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2.1 INTRODUCTION

The Terms of Reference (ToR) for the EIS requires Waratah Coal to undertake a climate and climate change adaption assessment.

This chapter is divided into two sections. The first section provides existing physical climatic descriptions along the proposed rail corridor. The second section of this chapter provides Waratah's preliminary Risk Assessment on climate change. The Risk Assessment analysed risks from a climate change perspective and identified measures in minimising risks to the Project from climate change. Potential impacts relating to the Project associated with climate change are also discussed.

This chapter does not address the greenhouse gas assessment. An assessment of greenhouse gas emissions generated from potential impacts from the construction and operation of the proposed mine are discussed in Volume 2, Chapter 10.

In addition, this chapter does not address the recent (2008, 2010, 2011) climate events that are likely to be relevant to this proposed rail alignment. This recent data will be assessed and included in Supplementary EIS (where relevant). The 2011 Garnaut Report (update) including, the revision of predicted climate change scenarios will also be reviewed and interpreted as part of the Supplementary EIS.

2.2 DESCRIPTION OF ENVIRONMENTAL VALUES

2.2.1 CLIMATE ALONG THE RAIL ALIGNMENT

The proposed corridor has a tropical climate, with hot and wet summers, and cool dry winters. Summer has monsoonal weather, frequently influenced by tropical cyclones and low pressure systems, which cause significant rainfall in the coastal areas. The wind direction is predominant from the east, south east and north east, influenced by the trade wind.

Climate conditions for the rail alignment have been assessed for three project locations:

- the coal terminal – the start of the railway;
- central region of the railway; and
- the mine site.

For the coal terminal, meteorological data was taken from the Bureau of Meteorology (BOM) weather station at Bowen Airport, except for evaporation data. Evaporation data was not available for Bowen Airport, and has been taken from the closest BOM weather stations: Ayr, Townsville and Te Kowai, which are approximately 115 km north west, 200 km north west and 200 km south east from Bowen, respectively.

To provide an indication of regional climate trends for the central region of the railway meteorological data has been taken from BOM weather stations at Collinsville and Moranbah.

Meteorological data from the BOM weather stations at Barcaldine, Emerald, Clermont and Blackall are used to represent the mine, as these are the closest stations to the mine site. Some data was not available for weather parameters, so data was taken from the next nearest station.

The location of each station and selected parameters is shown in Table 1.

2.2.2 TEMPERATURE

The long term averages of daily maximum and minimum temperature by the month of the year are presented at Figure 1. In the hot summer months, the mean daily maximum temperature reaches over 31°C at the coal terminal, over 35°C at the mine site, and in-between for other locations. The daily temperature ranges are less for the coal terminal (about 7 - 8°C) and are more near the mine (about 13 - 15°C), with other sites in between. In the cooler winter months, the mean daily maximum temperature drops to 23 - 25°C at these locations, and mean daily minimum temperature drop to 13.5°C at the coal terminal and as low as 7.6°C at the mine site, and in-between for other locations.

2.2.3 TEMPERATURE INVERSIONS

A temperature inversion refers to a layer of air in the atmosphere in which the temperature increases with height (instead of general profile of decreasing with height). During the night time the ground is cooled by radiating heat into space. Air in contact with the ground then becomes cooler than the air above it, forming a typical night-time near-ground inversion layer. Inversions can form from other mechanisms, such as when warm air moves over a cool surface, which can also form at high altitudes in the atmosphere.

The lack of convective mixing within the lower-level inversion layer means that lower-level pollution can be trapped within the inversion layer, resulting in high pollution levels.

The lower-level temperature inversion strength and frequency have been estimated based on meteorological modelling output datum for 2008 (at the mine site and coal terminal, respectively). Table 2 illustrates inversions occur at a greater percentage of the time at the mine site than the coal terminal. This is because temperature inversions are more pronounced over land than near water, as water holds its heat for longer than land does. From this, it can be expected that the frequency of inversions will increase as the rail corridor moves inland from the coal terminal to the mine site.

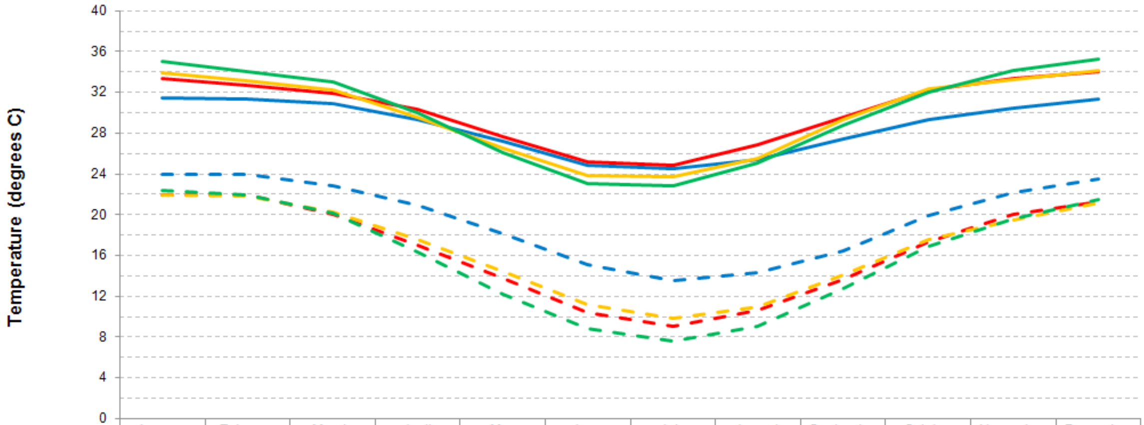
2.2.4 RAINFALL

A summary of the long term monthly average rainfall for the project locations are presented in Figure 2. It shows that rainfall is high in summer and low in winter, and coastal sites have more rainfall than inland sites.

Table 1. Bureau of Meteorology monitoring site locations and parameters

COMPONENT	METEOROLOGY STATION	COORDINATES	DATA RANGE	PARAMETERS
Mine	Blackall Township	Latitude: 24.42°S Longitude: 145.47°E	1880-current	Temperature, rainfall, relative humidity
	Longreach	Latitude: 23.44°S Longitude: 144.28°E	1949-current	Evaporation
	Emerald Airport	Latitude: 23.57°S Longitude: 148.18°E	1981-current	Temperature, rainfall, relative humidity, evaporation, wind speed and direction
	Clermont	Latitude: 22.82°S Longitude: 147.64°E	1870-current	Temperature, rainfall, relative humidity, evaporation
	Barcaldine Post Office	Latitude: 23.55°S Longitude: 145.29°E	1886-current	Temperature, rainfall, relative humidity, evaporation wind speed and direction
Rail	Collinsville	Latitude: 20.55°S Longitude: 147.85°E	1939-current	Temperature, rainfall, relative humidity, evaporation wind speed and direction
	Moranbah	Latitude: 21.99°S Longitude: 148.03°E	1972-current	Temperature, rainfall, relative humidity, evaporation wind speed and direction
Coal Terminal	Bowen Airport	Latitude: 20.02°S Longitude: 148.22°E	1987-current	Temperature, rainfall, relative humidity, wind speed
	Ayr	Latitude: 19.62°S Longitude: 147.38°E	1951-current	Evaporation
	Townsville	Latitude: 19.25°S Longitude: 146.77°E	1940-current	Evaporation
	Te Kowai	Latitude: 21.16°S Longitude: 149.12°E	1889-current	Evaporation
	Proserpine	Latitude: 20.49°S Longitude: 148.56°E	1978-current	Pressure

Figure 1. Long term average temperature summaries

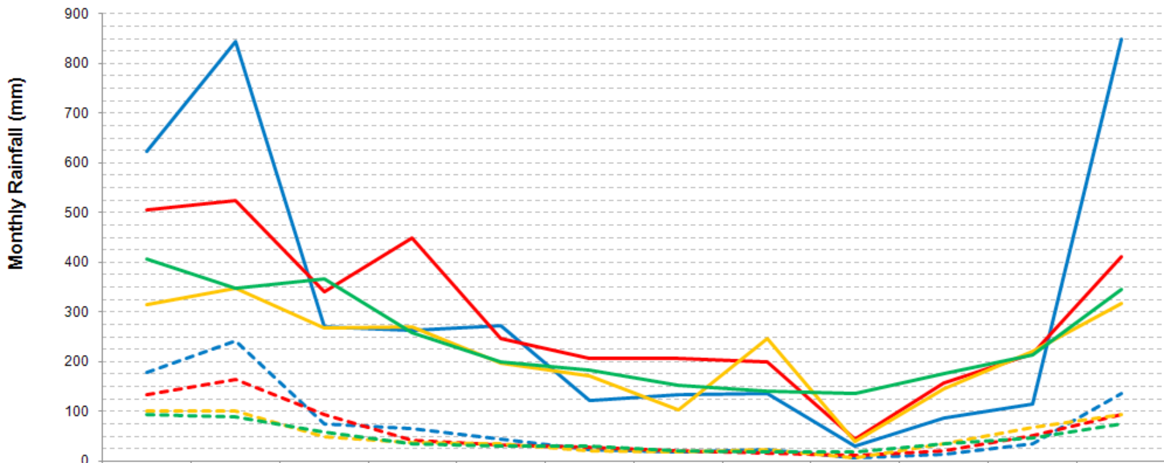


	January	February	March	April	May	June	July	August	September	October	November	December
Port - Mean Max	31.5	31.3	30.9	29.3	27.2	24.9	24.5	25.4	27.4	29.3	30.5	31.4
Port - Mean Min	23.9	23.9	22.8	20.9	18.1	15.1	13.5	14.3	16.4	19.9	22.2	23.5
Collinsville - Mean Max	33.4	32.7	31.9	30.3	27.6	25.2	24.9	26.9	29.6	32.2	33.4	34
Collinsville - Mean Min	21.9	21.9	20	17	13.8	10.4	9	10.6	13.6	17.3	20	21.3
Moranbah - Mean Max	33.9	33.1	32.2	29.6	26.5	23.8	23.7	25.5	29.3	32.4	33.3	34.1
Moranbah - Mean Min	21.9	21.8	20.2	17.6	14.4	11.2	9.8	11	14.1	17.6	19.5	21.1
Mine - Mean Max	35.1	34.0	33.0	30.0	26.1	23.0	22.8	25.0	28.8	32.1	34.2	35.3
Mine - Mean Min	22.4	22.0	20.1	16.4	12.2	8.9	7.6	9.0	12.8	16.9	19.6	21.5

Table 2. Temperature inversion at night time – mine site and coal terminal

NIGHT TIME INVERSION STRENGTH	MINE SITE		COAL TERMINAL	
	PERCENTAGE OF OCCURRENCE (%)	NUMBER OF HOURS	PERCENTAGE OF OCCURRENCE (%)	NUMBER OF HOURS
>3°C per 100 m	13	1169	1	63
>2°C per 100 m	20	1750	2	210
>1°C per 100 m	30	2595	12	1056
>0°C per 100 m	50	4410	34	2974

Figure 2. Long term average rainfall summary



	January	February	March	April	May	June	July	August	September	October	November	December
Port - Maximum	623.1	843.4	269.3	264.2	273	123	135	135.3	29.6	87	114.5	848.5
Port - Average	178.3	242.9	75.7	64.6	44.4	23.9	19.3	22.4	7.2	13.4	35.4	135.1
Collinsville - Maximum	505.8	524.6	341.8	448.6	246.6	207.6	207.4	200	45.4	158.3	216.2	410.4
Collinsville - Average	134	164.7	93.2	41.9	32.4	27.3	20.2	17.1	11	21.5	50.5	95
Moranbah - Maximum	315	347.4	268	271	196.6	170.3	103.6	247.3	39.4	146.6	220.3	318.2
Moranbah - Average	102	100.6	48.1	37.4	35.9	22.1	18.5	22.5	7.9	36.1	67.1	94.7
Mine - Maximum	406.0	349.0	366.1	259.3	199.1	183.7	152.7	139.9	136.8	175.0	214.8	344.5
Mine - Average	94.7	90.0	59.3	35.5	29.6	29.5	21.3	18.6	19.1	35.0	47.7	75.8

2.2.5 WIND SPEED AND DIRECTION

Wind roses show the frequency of wind occurrence by direction and strength. The bars correspond to the 16 compass points (N, NNE and NE). The bar at each wind direction in the wind rose diagram represents winds blowing from that direction. The length of the bar represents the frequency of occurrence of winds from that direction, and the widths of the bar sections correspond to wind speed categories, the narrowest representing the lightest winds. With the resulting figure it is possible to visualise how often winds of a certain direction and strength occur over a long period, either for all hours of the day, or for particular periods during the day.

2.2.5.1 Start of the Rail (coal terminal)

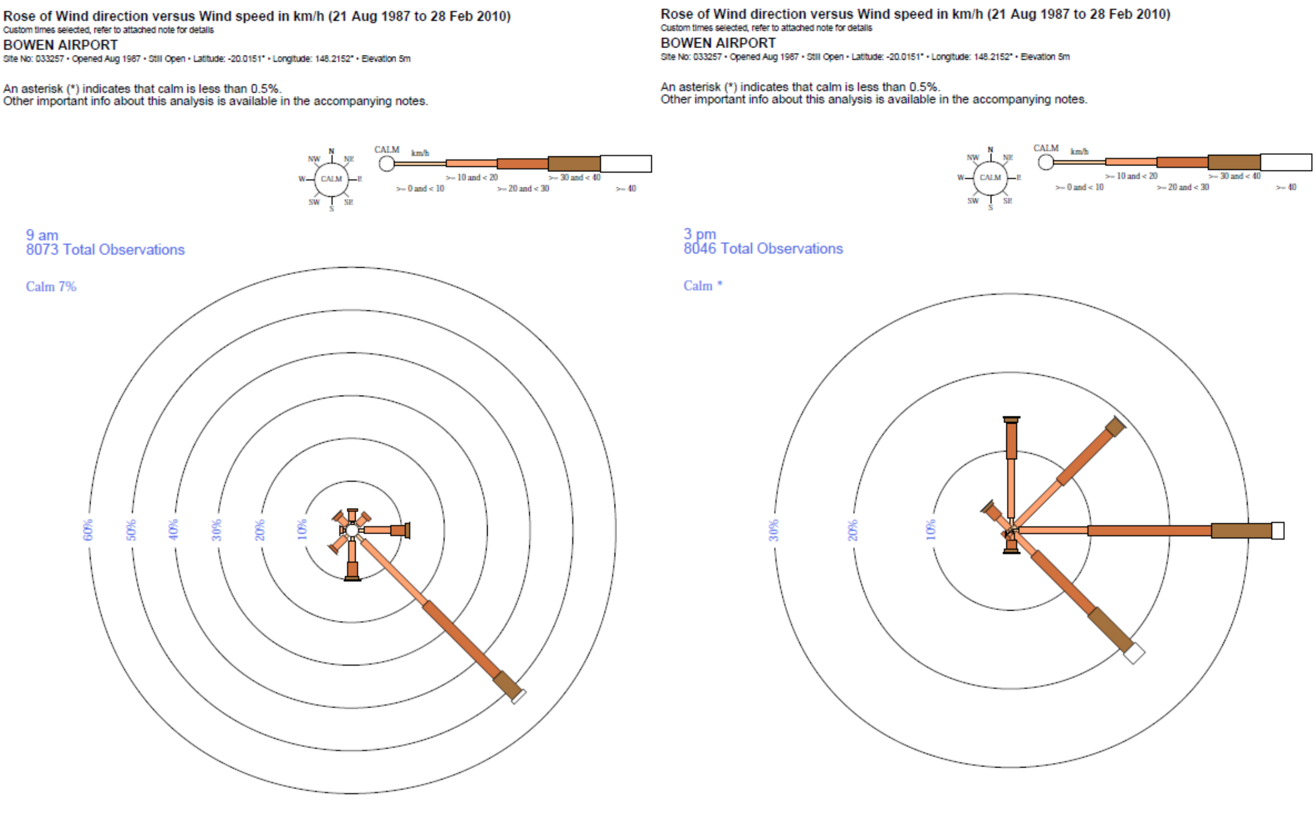
Long term 9 am wind roses for the coal terminal show that winds are predominately moderate to strong winds from the south-east, with calm conditions occurring for 7% of the monitored period (see Figure 3). The 3 pm wind is stronger, predominately from the east, and wind from the north, north-east and south-east is also common. Calm conditions form 0.5% of 3 pm winds.

2.2.5.2 Central Section of the Rail

Wind roses from the BOM stations at Proserpine and Moranbah were used to represent the central section of the railway, presented in Figure 4 and Figure 5. The Proserpine station rather than the Collinsvale station data were used because the wind data from the Collinsvale BOM station appear to be erroneous (showing long term average winds were almost evenly distributed for all directions which is considered to be not likely for this location).

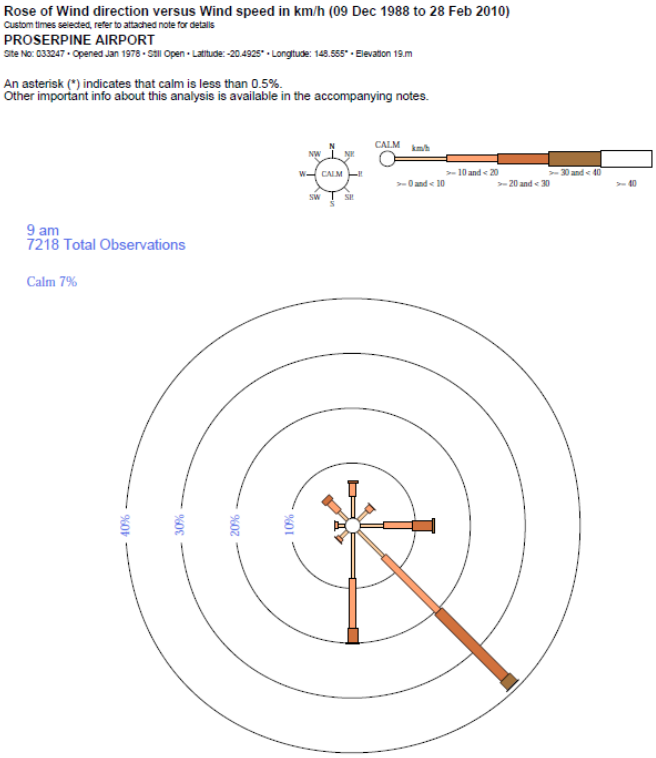
Based on wind roses from Proserpine and Moranbah, long term average 9 AM winds for the central section of the railway are predominately from the south-east to east, with calms between 7-24% of the monitored period. Long term average 3 PM winds are generally stronger than for 9 AM, and from the south-east to east. Calms form 0.5-15% of 3 PM winds.

