NSW GOVERNMENT

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Appendix X

Climate change and greenhouse gas calculations

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Technical working paper: Climate change and greenhouse gas calculations

December 2020

Prepared for

Transport for NSW

Prepared by

Jacobs Group (Australia) Pty Ltd

Contents

List of Tables

List of figures

Glossary

Acronym	Definition
AR5	Intergovernmental Panel on Climate Change's Fifth Assessment Report
BCC	Beijing Climate Center
CAM	Community Atmosphere Model
CCIA	Climate Change in Australia
CFT	Climate Futures Tool
CH_4	Methane
CMA	China Meteorological Administration
CO_2	Carbon dioxide
CO_2-e	CO_2 equivalent
DCCEE	Department of Climate Change and Energy Efficiency (former Australian Government Department)
ECF	Energy content factor
EPA	Environment Protection Authority
GCM	General Circulation Model
GHG Protocol	Greenhouse Gas Protocol
HC	Hydrocarbons
HFCs	Hydrofluorocarbons
ISCA	Infrastructure Sustainability Council Australia
ISMC	Infrastructure Sustainability Materials Calculator
N_2O	Nitrous oxide
NCAR	National Center for Atmospheric Research
NGA	National Greenhouse Accounts
PFCs	Perfluorocarbons
RCP	Representative Concentration Pathway
SF_6	Sulphur hexafluoride
SMPM	Sydney Motorway Project Model
TAGG	Transport Authorities Greenhouse Gas
TRAQ	Tools for Roadside Air Quality
UNFCCC	United Nations Framework Convention on Climate Change
VIS	Vegetation Information System
VKT	Vehicle kilometres travelled

Executive Summary

Transport for NSW is seeking approval under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* to construct and operate the Beaches Link and Gore Hill Freeway Connection project, which would comprise two components:

- Twin tolled motorway tunnels connecting the Warringah Freeway at Cammeray and the Gore Hill Freeway at Artarmon to the Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights, and an upgrade of the Wakehurst Parkway (the Beaches Link)
- Connection and integration works along the existing Gore Hill Freeway and surrounding roads at Artarmon (the Gore Hill Freeway Connection).

This report has been prepared to support the environmental impact statement for the project and presents an assessment of climate change projections and greenhouse gas calculations.

Climate change projections

Climate change projections are useful tools to guide decision-making about climate risks. They indicate the expected trend in climate variables under various future scenarios and the likely quantum of change.

Climate change projections included in this assessment are based on Representative Concentration Pathway (RCP) 8.5, which reflects the highest of emissions (or radiative forcing) scenarios considered in the Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5, IPCC (2013)). They follow the projections for this scenario through time from 2030 to 2090.

Climate change projections were developed for three periods, which broadly reflect the operating lives of different elements being constructed as part of the project. These were compared against a baseline (1986-2005) for some climate variables where relevant, as this relates to the period from which the changes to those variables are projected. For each period, the projections show increases in mean, minimum and maximum temperatures.

Greenhouse gas calculations

'Greenhouse gases' is a collective term for a range of gases that are known to trap radiation in the upper atmosphere, where they have the potential to contribute to the greenhouse effect (global warming). Creating an inventory of the likely greenhouse gas emissions associated with a project has the benefit of determining the scale of the emissions and providing a baseline from which to develop and deliver greenhouse gas reduction options.

The greenhouse gas inventory in this document is calculated in accordance with the principles of the Greenhouse Gas Protocol (GHG Protocol) and emissions that form the inventory can be split into three categories known as 'Scopes'. Scopes 1, 2 and 3 are defined by the GHG Protocol and can be summarised as follows:

- Scope 1 – Direct emissions from sources that are owned or operated by a reporting organisation (examples – combustion of diesel in company owned vehicles or used in on-site generators)
- Scope 2 – Indirect emissions associated with the import of energy from another source (examples – 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 (examples include business travel (by air or rail) and manufacture of construction materials).

An estimate of greenhouse gas emissions associated with construction of the project has been calculated for:

- Fuel combustion from construction plant and equipment, including barge movements
- Fuel combustion by generators during harbour construction activities
- Construction materials
- Fuel combustion from the transport of materials
- Fuel combustion from the transport of waste and spoil
- Electricity consumption
- Vegetation removal.

An estimate of greenhouse gas emissions associated with construction of the project has been calculated for:

- Operational electricity consumption
- Maintenance activities
- Fuel consumption by vehicles using the road network.

Table E-1 provides a summary of the emissions associated with construction and operation of the project.

Table E-1 Construction and operation greenhouse gas summary

Source	Greenhouse gas emissions (t CO_2-e)	
	Project only	Cumulative
Construction	723,707	1,521,365
Operation 2027	45,276	112,629
Operation 2037	52,526	139,363

Construction emissions are expected to be much higher than the annual increase in operational emissions over the network as a result of the project facilitating additional transport across northern Sydney. The efficiency of this transport is expected to improve for the project through the removal of congestion and the creation of freer-flowing routes.

Project related construction and annual operation emissions would contribute to national and State greenhouse gas inventories. The percentage contributions have been calculated and are presented in Section 3.2.3 of this report.

1. Introduction

This section provides an overview of the Beaches Link and Gore Hill Freeway Connection (the project) including its key features and location. It also outlines the Secretary's environmental assessment requirements addressed in this technical working paper.

1.1 Overview

The Greater Sydney Commission's *Greater Sydney Region Plan – A Metropolis of Three Cities* (Greater Sydney Commission, 2018a) proposes a vision of three cities where most residents have convenient and easy access to jobs, education and health facilities and services. In addition to this plan, and to accommodate for Sydney's future growth the NSW Government is implementing the *Future Transport Strategy 2056* (NSW Government, 2018), that sets the 40 year vision, directions and outcomes framework for customer mobility in NSW. The Western Harbour Tunnel and Beaches Link program of works is proposed to provide additional road network capacity across Sydney Harbour and Middle Harbour and to improve transport connectivity with Sydney's Northern Beaches. The Western Harbour Tunnel and Beaches Link program of works include:

- The Western Harbour Tunnel and Warringah Freeway Upgrade project which comprises a new tolled motorway tunnel connection across Sydney Harbour, and an upgrade of the Warringah Freeway to integrate the new motorway infrastructure with the existing road network and to connect to the Beaches Link and Gore Hill Freeway Connection project
- The Beaches Link and Gore Hill Freeway Connection project which comprises a new tolled motorway tunnel connection across Middle Harbour from the Warringah Freeway and the Gore Hill Freeway to Balgowlah and Killarney Heights and including the surface upgrade of the Wakehurst Parkway from Seaforth to Frenchs Forest and upgrade and integration works to connect to the Gore Hill Freeway at Artarmon.

A combined delivery of the Western Harbour Tunnel and Beaches Link program of works would unlock a range of benefits for freight, public transport and private vehicle users. It would support faster travel times for journeys between the Northern Beaches and areas south, west and north-west of Sydney Harbour. Delivering the program of works would also improve the resilience of the motorway network, given that each project provides an alternative to heavily congested existing harbour crossings.

1.2 The project

Transport for NSW is seeking approval under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* to construct and operate the Beaches Link and Gore Hill Freeway Connection project, which would comprise two components:

- Twin tolled motorway tunnels connecting the Warringah Freeway at Cammeray and the Gore Hill Freeway at Artarmon to the Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights, and an upgrade of the Wakehurst Parkway (the Beaches Link)
- Connection and integration works along the existing Gore Hill Freeway and surrounding roads at Artarmon (the Gore Hill Freeway Connection).

A detailed description of these two components is provided in Section 1.4.

1.3 Project location

The project would be located within the North Sydney, Willoughby, Mosman and Northern Beaches local government areas, connecting Cammeray in the south with Killarney Heights, Frenchs Forest and Balgowlah in the north. The project would also connect to both the Gore Hill Freeway and Reserve Road in Artarmon in the west.

Commencing at the Warringah Freeway at Cammeray, the mainline tunnels would pass under Naremburn and Northbridge, then cross Middle Harbour between Northbridge and Seaforth. The mainline tunnels would then split under Seaforth into two ramp tunnels and continue north to the Wakehurst Parkway at Killarney Heights and north-east to Balgowlah, linking directly to the Burnt Bridge Creek Deviation to the south of the existing Kitchener Street bridge.

The mainline tunnels would also have on and off ramps from under Northbridge connecting to the Gore Hill Freeway and Reserve Road east of the existing Lane Cove Tunnel. Surface works would also be carried out at the Gore Hill Freeway in Artarmon, Burnt Bridge Creek Deviation at Balgowlah and along the Wakehurst Parkway between Seaforth and Frenchs Forest to connect the project to the existing arterial and local road networks.

1.4 Key features of the project

Key features of the Beaches Link component of the project are shown in Figure 1-1 and would include:

- Twin mainline tunnels about 5.6 kilometres long and each accommodating three lanes of traffic in each direction, together with entry and exit ramp tunnels to connections at the surface. The crossing of Middle Harbour between Northbridge and Seaforth would involve three lane, twin immersed tube tunnels
- Connection to the stub tunnels constructed at Cammeray as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project
- Twin two lane ramp tunnels:
  - Eastbound and westbound connections between the mainline tunnel under Seaforth and the surface at the Burnt Bridge Creek Deviation, Balgowlah (about 1.2 kilometres in length)
  - Northbound and southbound connections between the mainline tunnel under Seaforth and the surface at the Wakehurst Parkway, Killarney Heights (about 2.8 kilometres in length)
  - Eastbound and westbound connections between the mainline tunnel under Northbridge and the surface at the Gore Hill Freeway and Reserve Road, Artarmon (about 2.1 kilometres in length).
- An access road connection at Balgowlah between the Burnt Bridge Creek Deviation and Sydney Road including the modification of the intersection at Maretimo Street and Sydney Road, Balgowlah
- Upgrade and integration works along the Wakehurst Parkway, at Seaforth, Killarney Heights and Frenchs Forest, through to Frenchs Forest Road East
- New open space and recreation facilities at Balgowlah
- New and upgraded pedestrian and cyclist infrastructure
- Ventilation outlets and motorway facilities at the Warringah Freeway in Cammeray, the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights
- Operational facilities, including a motorway control centre at the Gore Hill Freeway in Artarmon, and tunnel support facilities at the Gore Hill Freeway in Artarmon and the Wakehurst Parkway in Frenchs Forest
- Other operational infrastructure including groundwater and tunnel drainage management and treatment systems, surface drainage, signage, tolling infrastructure, fire and life safety systems, roadside furniture, lighting, emergency evacuation and emergency smoke extraction infrastructure, Closed Circuit Television (CCTV) and other traffic management systems.

Key features of the Gore Hill Freeway Connection component of the project are shown in Figure 1-2 and would include:

- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore & Western Line and T9 Northern Line and the Pacific Highway
- Modifications to the Reserve Road and Hampden Road bridges
- Widening of Reserve Road between the Gore Hill Freeway and Dickson Avenue
- Modification of the Dickson Avenue and Reserve Road intersection to allow for the Beaches Link off ramp

- Upgrades to existing roads around the Gore Hill Freeway to integrate the project with the surrounding road network
- Upgrade of the Dickson Avenue and Pacific Highway intersection
- New and upgraded pedestrian and cyclist infrastructure
- Other operational infrastructure, including surface drainage and utility infrastructure, signage and lighting, CCTV and other traffic management systems.

A detailed description of the project is provided in Chapter 5 (Project description) of the environmental impact statement.

Subject to obtaining planning approval, construction of the project is anticipated to commence in 2023 and is expected to take around five to six years to complete.

