials may reduce the life expectancy of buildings, structures and facilities, increasing the maintenance costs and leading to potential structural failure during extreme events.

A risk assessment for port infrastructure was undertaken for this report. The possible impacts on port and coastal infrastructure, for a high climate change scenario projected for 2070, are tabled below.

Table 4 Possible Impacts on Ports and Coastal Infrastructure (CSIRO 2007b)

Climate Change Variable	Impacts
More intense tropical cyclones and storms	» Degradation, failure and replacement of port, coastal and sea platform structures due to increase in power and reach of storm surge, coastal flooding, spray zone and erosion patterns. » Increase in magnitude and duration of storm currents and increase in the number of incidents of water over sea wall structures and low land flooding. » Reducing the capacity of natural systems to recover from storm erosion including permanent loss of sand offshore and degradation of structures. Retreat of coast landscapes. » The magnitude of the power of wave forces are increased while the height at which this power is concentrated on structures also increases. Water based infrastructure is designed for stress conditions on a specific area of the structure and as those conditions intensify and are focused higher on the structure, the vulnerability of the structure increases. » Almost certain increased maintenance and replacement costs of port, coastal and sea platform infrastructure. » Short term loss of port access. Increased service disruption due to increased maintenance regime. Back up of goods at the container terminals during closure generating a financial burden on businesses.

Climate Change Variable	Impacts
	» State wide coastal costs from increased storm surge damage to coastal protection infrastructure, seawalls, dunes, breakwater etc.
Sea level rise and coastal flooding	» Degradation over time of materials specifically designed for a particular range of sea level conditions due to a change in conditions. » Redevelopment of wharf fender arrangements (to barrier ships at dock). » Raising of the high risk exposure category of the water level, will increase exposure of decks of wharfs and jetties and accelerate corrosion levels to decks. » Likely, major increased maintenance and replacement costs of port, coastal and sea platform infrastructure. » State wide coastal costs from increased storm surge damage to coastal protection infrastructure, seawalls, dunes, breakwater etc. » Loss of viable residential land use where impacted by increased storm surge activity and intrusion.

2.4 Adaptation to Climate Change

The IPCC (2007) has acknowledged that additional adaptation measures will be required to reduce the adverse impacts of projected climate change and variability, regardless of the scale of mitigation undertaken over the next two to three decades. The IPCC (2007) has recognised that a wide array of adaptation options are available, and planned adaptation can reduce vulnerability, especially when embedded within broader sectoral initiatives.

Table 5 Sectoral Examples of Planned Adaptation (IPCC 2007)

Sector	Adaptation Option/Strategy	Policy Framework
Infrastructure/Settlement (including Coastal Zones)	Relocation; seawalls and storm surge barriers; dune reinforcement; land acquisition and creation of marshlands/wetlands as buffer against sea level rise and flooding; protection of existing natural barriers	Standards and regulations that integrate climate change considerations into design; land-use policies; building codes; insurance
Transport	Realignment/relocation; design standards and planning for roads, rail and other infrastructure to cope with warming and drainage	Integrating climate change considerations into national transport policy; investment in R&D for special situations

The IPCC (2007) has recognised that the capacity to adapt is connected to social and economic development, which is unevenly distributed across and within societies. Key constraints for planned adaptation include: technological and financial barriers; availability of relocation space; and availability of less vulnerable routes (IPCC 2007). Although constraints may limit the opportunity for adaptation measures, there are also opportunities which can be maximised with the implementation of adaptations – integrated policies and management plans; synergies with sustainable development goals; and improved technologies and integration with key sectors (IPCC 2007).

2.5 Climate Change Planning Instruments in Queensland

Requirements to assess potential risks associated with climate change on development projects and to implement adaptation strategies are included in the following planning instruments and guidelines.

- The Office of Climate Change leads the development of a whole-of-government policy framework to meet the climate change challenge. Queensland's Climate Change Strategy, ***ClimateSmart 2050***, along with the associated action plan *Climate Smart Adaptation 2007-2012* Action Plan, is currently being reviewed, updated and consolidated in light of the latest scientific assessments as well as national and international developments in climate change and climate change policy.
- The State Coastal Management Plan provides the direction for addressing potential impacts of climate change when undertaking planning for the coast. The Minister for Sustainability, Climate Change and Innovation has undertaken a review of the

Management Plan, and the draft is currently on hold pending the March 2009 election process.

Policy 2.2.1 Adaptation to Climate Change states that planning for the coast must address the potential risks associated with the impacts of climate change. Targets to achieve this are addressed through the following hierarchy of approaches:

1. *Avoid* – focus on locating new developments in areas not vulnerable to the impacts of climate change;
2. *Planned retreat* – focus on systematic abandonment of land, ecosystems and structures in vulnerable areas;
3. *Accommodate* – focus on continued occupation of near-coastal areas but with adjustments such as altered building design; and
4. *Protect* – focus on the defence of vulnerable areas, population centres, economic activities and coastal resources.

Policy 2.2.4 Coastal Hazards provides the framework for managing storm events, ensuring evaluation of new areas for storm tide hazard areas including the consideration of impacts from potential sea level rise.

» The ***State Planning Policy 1/03 Mitigating the Adverse Impacts of Flood, Bushfire and Landslide*** states that the projected impacts of climate change, in accordance with the precautionary principle, should be taken into account when undertaking natural hazard assessments. Predicted changes are likely to include: reductions in annual rainfall, but increases in rainfall intensity; coastal erosion; sea level rise; and increased damage to transport infrastructure and low-lying human settlements.

