Australian Government

BUILDING OUR FUTURE

NSW GOVERNMENT

# M1 Pacific Motorway extension to Raymond Terrace

## Climate Change Risk Working Paper

Transport for NSW | July 2021

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# Executive summary

## Background

Transport for New South Wales (Transport) proposes to construct the M1 Pacific Motorway extension to Raymond Terrace (the project). Approval is sought under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999*.

## Performance outcomes

This assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) (SSI 7319) relating to Climate Change Risk. In addition, the desired performance outcome for the project in relation to climate change risk as outlined in the SEARs (SSI 7319) is to:

- Ensure the project is designed, constructed and operated to be resilient to the future impacts of climate change.

## Overview of climate change risk impacts

### *Greenhouse gas emissions*

A greenhouse gas impact assessment has been carried out to assess the greenhouse gases that would potentially be generated by the project. Greenhouse gas sources were identified and quantified, including fuel combustion, emissions embedded in materials, vegetation clearance during construction, as well as from grid electricity usage, maintenance activities and road traffic during the operation period.

Overall, the project is estimated to result in the following impacts:

- 243 kilotonnes of carbon dioxide equivalent ($CO_2e$) during the construction of the project, approximately 91 kilotonnes of which are Scope 1 emissions and 153 kilotonnes are Scope 3 emissions
- 23 kilotonnes of $CO_2e$ annually during the operation of the project, approximately 0.3 kilotonnes of which are Scope 1 emissions, 0.2 kilotonnes of which are Scope 2 emissions and 22.8 kilotonnes of which are Scope 3 emissions.

The operation of the project would result in increased emissions due to increased capacity for vehicles compared to the existing design. However, with the increase in traffic numbers predicted to occur ten years after the project opening, the operation of the project would result in fewer emissions produced per kilometre travelled when compared with the 'Without project' approach, resulting in lower overall emissions. It is noted that no assessment of a move to low or zero carbon fuels (including a switch to electric vehicles) has been modelled.

### *Climate change risk and adaptation*

A climate change risk assessment identified risks relating to:

- Increased high temperatures extremes and more frequent incidence and severity of heatwaves and elevated fire weather conditions
- Increased length and severity of seasonal drought
- Increase in the frequency and intensity of severe rainfall events

- More severe fire weather and elevated fire weather conditions
- Increased rate of annual evaporation (along with more intense droughts and higher temperatures)
- Increased concentration of carbon dioxide in the atmosphere.

Of the above, four risks were identified as 'high', four risks were identified as 'medium' and eight risks were identified as 'low' and prior to the implementation of environmental management measures.

Following the implementation of current design controls or proposed risk treatments, three risks were identified as 'high', two risks were identified as 'medium' and eleven risks were identified as 'low'.

## Environmental management measures

Environmental management measures have been identified where appropriate to reduce the overall greenhouse gas emissions during construction and operation of the project. These include adopting low emission materials and energy efficient technology and exploring renewable energy opportunities during the construction and operation of the project.

Environmental management measures have been proposed to manage the impacts expected from climate change including the consideration of a full range of temperature projections, as well as expected life of bridge components, when materials are specified, during detailed design. Detailed design would also consider the potential impacts to structures, utilities and fauna connectivity structures in bushfire prone areas. Further, a material durability report will be prepared and actioned which will specifically review the potential impacts of climate change on concrete durability, including depth of cover over reinforcement.

## Conclusion

The greenhouse gas impact assessment has been performed to quantify the potential greenhouse gas emissions associated with the construction, operation and maintenance of the project. The assessment found that over the course of construction, 243 kilotonnes of $CO_2$e would be emitted, while over the 100-year design life operation of the project, 2,332 kilotonnes of $CO_2$e would be produced. Scope 3 emissions were the main source of $CO_2$e, making up nearly 95 per cent of the combined construction and operation $CO_2$e produced.

The climate risk assessment identified risks associated with increased temperatures and the effect that these risks would have on material tolerances. Following the implementation of current design controls or proposed risk treatments, three risks were identified as 'high' and two risks were identified as 'medium' associated with increases in flooding under climate conditions. Current design controls have sought to minimise flooding impacts and additional flooding modelling will be carried out during detailed design to address any design changes.

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# 1. Introduction

## 1.1 Background

Transport for New South Wales (Transport) proposes to construct the M1 Pacific Motorway extension to Raymond Terrace (the project). Approval is sought under Part 5, Division 5.2 of the EP&A Act and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The project would connect the existing M1 Pacific Motorway at Black Hill and the Pacific Highway at Raymond Terrace within the City of Newcastle and Port Stephens Council local government areas. The project would provide regional benefits and substantial productivity benefits on a national scale. The project location is shown in **Figure 1-1**.

## 1.2 Project description

The project would include the following key features:

- A 15 kilometre motorway comprised of a four lane divided road (two lanes in each direction)
- Motorway access from the existing road network via four new interchanges at:
  - Black Hill: connection to the M1 Pacific Motorway
  - Tarro: connection and upgrade (six lanes) to the New England Highway between John Renshaw Drive and the existing Tarro interchange at Anderson Drive
  - Tomago: connection to the Pacific Highway and Old Punt Road
  - Raymond Terrace: connection to the Pacific Highway.
- A 2.6 kilometre viaduct over the Hunter River floodplain including new bridge crossings over the Hunter River, the Main North Rail Line, and the New England Highway
- Bridge structures over local waterways at Tarro and Raymond Terrace, and an overpass for Masonite Road in Heatherbrae
- Connections and modifications to the adjoining local road network
- Traffic management facilities and features
- Roadside furniture including safety barriers, signage, fauna fencing and crossings and street lighting
- Adjustment of waterways, including at Purgatory Creek at Tarro and a tributary of Viney Creek
- Environmental management measures including surface water quality control measures
- Adjustment, protection and/or relocation of existing utilities
- Walking and cycling considerations, allowing for existing and proposed cycleway route access
- Permanent and temporary property adjustments and property access refinements
- Construction activities, including establishment and use of temporary ancillary facilities, temporary access tracks, haul roads, batching plants, temporary wharves, soil treatment and environmental controls.

A detailed project description is provided in Chapter 5 of the environmental impact statement (EIS). The locality of the project is shown in **Figure 1-1**, while an overview of the project is shown in **Figure 1-2**.

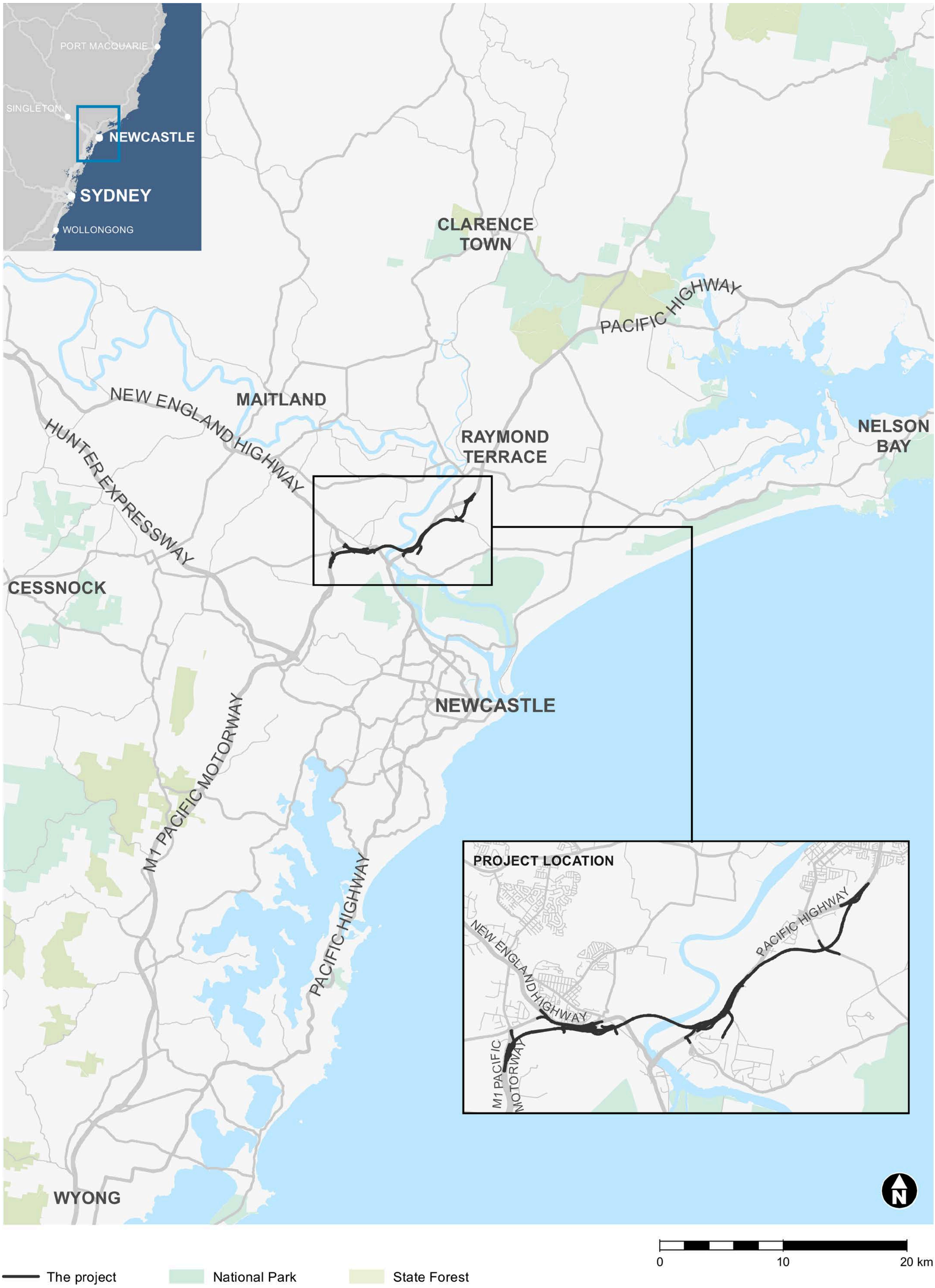


Figure 1-1 Regional context of the project

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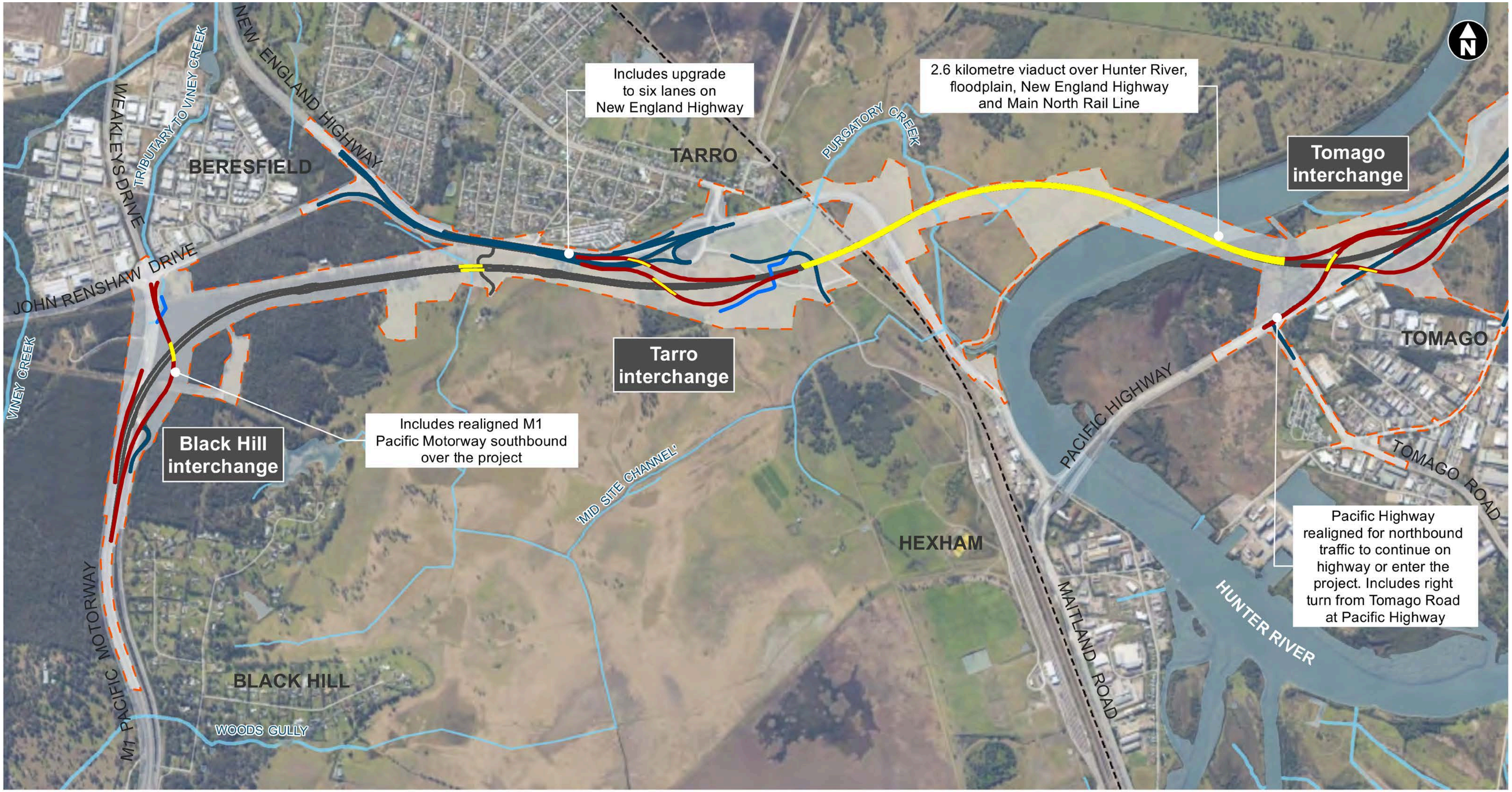


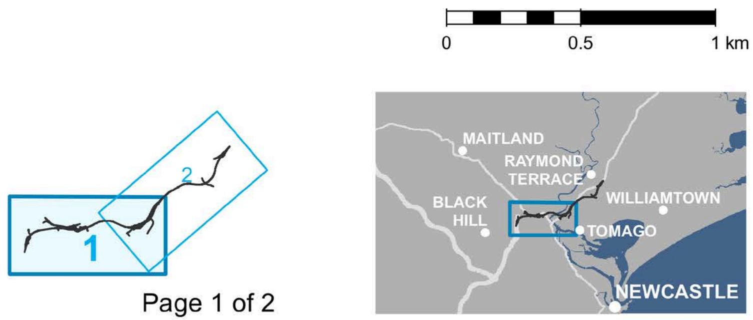


Figure 1-2 Project key features (map 1 of 2)

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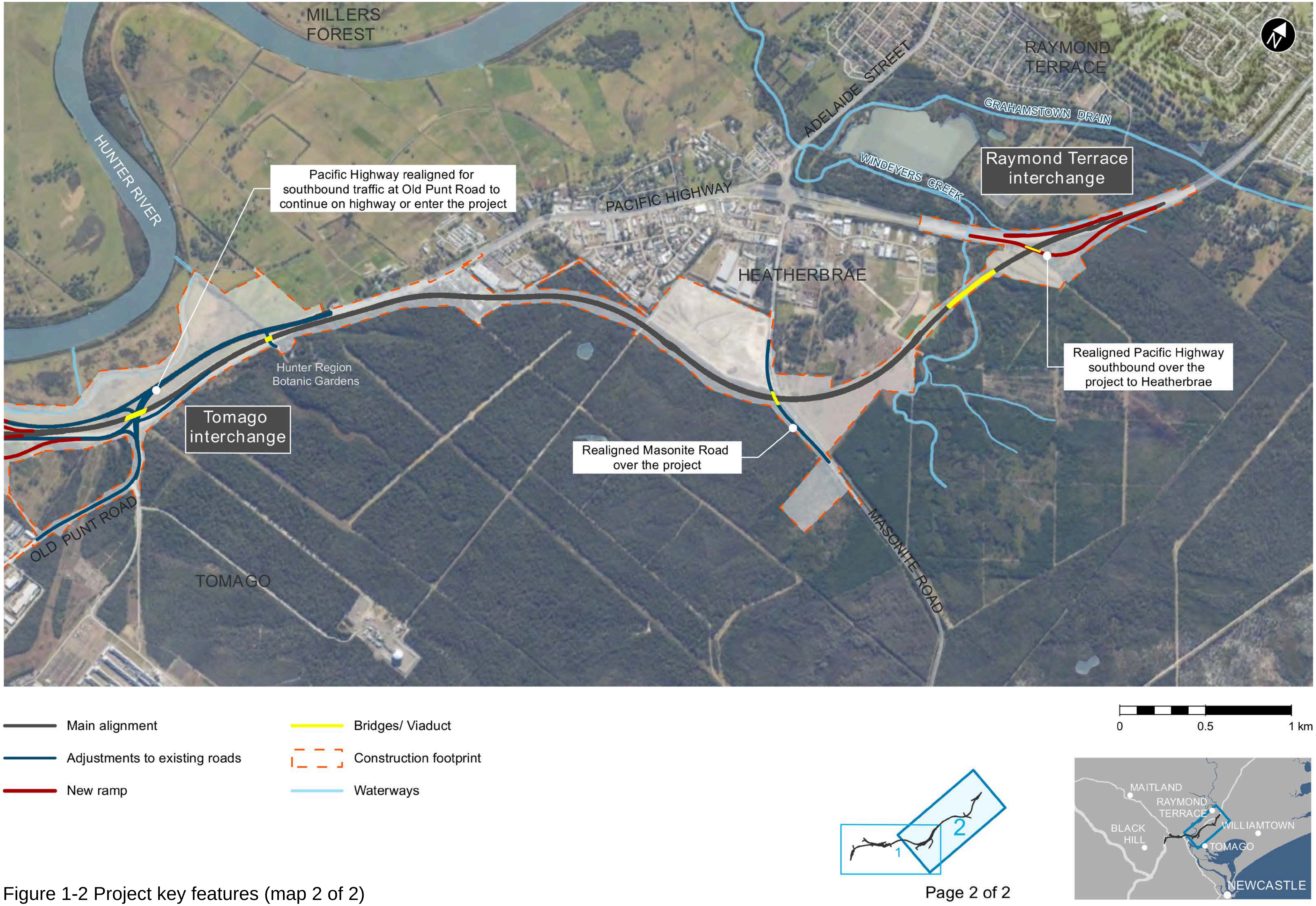


Figure 1-2 Project key features (map 2 of 2)

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## 1.3 Performance outcomes

The desired performance outcome for the project relating to climate change risk is to:

- Ensure the project is designed, constructed and operated to be resilient to the future impacts of climate change (refer to **Section 5.1**).

## 1.4 Secretary's Environmental Assessment Requirements

This assessment forms part of the EIS for the project. The EIS has been prepared under Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). This assessment has been prepared to address the SEARs (SSI 7319) relating to climate change risk and would assist the Minister for Planning and Public Spaces to make a determination on whether or not to approve the project. It provides an assessment of potential impacts of the project on climate change risk and outlines proposed environmental management measures.

In 2019 revised SEARs were issued for the project, which included climate change risk as a key issue. **Table 1-1** outlines the SEARs relevant to this assessment along with a reference to where these are addressed.

Table 1-1 SEARs relevant to climate change risk

| Secretary's requirement | Where addressed in this report |
|---|---|
| 9. Climate Change Risk | |
| 1. The Proponent must assess the risk and vulnerability of the project to climate change in accordance with the current guidelines. | Current guidelines are provided in **Section 2.4**.<br>Climate change risk assessment is provided in **Section 5.2**. |
| 2. The Proponent must quantify specific climate change risks with reference to the NSW Government's climate projections at 10km resolution (or lesser resolution if 10km projections are not available) and incorporate specific adaptation actions in the design.[1] | The assessment methodology is described in **Section 3.2**.<br>Outcomes of the assessment are provided in **Section 5.2** and proposed management measures are outlined in **Chapter 7**. |

[1] Note that the proponent has also received permission from The Department of Planning and Environment (as was) to use the Climate Futures Tool from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (BoM) (attenuated for the project region), to assess climate impacts (letter dated 26/3/2018, Ref IRF18/1522)

## 1.5 Report structure

The report is structured as follows:

- Chapter 1 – Introduces the project with a summary of the project background, project description, performance outcomes and SEARs
- Chapter 2 – Provides an overview of the policy and planning setting
- Chapter 3 – Provides a summary of the assessment methodology used to inform the assessment
- Chapter 4 – Details the historical climatic conditions of the study area and predicts future climate conditions of the study area under a number of climate change scenarios
- Chapter 5 – Displays the estimated greenhouse gas emissions associated with the project and evaluates the risk posed to the project by climate change related impacts
- Chapter 6 – Details the cumulative impacts within the context of NSW's and Australia's overall greenhouse gas emissions
- Chapter 7 – Details the proposed management measures for the project
- Chapter 8 – Conclusions
- References
- Terms and acronyms.

# 2. Policy and planning setting

## 2.1 International

### 2.1.1 Paris Agreement

Following the 2015 Paris Agreement, international agreements were made for signatories to:

- Keep global warming well below 2.0 degrees Celsius, with an aspirational goal of 1.5 degrees Celsius
- Submit revised emission reduction targets every five years (from 2018), with the first being effective from 2020, and goals set to 2050
- Define a pathway to improve transparency and disclosure of emissions
- Make provisions for financing the commitments beyond 2020.

In response to this challenge, Australia has committed to reduce emissions to between 26 and 28 per cent on 2005 levels by 2030. Greenhouse gas emissions from new developments and projects such as this one need to be understood in order to better position Australia to meet these commitments.

### 2.1.2 The Greenhouse Gas Protocol

The Greenhouse Gas Protocol is collaboration between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The Protocol provides a globally standardized framework and guideline for the calculation and reporting of carbon footprints and developing mitigation measures. The greenhouse gas inventory in this report has been carried out in accordance with the principles of the Greenhouse Gas Protocol.

## 2.2 Commonwealth policy

### 2.2.1 National Greenhouse and Energy Reporting Act 2007

The Commonwealth Government uses the National Greenhouse and Energy Reporting (NGER) legislation for the measurement, reporting and verification of Australian greenhouse gas emissions. This legislation is used for a range of purposes, including being used for international greenhouse gas (GHG) reporting purposes. Corporations which meet the thresholds for reporting under NGER must register and report their greenhouse gas emissions.

Under the *National Greenhouse and Energy Reporting Act 2007* (NGER Act), constitutional corporations in Australia which exceed thresholds for greenhouse gas emissions, energy production or consumption are required to measure and report data to the Clean Energy Regulator on an annual basis. The National Greenhouse and Energy Reporting (Measurement) Determination 2008 identifies a number of methodologies to account for greenhouse gases from specific sources relevant to the project. This includes emissions of greenhouse gases from direct fuel combustion (fuels for transport energy purposes), emissions associated with consumption of power from direct combustion of fuel (e.g. diesel generators used during construction), and from consumption of electricity from the grid.

## 2.3 State policy

### 2.3.1 NSW Net Zero Plan Stage 1: 2020 – 2030

The Net Zero Plan Stage 1: 2020–2030 is the foundation for NSW's action on climate change and goal to reach net zero emissions by 2050. It outlines the NSW Government's plan to grow the economy, create jobs and reduce emissions over the next decade.

The purpose of the plan is to support the uptake and expansion of a range of electricity and energy efficiency initiatives, including but not limited to carbon financing, low emission coal innovation technologies, electric vehicles and hydrogen technologies. The plan also supports businesses in modernising their plant and technologies and provide consumers with information to help them make more environmentally sustainable choices.

Through these, the plan intends to deliver a 35% cut to emissions compared to 2005 levels by 2030.

### 2.3.2 NSW Climate Change Policy Framework

The Australian Government has committed to reduce emissions to between 26 and 28 per cent on 2005 levels by 2030. In response, the NSW government has developed the NSW Climate Change Policy Framework which sets the objective of achieving net-zero emissions by 2050. It intends to achieve this through a combination of policy development, leading by example and advocacy. Energy generation and transport emissions form a significant part of the NSW emissions inventory, and as such the project would be assessed into the context of state and national emissions to determine its contribution.

The NSW Climate Change Policy Framework also aims to "Maximise the economic, social and environmental wellbeing of NSW in the context of a changing climate and current and emerging international and national policy settings and actions to address climate change" (OEH, 2016).

Within this framework, the NSW Government recognises its role with respect to development of appropriate policy, improving its own operations and advocacy with respect to climate change adaptation. It notes the following key policy directions:

- Reduce risks and damage to public and private assets in NSW arising from climate change: Climate change will lead to more extreme weather, heatwaves and sea level rise, which increase the risk of direct impacts on public and private assets and services. The government will manage the impact of climate change on its assets and services by embedding climate change considerations into asset and risk management. The government will also reduce barriers that will prevent effective private sector adaptation by providing information and a supportive regulatory framework for adaptation measures at the local level
- Reduce climate change impacts on health and wellbeing: The government will enable communities and individuals to be better prepared and more resilient to climate change impacts by anticipating increased demand for services, such as health and emergency services. The government will also identify ways to support communities that are more vulnerable to the health impacts of climate change
- Manage impacts on natural resources, ecosystems and communities: The government will provide long-term and coordinated efforts to increase the resilience of primary industries and rural communities as climate change impacts water availability and water quality. The government will also manage the environment impacts of climate change, such as the impacts on habitats, weeds and air pollution.

The NSW Climate Policy Framework will be delivered through the Climate Change Fund Strategic Plan, as well as through action plans and policies adopted by other government agencies. Two key features of the

NSW Climate Policy Framework include identifying options to manage climate risks to transport infrastructure, as well as well addressing key emissions sources across the NSW transport network.

## 2.4 Targets and guidelines

### 2.4.1 National Climate Resilience and Adaptation Strategy

The Commonwealth Government's approach to climate change adaptation is documented in its National Climate Resilience and Adaptation Strategy (DoE, 2015). The scope of this strategy is to, "Highlight resilience-building by governments, businesses and communities in Australia and our region; guide effective climate change adaptation with a set of principles; and establish priority areas for future consultation and action".

The strategy specifically highlights damage to roads and infrastructure that may result from the projected increased frequency and intensity of flooding and heatwave events is a major risk for Australia. The strategy also calls for the collaboration of state and federal governments to revise the Australian Transport Assessment and Planning Guidelines to include guidance on climate change adaption measures to address risks. The strategy also promotes the development of new technologies to also address the risks posed by climate change.

### 2.4.2 Climate Change Impacts and Risk Management – A Guide for Businesses and Development

The Australian Department of the Environment and Heritage (2016) document Climate Change Impacts and Risk Management – A Guide for Businesses and Development is a guide to integrating climate change impacts into risk management and other strategic planning activities. The guide aims to:

- Enumerate risks related to climate change impacts
- Prioritise risks that require further attention
- Establish a process for ensuring that these higher priority risks are managed effectively.

This guideline was considered when identifying relevant climate change risks and relevant environmental management measures.

