Section 3

CLIMATE AND NATURAL DISASTERS

3. Climate and Natural Disasters

The purpose of this Section is to describe the rainfall patterns, air temperatures, humidity, wind and other climatic features that may affect the management of the Project. Historic weather patterns, seasonal conditions, extremes and climate vulnerability are discussed.

Infrastructure with long life spans, such as railways, will be impacted by climatic conditions including natural disasters and the effects of climate change. This Section identifies these potential impacts and provides a high level assessment of possible implications of the environment on the Project in a commercial context. This Section does not address possible measures to reduce greenhouse gas emissions from the Project as this is specifically addressed in Section 7.

3.1 Methodology

Climate was assessed from observations at three monitoring stations related to the study area. The stations used were the Australian Bureau of Meteorology (BOM) sites at Taroom and Theodore, and the local meteorological station based at Wandoan. The data was compiled to show average trends in temperature, rainfall, relative humidity, wind speed and wind direction. A summary of this information is presented in Section 3.2 and in Appendix E. The data was also used to characterise the meteorological conditions for dispersal of air pollutants in the region. A detailed breakdown of the data analysed for air dispersal modelling is included in Section 7.3.3.

3.2 Description of Environmental Values

3.2.1 Climate Description

The Central Queensland location experiences a sub-tropical climate, characterised by warm and wet summer months shifting to cooler and drier winter months. The summer months (December to February) account for around 40% of the 673 mm average annual rainfall. The drier months from June to September account for only 20% of the average annual rainfall, equal to approximately 30-35 mm per month (Table 3-1).

Table 3-1: Average Rainfall at Taroom recorded from 1870 to 2008

Month	Minimum (mm)	Maximum (mm)	Average (mm)
January	1.8	273.1	98.9
February	2.6	421.1	87.1
March	0.0	403.1	62.1
April	0.0	200.0	34.9
May	0.0	270.1	40.8
June	0.0	228.6	36.4
July	0.0	240.8	33.5
August	0.0	181.9	28.2
September	0.0	185.7	30.9
October	0.0	228.7	55.4
November	0.2	292.0	75.0
December	0.0	380.9	89.4

Source: BOM, 2008

The study area is typical of the region with respect to temperatures, reaching average daily maxima of around 34 degrees Celsius in summer and 20 degrees Celsius in winter. Relative humidity is largely constant throughout the year at about 55%, with only a slight increase, up to 70% humidity, experienced in mid summer and mid winter.

The study area as a whole generally experiences similar wind conditions despite significant topographical features such as the Gilbert Range. Wind direction in summer tends to be from an easterly direction, shifting to a southerly direction in winter. Winds are generally lighter in autumn and spring. Wind rose diagrams that summarise wind direction, speed and frequency are provided in Appendix E.

3.2.2 Climate Patterns

Climatic patterns known as El Niño and La Niña strongly influence the variability of the climate in eastern Australia. El Niño refers to the situation when sea surface temperatures in the central to eastern Pacific Ocean are significantly warmer than normal. El Niño events occur every four to seven years, and typically last between 12 and 18 months. El Niño events are associated with an increased risk of drier than average and drought conditions, particularly from June to December. During winter and spring, El Niño events tend to be associated with warmer than normal day-time temperatures, which serve to worsen the effect of below average rainfall by increasing evaporation. La Niña is the reverse situation where sea surface temperatures in the eastern Pacific Ocean are much cooler than normal, and are associated with wetter and cooler than average conditions (BOM, 2005).

A potential effect of El Niño, including within the study area, is an increased risk of fires and dust storms due to hotter and dryer conditions, whereas a potential effect of La Niña is an increased risk of flooding.

3.2.3 Natural Disasters

Floods

More that 100 flood events have been recorded by the BOM for the Dawson River at Taroom and Theodore since 1862. Predominantly, these have occurred during the wet season in summer and the start of spring, however, records do show that flooding has been known to occur in winter and autumn also. A summary of the 100 flood events is provided in Appendix F.

Storms and Cyclones

The peak storm season in Queensland is spring and summer (BOM, 2008b). As such, the study area is likely to experience heavy rain, thunder or hail storms between November and April.

The direct effects of tropical cyclones do not usually impact the study area.

Drought

The eastern states of Australia have generally experienced low rainfall from the mid 1920's to the late 1940's and again more recently since 1980. Major droughts during these periods include 1937–1938, 1940–1941, and 1943–1945. Severe droughts also occurred during 1982–1983, 1991–1995 and Queensland continues to suffer from the ongoing drought that began around 2001.

The frequency and severity of droughts experienced in the study area are consistent with observed climatic trends across Queensland.

