Contents

11 Climate and climate change assessment

11.1 Chapter content

The Project impact assessment for climate and climate change assessment was provided in Chapter 11 of the Project EIS.

This chapter provides additional information to address the submissions received during the statutory public display period of the Project EIS. The key issues raised from the Project EIS submission process, relevant to the climate and climate change assessment, are summarised Table 11.1.

Table 11.1 Summary of submission issues received in relation to the Project EIS climate and climate change assessment chapter

Submitter ID number (refer Appendix A)	Summary of submission issue raised	Project EIS section (public notification version)	AEIS section containing information to address submission comments	Complete replacement section for Project EIS	Supplements the Project EIS information
12.95	Predictions for the frequency and intensity of cyclones	Sections 11.3.7 and 11.3.7.1	Section 11.2	✓	
12.94	Sources of information for prediction of sea level rise and design of proposed WBE reclamation area bund wall	Section 11.5.4	Section 11.3.1	✓	
		Sections 11.5.5.7 and 11.5.6	Section 11.3.2		✓
12.93	Chapter 11 to include reference to all climate change discussions included in other EIS chapters (e.g. Chapter 20 (hazard and risk))	Section 11.6.1	Section 11.4	✓	
		Section 11.8	Section 11.5[1]	✓	
12.04	Potential impacts and risk assessment rating tables in each draft EIS chapter should be amended to include effective mitigation measures to assist with their interpretation	Section 11.8.2	Section 11.5.2	✓	

Table note:

1 Chapter 20 of the AEIS has also been amended to be consistent with the changes included in AEIS Section 11.5.

11.2 Tropical cyclones

This section replaces the Project EIS Section 11.3.7 (tropical cyclones) and Section 11.3.7.1 (El Niño–Southern Oscillation (ENSO)/Pacific Decadal Oscillation (PSO) tropical cyclone).

The International Best Track Archive for Climate Stewardship (IBTrACS: Knapp et al. 2010) is a global archive of all tropical cyclone tracks from 1897 to 2017. It is updated annually with the best estimate of each individual storm track across all Ocean Basins. The analysis presented here uses a subset of the IBTrACS archive for the South Pacific Basin and East Australian sub basin. The dataset was refined to eliminate those events that would not have a direct impact of the weather and climate of Gladstone and the dataset was subset to only identify tropical cyclones whose path approached within a 400km radius of Gladstone. The analysis identified 118 tropical cyclones covering the period from 1908 to 2018.

The impacts of cyclone activity (wind or induced water level) can range in severity from heavy rain and little wind to high velocity wind and rain causing major structural damage and flooding over a wide area. For example, Tropical Cyclone Hamish which passed near the Gladstone coastline in March 2009, although it did not cross the coast, closed the Port of Gladstone temporarily due to severe weather conditions (GPC 2009). Tropical Cyclone Debbie, however, in 2017 created a mini tornado which swept through Miriam Vale, Agnes Water, Baffle Creek and Boyne Valley, and other areas were cut off completely and isolated due to flooding (GRC 2017).

On average 1.1 tropical cyclones can be expected to pass within 400km of Gladstone per year. However, this can range from zero to a maximum of seven, as was experienced in 1963 (refer Figure 11.1). The majority of tropical cyclones occur during the tropical cyclone season (1 November to 30 April); however tropical cyclones have occurred in May, June and July (refer Figure 11.2).