### 2.4.3 NSW Future Transport Strategy 2056

The NSW Future Transport Strategy 2056 is an update to the previous NSW Long Term Transport Master Plan. It incorporates the Regional NSW Services and Infrastructure Plan and Greater Sydney Service and Infrastructure Plan together along with several supporting plans to provide a 40-year vision, direction and outcomes for transport and traffic in NSW. Of relevance to greenhouse gas management, the strategy includes:

- Reducing emissions through the uptake of public transport over private vehicles
- Investing in technology to reduce emissions from public transport
- Improving the climate resilience of the public transport network.

### 2.4.4 Environmental Sustainability Strategy 2019 – 2023

Transport's Environmental Sustainability Strategy 2019-23 is an update and continuation of the previous 2015-19 strategy. It incorporates nine focus areas for sustainability objectives from the previous strategy and adds a tenth; Corporate Sustainability. These areas focus on priority environmental issues for the strategy, namely:

- Climate change resilience
- Air quality
- Energy and carbon management
- Sustainable procurement
- Resource use and waste management
- Pollution control
- Biodiversity
- Heritage, both Aboriginal and non-Aboriginal
- Liveable communities
- Corporate Sustainability.

With respect to energy and carbon management, an objective has been set to 'Minimise energy use and reduce greenhouse gas emissions without compromising the delivery of services to our customers'. This is delivered through several targets, including:

- Reducing operational energy consumption as measured against level of activity by 15% by 2023
- Improving year-on-year construction energy efficiency on all State significant infrastructure projects
- Improving year-on-year supply chain carbon emissions intensity (including embodied energy in materials) when sourcing construction materials for State significant infrastructure projects
- Improving the year-on-year average $CO_2$ emissions score for Transport's fleet of light vehicles up to 3.5 tonnes.

Regarding Climate Change Risk, Transport's 2019-2023 Environmental Sustainability Strategy has the following Climate Change Resilience Targets and Key Initiatives. These targets are used as guidance for the Climate Change Risk Assessment used in this document:

- Targets:
  - CC1 - Assess climate change risks for all potentially affected projects and programs
  - CC2 - Address all identified climate change risks ranked as high or above during project planning.
- Key Initiatives:
  - Reviewing climate change impacts and risks during the planning phase of potentially affected projects with a level of detail commensurate to the size of the project and the potential risk
  - Designing infrastructure for the predicted future climate or designing for cost-effective adaptation in the future
  - Consulting and partnering with key stakeholders to reduce vehicle carbon emissions and supporting new technologies to reduce road transport carbon emissions
  - Minimising the carbon impacts associated with vegetation clearance by reducing project footprints where possible
  - Maintaining our capacity to respond to significant events on our roads or waterways through emergency management plans to ensure our agency responds appropriately when required
  - Working within government agencies to identify interdependencies across transport, water, energy and telecommunications infrastructure during significant weather events

- Monitoring developments in climate modelling and ensure our approach is updated as new information is available
- Ensuring our specifications for delivery, maintenance and operation of infrastructure consider suitable climate and weather-related constraints which include current best practice climate change predictions.

### 2.4.5 Technical Guide for Climate Change Adaptation for the State Road Network (RMS, in draft)

This Technical Guide outlines the approach to carrying out a climate change risk assessment, including identification of potential impacts to road projects in NSW. This Technical Guide has been used to inform this assessment.

Transport's Climate Risk Assessment Guideline was developed to provide contractors and stakeholders with support on how to complete Climate Risk Assessments in line with Transport's latest Sustainable Design Guidelines (SDG) requirements.

# 3. Assessment methodology

## 3.1 Greenhouse gas

### 3.1.1 Greenhouse gas accounting

‘Greenhouse gases’ is an umbrella term for a range of gases that are known for their capability to trap radiation in the upper atmosphere, where then it could have the potential to contribute to the greenhouse effect (global warming). By creating an inventory of likely greenhouse gas emissions associated with the project, the scale of the emissions can be determined and a baseline from which to develop and deliver greenhouse gas reduction options can be formed. Prominent greenhouse gases, and their most common sources include:

- Carbon dioxide ($CO_2$): by far the most abundant, primarily released during fuel combustion
- Methane ($CH_4$): from the anaerobic decomposition of carbon-based material (including enteric fermentation and waste disposal in landfills)
- Nitrous oxide ($N_2O$): from industrial activity, fertiliser use and production
- Hydrofluorocarbons (HFCs): commonly used as refrigerant gases in cooling systems
- Perfluorocarbons (PFCs): used in a range of applications including solvents, medical treatments and insulators
- Sulphur hexafluoride ($SF_6$): used as a cover gas in magnesium smelting and as an insulator in heavy duty switch gear.

It is common practice to aggregate the emissions of these gases into the equivalent emission of carbon dioxide. This provides a simple, single figure for the comparison of emissions against targets. The aggregation is based on the potential of each gas to contribute to global warming relative to carbon dioxide and is known as the global warming potential. The resulting number is expressed as carbon dioxide equivalents ($CO_2$e).

The greenhouse gas inventory in this report is calculated in accordance with the principles of the Greenhouse Gas Protocol[2]. The greenhouse gas emissions that form the inventory can be split into three categories known as ‘Scopes’ as shown in **Figure 3-1**. Scopes 1, 2 and 3 are defined by the Greenhouse Gas Protocol and can be summarised as follows:

- **Scope 1**: Direct emissions from sources that are owned or operated by a reporting organisation (for example, combustion of diesel in company owned vehicles or on-site generators)
- **Scope 2**: Indirect emissions associated with the import of energy from another source (for example, importation of electricity or heat)
- **Scope 3**: Other indirect emissions (other than Scope 2 energy imports) which are a direct result of the operations of the organisation but from sources not owned or operated by them (for example, include business travel (by air or rail) and product usage).

[2] The Greenhouse Gas Protocol is collaboration between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The Protocol provides guidance on the calculation and reporting of carbon footprints.

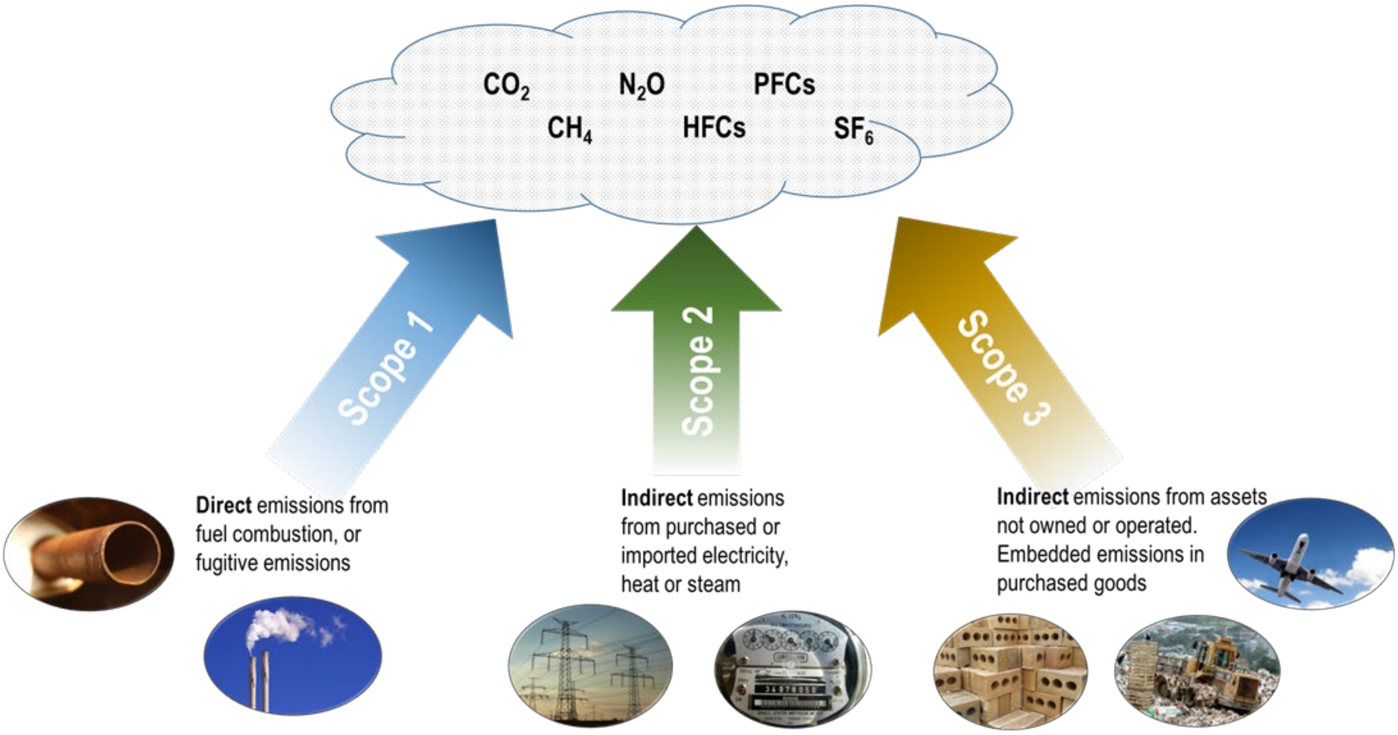



Figure 3-1 Sources of Greenhouse Gases - Adapted from World Business Council for Sustainable Development – Greenhouse Gas Protocol

The results of this assessment are presented in terms of the above-listed ‘scopes’ to help define and understand the direct and indirect sources of the greenhouse gas emissions generated by the project.

The GHG Protocol (and similar reporting schemes) dictates that reporting Scope 1 and 2 sources is mandatory, while reporting Scope 3 sources is optional. Reporting substantial Scope 3 sources is recommended. For this project, all ‘scopes’ have been assessed.

The initial action for a greenhouse gas inventory is to determine the potential sources of greenhouse gas emissions, assess their likely significance and set a provisional boundary for the assessment. Following this, data are collected to represent the activities carried out for the project and converted to greenhouse gas emissions typically using emissions factors (a published figure for the activity representing the aggregated greenhouse gas emissions per unit of the activity).

### 3.1.2 Greenhouse gas assessment boundary

The assessment boundary defines the scope of greenhouse gas emissions and the activities to be included in the assessment. **Table 3-1** and **Table 3-2** summarise the emission sources and activities considered within the project’s assessment boundary for construction and operation, according to scope. It is noted that some emission sources are accounted for in more than one scope. This is typically the case where there are direct emissions (e.g. combustion of fuel in a vehicle operated as part of the project) as well as indirect emissions (extraction and processing of the fuel before it is used).

Table 3-1 Construction greenhouse gas emission sources

| Emission source | Included in assessment | Scope 1 | Scope 2 | Scope 3 |
|---|---|---|---|---|
| Fuel use – diesel consumption in plant and equipment during construction | ✓ | ● | | ● |
| Construction materials | ✓ | | | ● |
| Fuel use – Transport of construction materials | x<br>(Materials are likely to be sourced from less than 50 km away*) | | | ● |
| Fuel use – Transport of construction waste, spoil or dredged material | x<br>(Materials are likely to be taken less than 50 km away from site*) | | | ● |
| Vegetation removal | ✓ | ● | | |

* The assessment methodology does not consider emissions associated with the transportation of material/waste less than 50 km to be material

Table 3-2 Operational greenhouse gas emission sources

| Emission source | Included in assessment | Scope 1 | Scope 2 | Scope 3 |
|---|---|---|---|---|
| Road use by vehicles (differential between 'Without project' and 'project' scenarios) | ✓ | | | ● |
| Electricity consumption – Lighting | ✓ | | ● | ● |
| Maintenance activities – Fuel | ✓ | ● | | ● |
| Maintenance activities – Materials | ✓ | | | ● |

### 3.1.3 Tools used for the assessment of greenhouse gas emissions

#### *Carbon gauge*

The calculation of greenhouse gas emissions for this assessment was facilitated using the Transport Authorities Greenhouse Group's (TAGG) Carbon Gauge greenhouse gas assessment tool.

Carbon Gauge is a tool which automates many of the calculations, assumptions and default greenhouse gas emissions factors presented in the Greenhouse Gas Assessment Workbook for Road Projects, developed by the TAGG.

Carbon Gauge works on several assumptions to allow greenhouse gas emissions to be calculated based on project design information. This includes:

- Making assumptions on the material usage and fuel required to construct and maintain roads based on the type of pavement used and the area of each pavement
- Making assumptions on the materials and fuel required to build bridges, drainage and other structures based on the type and length of the structures
- Calculating the fuel that would be used performing excavation or demolition works based on the number of buildings to be demolished and earth being excavated
- Calculate the embodied Scope 3 emissions associated with the extraction, processing and manufacturing of materials
- Calculating the fuel used transporting materials, earth and waste based on the assumptions above

- Calculating the carbon sink lost based on the biomass class of vegetation cleared
- Calculating the annual electricity used by street lighting and signalling based on the length of lit roads and number of intersections with road signals.

This tool provides a framework for assessing the greenhouse gas emissions associated with road construction projects through the completion of a materiality assessment, and then provision of standard carbon emissions factors for activities typically carried out. This allows the user to build a greenhouse gas profile through input of standard data on the length and area of pavement, road features included and cost of construction, amongst other, accessible data.

For this assessment, Carbon Gauge was used to determine the fuel combustion, material requirements and vegetation clearance associated with project. The tool was also used to calculate the projected electrical energy as well as maintenance fuel and materials requirements of the project during operation (with emissions factors updated from other sources as required).

### *Tool for Roadside Air Quality*

Emissions associated with the change in traffic resulting from the project have been calculated in the Tool for Roadside Air Quality (TRAQ). The tool calculates air quality and greenhouse gas emissions based on several factors, including:

- The type of roads in the scope of the project (e.g. arterial, highway, freeway etc.)
- Road length and grade
- Daily traffic count on the road
- Peak and average speeds on the road
- Traffic composition (light to heavy vehicle ratio)
- The year of the assessment (used to estimate the average emissions of each vehicle).

The total annual greenhouse gas emissions ($CO_2e$) have been calculated for eight assessment scenarios based on the traffic on the roads. These scenarios have been detailed in **Table 3-3**.

**Figure 3-2** shows the roads in the traffic and transport study area (see the Traffic and Transport Working Paper (Appendix G of the EIS)) and how they relate to the assessment scenarios described in **Table 3-3**.

Table 3-3 Assessment scenarios for the traffic GHG emission calculations

| Year | Strategic traffic model reference | Assessment scenario | Comment |
|---|---|---|---|
| Year of opening (2028) | Base Case/No Project | 'Without project' 2028 | The existing road layout, with only maintenance performed, **without the project** |
| | Direct M12RT Contribution | 'With project' 2028 | Emissions relating to traffic using the roads constructed as part of the project |
| | Change in traffic on pre-existing roads due to M12RT | 'With project' 2028 | Emissions relating to changes in traffic on roads within the study area as a result of the project |
| | Cumulative effect of M12RT and pre-existing roads | 'With project' 2028 | Emissions across the entire study area resulting from changes to traffic on existing roads and traffic on the roads constructed as part of the project (a sum of the two rows above) |
| Ten years after opening (2038) | 'Without project' | 'Without project' 2038 | Traffic conditions 10 years after the planned opening year, **without the project** |
| | 'With Project' Direct M12RT Contribution | 'With project' 2038 | Emissions relating to traffic using the roads constructed as part of the project, 10 years after the planned opening year |

| Year | Strategic traffic model reference | Assessment scenario | Comment |
|---|---|---|---|
| | 'With Project' Change in traffic on pre-existing roads | 'With project' 2038 | Emissions relating to changes in traffic on roads within the study area as a result of the project, 10 years after the planned opening year |
| | 'With Project' M12RT and pre-existing roads | 'With project' 2038 | Emissions across the entire study area resulting from changes to traffic on existing roads and traffic on the roads constructed as part of the project (a sum of the two rows above), 10 years after the planned opening year |

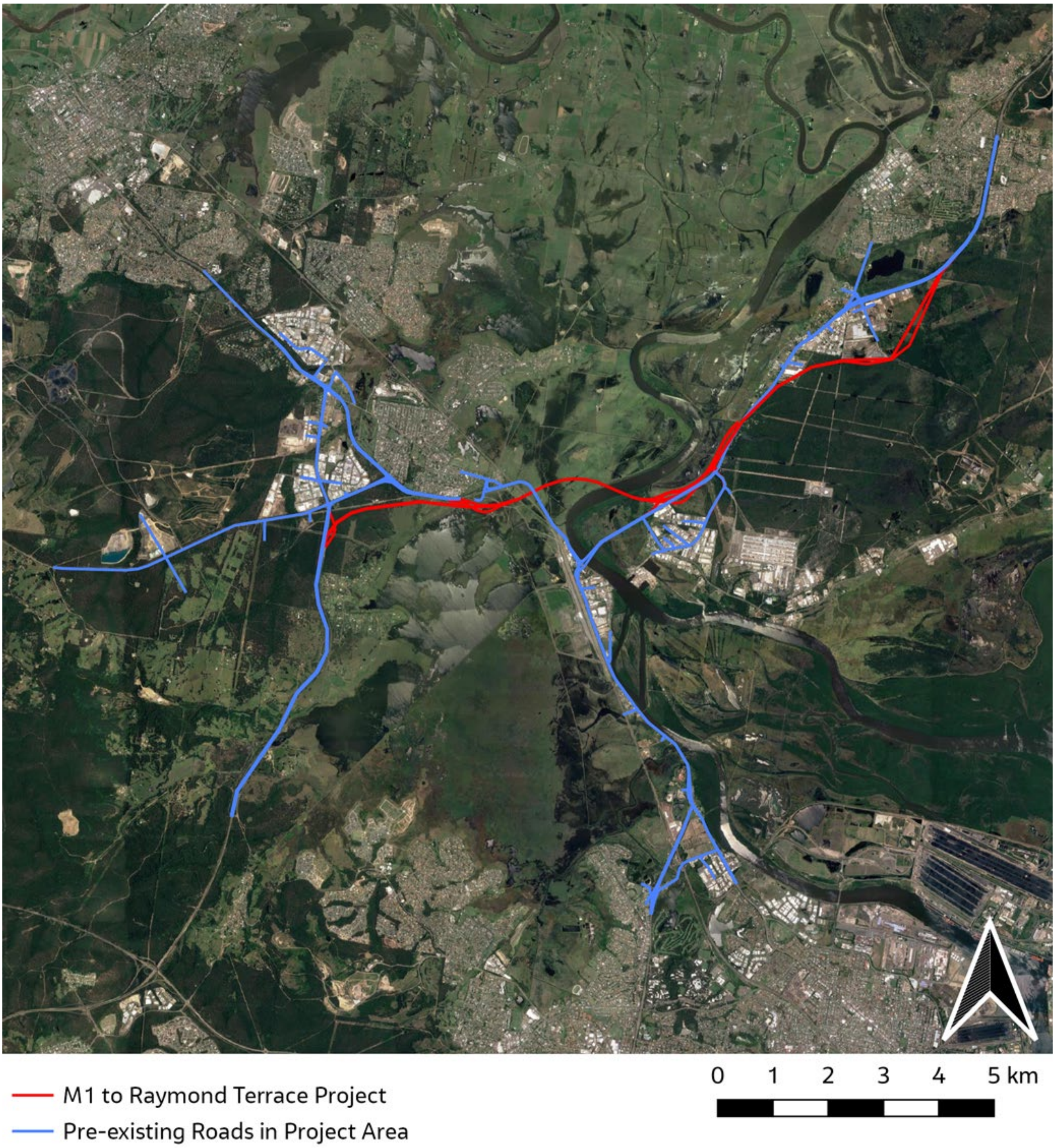



Figure 3-2 Extent and division of roads within the traffic and transport study area

### 3.1.4 Greenhouse gas factors

#### *Fuel combustion*

The National Greenhouse Accounts Factors (NGA) (DoE, 2019) provides the latest emission factors for the combustion of fuel from the operation of plant and equipment, as well as other fuel usage onsite such as site office generators and site vehicles. The emission factors for fuel combustion projected during the assessment are described in **Table 3-4**.

Table 3-4 NGA 2019 emission factors for fuel combustion

| Fuel | Unit | Scope 1 emission factor | Scope 3 emission factor |
|---|---|---|---|
| Diesel used in stationary plant | t $CO_2$e/kL | 2.71 | 0.139 |
| Unleaded petrol used in stationary plant | t $CO_2$e/kL | 2.32 | 0.123 |

#### *Embedded emissions in construction materials*

Emission factors for activities associated with the production of construction materials were derived from the Infrastructure Sustainability Council of Australia (ISCA) Materials Calculator. These represent the emissions 'embedded' in the production of one metric tonne of each material and are largely derived from the Australian Life Cycle Inventory (AusLCI) project. These are described in **Table 3-5**.

Table 3-5 Embedded emissions from materials

| Material | Unit | Emission factor (Scope 3) |
|---|---|---|
| Aggregate | t $CO_2$e/t | 0.006 |
| Asphalt | t $CO_2$e/t | 0.065 |
| Bitumen | t $CO_2$e/t | 0.390 |
| Cement | t $CO_2$e/t | 0.982 |
| Concrete | t $CO_2$e/t | 0.200 |
| Steel | t $CO_2$e/t | 2.324 |

#### *Vegetation clearance*

Vegetation in the vicinity of the project acts as a carbon sink. Emissions resulting from vegetation removal during construction were calculated in Carbon Gauge, based on data developed by the Department of Climate Change and Energy Efficiency (DCCEE) to estimate greenhouse gas emissions for Australia's international reporting requirements under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. This included an assumption of the carbon stored in the vegetation at the time of clearing in addition to carbon that could have been sequestered had the vegetation not been cleared. The emission factors associated with vegetation clearance are described in **Table 3-6**.

Table 3-6 Emission factors associated with Vegetation clearance (t $CO_2$e/ha)

| Vegetation class | Potential maximum biomass class (t dry matter/ha) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Class 1 (0 – 50 t/ha) | Class 2 (50 – 100 t/ha) | Class 3 (100 – 150 t/ha) | Class 4 (150 – 250 t/ha) | Class 5 (250 – 350 t/ha) | Class 6 (350 – 450 t/ha) | Class 7 (>450 t/ha) |
| Class A (Rainforest and vine thicket) | - | - | 227 | 384 | 532 | 594 | 768 |
| Class B (Eucalypt tall open forest) | - | - | 237 | 401 | 554 | 618 | - |
| Class C (Open forest) | 77 | 209 | 307 | 521 | 718 | - | - |
| Class D (Open woodlands) | 77 | 209 | 307 | - | - | - | - |
| Class E (Callitris forest and woodland) | 80 | 217 | 316 | - | - | - | - |
| Class F (Mallee and acacia woodland and shrubland) | 106 | 287 | - | - | - | - | - |
| Class G (Open shrubland) | 113 | - | - | - | - | - | - |
| Class H (Heathlands) | 115 | 309 | - | - | - | - | - |
| Class I (Grasslands) | 110 | 110 | 110 | 110 | 110 | 110 | 110 |

### *Electricity*

Emission factors for electricity usage in NSW have been taken from the NGA Factors of August 2019 (NGA, 2019). These are shown in **Table 3-7**.

Table 3-7 Grid electricity emission factor

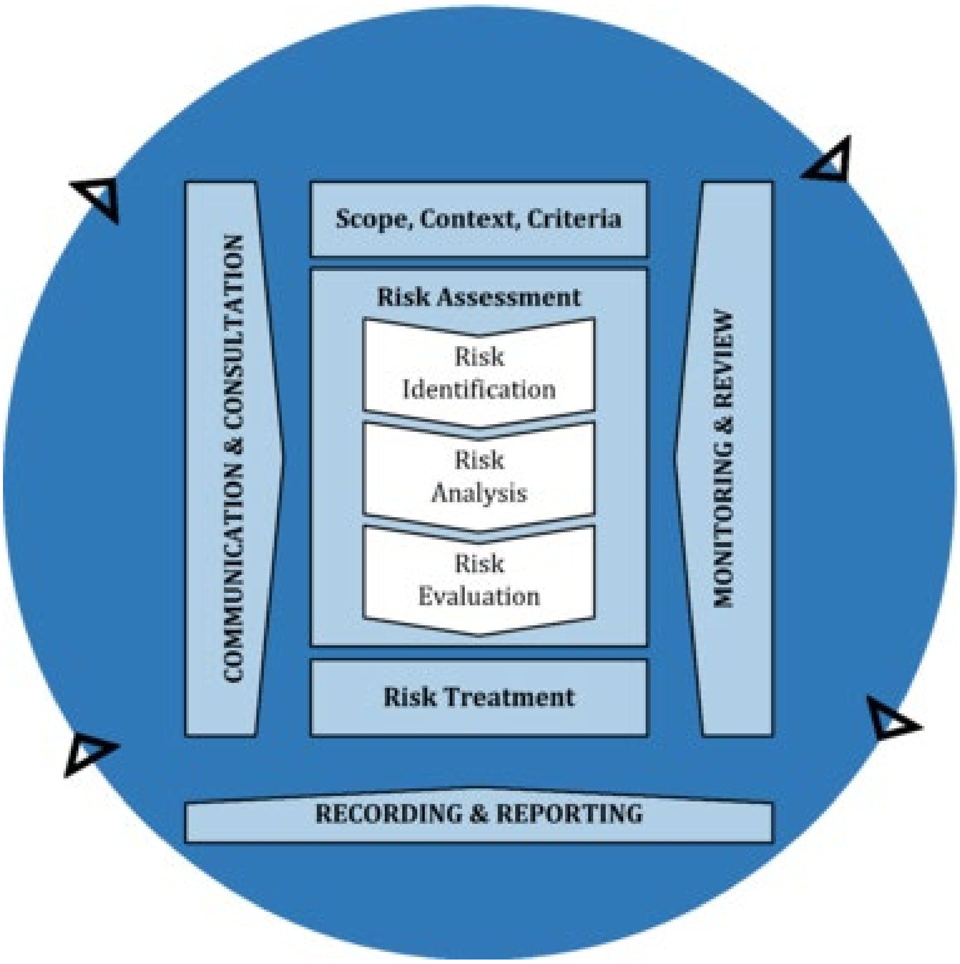
| State | Unit | Scope 2 emission factor | Scope 3 emission factor |
|---|---|---|---|
| NSW | t $CO_2$e/kWh | $0.81 \times 10^{-3}$ | $0.09 \times 10^{-3}$ |

## 3.2 Climate change risk

The methodology for conducting this climate change risk assessment has been based on the Australian Standard AS 5334-2013 Climate change adaptation for settlements and infrastructure – A risk-based approach. The risk assessment is intended to form part of a risk management process which involves communication and consultation with the design team, relevant stakeholders such as Transport as well as regular monitoring and review of the risk assessment plan as shown in **Figure 3-3**.

The standard follows the International Standard ISO 31000:2018, Risk management – Principles and guidelines (adopted in Australian and New Zealand as AS/NZS ISO 31000:2018), which provides a set of internationally endorsed principles and guidance on how organisations can integrate decisions about risks and responses into their existing management and decision-making processes.

It is noted that while the SEARs for the project (see **Section 1.4**) require modelling with reference to the NSW Government's climate projections at a resolution of 10 kilometres, Transport has received permission from the Department of Planning, Industry and Environment (formerly Department of Planning and Environment) to instead use the Commonwealth Scientific and Industrial Research Organisation's Climate Futures Tool to assess climate impacts.