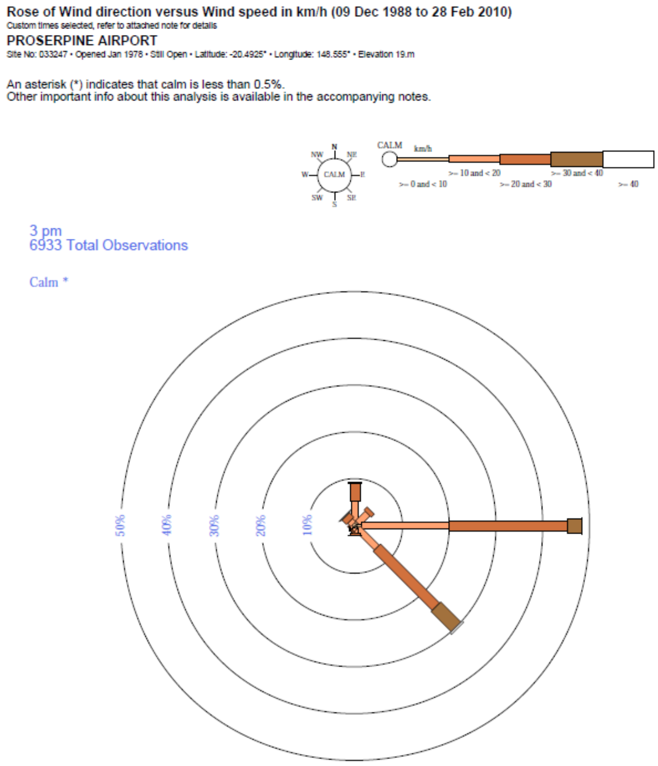
Figure 3. Long term average 9 am and 3 pm wind roses from Bowen Airport



Source: BOM accessed 28 February 2010

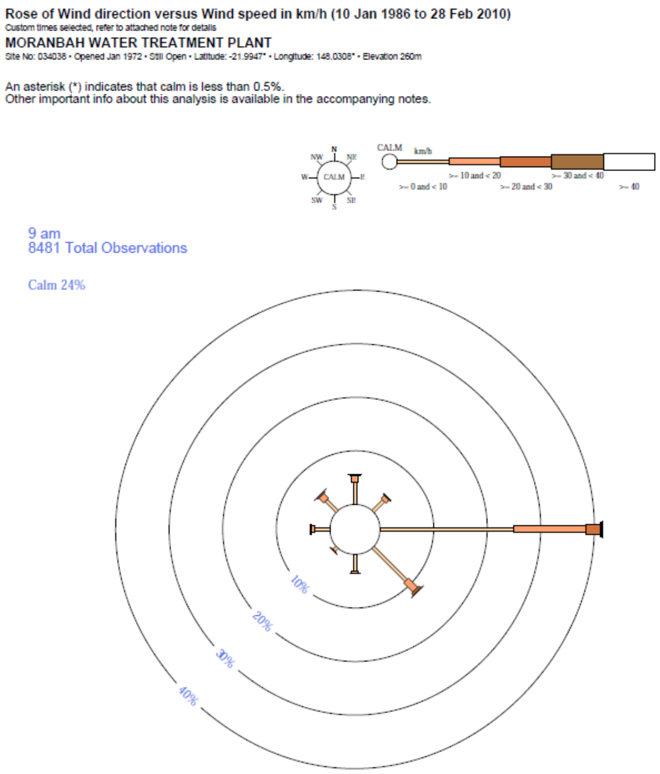
Figure 4. Long term average 9 am and 3 pm wind roses from Proserpine airport

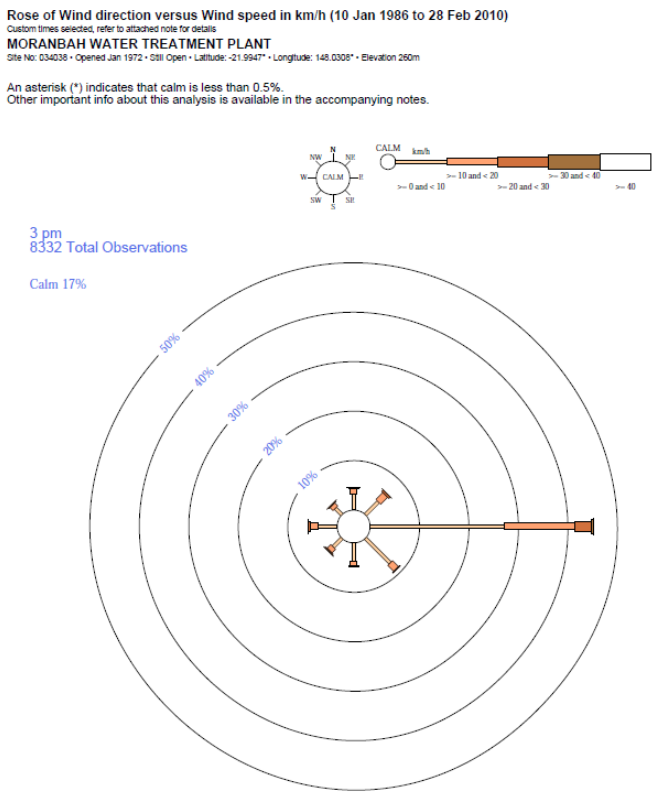




Source: BOM accessed 28 February 2010

Figure 5. Long term average 9 am and 3 pm wind roses from Moranbah



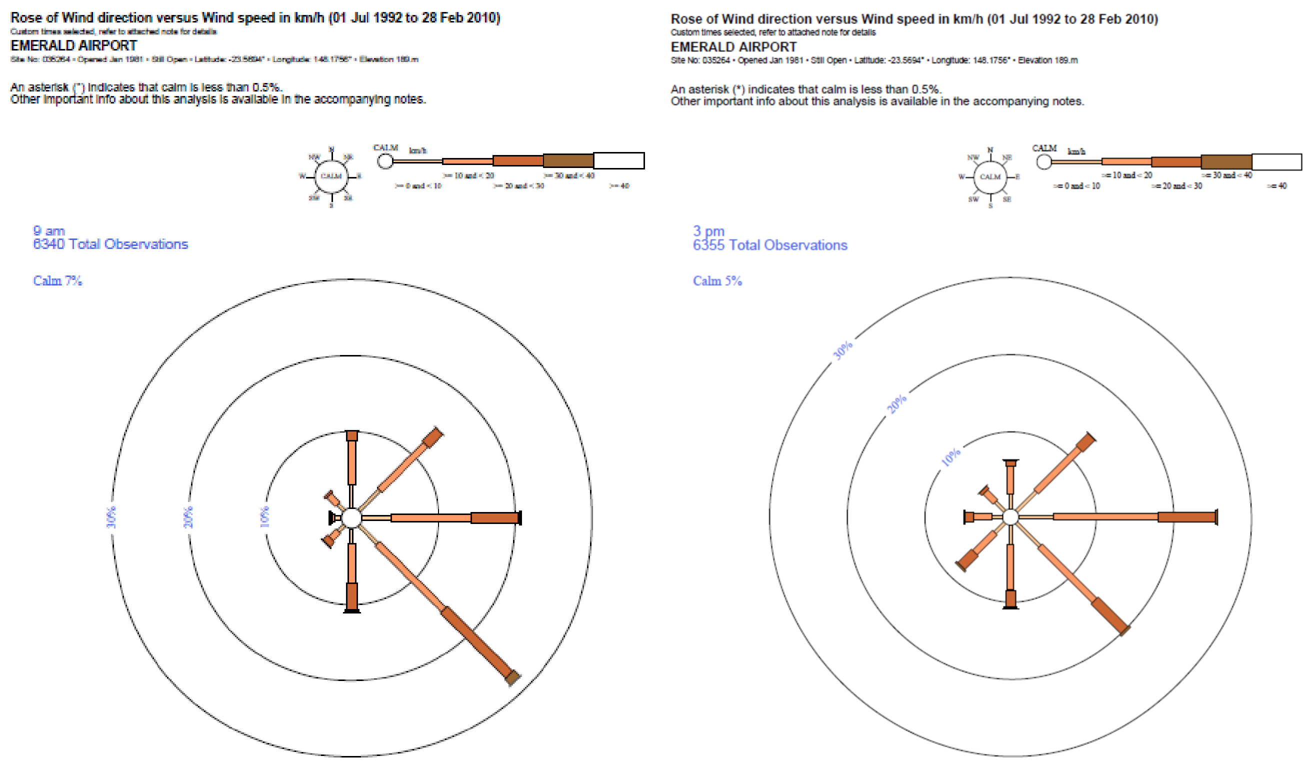


Source: BOM accessed 28 February 2010

2.2.5.3 Final Section of the Rail (mine site)

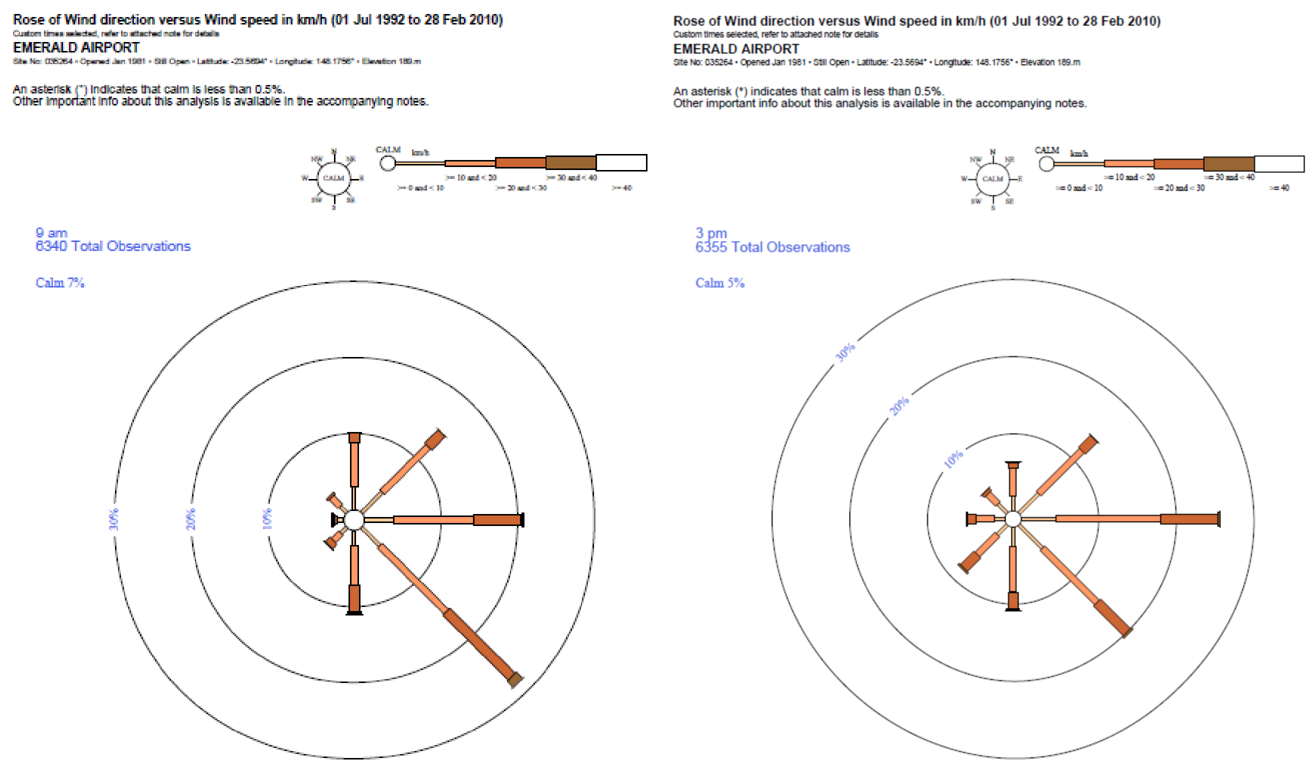
Long term wind roses from two representative locations in the study area (one from the east and one from the west of the study area) show very different wind strengths although similar wind directions across the study area. Emerald, shown in Figure 6, is located east of the study area and has winds that are frequently from the east with more moderate winds. Barcaldine, to the west of the study area (Figure 7), also shows more winds from the east but has a higher frequency of low wind speeds. Calms form between 3% and 7% of monitored 9 am and 3 pm data.

Figure 6. Long term average 9 am and 3 pm wind roses from Emerald airport



Source: BOM accessed 28 February 2010

Figure 7. Long term average 9 am and 3 pm wind roses from Barcaldine airport



Source: BOM accessed 28 February 2010

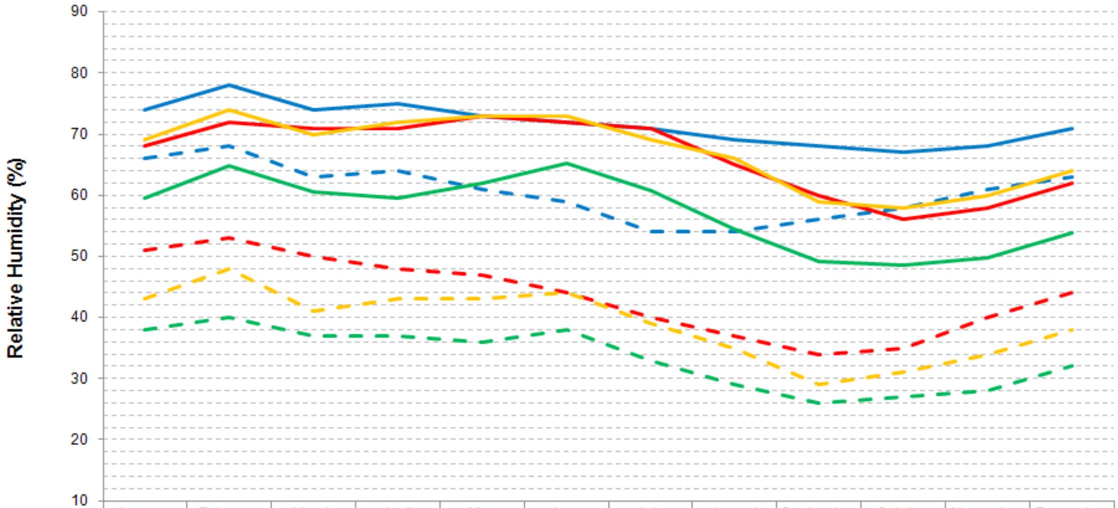
2.2.6 RELATIVE HUMIDITY

Relative humidity in the study area, presented in Figure 8, is typically the highest at the coal terminal and the lowest at the mine site. Relative humidity is affected by the distance from the sea with stations further from the ocean having less water vapour available and hence lower relative humidity. Relative humidity for all sections of the railway is highest during the summer, autumn and winter months, and lowest during the spring months.

2.2.7 EVAPORATION

Mean daily evaporation at each of the railway sections, presented in Figure 9, follow a similar trend, with evaporation during the summer months approximately twice as great as during winter months. This is predominantly due to higher solar radiation and longer hours of daylight during summer. Evaporation rates are also impacted by relative humidity: the drier the air, the higher evaporation would occur.

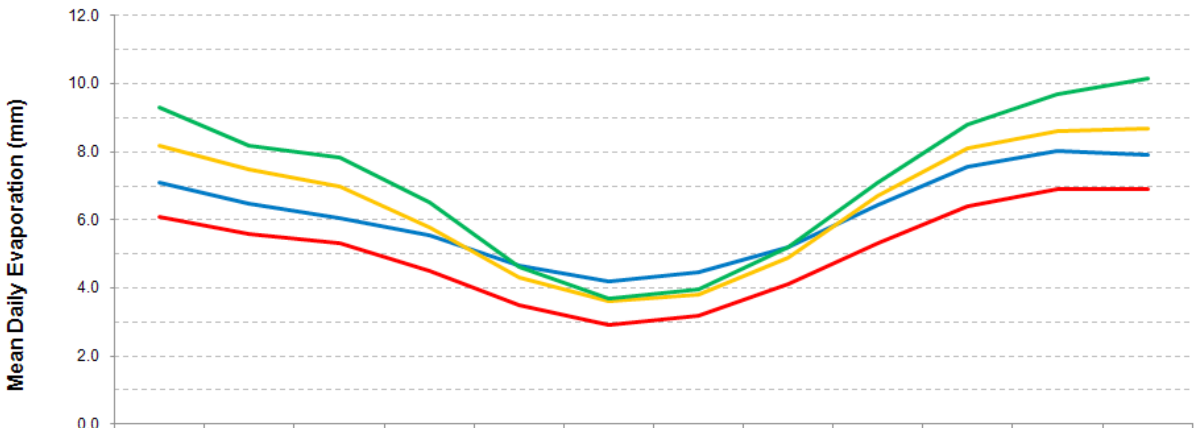
Figure 8. Long term average relative humidity summaries



	January	February	March	April	May	June	July	August	September	October	November	December
Port - 9AM	74	78	74	75	73	72	71	69	68	67	68	71
Port - 3PM	66	68	63	64	61	59	54	54	56	58	61	63
Collinsville - 9AM	68	72	71	71	73	72	71	65	60	56	58	62
Collinsville - 3PM	51	53	50	48	47	44	40	37	34	35	40	44
Moranbah - 9AM	69	74	70	72	73	73	69	66	59	58	60	64
Moranbah - 3PM	43	48	41	43	43	44	39	35	29	31	34	38
Mine - 9AM	59.5	64.8	60.5	59.5	62.0	65.3	60.8	54.5	49.3	48.5	49.8	53.8
Mine - 3PM	38	40	37	37	36	38	33	29	26	27	28	32

Source: BOM accessed 28 February 2010

Figure 9. Mean daily evaporation



	January	February	March	April	May	June	July	August	September	October	November	December
Port	7.1	6.5	6.1	5.6	4.7	4.2	4.5	5.2	6.4	7.6	8.0	7.9
Collinsville	6.1	5.6	5.3	4.5	3.5	2.9	3.2	4.1	5.3	6.4	6.9	6.9
Moranbah	8.2	7.5	7	5.8	4.3	3.6	3.8	4.9	6.7	8.1	8.6	8.7
Mine	9.3	8.2	7.9	6.5	4.6	3.7	4.0	5.2	7.1	8.8	9.7	10.2

There is no clear trend of mean daily evaporation increasing or decreasing as the railway moves inland. During the summer months the greatest evaporation occurs at the mine site (8-10 mm), and the least is at Collinsville (6-7 mm). During the winter months, the highest evaporation occurs at the coal terminal (4-5 mm) and the least is at Collinsville (3-4 mm).