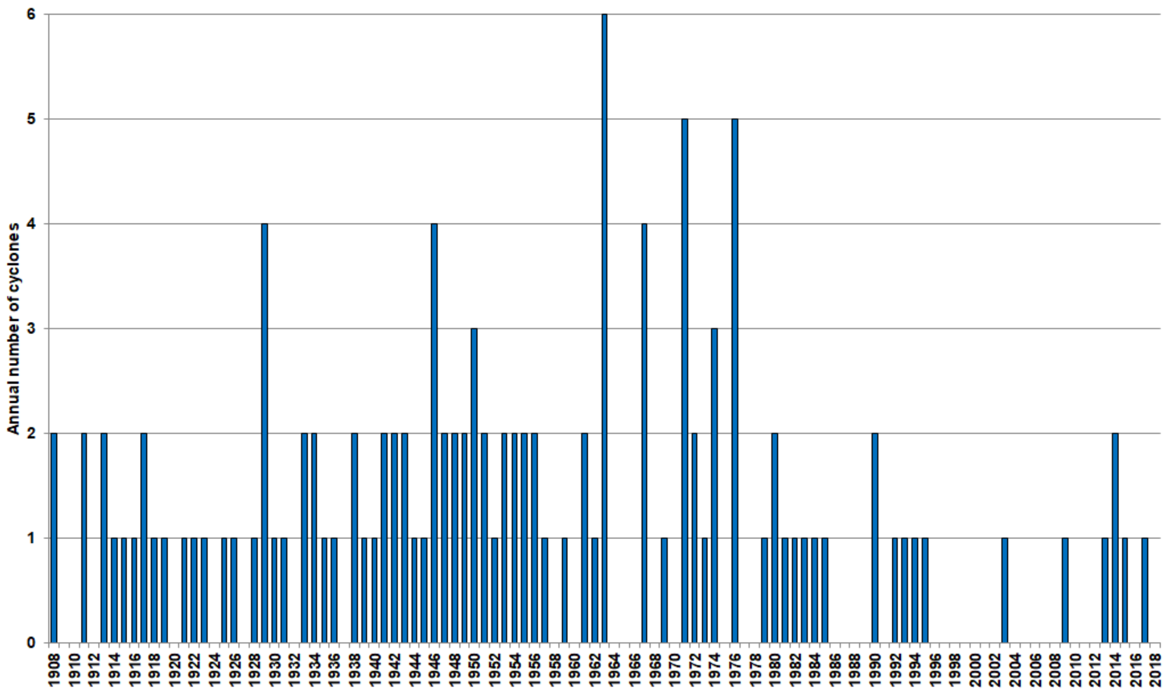

Figure 11.1 **Annual total number of tropical cyclones that passed within 400km of Gladstone for the period 1908 to 2018**