Source: Reproduced from AS/NZS ISO 31000

Figure 3-3 Risk Management Process

### 3.2.1 Risk evaluation and approach

Risks to the operation and maintenance of the project that might be influenced by climate change have been identified. The hazard-receptor pathway model has been applied to identify and describe risks. This model is outlined below:

- **Hazard**: climate or climate-influenced attributes with potential to influence the project's operation and maintenance. Example of hazards specific to the project can be found in **Table 5-10**
- **Receptor**: the component of the project's operation and/or maintenance impacted by the hazard. This may also include users of the project and affected elements of the surrounding environment. Key components of the project at risk can be found in **Table 5-11**

- **Risk rating**: utilising the likelihood (Table B-1) and consequence (Table B-2) rating system outlined in **Appendix B**, an assessment of the way hazards influence the project receptors was carried out and a risk rating awarded (Table B-3). The completed assessment is provided in **Appendix B**.

Within the risk assessment process, the risk resulting from the projected change in climate is assessed, whether this is a newly identified or elevated existing risk. For example, some risks are already present (flooding) but the frequency and intensification of these are projected to change. Other risks (such as migration of pests and weeds) may not be expected to happen in the absence of a changing climate.

### 3.2.2 Proposed risk treatment

Risk treatment options have begun to be developed for some of the higher climate change risks, including consideration of the full range of temperature projections in detailed design, a material durability report specifically aimed at climate change impacts will be developed in the detailed design and noting that the current motorway design performs above design criteria for flooding. These treatment options would, where necessary, build on existing design controls, and be developed further as the design progresses from concept design to detailed design, at which point detailed modelling and decisions surrounding design components would be further developed and/or incorporated.

# 4. Existing environment

## 4.1 Existing greenhouse gas environment

Greenhouse gases are gases that when released into the atmosphere effectively trap heat influencing global temperatures. The release of greenhouse gases into the atmosphere is caused by both natural processes (such as bushfires) and human activities (e.g. burning fossil fuels and land clearing).

Since the industrial revolution the concentration of greenhouse gases, in parts per million, was rapidly increasing which has led to an increase in the earth's average surface temperature and has contributed to the phenomenon of 'climate change'.

The term 'climate' refers to the typical weather conditions for a specific geographical area, usually averaged over at least 30 years. Climate variability represents the 'normal' day to day seasonal and year to year variability in the components of climate (e.g. temperature, rainfall). However, climate variability may also generate extreme conditions such as flooding, heatwaves and hail which require management.

The world's leading climate scientists presented the following key findings in the Intergovernmental Panel on Climate Change Fifth Assessment Report (AR5) (IPCC, 2013):

- Warming of the climate system is unequivocal and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and oceans have warmed, the amounts of snow and ice have diminished, and sea level has risen
- In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. Impacts are due to observed climate change, irrespective of its cause, indicating the sensitivity of natural and human systems to changing climate
- Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level will rise
- Many aspects of climate change and associated impacts will continue for centuries, even if anthropogenic emissions of greenhouse gases are stopped. The risks of abrupt or irreversible changes increase as the magnitude of the warming increases
- In urban areas, climate change is projected to increase risks for people, economies and ecosystems, including risks from heat stress, storms and extreme precipitation, inland and coastal flooding, water scarcity, sea-level rise, and storm surges
- Building adaptive capacity is crucial for effective selection and implementation of adaptation options.

## 4.2 Historical climate in the vicinity of the project

This section describes the historical climate in the vicinity of the project, based on meteorological observations from BoM station 061078 located at the Royal Australian Air Force Base (RAAF) Williamtown (operating from 1942 until present). RAAF Williamtown is located about 10 kilometres east of the project but is the nearest BoM station with a substantial level of historical climate data available (i.e. greater than 20 years). Rainfall observations are available for the years 1958-2020 and temperature observations are available for the years 1951-2020. No meteorological readings were available for 1942 and the period between 1946 and 1950. There were also no rainfall records for the period between 1953 and 1960, and the record between 2010 and 2015 contains some gaps.

### 4.2.1 Rainfall

#### *Annual rainfall*

Annual rainfall for the Southern Hunter over the full period of record is 1,120 millimetres. Average rainfall during the climate change projection reference period is shown in **Figure 4-1** and is equivalent to the long-term average at 1,122 millimetres. Rainfall has ranged between 541 and 1,739 millimetres over that period.

Rainfall in the Southern Hunter has trended downwards over the period of record, however the high level of year to year variability in rainfall means that this trend is not statistically significant.

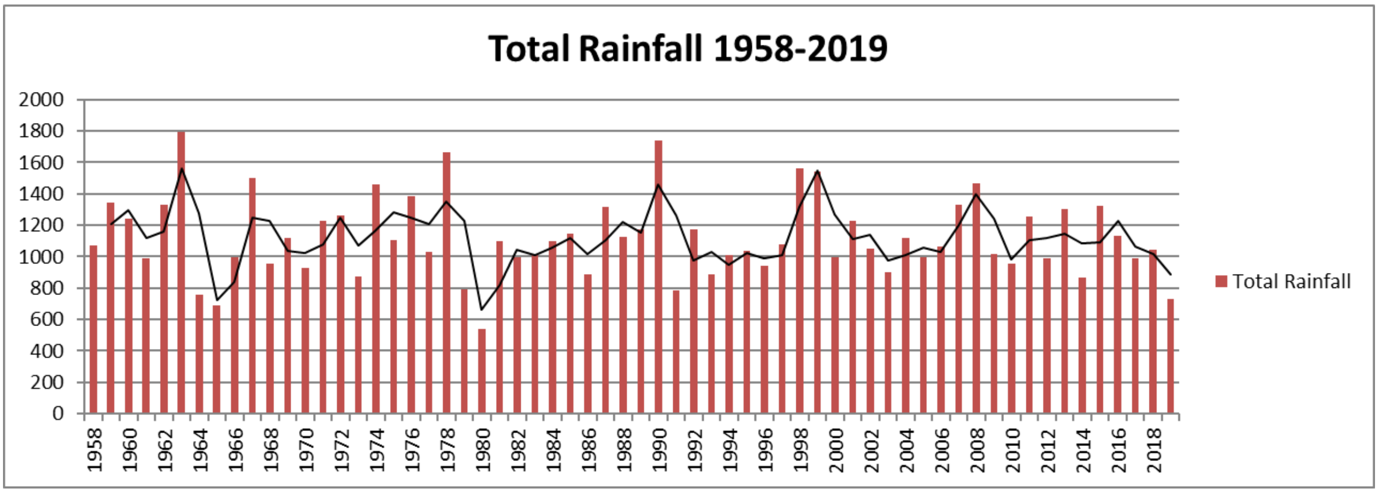



Figure 4-1 Annual rainfall for Williamtown (RAAF)

Source: BoM stations 61078. Graph plots total annual rainfall and the five-year moving average of annual rainfall. The latter highlights the influence of multi-year climate cycles, such as ENSO.

#### *Monthly rainfall*

Average monthly rainfall ranges between 61 millimetres in September and 130 millimetres in June (**Figure 4-2**). Average monthly rainfall during late winter and early spring (particularly July to September) is considerably lower than the average for autumn, where rainfall almost doubles. The pattern in extreme monthly rainfalls indicates that the potential for very wet months is highest during January to June.

The Southern Hunter's pattern of rainfall during the climate change projection reference period follows that of the long-term average reasonably closely. Average monthly rainfall over this period ranged between 59 millimetres in August and 125 millimetres in March.

#### *Daily rainfall*

Maximum recorded daily rainfalls are shown in **Figure 4-3**. Maximum recorded daily rainfall totals are typically greater during summer-autumn than at other times of year, which reflects that the warmer air is able to hold more water. The climate change projection reference period includes the highest daily rainfall total for the Southern Hunter for every month apart from January and May.

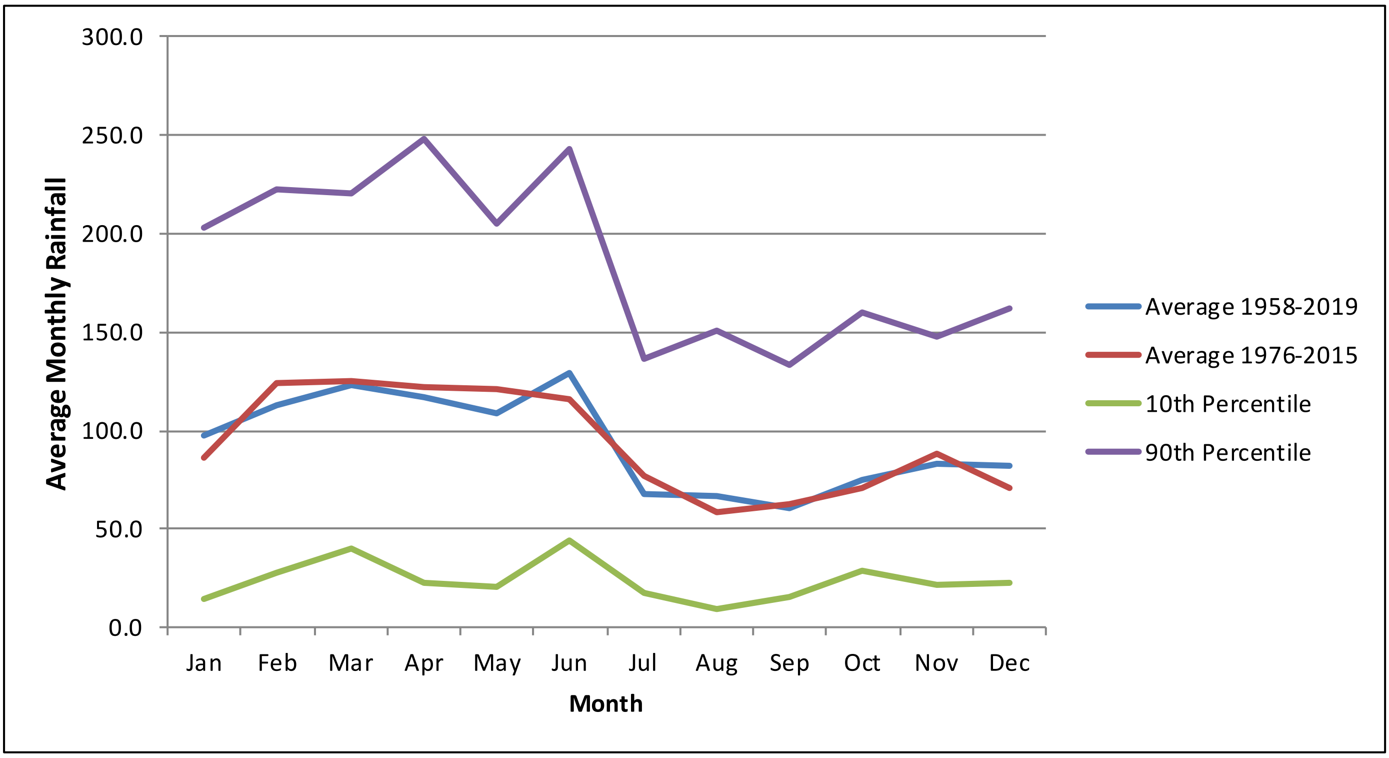



Figure 4-2 Average and extreme monthly rainfall totals for the Southern Hunter

Source: BoM station 61078. Graph shows average monthly rainfall for RAAF Williamtown, as well as the 10th and 90th percentile of monthly rainfall totals for each month. The latter are provided as an indication of rainfall variability. They are the monthly rainfall totals which are exceeded in 10 and 90 per cent of months, respectively.

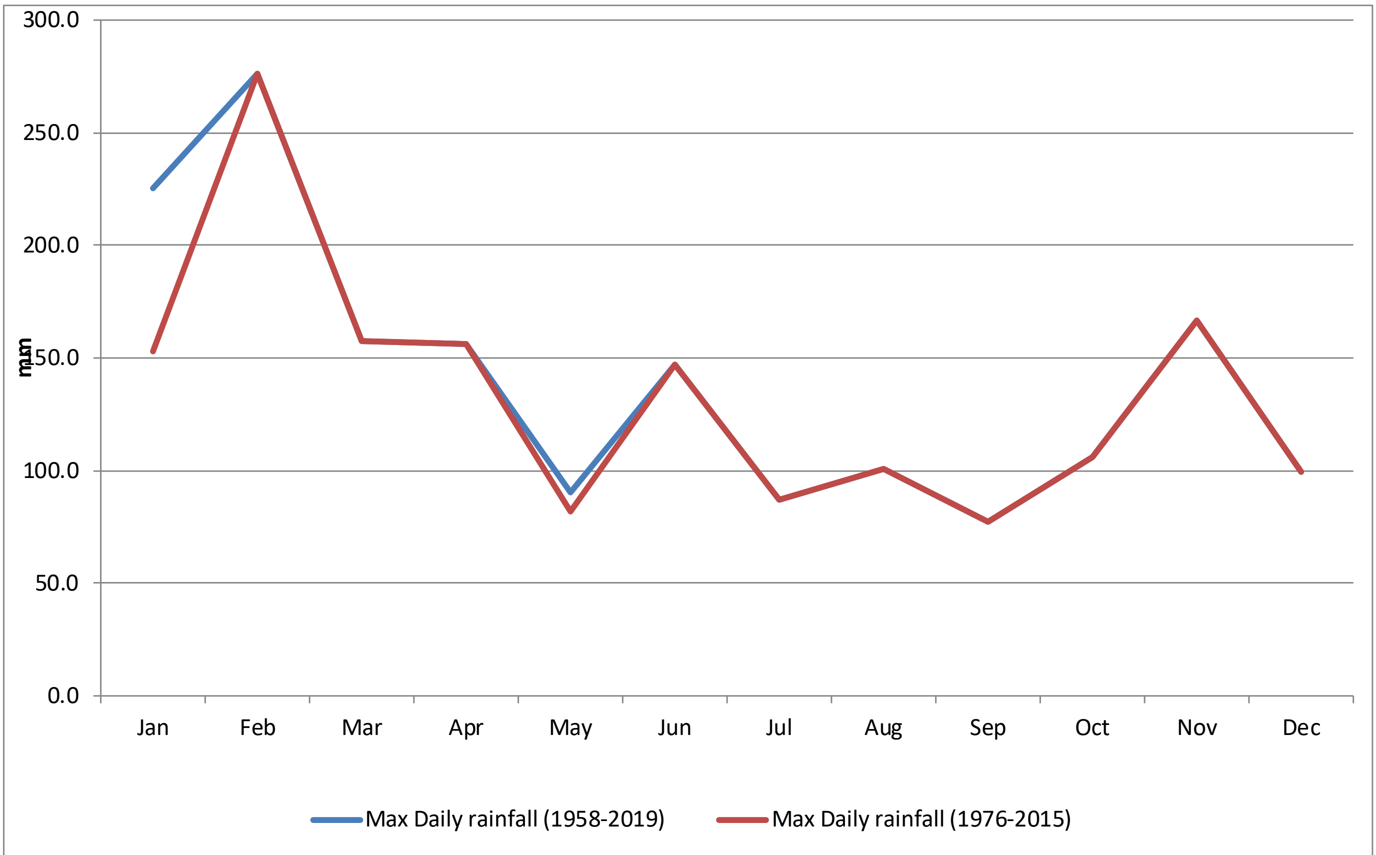



Figure 4-3 Highest recorded daily rainfall totals for the Southern Hunter

## 4.2.2 Temperature

### *Annual temperature*

**Table 4-1** shows the maximum, average and minimum annual temperatures for the Southern Hunter. There are consistent trends for increased maximum temperatures since about 2000. This trend is most obvious for maximum and minimum recorded temperatures. Average temperatures over the climate change projection reference period are 0.1 degrees Celsius to 0.2 degrees Celsius warmer than over the entire period of record.

Table 4-1 Maximum, average and minimum temperatures (degrees Celsius) for the Southern Hunter.

| Temperature measurement | 1951-2019 | 1976-2015 |
|---|---|---|
| Maximum recorded maximum temperature | 45.5 | 44.8 |
| Average maximum temperature | 23.2 | 23.4 |
| Average temperature | 17.8 | 17.9 |
| Average minimum temperature | 12.4 | 12.4 |
| Minimum recorded minimum temperature | -3.9 | -3.4 |

Source: BoM stations 61078. Table includes a comparison of the full period of record and the 1976-2015 climate change projection reference period. $T_{max}$ – maximum temperature; $T_{min}$ – minimum temperature.

There are consistent trends for increased maximum temperatures since about 2000 as shown in **Figure 4-4.** This trend is most obvious for maximum and minimum recorded temperatures.

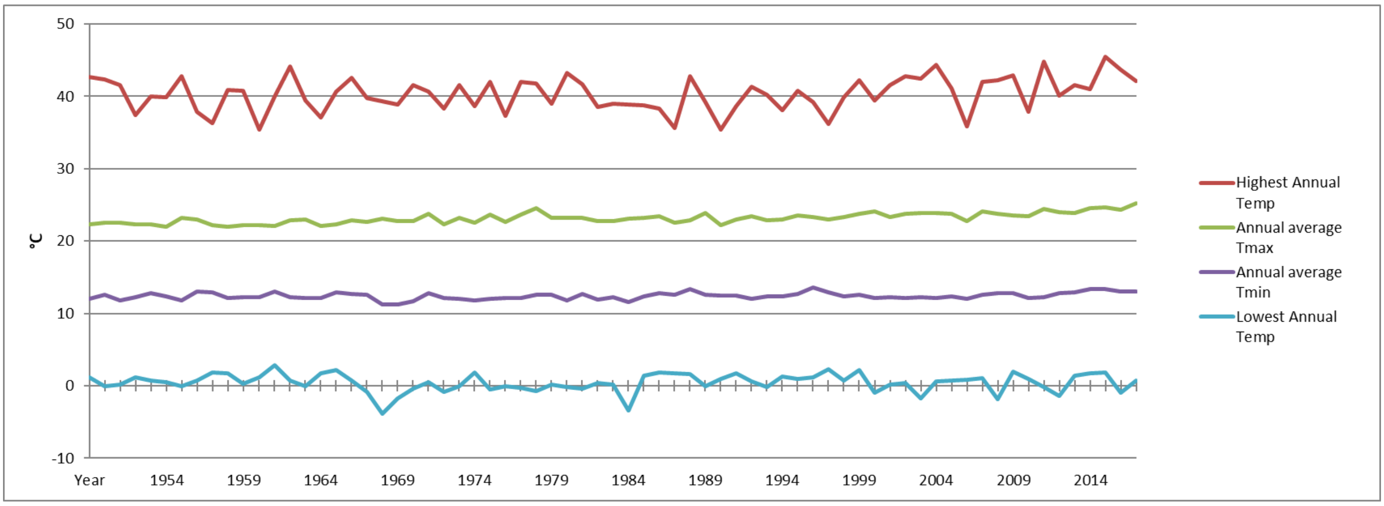



Figure 4-4 Temperature records for RAAF Williamtown, Southern Hunter

Source: BoM station 61078. Data presented for highest and lowest temperatures recorded each year and average $T_{max}$ (daily maximum temperature) and $T_{min}$ (daily minimum temperature) for each year of record, 1951-2019.

### *Monthly temperatures*

**Figure 4-5** shows the maximum, average and minimum monthly temperatures for the Southern Hunter. Monthly average and average maximum temperatures for the climate change projection reference period are typically higher than those for the full period of record. Average monthly minimum temperatures are generally the same.

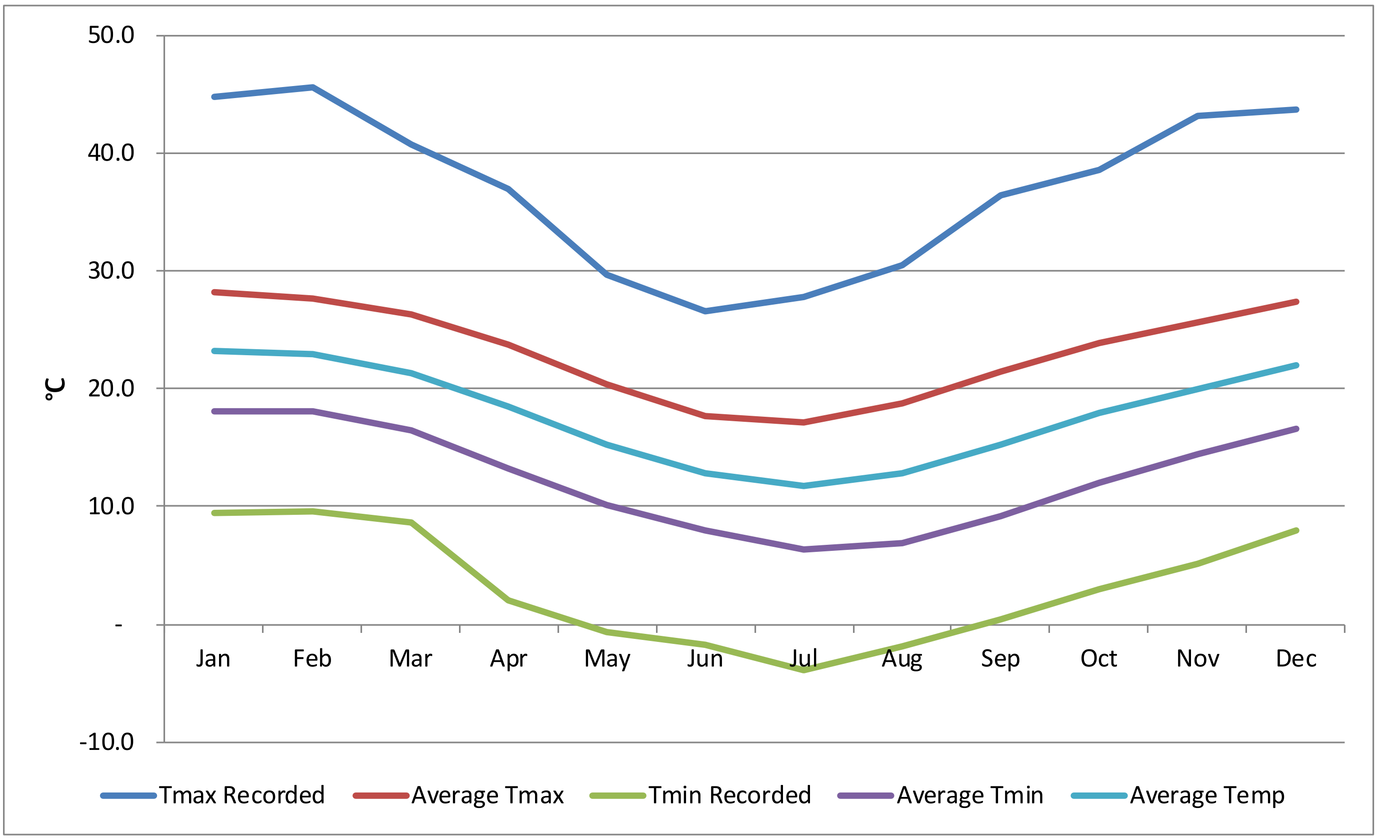
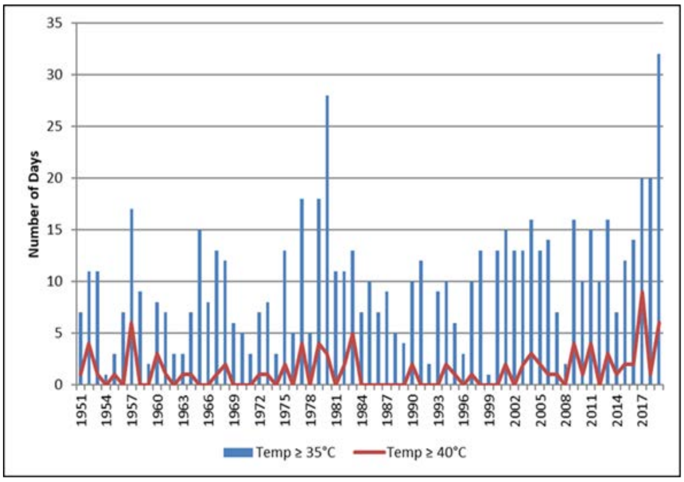



Figure 4-5 Monthly temperature profile for the Southern Hunter

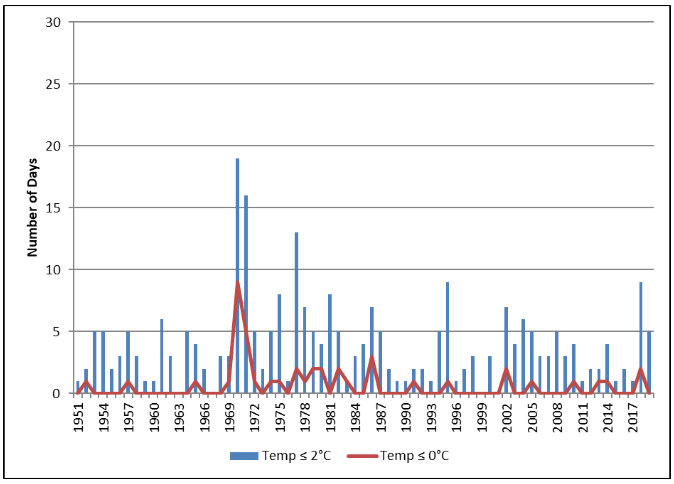
Source: BoM station 61078. Figure plots maximum and minimum temperatures recorded in each month ($T_{max}$/$T_{min}$ recorded), monthly average temperature and average monthly maximum and minimum temperature ($T_{max}$/$T_{min}$).

### *Daily temperature extremes*

As shown in **Figure 4-5**, days in which maximum temperatures exceed 35 degrees Celsius are reasonably common in the Southern Hunter, while days during which minimum temperatures are two degrees Celsius or less are less common as shown in **Figure 4-6**.




a) Incidence of days with maximum temperatures of 35 degrees Celsius or 40 degrees Celsius or more.




b) Incidence of days with minimum temperatures of 0 degrees Celsius or 2 degrees Celsius or less.

Figure 4-6 Incidence of days for Southern Hunter with extreme low or high temperatures

Source: BoM station 61078.

### *Heatwaves*

A heatwave may be defined as an event with at least two consecutive days of high temperature. The annual frequency of heatwave and severe heatwave days during the period of record for the Southern Hunter is plotted in **Figure 4-7**. Over the period of record there has been an annual average of 23.8 heatwave days and 2.2 severe heatwave days. The average incidence of heatwave days and severe heatwave days during the climate change projection reference period was 24.8 days per year and 1.9 days per year respectively.