2.2.8 SURFACE PRESSURE

Hourly and monthly mean sea level pressures for the coal terminal and mine site are presented in Figure 10 and Figure 11, respectively. Bars represent (top to bottom) 95th, 50th and 5th percentile values, with error bars representing maximum and minimum values. Data has been taken from the closest available BOM weather stations: Proserpine for the coal terminal and Blackall for the mine. Data was not available for the central railway region.

The hourly graph shows that the median pressure at the mine site and the coal terminal are similar (within 1 hpa), with the range of pressures from minimum to maximum greater at the mine site than at the coal terminal. Both locations follow similar diurnal cycle in pressure, with maximums in the mid morning (7 to 10 am) and minimums during the late afternoon (3 to 5 pm). This is due to a feature often referred to as atmospheric tides. This is where atmospheric solar heating, combined with upward eddy conduction of heat from the ground, generates internal gravity waves in the atmosphere at periods of the integral fractions of a solar day (primarily at the diurnal and semidiurnal periods).

An annual cycle is clearly visible in Figure 11 for both the coal terminal and the mine site. This reflects the fact that the summer temperature is high and hence pressure is low, opposite to winter.

2.2.9 CLIMATE EXTREMES

2.2.9.1 Floods

The proposed rail alignment traverses approximately 468 km from the Port of Abbot Point to the proposed mine area north west of Alpha. The rail alignment lies almost entirely within the Burdekin Catchment except KP5 to approximately KP40, which lies within the Don Catchment. The Burdekin Catchment includes several major river systems including the Belyando, Suttor, Bowen and Bogie Rivers.

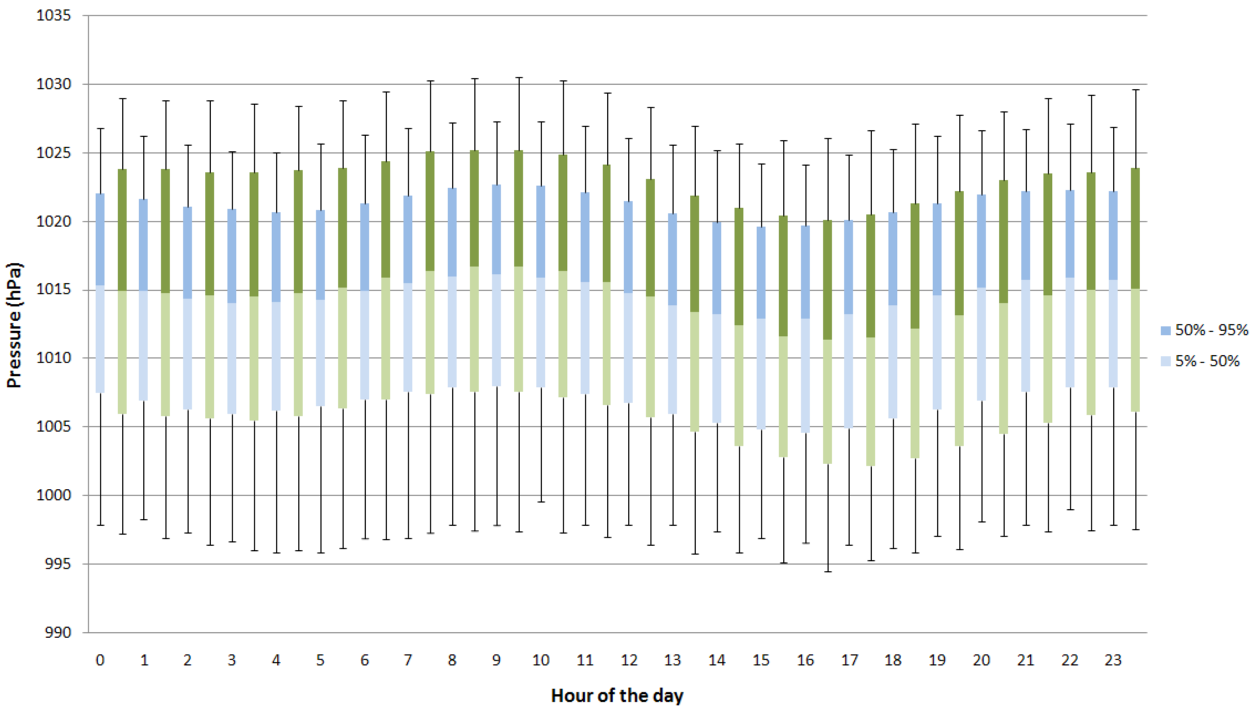
Topography varies over the length of the alignment with the internal areas south of Collinsville characterised by low relief floodplains with minor undulating slopes across the Belyando and Suttor River floodplains. North of Collinsville the terrain becomes relatively steep across the Leichardt and Clarke Ranges before moving into low lying coastal areas as the alignment approaches Abbot Point.

The variable rainfall and relatively flat topography over most of the alignment can result in localised flooding around creeks and rivers over the length of the railway during events of more than 200 mm over a 48 hour period. Flooding generally occurs during summer months as a result of heavy rainfalls caused by tropical lows and rain depressions generated from cyclones crossing the north eastern Queensland coastline.

In January and February 2008 a monsoonal low originating in the Gulf of Carpentaria caused significant rainfalls (upward of 300 mm in 24 hours in some areas) throughout the central west region. These falls resulted in a number of the rivers and creeks in the region overflowing their banks, including the Burdekin, Belyando, Bogie and Don Rivers. Flooding occurred at a number of isolated sites along the Belyando and Bogie Rivers between Charters Towers and Clermont, which includes areas in the vicinity of the proposed railway. This type of event is characteristic of the region where intense rainfall can result in localised flooding of a number of the river and creek systems.

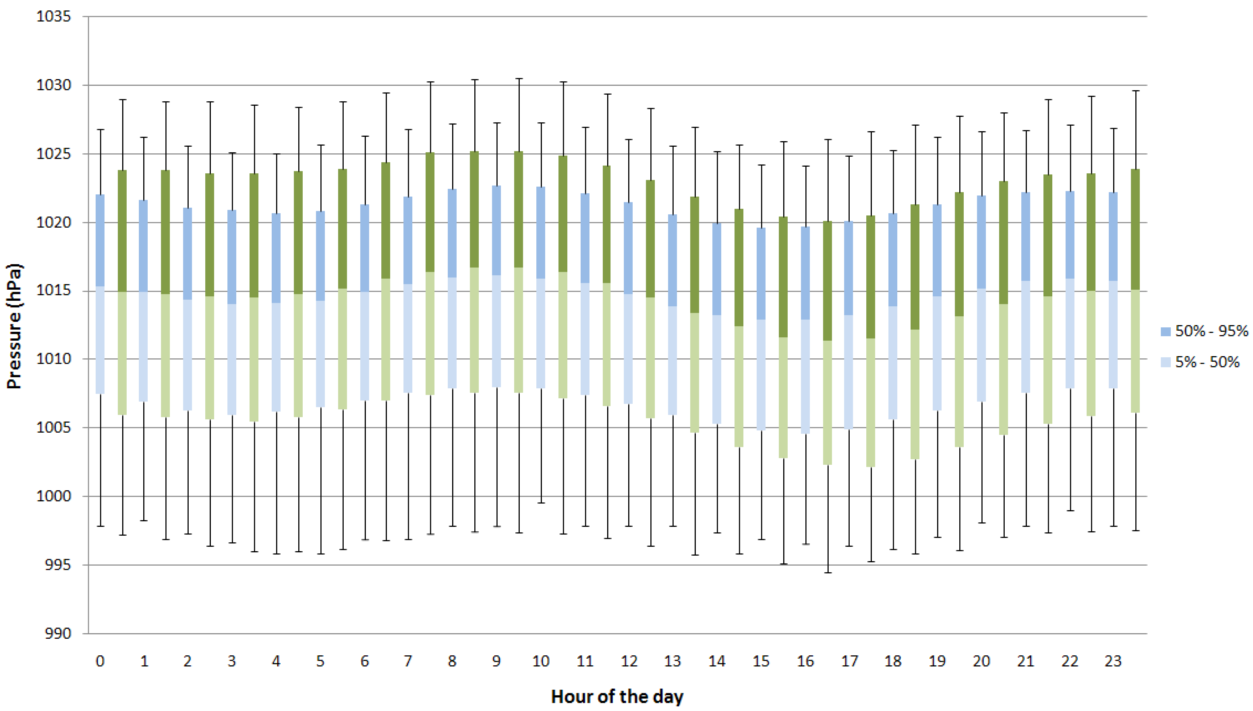
There are a number of stream flow or gauging stations in close proximity to the rail alignment. Three of these, Mistake Creek (part the Belyando sub-catchment) at Twin Hills, Suttor River at Eaglefield and Bowen River at Jacks Creek, have been used to provide an indication of historic flood levels along the rail corridor (Table 3).

Figure 10. Hourly average mean sea level pressure for the coal terminal (blue) and mine site (green)



Coal terminal values (blue) taken from the Proserpine BOM weather station.
Mine values (green) are the average of data taken from the Blackall BOM weather stations.

Figure 11. Monthly average mean sea level pressure for the coal terminal (blue) and mine site (green)



Coal terminal values (blue) taken from the Proserpine BOM weather station.
Mine values (green) are the average of data taken from the Blackall BOM weather stations.

Table 3. Flood levels for the rail corridor

120309A – TWIN HILLS		120209A – JACKS CREEK		120304A – EAGLEFIELD	
YEAR	FLOOD LEVEL (M) AHD	YEAR	FLOOD LEVEL (M) AHD	YEAR	FLOOD LEVEL (M) AHD
1978	101.09	1970	134.87	1970	28.53
1983	100.65	1979	129.52	1976	28.61
1987	100.13	1980	127.85	1978	29.79
1990	99.98	1988	132.13	1983	30.03
1994	99.98	1989	131.99	1988	32.38
1997	100.04	1991	131.73	1991	32.11
2003	100.65	1997	128.49	1997	29.49
1978	101.09			2000	28.53

Modelling was carried out to identify 1 in 100 year flooding levels and risks associated with flooding along the proposed rail alignment. The results of this modelling and measures proposed to reduce the risk of flooding to construction and operation of the railway are included in Volume 5, Appendix 16.

2.2.9.2 Flood event of 2010/2011

The period from late November 2010 to mid January 2011 was recorded as being an extremely wet one throughout eastern Australia. Several major rain events resulted in widespread flooding within rivers and catchments culminating in severe flooding in south-east Queensland. The flooding has been recorded as the most significant in Australia's recorded history in terms of its extent, impact and severity (National Climate Centre, 2011)

December 2010 rainfall levels were the highest on record in Queensland, with total highs of month levels and daily levels, set in 107 locations across the state. The state average level of rainfall of 209.45mm in December 2010 exceeded the previous record of 200.1mm set in December 1975, (BOM, 2011a). The December 2010 rainfall totals in Queensland are depicted in Figure 12.

Total rainfall exceeded 300 mm over most of the eastern half of Queensland for the period 28 November to 31 December, whereas most of the Queensland east coast; extending inland to many areas in the Central Highlands and adjacent areas, experienced totals in the 400 to 600 mm range (National Climate Centre, 2011).

Along the East Central Coast, a new record for highest December total rainfall was set in Collinsville. The previous record of 410.4mm set in 1956 was surpassed by the new record of 461.4mm in 2010 out of a total of 72 years of rainfall records.

The meteorological station at Moranbah, along the West Central Coast, recorded a new record for highest total December rainfall. The previous record of 318.2 mm set in 1991 was surpassed by the new record of 350 mm in 2010 out of a total of 72 years of rainfall records.

2.2.9.3 Tropical Cyclones

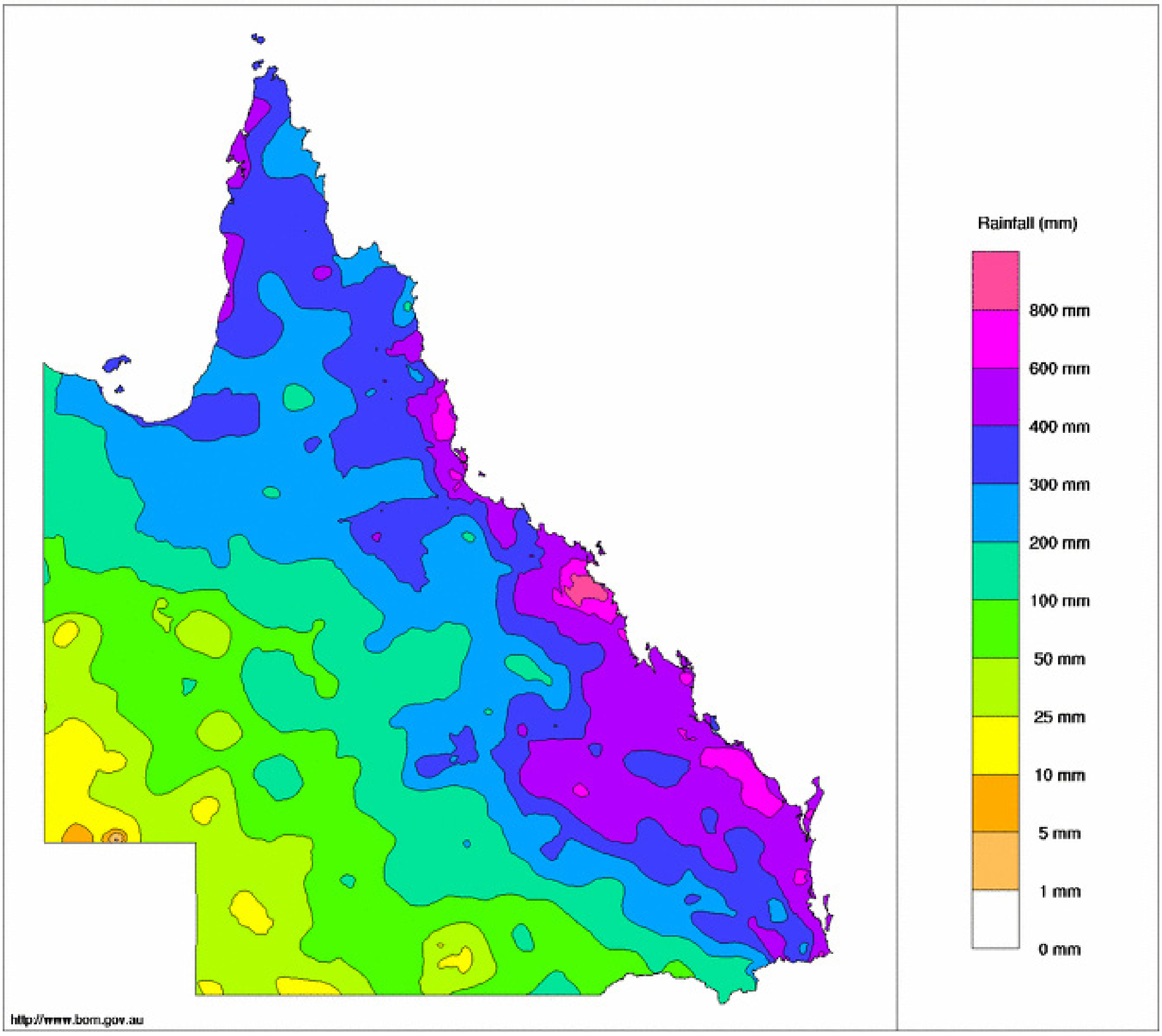
Tropical cyclones in the Queensland region mostly form from lows within the monsoon trough, between November and April. The considerable majorities of cyclones are formed over tropical waters off north Queensland, and occasionally track to inland and southern parts of the state, where they generally reduce in intensity and become known as ex-tropical cyclones or tropical lows. In some cases tropical lows do re-intensify and re-establish as a tropical cyclone, particularly where they interact with warmer coastal airflows associated with tropical waters.

The number of tropical cyclones in railway region decreases as the railway moves inland from the coal terminal. Between 1906-2006:

- 57 tropical cyclones passed within 200 km of the coal terminal (Figure 13);
- 27 tropical cyclones passed within 200 km of the centre of the rail corridor (Figure 14); and
- 15 tropical cyclones passed within 200 km of the mine site (Figure 15).

The average number of tropical cyclones at the coal terminal site is 0.2-0.4 per year and less than 0.1 per year, based on data from the 1975/76 to 2005/06 cyclone seasons (BOM, 2009). This period includes El Niño, La Niña and neutral years, however, tropical cyclones impacts in eastern Australia have been shown to occur almost twice more often during La Niña years than during El Niño years (BOM, 2010b).