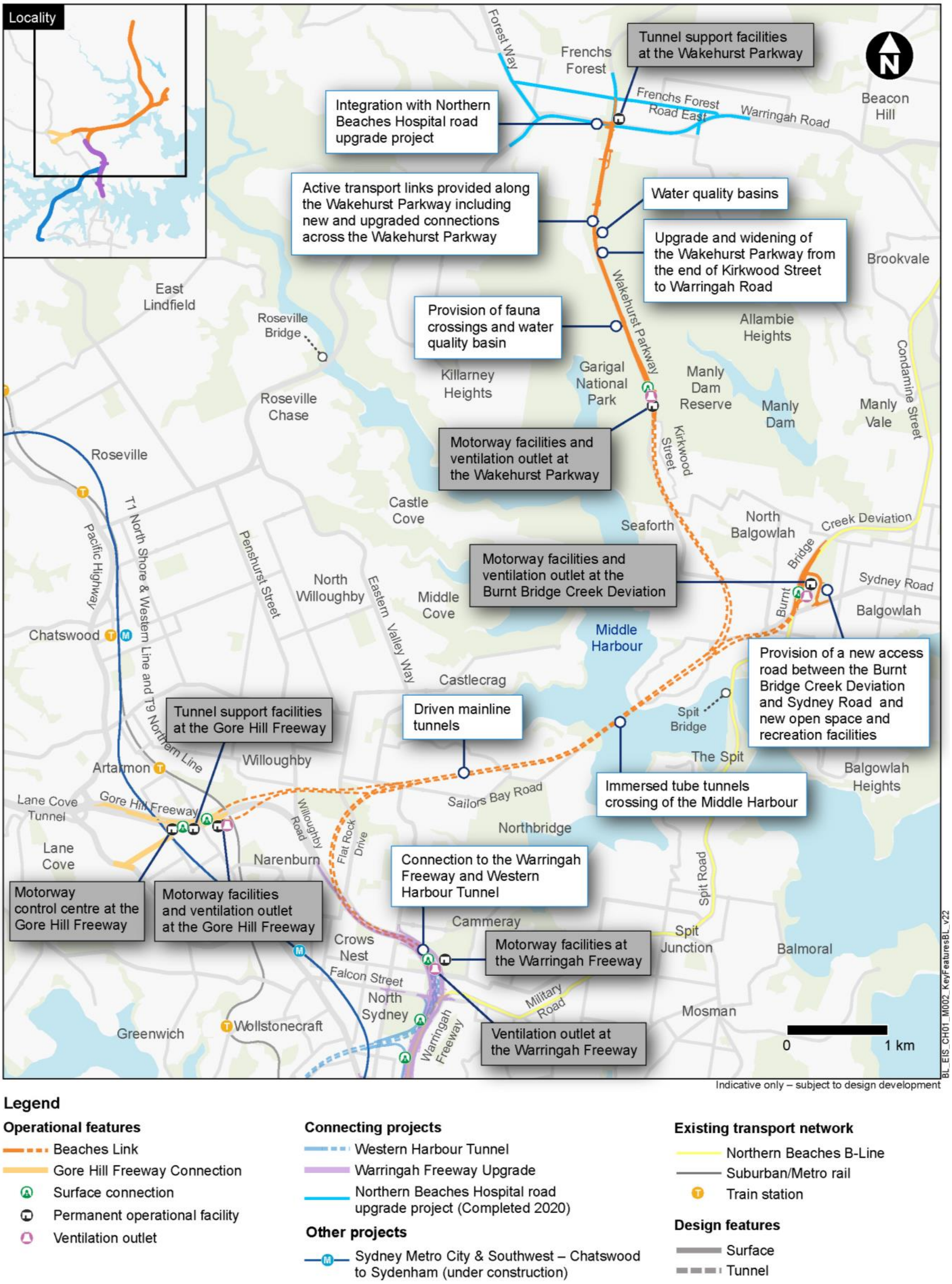


Figure 1-1 Key features of the Beaches Link component of the project

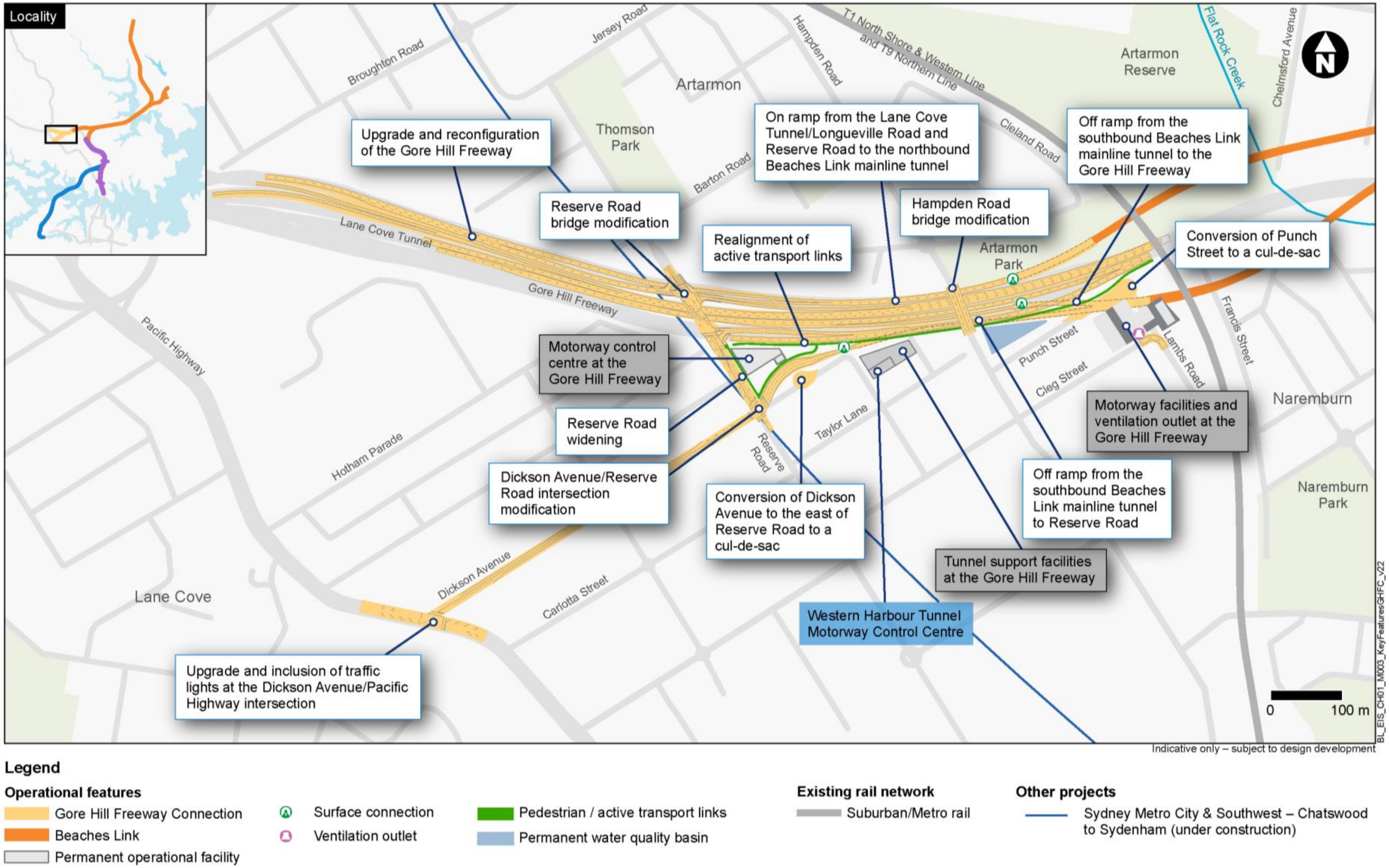


Figure 1-2 Key features of the Gore Hill Freeway component of the project

1.5 Key construction activities

The area required to construct the project is referred to as the construction footprint. The majority of the construction footprint would be located underground within the mainline and ramp tunnels. However, surface areas would also be required to support tunnelling activities and to construct the tunnel connections, tunnel portals, surface road upgrades and operational facilities.

Key construction activities would include:

- Early works and site establishment, with typical activities being property acquisition and condition surveys, utilities installation, protection, adjustments and relocations, installation of site fencing, environmental controls (including noise attenuation and erosion and sediment control), traffic management controls, vegetation clearing, earthworks, demolition of structures, building construction support sites including acoustic sheds and associated access decline acoustic enclosures (where required), construction of minor access roads and the provision of property access, temporary relocation of pedestrian and cycle paths and bus stops, temporary relocation of swing moorings and/or provision of alternative facilities (mooring or marina berth) within Middle Harbour
- Construction of the Beaches Link, with typical activities being excavation of tunnel construction access declines, construction of driven tunnels, cut and cover and trough structures, construction of surface upgrade works, construction of cofferdams, dredging and immersed tube tunnel piled support activities in preparation for the installation of immersed tube tunnels, casting and installation of immersed tube tunnels and civil finishing and tunnel fitout
- Construction of operational facilities comprising:
  - A motorway control centre at the Gore Hill Freeway in Artarmon
  - Tunnel support facilities at the Gore Hill Freeway in Artarmon and at the Wakehurst Parkway in Frenchs Forest
  - Motorway facilities and ventilation outlets at the Warringah Freeway in Cammeray (fitout only of the Beaches Link ventilation outlet at the Warringah Freeway (being constructed by the Western Harbour Tunnel and Warringah Freeway Upgrade project)), the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights
  - A wastewater treatment plant at the Gore Hill Freeway in Artarmon
  - Installation of motorway tolling infrastructure
- Staged construction of the Gore Hill Freeway Connection at Artarmon and upgrade and integration works at Balgowlah and along the Wakehurst Parkway with typical activities being earthworks, bridgeworks, construction of retaining walls, stormwater drainage, pavement works and linemarking and the installation of roadside furniture, lighting, signage and noise barriers
- Testing of plant and equipment and commissioning of the project, backfill of access declines, removal of construction support sites, landscaping and rehabilitation of disturbed areas and removal of environmental and traffic controls.

Temporary construction support sites would be required as part of the project (refer to Figure 1-3), and would include tunnelling and tunnel support sites, civil surface sites, cofferdams, mooring sites, wharf and berthing facilities, laydown areas, parking and workforce amenities. Construction support sites would include:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Dickson Avenue (BL4)
- Barton Road (BL5)

- Gore Hill Freeway median (BL6)
- Middle Harbour south cofferdam (BL7)
- Middle Harbour north cofferdam (BL8)
- Spit West Reserve (BL9)
- Balgowlah Golf Course (BL10)
- Kitchener Street (BL11)
- Wakehurst Parkway south (BL12)
- Wakehurst Parkway east (BL13)
- Wakehurst Parkway north (BL14).

A detailed description of construction works for the project is provided in Chapter 6 (Construction work) of the environmental impact statement.