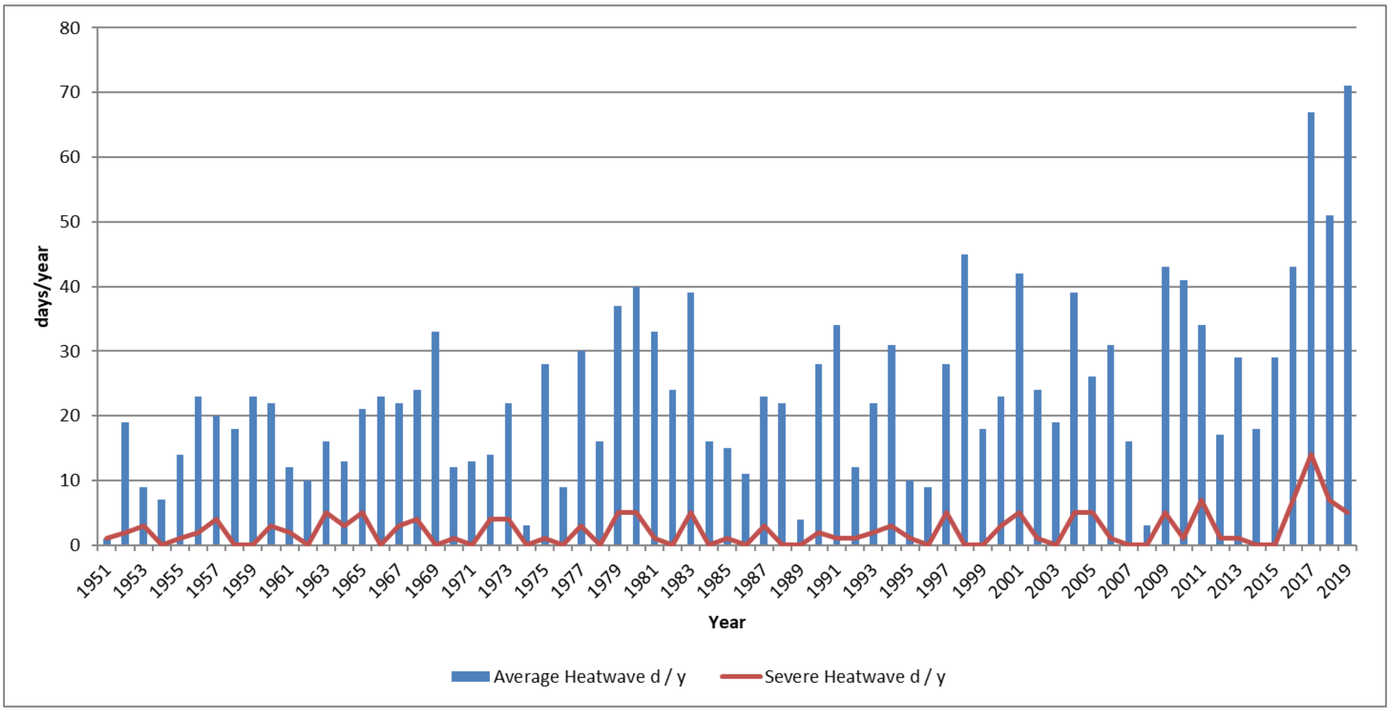



Figure 4-7 Annual incidence of heatwave (EHF>0) and severe heatwave days ($EHF>EHF_{85}$) for the Southern Hunter.

Source of underpinning data: BoM station 61078.

## 4.2.3 Wind

Wind speeds in the Southern Hunter typically increase through the day (**Figure 4-8**). Maximum recorded wind gusts in the Southern Hunter range between 98 kilometres per hour in February and 137 kilometres per hour in August and December.

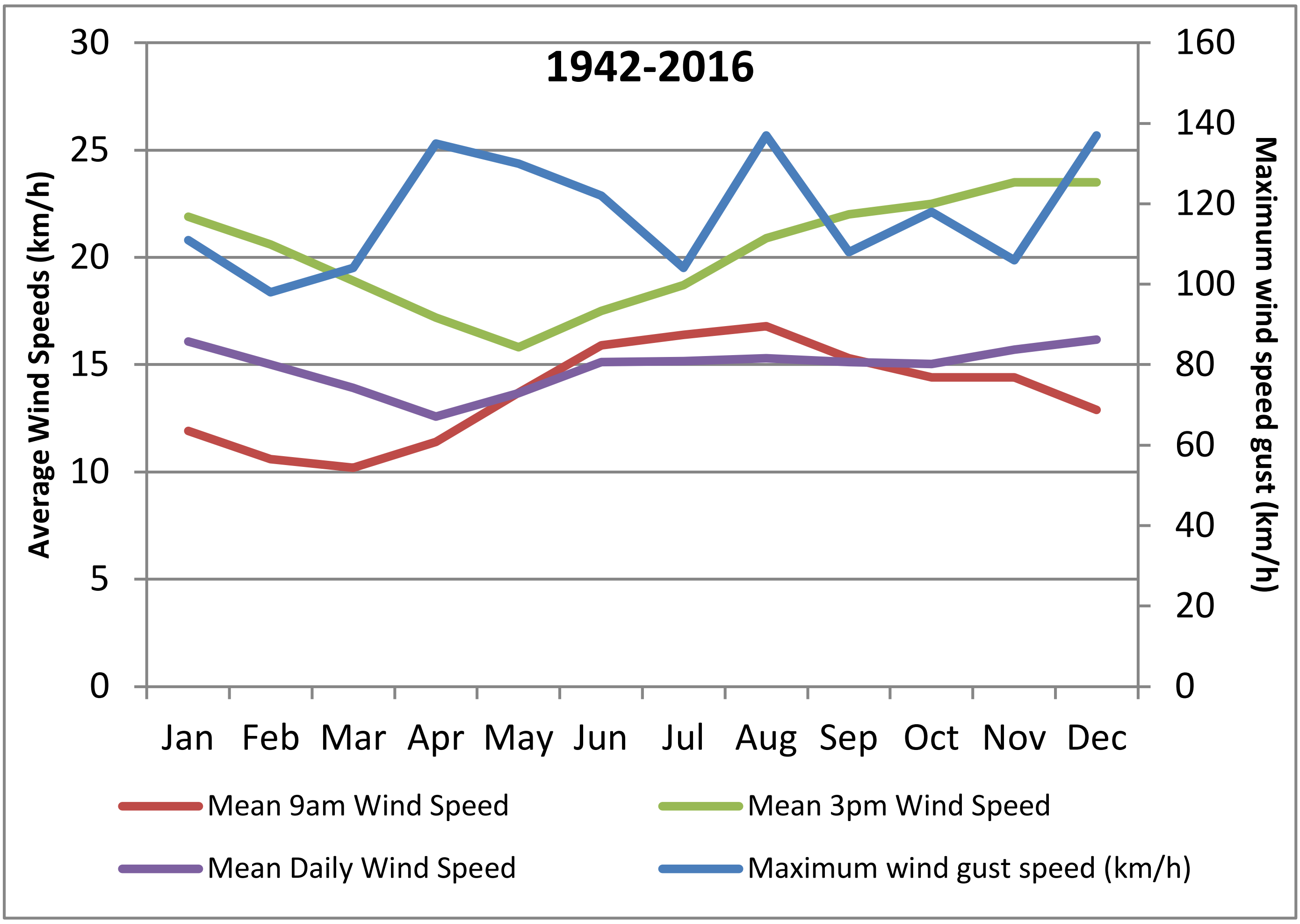



Figure 4-8 Monthly patterns in wind speed for the Southern Hunter

Source: BoM station 61078. Graph presents average daily wind speed (from 24 h wind run measurements), average 9 am and 3 pm wind speeds and maximum recorded wind gust for each month.

# 4.3 Climate change projections

## 4.3.1 Climate change

Carbon dioxide ($CO_2$) is a vital gas for photosynthesis and global climate regulation. Since $CO_2$ and other "greenhouse gases" trap long wave radiation, changes in their concentrations in the atmosphere would influence the Earth's radiation balance and contribute to the warming of both the atmosphere and the Earth's surface. This phenomenon is known as the greenhouse effect.

## 4.3.2 Overview

Climate change projections are derived using general circulation models (often referred to as global climate models or GCMs), which simulate the ocean, atmospheric and land surface processes which influence climate. The models are run under historical conditions and with scenarios representing long-term trajectories for greenhouse gas emissions or their effect on radiative forcing.

The GCMs selected as most able to model Australian East Coast climate were used to develop climate change projections to 2090. It is anticipated that the three scenarios included in this analysis represent a plausible range in projections for the course of the 21st century. They capture the central tendency for changes in rainfall and temperature for a lower radiative forcing scenario for 2030, 2050 and 2090. While some models project the lower emissions scenario would result in wetter conditions, this is not reflective of the broader group of more reliable models.

The IPCC's Fifth Assessment Report (AR5) (IPCC, 2013) provides a synthesis of climate change modelling carried out by leading international climate research organisations. Representative concentration pathways (RCP) were identified under AR5, one of which (RCP8.5) is used throughout this report as it reflects the highest of the emissions scenarios considered in AR5. They follow the projections for this scenario through time from 2030 to 2090.

The reliability of climate change projections varies between climate variables. In general, global projections are more certain than regional projections and temperature projections are more certain than those for rainfall. Changes in average conditions are also more certain than changes in extremes.

### 4.3.3 Rainfall

#### *Annual rainfall*

Projected changes in rainfall for the Southern Hunter are shown in **Table 4-2**. The average rainfall is projected to become less in 2030 and the climate is projected to become drier in 2050 and 2090. Maximum annual rainfall is projected increase very slightly between the baseline and 2090, while minimum annual rainfall is projected to decline by 2090.

Table 4-2 Annual rainfall projections for the Southern Hunter for 2030, 2050 and 2090, RCP8.5

| | 1976-2015 | 2030 (2021-2040) | 2050 (2041-2060) | 2090 (2081-2100) |
|---|---|---|---|---|
| Maximum (mm) | 1,739 | 1,739 | 1,723 | 1,784 |
| Mean (mm) | 1,122 | 1,063 | 1,053 | 1,028 |
| Minimum (mm) | 541 | 492 | 479 | 448 |

Based on BoM station 61078 and climate change factors from the Climate Futures Tool (***www.climatechangeinaustralia.gov.au***).

#### *Monthly rainfall*

**Figure 4-9** and **Figure 4-10** show projected changes in average and extreme monthly rainfall respectively. Seasonal patterns in rainfall are not projected to change much to 2030, although winter rainfall is projected to be slightly less.

#### *Daily rainfall*

With climate change, extreme daily rainfall values are generally projected to increase (**Figure 4-10**) in summer in 2090. Design of the project has considered very low frequency rainfall events, with average recurrence intervals (ARI) in excess of 500 years. Atmospheric warming may increase the frequency of the current 500-year ARI event, as well as increase the rainfall total during the projected 500-year daily rainfall event with 2050 or 2090 climate.

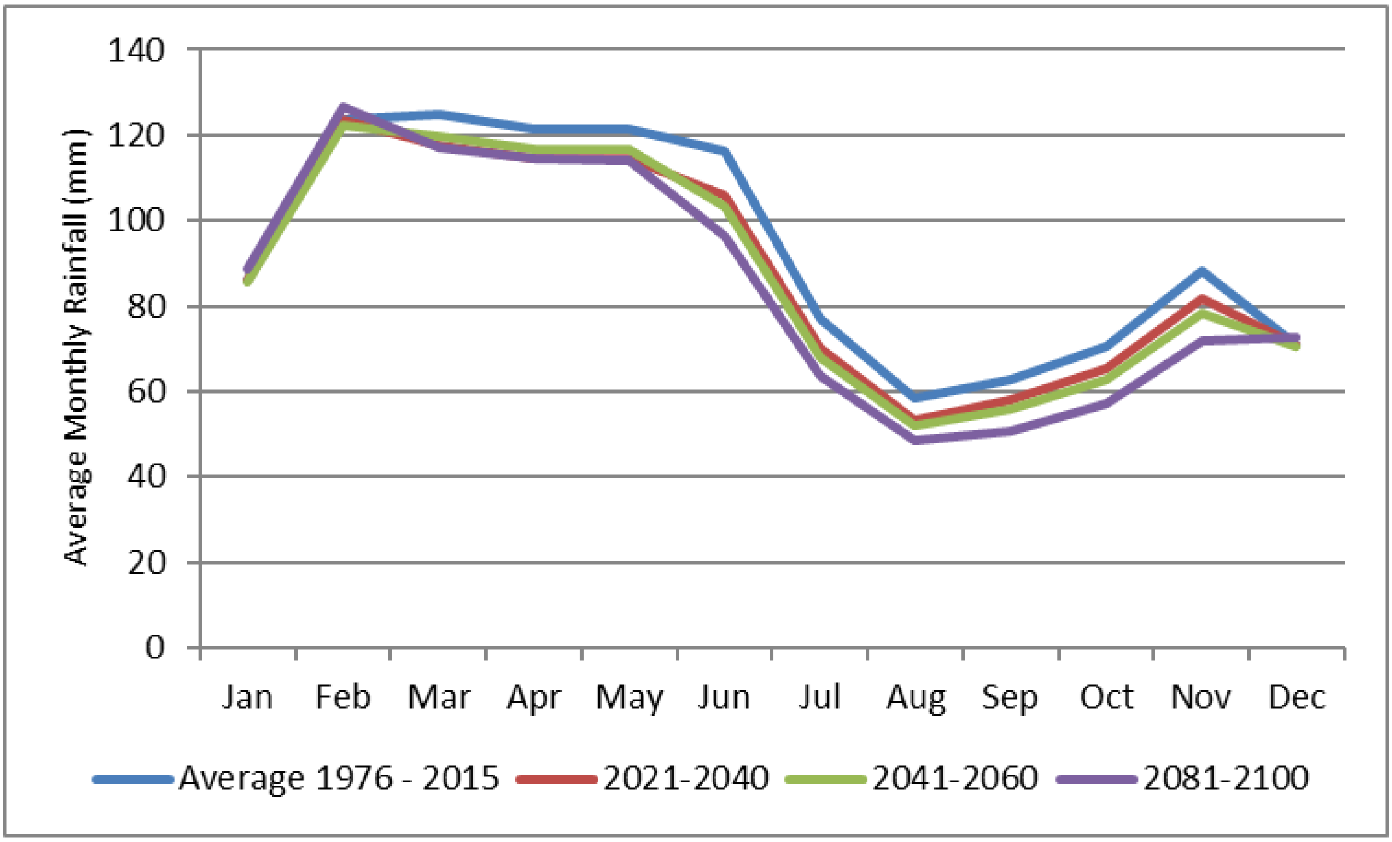



Figure 4-9 Change in average monthly rainfall (millimetres)

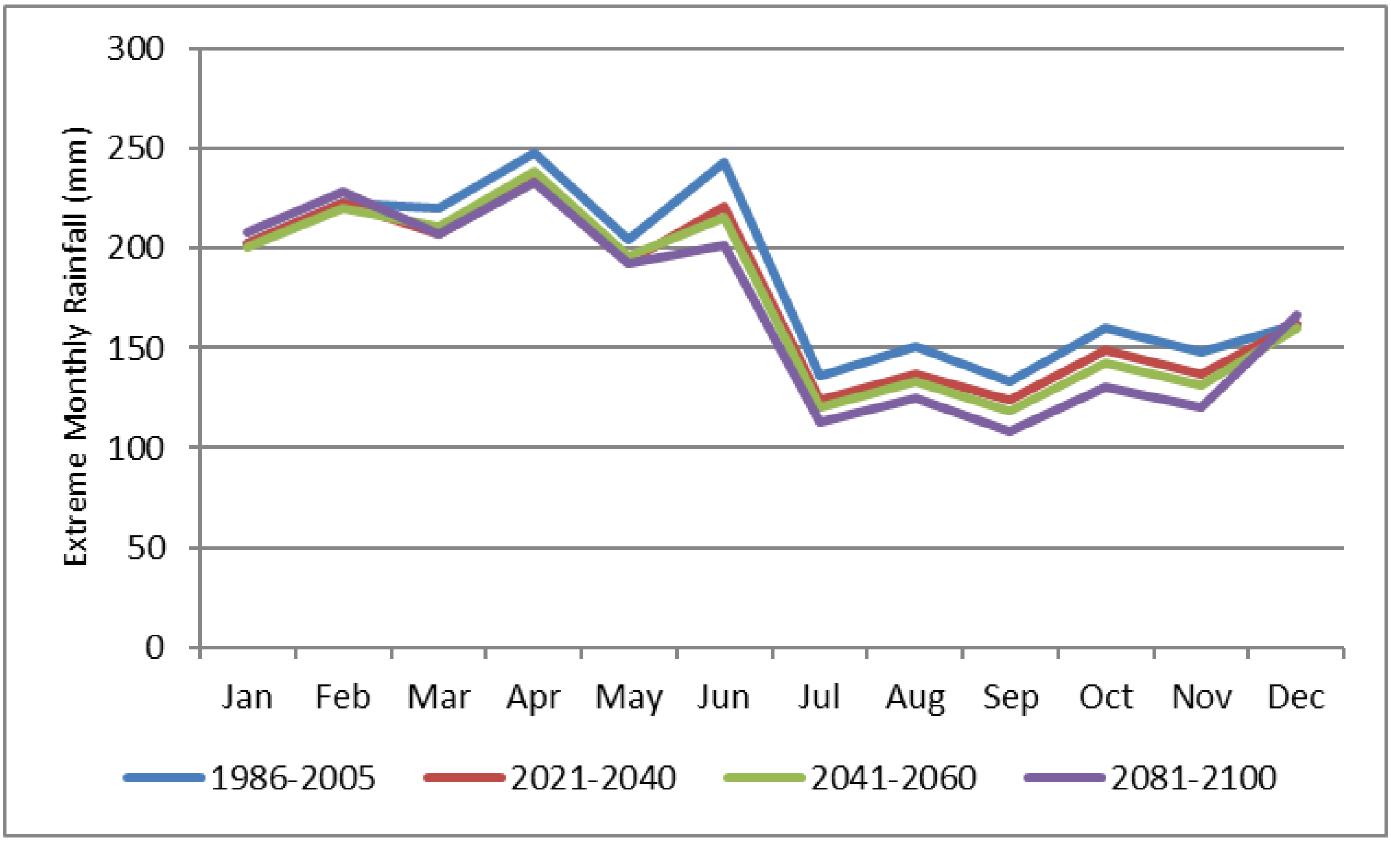



Figure 4-10 Change in extreme monthly rainfall (millimetres)

## 4.3.4 Temperature

### *Annual temperature*

Projected temperatures in the Southern Hunter are shown in **Table 4-3**. Average and extreme maximum and minimum temperatures are projected to increase 3.8 degrees Celsius and 3.9 degrees Celsius, respectively, under the ‘RCP8.5’ scenario (which represents a ‘business as usual’ scenario where no efforts are made to address climate change). The highest projected temperature exceeds the highest recorded temperature for the RAAF Williamtown meteorological station in the projections for 2030 onwards.

The historical trend for reduced incidence of extreme cold conditions is projected to continue (albeit with more recent slight increase in the number of these days). The number of days with freezing minimum temperatures is projected to reduce, with temperatures being less severe.

Table 4-3 Maximum, average and minimum temperatures (degrees Celsius) for the Southern Hunter in response to projected climate change.

| Parameter | 1951-2019 | 1976-2015 | 2030 RCP8.5 | 2050 RCP 8.5 | 2090 RCP8.5 |
|---|---|---|---|---|---|
| Maximum $T_{max}$ | 45.5 | 44.8 | 46.10 | 46.90 | 48.90 |
| Average $T_{max}$ | 23.2 | 23.4 | 24.59 | 25.39 | 27.29 |
| Average temperature | 17.8 | 17.9 | 19.00 | 19.80 | 21.80 |
| Average $T_{min}$ | 12.4 | 12.4 | 13.52 | 14.32 | 16.32 |
| Minimum $T_{min}$ | -3.9 | -3.4 | -2.40 | -1.60 | 0.40 |

Base data from BoM stations 61078. Table includes a comparison of the full period of record, the 1976-2015 climate change projection reference period and RCP8.5 climate change scenarios for 2030 (2021-2040), 2050 (2041-2060) and 2090 (2081-2100). $T_{max}$ – maximum temperature; $T_{min}$ – minimum temperature

### *Monthly temperatures*

Climate change is projected to increase average and extreme temperatures for the Southern Hunter throughout the year (**Figure 4-11**). Temperatures through the cooler months of winter are projected to increase to a lesser extent than those during other times of year. The range in average temperatures is projected to from 11.9-23.4 degrees Celsius during the climate change reference period to 15.8 to 27.2 degrees Celsius in 2090.

Days with maximum temperatures above 40 degrees Celsius are projected to increase from November to February, to September to April.

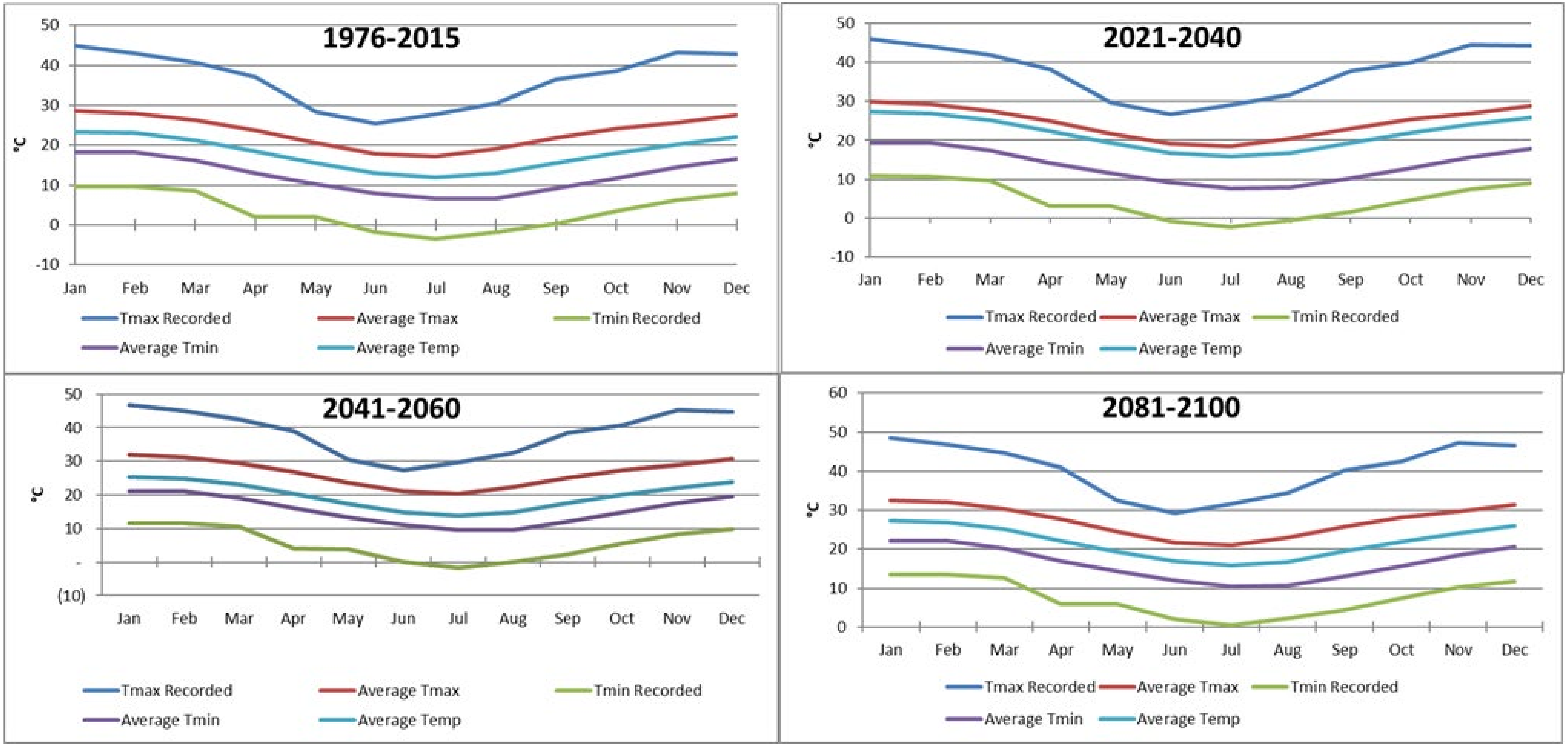



Figure 4-11 Monthly temperature profiles for the Southern Hunter (climate change reference period and 2030, 2050 and 2090 RCP8.5 climate change scenarios)

Base data from: BoM 61078. Figures plot maximum and minimum temperatures recorded in each month ($T_{max}/T_{min}$ recorded), monthly average temperature and average monthly maximum and minimum temperature ($T_{max}/T_{min}$).

### *Daily temperature extremes*

Days in which maximum temperatures reach high temperature benchmarks (35/40/45 degrees Celsius) in the Southern Hunter are projected to increase in frequency (**Table 4-4**). The frequency of days with temperatures exceeding 35 degrees Celsius is projected to more than triple relative to the climate change projection reference period by 2090. Days with temperatures exceeding 40 degrees Celsius are projected to experience a fivefold increase in frequency. Historically, temperatures exceeding 45 degrees Celsius have only been experienced in the last few years. Such days are projected to be experienced almost once every two years by 2090.

Days with extreme minimum temperatures are projected to decline in frequency over the course of this century under the RCP8.5 scenario. Freezing days occur at a rate of approximately 0.5 days per year over the reference period and are projected to decline to zero over the reference period by 2090. Days of frost are also projected to decline to zero days per year from 3.6 days per year by 2090.

Table 4-4 Frequency of extreme high and low temperatures (degrees Celsius) for the Southern Hunter in response to projected climate change, RCP8.5 scenario

| Temperature | 1951-2019 | 1976-2015 | 2030 RCP8.5 | 2050 RCP8.5 | 2090 RCP8.5 |
|---|---|---|---|---|---|
| Days/y ≥45 degrees Celsius | <0.1 | 0 | 0.1 | 0.1 | 0.6 |
| Days/y ≥40 degrees Celsius | 1.4 | 1.3 | 2.5 | 3.6 | 6.6 |
| Days/y ≥35 degrees Celsius | 10.1 | 10.5 | 15.2 | 19.3 | 31.4 |
| Days/y ≤2 degrees Celsius | 3.9 | 3.6 | 1.4 | 0.7 | 0 |
| Days/y ≤0 degrees Celsius | 0.6 | 0.5 | 0.1 | 0.1 | 0 |

Base data from: BoM stations 61078.

### *Heatwaves*

The frequency of days with an Excess Heat Factor (EHF) is greater than zero (resulting in a heatwave event) excess heat and severe heatwave conditions is projected to increase more than fourfold between the climate change reference period and 2090 (**Table 4-5**), with the frequency of such days increasing from 24.75 occurrences per year to 117 occurrences per year. Severe heatwave days (denoted as $EHF>EHF_{85}$, the 85th percentile value of excess heat factor) are projected to increase in frequency by a similar order.

Table 4-5 Change in incidence and duration of heatwaves in the Southern Hunter in response to projected climate change, RCP8.5 scenario

| Heatwave incidence | 1951-2019 | 1976-2015 | 2030 RCP8.5 | 2050 RCP 8.5 | 2090 RCP8.5 |
|---|---|---|---|---|---|
| Days/y EHF>0 | 23.8 | 24.8 | 45.5 | 66.2 | 117 |
| Days/y $EHF>EHF_{85}$ | 2.2 | 1.8 | 4.1 | 5.9 | 13.9 |

Base data from: BoM stations 61078. Analysis approach based on Nairn and Fawcett (2013). EHF (excess heat factor) >0 denotes a heatwave event. $EHF>EHF_{85}$ ($85^{th}$ percentile value of excess heat factor) denotes an extreme heatwave.