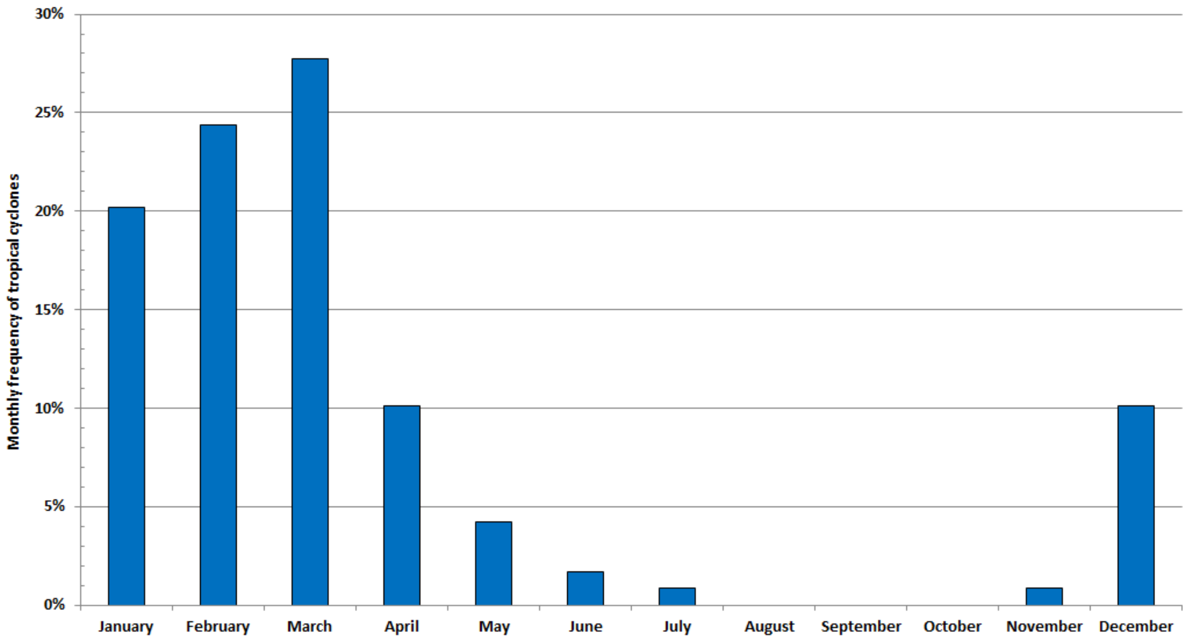

Figure 11.2 **Monthly frequency of tropical cyclones that passed within 400km of Gladstone for the period 1908 to 2018**

Table 11.2 shows the frequency of tropical cyclones passing within 400km of Gladstone for the period 1908 to 2017 by ENSO and PDO phases. The data shows that there is a higher frequency of tropical cyclones during La Niña periods than El Niño periods. The influence of the PDO is shown in the increase in tropical cyclone frequency during Cool PDO/La Niña from 34% to 44% and the decrease in frequency during Warm PDO/La Niña from 34% to 20%. Neutral ENSO is shown to have the highest frequency of tropical cyclone activity.

Table 11.2 **Tropical cyclone frequency within 400km of Gladstone from 1908 to 2017 by El Niño–Southern Oscillation and Pacific Decadal Oscillation phases**

Number of tropical cyclones within 400km of Gladstone	El Niño	La Niña	Neutral
1908 to 2018	14%	34%	53%
Cool phase PDO	10%	44%	46%
Warm phase PDO	20%	20%	60%
Undefined	14%	14%	71%

11.3 Sources of information used in sea level rise calculations and assessment

11.3.1 East Coast assessment

This section replaces Project EIS Section 11.5.4 (East Coast assessment).

The assessment for the East Coast is based on models that simulated the Representative Concentration Pathways (RCP) 8.5 scenario, which assumes a future with minimal mitigation of emissions, leading to rapidly rising CO_2 concentrations, (Dowdy et al. 2015). The assessment considered the 30-day period centred at 2050. For climate variables where analyses are not available for 2050, data available for other periods were used.

11.3.2 Storm surge and storm tide levels

This section supplements the Project EIS Section 11.5.5.7 and Section 11.5.6.

The Department of Transport and Main Roads (DTMR) guideline *Storm Tide – Issues for Design of Road Infrastructure in Coastal Areas* (DTMR 2014c) provides predicted storm surge and storm tide levels for a number of probability levels for future climatic conditions in the Gladstone area. The Gladstone predicted storm tide (i.e. tide, plus storm surge) and future climate change conditions included in the DTMR guideline are summarised in Table 11.3.

Table 11.3 Storm tide level data for Gladstone

Scenario		Storm tide level (m LAT)		
		100 year ARI	500 year ARI	1,000 year ARI
Gladstone (2003)	Storm tide level	5.09	5.78	6.07
	Storm surge allowance[2]	0.26	0.95	1.24
Gladstone (with future climate change conditions)[1]	Storm tide level	5.60	6.45[3]	6.78
	Storm surge allowance[2]	0.77	1.62	1.95

Table notes:

1 Based on Climate Change Scenarios for a 50 year planning period (DTMR 2014c)
2 Assumes that the HAT at Gladstone is 4.83m LAT and AHD is 2.27m LAT (MSQ 2018)
3 6.45m LAT has been used as an input into the EIS preliminary design for the BUF and WBE reclamation area bund walls

Within the Project EIS Section 11.5.5.7 the sources of information used in the calculations and discussions of predicted sea level rise are as referenced in Section 11.5.5.7 and also derived from the Climate Futures Tool (https://www.climatechangeinaustralia.gov.au/en/), with a particular focus on the East Coast (Northern) sub-cluster (Dowdy et al. 2015).