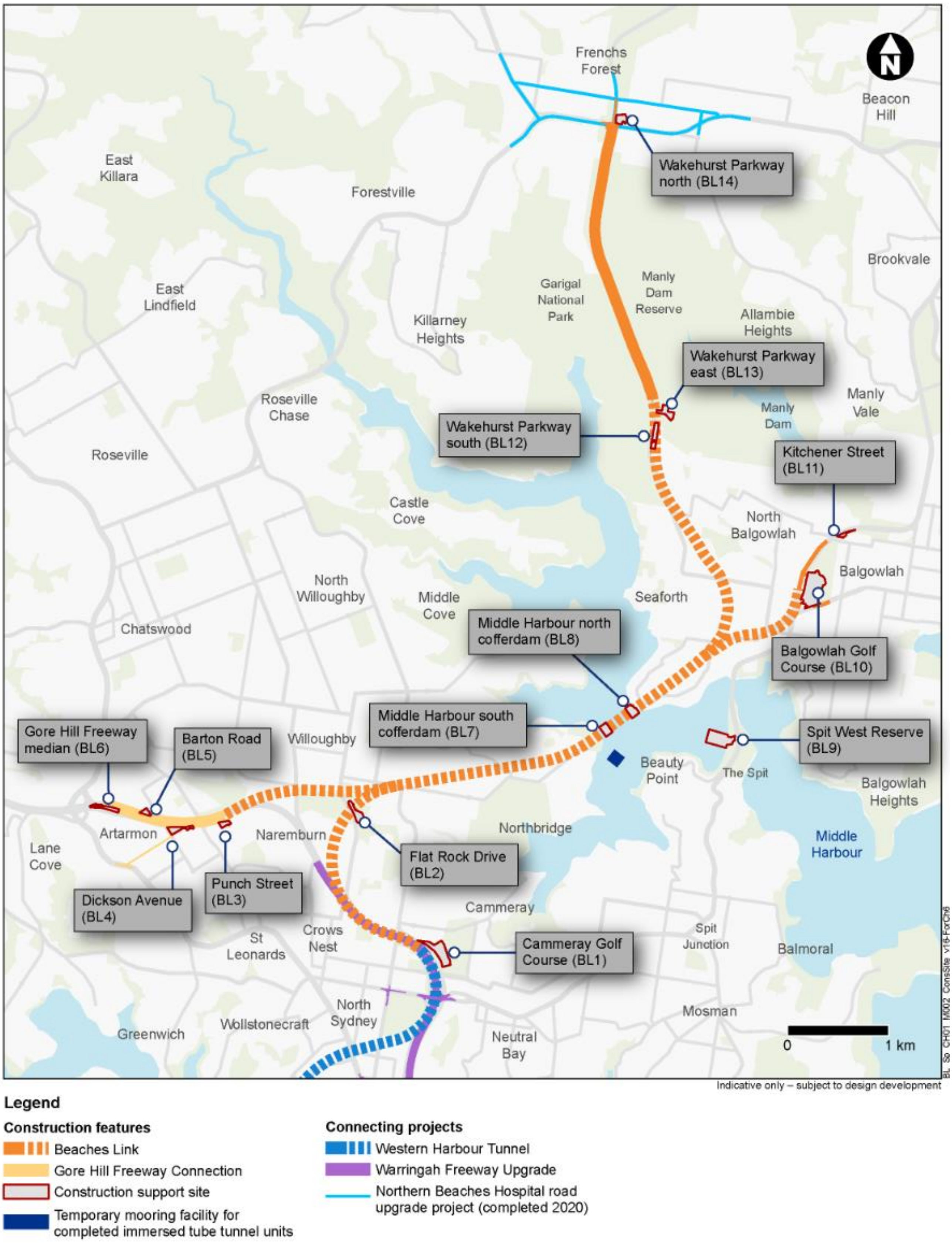


Figure 1-3 Overview of the construction support sites

1.6 Purpose of this report

This report has been prepared to support the environmental impact statement for the project and to address the environmental assessment requirements of the Secretary of the Department of Planning, Industry and Environment.

The purpose of this report is to outline climate change projections and associated climate risks. It includes:

- A review of existing climate change projections and the climate change risk assessment approach
- Assessment of construction greenhouse gas emissions
- Assessment of operational greenhouse gas emissions.

1.7 Secretary's environmental assessment requirements

The Secretary's environmental assessment requirements relating to climate change risk, and where these requirements are addressed in this report are outlined in Table 1-1.

Table 1-1 Secretary's environmental assessment requirements - climate change risk

Secretary's environmental assessment requirements	Where addressed
1) The Proponent must assess the risk and vulnerability of the project to climate change in accordance with the current guidelines.	Section 2.4 and Chapter 26 (Climate change and greenhouse gas)
2) The Proponent must quantify specific climate change risks with reference to either the NSW Government's climate projections at 10 km resolution (or lesser resolution if 10 km projections are not available) or equivalent projection tool (such as the Climate Futures Tool from CSIRO and BoM (attenuated for project region)) and incorporate specific adaptation actions in the design.	Section 2 and Chapter 26 (Climate change and greenhouse gas)

2. Climate change projections

2.1 Overview

The Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5, IPCC (2013)) provides a synthesis of climate change modelling undertaken by leading international climate research organisations. Outputs from this work for Australia are published on the Climate Change in Australia (CCIA) website (www.climatechangeinaustralia.gov.au), and specifically using its Climate Futures Tool (CFT) (Climate Change in Australia, 2020). They consolidate projections from General Circulation Model (GCM or global climate model) runs for the 21st century under a range of greenhouse gas emissions and Representative Concentration Pathway (RCP) scenarios and include data for a wide range of climate parameters, including rainfall, temperature and wind speed.

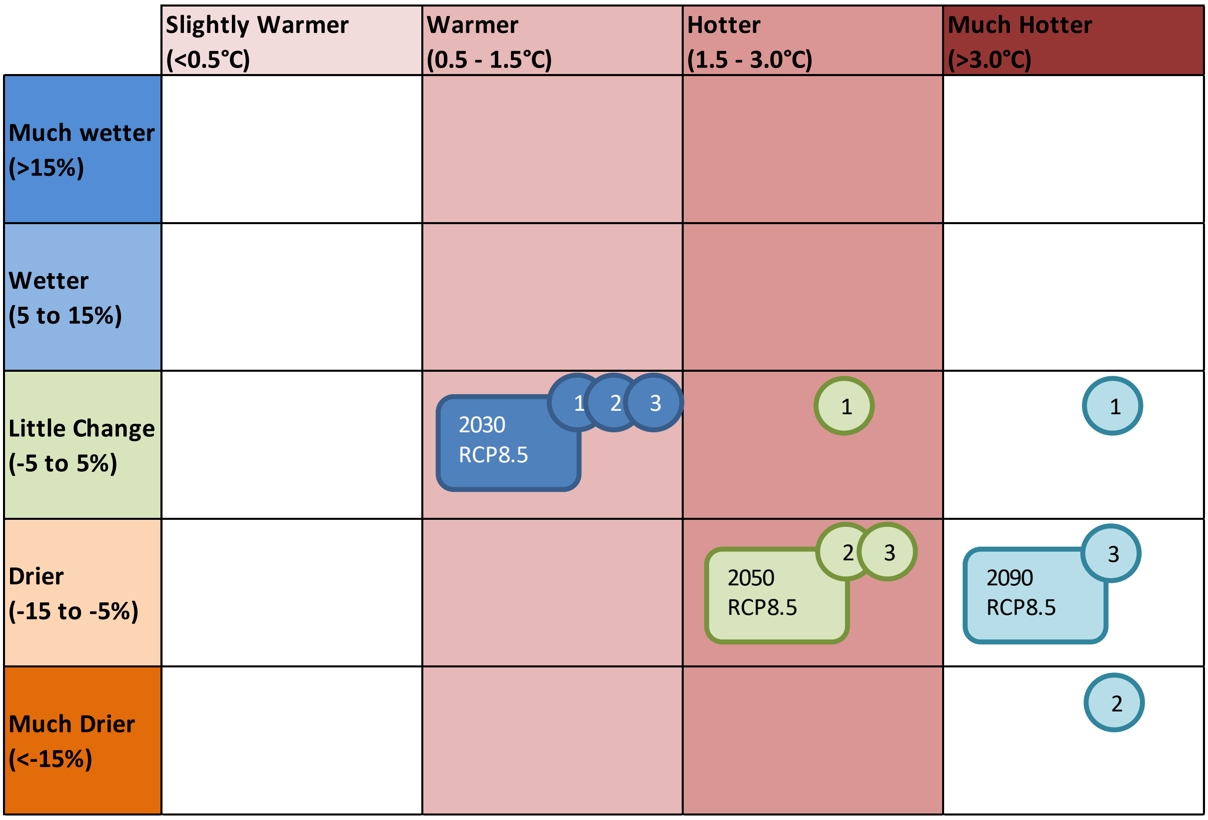
Climate change projections are useful tools to guide decision making about climate risks. They indicate the expected trend in climate variables under various future scenarios and the likely quantum of change. While probabilities may be provided for GCM projections for given RCP or emissions scenarios, no probabilities can be attached to the scenarios themselves. Confidence in climate change projections is greater for temperature and related climate attributes and much lower for rainfall, particularly extreme rainfall events.

Climate change projections included in this assessment are based on RCP8.5, which reflects the highest of the emissions (or radiative forcing) scenarios considered in AR5. They follow the projections for this scenario through time from 2030 to 2090.

2.2 Source of projections

The CFT collates the distribution of GCM change factors for each projection period and classifies models according to changes in average annual temperature and rainfall. The central tendency (see Figure 2-1) for the set of models which reliably reflect key climate drivers for south-eastern Australia is for warmer conditions, with little change in rainfall relative to 1986-2005, by 2030. By 2050, the central tendency in GCM projections is for the climate to be warmer and drier than the reference period. A large number of models project a hotter and drier climate or a warmer climate with little change in rainfall. In 2090, the most common projection is for the climate to be much hotter and drier than during the 1986-2005 climate change reference period.

An initial filtering of GCMs with the CFT was undertaken to only include AR5 models and of those; models which the web site advised were suitable for the East Coast of Australia. As noted above, the CFT was then used to identify the general pattern of climate change projections for 2030 and RCP8.5, with respect to changes in rainfall and temperature. Three GCMs which were considered by the CFT to best represent this pattern were then selected to provide the climate change factors for this period and for 2050 and 2090 under the RCP8.5 scenario. This ensures that climate change projections over each timeframe and for various climate characteristics are internally consistent.



Source: Data derived from CCIA web site www.climatechangeinaustralia.gov.au (Climate Change in Australia, 2020). The full ensemble of GCM used for AR5 and CMIP5 (Coupled Model Intercomparison Project Phase 5), on average project that climate will be warmer, with little change in rainfall in 2030, warmer and drier in 2050 and much hotter and drier in 2090. The three models used to develop climate change projections (1 – CESM1-CAM5, 2 – bcc-csm1-1, 3 – MPI-ESM-LR) broadly follow this trajectory. They were selected from the set of models which satisfactorily represent key processes influencing the climate of Eastern Australia.

Figure 2-1 Projected changes in annual rainfall and average temperature for the climate models used in this analysis

The three GCMs used in this assessment were:

- CESM1-CAM5 – Version 5.0 of the Community Atmosphere Model (CAM) – the latest in a series of global atmosphere models developed primarily at the National Center for Atmospheric Research (NCAR) – United States of America
- Bcc-csm1-1 – version 1.1 of the Beijing Climate Center Climate System Model (BCC_CSM1.1) developed at the Beijing Climate Center (BCC), China Meteorological Administration (CMA), based on NCAR CCSM2.0.1
- MPI-ESM-LR – Max Planck Institute Earth System Model (MPI-ESM) on low resolution (LR) grid. MPI-ESM is a comprehensive Earth-System Model, in the sense that it consists of component models for the ocean, the atmosphere and the land surface. These components are coupled through the exchange of energy, momentum, water and important trace gases such as carbon dioxide – Germany.

2.3 Projections

A summary of the projections identified in this section are presented below. Climate change projections were developed for three periods, which broadly reflect the operating lives of different elements being constructed as part of the project:

- 2030: Assets and systems with short operating lives, such as communications and other electronic systems and landscaping, as well as road surfaces
- 2050: Assets and systems with long operating lives, such as drainage structures and barriers/rails

- 2090: "Permanent" assets, which will become fixed and on-going features of project, such as: tunnel civil structures (including rock bolts), bridges, embankment culverts (and other inaccessible drainage), and buildings.

A baseline of 1986-2005 has been presented below (Table 2-1) for some climate variables where relevant, as this relates to the period from which the changes to those variables are projected.