Figure 12. Queensland rainfall totals in December 2010

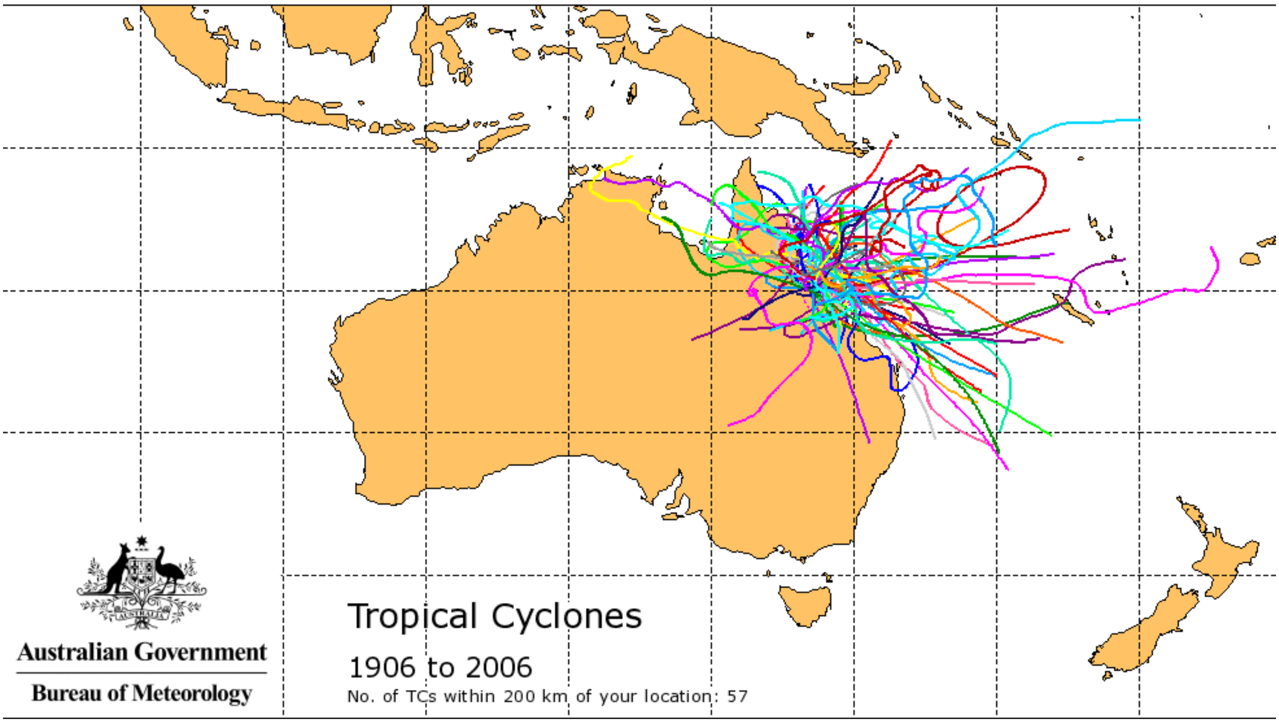


Source: BOM website, accessed August 2011

Trends in tropical cyclone activity in the Australian region have shown that the number of cyclones has decreased in recent decades, although the number of stronger cyclones (with minimum central pressure <970 hPa) has not declined. These trends may be associated with an observed increase in the frequency of El Niño events. It is difficult to determine if trends in tropical cyclone activity are the result of natural variations in large-scale environment in which tropical cyclones form and evolve, or if they are influenced by anthropologic climate change. The latest predictions indicate that the number of cyclones in eastern Australia is not expected to increase; however, projections show more long-lived tropical cyclones in eastern Australian (CSIRO and BOM, 2007).

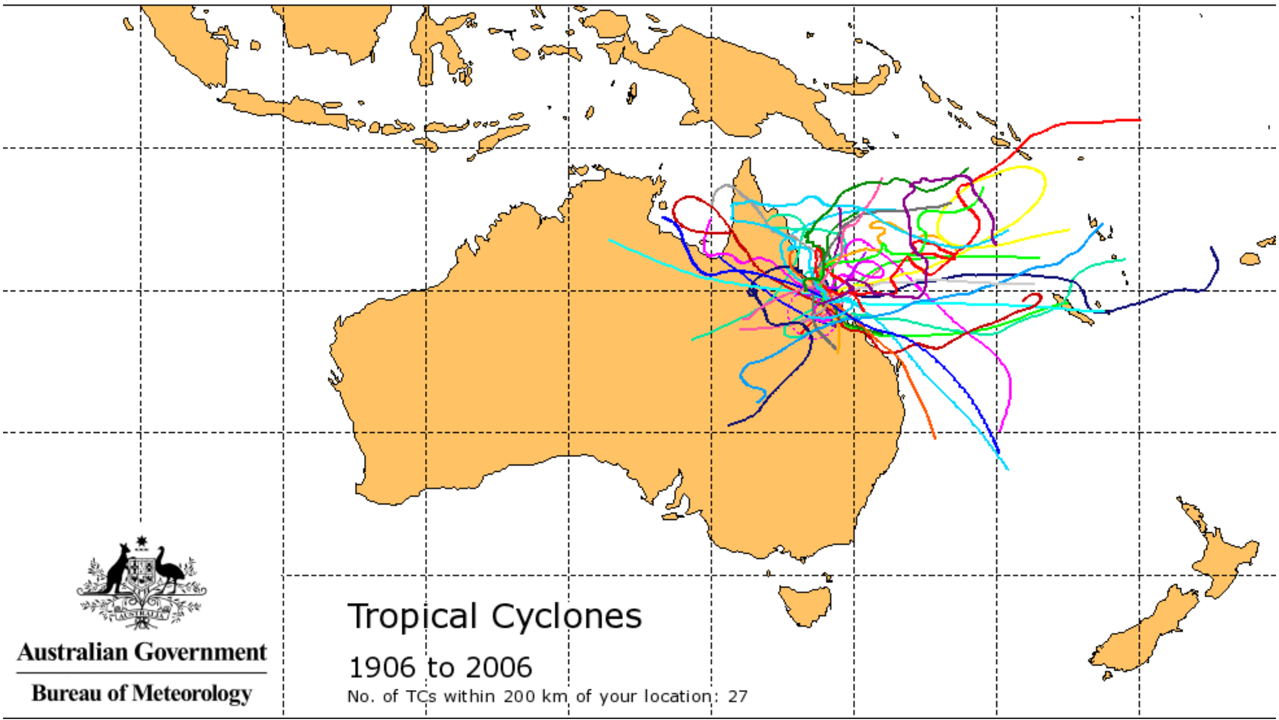
Tropical cyclone Yasi developed as a tropical low northwest of Fiji on 29th January and continued tracking on a general westward track. Yasi maintained a Category 3 intensity in a west-southwestward direction towards the tropical Queensland coast before being upgraded to a marginal Category 5 system. The Category 5 system maintained its intensity and made landfall on the southern tropical coast near Mission Beach between midnight and 1 am on 3rd February. Due to a large, intense system, Yasi maintained a strong core with damaging winds and heavy rain and continued to track westwards across northern Queensland where it finally weakened to a tropical low near Mount Isa almost nine hours later on 3rd February (BOM, 2011b).

Figure 13. Number of tropical cyclones within 200 km of the coal terminal (Bowen) between 1906 and 2006



Source – BOM, 2010 accessed 10 May 2010

Figure 14. Number of tropical cyclones within 200 km of the centre of the railway between 1906 and 2006

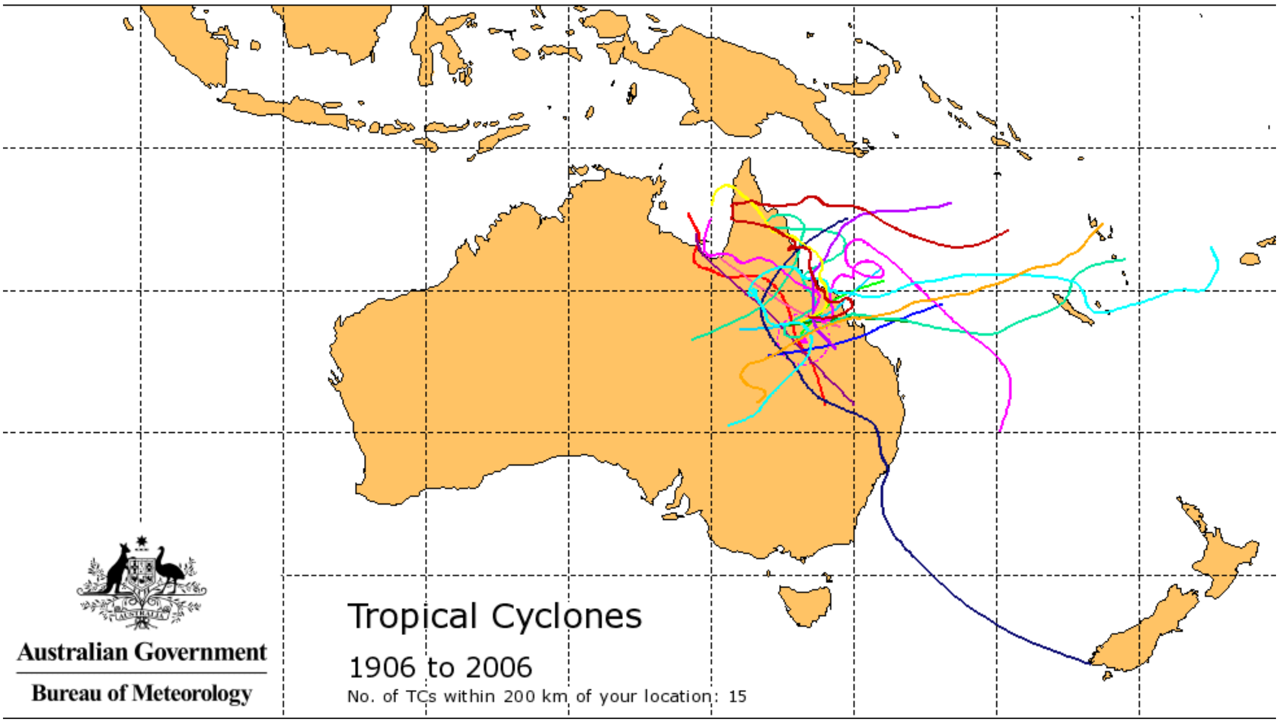


Source – BOM, 2010 accessed 10 May 2010

Yasi was one of the most powerful cyclones to have affected Queensland since records commenced, causing flooding in Cairns and Ayr due to rainfall totals in the order of 200-300 mm in a 24 hour period.

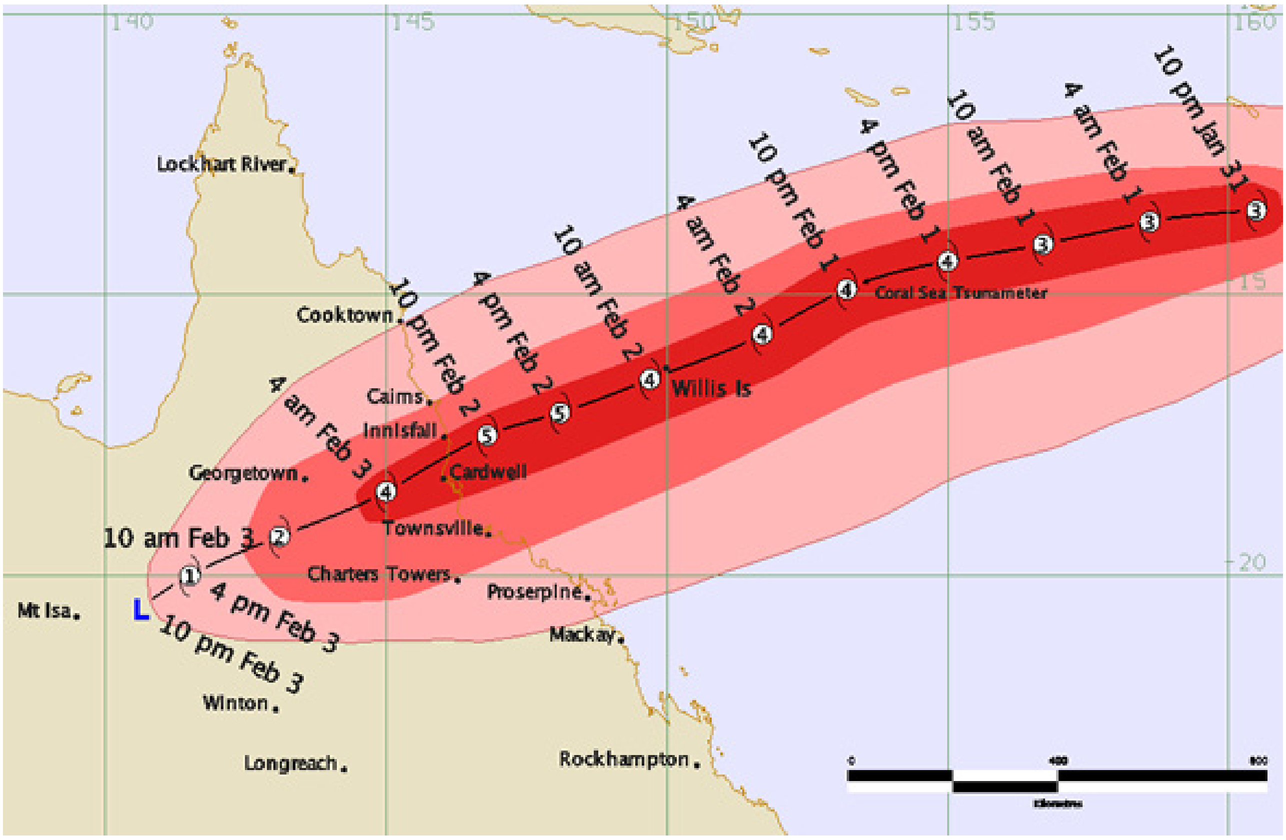
Towns along the rail corridor which were inundated by the cyclone track include Bowen and Collinsville, as shown in Figure 16. Roads around Mount Coolon were also cut off as a result of flooding. However, as Yasi tracked south westward it moved away from the rail corridor at the coal terminal end and central section of the corridor, and tracked inland towards Mount Isa.

Figure 15. Number of tropical cyclones within 200 km of the mine site between 1906 and 2006



Source – BOM, 2010 accessed 10 May 2010

Figure 16. Yasi Cyclone Track



Source: BOM, accessed August 2011

2.2.9.4 Droughts

Dry periods, or droughts are a natural part of life in Australia, particularly in the marginal areas away from the coast and ranges. A drought is generally considered to be an acute shortage of water resulting from a longer than usual period of time in which the water available from rainfall and water in storage is not enough to meet demand. Drought in Australia can typically be categorised into three general themes:

- a meteorological drought – where an area receives an extended period of below-average precipitation;
- a hydrological drought – where water under storage fall below a pre-determined capacity versus usage threshold ; and
- an agricultural drought where there is insufficient moisture for average stock carrying capacity and / or crop production.

Research indicates that severe drought affects some part of Australia about once every 18 years. This does not indicate that severe drought regularly and predictably recurs every 18 years; intervals between severe droughts have varied from four to 38 years (BOM, 2010b). Severe droughts spanning several years have affected the east coast of Australia in each decade since the 1960s (BOM, 2010c).

Large areas of the region surrounding the mine site have been drought declared for most of the last decade. Whilst surrounded by drought declared areas, the previous Jericho Shire (now part of Barcaldine Regional Council (BRC)) has not been drought declared since 15 March 2005 (Department of Primary Industries and Fisheries, 2010). Prior to that the area surrounding the mine had been drought declared since January 2003.

2.2.9.5 Thunderstorms and Lightning Strikes

The BOM has estimated that the rail alignment experiences 15 to 25 thunder days per year (see Figure 17), some of which can result in destructive winds, intense rainfall and flash flooding. Since 1995 BOM has also been monitoring lightning flashes as both total lightning flash density (including intracloud flashes) and cloud to ground flash density per km2 per year. Figure 18 and Figure 19 present long term (1995 - 2002) averages of expected annual lightning counts. These show that on average the study area might expect between 5 and 10 total flashes/km²/year and 1 to 3 ground flashes/km²/year.

2.3 CLIMATE CHANGE IMPACT ASSESSMENT

2.3.1 ASSESSMENT METHOD

A combination of desktop assessments was employed in establishing a baseline context to climate change impacts along the rail corridor. Using projection scenarios developed by the Garnaut Review, the United Nations Intergovernmental Panel on Climate Change (IPCC) and CSIRO, a Climate Change Risk Assessment (RA) process was undertaken by Waratah Coal. Projections from Garnaut, IPCC and CSIRO scenarios were utilised in assessing the Project's vulnerability to climate change and in particular where there may be a significant impact to human safety or property.

The Risk Assessment identified and analysed minimising and mitigation measures with associated potential risks from climate change. The RA is consistent with ToR's requirements (Section 3.1. to 3.1.2) and AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines.

This chapter details the results of the climate change risk assessment and will be used and designed for the Project. In particular, this chapter links to Sustainability Outcomes desired by Waratah Coal. These outcomes are identified as adaptation opportunities and will be incorporated into the project Environmental Management Plan (EMP).