The EIS preliminary design for the BUF and WBE reclamation area bund walls has allowed for a combined storm tide and sea level change up to 7m LAT. This is a 0.55m allowance above the predicted 500 year average recurrence interval (ARI) storm tide, including a climate change estimate of 6.45m LAT. The Project has considered and accounted for the 0.8m sea level rise for 2100 as contained within the *Coastal Protection and Management Regulation 2017.* The proposed reclamation area bund wall height of 7m LAT is consistent with adjoining Western Basin reclamation area and the Fisherman's Landing reclamation area.

A detailed analysis of storm surge and climate change allowances will be undertaken during detailed design of the BUF and WBE reclamation area outer bund walls.

11.4 Summary of potential impacts of climate change

This section replaces the Project EIS Section 11.6.1 (summary of potential impacts of climate change).

Changing climate and weather patterns associated with climate change have the potential to impact on the construction and operational phases of the Project. Table 11.4 contains a summary of the potential impacts of climate change on the Project. The potential impacts on aquatic ecological communities and species from climate change (e.g. coral bleaching) which has the potential to occur at the same time as Project activities is provided in the Project EIS Section 21.4.5.

Table 11.4 Potential impacts of climate change on the Project by project phase

Climate factor	Design	Construction	Operational
Rainfall	No effect	No effect	Changes in soil moisture balance of reclamation area leading to movement and instability
Extreme rainfall	Overload of stormwater management system	Dredging equipment incident (e.g. vessel swept to sea, collision, equipment failure or oil spill) Potential for delays in the construction schedule due to increased downtime Damage to bund walls of BUF resulting in an increased requirement for erosion and sediment control measures More frequent discharges from the dredging dewatering process	Changes in soil moisture balance of reclamation area leading to movement and instability Potential increase of runoff and flooding Potential movement of sediment Potential impacts to water quality
Temperature	Future failure or fault of bund walls due to temperature tolerances of design and materials (e.g. road surfacing and concreting)	No effect in short term	Higher temperatures/evaporation leading to change in soil moisture and subsequent instability of the reclamation area and long term future land use outcomes
Windspeed	No effect	No effect	No effect
Sea level	Future inundation of reclamation area resulting in structural damage	No effect in short term	Infrastructure that does not take climate change into consideration may be less efficient or fail during the operational phase, including impacting on long term future land use outcomes
Tropical storms and cyclones	Future inundation or instability of reclamation area resulting in structural damage	Dredging equipment incident (e.g. vessel swept to sea, collision, equipment failure or oil spill) Damage to bund walls and/or sheet piles or similar earth retaining structure Potential for delays in the construction schedule due to increased downtime	Infrastructure that does not take climate change into consideration may be less efficient or fail during the operational phase, including impacting on long term future land use outcomes Damage to bund walls and/or sheet piles or similar earth retaining structure, and movement of sediment, and decrease in marine water quality Maintenance dredging equipment incident (e.g. vessel swept to sea, collision, equipment failure or oil spill)

11.5 Risk assessment

This section replaces the Project EIS Section 11.8 (risk assessment).

11.5.1 Methodology

To assess and appropriately manage the climate change risks which need to be addressed by the Project, a risk assessment process has been implemented (herein referred to as ‘risk assessment’). The risk assessment methodology adopted is based on principles outlined in the:

- AS/NZS ISO 31000:2009 Risk management – Principles and guidelines
- HB 203:2012 Handbook: Managing environment-related risk.

The risk assessment identifies and assesses the climate change risks to the Project for the establishment of the BUF and WBE reclamation area, dredging activities, installing navigational aids and operational management of the WBE reclamation area.

The purpose of this risk assessment is to identify potential climate change impacts to prioritise environmental management actions and mitigation measures, and to inform the Project decision making process.

The risk management framework incorporates the Australian/New Zealand Standard for Risk Management (AS/NZS 4360:2004) and contains quantitative scales to define the **likelihood** of the potential impact occurrence and the **consequence** of the potential impact should it occur.

An overview of the interaction between Project activities (drivers/stressors), sensitive values/receptors and the risk impact assessment process is provided in Figure 11.3.