Table 2-1 Climate change projections

Project category	Baseline (1986 - 2005)	2030 (RCP8.5)	2050 (RCP8.5)	2090 (RCP8.5)
Temperature				
Mean Minimum Temperatures (°C) – Annual	14.4	15.5	16.3	18.4
Mean Minimum Temperatures (°C) – Summer	19.1	20.2	22.12	23.0
Mean Minimum Temperatures (°C) – Autumn	15.3	16.4	18.31	19.2
Mean Minimum Temperatures (°C) – Winter	9.4	10.5	12.44	13.3
Mean Minimum Temperatures (°C) – Spring	14.1	15.2	17.08	18.0
Mean Maximum Temperatures (°C) – Annual	22.4	24.3	24.4	26.5
Mean Maximum Temperatures (°C) – Summer	26.2	27.4	29.4	30.1
Mean Maximum Temperatures (°C) – Autumn	23.1	24.3	26.3	27.0
Mean Maximum Temperatures (°C) – Winter	18.2	19.4	21.4	22.1
Mean Maximum Temperatures (°C) – Spring	22.6	23.8	25.8	26.5
Days over 35°C – Annual	3.5	5.6	5.9	11.3
Days over 40°C – Annual	0.2	0.8	0.9	2.0
Days over 45°C – Annual	0	0	0	0
Nights below 2°C – Annual	0	0	0	0
Rainfall				
Mean Precipitation (mm) – Annual	1238	1206	1151	1049
Mean Precipitation (mm) – Summer	333	346	322	351
Mean Precipitation (mm) – Autumn	380	369	364	349
Mean Precipitation (mm) – Winter	287	257	277	208
Mean Precipitation (mm) – Spring	238	236	218	203
Extreme Rainfall Events – Max 1 Day Rainfall	Projected to increase 2 – 22%			
Extreme Rainfall Events – 20 year return level of max. 1 Day Rainfall	Projected to increase 5 – 42%			
Annual Runoff % Change	No data	No data	No data	-70% to 15%

Project category	Baseline (1986 - 2005)	2030 (RCP8.5)	2050 (RCP8.5)	2090 (RCP8.5)
Evapotranspiration				
Annual Change in Potential Evapotranspiration (% change)	375mm (1961 – 1990)	4.2	No data	14.3
Summer Change in Potential Evapotranspiration (% change)	495mm (1961 – 1990)	4.4	No data	13
Autumn Change in Potential Evapotranspiration (% change)	308mm (1961 – 1990)	5.2	No data	19.3
Winter Change in Potential Evapotranspiration (% change)	165mm (1961 – 1990)	5.7	No data	20.6
Spring Change in Potential Evapotranspiration (% change)	1350mm (1961 – 1990)	3	No data	11.4
Fire Regimes				
Change in Annual Mean Forest Fire Danger Index (% change)	2158	2-7%	5-19%	No data
The number of days where the FDR is 'very high' or 'extreme'	8.7	9.2 - 11.1	9.8-15.2	No data
Severe Wind				
Average maximum daily wind speed (% change)	120 kph	-0.2 to 1.9	1.8 to 3.2	0.3 to 5.7
Sea Conditions				
Sea Level Rise (m)	0	0.14	No data	0.66
Sea surface temperature (°C)	Varies	1.0	No data	3.1
Ocean pH	Varies	No data	No data	-0.3
Atmospheric CO_2				
Atmospheric CO_2 concentration	401 ppm	No data	No data	940ppm (2100)

Note: "No data" is where projections are not available for the time period; "Varies" is where data varies both within the year and range identified.

2.4 Climate change risk assessment

The methodology for the climate change risk assessment was based on the Australian Standard AS 5334-2013 *Climate change adaptation for settlements and infrastructure – A risk based approach*. This standard follows the International Standard ISO 31000:2009, *Risk management – Principles and guidelines* (adopted in Australian and New Zealand as AS/NZ ISO 31000:2009), which provides a set of internationally endorsed principles and guidance on how organisations can integrate decisions about risks and responses into its existing management and decision-making processes. The methodology was also guided by the draft *Technical Guide: Climate Adaptation for the Road Network* (Roads and Maritime Services, 2015j).

While adhering to the above guidance documents, the following key steps were carried out to complete the climate change risk assessment:

- Determination of the climate change context, including greenhouse gas emissions scenarios and projections, data on climate variables and past meteorological record
- Identification of the climate risks and assessment of the likelihood and consequence of each risk
- Identification of adaptation responses.

To assist with the determination of the climate change context as well as the identification of climate change risks and the likelihood of such risks, a multidisciplinary risk workshop was held with members of the project team (ie members of the design and environmental assessment teams) early in the design phase. The preliminary risks identified at the workshop were then formalised in a risk register and thorough risk descriptions, including cause, impact/consequence and current and proposed future treatment were identified.

A climate change risk update was subsequently carried out based on the design that forms the basis of this environmental impact statement. The update identified treatments that had been incorporated into the design since the initial climate change risk workshop, risk treatments to be implemented or investigated in future design stages, and some updates to risk ratings.

The hazard-receiver pathway model was applied to identify and analyse climate change risks. This model considers the following:

- Hazard – climate or climate influenced attributes with the potential to influence the operation and maintenance of the project
- Receiver – the component of the operation and/or maintenance of the project that would be impacted by the hazard. This may also include users of the project and affected elements of the surrounding environment
- Risk rating – utilising the likelihood (Table 2-2) and consequence (Table 2-3) rating system, an assessment of the way hazards influence the project receivers is carried out and a risk rating (Table 2-4) awarded.

Table 2-2 Likelihood descriptions

Likelihood Rating	Description	Probability	Life cycle
Almost Certain	The event is expected to occur in most circumstances	>90% probability	>1 in one year
Likely	The event will probably occur in most circumstances	51% to 90% probability	1 in 10 years
Moderate	The event should occur at some time	21% to 50% probability	1 in 50 years
Unlikely	The event could occur at some time	10% to 20% probability	1 in 100 years
Rare	The event might occur in exceptional circumstances	<10% probability	1 in 1000 years

Table 2-3 Consequence descriptions

Consequence Rating	Time		Cost		Safety		Environment Delivery Operation	Traffic Flow Peak Hour	Local Traffic	Community Attitude	Fit for purpose defects / Accidents / Maintenance Costs
	Develop-ment	Delivery	Develop-ment	Delivery	Delivery	Operation					
Critical	Year	Months	$(25% overall construction cost)	$(10% overall construction cost)	Worker's Compensation Liability >$250,000 Death/perm. loss of physical/ mental amenity	Multiple Worker's Compensation Liability >$250,000 Death, permanent loss of physical or mental amenity	Major environmental damage and/or delay due to legal finding in the Land and Environment Court	No improvement	Severe disruption	Severe community protests	Functional failure
Major	Months	Months	$(15% overall construction cost)	$(7% overall construction cost)	Worker's Compensation Liability $10,001 - $250,000 Lost time >= 5 days	Worker's Compensation Liability >$250,000 Death, permanent loss of physical or mental amenity	Serious environmental damage and/or delay due to Public Enquiry. EPA Major Notice	Marginal improvement	Disruption	Community protests	Serious functional failure
Moderate	Months	Months	$(7.5% overall construction cost)	$(4% overall construction cost)	Worker's Compensation Liability $1001 - $10,000 Lost time 1-4 days	Worker's Compensation Liability $10,001 - $250,000 Lost time >=5 days	Environmental damage and/or EPA Infringement Notice	N/A	N/A	Daily Complaints	Minor functional failure

Consequence Rating	Time		Cost		Safety		Environment Delivery Operation	Traffic Flow Peak Hour	Local Traffic	Community Attitude	Fit for purpose defects / Accidents / Maintenance Costs
	Develop-ment	Delivery	Develop-ment	Delivery	Delivery	Operation					
Minor	Months	Weeks	$(1% overall construction cost)	$(1% overall construction cost)	Worker's Compensation Liability $251 - $1000 Lost time >= 1 days	Worker's Compensation Liability $1001 - $10,000 Lost time 1-4 days	Minor environmental damage and/or minor EPA infringement notices. Written Community comments	N/A	N/A	Complaints	N/A
Insignificant	Weeks	Nil	$(0.1% overall construction cost)	$(0.1% overall construction cost)	Worker's Compensation Liability $1 - $250 First aid treatment (no lost time)	Worker's Compensation Liability $251 - $1000 Lost time >= 1 days	Minor repairable environmental damage. Verbal Community comment	N/A	N/A	Negligible Complaints	N/A

Table 2-4 Risk matrix

		Consequence				
		Insignificant	**Minor**	**Moderate**	**Major**	**Critical**
Likelihood	**Almost certain**	Medium	High	Extreme	Extreme	Extreme
	Likely	Low	Medium	High	Extreme	Extreme
	Moderate	Negligible	Low	Medium	High	Extreme
	Unlikely	Negligible	Negligible	Low	Medium	High
	Rare	Negligible	Negligible	Negligible	Low	Medium

2.5 Results

Climate change risks with a medium or high rating (based on the design presented in this environmental impact statement), prior to the implementation of further treatment measures, are summarised in Table 2-5 (i.e. 'initial rating'). These 'initial ratings' assume the incorporation of business as usual design, construction and operational controls. Treatment methods have been identified and are proposed for those 'initial ratings', based on the current design, or are proposed to be carried out as part of future investigations during further design development.

The 'final rating' (i.e. post-treatment), incorporating further additional treatment options and investigations, is also presented in Table 2-5.

Low risks identified during the assessment were not considered to require any additional risk treatment, as these risks are considered tolerable. As such, risks classified as 'low' or 'negligible' have not been included in the table below.

In summary, the assessment of climate change risks identified no extreme or high initial risk ratings, and only four medium risk ratings. These medium risks are anticipated in respect to rainfall and surface flooding, bushfires (particularly in the area adjoining to Wakehurst Parkway), and sea level rise. Two of these medium risks, for rainfall and surface flooding and sea level rise, drop to a final risk rating of low when incorporating further additional treatment or investigations.

Table 2-5 Climate change risk assessment

Risk ID	Hazard Category	Description	Initial Rating	Measures incorporated into the current design and business as usual practice	Proposed further treatment or investigation	Final Rating
38	Rainfall and surface flooding	Potential for key project elements (ie tunnel portals, motorway facilities and motorway control centre) to be flooded in extreme rainfall/stormwater events, resulting in operational failure.	Medium	Facilities have been designed to be immune in the probable maximum flood.	Further flood modelling for detailed design will continue to use sea level rise projections and rainfall projections.	Low
18	Bushfires	Damage to road infrastructure especially along Wakehurst Parkway from bushfires where bushland surrounds the project.	Medium	Standard asset protection zones around buildings.	No additional measures.	Medium
22	Bushfires	An increased likelihood in the occurrence of bushfires which may increase the potential for injuries and/or fatalities to pedestrians and cyclists along Wakehurst Parkway. An increased patronage is anticipated as a result of improved access facilitated by the project.	Medium	Variable message signs incorporated into the design at Wakehurst Parkway.	No additional measures.	Medium
26	Sea level rise	Potential for key project elements (ie tunnel portals, motorway facilities and motorway control centre) to be flooded as a result of sea level rise, resulting in operational failure.	Low	Key project elements are designed above probable maximum flood and above future projected sea levels.	Further flood modelling in detailed design will continue to use sea level rise projections and rainfall projections.	Low

3. Greenhouse gas calculations

3.1 Assessment methodology

This section describes the methodology used in this assessment to estimate the greenhouse gas emissions that would be generated during construction and operation of the project.

3.1.1 Greenhouse gas accounting

'Greenhouse gases' is a collective term for a range of gases that are known to trap radiation in the upper atmosphere, where they have the potential to contribute to the greenhouse effect (global warming). Creating an inventory of the likely greenhouse gas emissions associated with a project has the benefit of determining the scale of the emissions and providing a baseline from which to develop and deliver greenhouse gas reduction options. Greenhouse gases 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 emissions produced during digestion in some livestock 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 greenhouse gases to the equivalent emission of carbon dioxide. This provides a simple figure for comparison of emissions against targets. 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 a carbon dioxide equivalent (or CO_2-e).

The greenhouse gas inventory in this document is calculated in accordance with the principles of the Greenhouse Gas Protocol (GHG Protocol)[1]. The greenhouse gas emissions that form the inventory can be split into three categories known as 'Scopes'. Scopes 1, 2 and 3 are defined by the GHG Protocol and can be summarised as follows:

- Scope 1 – Direct emissions from sources that are owned or operated by a reporting organisation (examples – combustion of diesel in company owned vehicles or used in on-site generators)
- Scope 2 – Indirect emissions associated with the import of energy from another source (examples – 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 (examples include business travel (by air or rail) and product usage).