» The **Operational Policy for Coastal Development – Building and Engineering Standards for Tidal Works** provides guidelines for the minimum standards that must be adopted for tidal works under the Integrated Planning Act 1997.

» The ***AS/NZS 1170.2:2002 Structural design actions – Wind actions*** provides design guidance in reference to wind. The wind speeds provided in this standard are based on current conditions and do not include consideration of projected changes in climate.

» The ***Australian Standard 4997-2005 Guidelines for the design of maritime structures*** currently includes a requirement for the design of maritime structures to factor in the sea level rise factors for different structure design lives. The AS 4997-2005 guideline states that the allowance for sea level rise does not necessarily include the construction of the deck of the facility at a higher level, although in some cases this may be prudent. Allowance for sea level rise may include options to raise the heights of restraining piles on floating structures at a later time, or installing substructure of adequate strength to permit future topping slabs etc.

Table 6 AS 4997-2005 Sea Level Rise Factors

Design Life	Sea Level Rise
25 years	0.1m
50 years	0.2m
100 years	**0.4m**

The sea level rise amounts for the AS 4997-2005 standard were based on *mid-range* scenarios from the 2001 Intergovernmental Panel on Climate Change (IPCC) third assessment report *Climate Change 2001 - the Scientific Basis.*

» The QLD Office of Climate Change (EPA) has produced ***Guidelines for Preparing a Climate Change Impact Statement*** (QOCC 2008). From 1 July 2008, a Climate Change Impact Statement (CCIS) became a required inclusion in all submissions to Cabinet. The CCIS is intended to provide cabinet with specific information in relation to future climate change risks associated with proposals. In relation to sea level rise, the guideline for undertaking a climate change adaptation assessment as part of a CCIS includes the following sea level rise figures.

Table 7 CCIS Sea Level Rise Requirements

Expected life of proposal	Assess the impact of the following sea level
2015 and up to 2030	0.17 m
between 2031 and 2070	0.49 m
beyond 2070	0.79 m

These sea level rise figures have been based on the projected global mean sea level increases for 2100 reported in the IPCC (2007) Fourth Assessment Report, adjusted, in accordance with advice from CSIRO, to reflect the shorter timescales used in the climate change adaptation assessment. The sea level rise figure for projects expected to exist beyond 2070 is based on the IPCC (2007) upper estimate of the high emissions (A1FI) scenario for 2100 (0.59m) with the additional 0.2m from additional ice melt included (QOCC 2008).

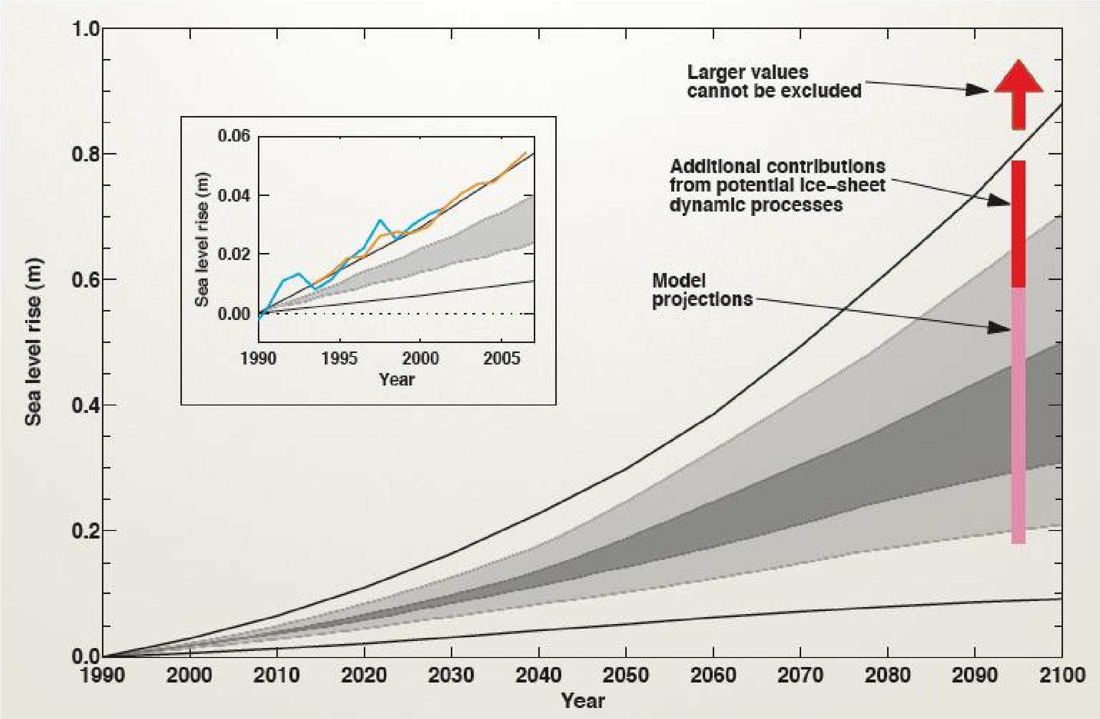
2.6 Climate Change Timeframes & Scenarios

This risk assessment has assessed the impacts of climate change on this project over a 100 year timeframe. This timeframe was chosen as it represents the projected design life of the project.

The Intergovernmental Panel on Climate Change (IPCC 2000) has defined a number of different emissions scenarios which are used for driving global climate models to produce climate change scenarios. These emissions scenarios were defined in the Special Report on Emissions Scenarios and are referred to as the SRES scenarios. The emissions scenarios are based on a range of driving forces of future emissions such as changes in demographics, technology and economics.