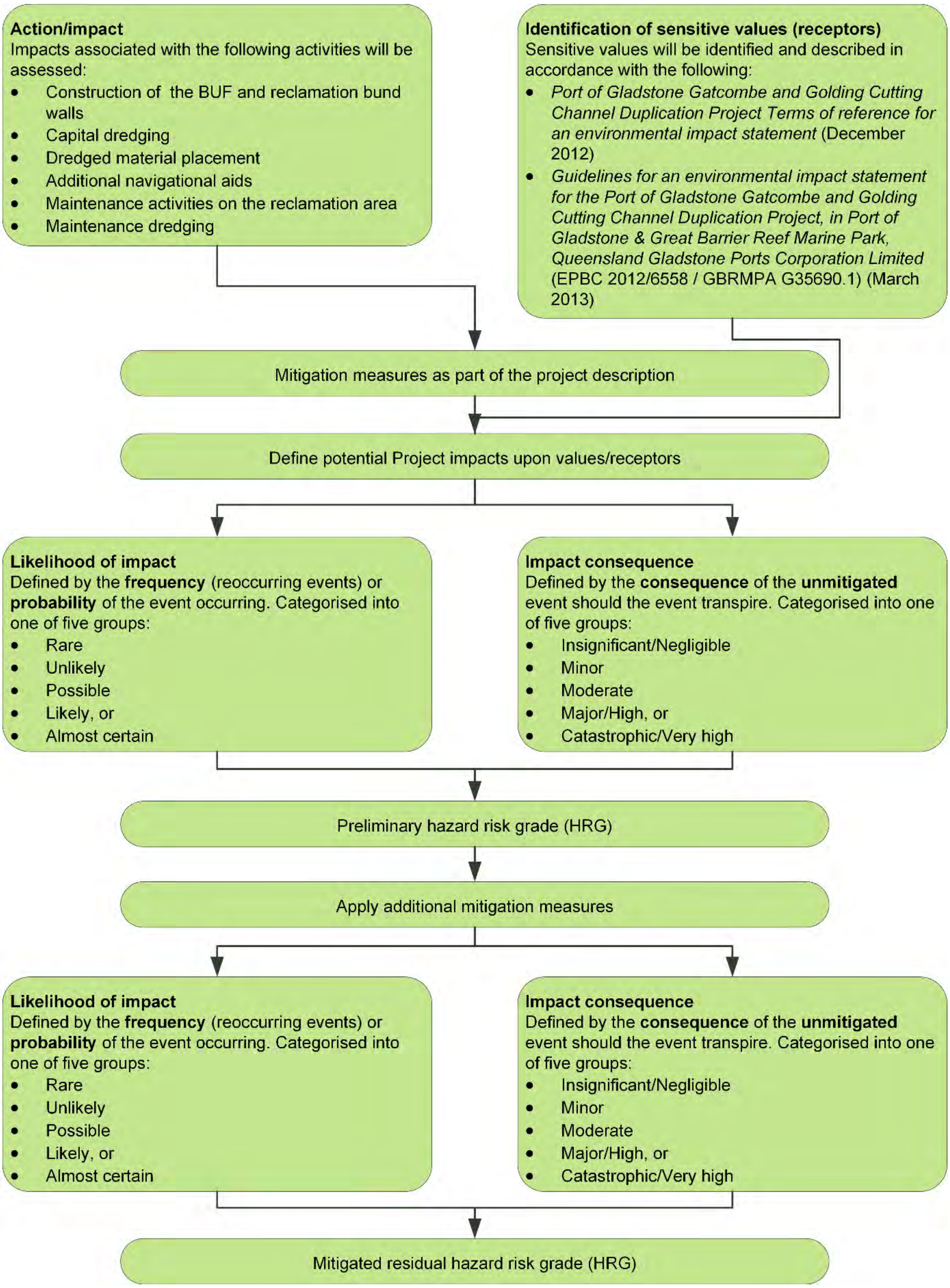

Figure 11.3 Risk assessment framework

Criteria used to rank the **likelihood** and **consequence** of potential impacts are provided in Table 11.5 and Table 11.6, respectively.