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

[1] 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. World Resources Institute and World Business Council for Sustainable Development, March 2004

The GHG Protocol (and similar reporting schemes) dictates that reporting Scope 1 and 2 sources is mandatory, whilst reporting Scope 3 sources is optional. Reporting significant 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 is collected to represent the activities being carried out for the project and converted to greenhouse gas emissions typically using emissions factors – a published figure for the particular activity representing the aggregated greenhouse gas emissions per unit of the activity. These are aggregated for the whole project.

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 key emission sources and activities considered within the project's assessment boundary for construction and operation, according to scope. Note that some emissions sources are split into more than one scope. This is typically the case where there are direct emissions (eg 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).

Adopting the guidance provided by the Infrastructure Sustainability Council Australia (ISCA (2016)), any source of energy use or greenhouse gas emissions that is likely to account for more than five per cent of the infrastructure lifecycle footprint is considered significant and has been included in this assessment.

Further, the assessment has also considered greenhouse gas emissions generated by ongoing maintenance activities in accordance with ISCA guidance.

Table 3-1 Construction greenhouse gas emission sources

Emission Source	Scope 1	Scope 2	Scope 3
Fuel use – diesel consumption in plant and equipment during construction	✓		✓
Fuel use – diesel consumption by generators associated with harbour construction activities	✓		✓
Construction materials			✓
Fuel use – transport of construction materials			✓
Fuel use – transport of construction waste, spoil or dredged material			✓
Electricity consumption – construction support sites and roadheaders		✓	✓
Vegetation removal	✓		

Table 3-2 Operational greenhouse gas emission sources

Emission Source	Scope 1	Scope 2	Scope 3
Road use by vehicles (difference between Do minimum and Do something scenarios)			✓
Electricity consumption – lighting		✓	✓
Electricity consumption – hydraulics and water treatment		✓	✓
Electricity consumption – substation for air conditioning		✓	✓

Emission Source	Scope 1	Scope 2	Scope 3
Electricity consumption – motorway control centre		✓	✓
Electricity consumption – tunnel ventilation		✓	✓
Maintenance activities – fuel	✓		✓
Maintenance activities – materials			✓

3.1.3 Tools for assessment of greenhouse gas emissions

The calculation of greenhouse gas emissions for this assessment was facilitated through the use of a number of different tools. These are presented in Table 3-3. The tools were used to determine the emissions associated with discrete components of the assessment, but do not represent the whole assessment.

In addition to the tools, bespoke calculations were carried out for a large proportion of this assessment due to its complexity. All tools source a variety of emissions factors, but preference was taken for the National Greenhouse Accounts (NGA) factors (2017) where required.

Table 3-3 Tools for assessment of greenhouse gas emissions

Greenhouse Gas Assessment Tool	Description	Application
Carbon Gauge	• Framework for assessing greenhouse gas emissions from road construction projects • Automates calculations, assumptions and greenhouse gas emission factors presented in Greenhouse Gas Assessment Workbook for Road Projects • The greenhouse gas emission profile is built through the selection of a number of defined inputs, such as of road pavement lengths and areas, areas of vegetation, road features, cost of construction and other accessible data.	• Some elements of greenhouse gas emissions within construction (vegetation removal) • Fuel use/materials during maintenance • Review calculations conducted using different methods.
Infrastructure Sustainability Materials Calculator (ISMC)	• Developed by ISCA, to evaluate environmental impacts in relation to the use of materials on infrastructure projects, including the transport of materials to and from project sites • Emissions profile is built by inserting material quantities, concrete strengths, aggregate, plastic and steel types, as well as transport types into the model.	• Materials assessment • Transport of materials to and from project sites.
Tools for Roadside Air Quality (TRAQ)	• Tool for modelling emissions to air from vehicles using roads • Input data include traffic numbers and type, speed, lane numbers and standard emission factors.	• Greenhouse gas emissions associated with current and future road use, with and without the project.

3.1.4 Greenhouse gas emissions estimation – construction

This section presents the methodology used to estimate greenhouse gas emissions associated with construction of the project.

3.1.4.1 Fuel combustion from construction plant and equipment, including barge movements

The method to calculate the greenhouse gas emissions resulting from fuel combustion by construction equipment and plant involved the following:

- Identification of the plant and equipment to be used for each construction stage (as detailed in the environmental impact statement)
- Determination of hourly fuel consumption rates and duration of use for each piece of plant and equipment, as well as total construction stage durations. Fuel consumption data were sourced from the equipment manufacturer specification sheets
- Daily operational hours of each piece of equipment and plant (percentage of maximum hours) were assumed as either 100 per cent, 80 per cent, 50 per cent or 25 per cent in each construction stage, and the fuel consumption was calculated according to this assumed usage rate for each equipment and plant.

To calculate the Scope 1 greenhouse gas emissions from the combustion of fuel by construction equipment and plant, the following formula was used, sourced from the National Greenhouse Accounts (NGA) Factors, 2017. This formula was applied to each piece of relevant equipment and plant identified, with usage rates and fuel consumption applied as above, accordingly.

Greenhouse Gas Emissions (t CO_2-e) = ((Q x ECF)/1000) x ($EFCO_2$ + $EFCH_4$ + EFN_2O)

Where:

- Q is quantity of fuel (kL)
- ECF is the relevant energy content factor (in GJ/kL)
- $EFCO_2$ is the relevant carbon dioxide emission factor (kg CO_2-e/GJ)
- $EFCH_4$ is the relevant methane emission factor (kg CO_2-e/GJ)
- EFN_2O is the relevant nitrous oxide emission factor (kg CO_2-e/GJ).

To calculate the Scope 3 greenhouse gas emissions from the combustion of fuel by construction equipment and plant, the following formula was used, as per NGA Factors 2017. As with Scope 1 calculations, this formula was applied to each piece of equipment and plant identified, with usage rates and fuel consumption applied as above, accordingly:

Greenhouse Gas Emissions (t CO_2-e) = (Q x ECF x $EF_{Scope\ 3}$)/1000

Where:

- Q is the quantity of fuel (kL)
- ECF is the relevant energy content factor (GJ/kL)
- $EF_{Scope\ 3}$ is the relevant emission factor (kg CO_2-e/GJ).

Table 3-4 presents the energy content factors (ECF) and the emission factor which applies to the above equations.

Table 3-4 Diesel Fuel Emissions Factor (NGA, 2017)

Fuel	Energy content factor (GJ per kL)	Scope 1 emission factor (kg CO_2-e/GJ)			Scope 3 emission factor (kg CO_2-e/GJ)	Emissions per unit quantity (t CO_2-e per kL)	
		CO_2	CH_4	N_2O		Scope 1	Scope 3
Diesel	38.6	69.9	0.01	0.6	3.6	2.7217	0.1390

The above equations were applied assuming that all equipment and plant (including barges) to be used would operate on diesel fuel and are 'post 2004' vehicles.

Barges associated with the transport of personnel, equipment and construction materials between construction support sites have been classified as construction equipment for this assessment and are considered in the assessment of greenhouse gas emissions from the combustion of fuel from construction plant and equipment.

Greenhouse gas emissions generated by barges transporting dredged material, spoil and waste removal have been captured under emissions resulting from the transport of spoil and waste.

3.1.4.2 Fuel combustion by generators during harbour construction activities

Harbour construction activities (including dredging) would consume electricity from diesel generators. The inputs for calculating the greenhouse gas emissions from these harbour construction activities are presented in Table 3-5, including the total fuel consumption per equipment and plant. This includes the equipment and plant that would be used for trench dredging and excavation in cofferdams.

For equipment, electrical power consumption and time in use data were identified. To determine the total fuel consumption by the generators powering each equipment and plant in Table 3-5, fuel efficiency data from a 1.25MW generator (assumed to be operating at 75 per cent capacity) was used.

To then calculate the Scope 1 and Scope 3 greenhouse gas emissions, the equations in the previous section were applied.

Table 3-5 Construction equipment and assumed diesel consumption

Equipment	No. of units	Total average power (kW)	No. of weeks of operation	Total power use (MW)	Total diesel fuel consumption (kL)
Site offices	1	50	70	210	45
Survey boat	1	100	65	260	56
Backhoe dredger	1	2000	50	4000	866
Hopper barges	3	450	50	900	195
Multi cat tug	1	250	50	563	122
Tug and sweep bar	1	200	6	12	3
Crane barge	1	300	5	68	15
Flat top	2	100	5	23	5
Wheel loader	1	75	5	15	3
Tug (curtain mount)	1	75	65	293	63

Equipment	No. of units	Total average power (kW)	No. of weeks of operation	Total power use (MW)	Total diesel fuel consumption (kL)
Cofferdam dry-excavation with disposal of suitable material offshore					
Site offices	1	40	35	84	18
Survey boat	1	100	30	120	26
Excavators					
Large	2	150	25	169	37
Small	2	400	25	450	97
Hopper barge	1	25	25	16	3
Tug	1	100	25	75	16
Crane barge	1	400	25	450	97

3.1.4.3 Construction materials

Greenhouse gas emissions associated with construction materials have been determined using the emission factors provided by the Infrastructure Sustainability Materials Calculator (ISMC), developed by the ISCA. This calculator evaluates environmental impacts in relation to the use of materials on infrastructure projects and assets. To determine the greenhouse gas emissions from construction materials, the following steps were undertaken:

- Material quantity estimates were determined by cost estimators, in the form of Bills of Quantity for major construction materials
- The Bills of Quantity were refined to provide greater detail as required. This included tasks such as differentiating between different concrete strength grades, and translating data where quantities were provided as a number, which could not be directly applied to a relevant emissions factor (such as volume or weight)
- A gap analysis was undertaken to determine those areas not addressed in the Bills of Quantity, which would need to be addressed separately. Separate calculations were made as needed to fill the gaps.

The quantities of construction materials determined for each project is presented in Table 3-6.

The quantities presented in Table 3-6 were multiplied against corresponding emission factors as provided in the ISMC for individual materials to determine the resulting Scope 3 greenhouse gas emissions.

Table 3-6 Construction materials input volumes

Material	Units	Total
Asphalt	t	124,400
Sprayed bitumen	t	500
Ready mixed concrete		
25 MPa	m^3	5700
32 MPa	m^3	1000
40 MPa	m^3	312,000

Material	Units	Total
50 MPa	m^3	3400
Precast concrete*		
40 MPa	m^3	5200
50 MPa	m^3	3400
Aggregates		
Gravel	m^3	25,400
General fill	m^3	183,400
Other		
Steel	t	58,400
Aluminium	t	20
Glass	m^3	2
Piping – PVC	t	3000
Piping – concrete	t	2100
Plastic sheet/film	m^3	30
Composites – cement fibreboard	t	500
Coatings	t	<1
Water treatment chemicals	t	1

*Precast concrete with a strength of 32 MPa has been modelled as 40 MPa, as 32 MPa is not an optional input in the ISMC.

3.1.4.4 Fuel combustion from the transport of materials

To determine the greenhouse gas emissions resulting from the transport of materials to the construction support sites, the quantity and type of material, the distance for individual materials to be transported and the modes of transport were determined.

Using the emission factors in the ISCA calculator (2016b) for the transport of materials by specific modes of transport, the following formula was used:

Greenhouse Gas Emissions (t CO_2-e) = M x EF x D

Where:

- M is the material quantity to be transported in (either tonnes or cubic metres) (see Table 3-6)
- EF is the relevant emission factor (tonnes CO_2e/unit) (refer to Table 3-7)
- D is the distance the material is required to be transported (kilometres).

The above equation was applied to road and ship transport that would be used to import material to project sites. It was assumed that any imported overseas material would be transported from Shanghai, China by ship, to Botany Bay, and then by rigid truck to the construction support sites. As the source of imported overseas material would be confirmed during detailed construction planning, Shanghai, China was selected as a conservative assumption as the furthest possible location within Asia-Pacific region.