The figure below summarises sea level rise projections from the IPCC 2001 and 2007 assessment reports from the range of SRES scenarios. The shaded regions and curved lines represent the upper and lower limits of the 2001 projections and the bars plotted at 2095 represent the 2007 projections. The inset shows sea level observed with satellite altimeters from 1993 to 2006 (orange line) and observed with coastal sea-level measurements from 1990 to 2001 (blue line) (Church et. al. 2008).

Figure 1 Global average sea level rise for the SRES scenarios (Church et. al. 2008)



Due to evidence that observed carbon dioxide concentration, global mean temperatures and sea level rise have been tracking the upper end of IPCC scenario range from 1990 to 2006 (Rahmstorf et. al. 2007, Church et. al. 2008), the CSIRO advises that the mid and low projections may be less likely than the high projections, with significant implications for risk management (CSIRO 2007a). For this reason, the high scenario projections for 2070 – 2100 have been used in this risk assessment.

CSIRO (2008) has produced climate change projections for the Townsville region based on the most recent generation of climate models, and consistent with the most up-to-date assessment of climate change in Australia by the CSIRO and Australian Bureau of Meteorology. The uncertainties associated with: future rates of greenhouse gases; future global average surface temperatures; and regional climates in response to increases in global average surface temperature, have been addressed in *Climate Change Projections for the Townsville Region* (CSIRO 2008). Thus, this report is based on the CSIRO's preferred IPCC SRES scenarios for Townsville - A1FI (high) for projections to 2070.

2.7 Climate Change Projections for Townsville

2.7.1 Climate Change Projections – Temperature

Average annual temperatures for the Townsville region are expected to increase, with warming being greatest in the autumn and summer. The number of hot days is extremely likely to increase with major increases in the number of days over 30°C, and with increases of up to 24% more days over 35°C by 2070 under a high emission scenario.

Table 8 Projected Changes in Average Annual Temperature (relative to 1980-1999) for the Townsville Region

Projections (°C)	Current	2070 (High emission scenario)
CSIRO 2008	21 - 24	+2.7 (-0.9 to +1.1)

(Figures in brackets respond to the °C of uncertainty from the average annual temperature projected).

Table 9 Projected Changes in Annual Average Numbers of Hot Days for the Townsville Region (CSIRO 2008)

Annual average number of days over:	1971-2000 Baseline	2070 (High emission scenario)
30°C	43%	63 - 83%
35°C	1%	5 - 24%
40°C.	0	0.3 - 0.6%

2.7.2 Climate Change Projections – Rainfall (Intensity, Timing and Distribution)

Projections for rainfall are more uncertain then the projections for temperature changes. Changes in annual average rainfall are likely to decrease in the Townsville region by 2030 and 2070, although the ranges of uncertainty for all projections include decreases and increases in annual averages. Slightly fewer rain days are likely, but again the range of uncertainty includes increases in rain days. The intensity of heavy daily rainfall is also likely to decrease slightly, although projections are highly uncertain. OzClim, the CSIRO's online climate change scenario generator, projects the greatest decrease in seasonal rainfall in the winter months.

Table 10 Projected Changes in Rainfall Statistics for the Townsville Region (CSIRO 2008)

Change in:	Current	2070 (High emission scenario)
Average Annual Rainfall %	1117mm	-8% (-32 to +18%)
Number of Rain Days	73	-3 (-17 to +7)
Rainfall Intensity		+1% (-30 to +20%)

Figure 2 Current monthly rainfall for Townsville (BOM 2009)

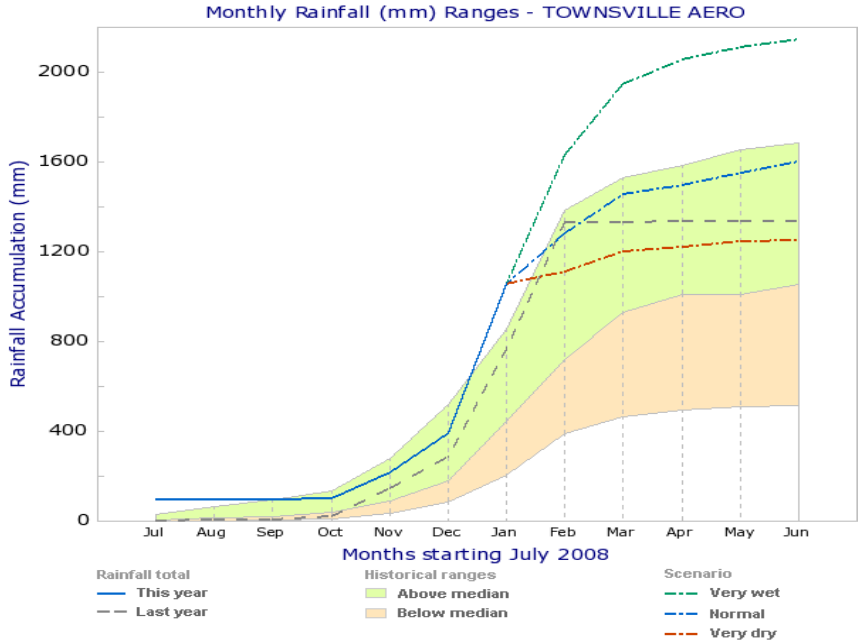


Table 11 OzClim projections for seasonal change in rainfall (%) from baseline 1990 for the Townsville Region

Rainfall	2070 (%) (High emission scenario)
Summer	-5 to 0
Autumn	-20 to -10
Winter	-30 to -20
Spring	-20 to -10

2.7.3 Climate Change Projections – Sea Level Rise

Although the mean predictions for each scenario in the IPCC fourth assessment report (IPCC 2007) do not differ greatly from the IPCC 2001 projections, the added uncertainty relating to potential accelerations in ice flow of the kind recently observed in Greenland and West Antarctica is noted. An additional 10-20 cm is suggested to be added to the projections to take these changes into account, although it is noted that there is a large degree of uncertainty regarding these processes and there is potential for the upper level of sea level rise to increase substantially.