Table 11.5 Environmental (ecosystem), public perception and financial consequence category definitions (adapted from GBRMPA 2009a)

Description	Definition/quantification[1]		
	Environmental*	Public perception	Financial
Negligible (Insignificant)	No impact or, if impact is present, then not to an extent that would draw concern from a reasonable person No impact on the overall condition of the ecosystem	No media attention	Financial losses up to $500,000
Low (Minor)	Impact is present but not to the extent that it would impair the overall condition of the ecosystem, sensitive population or community in the long term	Individual complaints	Financial loss from $500,001 to $5 million
Moderate	Impact is present at either a local or wider level Recovery periods of 5 to 10 years likely	Negative regional media attention and region group campaign	Financial loss from $6 million to $50 million
High (Major)	Impact is significant at either a local or wider level or to a sensitive population or community Recovery periods of 10 to 20 years are likely	Negative national media attention and national campaign	Financial loss from $51 million to $100 million
Very high (Catastrophic)	Impact is clearly affecting the nature of the ecosystem over a wide area **or** impact is catastrophic and possibly irreversible over a small area or to a sensitive population or community Recovery periods of greater than 21 years likely **or** condition of an affected part of the ecosystem irretrievably compromised	Negative and extensive national media attention and national campaigns	Financial loss in excess of $100 million

Table notes:

1 Quantification of impacts should use the impact with the greatest magnitude in order to determine the consequence category

* For Matters of National Environmental Significance (MNES) protected under the provisions of the EPBC Act the *Matters of National Environmental Significance – Significant Impact Guidelines 1.1 – Environmental Protection and Biodiversity Conservation Act 1999* (DoE 2013) are to be used to determine the consequence category

Table 11.6 Likelihood category definitions (adapted from GBRMPA 2009a)

Description	Frequency	Probability
Rare	Expected to occur once or more over a timeframe greater than 101 years	0-5% chance of occurring
Unlikely	Expected to occur once or more in the period of 11 to 100 years	6-30% chance of occurring
Possible	Expected to occur once or more in the period of 1 to 10 years	31-70% chance of occurring
Likely	Expected to occur once or many times in a year (e.g. 1 to 250 days per year)	71-95% chance of occurring
Almost certain	Expected to occur more or less continuously throughout a year (e.g. more than 250 days per year)	96-100% chance of occurring

Once the likelihood and the consequence has been defined, determination of the HRG of the potential hazard will be determined through the use of a five by five matrix (refer Table 11.7).

Table 11.7 Hazard risk assessment matrix (adapted from GBRMPA 2009a)

Likelihood	Consequence rating				
	Negligible (insignificant)	Low (minor)	Moderate	High (major)	Very high (catastrophic)
Rare	Low	Low	Medium	Medium	Medium
Unlikely	Low	Low	Medium	Medium	High
Possible	Low	Medium	High	High	Extreme
Likely	Medium	Medium	High	High	Extreme
Almost certain	Medium	Medium	High	Extreme	Extreme

Table note:
Hazard risk categories identified in Table 11.7 are defined in Table 11.8

Table 11.8 Risk definitions and actions associated with hazard risk categories (adapted from GBRMPA 2009a)

Hazard risk category	Hazard risk grade definition
Low	These risks should be recorded, monitored and controlled. Activities with unmitigated environmental risks that are graded above this level should be avoided.
Medium	Mitigation actions to reduce the likelihood and consequences to be identified and appropriate actions (if possible) to be identified and implemented.
High	If uncontrolled, a risk event at this level may have a significant residual adverse impact on MNES, MSES, GBRWHA and/or social/cultural heritage values. Mitigating actions need to be very reliable and should be approved and monitored in an ongoing manner.
Extreme	Activities with unmitigated risks at this level should be avoided. Nature and scale of the significant residual adverse impact is wide spread across a number of MNES and GBRWHA values.

11.5.2 Summary of risk assessment.

The risk assessment framework developed for the Project was applied to the potential impacts of climate change on construction and operational activities as identified by Table 11.4. A summary of the risk assessment for climate change impacts is provided in Table 11.9. In general, the potential impacts identified can be managed through a combination of design mitigation measures for extreme events and the implementation of the Project EMP, Dredging EMP, site management plan (ground stability), and cyclone management plan.