Table 3-7 presents the emission factors used to determine the greenhouse gas emissions resulting from different modes of transport. The table presents the emission factors based on the quantity of materials in tonnes and cubic metres. Table 3-8 presents the inputs for calculating the greenhouse gas emissions resulting from the transport of materials to construction support sites.

Table 3-7 Emission factors for modes of transport (ISCA)

Mode of transport	Emission factor (t CO_2-e/ tonne of material/km)	Emission factor (t CO_2-e/ m^3 of material/km)
Rigid truck	0.000216	0.00034
Concrete agitator	0.000128	0.00031
Shipping domestic (including barge)	0.000035	0.00006
Shipping international freight	0.000009	0.00001

Table 3-8 Material transport inputs

Material	Total	Anticipated sources	Assumed distance (km)	Assumed mode of transport
Asphalt (t)	124,400	Sydney suppliers	30	Rigid truck
Sprayed bitumen (t)	500	Sydney suppliers	30	Rigid truck
Ready mixed concrete (m^3)	322,100	Sydney suppliers close to project	30	Concrete agitator truck
Precast concrete (m^3)	4300	Sydney	50	Rigid truck
	4300	Northern NSW	300	Rigid truck
	8600 (total)			
Aggregates – gravel (m^3)	25,400	NSW South Coast and Central Coast	120	Rigid truck
Aggregates – general fill (m^3)	183,400	Project tunnel spoil or sourced from within the Sydney	20	Rigid truck
Steel (t)	29,200	Sydney	50	Rigid truck
	29,200	Overseas	8500	Ship (assumed from Shanghai, China)
			40	Rigid truck (Botany Bay to project)
	58,400 (total)			
Aluminium (t)	20	Overseas (assumed Shanghai, China)	8500	Ship (assumed from Shanghai, China)
Glass (m^3)	2	Australia or overseas	50	Rigid truck (assumed from Sydney – small quantities)

Material	Total	Anticipated sources	Assumed distance (km)	Assumed mode of transport
Piping – PVC (t)	3000	Australia or overseas	50	Rigid truck (assumed from Sydney – small quantities)
Piping – concrete (t)	2100	Australia	50	Rigid truck
Plastic sheet/Film (m^2)	30	Australia or overseas	50	Rigid truck (assumed from Sydney – small quantities)
Composites – cement fibreboard (t)	500	Australia	50	Rigid truck
Coatings	<1	Australia	50	Rigid truck (assumed from Sydney – small quantities)
Water treatment chemicals (t)	1	Australia or overseas	50	Rigid truck (assumed from Sydney – small quantities)

3.1.4.5 Fuel combustion from the transport of waste and spoil

The fuel consumption associated with the transport of construction waste, dredged material and spoil was calculated using the following steps:

- Identify or obtain data on the quantities of excavated spoil generated by tunnelling and surface works
- The distances between each of the proposed disposal facilities and the construction support sites were estimated using Google Earth where identified, or otherwise on a conservative basis
- The quantity of all imported spoil was determined, including the transport of spoil from one part of the project to another. The distances of transport for imports were estimated using Google Earth
- Dredged material unsuitable for offshore disposal has been assumed to be transported to a licensed facility in Kemps Creek, NSW
- Dredged material quantities and disposal locations were determined, assuming the majority is disposed offshore.

The following formula was used to determine the greenhouse gas emissions generated from the transport of waste, dredged materials and spoil:

Greenhouse Gas Emissions (t CO_2-e) = M x EF x D

Where:

- M is the material quantity to be transported (in tonnes)
- EF is the relevant emission factor, depending on the mode of transport (tonnes CO_2-e/unit) (see Table 3-7)
- D is the distance the material is required to be transported (kilometres).

The waste material, dredged material and spoil quantities used to determine emissions from transport are presented in Table 3-9.

Table 3-9 Waste and spoil material quantities

Type	Disposal or import location	Distance (kilometres)	Total (tonnes)
Terrestrial activities			
Disposal – spoil excavation and crushed rock removal/top soil removal	Penrith Lakes, NSW	66	6,765,000
Disposal – construction waste (from building and other demolition)	Camelia, NSW	30	19,100
Import of spoil	Western Sydney, NSW	50	560,000
Import of aggregates	Bombo, NSW	123	75,400
Dredged material spoil			
Dredged material unsuitable for offshore disposal	Kemps Creek	52	19,200
Dredged material suitable for offshore disposal	Offshore	20	241,600

3.1.4.6 Electricity consumption

The method used to calculate the Scope 2 and Scope 3 greenhouse gas emissions resulting from the consumption of purchased electricity is given by the formula below, as given by the NGA Factors 2017:

Greenhouse gas emissions (t CO_2-e) = Q x EF_{Scope} x /1000

Where:

- Q is the quantity of purchased electricity (kWh)
- EF_{Scope} x is the Scope 2 or Scope 3 emissions factor for NSW (kg CO_2-e/kWh).

Scope 2 factors relate to the emissions resulting from the generation of the electricity itself, whereas the Scope 3 emissions relate to the extraction and production of fuels, as well as distribution losses.

Multiple roadheaders would be used concurrently for the project with tunnelling occurring 24 hours a day, 7 days a week until completion. Power for roadheaders would be sourced from the electricity grid, with power delivered to roadheaders (and support equipment / offices) via the relevant construction support site. Other site electrical power consumption (eg for marine construction management) is supplied by generator and hence is calculated as a diesel fuel requirement.

The inputs for calculating the total power to be consumed by roadheaders and by each of the construction support sites, including site offices and other plant and equipment is presented in Table 3-10. The Scope 2 and Scope 3 greenhouse gas emission factors for electricity consumption are presented in Table 3-11.

Table 3-10 Roadheaders and construction support sites indicative power consumption

Construction support site (Site ID)	Total indicative power requirements (megavolt ampere)	No. of roadheaders	Duration of tunnelling (months)	Assumed load (%)
Cammeray Golf Course (BL1)	3	3	12	80
Flat Rock Drive (BL2)	7	7	40	80
Punch Street (BL3)	3	3	24	80
Balgowlah Golf Course (BL10)	3	3	33	80
Wakehurst Parkway east (BL13)	3	3	33	80

Table 3-11 Emission factors for electricity consumption (NGA 2019)

Source	Scope 2 Emission Factor	Scope 3 Emission Factor
Electricity	0.81 $kgCO_2$-e / kWh	0.09 $kgCO_2$-e / kWh

3.1.4.7 Vegetation removal

The Transport Authorities Greenhouse Gas (TAGG) Workbook (2013) outlines the method for estimating greenhouse gas emissions as a result of carbon loss associated with the removal of vegetation. This assessment employs vegetation data used 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 methodology can be considered conservative, in that there is an assumption that all carbon pools are removed, and all carbon that is removed is converted to carbon dioxide and released to the atmosphere. It is also assumed that sequestration from the revegetation of project sites is not included.

The methodology for estimating the loss of carbon dioxide equivalent sequestration potential from vegetation during road construction involves the following steps:

1) Determine the 'Maxbio' class, by determining the location of the project area on a colour coded map presenting the maximum potential biomass class for all areas of Australia (provided in the TAGG 2013 workbook)
2) Identify the vegetation classes within the project area, and the area of each class to be cleared (from ecological surveys undertaken as part of this approval)
3) Using default emission factors provided for Maxbio values against vegetation classes, determine the potential greenhouse gas emissions by multiplying the area to be cleared by the relevant emissions factor.

To determine the emissions from the vegetation clearance associated with the project, vegetation species were identified by qualified ecology personnel. The identified species were categorised into the required vegetation classes for this assessment. This data and the area to be cleared per class are presented below in Table 3-12. The Maxbio class for the project areas was determined to be Class 3, which represents areas which have around 100 to 150 tonnes of dry matter per hectare, as per the TAGG Greenhouse Gas Assessment Workbook (2013).

Vegetation classified as ‘miscellaneous ecosystems’ or ‘exotic plants’ consists of landscaped and maintained areas. These areas are more urban in classification and have been classified as ‘grassland’ (classification I), as per guidance in the TAGG Supporting Document for the Greenhouse Gas Assessment Workbook.

Table 3-12 Vegetation input data

Identified Plant Community Type	Vegetation Class (VIS database)	Description	Area to be cleared (ha)
PCT 1250 / ME012 Sydney Peppermint – Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	D	Eucalypt tall open forest	0.2
PCT 1292 / ME035 Water Gum – Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	F	Eucalypt tall open forest	0.4
PCT 1783 / ME106 Red Bloodwood – Scribbly Gum / Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	D	Open forest	4.2
PCT 1786 / ME98 Red Bloodwood – Silvertop Ash – Stringybark open forest on ironstone in the Sydney region	D	Open forest	1.4
PCT 1824 / ME100 Mallee – Banksia – Tea-tree – Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	F	Open forest	6.2
PCT 1841 / ME59 Smooth-barked Apple – Turpentine – Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region	B	Open forest	1.4
PCT 1845 / ME61 Smooth-barked Apple – Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney	B	Open forest	0.4
Native plantings	I*	Grassland	0.4
Urban native/exotic plantings	I*	Grassland	4.9
Native regeneration	l*	Grassland	1.3
Weeds and exotics	I*	Grassland	0.2
Total			**20.9**

Note:

Vegetation classes based on the National Vegetation Inventory System (NVIS) Major Vegetation Groups as per guidance in the TAGG Supporting Document for the Greenhouse Gas Assessment Workbook. Definitions are: B= Eucalypt Tall Open Forest, D= Open woodlands, F= Mallee and Acacia Woodland and Shrubland, l= Grassland

* Assumed grassland - areas to be cleared consist of highly landscaped areas, with very few trees.

3.1.5 Greenhouse gas emissions estimation – operation

This section presents the methodology used to estimate greenhouse gas emissions associated with operation of the project.

3.1.5.1 Operational electricity consumption

Annual electricity consumption of road infrastructure and associated management systems are presented below in Table 3-13. The emission factors used to calculate the greenhouse gas emissions from this electricity consumption are presented in Table 3-11.

The assessment has (conservatively) assumed there will not be any use of 'green power', or that the NSW grid will become less emissions intensive over time.

Table 3-13 Annual operational electricity consumption

Source	Quantity (kWh/y)
Lighting	6,167,040
Hydraulics	311,314
Wastewater treatment plant	87,600
Substation ventilation and air conditioning	2,628,000
Motorway control centre	1,314,000
Tunnel ventilation system (2027)	23,948,000
Tunnel ventilation system (2037)	25,546,000

3.1.5.2 Maintenance activities

Fuel consumption and materials associated with ongoing maintenance activities were assessed using Carbon Gauge (TAGG, 2013). The maintenance works assessed apply to the road pavement only (for which values were available) and were inputted into Carbon Gauge with the area and proposed paving type. Carbon Gauge then provided an assessment of the emissions for a 50-year period.

For this assessment, pavement areas were summed and allocated as either 'full depth asphalt' or 'plain concrete' according to Bill of Quantity data. These values were then added to Carbon Gauge, which in turn provided an assessment of the fuel consumption and materials required for expected maintenance activities over the life of the project. The values were divided by 50 to provide an annualised figure.

3.1.5.3 Fuel consumption by vehicles using the road network

The operational assessment was designed to determine the net greenhouse gas effect of the project from changes to road traffic, given that its introduction would contribute to changes in traffic over a wide area. Although the project would facilitate some increases in localised intersection delays in some areas, road users would generally benefit from substantial overall travel time savings on the broader network.

To assess this, a wide network model was required, including modelling of selected roads which would not be upgraded as part of the project. The model would establish a baseline against which a project scenario could be compared to display the impact of the project.

Traffic emissions were modelled using Tools for Roadside Air Quality (TRAQ) (Roads and Maritime Services, 2017d), which takes outputs from the Sydney Motorway Project Model (SMPM) – provided by Transport for NSW. SMPM provides estimates of the traffic volumes on around 6000 road links, for each assessment scenario, across a domain that covers an area in the order of 20 kilometres by 20 kilometres.