There is also more evidence to suggest that sea level rise is already tracking above the rates noted in the 'high emissions' scenarios used by the IPCC. Research presented by Rahmstorf et al. (2007) states that observed carbon dioxide concentration, global mean temperatures and sea level rise have been tracking at the upper end of IPCC scenario range from 1990 to 2006. Projections based on the mid and low IPCC scenarios therefore may be less likely than the high projections. Around Australia, the rate of sea level rise was approximately 1.2mm per year during the 20th century.

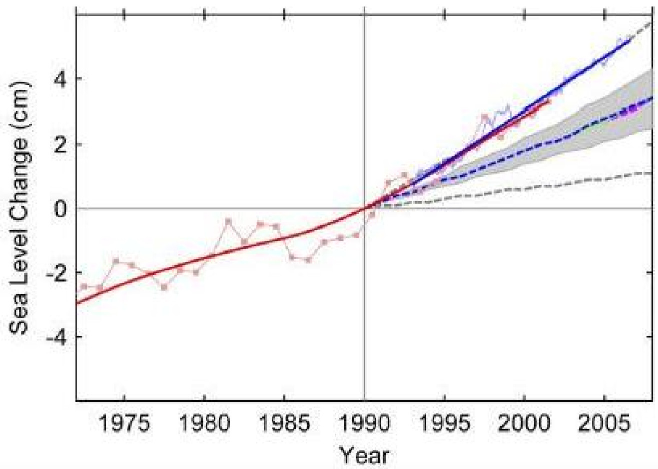
With this in mind, some planning and policy documents are now recommending 0.8m as the sea level rise to be planned for, for projects that are expected to have a lifespan beyond 2070. This level is a combination of the upper estimate of the high emissions scenario from the IPCC Fourth Assessment Report (2007) of 0.59m, combined with the suggested additional 0.2m to take into account potential accelerations in ice flow from glaciers.

Current examples where these recommendations have been implemented are:

» The Queensland EPA's Guidelines for Preparing a Climate Change Impact Statement (CCIS) which recommends assessing potential impacts and adapting for the effects of a 0.79m rise in sea level for projects expected to exist beyond 2070 that require a cabinet submission; and

» The Victorian Coastal Strategy 2008 which recommends policy to plan for sea level rise of not less than 0.8m by 2100, and to allow for the combined effects of tides, storm surges, coastal processes and local conditions, such as topography and geology when assessing risks and impacts associated with climate change.

Figure 3 Projected and actual global sea level rise (Rahmstorf et.al. 2007)



2.7.4 Climate Change Projections – Extreme Events

Storm Surge

It is very likely that Townsville will experience increases in storm tide height due to mean sea level rise and increases in tropical cyclone intensity. Higher mean sea levels will enable inundation and waves resulting from storm surges to penetrate further inland, increasing flooding, erosion and damage to infrastructure.

Figure 4 Semidiurnal tidal planes (Maritime Safety Queensland 2008)

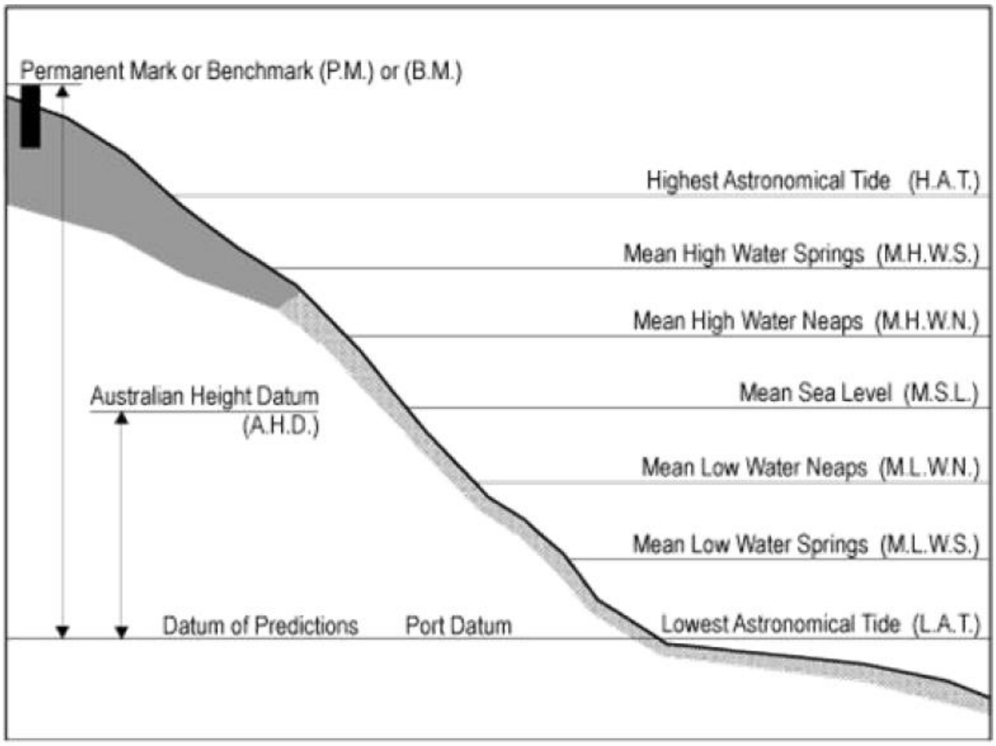


Table 12 Semidiurnal Tidal Planes for the Port of Townsville

Tidal Plane	Abbreviation	m AHD	Projected 2100 m AHD (+0.79m)
Highest Astronomical Tide	HAT	+2.15	+2.94
Mean High Water Springs	MHWS	+1.21	+2.00
Mean High Water Neap	MHWN	+0.36	+1.15
Mean Sea Level	MSL	+0.10	+0.89
Mean Low Water Neap	MLWN	-0.27	+0.52
Mean Low Water Springs	MLWS	-1.13	-0.34
Lowest Astronomical Tide	LAT	-1.86	-1.07