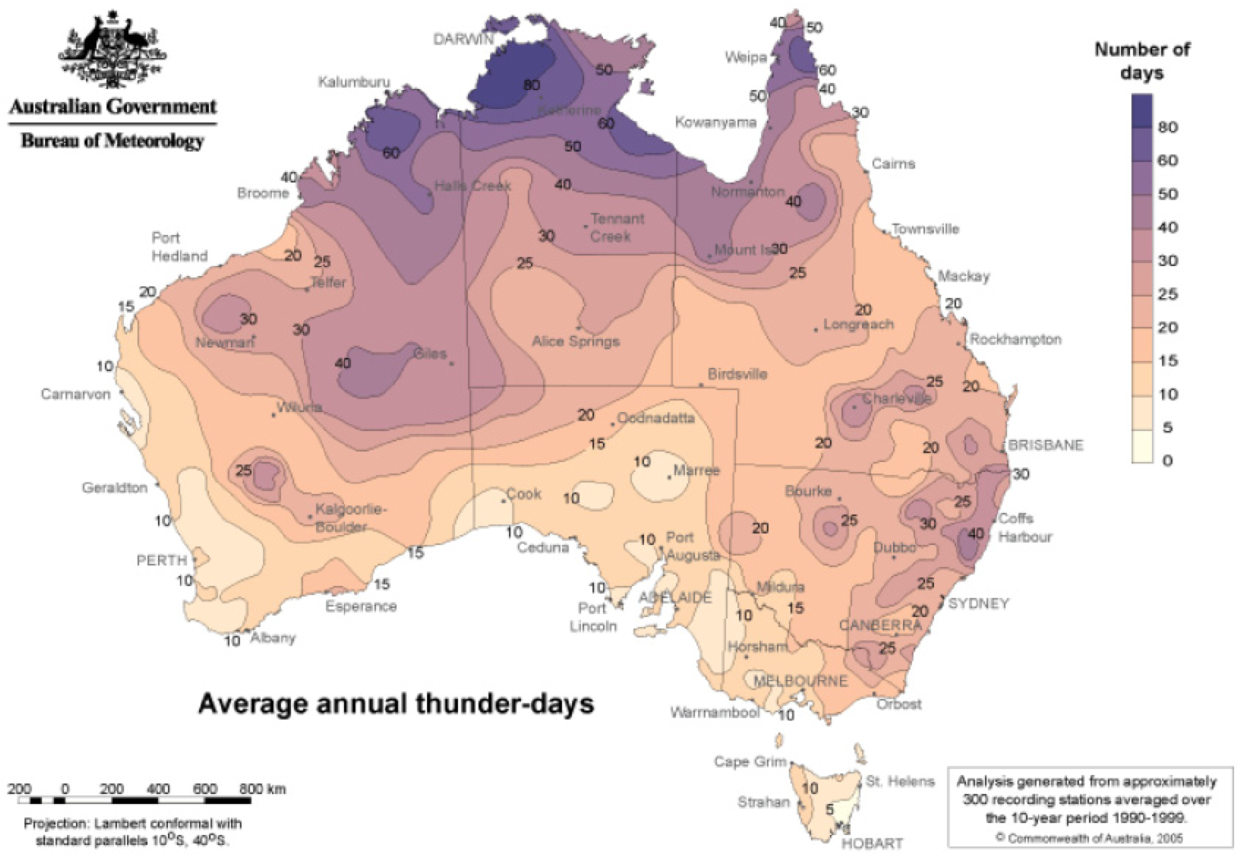
2.3.1.1 Projections Background

2.3.1.1.1 United Nations Intergovernmental Panel on Climate Change (IPCC)

IPCC Special Report on Emissions Scenarios (SRES) developed a range of scenarios as part of modeling global climate change projections. IPCC prepared 40 greenhouse gas and sulfate aerosol emission scenarios for the 21st century that combine a variety of assumptions about demographic, economic and technological factors likely to influence future emissions. A full list and description of each scenario can be found at IPCC (2000). For the purpose of this assessment only:

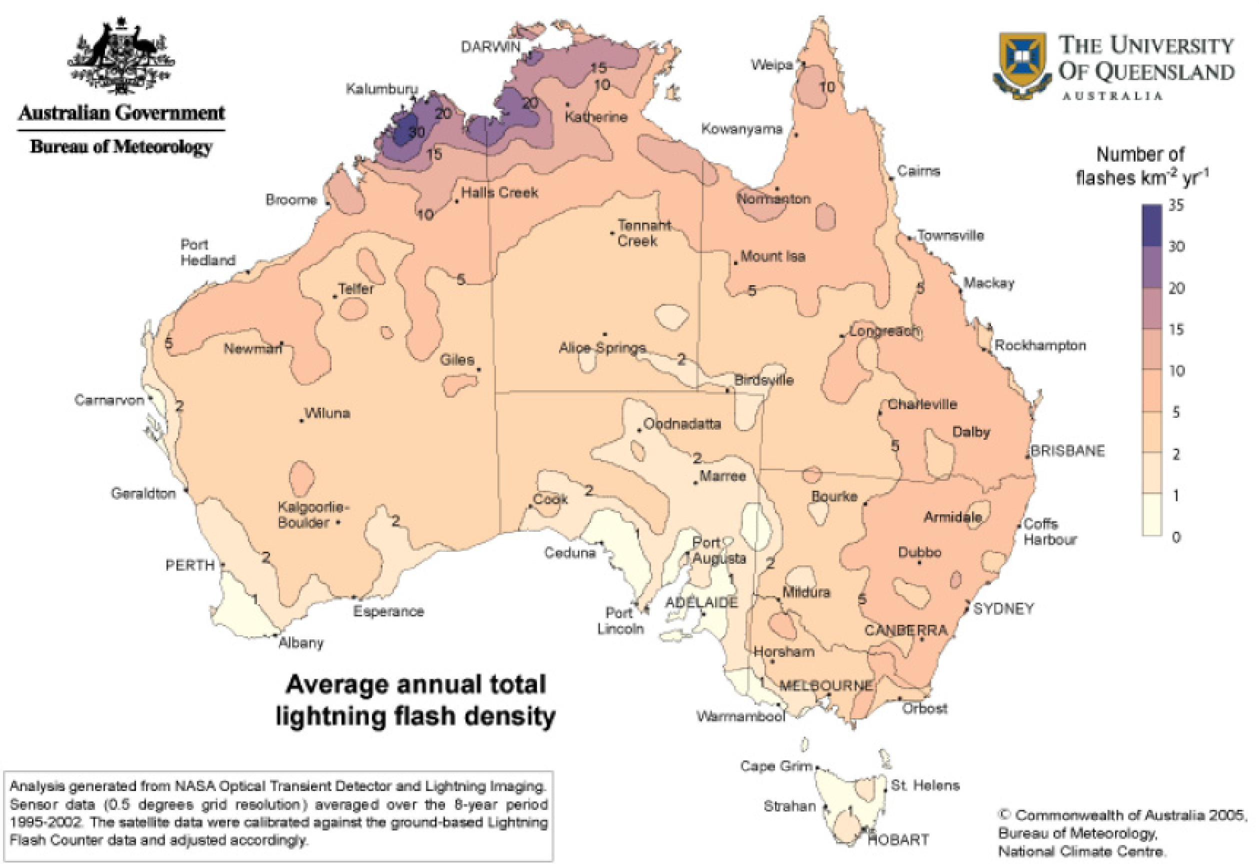
- Scenarios: A1B, B1 and A1FI have been selected for use.

Figure 17. Average annual thunder days between 1990 – 1999 (BOM, 2010 accessed 10 May 2010)



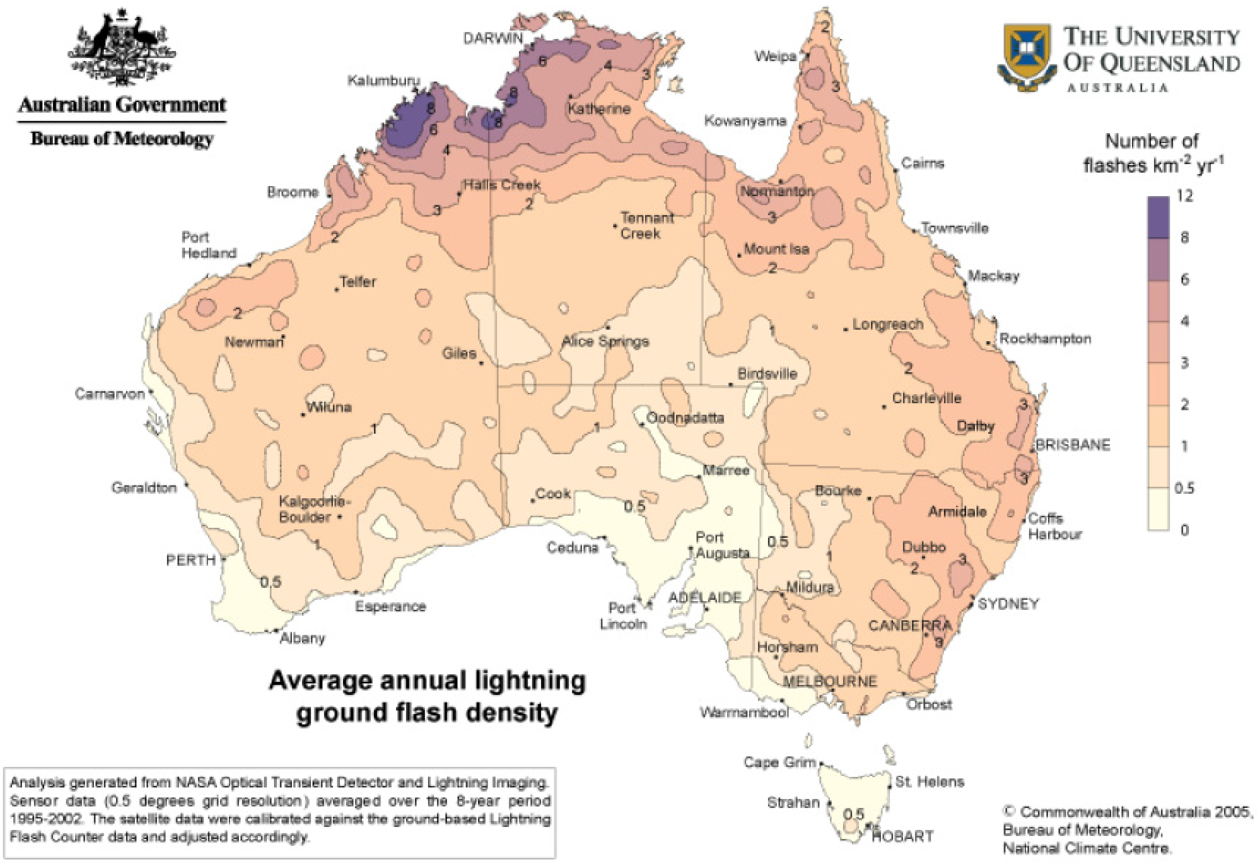
Source – BOM, 2010 accessed 10 May 2010

Figure 18. Average annual total lightning flash density between 1906 – 2006



Source – BOM, 2010 accessed 10 May 2010

Figure 19. Average annual total lightning flash density between 1906 – 2006



Source – BOM, 2010 accessed 10 May 2010

A definition of each scenario, as taken from IPCC (2000) follows:

- The A1 storyline describes a future world of very rapid economic growth, a global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 storyline develops into three scenario groups that describe alternative directions of technological change in the energy system. They are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources and technologies (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).
- The B1 storyline describes a convergent world with the same global population as in the A1 storyline (one that peaks in midcentury and declines thereafter) but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

Discussion regarding the three projections models considered is provided in the following sections.

2.3.1.1.2 National Garnaut Review Predictions

The most recent and authoritative work in predicting the future impacts that global Greenhouse Gas (GHG) emissions will have on Australian climate patterns and the Australian economy is the Garnaut Climate Change Review (Garnaut, 2008). The Garnaut review builds on previous attempts to quantify the social and economic impacts of climate change; in particular, the Stern Review on the Economics of Climate Change, which was prepared for the British Government and released in October 2006 (Stern, 2006).

The Garnaut review found that actual emissions between 2000 and 2005 were higher than those projected by the IPCC's emissions scenarios. An updated emissions scenario was developed based on the most recent projections of the International Energy Agency.

Predicted climate change impacts and emission trajectories identified by the Garnaut Review are divided into three global emission scenarios, no mitigation, 550 parts per million (ppm) carbon dioxide (CO_2) stabilisation and 450 ppm CO_2 stabilisation with overshoot.

- No mitigation

  No action to mitigate climate change. Emissions continue to increase throughout the 21st century, leading to an accelerating rate of increase in atmospheric concentrations of greenhouse gases. Greenhouse gas concentrations reach 1,565 ppm CO_2-e, more than 3.5 times higher than pre-industrial concentrations by 2100.

- 550 ppm stabilisation

  Emissions peak and decline steadily, so that atmospheric concentrations stop rising in 2060 and stabilise around 550 ppm CO_2-e (one third the concentration reached in the no mitigation scenario).

- 450 ppm stabilisation with overshoot

  Emissions are reduced immediately and decline more sharply than in the 550 ppm case. Atmospheric concentrations overshoot to 530 ppm CO_2-e mid-century and decline toward stabilisation at 450 ppm CO_2-e early in the 22nd century.

The Garnaut review details Australian emission trajectories for each of the three global emission scenarios, in the context of Australia playing a fair and proportionate part in an effective global agreement to constrain greenhouse emissions. The trajectories give an indication of the greenhouse emission cuts required to achieve the 550 ppm and 450 ppm CO_2-e stabilisation goals, so they can be related to potential impacts predicted by the Garnaut review.

Annual GHG emissions associated with the Project, as a proportion of emissions trajectories detailed by the Garnaut Review are shown in Table 4.

Table 4. Garnaut target emissions for 2020 and 2050 for Australia and portion of 2020 target associated with the Project (Target values adapted from Garnaut Climate Change Review, 2008)

GLOBAL AGREEMENT	AUSTRALIAN TARGET			
	2020	PROJECT % OF 2020 TARGET	2050	PROJECT % OF 2050 TARGET
450 ppm stabilisation with overshoot	405.8 Mt CO_2-e/a 32% reduction from current Kyoto commitment target 2008-2012	0.58%	59.7 Mt CO_2-e/a 90% reduction from current Kyoto commitment target 2008-2012	3.95%
550 ppm stabilisation	495.3 Mt CO_2-e/a 17% reduction from current Kyoto commitment target 2008-2012	0.48%	107.4 Mt CO_2-e/a 82% reduction from current Kyoto commitment target 2008-2012	2.19%
No global agreement	519.2 Mt CO_2-e/a 13% reduction from current Kyoto commitment target 2008-2012	0.45%	220.8 Mt CO_2-e/a 63% reduction from current Kyoto commitment target 2008-2012	1.08%

Source: Fraction of Australia's target emissions in 2020 and 2050 includes scope 1 and 2 emissions based on annual emissions forecast associated with the Project of 2.326 Mt/a.

Forecasted climate change impacts identified by Garnaut Review for the global emission scenarios are summarised in Table 5. It is problematic to predict how emissions from a specific source will impact future climate change, as changes in the global concentration of greenhouse gases are unknown and factors other than greenhouse gas concentrations affect global climatic systems.

Australia's commitment to the Kyoto Protocol effectively limits Australia's total greenhouse emissions, in the short term. Post-Kyoto, the GHG emissions from the Project would be regulated by the proposed Carbon Pollution Reduction Scheme (CPRS) under a cap and trade scheme, which outlines a reduction target between 5-25%, with the upper target subject to global agreement stabilising greenhouse gas levels at 450 parts per million (ppm) or lower. It is unclear how or if Australia's emissions would be regulated if the CPRS is not adopted. However, currently Australia has a long-term greenhouse emission goal of a reduction of 60% from 2000 levels by 2050.

2.3.1.2 CSIRO Climate Change Scenarios

Climate change projections relevant to Australia have been developed by CSIRO (2007) for years 2030, 2050 and 2070. These projections were extrapolated as background data for the climate change risk assessment.

The proposed rail alignment has an expected life of over 30 years commencing with the construction period starting in 2014 and as such the projections for 2030 and 2050 are considered to be the most relevant. The projections for 2070 are considered, however they are not as relevant as the other projections. Data input from 2070 projections were included for completeness.

CSIRO (2007) has developed climate change prediction summaries for Brisbane, Cairns and St George in Queensland. Whilst not individually relevant to the mine area, collectively the three data sets provide an indication of what is projected for Queensland. As such, where an increase is predicted for a certain parameter for each of the three sites in Queensland, it was assumed for the risk assessment that an increase would be projected for the proposed rail corridor, collectively the three data sets provide an indication of what is projected for Queensland.

As such, where an increase is predicted for a certain parameter for each of the three sites in Queensland, it was assumed for the risk assessment that an increase would be projected for the Project area. For the RA workshop the climate change trends identified for St George were adopted for the mine site and those for Cairns were adopted for the coal terminal. For the rail the worst case scenarios from the Cairns and St George projections were adopted.

The data presented in the Queensland Government (2009) Climate Change Predictions were incorporated into the risk assessment as additional data to the IPCC projections, noting however, that those data do not provide results for the adopted project life. Where IPCC did not project changes in climate for a number of parameters, projected changes from the Garnaut (2008) review were used (i.e. bushfire days, cyclones and sea level rise). See interpretation of climate change models below.

2.3.1.2.1 Interpretation to CSIRO Climate Change Projections

Background

In *Climate Change in Australia*, annual or seasonal average changes in temperature, mean precipitation, humidity, radiation, wind speed, potential evaporation and sea surface temperature, projections are provided in a probabilistic form, with 10th, 50th, and 90th percentiles provided. It is important to note that the site-specific probability distribution represents the range of model results. It is still a leap of faith to assume that the range of model results gives a representation of the expected change of the real world to a specific emission scenario. The real world may end up with different climate changes than any of these models have predicted, or the future climate changes may truly be within the bounds of these models' predictions.

Uncertainties in model predictions lie in how the models simulate the complicated physical and chemical processes of earth systems. Some of the processes are straight forward, but others may be complex systems with potential feedback mechanisms; some changes may be gradual and some others may be abrupt changes (such as the possible route changes of ocean currents). Processes may be known to scientists and hence incorporated into the existing climate models and others may remain unidentified by scientific communities. Because of the complexity of earth systems in response to increases in greenhouse gases contents in atmosphere and the uncertainties of model predictions, it is important to treat the predictions with caution.