Fire

The Queensland Bushfire Risk Analysis is a state-wide model of potential bushfire risk areas based on three variables: slope, aspect and vegetation. The Queensland Fire and Rescue Service (QFRS) publish Bushfire Risk Maps for Queensland based on this model. This mapping indicates the study area has low and medium bushfire hazard (refer to Map 5 – Bushfire Risk in the Map Folio). For the most part, the corridor is considered a low bushfire hazard due to the extensive cleared grazing land. The exception is the Gilbert Range where the bushland has not been cleared and presents a medium bushfire hazard. Peak fire season for the region is spring and summer.

Earthquakes

Australia has witnessed 17 earthquakes registering six or more on the Richter Scale in the past 80 years. Queensland is seismically active with most activity occurring along the eastern coast and near offshore regions (UQ, 2000). Earthquakes of a magnitude greater than five (which are considered to have the potential to cause serious damage or fatalities) occur, on average, about every five years in Queensland (UQ, 2000).

Figure 3-1 shows the location of recorded earthquakes (Richter magnitude greater than 0) in the Bundaberg region in relation to the Project. This figure shows the majority of seismic activity occurs to the east of the study area.

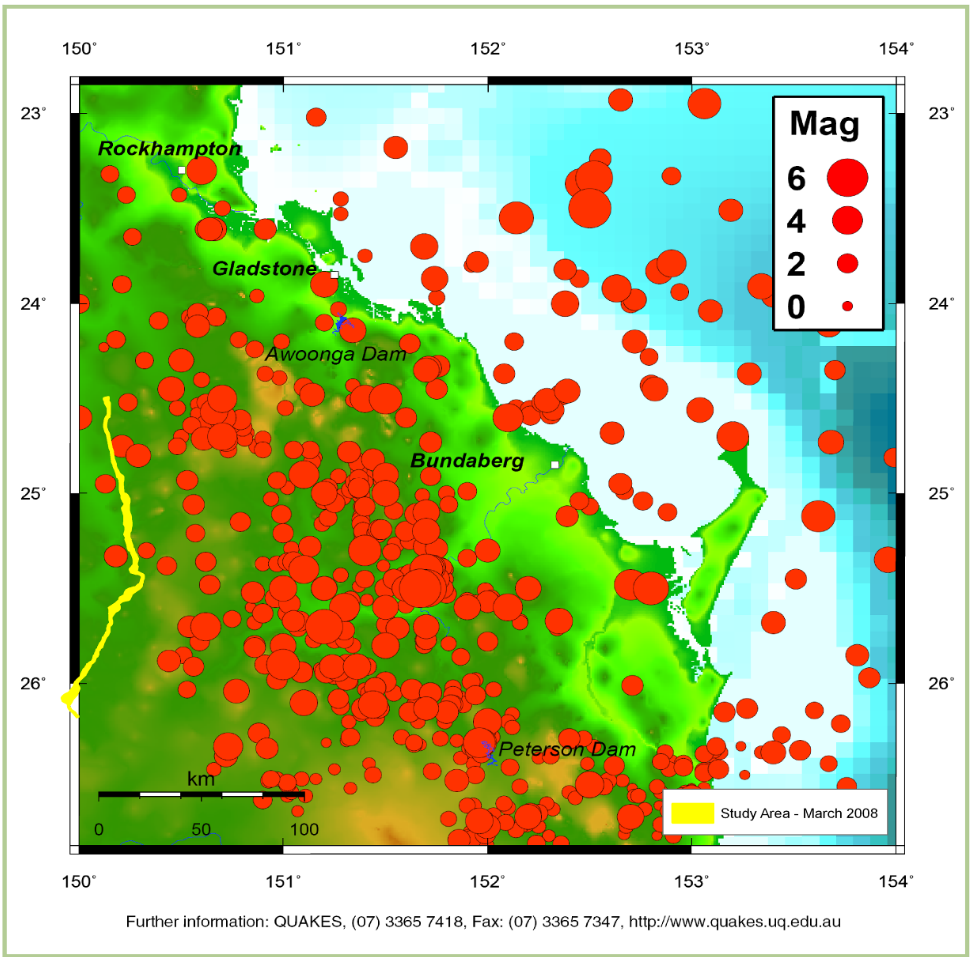

Figure 3-1: Earthquakes in the Bundaberg Area from 1866 to 2000

Source: UQ, 2000

3.3 Climatic Trends

3.3.1 Observed Climatic Trends

The BOM has mapped the observed changes in Australia's climate over the past century. These trend maps show that since 1910, average temperatures have risen throughout Queensland, while rainfall has declined, predominantly in the coastal areas (OCC, 2008). Over the past 60 years, Queensland's annual average temperature has increased at a more rapid rate (0.7°C/decade in the far north to 0.32°C/decade in the south-west) than the national average (OCC, 2008). Analysis of trends also shows that over this period, minimum temperatures in most areas of the State have increased more rapidly than maximum temperatures. In addition, recent years have been especially warm compared to the 1961-1990 average. Queensland is experiencing more >35°C days and more temperature records such as four of the state's seven hottest years on record having occurred since 2002 (OCC, 2008).