The *Townsville-Thuringowa Storm Tide Study* report, produced for the Townsville and Thuringowa City Councils (2007), estimated the increase in total storm tide levels (storm surge plus tide including wave set-up) for selected return periods under an enhanced greenhouse scenario for the years 2050 and 2100.

Table 13 Estimated Increase in Total Storm Tide Level (m AHD) under Enhanced Greenhouse Scenarios (Townsville/Thuringowa City Council 2007)

Location – Ross River	50y	100y	500y	1000y
Current	2.9	3.0	3.2	3.7
2050	+0.1	+0.1	+0.6	+0.8
2100	+0.4	+0.5	+1.4	+1.7

Tropical Cyclones

Tropical cyclone tracks can be grouped according to their El Niño – Southern Oscillation (ENSO) category – El Niño, neutral or La Niña. Usually La Niña years experience an increase in tropical cyclone numbers closer to the east Australian coast, while in El Niño years, the centre of activity moves further east to the Pacific Islands. For most of the time, neutral conditions prevail, which are similar to the combined statistics.

In the *Townsville-Thuringowa Storm Tide Study* (Townsville/Thuringowa City Council 2007) ENSO variability was modelled, showing estimated differences in long term storm tide levels.

Table 14 Estimated differences in the long term storm tide levels (m) due to ENSO variability (Townsville/Thuringowa City Council 2007)

ENSO	100y	500y	1000y
El Niño	-0.1	-0.2	-0.3
Neutral	-0.1	-0.2	-0.3
La Niña	+0.1	+0.2	+0.1

For the Townsville region, the CSIRO (2008) projects that little change is likely in the annual average number of cyclone days, although severe cyclones may occur more often.

Fire

For eastern Australia, increases in fire risk are likely, along with an increase in the number of extreme high fire days and the fire season is likely to become longer, starting earlier then at present.

2.8 Overview of Projected Climate Changes for the Townsville Region

Climate Variable	Current Average	Source	Climate Change Projection	Scenario / Info	Source
Sea Level	HAT: +2.15 m, relative to AHD	Hardy et al. 2004, p.20	Sea Level: +0.59 (+0.2) Total +0.79	2090 - 2099 relative to 1980 - 1999 High emissions (A1FI) emissions scenario High range model result (plus 0.2m to account for additional contribution from ice sheets)	IPCC 2007
Wind and Wave Climate	100 year return period for storm surge plus tide: +3.00 m, relative to AHD	Townsville and Thuringowa City Councils 2007, p.63	100 year return period for storm surge plus tide: +0.5 m (+3.5 m relative to AHD)	Climate change scenarios include: Increase in cyclone MPI of 20%, Increase in frequency of tropical cyclones of 10% Mean Sea Level rise of 0.9m (based on the upper level IPCC (2001) prediction of MSL rise for 2100)	Townsville and Thuringowa City Councils 2007, p.96
Rainfall/Runoff (Highest Daily Rainfall 548.8 mm 11Jan98)	Annual average rainfall: 1117 mm	BoM	-8%	2070 A1FI emission scenario with high climate sensitivity (IPCC 2001 global warming values)	CSIRO 2008
	Average summer monthly rainfall 230.3 mm	BoM	-5%		
	Average winter monthly rainfall 17.0 mm	BoM	-4%		
Air Temp	Annual mean max temp: 28.9°C	BoM	Average temp increase: +2.7°C	2070 A1FI emission scenario with high climate sensitivity (IPCC 2001 global warming values)	CSIRO 2008
	Annual mean min temp: 19.8°C	BoM			
	Highest temp recorded: 44.3°C	BoM			
	Lowest temp recorded: 1.1°C	BoM			
	Annual average number of hot days (over 35°C): 3.5	BoM	Increase in number of days over 35°C : +38 days (+18 to +86)		

3. Climate Change Risk Assessment

3.1 Risk Evaluation Framework

The following risk evaluation framework was used to assign risk levels to impacts identified in the climate change risk workshop. These have been sourced from Port of Townsville risk assessment framework, with the addition of likelihood ratings adapted to a time scale for a design life of 100 years.