Table 5. Summary of forecast impacts from the Garnaut Climate Change Review, 2008

ASPECT	LOCATION	YEAR	PREDICTED IMPACT			NOTES	REFERENCE
			NO MITIGATION	450 PPM	550 PPM		
Temperature	Global	2030	Predicted increase in average temperature 1.3°C	Predicted increase in average temperature 1.2°C	Predicted increase in average temperature 1.2°C	Approximates estimated from Figure 4.5 Garnaut Climate Change review, best estimate median probability, increases over 1990 levels	Chapter 4 Figure 4 p88
		2070	Predicted increase in average temperature 3.5°C	Predicted increase in average temperature 2°C	Predicted increase in average temperature 2°C		
		2100	Predicted increase in average temperature 4.5°C	Predicted increase in average temperature 1.5 °C	Predicted increase in average temperature 2°C		
Sea level rise	Global	2100	29 to 59 cm rapid changes in ice flow could add another 10 to 20cm to the upper range	Not specifically determined	Not specifically determined	Based on IPCC estimations for SRES scenario A1F1 similar to no mitigation case	Chapter 4 p93
Ocean acidity	Global	NA	Increasing ocean acidity proportionate to increased atmospheric carbon dioxide concentrations, consequences for aquatic life, increased impact in colder waters			This is directly related to CO_2 concentration in atmosphere	Chapter 4 p80
Precipitation	Queensland	2030	Decrease from 1990 level -2.4%	Not specifically determined	Not specifically determined	Based on median annual average	Chapter 5 Table 5.1 p115
		2070	Decrease from 1990 level -8.6%	Not specifically determined	Not specifically determined	Based on median annual average	
		2100	Decrease from 1990 level -12.7%	Not specifically determined	Not specifically determined	Based on median annual average	
Cyclones and storms	Global	NA	Increased intensity			Not based on a specific scenario	Chapter 5 p117
		NA	Frequency same or decreased			Not based on a specific scenario	

ASPECT	LOCATION	YEAR	PREDICTED IMPACT			NOTES	REFERENCE
			NO MITIGATION	450 PPM	550 PPM		
Bushfires	Australia	2013	5 to 25% increase in number of days with extreme fire weather	Not specifically determined	Not specifically determined	Based on 0.4°C increase	Chapter 5 Table 5.4 p118
		2034	15 to 65% increase in number of days with extreme fire weather	Not specifically determined	Not specifically determined	Based on 1°C increase	
		2067	100 to 300% increase in number of days with extreme fire weather	Not specifically determined	Not specifically determined	Based on 2.9°C increase	
Heatwaves	Brisbane	2008	0.9 days over 35°C	Not specifically determined	Not specifically determined	Increase over 1990 baseline	Chapter 5 Table 5.3 p117
		2030	1.7 days over 35°C	Not specifically determined	Not specifically determined		
		2070	8 days over 35°C	Not specifically determined	Not specifically determined		
		2100	21 days over 35°C	Not specifically determined	Not specifically determined		
Agriculture	Australia	NA	Crop production affected by changes in average rainfall and temperature. Livestock affected by quantity and quality of pastures. Severe weather events (bushfire, flooding) reduce production. Increased temperature alters occurrence of pests and disease. Potential for carbon fertilisation if not crop growth is not restricted by temperature and rainfall.			Not based on specific scenario	Chapter 6 p129

ASPECT	LOCATION	YEAR	PREDICTED IMPACT			NOTES	REFERENCE
			NO MITIGATION	450 PPM	550 PPM		
Dryland cropping - wheat	Dalby, Queensland	2030	8.2% cumulative yield change	1.6% cumulative yield change	4.8% cumulative yield change	Percentage cumulative yield change from 1990	Chapter 6 Table 6.5 p132
		2100	-18.5% cumulative yield change	-3.7% cumulative yield change	-1.0% cumulative yield change	Based on median probability of rainfall, relative humidity, temperature	
Dryland cropping - wheat	Emerald, Queensland	2030	7.2% cumulative yield change	1.8% cumulative yield change	4.4% cumulative yield change	Percentage cumulative yield change from 1990	Chapter 6 Table 6.5 p132
		2100	-10.1% cumulative yield change	-2.5% cumulative yield change	0% cumulative yield change	Based on median probability of rainfall, relative humidity, temperature	
Irrigated agriculture	Murray Darling	2030	12% decline in economic value of production	3% decline in economic value of production	3% decline in economic value of production	Based on median probability of rainfall, relative humidity, temperature	Chapter 6 Table 6.4 p130
		2050	49% decline in economic value of production	6% decline in economic value of production	6% decline in economic value of production	Based on median probability of rainfall, relative humidity, temperature	
		2100	92% decline in economic value of production	6% decline in economic value of production	20% decline in economic value of production	Based on median probability of rainfall, relative humidity, temperature	
Water supply infrastructure	Australia	2100	34% increase in cost of supplying water	4% increase in cost of supplying water	5% increase in cost of supplying water	Based on median probability	Chapter 6 Table 6.3
Coastal buildings	Queensland	2030	Medium magnitude of net impact	Medium magnitude of net impact	Medium magnitude of net impact	Based on median probability of rainfall, relative humidity, temperature	Chapter 6 Table 6.8
	Queensland	2100	Extreme magnitude of net impact	Medium magnitude of net impact	Medium magnitude of net impact		

ASPECT	LOCATION	YEAR	PREDICTED IMPACT			NOTES	REFERENCE
			NO MITIGATION	450 PPM	550 PPM		
Temperature related deaths	Queensland	2100	Over 4000 additional heat-related deaths relative to no climate change	Fewer deaths relative to no climate change	Fewer than 80 additional heat-related deaths relative to no climate change	Based on median probability	Chapter 6 Table 6.3 p128
Geopolitical stability in Asia-Pacific	Asia Pacific	2100	Displacement of people from South East Asian cities (sea rise)	Less displacement (lower sea rise)	Less displacement (lower sea rise)	Based on median probability	Chapter 6 Table 6.3 p128
Ecosystems	Global	NA	Loss of biodiversity in high altitudes, wet tropics, coastal freshwater wetlands, coral reefs increasing with higher impact scenarios			Impact is specific to each ecosystem	Chapter 6 p142
International trade	Global	NA	Affected economies (China, India, Indonesia) reducing demand for Australian goods			not based on a specific scenario	Chapter 6 p145

Climate

Climate change models generally predict mean temperature changes in the most consistent way, in other words, the range of model predictions are narrow. For most other climate variables such as rainfall, relative humidity, solar radiation, the predicted changes vary significantly among models. For example, in *Climate Change in Australia*, predicted mean temperature changes for 2030 A1B are all positive, with less than 1 degree of uncertainties; in comparison, the predicted changes for rainfall, relative humidity, and solar radiation range from positive to negative, with mean model predictions near zero for the 2030 A1B scenario. Due to the large variations in the model predictions in these climate variables, the best estimate of the change is the ensemble average or multi-model mean. The upper and lower bounds of model predictions should not be taken as the bounds of climate changes in the future real world.

Rainfall

Rainfall is one of the most important climate variables for the Project. But, it is hard for climate models to predict it with any certainty. Cumulative rainfall is influenced by many different scales of weather systems, from the small-scale systems such localised thunderstorms, tropical cyclones, to large-scale frontal systems. Global climate change models (general circulation models – GCM) are mostly run at a coarse resolution, say 250 km, and this resolution is not fine enough to resolve small scale rainfall systems such as thunderstorms and tropical cyclones. Rainfall tends to vary locally, and is impacted by local terrains, distance to the coastal, etc. Current global climate change models cannot resolve such fine geographic changes. Many other climate variables suffer similar constraints. For example, solar radiation is associated with cloud cover, which is related to predicted rainfall and other climate variables such as relative humidity.

Many climate variables, such as climate extremes, have not been presented in *Climate Change in Australia* in a probabilistic manner; the uncertainties in predicting them are even greater. For these climate variables, the scientific understanding of the topic may be such that a qualitative assessment was all that was warranted.

Trends and ranges of climate change projections are location specific. Hence, predictions for the three locations in Queensland, Brisbane, Cairns, and St George may not be applicable to the Project region for all climatic parameters. Brisbane and Cairns are both coastal areas, while the Project is located approximately 500 km inland. St George is inland Australia, but it is far south of the Project area. Climate change projections by the Queensland Government, derived from downscaled runs of the CSIRO's climate change modeling, provide more region-specific predictions for temperature, rainfall and evaporation; however, the projections for 2070 fall outside of the life of the Project.

Temperature

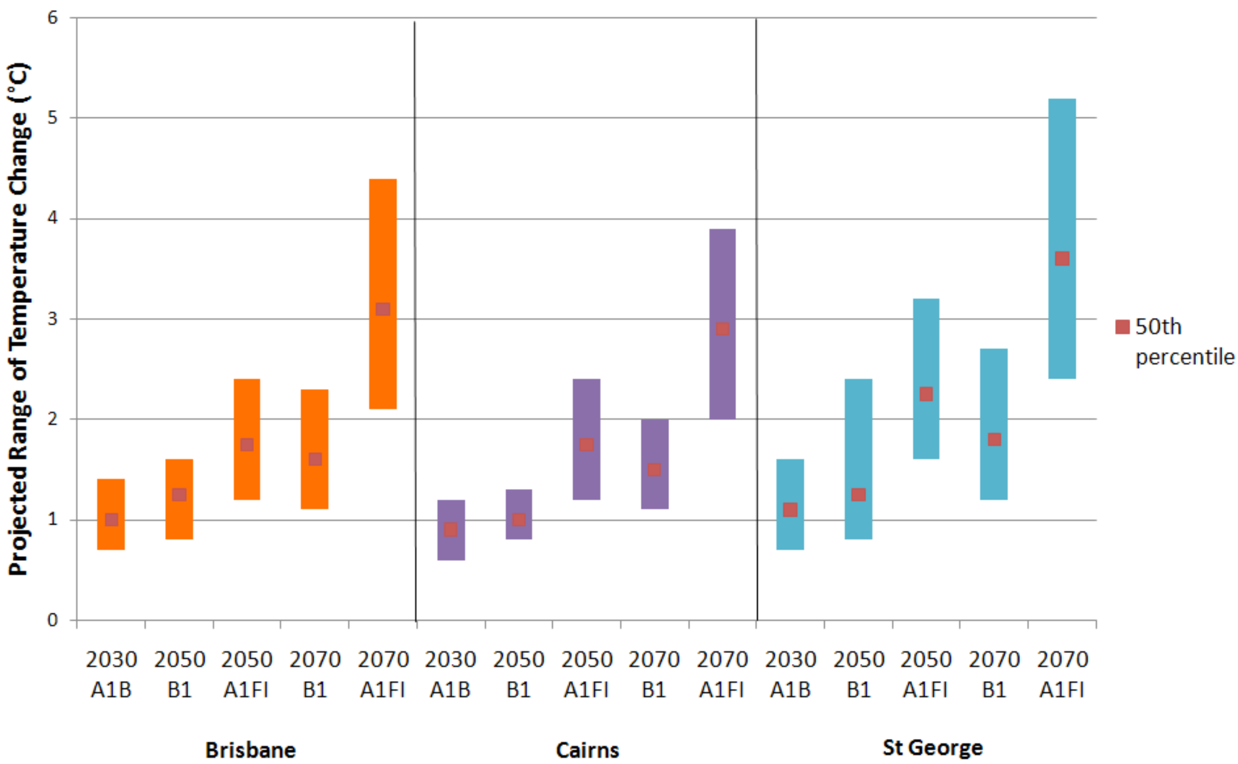
Increased concentrations of GHGs in the earth's atmosphere directly impact temperature change. Therefore projected temperature change is the climatic parameter that can be most accurately modelled.

Projected annual average temperature changes for Brisbane, Cairns and St George show similar upward trends for low, medium and high emissions scenarios (Figure 20). It is reasonable to suggest annual average temperatures for the Project region will follow similar upward trends.

Number of Days above 35°C

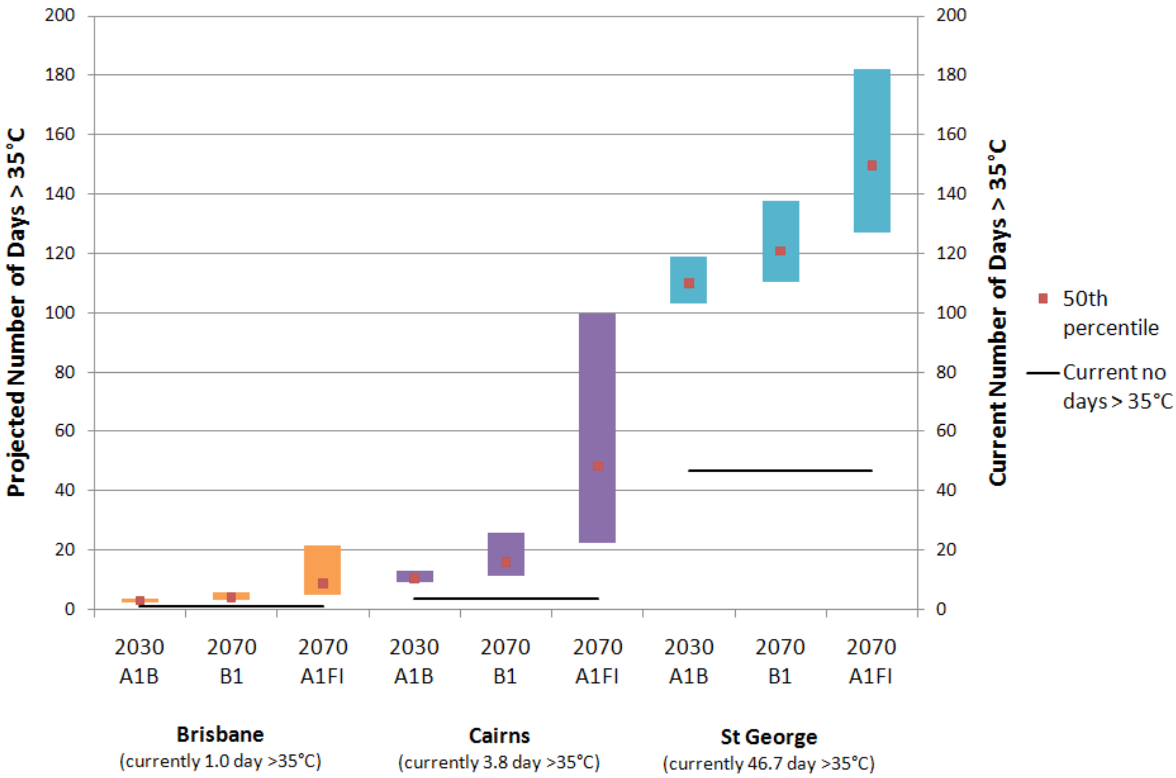
The projected number of days greater than 35°C gives an indication of future climate extremes. Figure 21 shows the number of days greater than 35°C is expected to increase in Brisbane, Cairns and St George; however, the absolute number of days and the projected range varies significantly between cities. It can be assumed that under the various emissions scenarios, the future number of days greater than 35°C will increase in the Project region. Further detail for the Project region is provided in Table 6 sourced from the Queensland Government; however, the projections are for 2070 and therefore fall outside the adopted context of the assessment.

Figure 20. Projected annual average temperature change for Brisbane, Cairns and St George relative to 1990 baseline



Source: Values adapted from Climate Change in Australia – Technical Report 2007
Bars represent range from 10th percentile to 90th percentile

Figure 21. Projected annual average number of days > 35°C for Brisbane, Cairns and St George relative to 1990 baseline



Source: Values adapted from Climate Change in Australia – Technical Report 2007
Bars represent range from 10th percentile to 90th percentile
Values for 2050 not available

Rainfall

Best estimate (50th percentile) model projections indicate that rainfall is expected to decrease at Brisbane, Cairns and St George; however, the range of uncertainty is great for all model scenarios at all cities, and shows that rainfall could either increase or decrease. Figure 22 shows the projected rainfall changes for Brisbane, Cairns and St George.

Rainfall predictions are location specific, so using the trends for Brisbane, Cairns and St George to predict rainfall for the Project region are not ideal. More regional specific rainfall predictions, sourced from the Queensland Government, are shown in Table 6; however, the projections are for 2070 and therefore fall outside the adopted context of the assessment.

2.3.1.2.2 Potential Evaporation

Potential evaporation for Brisbane, Cairns and St George is projected to increase under all emissions scenarios; however the range of uncertainty is large, especially for a high emissions scenario (A1FI) at 2070. Figure 23 shows the projected potential evaporation changes for Brisbane, Cairns and St George.

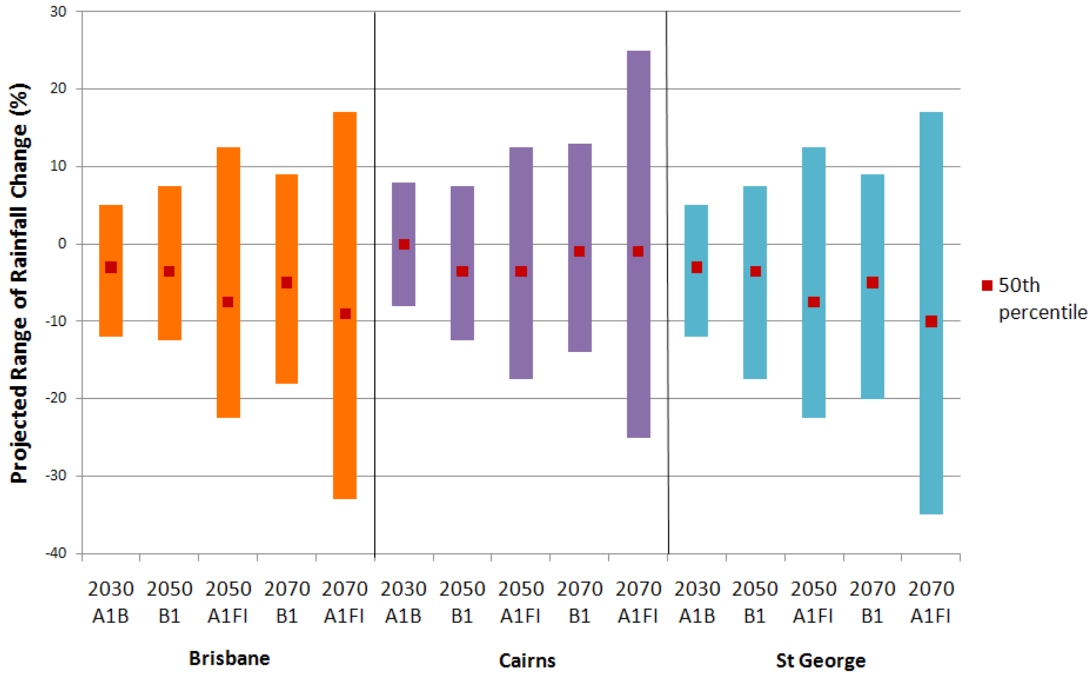
2.3.1.2.3 Wind-speed

Best estimate (50th percentile) model projections indicate that wind-speed is expected to increase at Brisbane, Cairns and St George (Figure 24). The range of uncertainty is great for all model scenarios at all cities; however, the probability of increasing wind-speed is greater than decreasing wind-speed. It is reasonable to assume that annual average wind-speed at the Project region will increase. However, as wind-speed is location specific, the projected changes should be used as a guide showing potential trends rather than absolute projections for the Project area.