Queensland has also experienced substantial rainfall changes over the past century and particularly over the past 60 years. Since 1950, most of Queensland, especially in coastal regions, has experienced substantial decreases in the amount of rainfall (OCC, 2008). However, a greater proportion of total rainfall now falls in extreme events and there are longer periods between rainfall events (CSIRO, 2007). Queensland has also seen decline in tropical cyclonic activity and an increase in the number of severe tropical cyclones over the past half century (CSIRO *et al,* 2007).

3.3.2 Future Climate Change

Climate change projections specific to the study area are not available. However, general (Queensland) and regional (Rockhampton) projections can be used to identify the types of changes likely to be experienced in the study area. Climate projections prepared by the Commonwealth Government and BOM suggest that the future climate of Queensland, relevant to the Project, will generally be characterised by:

- An increase in both daily precipitation intensity (rain per rain-day) and the number of dry days, leading to longer dry spells interrupted by heavier rainfall events;
- An increase in the frequency of hot days and warm nights, and a decrease in the frequency of cold nights;
- More frequent occurrence of extreme temperatures;
- More extreme weather events such as severe storms involving hail and lightning causing changes in flood, bushfire and storm risks;
- More frequent extreme fire danger days;
- Drier El Niño and wetter La Niña events; and
- Increased annual potential evapotranspiration resulting in an increase in aridity and the severity of droughts (CSIRO, 2007; IPPC, 2007; OCC, 2008).

The main climatic constraints or issues likely to be experienced in the study area are an increase in extreme weather events (storms, floods and bushfires), a strong decline in rainfall, increased evaporation and increased temperatures and drought conditions. Temperature change projections are shown in Table 3-2 specifically for the area of Rockhampton, approximately 350 km north of the study area. All three scenarios shown (for different emission rates in the years 2030 and 2070) indicate an increase in annual temperature and the number of days with temperatures above 35°C.

Table 3-2: Temperature Projections for Rockhampton (OCC 2008)

Rockhampton	Increase in Annual Temperature (°C)	Number of days >35°C
Present	-	16.4
2030 average (mid emissions)	1.0 (0.6-1.3)	26 (22-33)
2070 average (low emissions)	1.6 (1.1-2.2)	36 (27-48)
2070 average (high emissions)	3.0 (2.1-4.2)	65 (42-102)

3.4 Potential Impacts and Mitigation Measures

3.4.1 Impacts of Climate on the Project and Environment

Potential impacts and management strategies to address potential impacts of severe weather, natural hazards and climate change during construction are outlined in Table 3-3. Hazard and risk assessment and management is provided in Section 15.

Table 3-3: Potential Impact and Mitigation Measures of Climate and Natural Disaster during Construction

Potential Impact	Mitigation Measure
Increased erosion and sedimentation during the wet season and extreme rainfall events	• Observe BOM flood and weather warnings; • Include specific and contingency measures for the wet season and for extreme weather events in the Erosion and Sediment Control Plan (ESCP); • Schedule major earthworks to avoid periods of expected seasonal rainfall (as far as practicable); • Ensure the water quality mitigation measures described in Section 6.1.9 are in place and effective before the start of the wet season.
Water ponding and flooding during wet season and extreme rainfall events	• Observe BOM flood and weather warnings; • Observe Emergency Services public notices, including evacuation notices; • Position storage areas and site camps on higher grounds and away from drainage lines; • Secure loose items and move assets to higher ground in the event of a flood warning for the area. • Locate sediment basins and collection points away from flood prone areas (see Section 6.1.9).