The environmental impact statement assesses the scenarios provided in Table 3-14 for the year of opening (taken to be 2027) and 10 years after opening (2037). The 'Do minimum' scenario reflects the business as usual road network conditions that would occur if the project was not built. The two 'Do something' scenarios reflect the road network conditions once the project is built both on its own and in conjunction with other projects that connect to it.

To determine how greenhouse gas emissions from vehicles using the road network changes as a consequence of the project, the 'Do minimum' has been considered against the 'Do something' and 'Do something cumulative' scenarios.

Table 3-14 Summary of modelled scenarios

Scenario	Description
'Do minimum'	Traffic model scenario with approved and under construction motorway projects (NorthConnex and WestConnex) but without Western Harbour Tunnel and Warringah Freeway Upgrade, Beaches Link and Gore Hill Freeway Connection, Sydney Gateway and M6 Stage 1 projects. Also reflects operational effects of approved and under construction major public transport projects (e.g. Sydney Metro City and Southwest).
'Do something'	Traffic model scenario with NorthConnex, WestConnex, Beaches Link and Gore Hill Freeway Connection, and Warringah Freeway Upgrade projects but without Western Harbour Tunnel, Sydney Gateway and M6 Stage 1 projects. Also includes Sydney Metro City and Southwest.
'Do something cumulative'	Traffic model scenario with NorthConnex, WestConnex, Western Harbour Tunnel and Warringah Freeway Upgrade, Beaches Link and Gore Hill Freeway Connection, Sydney Gateway and M6 Motorway Stage 1 projects. Also includes Sydney Metro City and Southwest.

Notes

1: M6 Motorway (Stage 1) is considered as part of the 2027 'Do something cumulative' scenario

2: M6 Motorway (full project) is considered as part of the 2037 'Do something – cumulative' scenario

The SMPM outputs provides information on the length and type of each road, as well as the traffic volumes, speeds and vehicles composition (heavy, light commercial and passenger vehicles) for each road link.

Greenhouse gas emissions have been calculated within TRAQ (Roads and Maritime Services, 2017d) for every road link in the strategic model, then summed to obtain the estimates for each scenario. Emissions for each link have been calculated using traffic data supplied by Transport for NSW (for every hour of the day, using hourly traffic mix, and hourly speed data) in combination with emission factors from the Environment Protection Authority (EPA) Motor Vehicle Emissions Inventory (MVEI).

The calculation for each link involved:

- Distributing the traffic volumes, heavy vehicle percentages and traffic speed for the four time of day periods (7am–9am, 9am-3pm, 3pm-6pm and 6pm-7am) from the SMPM into volumes for each hour of the day
- Matching the SMPM road types to the EPA road types
- Categorising the traffic into nine vehicle types for each hour of the day. The traffic mix data by road type and year were derived from data used in Appendix H (Technical working paper: Air quality)

- Calculating emissions of CO, hydrocarbons (HC) and CO_2 (primarily) in kilograms per hour (kg/h) for each hour of the day, for each vehicle type, by multiplying the vehicle numbers for each vehicle type by the respective EPA emission factors. Emissions of NO_x, PM_{10} were also calculated but not used further for the CO_2-e calculation. The maximum of the summer, winter and spring/autumn emission factors were used
- Applying EPA speed correction factors for each vehicle type, based on the road type
- Calculating fuel consumption for petrol and diesel vehicle types by carbon balance where:
  - Fuel consumption (litres per kilometre) = (CO x 0.429 +CO_2 x 0.273 + HC x 0.866)/ (0.866 x fuel density x 10)
  - 0.429, 0.273 and 0.866 are the carbon mass fractions of the exhaust gases CO, CO_2 and HC respectively
  - Petrol density is 0.74 kilograms per litre
  - Diesel density is 0.84 kilograms per litre
  - CO, CO_2 and HC are in grams per kilometre
- Estimating CO_2-e emissions using fuel consumption and Department of Environment and Energy emission factors
- Collating total CO_2-e emissions for each assessment scenario.

Traffic data is presented in terms of vehicle kilometres travelled (VKT). This is a measure of one vehicle travelling one kilometre and is used in traffic studies to report and present on traffic volumes. Table 3-15 presents the total VKT modelled for 2027 and 2037 scenarios.

Table 3-15 Traffic VKT for Do minimum case/Do something/Do something cumulative – year of opening (2027) and future year (2037)

Year	Scenario	VKT/day
2027	'Do minimum'	12,637,193
	'Do something'	12,859,303
	'Do something cumulative'	13,261,788
2037	'Do minimum'	13,633,873
	'Do something'	13,945,836
	'Do something cumulative'	14,584,266

3.2 Assessment

3.2.1 Construction

3.2.1.1 Fuel combustion from construction plant and equipment

The projected greenhouse gas emissions from fuel consumption during the construction of the project is presented in Table 3-16 with surface works predicted to be the largest contributor of greenhouse gases. Diesel fuel consumption data is not provided for the Dickson Avenue (BL4), Barton Road (BL5), Kitchener Street (BL11) and Wakehurst Parkway south (BL12) construction support sites, as diesel fuel usage would be minor.

Table 3-16 Greenhouse gas emissions from diesel fuel consumption during construction

Construction support site/component (site ID)	Total fuel consumption (kL)	Greenhouse gas emissions (t CO_2-e)		
		Scope 1	Scope 3	Total
Cammeray Golf Course (BL1)	804	2179	112	2291
Flat Rock Drive (BL2)	624	1692	87	1779
Punch Street (BL3)	595	1613	83	1696
Middle Harbour crossing (BL7, BL8, BL9)	132	359	18	377
Spit West Reserve (BL9)	143	389	20	408
Balgowlah Golf Course (BL10)	851	2306	118	2424
Wakehurst Parkway east (BL13)	723	1958	100	2059
Wakehurst Parkway north (BL14)	535	1450	74	1524
Surface works	3935	10,662	547	11,209
Barge movements (materials and personnel)	461	1249	64	1313
Total	**8803**	**23,857**	**1223**	**25,080**

3.2.1.2 Fuel combustion from generators during harbour construction activities

Projected greenhouse gas emissions resulting from the consumption of fuel by generators during harbour construction activities is presented in Table 3-17.

Table 3-17 Greenhouse gas emissions from fuel consumption by generators for harbour construction activities

Total fuel consumption (kL)	Greenhouse gas emissions (t CO_2e)		
	Scope 1 emissions	Scope 3 emissions	Total
1668	4521	232	4753

3.2.1.3 Construction materials

The projected greenhouse gas emissions resulting from individual construction materials for specific construction stages are presented in Table 3-18. Due to the large quantity required for the project, 40 MPa strength ready mixed concrete is projected to have the highest contribution to the total emissions from materials, followed by steel. These high contributions can be directly attributed to the quantity required, as well as the higher energy required to produce concrete.

Table 3-18 Projected greenhouse gas emissions from material production

Material*	Scope 3 greenhouse gas emissions (t CO_2-e)
Asphalt	8058
Sprayed bitumen	194
Ready mixed concrete	
25 MPa	1967
32 MPa	315

Material*	Scope 3 greenhouse gas emissions (t CO_2-e)
40 MPa	155,806
50 MPa	850
Precast concrete	
40 MPa	2539
50 MPa	2016
Aggregates	
Gravel	201
Other	
Steel	124,739
Aluminium	369
Glass	23
Piping – PVC	7352
Piping – concrete	643
Composites – cement fibreboard	525
Coatings	<1
Water treatment chemicals	1
Total	**305,598**

*The production of general fill has no greenhouse gas emission impacts as this material is sourced elsewhere in the project (and transport impacts are already included elsewhere)

3.2.1.4 Fuel combustion from the transport of materials

Table 3-19 presents projected greenhouse gas emissions from the transport of materials to the project based on volumes of materials, assumed travel distances and modes of transport. It is projected that the transport of ready mix concrete, precast concrete and steel would generate the most greenhouse gas emissions, due to the volume of material required to be transported and the distance of transporting these materials. This is especially the case for the transport of steel, due to the assumption that the material could be sourced from Shanghai, China.

Table 3-19 Greenhouse gas emissions from the transport of materials to project construction support sites

Material	Assumed mode of transport	Scope 3 greenhouse gas emissions (t CO_2-e)
Asphalt (t)	Rigid truck	808
Sprayed bitumen (t)	Rigid truck	3
Ready mixed concrete (m^3)	Concrete agitator truck	2947
Precast concrete (total) (m^3)	Rigid truck (Sydney)	110
	Rigid truck (north NSW)	658
Aggregates – gravel (m^3)	Rigid truck	921

Material	Assumed mode of transport	Scope 3 greenhouse gas emissions (t CO_2-e)
Aggregates – general fill (m^3)	Rigid truck	1270
Steel (t)	Rigid truck (domestic sources)	316
	Ship (assumed from Shanghai, China)	2208
	Rigid truck (overseas sources) (Botany Bay to project)	252
Aluminium (t)	Ship (assumed from Shanghai, China)	1
Glass (m^3)	Rigid truck (assumed from Sydney – small quantities)	<1
Piping – PVC (t)	Rigid truck (assumed from Sydney – small quantities)	32
Piping – concrete (t)	Rigid truck	22
Plastic sheet/film (m^2)	Rigid truck (assumed from Sydney – small quantities)	<1
Composites – cement fibreboard (t)	Rigid truck	5
Coatings (t)	Rigid truck (assumed from Sydney – small quantities)	<1
Water treatment chemicals (t)	Rigid truck (assumed from Sydney – small quantities)	<1
Total		**9553**

3.2.1.5 Fuel combustion from the transport of spoil and waste

The projected greenhouse gas emissions resulting from the transport of construction waste, construction associated spoil and imported spoil is presented in Table 3-20. The majority of waste spoil has been conservatively assumed to be transported to Penrith Lakes waste facility, and therefore the highest emissions would result from transporting spoil to this location.

Table 3-20 Greenhouse gas emissions from the transport of construction waste and spoil

Activity	Sub activity	Location	Scope 3 emissions (t CO_2-e)
Disposal of land waste	Spoil excavation/ crushed rock removal/ top soil removal	Disposal to Penrith Lakes waste facility	96,646
	Construction waste (from building demolition)	Disposal to Camelia waste facility	124
Land based import of spoil	Import of spoil	Import from elsewhere in project	605
	Import of spoil	Import from Western Sydney	816

Activity	Sub activity	Location	Scope 3 emissions (t CO_2-e)
Dredging	Unsuitable for offshore disposal	Disposal to Kemps Creek	216
	Suitable for offshore disposal	Offshore disposal	169
Total			**98,576**

3.2.1.6 Electricity consumption

The projected greenhouse gas emissions relating to projected grid electricity consumption, for the proposed use by roadheaders, land based ancillary sites, plant and equipment is presented in Table 3-21.

Table 3-21 Greenhouse gas emissions from electricity consumption – construction support sites and associated equipment

Construction support sites (site ID)	Emissions (t CO_2-e)		
	Scope 2	Scope 3	Total
Cammeray Golf Course (BL1)	15,326.5	1702.9	17,029.4
Flat Rock Drive (BL2)	119,206.1	13,245.1	132,451.2
Punch Street (BL3)	30,653.0	3405.9	34,058.9
Balgowlah Golf Course (BL10)	42,147.9	4683.1	46,831.0
Wakehurst Parkway east (BL13)	42,147.9	4683.1	46,831.0
Total	**249,481.4**	**27,720.1**	**277,201.5**

3.2.1.7 Vegetation removal

The projected greenhouse gas emissions from the removal of vegetation as a loss of a carbon sink is presented in Table 3-22.

Areas of vegetation proposed to be removed which consist of non-native, landscaped areas have been classified as grassland for the purpose of this assessment, as per guidance in the TAGG Supporting Document for the Greenhouse Gas Assessment Workbook.