Table 15 Likelihood Ratings (adapted Port of Townsville)

Rating	***Port of Townsville***
Almost Certain	*Expected to occur in most circumstances (more then once a year)*
Likely	*Will probably occur in most circumstances (once in 1-10 years)*
Possible	*Might occur at some time (once in 10-50 years)*
Unlikely	*Could occur at some time (once in 50-100 years)*
Rare	*May only occur in exceptional circumstances (less then once in 100 years)*

Table 16 Consequence Scales (Port of Townsville)

Key Elements → / Rating ↓	Financial Loss	Asset Loss	Interruption to Services	Reputation & Image	Performance	Criminal Penalty	Safety	Health	Nature & Extent of Environmental Harm	Sensitivity of Receiving	Frequency & intensity of activity
Catastrophic	> $5m	Complete loss of assets	> 1 month	Substantiated, public embarrassment, very high multiple impacts, high widespread news profile, third party actions.	>50% variation to KPI	Imprisonment	Multiple fatalities	Long term, possibly irreversible or chronic health effects to many people	Serious environmental harm – irreversible, high or widespread impact on environment, high conservation or special significance area	Severe impact on environment. Permanent or irreversible affects to amenity or life. Activity is in close proximity to residential and business areas.	Permanent high frequency / intensity activity carried out 24/7.
Disastrous	$1m - $5m	Significant loss of assets	1 week – 1 month	Substantiated, public embarrassment, high impact, high news profile, third party actions	25-50% variation to KPI.	Imprisonment	Major permanent – single fatality, total blindness, quadriplegia	Life threatening or disabling illness	Material environmental harm. Significant impact on community, plants and animals as a result of duration or magnitude/nature of impact.	Significant adverse impact on environment within surrounding area (including business/ residential areas) which will adversely affect amenity or life in the long term.	Long term (decades) high frequency / intensity activity carried out during most hours of the day.
Serious	$250K - $1m	Major damage to assets	1 day – 1 week	Substantiated, public embarrassment, moderate impact, moderate news profile	10-25% variation to KPI	Imprisonment	Major permanent – loss of body part or function	Irreversible health effects of concern	Actual or potential material environmental harm – local adverse impact on community, plants and animals within surrounding area	Noticeable adverse impact on environment in surrounding area (including business/ residential areas), which may affect amenity or life	Medium frequency / intensity activity carried out for a significant period of time on most days.
Minor	$50K - $250K	Minor loss or damage to assets	½ - 1 day	Substantiated, low impact, low news profile	5 -10% variation to KPI	Pecuniary	Minor temporary – medical treatment required	Severe reversible health effects of concern	Environmental harm or nuisance resulting in minor adverse impacts on or unreasonable interference with the community, plants and wildlife	Minor impact on or interference with the environment in surrounding area but negligible affect on amenity or life in residential/ business areas	frequency / intensity activity carried out during business hours in the short term (3 months).
Insignificant	$0 - $50K	Little or no impact on assets	< ½ day	Unsubstantiated, low impact, low profile or no news items	Up to 5% variation to KPI	Pecuniary	Minor temporary – irritation, first aid treatment required	Reversible health effects of concern	Minimal environmental harm resulting in minor impacts on community, plants and wildlife	No real impact on community, plants and wildlife within surrounding area	Low frequency / intensity / duration activity (temporary - days).

Table 17 Risk matrix (Port of Townsville)

Likelihood		Consequence				
		Insignificant	Minor	Serious	Disastrous	Catastrophic
	Almost Certain	Medium	Substantial	High	Extreme	Extreme
	Likely	Low	Medium	Substantial	High	Extreme
	Possible	Low	Medium	Medium	Substantial	High
	Unlikely	Low	Low	Medium	Medium	Substantial
	Rare	Low	Low	Low	Low	Medium

Table 18 Risk Level Descriptors (Port of Townsville)

Risk Level	Delegate	Meaning	Criteria for management of Risk (Risk Treatments)
Extreme	Committee/Board	Significant capability Loss and the achievement of objectives is unlikely.	Unacceptable. Eliminate or reduce risk through Control measures. Risk requires documented action plans.
High	General Managers CEO	Significantly degrades the achievement of objectives or capability.	Undesirable. Risk must be eliminated or reduced. Risk requires documented action plans.
Substantial	Senior Management	Will degrade the achievement of objectives or capability.	Only acceptable with formal review. Risk requires documented action plans.
Medium	Employee	Degrades the achievement of objectives or capability.	May be acceptable with review. Rationale should be documented.
Low	Employee	Little or no impact on the achievement of objectives or capability.	Acceptable without review. Rationale should be documented.

3.2 Climate Change Risk Workshop

The climate change risk assessment workshop was conducted on 12th March 2009 at GHD's Brisbane offices.

The workshop participants are included in Table 19 below:

Table 19 Risk Assessment Workshop Participants

Participant	Position
Samantha McKenzie	Principal Risk Consultant
Amanda Tunbridge	Senior Climate Change Consultant
Kathryn Smith	Climate Change Consultant
Kerry Neil	Job Manager
Julie Keane	Principal Impact Assessment Manager
Scott Vivien	Marine Engineer
Paul O'Keeffe	Principal Coastal Engineer
Ross Fryar	Engineer –Civil, Hydrology

3.2.1 Impacts Identified

The main potential impacts identified were recorded in the risk register (see Appendix A), and where sufficient information was available, the consequence, likelihood and risk level of each impact was evaluated by the workshop participants.

Overall, 11 main potential impacts to the Port of Townsville Marine Precinct project as a result of projected changes in climate were identified. These are listed in Table 20.