Potential Impact	Mitigation Measure
Fire causing safety hazard to construction workforce, delays to construction timeframe, increased construction costs and damage to infrastructure	• Maintain fire breaks around the construction site and construction camps; • Maintain fire extinguishers at site offices, and site and construction vehicles; • Observe fire warnings and notices, including evacuation notices; • If fires are in the area, secure a fire fighting water supply if practicable.
Storms causing safety hazard to construction workforce, delays to construction timeframe, increased construction costs and damage to infrastructure	• Observe BOM weather forecasts and severe weather warnings. If storms are forecast: • Secure loose items and move from drainage lines; • Move vulnerable items to sheltered areas; • Prior to wet season and extreme rainfall forecast, secure drainage, erosion and sediment controls; • Observe Emergency Services public notices.
Greater demand for limited water resources during the dry season or due to persistent drought conditions and new demand for water during Project construction	• Reduce water consumption for dust suppression by undertaking other preventative measures; • Treat and reuse water where practicable.

Management strategies to address potential impacts of severe weather, natural hazards and climate change during operation are outlined in Table 3-4.

Table 3-4: Potential Impact and Mitigation Measures of Climate and Natural Disasters during Operation

Potential Impact	Mitigation Measure
Water ponding and flooding during extreme rainfall events causing damage to infrastructure, environmental degradation, disruption to services and increased maintenance and operational costs	• Design railway and supporting infrastructure to provide appropriate flood immunity; • Maintain drainage infrastructure in working condition.
Fire causing safety hazard to operational workforce, damage to infrastructure, disruption to operations and increased maintenance and operational costs	• Maintain fire breaks along the preferred alignment; • Postpone trains if fires are burning along the rail route; • Observe BOM weather forecasts and severe weather warnings.
Storms causing safety hazard to operational workforce, damage to infrastructure, disruption to operations and increased maintenance and operational costs	• Observe BOM weather forecasts and severe weather warnings; • Maintain safe clearing distance of trees; • Maintain drainage infrastructure in working condition.

Potential Impact	Mitigation Measure
Greater demand for limited water resources due to persistent drought conditions and potential additional demand for water during Project maintenance	• Treat and reuse water where practicable.
Safety hazard to operational workforce and community as a result of accelerated material and structure degradation attributable to climate change. Increased operations and maintenance costs as a result of accelerated damage to infrastructure attributable to climate change	• Adopt maintenance regimes to accommodate acceleration in the degradation of materials and structures.

All climatic factors and hazards will potentially impact the construction and operation of the Project although it is only the extreme climatic and hazard events that are likely to have a significant impact.

The extent of impact on infrastructure and the frequency of extreme climatic events need to be considered within our current understanding of climate change.

3.4.2 Impacts of Climate Change

Recent infrastructure typically has a projected functional life span of many decades. Therefore, an understanding of the projected climate change impacts on infrastructure help to appreciate the potential implications of climate change on the Project.

Numerous reports and publications, including the Australian Greenhouse Office *National Climate Change Adaptation Program*, the Queensland Government’s *Climate Smart 2050*, the CSIRO's *Climate Change in Australia: technical report*, the Local Government Association of Queensland’s’ *Climate Change Adaptation Actions for Local Government,* the Office of Climate Change’s *Climate Change in Queensland* and the *Garnaut Climate Change Review*, comment that major infrastructure, which includes transport infrastructure, will be vulnerable to a range of climate change impacts.

The Garnaut Climate Change Review states that “climate change will have wide-ranging and significant impacts on the infrastructure critical to the operation of settlements and industry across Australia” (COA 2008, p.175). More specifically, climate change projections indicate that the degradation of materials, structures and foundations may accelerate, mainly due to increased ground movement, changes in groundwater affecting the chemical structure of foundations and fatigue of structures from extreme storm events.

Climate change projections also show that increased temperature and solar radiation may reduce the useful life of infrastructure due to temperature causing increased expansion and the degradation of materials such as concrete joints, steel, asphalt, protective cladding sealants and coatings (CSIRO *et al* 2007; COA, 2008). This accelerated degradation of materials has the potential to reduce the life expectancy of infrastructure, also increase maintenance costs and leading to potential structural failure during extreme events (CSIRO *et al* 2007; COA, 2008). Such degradation also increases the probability that extreme weather events will result in structural failure.

Table 3-5 contains a risk matrix of potential climate change impacts on railway infrastructure.