### *Wind*

Climate change is anticipated to have only marginal impact on average and extreme wind events (**Figure 4-12**). Average wind speed is projected to decline by up to five per cent in all seasons, except winter in 2050 and summer in 2090 under the RCP8.5 scenario, when small increases in wind speed are projected.

The severity of the 1 in 20-year wind gust is projected to decline slightly in summer and autumn throughout the projection period and in winter in 2030 and spring in 2090, under the RCP8.5 scenario.

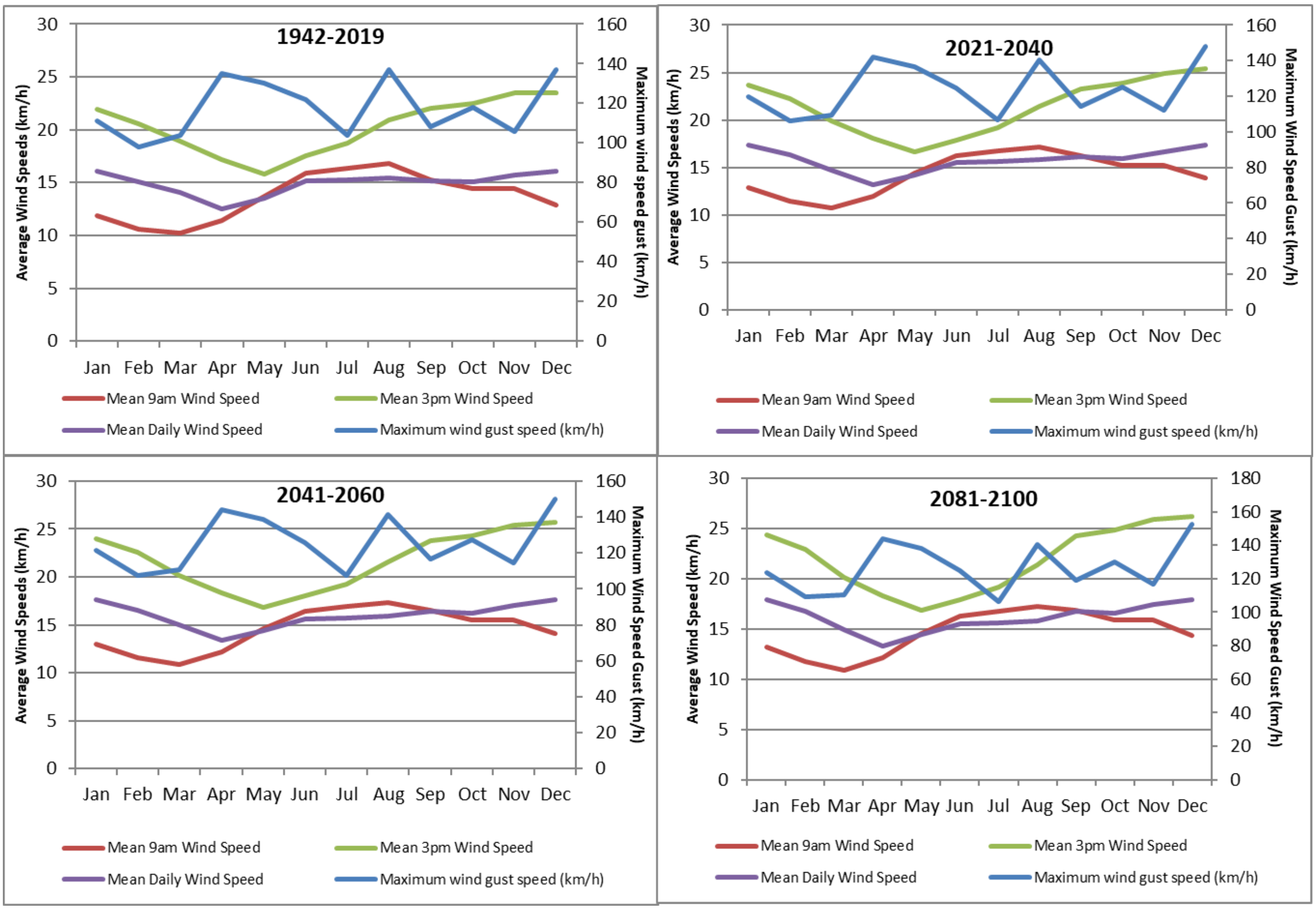



Figure 4-12 Projected changes in average wind speed for Southern Hunter, RCP8.5 scenario.

Base data from: BoM stations 61078. Projections based on change from full length of record (1942-2019) rather than the climate change reference period (1976-2015).

### 4.3.5 Discussion

The Southern Hunter has a highly variable climate. Annual and season rainfall and temperatures vary over a wide range. The area is periodically subject to extreme weather and climatic events which may disrupt the community, threaten health and safety and damage infrastructure and the environment. The Southern Hunter’s climate is also changing, with signs evident in records of temperature. Those and other changes are projected to continue as increasing atmospheric concentrations of greenhouse gases drive warming and other changes in the climate system.

Over the course of the 21st century, the Southern Hunter’s climate is expected to become:

- Warmer: with increased average and extreme high temperatures, but fewer extreme cold temperatures
- Drier: rainfall is projected to decline. Reduced annual rainfall and increased evaporation is anticipated to result in drier soil conditions, less run-off in water supply catchments and reduced average river flows and groundwater recharge
- Subject to more extreme weather conditions: hydrological cycles are projected to intensify with atmospheric warming, leading to more intense extreme rainfall events. Heatwaves would become more frequent, intense and prolonged. While extreme weather conditions may become more extreme, they may become less frequent.

Projected changes in climate over the course of the 21st century may be disruptive to the operations of the project and users of the Southern Hunter road network, increase operations and maintenance costs and shorten its operating life. While climate change projections are uncertain, the opportunity exists to assess its implications for the project and to incorporate appropriate, proportional measures to help ensure its resilience under the climate it would experience over its operating life.

# 5. Impact assessment

## 5.1 Greenhouse gas emission assessment

This section presents the greenhouse gas estimates for the project. The full input data for these estimates and relevant assumptions are provided in **Appendix A**. While construction of the project would generate GHGs as described in the below section, the resulting climate change impacts are not anticipated to occur during construction due to the short-term nature of construction. As a result, the risks associated with climate change are operational and have been assessed in **Section 5.2**.

### 5.1.1 Construction greenhouse gas emissions

#### *Construction fuel combustion*

Fuel usage and resultant emissions are described in **Table 5-1**. Combustion factors for demolition, earthworks and vegetation clearance based on the amount of material being removed have been provided in **Appendix A**. In summary, construction fuel combustion is estimated to produce 31,669 tonnes of $CO_2e$ throughout the duration of construction (based on a construction period of 2024 to 2028 – 36 months).

Table 5-1 Projected emissions from fuel combustion during construction

| Source | Fuel | Diesel combusted (kL) | Scope 1 EF (t $CO_2e$/kL) | Scope 3 EF (t $CO_2e$/kL) | Scope 1 emissions (t $CO_2e$) | Scope 3 Emissions (t $CO_2e$) | Total Emissions (t $CO_2e$) |
|---|---|---|---|---|---|---|---|
| Site offices and site vehicles | Diesel | 234 | 2.71 | 0.139 | 634 | 33 | 667 |
| Construction works | Diesel | 5,759 | 2.71 | 0.139 | 15,607 | 801 | 16,407 |
| Demolition and earthworks | Diesel | 4,656 | 2.71 | 0.139 | 12,618 | 647 | 13,265 |
| Vegetation removal | Diesel | 467 | 2.71 | 0.139 | 1,266 | 65 | 1,330 |
| **Total** | | **11,116** | | | **30,124** | **1,545** | **31,669** |

### *Construction material embedded emissions*

The materials required for the project and their associated embedded emissions are provided in **Table 5-2**. In summary, 151,210 tonnes of $CO_2$e are estimated to be embedded in the materials used for the construction of the project.

Table 5-2 Material quantities and embedded emissions

| Material | Material used (t) | EF (t $CO_2$e/t) | Scope 1 emissions (t $CO_2$e) | Scope 2 emissions (t $CO_2$e) | Scope 3 emissions (t $CO_2$e) |
|---|---|---|---|---|---|
| Aggregate | 854,587 | 0.006 | - | - | 5,128 |
| Asphalt and bitumen | 2,495 | 0.390 | - | - | 973 |
| Cement and concrete | 403,257 | 0.200 | - | - | 80,651 |
| Steel | 27,736 | 2.324 | - | - | 64,458 |
| **Total** | **1,288,076** | | **-** | **-** | **151,210** |

### *Transport of materials, fill and spoil*

The Carbon Gauge tool used to estimate emissions does not calculate the combustion of fuel associated with the transport of materials to site if the transport distance is less than 50 kilometres. As all materials required for the project would be sourced from within 50 kilometres, the transport of these materials has not been considered in this assessment. Similarly, as the source and destination of fill and spoil would also be less than 50 kilometres away, their transport has also not been considered significant and has not been considered in this assessment.

### *Vegetation clearance*

**Table 5-3** shows the vegetation clearance emissions associated with the project, based on the relevant biomass vegetation class and the total amount of land cleared within each class. In summary, clearing of vegetation is estimated to produce 60,384 tonnes of $CO_2$e.

Table 5-3 Vegetation clearance emissions

| Vegetation Class | EF (t $CO_2$e/ha) | Vegetation cleared (ha) | Scope 1 emissions (t $CO_2$e) | Scope 2 emissions (t $CO_2$e) | Scope 3 emissions (t $CO_2$e) |
|---|---|---|---|---|---|
| Class A (Rainforest and vine thicket) | 384 | 0 | 0 | - | - |
| Class B (Eucalypt tall open forest) | 401 | 12 | 4,754 | - | - |
| Class C (Open forest) | 521 | 90 | 47,551 | - | - |
| Class I (Grasslands) | 110 | 69 | 8,079 | - | - |
| **Total** | | **171** | **60,384** | **-** | **-** |

## 5.1.2 Operational greenhouse gas emissions

### *Grid electricity consumption*

Electricity usage details from street lighting and traffic signals are provided in **Appendix A**. **Table 5-4** shows the annual energy usage generated by street lighting and traffic signals during the operation of the project, and the resultant emissions. In summary, operational electricity usage by the project is estimated to produce 217 tonnes of $CO_2$e per year.

Table 5-4 Annual emissions from electricity consumption

| Electricity consumption source | Scope 2 EF (t $CO_2$e/kWh) | Scope 3 EF (t $CO_2$e/kWh) | Annual electricity consumed (kWh/year) | Annual Scope 1 emissions (t $CO_2$e/ year) | Annual Scope 2 emissions (t $CO_2$e/ year) | Annual Scope 3 emissions (t $CO_2$e/ year) | Annual total emissions (t $CO_2$e/ year) |
|---|---|---|---|---|---|---|---|
| Street lighting | $0.81 \times 10^{-3}$ | $0.09 \times 10^{-3}$ | 229,111 | - | 186 | 21 | 206 |
| LED traffic lights | $0.81 \times 10^{-3}$ | $0.09 \times 10^{-3}$ | 12,111 | - | 10 | 1 | 11 |
| **Total** | | | **241,222** | **-** | **195** | **22** | **217** |

### *Maintenance*

**Table 5-5** shows the annual emissions resulting from maintenance activities during the operation of the project, based on the types of pavements required to be maintained. In summary, maintenance activities are estimated to produce 361 tonnes of $CO_2$e per year.

Table 5-5 Annual maintenance emissions

| Pavement type | Annual maintenance Scope 1 emissions (t $CO_2$e) | Annual maintenance Scope 2 emissions (t $CO_2$e) | Annual maintenance Scope 3 emissions (t $CO_2$e) | Total annual maintenance emissions (t $CO_2$e) |
|---|---|---|---|---|
| Full depth asphalt | 27 | - | 35 | 62 |
| Deep strength asphalt | 7 | - | 9 | 16 |
| Plain concrete | 245 | - | 38 | 283 |
| **Total** | **279** | **-** | **82** | **361** |

### *Traffic*

The annual projected $CO_2$e emissions from traffic for each scenario described in **Section 3.1.3** are shown in **Table 5-6**.

Table 5-6 Annual projected $CO_2$e emissions from traffic

| Year | Strategic traffic model reference | Assessment scenario | Comment | Estimated $CO_2$e emissions (t $CO_2$e/year) |
|---|---|---|---|---|
| Year of opening (2028) | Base Case/No Project | 'Without project' 2028 | The existing road layout, with only maintenance performed**, without the project** | 198,838 |
| | Direct M12RT Contribution | 'With Project' 2028 | Emissions relating to traffic using the roads constructed as part of the project | 35,036 |
| | Change in traffic on pre-existing roads due to M12RT | 'With Project' 2028 | Emissions relating to changes in traffic on roads within the study area as a result of the project | 177,707 |
| | Cumulative effect of M12RT and pre-existing roads | 'With Project' 2028 | Emissions across the entire study area resulting from changes to traffic on existing roads and traffic on the roads constructed as part of the project (a sum of the two rows above) | 212,743 |
| Ten years after opening (2038) | 'Without project' | 'Without project' 2038 | Traffic conditions 10 years after the planned opening year, **without the project** | 217,997 |
| | 'With Project' Direct M12RT Contribution | 'With Project' 2038 | Emissions relating to traffic using the roads constructed as part of the project, 10 years after the planned opening year | 40,014 |
| | 'With Project' Change in traffic on pre-existing roads | 'With Project' 2038 | Emissions relating to changes in traffic on roads within the study area as a result of the project, 10 years after the planned opening year | 201,709 |
| | 'With Project' M12RT and pre-existing roads | 'With Project' 2038 | Emissions across the entire study area resulting from changes to traffic on existing roads and traffic on the roads constructed as part of the project (a sum of the two rows above), 10 years after the planned opening year | 241,724 |

In order to determine the overall $CO_2$e contribution of traffic to the project $CO_2$e emissions, the differences between the 'Without project' and 'With Project' M12RT and pre-existing roads' emissions have been calculated. This difference represents the change in $CO_2$e emissions as a direct result of the project. These have been detailed in **Table 5-7** below.

Table 5-7 $CO_2e$ Contribution of traffic to the project emissions

| Emissions Source | Scope 3 Emissions as a result of traffic (t $CO_2e$/year) | | | | | |
|---|---|---|---|---|---|---|
| | 'Without project' 2028 | 'With project' 2028 | Project Contribution 2028 | 'Without project' 2038 | 'With project' 2038 | Project Contribution 2038 |
| Project roads | 0 | 35,036 | 35,036 | 0 | 40,014 | 40,014 |
| Pre-existing roads | 198,838 | 177,707 | -21,131 | 217,997 | 201,709 | -16,288 |
| **Total** | **198,838** | **212,743** | **13,905** | **217,997** | **241,724** | **23,726** |

Considering the difference between the 'Without project' and 'With Project' scenarios, the 2028 emission contribution of the traffic is 13,905 t $CO_2e$ per year and the 2038 emission contribution is 23,726 t $CO_2e$ per year.

In order to model 100 years of traffic operations, it is assumed that the first 10 years of operation produce emissions equal to the 2028 contribution annually, while every year afterwards produces emissions equal to the 2038 contribution annually. It is noted that no assessment of a move to low or zero carbon fuels (including a switch to electric vehicles) has been modelled.

**Table 5-7** shows that the emissions of the scenarios that include the project (i.e. 'With Project') produce more emissions than those that do not include the project (i.e. 'Without project'). Regarding this, **Table 5-8** displays the annual 'vehicle kilometres travelled' (the numbers of vehicles travelled per kilometre of the study area roads). As displayed in the table, the 'vehicle kilometres travelled' (vkt) are higher in the equivalent 'With Project' scenario compared to 'Without project' scenario, while the t $CO_2e$/vkt values are lower in the 'With Project' scenarios compared to the 'Do Minimum' scenarios.

This indicates that roads are less congested in the 'With Project' scenario, meaning that more vehicles can use the roads in the 'With Project' scenario, leading to the higher $CO_2e$ per year values. The t $CO_2e$/vkt values also indicate that in terms of emissions produced per kilometre travelled, the 'With Project' scenario is more carbon efficient than the 'Without project' scenario.

Table 5-8 Comparison of vehicle kilometres travelled between model scenarios

| Strategic traffic model reference | Scope 3 emissions (t $CO_2e$/year) | Vehicle kilometres travelled (vkt) | t $CO_2e$/vkt |
|---|---|---|---|
| 'Without project' 2028 | 198,838 | 921,662,910 | 0.000216 |
| 'With project' 2028 | 212,743 | 1,009,609,085 | 0.000211 |
| 'Without project' 2038 | 217,997 | 1,033,154,080 | 0.000211 |
| 'With project' 2038 | 241,724 | 1,174,701,268 | 0.000206 |

## 5.1.3 Combined estimated greenhouse gas emissions

The combined emissions of the construction of the project, as well as the operation of the project over the design life of the project (100 years) are detailed in **Table 5-9**.

Overall, the project is estimated to result in the generation of:

- 243 kilotonnes of carbon dioxide equivalent ($CO_2e$) during the construction of the project
- 23 kilotonnes of $CO_2e$ annually during the operation of the project.

Table 5-9 Combined emission contributions

| Emissions source | Emissions | | | |
|---|---|---|---|---|
| | Scope 1 ($t\ CO_2e$) | Scope 2 ($t\ CO_2e$) | Scope 3 ($t\ CO_2e$) | Total ($t\ CO_2e$) |
| **Construction** | | | | |
| **Fuel consumption** | | | | |
| Site offices and site vehicles | 634 | - | 33 | 667 |
| Construction works | 15,607 | - | 801 | 16,408 |
| Demolition and earthworks | 12,618 | - | 647 | 13,265 |
| Vegetation removal | 1,266 | - | 65 | 1,331 |
| **Materials** | | | | |
| Aggregate | - | - | 5,128 | 5,128 |
| Asphalt and bitumen | - | - | 973 | 973 |
| Cement and concrete | - | - | 80,651 | 80,651 |
| Steel | - | - | 64,458 | 64,458 |
| **Vegetation clearance** | | | | |
| Class A (Rainforest and vine thicket) | - | - | - | - |
| Class B (Eucalypt tall open forest) | 4,754 | - | - | 4,754 |
| Class C (Open forest) | 47,551 | - | - | 47,551 |
| Class I (Grasslands) | 8,079 | - | - | 8,079 |
| **Total construction emissions** | **90,509** | **-** | **152,756** | **243,265** |
| **Operation (based on a 100 year design life)** | | | | |
| **Electricity consumption** | | | | |
| Street lighting | - | 18,558 | 2,062 | 20,620 |
| LED traffic lights | - | 981 | 109 | 1,090 |
| **Maintenance** | | | | |
| Full depth asphalt | 2,720 | - | 3,492 | 6,212 |
| Deep strength asphalt | 698 | - | 896 | 1,594 |
| Plain concrete | 24,474 | - | 3,840 | 28,314 |
| **Traffic** | | | | |
| Traffic emissions | - | - | 2,274,390 | 2,274,390 |
| **Total operation emissions** | **27,872** | **19,539** | **2,284,789** | **2,332,220** |
| **Project total** | | | | |
| **Total** | **118,400** | **19,539** | **2,437,545** | **2,575,484** |

### 5.1.4 Discussion

Greenhouse gas emissions during the construction phase of the projects have been projected to be predominately sourced from the embedded emissions of the materials used to construct the project, accounting for just over 50 per cent of the emissions of the construction phase. Vegetation clearance accounts for about 30 per cent of construction phase emissions and construction fuel combustion accounts for the remainder.

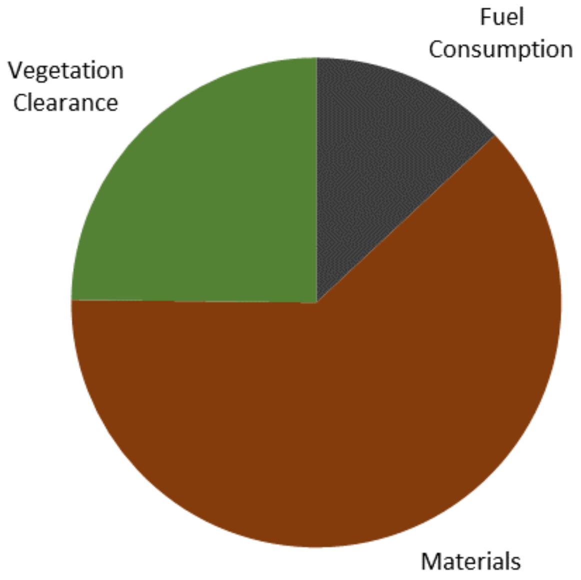



Figure 5-1 Proportion of emission sources during the construction phase

Traffic emissions dominate the emissions of the maintenance and operation phase of the project. Traffic related emissions account for nearly 98 per cent of emissions over the 100-year design life of the project, with the remainder generated by maintenance activities and the electricity consumption associated with street lighting and traffic signals.

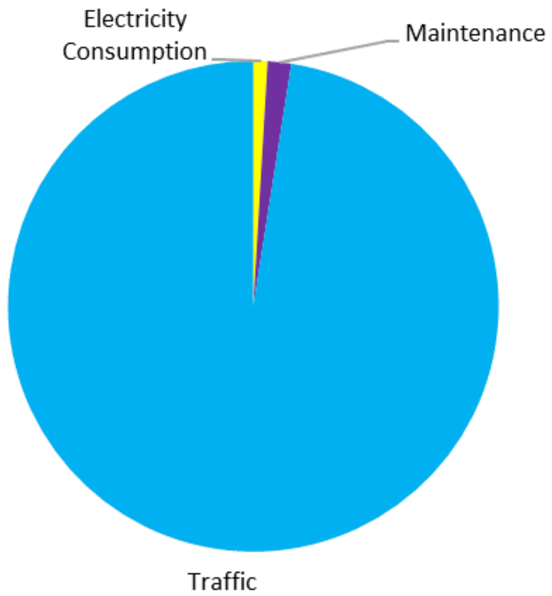



Figure 5-2 Proportion of emission sources during the operation phase

Due to the significance of the traffic related emissions compared to other sources, the operation phase emissions make up a much more significant portion of the overall project emissions compared to the construction phase emissions.

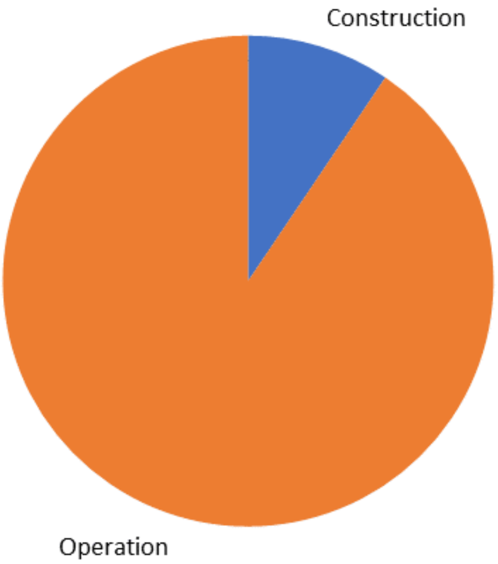



Figure 5-3 Proportion of construction and operation emissions sources over the project lifetime

When divided by scope, the overall emissions of the project are dominated by Scope 3 emissions as a result of the significance of traffic emissions. Scope 3 emissions account for nearly 95 per cent of all emissions of the project, with the majority of the remainder Scope 1 emissions.

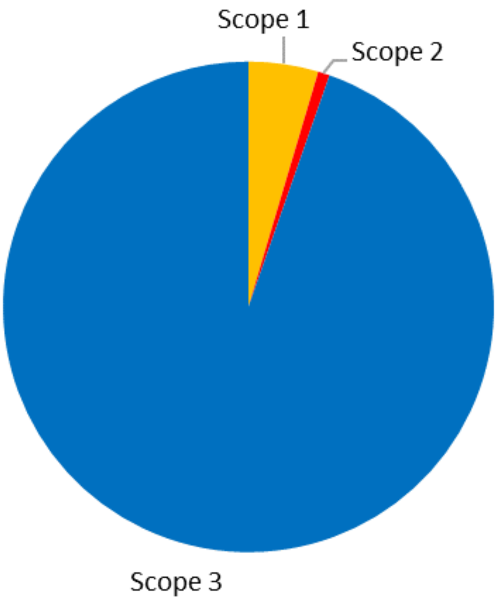



Figure 5-4 Proportion of Scope 1, Scope 2 and Scope 3 emissions over the project lifetime

Given how significant a contribution traffic makes to the overall projected emissions for the project, it should be noted that due to potential future changes in technology regarding road vehicles in Australia, emissions projected from traffic may significantly decrease in the future. The modelling method used assumes improved fuel efficiency in new models of cars in when predicting future emissions, however it does not yet account for the growing adoption of lower emission electric vehicles. It is likely that the increased production and adoption of electric vehicles is anticipated to mean that by 2028 and 2038 there would be a much greater number of electric vehicles using the project roads, hence resulting in lower traffic emissions than estimated.

## 5.2 Climate change risk assessment

### 5.2.1 Overview

Climate change is anticipated to have direct and indirect impacts on the project. The types of impacts are relatively well understood however their severity and extent are uncertain. As such, risks need to be identified and assessed and strategies to treat them developed.

The combined direct and indirect impacts of climate change may contribute to one or more of the following categories:

- Accelerated infrastructure deterioration and increased maintenance requirement
- Safety incidents
- Increased frequency and/or duration of road closures
- Infrastructure loss (total or partial loss as a result of a severe weather event).

This is anticipated to have implications for capital and/or operational expenditure. In catastrophic situations, such as infrastructure failure related to extreme climate events, impacts may include major road accidents or loss of life (although with appropriate risk controls such an event is extremely unlikely).

### 5.2.2 Identification of hazards

A hazard is described as the potential for harm. Sources of hazards of relevance to the project (**Table 5-10**) include climate phenomena such as flooding and heatwaves. Hazards may occur in isolation or in combination with one another. The confluence of natural events, such as extreme rainfall combined with severe wind, may intensify projected impacts. The influence of climate change on such events is not well understood.