Table 20 Potential Project Impacts Identified

ID	Project Impact
MSL1	Ground water rise impacts on foundations and services leading to asset deterioration
W1	Wind impacts on buildings and structures - potential operational restrictions on lifting operations (Not applicable to project as the design and construction of structures is not included within the project scope – therefore risk level not assessed)
ST1	Increased ship queuing due to interruptions of on-shore services eg. ship lift/rack & stack
ST2	Restrictions on accessing the harbour facilities (no impact considered likely once inside the breakwater, therefore no risk level assessed)

ID	Project Impact
ST3	Breakwaters - overtopping Potential degradation of breakwater structure
ST4	Breakwaters - Reduced harbour tranquillity leading to interruption to service and potential injuries to people and property moored at breakwater
ST5	Reclamation and pavement areas- Potential degradation of assets installed in reclaimed areas
ST6	Reclamation and pavement areas- Environment Overtopping and run-off - water quality impacts
ST7	Reclamation and pavement areas- Safety Potential for health issues associated with inundation of reclamation and pavement area
RR1	Environmental impact due to water pollutant loadings in stormwater
T1	Increases in ambient temperatures will result in greater thermal movement of concrete pavements, increasing the risk of cracking and subsequent degradation. Bitumen binder in pavements will be more at risk of soften at higher temperatures leading to excessive deformation and rutting of the road surfaces

3.2.2 Risk Analysed

Of the impacts identified, two were noted as key considerations, but the level of risk was not assessed due to the conclusion that the impact was outside the scope of this study. Of the remaining nine impacts identified, two were assessed as having a 'low' risk level, two as having a 'medium' risk level, four as having a 'substantial' risk level and one as having a 'high' risk level.

Table 21 Summary of Risk Ratings

		Consequence				
		Insignificant	Minor	Serious	Disastrous	Catastrophic
Likelihood	Almost Certain					
	Likely			**T1**	**ST6**	
	Possible	**ST1**		**MSL1**	**ST3, ST4, ST5**	
	Unlikely		**RR1**		**ST7**	
	Rare					

Table 22 Risk Level Treatments

Risk Level	Risk Treatment Summary
Extreme	Unacceptable. Eliminate or reduce risk through Control measures. Risk requires documented action plans.
High	Undesirable. Risk must be eliminated or reduced. Risk requires documented action plans.
Substantial	Only acceptable with formal review. Risk requires documented action plans.
Medium	May be acceptable with review. Rationale should be documented.
Low	Acceptable without review. Rationale should be documented.

Based on the risk level treatments identified in Port of Townsville's risk framework, potential impacts that are assigned a risk level of substantial, high or extreme are required to document action plans to reduce the risk level.

3.2.3 Risks Evaluated and Reviewed

For impacts that were assigned a risk level of 'high' or 'substantial', current and potential controls and adaptation measures that could reduce the potential risk level over the life of the project were identified. All of the impacts assigned these higher levels of risk were related to the effect of increased sea level on the height and recurrence interval of storm tide events in the project area. The main areas for potential impacts from this variable will be the breakwater structures and the reclamation and pavement areas.

» **Breakwater**

Impacts ST3 and ST4 were both related to the event of a high storm tide leading to overtopping of the breakwater structure. The risk of this event was assessed, taking into account the projected increase in sea level due to climate change. Specific impacts including degradation of the structure, reduced harbour tranquillity, disruption of services and potential injuries to people and property moored at the breakwater were assessed as having a 'substantial' level of risk.

– Current Controls in Place

At the time of the workshop, it was understood that the breakwater structure was being designed for a current day 1 in 100 year event. To avoid the projected sea levels rises as a result of climate change during the design life of this project, the breakwater will no longer be designed for a 1 in 100 year event.

The DRAFT Queensland Coastal Plan consisting of the new State Planning Policy for Coastal Protection and the new Coastal Management Policy was also noted as a control that will need to be taken into consideration for the design of this project. The recommended sea level rise proposed in the draft document is 0.8m for a design life of 100 years. However, this policy is yet to be finalised.

– Potential Control Actions

Implementation of the new coastal management policy.

» **Reclamation and Pavement Areas**

Impacts ST5, ST6 and T1 were related to the reclamation and pavement areas.

Impact ST5 related to the potential for more frequent inundation of the reclamation area during storm tide events leading to degradation of assets stored in these areas. This impact was assessed as having a 'substantial' risk for asset loss.

Impact ST6 was related to the potential for inundation of the reclamation and pavement areas during storm tide events leading to spills from dangerous chemicals stored in facilities within the reclamation area which would then impact on water quality. The risk of this impact was assessed as being 'high'.

Impact T1 regarded the impacts of increases in ambient temperatures on the concrete and bitumen used for the pavement area and roads. Greater thermal movement of concrete pavements will increase the risk of cracking and subsequent degradation of the concrete. Bitumen binder in pavements will also be more at risk to soften at higher temperatures leading to excessive deformation and rutting of the road surfaces.

– Current controls

At the time of the workshop it was understood that a design height of 5m LAT was being used for the height of the reclamation and pavement areas. It is believed that this design level will be insufficient, especially when the increase in risk associated with sea level rise due to climate change is taken into account.

The DRAFT Queensland Coastal Plan was also noted as a control that will need to be taken into consideration for the design of this project.

Australian Standards for material specifications do not currently take potential changes in temperature over the design life of the project into account

– Potential control actions:

ST5 and ST6: It is suggested that the 5m design height for the reclamation and pavement areas should be reviewed to reduce the risk associated with storm tide events inundating these areas.

T1: 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

T1: 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.

4. Climate Change Adaptation Assessment

Table 23 Summary of Adaptation Assessment

Risk Level	Risk	Adaptation Option
High	ST6 - Reclamation and pavement areas- Environment Overtopping and run-off - water quality impacts	Consideration for design of 0.8m SLR as per DRAFT Queensland Coastal Plan, Consideration for the projected increase in total storm surge and tide figures for the 100 year return period of an additional 0.5m.
Substantial	ST5 - Reclamation and pavement areas- Potential degradation of assets installed in reclaimed areas	
Substantial	ST3 - Breakwaters - overtopping Potential degradation of breakwater structure	Current design standard to be revised to the 1 in 100 year event for the year 2100, rather then to current conditions.
Substantial	ST4 - Breakwaters - Reduced harbour tranquillity leading to interruption to service and potential injuries to people and property moored at breakwater	

The risk level of impact ST6 was re-assessed by workshop participants taking into account the identified adaptation options. The revised risk level was assessed as medium as the likelihood rank decreased to unlikely.