Table 3-5: Risk Matrix of Potential Climate Change Impacts on Railway Infrastructure

Risk Scenario	Climate Variable (cause(s))	Potential Climate Change Impact	Potential Consequence
Movement of rail tracks	• Increased temperatures and heatwaves	• Stress on rail tracks and decreased integrity due to line expansion and movement under high temperatures	• Potential degradation or failure of rail structure due to increased ground movement. • Potential need to replace rail structures due to damage from ground movement and distortion of structures from solar radiation. • Potential increased maintenance and replacement costs to repair damage and maintain the infrastructure. • Potential increased costs incurred and loss of revenue from ceasing use of the rail infrastructure during maintenance, repair and replacement works.
Storm damage to rail	• Increased extreme daily rainfall • Increased frequency and storm intensity • Increased electrical activity	• Potential for major and minor damage during storm and high intensity rainfall events	• Potential degradation and failure of rail structures due to increase in damage from flooding, debris, fallen trees and landslides in rail cuttings. • Potential need to replace rail structures due to storm damage. • Potential increased costs incurred and loss of revenue from ceasing use of the rail infrastructure during maintenance, repair and replacement works.
Degradation of bridge material	• Increased temperatures and heatwaves • Increased solar radiation • Decreased annual rainfall	• Stress on bridge integrity due to temperature expansion of concrete joints, steel, asphalt, protective cladding, coatings and sealants • Masonry work impacted by temperature affecting the mortar	• Potential degradation and failure of bridges due to increased ground movement, changes in groundwater and material breakdown. • Potential increased costs incurred and loss of revenue from ceasing use of the rail infrastructure during maintenance, repair and replacement works.

Risk Scenario	Climate Variable (cause(s))	Potential Climate Change Impact	Potential Consequence
Storm damage to bridges	• Increased extreme daily rainfall • Increased frequency and storm intensity • Increased extreme wind intensity	• Stress on bridge structures due to increased rainfall intensities, stronger winds and more frequent and more intensity storm events	• Potential degradation and failure of bridges due to increases in frequency and intensity of high stress events on structural integrity. • Potential increased costs incurred and loss of revenue from ceasing use of the rail infrastructure during maintenance, repair and replacement works.
Risk Assessment: the severity of the impact and by association the level of risk is dependent on the degree of climate change that is experienced in the study area. This in turn depends on the global greenhouse gas emissions pathway (low or high emissions scenarios) in the coming decades. Therefore, no attempt has been made to allocate a likelihood, consequence or overall risk rating at this stage. Further risk assessment is best assessed against purpose-built climate change projections for a range of greenhouse gas emissions scenarios and timeframes.			

Note: Table 3-5: adapted from CRISO *et al* 2007, Infrastructure and Climate Change Risk Assessment for Victoria, Consultancy Report to the Victorian Government prepared by CSIRO, Maunsell Australia Pty Ltd, and Phillips Fox.

3.5 Implications for the Project

Table 3-5 shows that without implementing climate change adaptation measures, changes in average climatic conditions and extreme weather events are likely to impact the Project in the following key ways:

- An increased risk that the rail infrastructure, including tracks and bridges will be exposed to extreme wind and rainfall events that exceed the design criteria. The structural integrity and durability of the infrastructure may be compromised as a result of ongoing exposure to extreme weather events;
- The durability of the rail infrastructure will also be reduced from increased temperature and solar radiation causing temperature expansion and breakdown of materials including concrete joints, steel, asphalt, protective cladding, coatings and sealants (CSIRO *et al*., 2007); and
- Bridges, tracks and foundations will experience more severe degradation and stress through increased ground movement and changes in groundwater levels.

Proactively considering adaptation strategies can decrease the risk of asset damage and failure, which would represent an economic and social cost. Incorporating adaptation strategies early will in many cases cost less than adapting in the future.

In the medium term (2030 to 2070), these projected climatic changes are likely to result in some increase in operational maintenance costs and expenditure as well as shortened infrastructure life expectancy and lessened durability. The additional extent of these maintenance works or the lifespan of the Project will be dependant on a number of factors including the intensity and extent of climatic changes experienced in the region and the success of any implemented adaptation measures.

However, while climate changes are uncertain, climate change adaptation strategies that decrease the risk of asset damage and failure can be identified. Specific climate change impacts and consequent design, construction and operation management strategies will depend on the physical elements and final preferred alignments of the railway and supporting infrastructure, along with the type and severity of the climate change impacts and the inherent climate and landscape characteristics. Generally though, climate change management strategies can be divided into four categories, namely:

- A change in the selection of materials for infrastructure exposed to changed climatic conditions, based on the desired life expectancy of the infrastructure and maintenance regime;
- A change in the design standards of particular components of infrastructure allowing for changes in the range of expected extreme events as well as accelerated degradation of materials and structures;
- A change in the maintenance regimes over time to accommodate acceleration in the degradation of materials and structures; and
- A change in technologies where an existing technology may not be able to deliver the required standard of performance or service under changed climatic conditions (CSIRO *et al*., 2007).

Specific strategies from these categories should be identified by the Project team through risk management workshops. These workshops should address the technical and financial feasibility and viability of potential climate change adaptation strategies. This process will be implemented through the EMP(P).