Table 5-10 Project hazards resulting from projected climate change

| Hazard | Description and impact |
|---|---|
| Temperature and the incidence of heatwave | Increased average temperature and more frequent heatwave events may affect the structural integrity of the road surface, bridges, (and supporting infrastructure (i.e. electronic signals)). It may also lead to higher operational and maintenance costs through more rapid deterioration of infrastructure or disruption of services such as closures and delays. |
| Severity of seasonal drought | Climate change is likely to influence the severity and duration of drought. These changes may affect the geotechnical stability of the land, hence undermining the structural integrity of road infrastructure.<br>Drought may also alter the natural physical surroundings along the project. This is a potential issue for vegetation cover, especially when used for erosion protection. |
| Rainfall amount and frequency | Decreased rainfall depth and frequency may result in changes to water table levels, which would affect groundwater flows. Drying of drainage channels may result in weakening which in periods of severe rainfall are eroded more easily. |
| Severe rainfall events resulting in floods | Excessive rainfall can lead to flash or prolonged flooding (both from excessive stormwater and river flooding). The potential implications include infrastructure damage and/or failure and operational delays. Greater levels of surface water flow during extreme events may cause dangerous driving conditions and instability for embankments and retaining walls along the project. |

| Hazard | Description and impact |
|---|---|
| Frequency and intensity of bushfire | Higher temperatures and changes to rainfall patterns suggest an increase in the frequency of extreme fire weather, which if fires occur, may make their behaviour more difficult to manage. Given its semi-rural location, the project may be directly affected by the impact of bushfire, and indirectly the local air quality may be affected by smoke and dust, along with reduced visibility for drivers. |
| Rate of annual evaporation | Increased annual evaporation would have an impact on the influence soil wetting and drying cycles, river flooding and fire. Drier climate (warmer, less rain, less humidity and increased evaporation) is associated with reduce road pavement deterioration). |
| Carbon dioxide concentration in the atmosphere | An increase in concentration of carbon dioxide combined appropriate temperatures and humidity levels, would lead to increased depth of carbonation of concrete, which in turn can increase the likelihood of carbonation induced reinforcement deterioration (CSIRO, 2010). For the project this may involve enhanced deterioration of the reinforced concrete elements and shortening of its operational life. |

## 5.2.3 Identification of receptors

Project components (receptors) that may be affected by the hazards described above are displayed in **Table 5-11**.

Table 5-11 Potential impact receptors

| Receptor | Receptor components |
|---|---|
| Road infrastructure | • Roadway and footpaths<br>• Embankments, retaining walls and noise walls.<br>• Ancillary infrastructure – signals, power<br>• Signage<br>• Lighting<br>• Drainage and culverts. |
| Bridges | • Ramps<br>• Piers and Footings<br>• Bridge Deck and Railings<br>• Drainage. |
| Maintenance staff | • Maintenance workers. |
| Electrical supply | • Supply points<br>• Transformers<br>• Back –up generation<br>• Substations. |

## 5.2.4 Identified operational risks

Risk analysis and evaluation was carried out through desktop assessment, and in liaison with other specialist studies (such as hydrology). The risk assessment involved the following steps:

- Identify the hazard and receptor
- Assess the potential exposure
- Identify existing controls and their effectiveness

- Identify the consequence rating corresponding to the maximum credible impact across the consequence categories (may be more than one), given the existing controls and their effectiveness
- Identify the likelihood of occurrence of those consequences at that level, considering business as usual controls and their effectiveness
- Determine the level of risk based on the intersection of the consequence and likelihood rating
- Determine any action (e.g. risk treatment) and escalation based on the level of risk
- Recommend next steps for detailed design to carry out prior to reconsideration of the level of consequence and likelihood (and therefore residual risk).

Prior to the implementation of environmental management, four risks were identified as ‘high’, four risks were identified as ‘medium’ and eight risks were identified as ‘low’. Medium and high risks are presented in **Table 5-12**. For low risks, no risk treatment is proposed at this stage, although where practicable environmental management measures will be identified for these risks during future design stages.

Following the implementation of current design controls or proposed risk treatments, three risks were identified as ‘high’, two risks were identified as ‘medium’ and eleven risks were identified as ‘low’.

The full results of the risk assessment are presented in **Appendix C**.

Table 5-12 Climate change risks with a residual risk of ‘medium’ or higher

| ID | Cause, trigger or issue | Risk, hazard or opportunity | Potential consequences | Inherent (original) risk rating | Current control/Proposed risk treatment | Residual risk |
|---|---|---|---|---|---|---|
| 1 | Increased high temperatures extremes and more frequent incidence and severity of heatwaves. | Road surface cracks or becomes degraded due to inability to cope with extreme heat. | Partial road closures, increased maintenance requirements, potential for car accidents. | Medium | Heavy duty pavements have been specified for the project which have low susceptibility to damage caused by high ambient temperatures. Regular resurfacing of flexible pavements will also occur as part of maintenance program. | Low |
| 2 | | Bridge infrastructure components are unsuited to future climate extremes. Example is bridge deck expansion joints are inadequately sized or unable to cope with greater maximum temperatures. | Additional wear on infrastructure causing damage or increased maintenance requirement. | Medium | Detailed design should incorporate the full range of temperature projections, as well as expected life of bridge components, when materials are specified. | Low |
| 9 | Increase in the frequency and intensity of severe rainfall events coupled with Sea Level Rise. | Increased flooding (extent and depth) covers and damages areas previously modelled/designed to be immune from flooding (to the 5% AEP design standard). | Flooding damage to road and road infrastructure which could temporarily close the road which will severely delay traffic. Impact will require clean up and repair depending on level of damage. Impact could extend to neighbouring properties due to inability of flood waters to dissipate. | High | Much of the current alignment achieves immunity to the 1% AEP event and as such provides a level of immunity above the design parameter 5% AEP event. With 5% AEP immunity, the road is expected to flood at times, and is therefore designed to provide a level of resilience to this.<br>Additional flood modelling will be carried out if any design changes are made during detailed design. Additional flood modelling would consider climate change related flood risks to the project and the flood impacts from the project. | High |

| ID | Cause, trigger or issue | Risk, hazard or opportunity | Potential consequences | Inherent (original) risk rating | Current control/Proposed risk treatment | Residual risk |
|---|---|---|---|---|---|---|
| 10 | | Increased flooding (extent and depth) overwhelms areas previously modelled/designed to be immune from flooding (to the 5% AEP design standard). | Flooding/standing water causes accidents for motor vehicles and cyclists resulting in safety incidents for road users. | High | Much of the current alignment achieves immunity to the 1% AEP event and as such provides a level of immunity above the design parameter 5% AEP event.<br>Access to the motorway would be limited during a flood event as local roads would be inundated (the motorway would be one of the more flood proof areas). Number of road users would therefore be greatly reduced and limited to those already travelling north or south along the M1 Pacific Motorway. Variable messaging signs would inform road users of hazards.<br>Additional flood modelling will be carried out if any design changes are made during detailed design. Additional flood modelling would consider climate change related flood risks to the project and the flood impacts from the project. | High |
| 11 | Increase in the frequency and intensity of severe rainfall events. | Drainage channels and culverts are too small as 5% AEP storms (the design standard) are more severe as a result of climate change. Exits of culverts suffer increased scour. | Culverts and drainage channels are overwhelmed causing increased flooding on the up-flow side of the culverts, and increased scour at the outflows. This results in increased road closures, and increased maintenance/rectification costs. Diverted water may lead to increased flooding at existing properties. | High | Additional drainage and flood assessment will be carried out if any design changes are made during detailed design. This is presented as management measure FH02 (Hydrology and Flooding Working Paper (Appendix J of the EIS)). | High |

| ID | Cause, trigger or issue | Risk, hazard or opportunity | Potential consequences | Inherent (original) risk rating | Current control/Proposed risk treatment | Residual risk |
|---|---|---|---|---|---|---|
| 13 | More severe fire weather and elevated fire weather conditions. | Increased local bushfires cause decreased visibility due to smoke | Road users suffer reduced visibility due to smoke resulting in accidents. | Medium | The project includes Variable Message Signs to warn road users of potential hazards. | Medium |
| 14 | | Increased local bushfires cause damage to structures such as retaining walls and bridges. | Bushfires in proximity to the project may cause direct damage to structures, utilities and fauna connectivity measures, resulting in road closures while repairs / damage assessment is carried out. | High | Concept design has considered potential impacts to structures, utilities and fauna connectivity structures in bushfire prone areas. Access to fire trails will be maintained. | Medium |
| 16 | Increased concentration of carbon dioxide in the atmosphere. | Carbonation occurs to a greater depth in concrete structures, allowing exposure and degradation of reinforcement. Retaining walls, piers and bridge deck elements are degraded quicker than anticipated shortening their design life. | Shorter design life results in greater levels of inspection and maintenance needed, increase asset operational costs. | Medium | During detailed design, a material durability report will be prepared and actioned which will specifically review the potential impacts of climate change on concrete durability, including depth of cover over reinforcement. | Low |

# 6. Cumulative impacts

## 6.1 Cumulative impacts

Cumulative climate change impacts may arise from the interaction of construction and operation activities of the project, with other approved or proposed projects within the greenhouse gas assessment boundary. When considered in isolation, specific project impacts may be considered minor. These minor impacts may, however, be more substantial, when the impact at a state or national scale is considered.

The annual emission contributions of the project towards the total annual transport based emissions of NSW and Australia (from the State and Territories Greenhouse Gas Inventory 2018 (DIESER, 2020)) are detailed in **Table 6-1**.

Table 6-1 Emission contributions of the project in the context of state and national transport emissions

| Stage of project | Project emissions (Mt $CO_2$e/year) | 2018 NSW transport emissions (Mt $CO_2$e/year) | 2018 National transport emissions (Mt $CO_2$e/year) | Project contribution to NSW annual emissions | Project contribution to national annual emissions |
|---|---|---|---|---|---|
| Construction | 0.08 | 24 | 82.2 | 0.333% | 0.1% |
| Operation – year of opening | 0.01 | 24 | 82.2 | 0.042% | 0.012% |
| Operation – 10 years after opening | 0.02 | 24 | 82.2 | 0.083% | 0.024% |

Emissions from the project have been compared to the overall state and national emissions in **Table 6-2**. All stages have been projected to produce well less than one per cent of NSW and Australia's total emissions.

Table 6-2 Emission contributions of the project in the context of overall state and national emissions

| Stage of project | Project emissions (Mt $CO_2$e/year) | 2018 NSW emissions (Mt $CO_2$e/year) | 2018 national emissions (Mt $CO_2$e/year) | Project contribution to NSW annual emissions | Project contribution to national annual emissions |
|---|---|---|---|---|---|
| Construction | 0.08 | 131.7 | 536.5 | 0.061% | 0.015% |
| Operation – year of opening | 0.01 | 131.7 | 536.5 | 0.008% | 0.002% |
| Operation – 10 years after opening | 0.02 | 131.7 | 536.5 | 0.02% | 0.004% |

It should be noted that a proportion of construction related emissions may be produced in jurisdictions outside of NSW.

# 7. Environmental management measures

The management measures presented in **Table 7-1** have been developed to specifically manage potential impact which have been predicted as a result of the proposed works. These measures should be incorporated into relevant Environmental Management Plans (EMPs) during construction and operations.

Table 7-1 Environmental management measures (climate change risk)

| Impact | Reference | Management | Responsibility | Timing |
|---|---|---|---|---|
| Flood risk | CC01 | Hydrological and hydraulic assessments would be carried out for any design changes during detailed design and would consider the climate change related flood risks to the project and flood impacts from the project. | Contractor | Detailed design |

# 8. Conclusions

This report has provided the results of the assessment into climate change risks associated with the project. The two objectives achieved in this report were to quantify the potential greenhouse gas emissions associated with the project and identify the key risks to the project posed by climate change.

The assessment determined several key emissions sources producing $CO_2e$, including:

- Fuel use by plant and equipment during construction
- Embedded emissions in materials
- Vegetation clearance
- Vehicles using the road
- Electricity consumption associated with the operation of street lighting and signaling
- Fuel consumption and embedded emissions in materials used during maintenance activities.

The key outcomes of the Greenhouse Gas Impact Assessment are:

- 243 kilotonnes of $CO_2e$ will be emitted over the course of construction
- 2,332 kilotonnes of $CO_2e$ will be emitted over the 100-year design life operation of the project
- Scope 3 emissions were the main source of $CO_2e$, making up nearly 95 per cent $CO_2e$ produced over the project lifespan.

Environmental management measures were identified to reduce overall emissions, including exploring options for the adoption of low emission construction materials or the application of energy efficient measures during the operation of the project.

The climate change risk and adaptation assessment has identified climate change projections for the region through which the project will traverse and highlighted a range of potential risks to the project as a result. The highest risks include:

- Risks associated with an increased rainfall intensity (from storm events) and stormwater/riverine flooding, coupled with Sea Level Rise
- Material durability risks relating to tolerances to extreme heat.

Environmental management measures have been proposed to address the risks which are analysed as ‘medium’ or above, the majority of which are to be closed out in detailed design.

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# Terms and acronyms

| Term/Acronym | Description |
|---|---|
| Adaptation | Adjustment in natural or human systems that are taken in response to actual or expected climatic [and other] stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation is concerned with managing the unavoidable impacts of climate change (and variability) and considers what needs to be done differently – both more and better – to cope with the change |
| AR5 | Fifth Assessment Report of the Intergovernmental Panel on Climate Change. |
| BoM | Australian Bureau of Meteorology. |
| CCIA | Climate Change in Australia web site and technical report; see www.climatechangeinaustralia.gov.au. |
| CFT | Climate Futures Tool. |
| Climate | A statistical description of “average” weather in terms of the mean and variability of relevant quantities over time scales ranging from months to millennia. It is influenced by factors that operate at various time and spatial scales, including: atmospheric energy balance, atmospheric composition and ocean and atmospheric circulation patterns. |
| Climate change | Refers to a change in the state of the climate that can be identified by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer.<br>Climate change may occur because of: internal changes within the climate system; interaction between its components; or because of changes in external forces either for natural reasons or because of human activities. It is generally not possible to clearly attribute causation between these causes. Projections of future climate change generally consider only the influence on climate of anthropogenic increases in greenhouse gases and other human-related factors. |
| Climate change factors | The percentage or absolute change in rainfall, temperature or other climate variable that results from climate change under a particular scenario. Climate change factors describe the change from averages during the 1986-2005 reference period. |
| $CO_2$ | Carbon dioxide. |
| $CO_2e$ | Carbon dioxide equivalent – an amalgamation of all greenhouse gases into a single indicator |
| COP | Conference of the Parties, referring to the countries that have signed up to the 1992 United Nations Framework Convention on Climate Change. |
| DCCEE | Department of Climate Change and Energy Efficiency |
| EF | Emissions Factor |
| EPA | Environment Protection Authority |
| ERF | Emissions Reduction Fund – Australian national GHG related legislation |
| ETS | Emissions Trading Scheme |
| FC | Fuel consumption |
| GCM | General Circulation Model or Global Climate Model. Computer model that runs mathematical representations of the global climate system. They are used to project the influence of emissions or other global change scenarios on climate. Climate change projections are typically based on an ensemble or group of models rather than the results of an individual GCM. |
| GHG | Greenhouse gas |
| GWP | Global Warming Potential |

| Term/Acronym | Description |
|---|---|
| Heat wave | An event with at least two consecutive days of high temperature. High temperature may be based on maxima of 35 or 40 degrees Celsius or more or average temperatures (average of daily maximum and minimum temperature) of 32 degrees Celsius or more. Nairn and Fawcett (2013) developed a heatwave index (based on an excess heat factor) which reflects whether hot weather is unusual for the location and grossly different to the antecedent conditions. |
| HFC | Hydrofluorocarbon |
| IPCC | Intergovernmental Panel on Climate Change. |
| ISCA | Infrastructure Sustainability Council of Australia. It is proposed that the project be designed to achieve an overall excellence rating under ISCA's sustainability rating tool. This may require the project to satisfy one or both of the climate change criteria. |
| Kilotonne | One thousand tonnes |
| kL | Kilolitre |
| kWh | Kilowatt Hour |
| OEH | New South Wales Office for Environment and Heritage |
| PFC | Perfluorocarbon |
| RCP | Representative concentration pathway. A future trajectory for radiative forcing, reflecting changes in atmospheric greenhouse gas concentrations. Four RCP scenarios are commonly presented, ranging from RCP2.6 to RCP8.5. The numeric factor represents the 2100 RF value of the scenario (or in the case of RCP2.6, the peak value). |
| Resilience | The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change. |
| Transport | Transport for New South Wales |
| TRAQ | Tools for roadside air quality |
| UNFCCC | United Nations Framework Convention on Climate Change |
| VKT | Vehicle kilometres travelled |

# Appendix A – Carbon Gauge inputs and results

Carbon Gauge

# Summary Report

**Note:** This Workbook is designed to enable a consistent methodology for the assessment of significant emission sources and estimation of greenhouse gas emissions. As such it deliberately does not cover activities and emission sources assessed as insignificant, and it is not designed for compliance reporting.

## Project Description

| | |
|---|---|
| Project title | M1 to Raymond Terrace |
| Project location | Raymond Terrace |
| State | NSW |
| Description | New road and bridge linking the M1 motorway between Blackhill and Raymond Terrace |

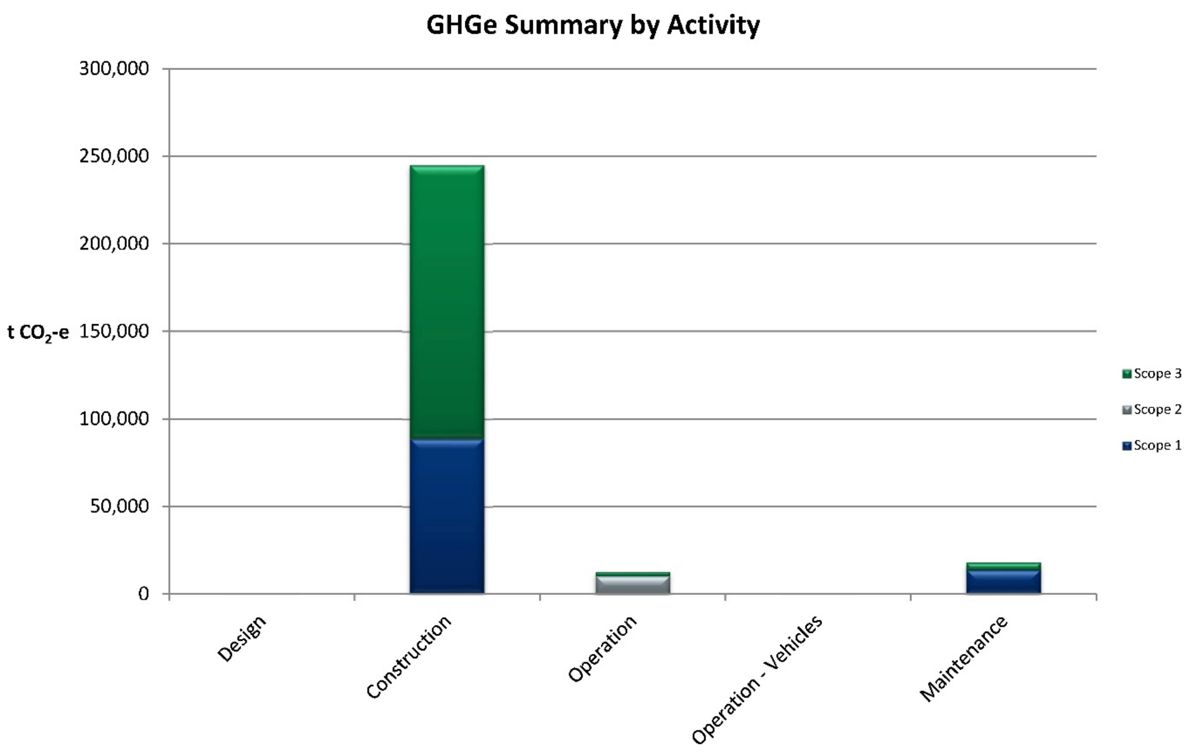
| | |
|---|---|
| Project Value ($m) | 1645000000 |
| Project Duration (Months) | 36 |

## Greenhouse Gas Emissions

| | |
|---|---|
| **Scope 1 emissions** | Emissions released into the atmosphere as a direct result of an activity, or series of activities (including ancillary activities) that constitutes the facility. |
| **Scope 2 emissions** | Emissions released as a result of one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but that do not form part of the facility. |
| **Scope 3 emissions** | Emissions that occur outside the site boundary of a facility as a result of activities at a facility that are not Scope 2 emissions. |

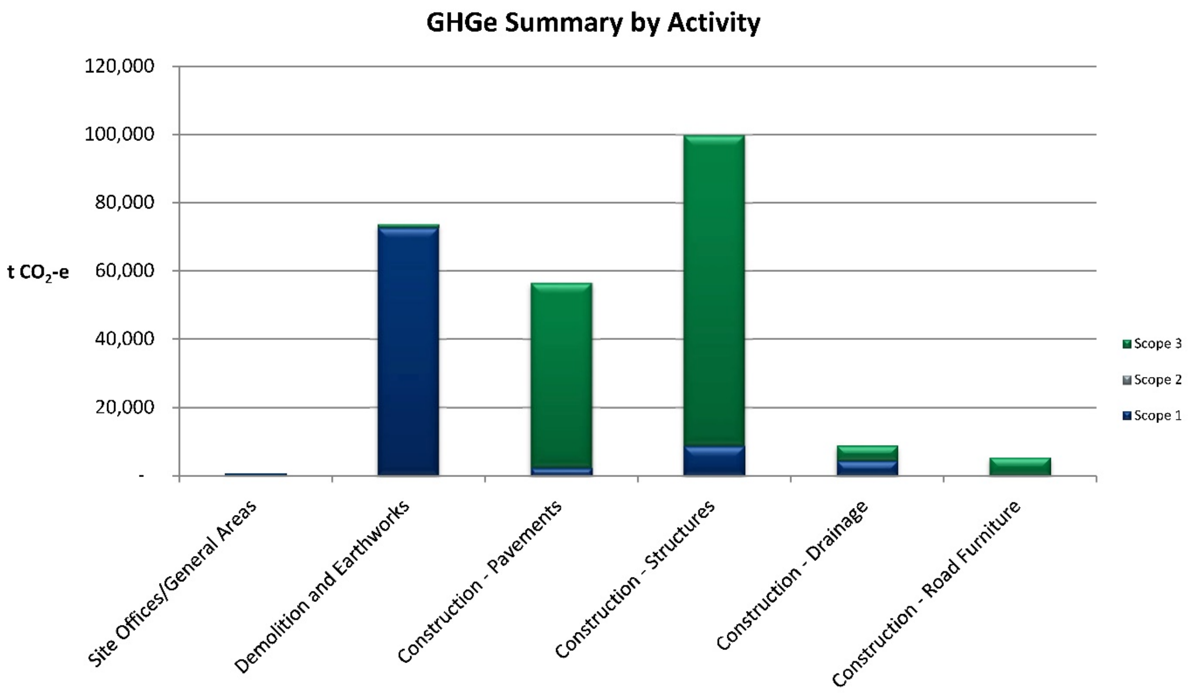
## Project Summary

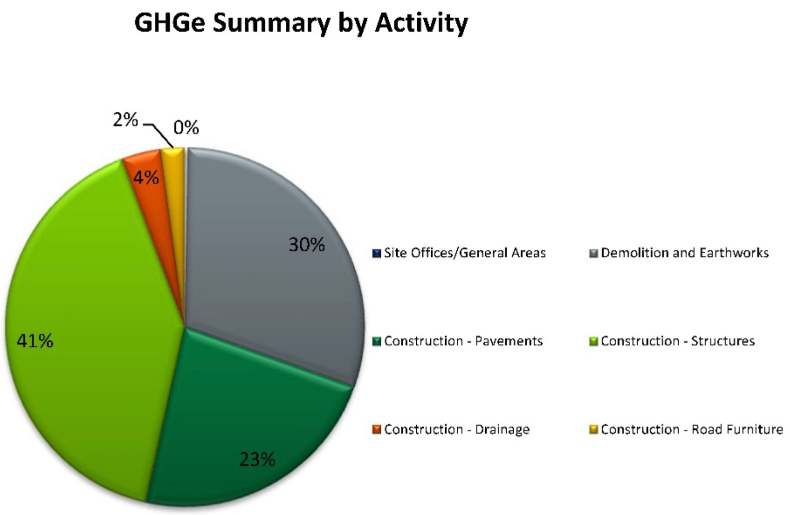
| Major Activity | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| Design | 0 | 0 | 0 | **0** |
| Construction | 88,878 | 0 | 155,948 | **244,826** |
| Operation | 0 | 10,614 | 2,171 | **12,784** |
| Operation – Vehicles | 0 | 0 | 0 | **0** |
| Maintenance | 13,946 | 0 | 4,113 | **18,059** |
| **Total** | **102,823** | **10,614** | **162,233** | **275,669** |



## Construction Summary

| GHGe Summary by activity | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| Site Offices/General Areas | 628 | 0 | 48 | **676** |
| Demolition and Earthworks | 72,799 | 0 | 1,030 | **73,829** |
| Construction - Pavements | 2,321 | 0 | 54,140 | **56,461** |
| Construction - Structures | 8,724 | 0 | 91,119 | **99,843** |
| Construction - Drainage | 4,322 | 0 | 4,460 | **8,782** |
| Construction - Road Furniture | 83 | 0 | 5,152 | **5,235** |
| **Total** | **88,878** | **0** | **155,948** | **244,826** |

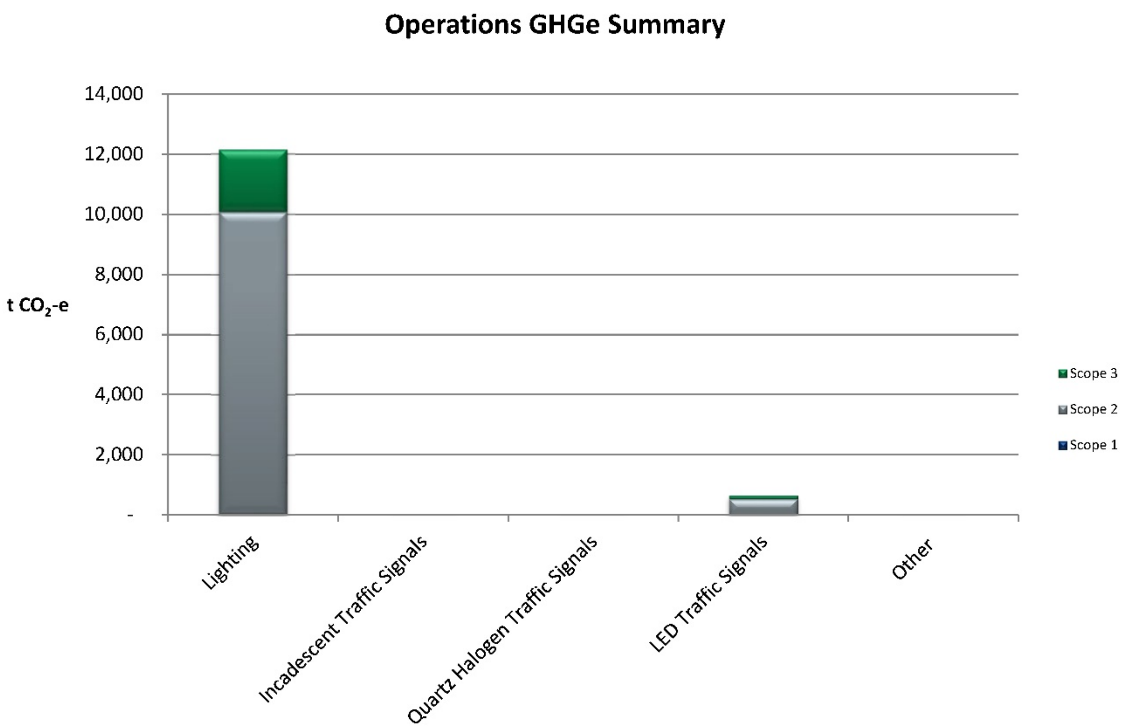


## Operations Summary (Emissions are calculated for a 50 year period)

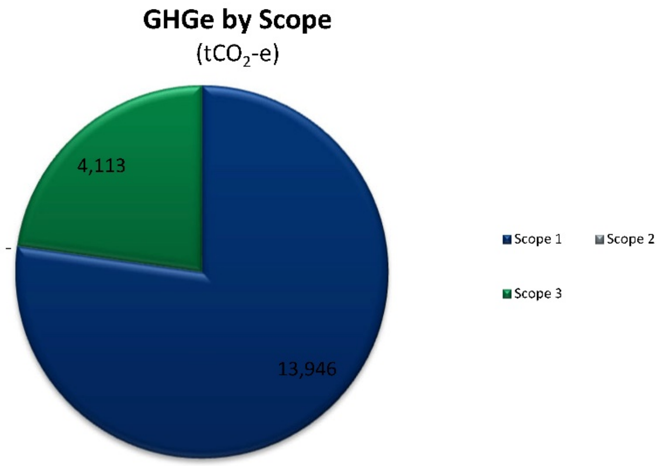
| Summary | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| Lighting | - | 10,080 | 2,062 | **12,141** |
| Incadescent Traffic Signals | - | - | - | **-** |
| Quartz Halogen Traffic Signals | - | - | - | **-** |
| LED Traffic Signals | - | 534 | 109 | **643** |
| *Other* | - | - | - | **-** |
| **Total** | **-** | **10,614** | **2,171** | **12,784** |

| Summary - Vehicles | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| Vehicle Use | - | - | - | **-** |
| **Total** | **-** | **-** | **-** | **-** |



## Maintenance Summary (Emissions are calculated for a 50 year period)

| Summary by Pavement | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| 01. Full Depth Asphalt | 1,359.74 | - | 1,745.53 | **3,105** |
| 02. Deep Strength Asphalt | 348.96 | - | 448.15 | **797** |
| 03. Granular with Spray Seal | - | - | - | **0** |
| 04. Stablised Pavement | - | - | - | **0** |
| 04. Plain Concrete (PC) | 12,236/95 | - | 1,919.68 | **14,157** |
| 05. Reinforced Concrete (RC) | - | - | - | **0** |
| *Other* | - | - | - | **0** |
| **Total** | **13,946** | **0** | **4,113** | **18,059** |



# Construction Report

**Note 1:** This Workbook is designed to enable a consistent methodology for the assessment of significant emission sources and estimation of greenhouse gas emissions. As such it deliberately does not cover activities and emission sources assessed as insignificant, and it is not designed for compliance reporting.
**Note 2:** All emission values shown on this report are in tonnes of carbon dioxide equivalent (t CO2-e) unless otherwise stated.