This risk assessment highlighted that some existing standards need to be updated to reflect projected climate changes. The design for the marine precinct will need to be assessed to ensure that future climate change is considered to reduce the identified risks for the reclaimed and pavement areas, as well as the breakwaters.

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Appendix A

Risk Register

						(2070 or 2100- A1FI Scenario)			Residual Risk				
No	**Climate Change Variable**	**Projected Change**	**Project Impact**	**Current Controls**	**Risk Category**	**Consequence Rank**	**Likelihood Rank**	**Risk Level**	**Potential Controls (Adaptation Measures)**	**Consequence Rank**	**Likelihood Rank**	**Risk Level**	**Comments**
MSL1	Mean Sea Level Rise	+0.79m (2100) *Larger values can not be excluded	*Ground water rise impacts on foundations and services asset deterioration*	not considered in design	Asset Loss	Serious	Possible	Medium	considered in design	Serious	Unlikely	Medium	
W1	Wind & Wave Climate (Wind)	Potential for stronger winds associated with increased intensity of cyclones	*Wind impacts on buildings and structures - potential operational restrictions on lifting operations Not applicable to Port of Townsville project as the construction of structures is not included within the project scope*	Current wind loading code does not include CC considerations				0				0	
ST1	Wind & Wave Climate (Storm Tide)	100 year return period +0.5m AHD (3.0m + 0.5 =3.5m AHD) (HAT+1.35m)	*Increased ship queuing due to interruptions of on-shore services eg. ship lift/rack & stack*	Design includes berths provided to reduce queued vessels	Interruption to Services	Insignificant	Possible	Low				0	Potentially outside scope of project
ST2	Wind & Wave Climate (Storm Tide)	100 year return period +0.5m AHD (3.0m + 0.5 =3.5m AHD) (HAT+1.35m)	*Restrictions on accessing the harbour facilities (no impact considered likely once inside the breakwater)*	Design parameter	Interruption to Services			0				0	NA
ST3	Wind & Wave Climate (Storm Tide)	100 year return period +0.5m AHD (3.0m + 0.5 =3.5m AHD) (HAT+1.35m)	*Breakwaters - overtopping Potential degradation of structure*	Design standards - current day 1 in 100yr event 7m LAT (DRAFT coastal management policy)	Asset Loss	Disastrous	Possible	Substantial				0	
ST4	Wind & Wave Climate (Storm Tide)	100 year return period +0.5m AHD (3.0m + 0.5 =3.5m AHD) (HAT+1.35m)	*Breakwaters - Reduced harbour tranquillity Interruption to service Potential injuries to people and property moored at breakwater*	Design standards - current day 1 in 100yr event 7m LAT (DRAFT coastal management policy)	Safety	Disastrous	Possible	Substantial				0	
ST5	Wind & Wave Climate (Storm Tide)	100 year return period +0.5m AHD (3.0m + 0.5 =3.5m AHD) (HAT+1.35m)	*Reclamation and pavement areas- Potential degradation of assets installed in reclaimed area*	Design standards - current day 1 in 100yr event 5m LAT (DRAFT coastal management policy)	Asset Loss	Disastrous	Possible	Substantial				0	
ST6	Wind & Wave Climate (Storm Tide)	100 year return period +0.5m AHD (3.0m + 0.5 =3.5m AHD) (HAT+1.35m)	*Reclamation and pavement areas- Environment overtopping and run-off - water quality impacts*	Design ??? - 5m LAT (DRAFT coastal management policy)	Nature & Extent of Environmental Harm	Disastrous	Likely	High	Review design height - 5m not high enough - even for current design criteria	Disastrous	Unlikely	Medium	
ST7	Wind & Wave Climate (Storm Tide)	100 year return period +0.5m AHD (3.0m + 0.5 =3.5m AHD) (HAT+1.35m)	*Reclamation and pavement areas- Safety Potential for health issues associated with inundation -*	Design ??? - 5m LAT (DRAFT coastal management policy)	Safety	Disastrous	Unlikely	Medium				0	
RR 1	Rainfall/ Runoff	8% less annual average rainfall (variable projections -32 to +18%)	*Environmental impact due to water pollutant loadings in stormwater*	Drainage systems designed to current design standards	Nature & Extent of Environmental Harm	Minor	Unlikely	Low				0	Variability in rainfall should be considered in design of stormwater
T1	Temperature	Average annual temperature increase of 2.7°C 60 - 80% of days with temps above 30°C 34 extra days above 35°C	*Increases in ambient temperatures will result in greater thermal movement of concrete pavements, increasing the risk of cracking and subsequent degradation.* *Bitumen binder in pavements will be more at risk to soften at higher temperatures leading to excessive deformation and rutting of the road surfaces*	Australian Standards for material specifications do not currently take potential changes in temperature over the design life of the project into account	Asset Loss	Serious	Likely	Substantial	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 suite projected climate conditions. This might include higher penetration grade bitumen, alternate mix designs or the use of polymer modified bitumen.			0	Information received from Dr Gavin Chadbourn (Civil Engineer - Materials Technology) post workshop - 13/03/09

GHD

201 Charlotte Street Brisbane QLD 4000
GPO Box 668 Brisbane QLD 4001
T: (07) 3316 3000   F: (07) 3316 3333   E: bnemail@ghd.com.au

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		Name	Signature	Name	Signature	Date
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