The Dredging EMP (refer AEIS Appendix F) and the Project EMP (refer AEIS Appendix G) provide a range of mitigation measures to reduce the potential climate and climate change impacts of the Project. As part of the risk assessment, the management plans and associated mitigation measures below have been applied to determine the post mitigation HRG shown in Table 11.9:

- Dredging EMP (refer AEIS Appendix F)
  - General environmental management measures (refer Section 8)
  - Water quality management plan (refer Section 9.10)
- Project EMP (refer AEIS Appendix G)
  - Water quality management plan (refer Section 8.10).

Risk is the likelihood of disaster or hazard. This probability is implied to occur to an asset or a resource. In determining risk, mitigation measures could be implemented in order to reduce the likelihood of risk.

The risk associated with the potential impacts of climate change variables on the Project was assessed using the risk assessment methodology provided in Section 11.5.1.

Table 11.9 Potential climate change impacts and risk assessment ratings

Potential impact	Project phase					Preliminary HRG			Post mitigation HRG		
	Reclamation area and BUF establishment	Dredging	Navigational aids	Demobilisation	Maintenance	Likelihood	Consequence	HRG	Likelihood	Consequence	HRG
Extreme rainfall, exacerbated by climate change (including storm surge/flooding)											
Potential injury or death ▪ Falling from dredging vessel or other Project vessel; swept to sea from BUF, WB or WBE reclamation areas ▪ Equipment failure ▪ Vehicle loss of control due to wet conditions	✓	✓		✓	✓	Possible	High	High	Unlikely	High	Medium
Overload of stormwater management system, causes runoff and localised flooding	✓				✓	Possible	Low	Medium	Unlikely	Low	Low
Damage to bund walls or BUF and movement of sediment leading to potential decrease in surrounding water quality, time delays due to additional dredging and clean up requirements including additional costs	✓	✓			✓	Possible	Moderate	High	Unlikely	Moderate	Medium
Increase in average and seasonal temperatures											
Damage of outer BUF and/or bund walls due to exceeding heat tolerances of construction materials	✓				✓	Possible	Moderate	High	Unlikely	Low	Low
Instability of the final landform of the reclamation area and long term future land use outcomes					✓	Possible	Moderate	High	Unlikely	Low	Low
Increase in average and seasonal temperature profiles and decrease in annual rainfall											
Increased evaporation rates and annual rainfall leading to changes in the soil moisture profile resulting in instability and movement of the reclamation area	✓				✓	Unlikely	Low	Low	Unlikely	Low	Low

Potential impact	Project phase					Preliminary HRG			Post mitigation HRG		
	Reclamation area and BUF establishment	Dredging	Navigational aids	Demobilisation	Maintenance	Likelihood	Consequence	HRG	Likelihood	Consequence	HRG
Sea level rise											
Future inundation of the BUF and reclamation area, and not providing long term beneficial land use outcomes	✓				✓	Possible	Low	Medium	Unlikely	Low	Low
Tropical storms and cyclones, increased intensity											
Potential injury or death – drowning from dredging vessel or swept to sea from the BUF, WB or WBE reclamation areas	✓	✓		✓	✓	Possible	High	High	Unlikely	High	Medium
Dredging vessels and/or other Project equipment incident potential injury or death or damage to equipment	✓	✓	✓	✓	✓	Possible	High	High	Unlikely	High	Medium
Damage of outer BUF and/or bund walls resulting in decrease in marine water quality	✓	✓			✓	Possible	Moderate	High	Unlikely	Moderate	Medium
Increased sediment load in the channel resulting in an increased requirement for maintenance dredging and associated costs					✓	Possible	Low	Medium	Unlikely	Low	Low
Tropical storms and cyclones, increased intensity and increase in sea level											
Damage to BUF and/or bund walls, and movement of sediment leading to potential decrease on surrounding water quality, time delays due to additional dredging and clean up requirements including additional costs	✓	✓			✓	Possible	Moderate	High	Unlikely	Moderate	Medium