## Project Description

| | |
|---|---|
| Project title | M1 to Raymond Terrace |
| Project location | Raymond Terrace |
| State | NSW |
| Description | New road and bridge linking the M1 motorway between Blackhill and Raymond Terrace |

| | |
|---|---|
| Project Value ($m) | 1645000000 |
| Project Duration (Months) | 36 |

## Construction

### Materiality Checklist Options

| Checklist Option | Selection | Details |
|---|---|---|
| Will a diesel generator be used to provide power to the project site office for more than 12 months? | YES | Fuel combusted in powering site offices will be included. |
| Will more than 120 buildings be required to be demolished per 1km of road? | YES | Fuel combusted in demolishing buildings will be included. |
| Will more than 0.5 ha (5,000m $^2$) of vegetation be removed? | YES | Vegetation removal and/or revegetation will be included. |
| Will the project involve tunnelling? | NO | Electricity consumption and explosives used will NOT be included. |
| Is the project located more than 200 km from the nearest material suppliers/quarry/city? | YES | The emissions associated with the transport of materials to site will be included. |
| Will the project utilise on-site batching plants or other continuously operating stationary plant and equipment for more than 6 months? | NO | Fuel combusted in stationary engines will NOT be included. |
| Will the project include road safety barriers along more than 50% of the road length if barriers are used on both sides of a dual carriageway (i.e. 4 sets) or 100% of the road length if used on both side of a single carriageway (i.e. two sets)? | YES | The emissions from the construction and installation of road safety barriers will be included. |
| Will the project include noise walls along more than 75% of the road length? | YES | The emissions from the construction and installation of noise walls will be included. |

## Fuel Types

| | Construction Activity | Fuel Type | GHGe (t $CO_2$-e) |
|---|---|---|---|
| Plant Equipment Fuel | Site Offices | Diesel | 676 |
| | | Petrol | - |
| | Construction | Diesel | 16,629 |
| | Demolition and Earthworks | Diesel | 13,444 |
| | Vegetation Removal | Diesel | 1,088 |
| | | | **31,837** |

## Pavements

| | Pavement Type | Total Area (m2) | GHGe (t $CO_2$-e) | Pavement Option Selected |
|---|---|---|---|---|
| Pavement 1 | 04. Plain Concrete (PC) | 252,606 | 31,166 | No |
| Pavement 2 | 05. Reinforced Concrete (RC) | - | - | No |
| Pavement 3 | 02. Deep Strength Asphalt | 29,563 | 1,437 | No |
| Pavement 4 | 01. Full Depth Asphalt | 63,357 | 2,427 | No |
| Pavement 5 | 04. Plain Concrete (PC) | 173,696 | 21,430 | No |
| Pavement 6 | 01. Full Depth Asphalt | - | - | No |
| | | | **56,461** | |

Carbon Gauge

## Structures

| | Structure Type | Total Length (km) | Width/Height (m) | GHGe (t $CO_2$-e) |
|---|---|---|---|---|
| Bridges (including interchanges and overpasses) | Bridge constructed using precast reinforced concrete beams | 3.60 | 23.0 | 99,285 |
| | Bridge constructed using steel beams | - | - | - |
| Reinforced Soil Walls | Reinforced Soil Walls | 0.40 | 5.5 | 558 |
| Retaining Walls | Concrete retaining walls | - | - | - |
| | Timber retaining walls | - | - | - |
| | Rock retaining walls | - | - | - |
| | | | | **99,843** |

## Material Transport

| | Truck Size per Load of Material (GVM) | Distance from source to site (km) | GHGe (t $CO_2$-e) |
|---|---|---|---|
| Aggregate | | - | - |
| Asphalt & Bitumen | | - | - |
| Cement and Concrete | | - | - |
| Steel | | - | - |
| Timber | | - | - |
| | | | **-** |

## Drainage

| | Drainage Type | Total Length (km) | GHGe (t $CO_2$-e) |
|---|---|---|---|
| Kerbing | Mountable Kerb | - | - |
| | Semi-mountable Kerb | 11.03 | 203 |
| | Upright kerb and Gutter (Channel) | 1.48 | 36 |
| | Invert drain | 18.66 | 1,381 |
| Culverts – pipes or box culverts for water drainage | Small <450 RCP | 11.50 | 1,713 |
| | Medium 450 – 750 RCP | 17.50 | 3,538 |
| | Large 750 – 1200 RCP | 1.30 | 484 |
| | 375x 600 RCBC | 0.10 | 32 |
| | 600 x 1200 RCBC | 2.50 | 1,351 |
| Open, Unlined Drains | Form open, unlined drains | 30.40 | 44 |
| | | | **8,782** |

## Road furniture

| | Road Furniture Type | Total Length (km) | GHGe (t $CO_2$-e) |
|---|---|---|---|
| Road Safety Barriers | Wire rope barrier | 16.80 | 752 |
| | W-beam barrier | 5.70 | 301 |
| | F-type (New Jersey) barrier | 18.10 | 4,182 |
| Noise Walls | Reinforced concrete wall | - | - |
| | Hebel noise wall | - | - |
| | Timber wall | - | - |
| | Steel plate wall | - | - |
| | | | **5,235** |

## Vegetation Removal

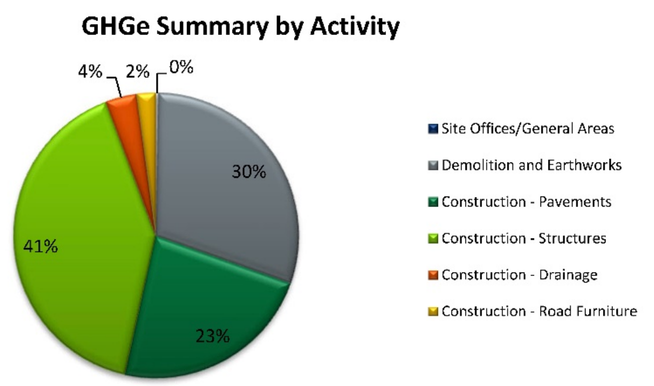
| | | Selected Biomass Class |
|---|---|---|
| Biomass Class | Potential maximum biomass class | Class 4: 150 - 250 (t dry matter/ha) |

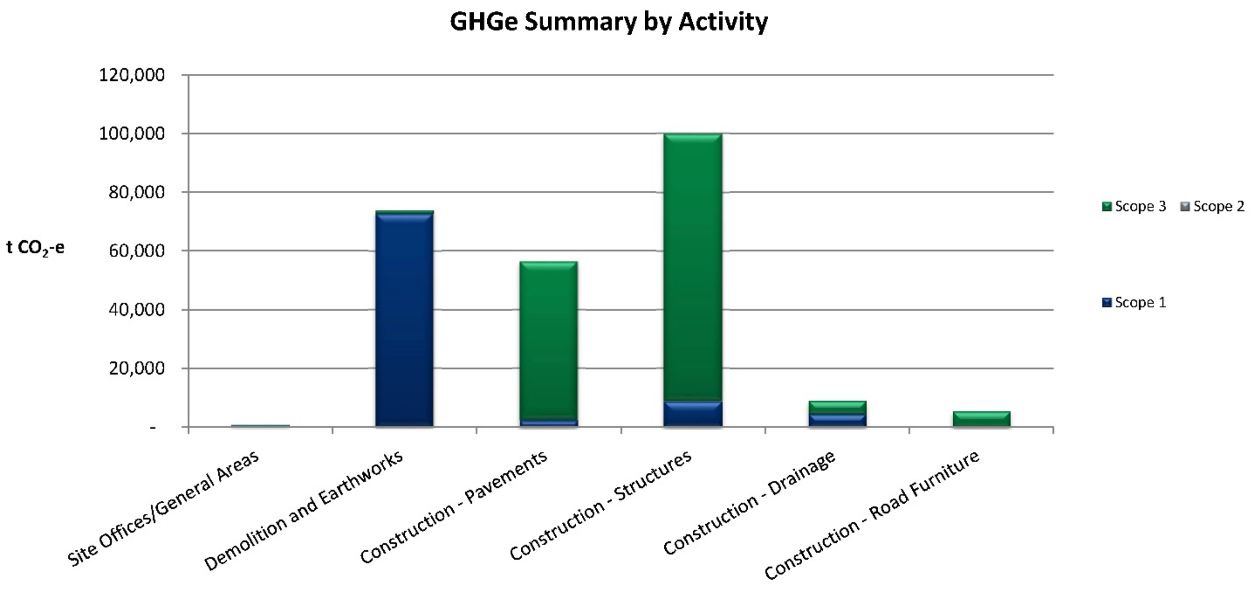
| | Vegetation Class | Area cleared (ha) | GHGe (t $CO_2$-e) |
|---|---|---|---|
| Vegetation Removed | Class A (Rainforest and vine thicket) | - | - |
| | Class B (Eucalypt tall open forest) | 12 | 4,754 |
| | Class C (Open forest) | 90 | 47,551 |
| | Class D (Open woodlands) | Rare Class | - |
| | Class E (Callitris forest & woodland) | Rare Class | - |
| | Class F (Mallee & Acacia woodland) | Rare Class | - |
| | Class G (Open shrubland) | Not Possible | - |
| | Class H (Heathlands) | Rare Class | - |
| | Class I (Grasslands) | 69 | 8,079 |
| | | | **60,385** |

## Greenhouse Gas Emissions

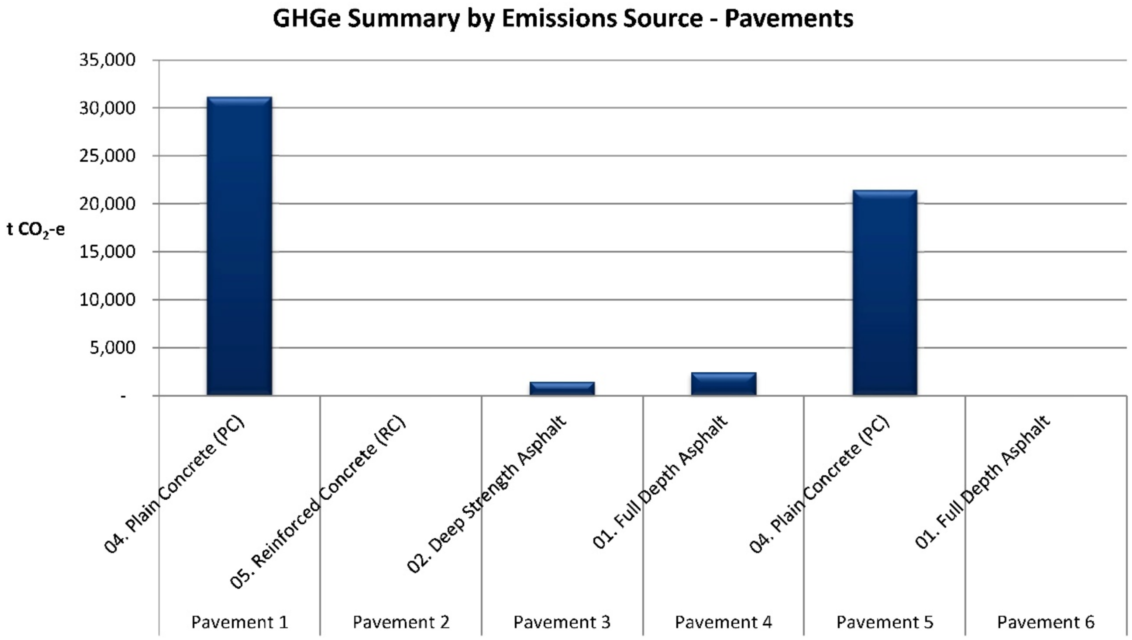
| | |
|---|---|
| **Scope 1 emissions** | Emissions released into the atmosphere as a direct result of an activity, or series of activities (including ancillary activities) that constitutes the facility. |
| **Scope 2 emissions** | Emissions released as a result of one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but that do no form part of the facility. |
| **Scope 3 emissions** | Emissions that occur outside the site boundary of a facility as a result of activities at a facility that are not Scope 2 emissions. |

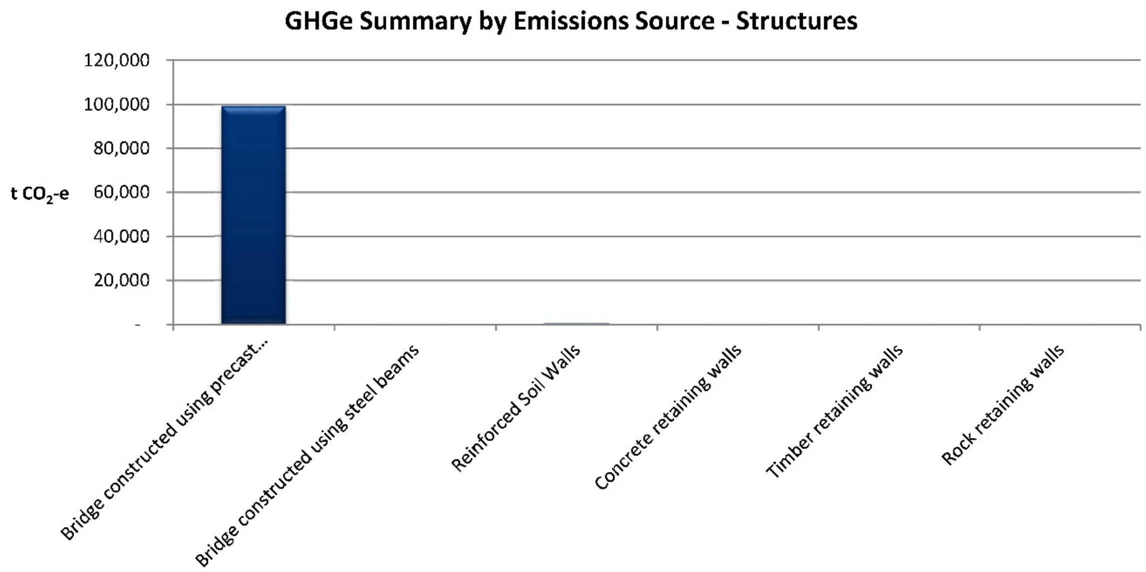
### Greenhouse Gas Emissions Summary by Activity

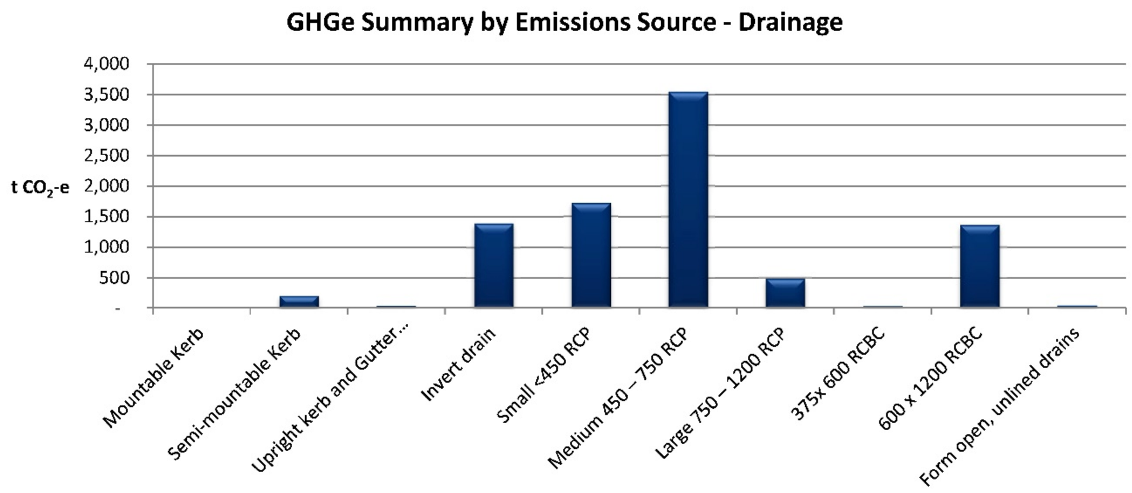


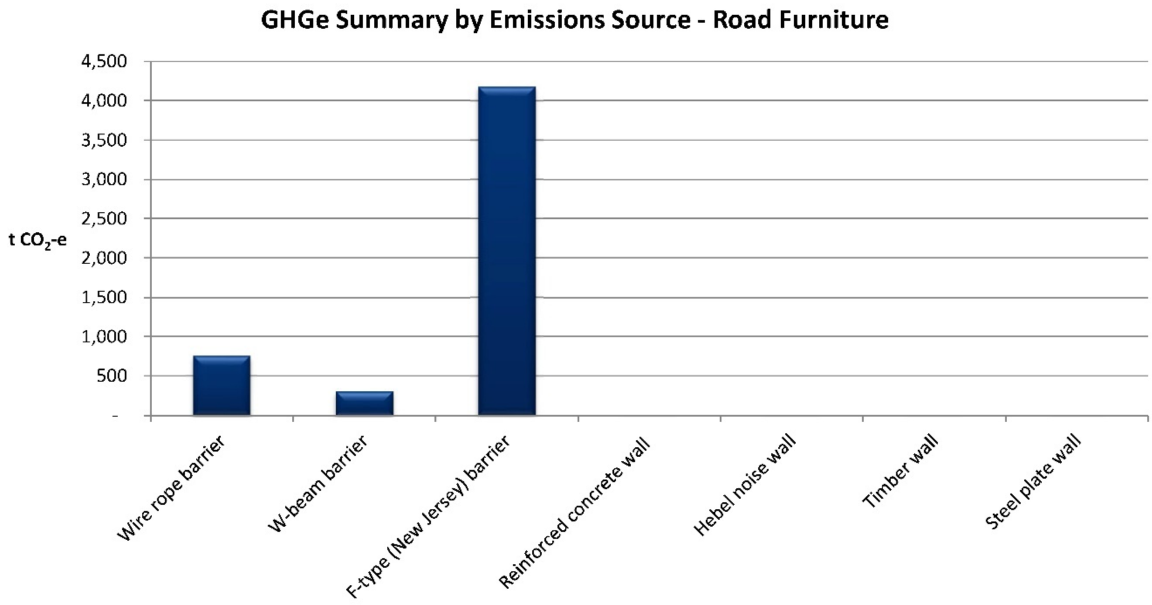



## Greenhouse Gas Emissions Summary by Emissions Source

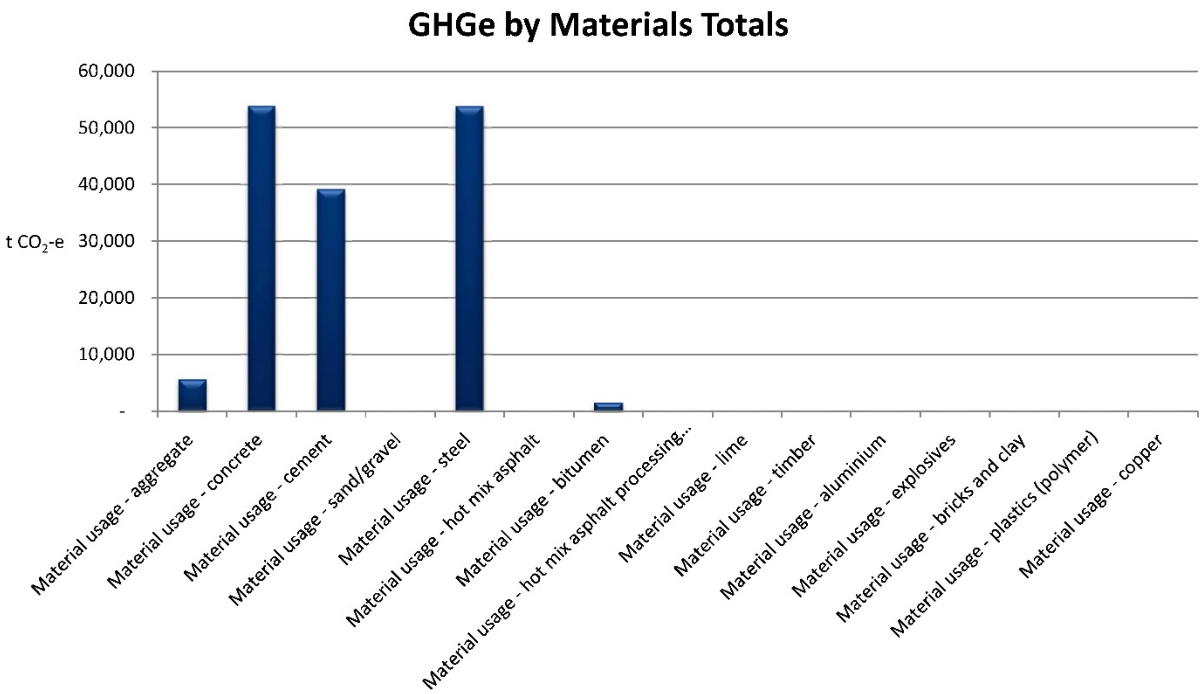



GHGe Summary by Emissions Source - Road Furniture
t CO2-e
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
Wire rope barrier
W-beam barrier
F-type (New Jersey) barrier
Reinforced concrete wall
Hebel noise wall
Timber wall
Steel plate wall

## Materials


GHGe by Materials Totals
t CO2-e
60,000
50,000
40,000
30,000
20,000
10,000
-
Material usage - aggregate
Material usage - concrete
Material usage - cement
Material usage - sand/gravel
Material usage - steel
Material usage - hot mix asphalt
Material usage - bitumen
Material usage - hot mix asphalt processing...
Material usage - lime
Material usage - timber
Material usage - aluminium
Material usage - explosives
Material usage - bricks and clay
Material usage - plastics (polymer)
Material usage - copper

# Operation Report

**Note:** This Workbook is designed to enable a consistent methodology for the assessment of significant emission sources and estimation of greenhouse gas emissions. As such it deliberately does not cover activities and emission sources assessed as insignificant, and it is not designed for compliance reporting.

## Project Description

| | |
|---|---|
| Project title | M1 to Raymond Terrace |
| Project location | Raymond Terrace |
| State | NSW |
| Description | New road and bridge linking the M1 motorway between Blackhill and Raymond Terrace |

| | |
|---|---|
| Project Value ($m) | 1645000000 |
| Project Duration (Months) | 36 |

## Operations (Emissions are calculated for a 50 year period)

### Materiality Checklist Options

| Checklist Options | Selection | Details |
|---|---|---|
| Will the project include lighting continuously along the road length? | YES | The emissions from the operation of street lighting will be included. |
| Will the project include traffic signals and/or interchanges using incandescent lights? | YES | The emissions from the operation of traffic signals using incandescent lights wil be included. |
| Will the project include traffic signals and/or interchanges using quartz halogen lights? | YES | The emissions from the operation of traffic signals using quartz halogen lights wil be included. |
| Will the project include traffic signals and/or interchanges using LED lights? | YES | The emissions from the operation of traffic signals using LED lights wil be included. |
| Will the project include vehicle use during the operation of the road? | YES | The emissions from the operation of vehicles on this section of road will be included. |

### Street Lighting

| | Lighting Area | Street Length (m) | GHGe (t $CO_2$-e) |
|---|---|---|---|
| Lighting | Freeway through carriageways | 2,800 | 2,439 |
| | Freeway ramps and arterial roads | 13,566 | 7,640 |
| | Underpasses | - | - |
| | | | **10,080** |

### Traffic Signals

| | Intersection Type | Number of Intersections | GHGe (t $CO_2$-e) |
|---|---|---|---|
| Incadescent Traffic Signals | Major urban intersection - Divided Road | - | - |
| | Major intersection - Undivided Road | - | - |
| | Freeway with divided road (full diamond interchange) | - | - |
| Quartz Halogen Traffic Signals | Major urban intersection - Divided Road | - | - |
| | Major intersection - Undivided Road | - | - |
| | Freeway with divided road (full diamond interchange) | - | - |
| LED Traffic Signals | Major urban intersection - Divided Road | 2 | 534 |
| | Major intersection - Undivided Road | - | - |
| | Freeway with divided road (full diamond interchange) | - | - |
| | | | **534** |

### Vehicle Use

| | Vehicle Type | GHGe (t $CO_2$-e) |
|---|---|---|
| Vehicles | Emissions from vehicles using road | - |
| | | - |

## Greenhouse Gas Emissions

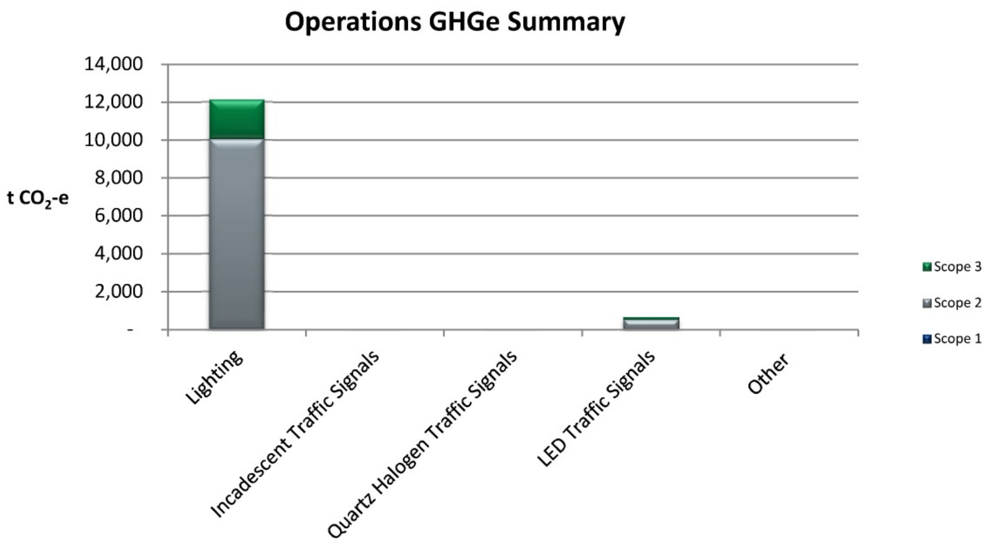
Emissions are calculated for a 50 year period.