Relative Humidity

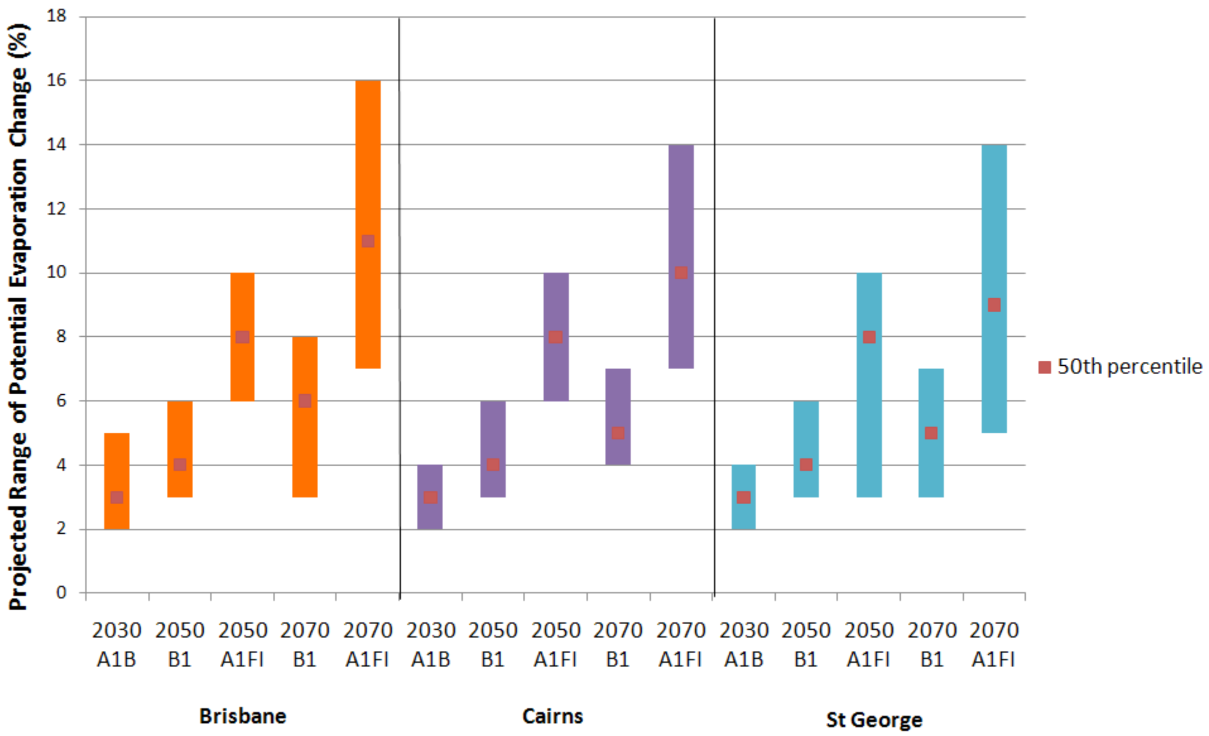
Best estimate (50th percentile) model projections indicate that relative humidity is expected to slightly decrease at Brisbane, Cairns and St George; however, the range of uncertainty at all cities shows that the relative humidity could either increase or decrease. Figure 25 shows the projected relative humidity changes for Brisbane, Cairns and St George.

Figure 22. Projected annual average rainfall change for Brisbane, Cairns and St George relative to 1990 baseline



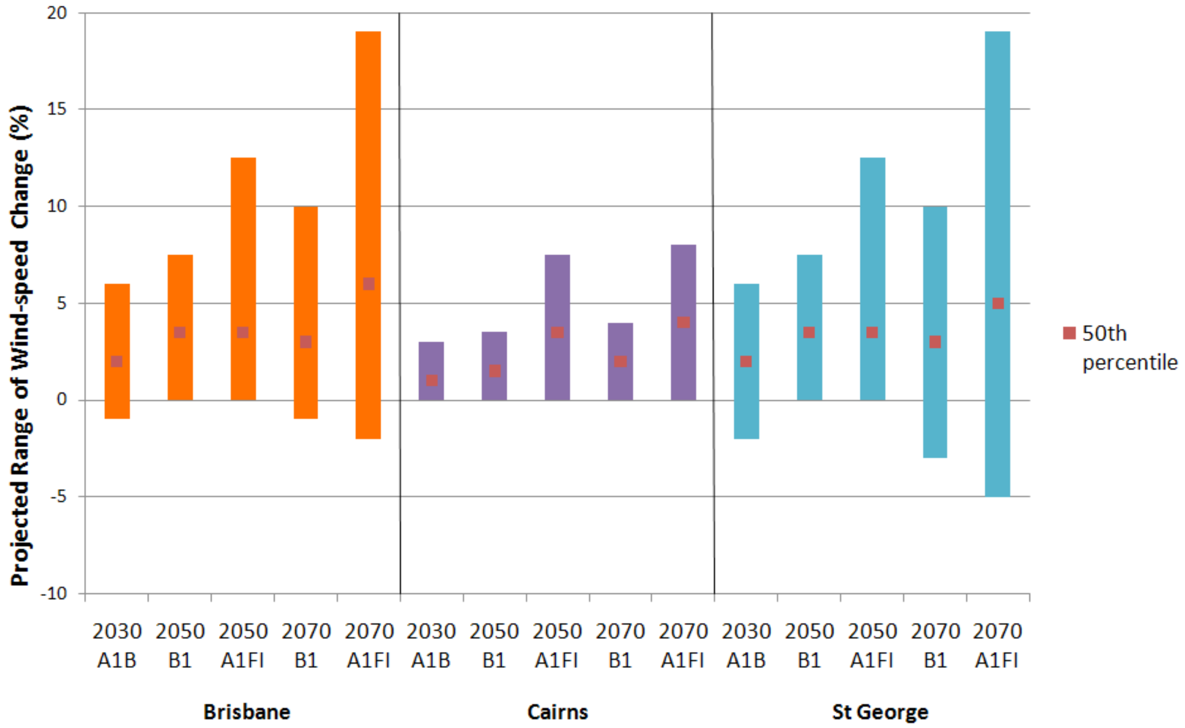
Source: Values adapted from Climate Change in Australia – Technical Report 2007
Bars represent range from 10th percentile to 90th percentile

Figure 23. Projected annual average evaporation change for Brisbane, Cairns and St George relative to 1990 baseline



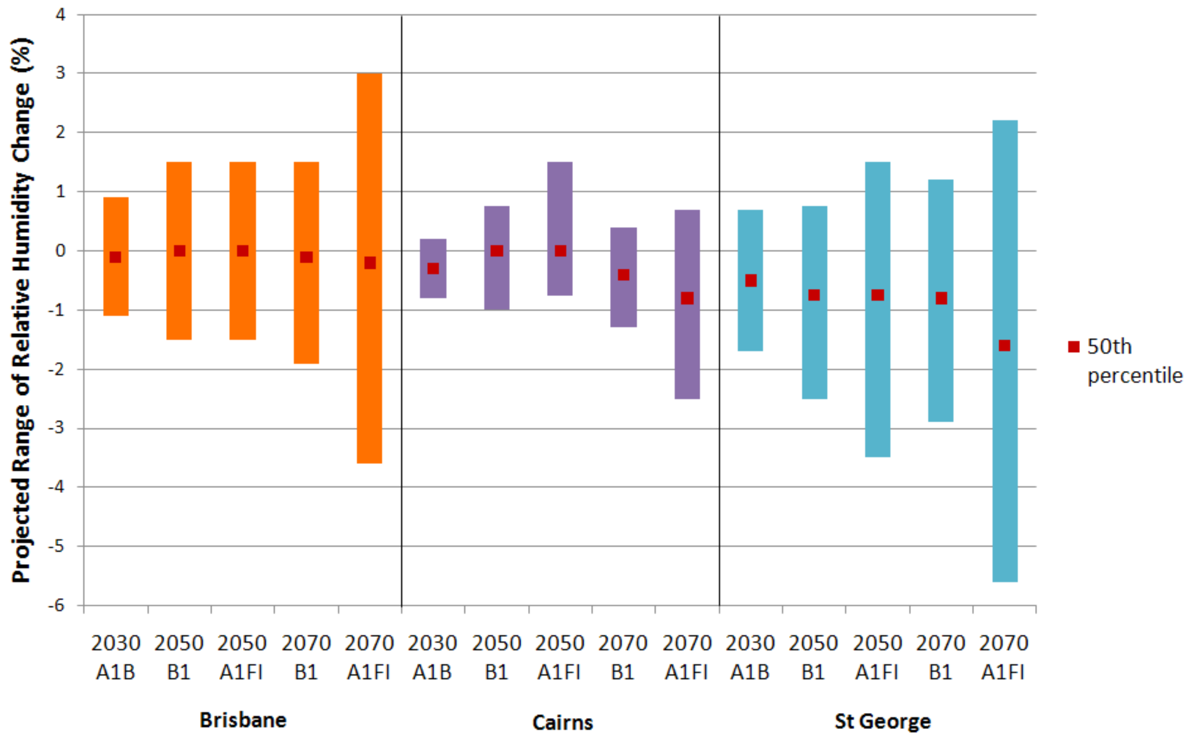
Source: Values adapted from Climate Change in Australia – Technical Report 2007
Bars represent range from 10th percentile to 90th percentile

Figure 24. Projected annual average wind-speed change for Brisbane, Cairns and St George relative to 1990 baseline



Source: Values adapted from Climate Change in Australia – Technical Report 2007
Bars represent range from 10th percentile to 90th percentile

Figure 25. Projected annual average relative humidity change for Brisbane, Cairns and St George relative to 1990 baseline



Source: Values adapted from Climate Change in Australia – Technical Report 2007
Bars represent range from 10th percentile to 90th percentile

As relative humidity is location specific, the projected changes should be used as a guide showing potential trends rather than absolute projections for the Project area.

Solar Radiation

Best estimate (50th percentile) model projections indicate that solar radiation is expected to slightly increase or remain the same at Brisbane, Cairns and St George. The ranges of uncertainty for the model scenarios show solar radiation at all cities could either increase or decrease with almost equal probability. Figure 26 shows the projected changes in solar radiation for Brisbane, Cairns and St George.

As solar radiation is location specific, the projected changes should be used as a guide showing potential trends rather than absolute projections for the Project area.

After 2030, climate change projections are increasingly dependent on the level of emissions, so both low and high emissions scenarios are used for 2050 and 2070.

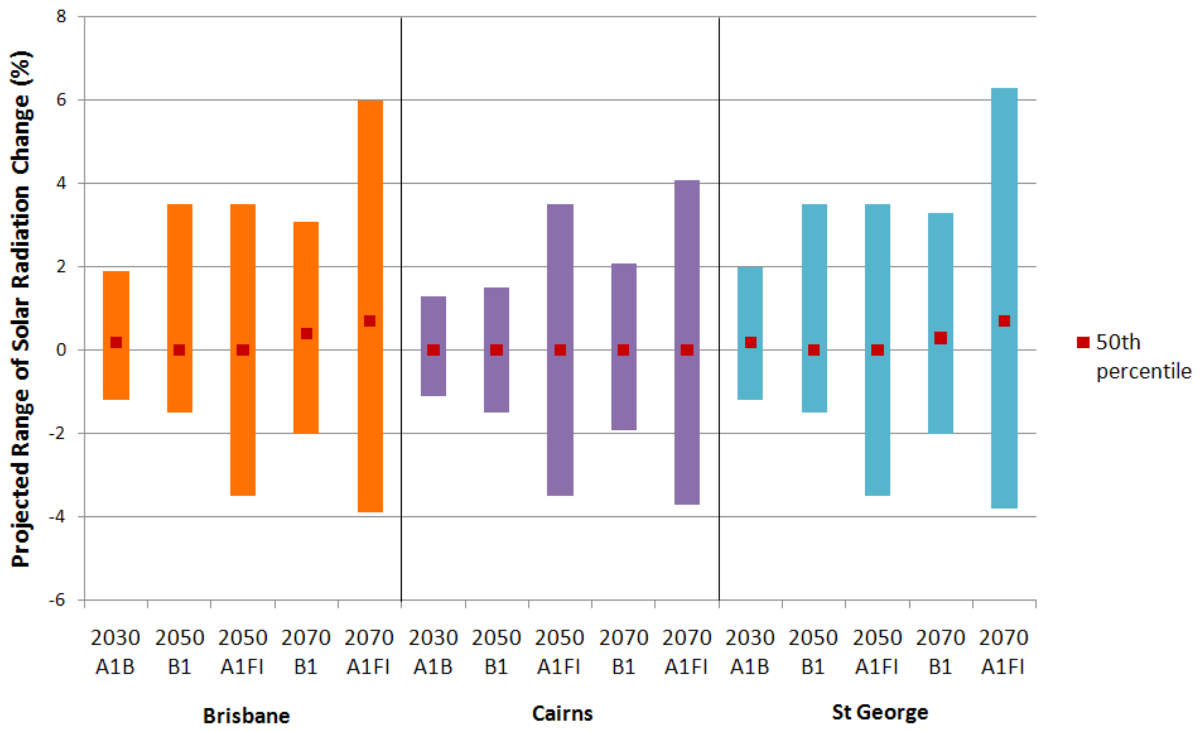
2.3.1.2.4 Queensland Government Predictions

The Queensland Government has built on the modeling conducted for the Climate Change in Australia report, providing climate change projections for Queensland region Table 6 presents a summary of the predicted impacts of climate change by 2070, under a high emissions scenario (A1FI) best estimate (50th percentile) projection, sourced from *ClimateQ: Towards a Greener Queensland*. The shaded data reflect the area identified as most representative of the project area.

2.3.1.2.5 Queensland Government Predictions

The Queensland Government has built on the modelling conducted for the Climate Change in Australia report, providing climate change projections for Queensland regions. Table 6 presents a summary of the predicted impacts of climate change by 2070, under a high emissions scenario (A1FI) best estimate (50th percentile) projection, sourced from *ClimateQ: Towards a Greener Queensland*. The shaded data reflect the area identified as most representative of the project area. Figure 27 shows the regions used for Queensland climate change projections and the approximate location of the Project.

Figure 26. Projected annual average solar radiation change for Brisbane, Cairns and St George relative to 1990 baseline



Source: Values adapted from Climate Change in Australia – Technical Report 2007
Bars represent range from 10th percentile to 90th percentile

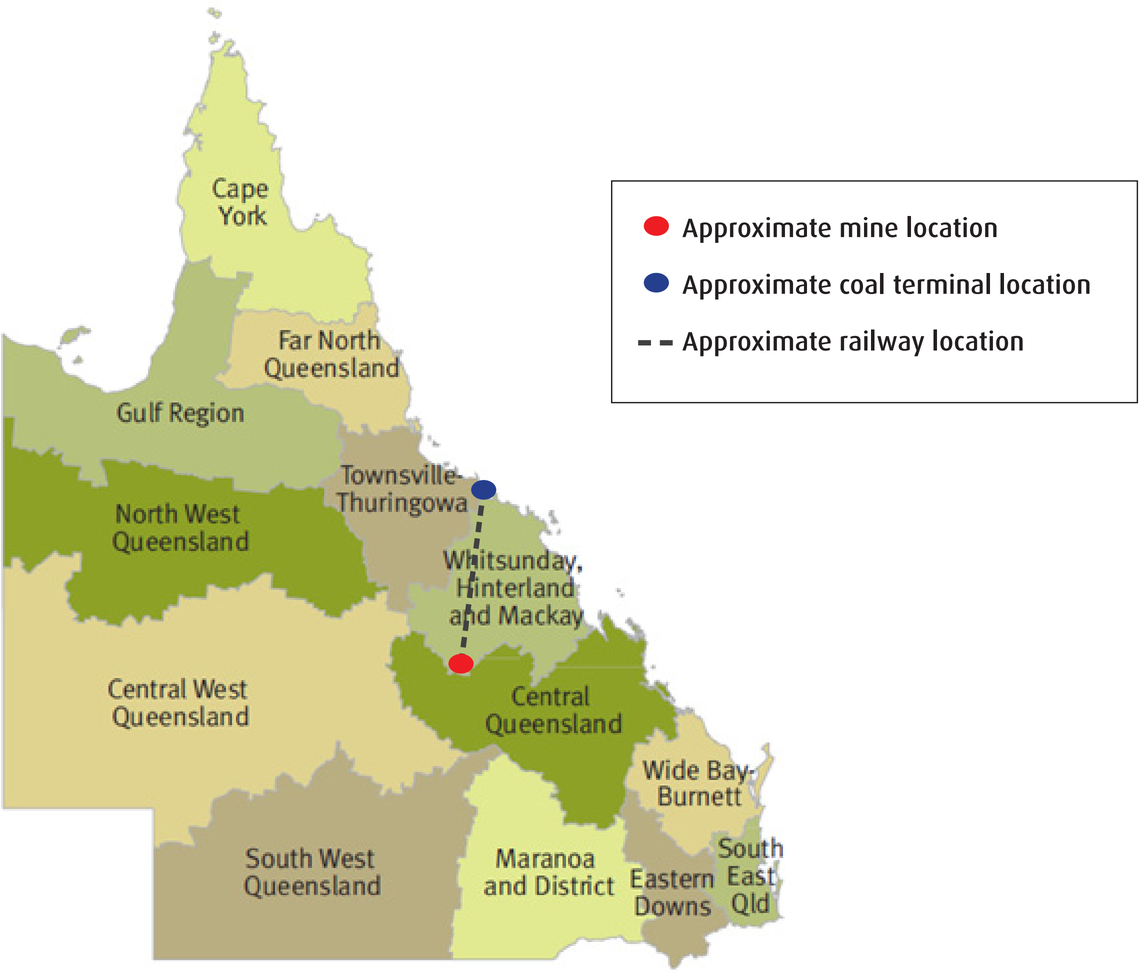
2.3.2 CLIMATE CHANGE RISK ASSESSMENT

The climate change risk assessment included each parameter being assessed in the identification the potential impacts associated to the Galilee Basin with each climate change variable. Where a projected change in the climate parameter will potentially have a high or extreme impact on the mine site, the details were recorded for further analysis and a risk was assigned to each of the identified *"potential risks"* requiring further consideration. This assessment was undertaken using the AGO Risk Likelihood Ratings (Table 7) and Risk Consequence Scales (Table 8).