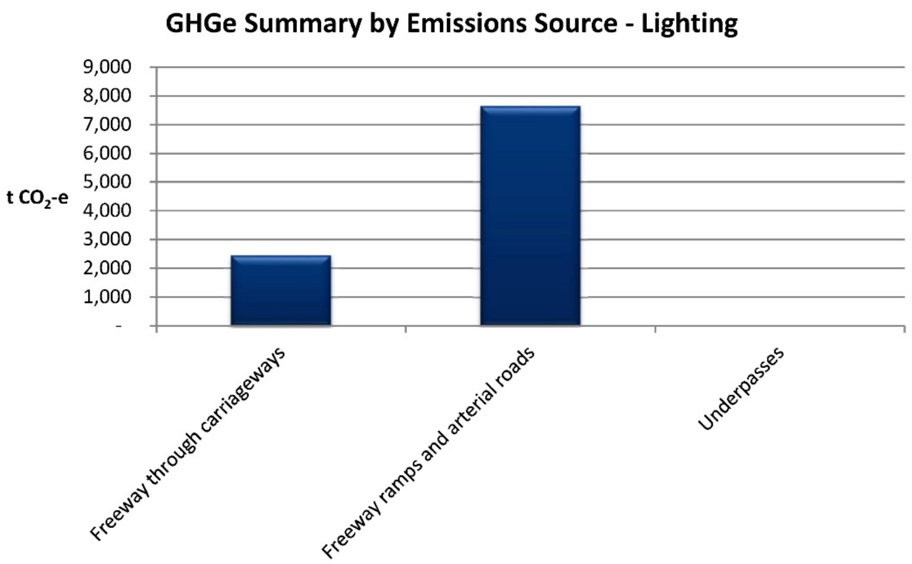
| | |
|---|---|
| Scope 1 emissions | Emissions released into the atmosphere as a direct result of an activity, or series of activities (including ancillary activities) that constitutes the facility. |
| Scope 2 emissions | Emissions released as a result of one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but that do not form part of the facility. |
| Scope 3 emissions | Emissions that occur outside the site boundary of a facility as a result of activities at a facility that are not Scope 2 emissions. |

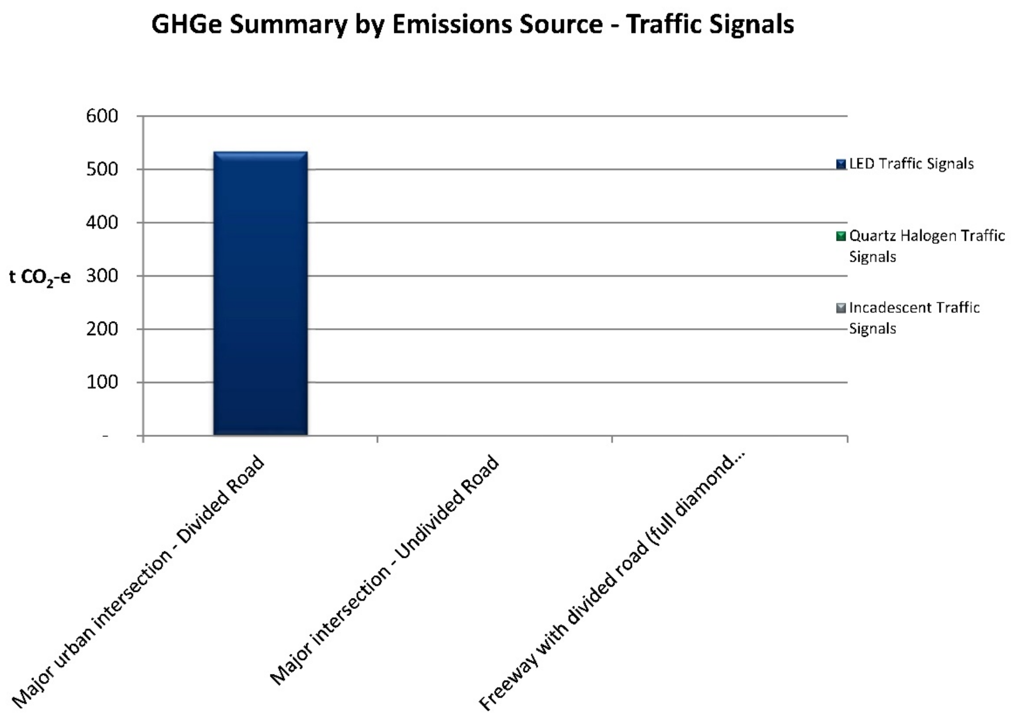
## Operations

| Summary | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| Lighting | - | 10,080 | 2,062 | **12,141** |
| Incadescent Traffic Signals | - | - | - | **-** |
| Quartz Halogen Traffic Signals | - | - | - | **-** |
| LED Traffic Signals | - | 534 | 109 | **643** |
| *Other* | - | - | - | **-** |
| **Total** | **-** | **10,614** | **2,171** | **12,784** |

| Summary - Vehicles | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| Vehicle Use | - | - | - | **-** |
| **Total** | **-** | **-** | **-** | **-** |


Operations GHGe Summary
t CO2-e
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Lighting
Incadescent Traffic Signals
Quartz Halogen Traffic Signals
LED Traffic Signals
Other
Scope 3
Scope 2
Scope 1


GHGe Summary by Emissions Source - Lighting
t CO2-e
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
Freeway through carriageways
Freeway ramps and arterial roads
Underpasses


GHGe Summary by Emissions Source - Traffic Signals
600
500
400
300
200
100
-
t CO2-e
LED Traffic Signals
Quartz Halogen Traffic Signals
Incadescent Traffic Signals
Major urban intersection - Divided Road
Major intersection - Undivided Road
Freeway with divided road (full diamond...

# Maintenance Report

**Note:** This Workbook is designed to enable a consistent methodology for the assessment of significant emission sources and estimation of greenhouse gas emissions. As such it deliberately does not cover activities and emission sources assessed as insignificant, and it is not designed for compliance reporting.

## Project Description

| | |
|---|---|
| Project title | M1 to Raymond Terrace |
| Project location | Raymond Terrace |
| State | NSW |
| Description | New road and bridge linking the M1 motorway between Blackhill and Raymond Terrace |

| | |
|---|---|
| Project Value ($m) | 1645000000 |
| Project Duration (Months) | 36 |

## Maintenance (Emissions are calculated for a 50 year period)

### Maintenance Activities

| | Pavement Type | Pavement area (m2) | GHGe (t $CO_2$-e) |
|---|---|---|---|
| Pavements - Flexible | 01. Full Depth Asphalt | 63,357 | 3,105 |
| | 02. Deep Strength Asphalt | 29,563 | 797 |
| | 03. Granular with Spray Seal | - | - |
| Pavements - Rigid | 04. Plain Concrete (PC) | 426,302 | 14,157 |
| | 05. Reinforced Concrete (RC) | - | - |
| | | | **18,059** |

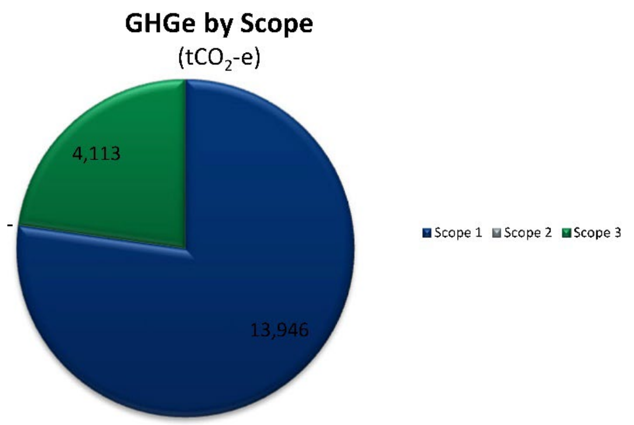
## Greenhouse Gas Emissions

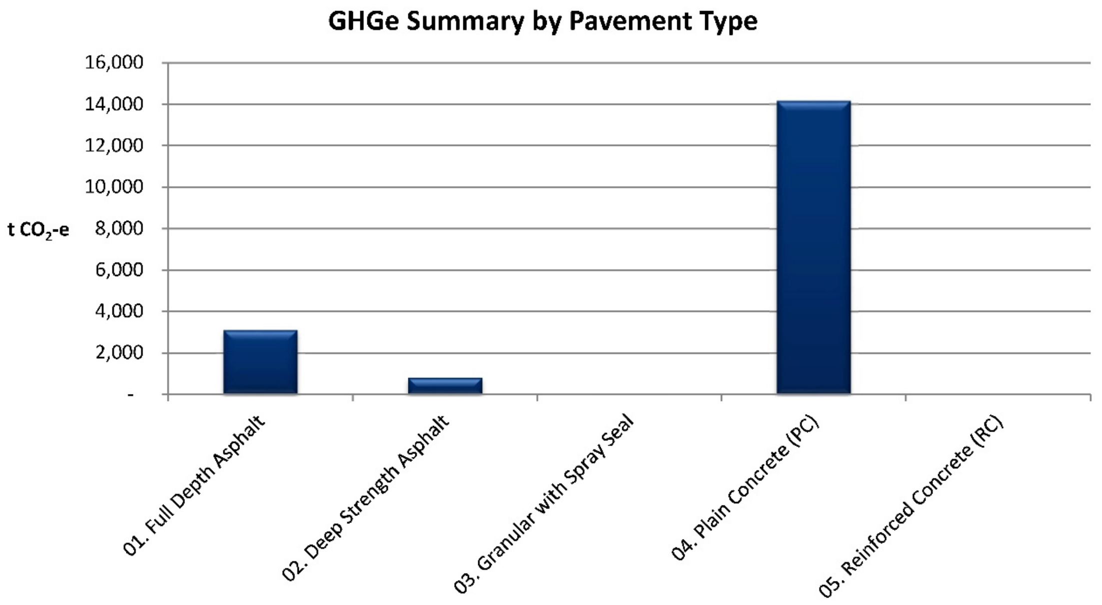
Emissions are calculated for a 50 year period.

| | |
|---|---|
| **Scope 1 emissions** | Emissions released into the atmosphere as a direct result of an activity, or series of activities (including ancillary activities) that constitutes the facility. |
| **Scope 2 emissions** | Emissions released as a result of one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but that do not form part of the facility. |
| **Scope 3 emissions** | Emissions that occur outside the site boundary of a facility as a result of activities at a facility that are not Scope 2 emissions. |

### Maintenance

| Summary by Pavement | Scope 1 | Scope 2 | Scope 3 | Total |
|---|---|---|---|---|
| 01. Full Depth Asphalt | 1,360 | - | 1,746 | **3,105** |
| 02. Deep Strength Asphalt | 349 | - | 448 | **797** |
| 03. Granular with Spray Seal | - | - | - | **-** |
| 04. Plain Concrete (PC) | 12,237 | - | 1,920 | **14,157** |
| 05. Reinforced Concrete (RC) | - | - | - | **-** |
| *Other* | - | - | - | **-** |
| **Total** | **13,946** | **-** | **4,113** | **18,059** |



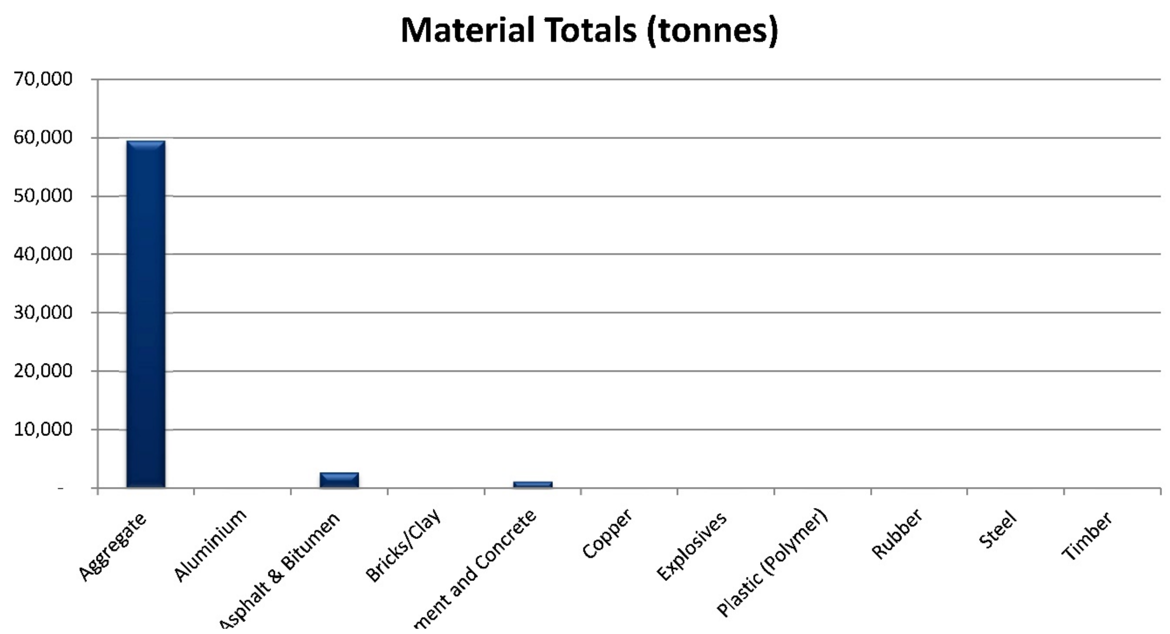




## Material Totals (t)

| | Pavements | Total |
|---|---|---|
| Aggregate | 59,441 | **59,441** |
| Aluminium | - | **0** |
| Asphalt & Bitumen | 2,682 | **2,682** |
| Bricks/Clay | - | **0** |
| Cement and Concrete | 1,151 | **1,151** |
| Copper | - | **0** |
| Explosives | - | **0** |
| Plastic (Polymer) | - | **0** |
| Rubber | - | **0** |
| Steel | - | **0** |
| Timber | - | **0** |
| **Total** | **63,275** | **63,275** |

Fuel Totals (kL)

| | Pavements | Total |
|---|---|---|
| Biodiesel | - | 0 |
| Diesel | 5,198 | 5,198 |
| Fuel Oil | - | 0 |
| Kerosene | - | 0 |
| LPG | - | 0 |
| Unleaded Petrol | - | 0 |
| Total | 5,198 | 5,198 |



# Appendix B – Risk Assessment Tables

Source: RMS Risk Management Guideline ilc-mi-tp0-201-g01

Table B-1 Likelihood Criteria

| Likelihood rating | Description | | Probability parameters | |
|---|---|---|---|---|
| **Extreme (E)** | Almost certain | The event is expected to occur in most circumstances | >90% and <100% probability | >1 in 1 year |
| **High (H)** | Likely | The event will probably occur in most circumstances | 51% to 90% probability | 1 in 10 years |
| **Medium (M)** | Moderate | The event should occur at some time | 21% to 50% probability | 1 in 50 years |
| **Low (L)** | Unlikely | The event could occur at some time | 10% to 20% probability | 1 in 100 years |
| **Negligible (N)** | Rare | The event might occur in exceptional circumstances | <10% probability | 1 in 100 years |

Table B-2 Consequence Criteria

| CONSEQUENCE CRITERIA | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Consequence Rating | IMPACTS ON PROJECT OBJECTIVES | | | | | | | | | | |
| | TECHNICAL PERFORMANCE | | | | | | | | | | |
| | Time | | Cost | | Safety | | Environment Implementation Operation | Traffic Flow Peak Hour | Local Traffic | Community Attitude | Fit for Purpose Defects Accidents Maintenance Costs |
| | Development | Implementation | Development | Implementation | Implementation | Operation | | | | | |
| CONSEQUENCE – **Extreme** | YEAR | MONTHS | $ (25% o/c) | $ (10% o/c) | WCL: >$250,000 Death/Perm. loss of physical/mental amenity | Multiple WCL: > $250,000 Death/Per. loss of physical/mental amenity | Major environmental damage &/or Delay due to Legal Finding in Land & Environment | No Improvement | Severe Disruption | Severe Community Protests | Functional Failure |
| **High** | MONTHS | MONTHS | $ (15% o/c) | $ (7% o/c) | WCL: $10,001-250,000 Lost time =>5 days | WCL: >$250,000 Death/Perm. loss of physical/mental amenity | Serious environmental damage &/or Delay due to Public Enquiry. EPA Major Notice | Marginal Improvement | Disruption | Community Protests | Serious Functional Failure |
| **Medium** | MONTHS | MONTHS | $ (7.5% o/c) | $ (4% o/c) | WCL: $1,001-10,000 Lost time 1-4 days | WCL: $10,001-250,000 Lost time =>5 days | Environmental damage & / or EPA Infringement Notice | | | Daily Complaints | Minor Functional Failure |
| **Low** | MONTHS | WEEKS | $ (1 % o/c) | $ (1% o/c) | WCL: $251-1,000 Lost time =>1day | WCL: $1,001-10,000 Lost time 1-4 days | Minor environmental damage &/or Minor EPA Infringement Notices. Writen Community comments | km/hr Give a value | | Complaints | |
| **Negligible** | WEEKS | NIL | $ (0.1% o/c) | $ (0.1% o/c) | WCL: $1-250 First Aid treatment (no lost time) | WCL: $251-1,000 Lost time =>1day | Minor repairable environmental damage Verbal Community Comment | km/hr Give a value | | Negligible Complaints | |

O/C – Overall Construction Cost
WCL – Worker's Compensation Liability

Table B-3 Risk Ranking matrix

| | | Risk Levels | | | | |
|---|---|---|---|---|---|---|
| Likelihood | Extreme | M | H | E | E | E |
| | High | L | M | H | E | E |
| | Medium | N | L | M | H | E |
| | Low | N | N | L | M | H |
| | Negligible | N | N | N | L | M |
| | | Negligible | Low | Medium | High | Extreme |
| | | Consequences | | | | |

# Appendix C – Climate Change Risk Register

| Risk ID | Cause, trigger or issue | Risk, hazard or opportunity | Potential consequences | Original rating | | | Proposed risk treatment | Responsible person | Residual rating | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Likelihood | Consequence | Original | | | Likelihood | Consequence | Residual |
| 1 | Increased high temperatures extremes and more frequent incidence and severity of heatwaves. | Road surface cracks or becomes degraded dueto inability to cope with extreme heat. | Partial road closures, increased maintenance requirements, potential for car accidents. | M | M | M | Heavy duty pavements have been specified for the project which have low susceptibility to damage caused by high ambient temperatures.<br>Regular resurfacing of flexible pavements will also occur as part of maintenance program. | | L | M | L |
| 2 | Increased high temperatures extremes and more frequent incidence and severity of heatwaves. | Bridge infrastructure components are unsuited to future climate extremes. Example is bridge deck expansion joints are inadequately sized or unable to cope with greater maximum temperatures. | Additional wear on infrastructure causing damage or increased maintenance requirement. | M | M | M | Detailed design should incorporate the full range of temperature projections, as well as expected life of bridge components, when materials are specified. | | L | M | L |
| 3 | Increased high temperatures extremes and more frequent incidence and severity of heatwaves. | Maintenance activities have to be postponed due to extreme heat. | Delay in maintenance activities causes a backlog inwork. | H | N | L | Accept risk and use standard TfNSW procedures for working in extreme heat. Examples of potential work health safety practices may include stop work protocols for extreme heat days, or increased training and education for personnel regarding health and safety procedures during periods of extreme heat. | | H | N | L |
| 4 | Increased high temperatures extremes and more frequent incidence and severity of heatwaves. | Transformers / back up generation and substations used for traffic control systems are unable to cope with periods of extreme heat and fail. | Failure of electronic monitoring and communication systems along the roadway provides less control forstaff, and increases risk of traffic jams. Increased maintenance requirement and need to replace equipment more frequently. Potential additional costs associated with providing cooling for electronic equipment. | M | L | L | Ensure full range of temperature projections, as well as expected life of electronic equipment are considered when designing electrical infrastructure. | | L | L | L |
| 5 | Increased high temperatures extremes and more frequent incidence and severity of heatwaves. | Revegetated areas are unable to survive inhigher temperatures and during extreme heatwaves. | Reduction of visual amenity results in complaints. Reduction in vegetation cover results in instability to embankments and drainage channels requiring increased maintenance. | M | L | L | Ensure revegetation plan considers climate change projections in specification of species (both in and outside the floodplain). Wherepossible, avoid carrying out revegetation work during Summer. | | M | L | L |
| 6 | Increased length and severity of seasonal drought. | Embankments, retaining walls and noise walls become destabilised due to cracking in soil surrounding foundations as it dries out. | Increased maintenance / repair requirements. Potential closure of road during maintenance / repair. | L | M | L | Ensure revegetation plan considers use of drought tolerant species whichwill assist in maintaining structural integrity of soils. | | L | M | L |
| 7 | Increased length and severity of seasonal drought. | Revegetated areas are unable to survive indrought conditions. | Reduction of visual amenity results in complaints. Reduction in vegetation cover results in instability to embankments and drainage channels requiring increased maintenance. | M | L | L | | | M | L | L |
| 8 | Decrease in average annual rainfall and drought conditions. | Revegetation along the proposal is unable to survive due to insufficient rainfall. | Reduction of visual amenity results in complaints. Reduction in vegetation cover results in instability to embankments and drainage channels requiring increased maintenance. | M | L | L | Ensure revegetation plan considers climate change projections inspecification of species (both in and outside the floodplain). | | M | L | L |
| 9 | Increase in the frequency and intensity of severe rainfall events with Sea Level Rise | Increased flooding (extent and depth) covers and damages areas previously modelled / designed to be immune from flooding (to the 5% AEP design standard). | Flooding damage to road and road infrastructure (including electrical infrastructure) which could temporarily close the road and would which would severely delay traffic. Impact would require clean up and repair depending on level of damage. Impact could extend to neighbouring properties due to inability of flood waters to dissipate | H | M | H | Much of the current alignment achieves immunity to the 1% AEP event and as such provides a level of immunity above the design parameter 5% AEP event. With 5% AEP immunity, the road is expected to flood at times, and is therefore designed to provide a level of resilience to this.<br><br>Additional flood modelling will be carried out if any design changes are made during detailed design. Additional flood modelling would consider climate change related flood risks to the project and the flood impacts from the project. | | H | M | H |

| Risk ID | Cause, trigger or issue | Risk, hazard or opportunity | Potential consequences | Original rating | | | Proposed risk treatment | Responsible person | Residual rating | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Likelihood | Consequence | Original | | | Likelihood | Consequence | Residual |
| 10 | Increase in the frequency and intensity of severe rainfall events with Sea Level Rise | Increased flooding (extent and depth) overwhelms areas previously modelled / designed to be immune from flooding (to the 5%AEP design standard). | Flooding/standing water causes accidents for motor vehicles and cyclists resulting in safety incidents for road users | H | M | H | Much of the current alignment achieves immunity to the 1% AEP event and as such provides a level of immunity above the design parameter 5% AEP event. Access to the motorway would be limited during a flood event as local roads would be inundated (the motorway would be one of the more flood proof areas). Number of road users would therefore be greatly reduced and limited to those already travelling north or south along the M1 Pacific Motorway. Variable messaging signs would inform road users of hazards.<br><br>Additional flood modelling will be carried out if any design changes are made during detailed design. Additional flood modelling will be carried out if any design changes are made during detailed design. Additional flood modelling would consider climate change related flood risks to the project and the flood impacts from the project. | | H | M | H |
| 11 | Increase in the frequency and intensity of severe rainfall events. | Drainage channels and culverts are too small as5% AEP storms (the design standard) are more severe as a result of climate change. Exits of culverts suffer increased scour. | Culverts and drainage channels are overwhelmed causing increased flooding on the up flow side of theculverts, and increased scour at the outflows. This results in increased road closures, and increased maintenance / rectification costs. Diverted water may lead to increased flooding at existing properties. | H | M | H | Additional flood modelling will be undertaken during detailed design toaccount for design changes. | | H | M | H |
| 12 | Increase in the frequency and intensity of severe rainfall events. | Increased flooding and inundation destroys or severely stunts the growth of surrounding areas. | Revegetated areas must be replanted or mayrequired increased maintenance. | M | L | L | Ensure revegetation plan considers climate change projections inspecification of species (both in and outside the floodplain). | | M | L | L |
| 13 | More severe fire weather and elevated fireweather conditions. | Increased local bushfires cause decreasedvisibility due to smoke | Road users suffer reduced visibility due to smoke resulting in accidents. | M | M | M | The project includes new and relocated Variable Message Signs to warn road users of potential hazards. | | M | M | M |
| 14 | More severe fire weather and elevated fireweather conditions. | Increased local bushfires cause damage to structures such as retaining walls and bridges. | Bushfires in proximity to the project may cause direct damage to structures, utilities and fauna connectivity measures, resulting in road closures while repairs / damage assessment is carried out. | M | H | H | Concept design has considered potential impacts to structures, utilities and fauna connectivity structures in bushfire prone areas. Access to firetrails will be maintained. | | M | M | M |
| 15 | More severe fire weather and elevated fireweather conditions. | Increased local bushfires destroy localrevegetation. | Revegetated areas are not tolerant to bushfires (i.e. do not have the capacity to regenerate) meaning increased maintenance is required following such events. Potential for burnt/dead tree impacts onto motorway. | M | L | L | Detailed design will include a requirement to ensure plant/tree species selection (and location of trees) caters for potential impacts if burnt (e.g. falling onto Motorway). | | M | L | L |
| 16 | Increased concentration of carbon dioxide in the atmosphere. | Carbonation occurs to a greater depth in concrete structures, allowing exposure and degradation of reinforcement. Retaining walls, piers and bridge deck elements are degraded quicker than anticipated shortening their design life. | Shorter design life results in greater levels of inspection and maintenance needed, increase asset operational costs. | M | M | M | During detailed design, a material durability report will be prepared and actioned which will specifically review the potential impacts of climate change on concrete durability, including depth of cover over reinforcement. | | L | M | L |