2.3.3 CLIMATE CHANGE RISK EVALUATION

Those risks with rankings of high and extreme were revisited and potential adaptation strategies and / or management control process changes were recorded and the mitigated risk was assigned. The method used for the identification and assessment of risk is consistent with the risk management process as outlined in AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines and the Australian Greenhouse Office Climate Change Impacts and Risk Management Guide for Business and Government.

Figure 27. Regions used for Queensland climate change projections and the approximate location of the Project



Source: Figure taken from Qld Government, 2009, *ClimateQ: Towards a Greener Queensland* (Chapter 5: Climate Change Impacts on Queensland's Regions)

Table 6. Queensland Government's climate change predictions

PARAMETERS	QUEENSLAND AVERAGE	WHITSUNDAY, HINTERLAND AND MACKAY	CENTRAL QUEENSLAND
Temperature			
Change previous decade	0.4 °C	0.3 °C	0.5 °C
Predicted change by 2070	4.4 °C	4.2 °C	4.5 °C
Predicted no. days above 35°C (% change)	437 %	1,200 %	400 %
Rainfall			
Change in last decade in comparison with previous 30 years[a]	-8 %	-14 %	-14 %
Predicted change (% change)[b]	-4.3 %	-35 to 17 %	-35 to 17 %
Evaporation			
Predicted change (% change)	10.5 %	7-15 %	7-15 %

[a] This is generally consistent with natural variability experienced over the last 110 years, which makes it difficult to detect any influence of climate change at this stage

[b] The 'best estimate' of projected rainfall change shows a decrease under all emissions scenarios

Source: Qld Government, 2009, *ClimateQ: Towards a Greener Queensland* (Chapter 5: Climate Change Impacts on Queensland's Regions)

Table 7. Risk likelihood ratings

RATING	RECURRENT RISKS	SINGLE EVENTS
Almost Certain	Could occur several times per year	More likely than not – Probability greater than 50%
Likely	May arise about once per year	As likely as not – 50/50 chance
Possible	Mar arise once in ten years	Less likely than not but still appreciable – Probability less than 50% but still quite high
Unlikely	May arise once in 10 to 25 years	Unlikely but not negligible – Probability low but noticeably greater than zero
Rare	Unlikely to occur during the next 25 years	Negligible – Probability very small, close to zero

Source: AGO 2006

Table 8. Consequence ratings (adapted from AGO, 2006)

CONSEQUENCE RATING	SUCCESS CRITERIA				
	WORKPLACE SAFETY	ENVIRONMENT AND SUSTAINABILITY	SHAREHOLDER VALUE	GROWTH	COMPLIANCE
CATASTROPHIC	Large numbers of serious injuries or loss of lives	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage	The business would have to be wound up	The business would contract markedly placing its long term viability in question	Obvious and proven breaches of legal and regulatory requirements with the prospect of corporate or individual penalties
MAJOR	Isolated instances of serious injuries or loss of lives	Severe loss of environmental amenity and danger of continuing environmental damage	Shareholder value would decline markedly and necessitate significant remedial action	The business would contract and require significant remedial action	Significant amounts of management and adviser's effort would be required to answer charges of compliance failures
MODERATE	Small number of injuries	Isolated but significant instances of environmental damage that might be reversed with intensive efforts	Shareholder value would stagnate	There would be no growth	Formal action would be required to answer perceived breaches or charges of compliance failure
MINOR	Serious near misses	Minor instances of environmental damage that could be reversed	Shareholder value would increase but fail to meet expectations	Growth would be achieved but it would fail to meet expectations	Minor perceived or actual breaches of compliance would be resolved
INSIGNIFICANT	Appearance of threat but no actual harm	No environmental damage	There would be a minor shortfall in meeting expectations for shareholder value but they would pass unnoticed	There would be a minor shortfall in growth but this would not attract much attention	Concerns about compliance would be resolved without special action

For each identified risk ranked as high or extreme an assessment of:

- any existing controls (features of the environment, natural or made structures, mechanisms, procedures and other factors) that are already in place to mitigate the risk were identified;
- the consequences of the risk, if it were to arise, given the controls, in each of the scenarios under consideration was described;
- the likelihood of that level of consequence, given the controls, in each of the scenarios under consideration, were also described; and
- an initial priority was assigned in each scenario (2030 and 2070) based on the likelihood and consequence of the risk.

At the completion of the risk analysis and evaluation, the risk assessment matrix in Table 9 was used to identify the mitigated potential risk for each scenario. The raw risk and mitigated risk differ as the risk profile changes through the included mitigation or management controls influencing the likelihood of the event occurring and / or reduces the predicted intensity of the consequence. The descriptors applied to the risk rankings in the risk ranking matrix are provided in Table 10.

2.3.4 POTENTIAL IMPACTS

For the rail operations, the risk assessment identified that the projected increase in the number of extreme fire risk days posed a high risk to the environment. During the 2009 / 2010 fire season there was several large wild fires started as a result from sparks generated by the wagons landing in dry vegetation. It was considered that with increased temperature and winds resulting in extreme fire risk conditions that it was likely that fires resulting in environmental damage may occur about once every year. Projected increases in temperature and wind speed in isolation posed a medium risk; however, the combination of both resulted in the higher ranking for increases in extreme fire risk days.

Table 9. Risk ranking matrix

DEFINITIONS		CONSEQUENCE				
		Insignificant	Minor	Moderate	Major	Catastrophic
LIKELIHOOD	Almost Certain	Medium	Medium	High	Extreme	Extreme
	Likely	Low	Medium	High	High	Extreme
	Possible	Low	Medium	Medium	High	High
	Unlikely	Low	Low	Medium	Medium	Medium
	Rare	Low	Low	Low	Low	Medium

(Source: AGO 2006)

Table 10. Risk ranking descriptors

RANKING	DESCRIPTION
Extreme	Risks demand urgent attention at the most senior level and cannot be simply accepted as part of routine operations without executive sanction.
High	Risks are the most severe that can be accepted as part of routine operations without executive sanction but they will be the responsibility of the most senor operational management and reported upon at the executive level.
Medium	Risks can be expected to form part of routine operations but the will be explicitly assigned to relevant managers for action, maintained under review and reported upon at senior management level.
Low	Risks will be maintained under review but it is expected that existing controls will be sufficient and no further action will be required to treat them unless they become more severe.

(Source: AGO 2006)

There may be an increase in erosion if projected rises in temperature and reductions in precipitation result in reduced vegetation cover in the rail corridor. Whilst it was agreed that maintenance works will be required to manage this should it eventuate, it was assessed that this will likely result in only minor instances of environmental damage that is easily rectified.

For the remainder of the projections the risks were assessed as being medium to low. The key factors for this were:

- the base design parameters for flooding were established at 1 in 100 year events;
- rail infrastructure at the coastal end is not expected to be impacted by sea level rise due to the distance from the shoreline;
- only a small workforce exists for the operation of the rail and aside from a small maintenance team, this workforce is predominantly based a the mine in office accommodation;
- changes in temperature, wind speed, precipitation and humidity were not expected to impact the materials used in the operation of the infrastructure and rolling stock; and
- the design of the rail infrastructure and the materials used for the rail were suitable to mitigate high or extreme impacts associated with storms and / or cyclones.

The results of the climate change risk assessment for the rail are presented in Table 11.

2.3.4.1 Climate Change Adaption Summary

The risk assessment identified that there were no potential extreme risks as a result of projected climate change to the project or to employees of the Project.

Risks ranked as high are considered to be risks that are most severe. A high risk can be accepted as part of routine operations without executive sanction, however, responsibility of the most senior management will report upon an executive level.

For the rail operations, the risk assessment identified a projected increase in the number of extreme fire risk days posed a high risk to the environment. The risks were associated with sparks from by the moving wagons igniting dry vegetation within the easement and the subsequent fire burning out of control. It was assessed that such a fire could result in isolated but significant instances of environmental damage that might be reversed with intensive efforts. It was also considered possible that minor perceived or actual breaches of compliance could arise if fires were significant.

It is expected rather than implementing new measures in addressing potential high risks it will be the case that existing measures will be adopted in accordance with variable change and the extant operating licenses.

To mitigate the potential high fire risk along the rail corridor the monitoring, vegetation management and reporting procedures would be reassessed to take into account the fire risk increase as a result of increased extreme fire weather periods associated with climate change. This will be in addition to the adjusting the routine measures that would already be established in the such as increasing the frequency of easement inspections in the period leading up to high fire danger period, increased liaison with stakeholders during high fire danger periods and the implementation of a range of vegetation management procedures.

In addition to specific measures to address high risks, a range of measures will be imbedded into the design phase and routine operating procedures to take into account potential climate change. The following provides an indication of the type of measures that will be considered to take into account climate change.

Table 11: Initial climate change risk assessment results – rail corridor

PARAMETER	PROJECTIONS	VARIATION RANGE	WORKPLACE SAFETY	ENVIRONMENT AND SUSTAINABILITY	COMPLIANCE	SHAREHOLDER VALUE	GROWTH	HIGHEST RISK RANKING
Temperature (°C)	2030	0.7 - 1.6 (m=1.1)	Low	Medium	Medium	Low	Low	Medium
	2050	1.6 – 3.2 (m=2.25)	Medium	Medium	Medium	Low	Low	Medium
Extreme Heat Days (>35°C)	2030	56.3 - 72.3 (m=63.1)	Medium	Medium	Medium	Low	Low	Medium
	2050	N/A	Medium	Medium	Medium	Low	Low	Medium
Annual Rainfall (%)	2030	-12.0 – 5.0 (m=-3.0)	Low	Medium	Medium	Low	Low	Medium
	2050	-22.5 – 12.5 (m=-7.5)	Low	Medium	Medium	Low	Low	Medium
Potential Evaporation (%)	2030	2.0 – 4.0 (m=3.0)	Low	Medium	Medium	Low	Low	Medium
	2050	3.0 – 10.0 (m=6.0)	Low	Medium	Medium	Low	Low	Medium
Wind Speed (%)	2030	-2.0 – 6.0 (m=2.0)	Low	Medium	Medium	Low	Low	Medium
	2050	0.0 – 12.5 (m=3.5)	Low	Medium	Medium	Low	Low	Medium
Relative Humidity (%)	2030	-1.7 – 0.7 (m=-0.5)	Low	Low	Low	Low	Low	Low
	2050	-3.5 – 1.5 (m=-0.75)	Low	Low	Low	Low	Low	Low
Solar Radiation (%)	2030	-1.2 – 2.0 (m=0.2)	Medium	Medium	Medium	Low	Low	Medium
	2050	-3.5 – 3.5 (m=0.0)	Medium	Medium	Medium	Low	Low	Medium
Extreme Rainfall Events 1 in 40 year event	Assumed 10% increase in events annually		Low	Medium	Medium	Low	Low	Medium
Extreme Rainfall Events 1 in 100 year event	Assumed 5% increase in events annually		Medium	Medium	Medium	Low	Low	Medium
Increase in Fire Risk days	Assumed 20% increase in extreme fire days		Medium	High	Medium	Low	Low	High
Increased Sea Level Rise	Assumed 50 cm increase in sea levels		Low	Low	Low	Low	Low	Low
Cyclones and Storms	Increased intensity but fewer storms		Medium	Medium	Medium	Medium	Medium	Medium

Note: A1B data is presented for 2030 projections and A1FI data is presented for 2050

The infrastructure for the Project will be designed for tropical conditions. As such the projected increases in ambient temperature will be within designed operating ranges. Therefore it is unlikely that there will be material changes to the infrastructure or its operation as a result of climate change. Increases in extreme heat days and how this may impact the workforce will be addressed through the ongoing review of workplace operating procedures and the health and safety system. Again, given the proximity of the project in areas that are already subjected to a significant number of high weather days annually it is not expected that the projected increases will have a detrimental impact on the operational or safe working environment an any of the project sites.

It is possible that either increases or decreases in the amount of precipitation could result in erosion occurring onsite and / or the failure of rehabilitation activities. It is expected that the operating license conditions will establish criteria for managing erosion and rehabilitation and these will be implemented through routine maintenance activities. Where erosion control and rehabilitation activities do not achieve the desired outcomes, procedures will be adapted to achieve compliance. The process of adapting management and control measures to meet license requirements will occur as a routine part of managing the site. It is therefore considered that the adaptive management approach will adequately address variations associated with climate change.

Projected changes in average wind speed will potentially result in increased dust dispersal at the mine and possibly at the coal terminal. Routine air quality monitoring will be established from the commencement of the Project in accordance with operating license conditions. Where emission trends occur, onsite management procedures will be established to review the existing operational activities and associated mitigation strategies and adaptations will be implemented to cater for variances in emissions. In terms of impacts to operational capacity, it is expected that the Project increases will be within design tolerances and will not pose a significant risk to operations or workplace safety. For example infrastructure such as communication towers, the Coal Handling and Preparation Plant (CHPP), conveyor structures will all be designed with inbuilt tolerances to accommodate projected increases in wind loadings.

Changes in relative humidity levels are considered to be within the design tolerances of the infrastructure and are not expected to have a material impact on the Project.

It is projected that there will be a decrease in the number of storms; however, storm intensity is projected to increase. Changes in the frequency and intensity of 1 in 40 and 1 in 100 year events will be addressed as part of the flood immunity design for the infrastructure. This will take into consideration the protection of assets, in particular underground mines and water storages, and the maintenance of the overall safe working conditions on each site.

It is expected that that the operating license conditions will establish criteria for managing flood runoff and protecting offsite water quality and these will be implemented through routine monitoring and maintenance activities. Where these activities do not achieve the license conditions, procedures will be adapted to achieve compliance. The process of adapting management and control measures to meet license requirements will be similar as that for managing dust and erosion in that it will occur as a routine part of managing the site. As such it is considered that the adaptive management approach will adequately address variations associated with climate change.

The projected increase in temperatures and evaporation, together with a potential decrease in annual rainfall will add to the number of fire risk days in the Project area. A Bushfire Management Plan (BMP) will be prepared that provides a strategic approach to the management of bushfires in the Project area and follows on from previous research and strategies prepared by CSIRO in Northern Australia. This document will provide plans and processes based on contemporary "best-practice" for managing fires in tropical Savannah systems that best mitigate wild fire risks. The BMP will be focused on preservation of life and infrastructure in a context that adheres to ecological needs wherever possible. Moreover the strategy also aims to implement measures that minimise the risk of fires leaving the Project area.

In addition to the BMP the infrastructure will have bushfire protection embedded into the design in order to protect workers and equipment. The maintenance of the fire protection equipment will be carried out as part of routine site management. It is therefore expected that the bushfire risk to the Project will largely be managed through routine maintenance, albeit with review and revision of the procedures if the projected changes occur.

The rail infrastructure at the coal terminal will be sufficiently located away from the coastline and designed to ensure any inward encroachment of the shoreline does not impact on the operability of the infrastructure or create a workplace health and safety risk. Projected sea level and extreme water level heights will be factored into the design tolerance and as such it is expected that the projected increases in sea level will not have a significant impact on the Project.

Climate change projections show that the frequency of cyclones is predicted to decrease; however, the intensity could increase. The Project area is already influenced by cyclonic activity, particularly the rail infrastructure at the coal terminal. As such the infrastructure will be designed in accordance with the necessary building code requirements relating to cyclonic activity mitigation. It is expected that the projected intensification in cyclonic activity will be managed adequately through the initial design of the infrastructure and the implementation of routine management and maintenance systems. Health and safety procedures for working during periods of extreme cyclonic conditions would be implemented from the onset of construction. These systems would be regularly reviewed and amended as part of routine management and would be adapted to address any changes required due to climate change.

2.3.5 CONCLUSION

A climate change risk assessment was undertaken for the Project. The approach adopted for the risk assessment was consistent with AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines. The methodology used in the risk assessment was adapted from *Climate Change Impacts and Risk Management - A Guide for Business and Government* (AGO, 2006). Emission scenarios were adopted from the IPCC's *Special Report on Emissions Scenarios* (2001) and these were considered against climate change projection data sets derived from CSIRO (2007), Garnaut (2008) and the Queensland Government (2009).

The risk assessment identified increases in average wind speed associated with climate change may pose a potential high risk to environment and sustainability. This in turn could potentially result in minor breaches in compliance. The assessment further considered that the projected increase in the number of extreme fire risk days posed a potential high risk to the environment and sustainability. The remainder and by far the majority of the risks to the Project and workforce associated with climate change were assessed as being medium to low.

The risks ranked as high during the assessment are considered as the most severe risks that can be accepted as part of routine operations without executive sanction. To ensure that appropriate action is taken to address these risks they will be managed by the senior management team and monitoring and reporting will be undertaken at the executive level. The risks ranked as medium to low will be managed as part of routine operations and they will be maintained under review and reported upon at senior management level.

The Project is located predominantly in a hot, arid environment that is subjected to high volume flooding and intense storms and as such the design tolerances will already largely be addressed at the initial design stage, therefore, designing the Project infrastructure ensuring operating tolerances include climate change projections or are able to be adapted to meet changing conditions is a key mitigating factor. It is expected that any areas requiring adaption to take into consideration changes associated with climate change will be identified as part of routine operational monitoring and performance reporting.

Implementing appropriate workplace health and safety procedures is the other key mitigating factor to address potential impacts associated with climate change. The procedures established to address the existing conditions are expected to adequately mitigate the projected changes to the climate. Similarly it is expected that any areas requiring adaption to take into consideration changes associated with climate change will be picked up as part of routine operational monitoring and performance reporting.

Potential impacts to the Project and Waratah's workforce associated with climate change will be adequately managed through appropriate design of infrastructure and the implementation of a sound workplace health and safety system. It is expected that these two factors, combined with the standard monitor, review and adapt continuous improvement management system will adequately mitigate climate change risk.

2.3.6 COMMITMENTS

In order to manage potential impacts of climate and climate change associated with the rail (and associated infrastructure), Waratah will:

- incorporate adaptive management approach to climate change throughout the life of the rail;
- incorporate climate change adaption strategies into each major design element of the rail; and
- co-operate with government, other industry and other sectors to address adaptation to climate change.