Table 3-22 Greenhouse gas emissions during resulting from vegetation removal during construction

Identified Plant Community Type	Description	Area to be cleared (hectares)	Scope 1 greenhouse gas emissions (t CO_2-e)
PCT 1250 / ME012 Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	Eucalypt tall open forest	0.2	61
PCT 1292 / ME035 Water Gum – Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	Eucalypt tall open forest	0.4	0

Identified Plant Community Type	Description	Area to be cleared (hectares)	Scope 1 greenhouse gas emissions (t CO_2-e)
PCT 1783 / ME106 Red Bloodwood – Scribbly Gum / Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	Open forest	4.2	1299
PCT 1786 / ME98 Red Bloodwood – Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (EEC)	Open forest	1.4	424
PCT 1824 / ME100 Mallee – Banksia – Tea-tree – Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	Open forest	6.2	0
PCT 1841 / ME59 Smooth-barked Apple – Turpentine – Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region	Open forest	1.4	325
PCT 1845 / ME61 Smooth-barked Apple - Red Bloodwood – Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney	Open forest	0.4	92
Native plantings	Grassland	0.4	40
Urban native/exotic plantings	Grassland	4.9	538
Native regeneration	Grassland	1.3	142
Weeds and exotics	Grassland	0.2	25
Total		**20.9**	**2946**

3.2.1.8 Summary of greenhouse gas emission from construction

Table 3-23 and Figure 3-1 presents the summary of emissions estimated to result from the construction of the project, reported for Scope 1, Scope 2 and Scope 3 and total emissions. Table 3-23 shows that the construction of the project is expected to generate 723,707 t CO_2-e. Of this, the greatest proportion of emissions is related to construction materials at 305,598 t CO_2-e and electricity consumption at 277,201 t CO_2-e.

Table 3-23 Summary of construction greenhouse gas emission results

Construction - sources of greenhouse gas emissions	Emissions (t CO_2-e)			
	Scope 1	Scope 2	Scope 3	Total
Diesel combustion – plant and equipment	23,857	-	1223	25,080
Diesel combustion – generators for harbour activities	4521	-	232	4753
Diesel combustion – transport of materials to site (terrestrial only)	-	-	9553	9553
Diesel combustion – transport of waste, dredged material and spoil	-	-	98,576	98,576
Vegetation removal	2946	-	-	2946
Electricity consumption	-	249,481	27,720	277,201
Construction materials	-	-	305,598	305,598
Total	31,324	249,481	442,902	723,707

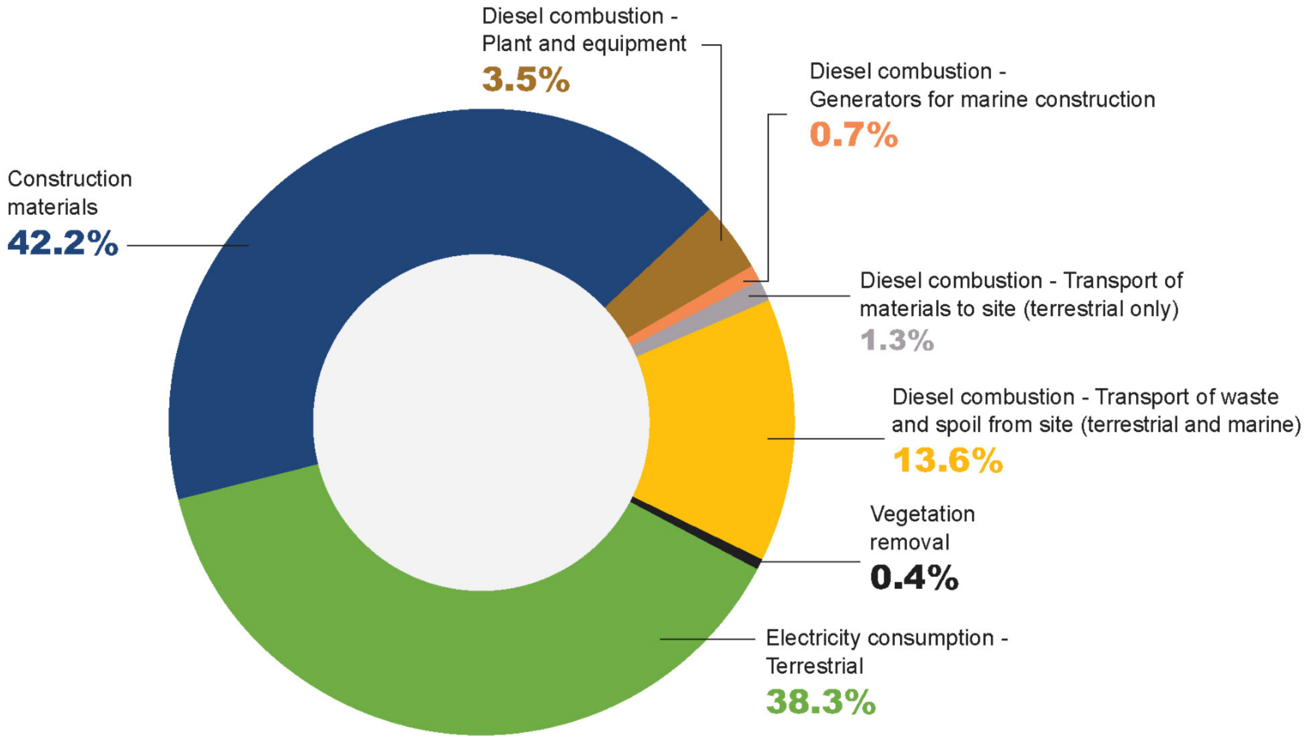


Figure 3-1 Projected contribution of greenhouse gas emissions (construction)

3.2.2 Operation

3.2.2.1 Operational electricity consumption

The projected greenhouse gas emissions resulting from the operational consumption of electricity is presented in Table 3-24. The results show that the electricity demand for tunnel ventilation would increase in 2037 in comparison with 2027, due to the projected increase in traffic volume.

Table 3-24 Projected greenhouse gas emissions from operational electricity consumption

Source	Quantity (kWh/y)	Greenhouse gas emissions (t CO_2-e/year)		
		Scope 2	Scope 3	Total
Lighting	6,167,040	4995	555	5550
Hydraulics	311,314	252	28	280
Wastewater treatment plant	87,600	71	8	79
Substation MVAC	2,628,000	2129	237	2366
Motorway control centre	1,314,000	1064	118	1182
Tunnel ventilation system (2027)	23,948,000	19,398	2155	21,553
Tunnel ventilation system (2037)	25,546,000	20,692	2299	22,991
Total (2027)	**34,455,954**	**27,909**	**3101**	**31,010**
Total (2037)	**36,053,654**	**29,203**	**3245**	**32,448**

3.2.2.2 Maintenance activities

Greenhouse gas emissions associated with maintenance activities (projected annual average) are presented in Table 3-25. These emissions are a result of the combustion of diesel fuel in maintenance vehicles and equipment (Scope 1) as well as embedded emissions in construction materials used for maintenance activities (Scope 3).

Table 3-25 Projected greenhouse gas emissions from maintenance activities

Source	Greenhouse gas emissions (t CO_2-e/year)			
	Scope 1	Scope 2	Scope 3	Total
Maintenance (annual)	268	0	326	594

3.2.2.3 Fuel consumption by vehicles on the road network

The projected greenhouse gas emissions generated by vehicles within the assessed model domain is provided in Table 3-26.

The ‘Do minimum’ scenario represents the baseline for the road network in the absence of the Western Harbour Tunnel and Beaches Link program of works, as well as other planned motorway projects (Sydney Gateway and F6 Extension). The ‘Do something’ scenario represents the addition of the project to the baseline road network, with the ‘Do something cumulative’ scenario representing the full Western Harbour Tunnel and Beaches Link program of works alongside other planned motorway projects.

The greenhouse gas emissions associated with the predicted traffic volumes were calculated using traffic speeds, gradients and traffic mix types, number of road links as well as the numbers of vehicles.

As can be seen in Table 3-26, under a 'Do minimum' scenario, the VKT is projected to increase from year of opening to 10 years' post opening by around eight per cent. This projected change in VKT is due to a number of factors, including (but not limited to) population growth, travel mode shifts and constraints of the road network. This would result in an increase in greenhouse gas emissions for the 'Do minimum' scenario between 2027 and 2037.

Under the 'Do something' scenario, greenhouse gas efficiency is projected to only slightly increase from the 'Do minimum' scenario, both in 2027 and 2037. This represents a greater volume of traffic which is able to flow more freely, with an improved fuel efficiency.

As traffic volumes across the network are projected to grow, greenhouse gas emissions are also projected to increase. However, over time, fuel efficiency is expected to improve (0.209 t CO_2-e / VKT on average for 2027 versus 0.205 t CO_2-e / VKT for 2037).

Factors applied to 2037 forecasts are (in the majority) slightly better than that for the earlier projection (2027), but this improvement is also a function of expected reduction in congestion – the project would allow for a greater number of vehicles to bypass existing roads and use the project – resulting in fewer stop / starts, less congestion and an increased average speed.

Table 3-26 Greenhouse gas emissions (both directions) for Do minimum and Do something (with project and cumulative) cases – year of opening (2027) and future year (2037)

Greenhouse gas emissions – estimated CO_2-e emissions (t/year)						Difference estimated CO_2-e emissions (t/year)			
Do minimum		Do something (with project)		Do something cumulative		Do something minus Do minimum		Do something cumulative minus Do minimum	
2027	2037	2027	2037	2027	2037	2027	2037	2027	2037
968,703	1,022,317	982,375	1,041,801	1,013,739	1,090,267	13,672	19,484	45,036	67,950

3.2.2.4 Operational summary

Table 3-27 provides a summary of the operational emissions associated with the project. For this summary, only the difference between the 'Do minimum' and 'Do something' traffic emissions are presented for year of opening (2027) and ten years post opening (2037).

Table 3-27 shows that the emissions associated with operational electricity consumption are comparable (same order of magnitude) as the difference in traffic emissions between the 'Do minimum' scenario and the 'Do something' scenario. It should be noted that the vehicle emissions from traffic (for the extent of the modelled area) are greater than the operational electricity emissions.

Road traffic emissions are forecast to grow slightly from the current level due to an increase in road links associated with the project. However, due to improvements in road layout and widening, the efficiency of vehicles using the road network in the study area is forecast to improve. This, as well as analysis of the benefits of future fuel efficiency, suggests that efforts to support the free flow of traffic along the project would likely have life cycle benefits.

Table 3-27 Operational emissions summary

Source	Greenhouse gas emissions (t CO_2-e)	
	Project only	Cumulative
2027		
Operational electricity	31,010	65,995
Maintenance	594	1598
Vehicle emissions – traffic (difference between the Do minimum and Do something)	13,672	45,036
Total	**45,276**	**112,629**
2037		
Operational electricity	32,448	69,815
Maintenance	594	1598
Vehicle emissions – traffic (difference between the Do minimum and Do something)	19,484	67,950
Total	**52,526**	**139,363**

3.2.3 Greenhouse gas emissions summary

Table 3-28 provides a summary of the emissions associated with construction and operation of the project. Emissions associated with operation have been annualised, and as no traffic projections beyond 2037 are available, no data past this point is presented. The project would have an expected lifespan of 100 years, although during this time it is likely that traffic volumes and composition would change significantly, as would technology used in cars affecting fuel types and therefore emissions rates.

Table 3-28 Construction and operation greenhouse gas emissions summary

Source	Greenhouse gas emissions (t CO_2-e)	
	Project only	Cumulative
Construction	723,707	1,521,365
Operation 2027	45,276	112,629
Operation 2037	52,526	139,363

Construction emissions are expected to be much higher than the annual increase in operational emissions over the network as a result of the project facilitating additional transport across Sydney. The efficiency of this transport is expected to improve for the project through the removal of congestion and the creation of freer-flowing routes.

The construction and operational emissions are set in the context of state and national greenhouse gas inventories to determine their potential contribution. Based on the latest dataset available (from the Australian Greenhouse Emissions Information System (AEGIS), 2018) the NSW and national emissions inventories were:

- 537,446 kt CO_2-e (national emissions)
- 131,685 kt CO_2-e (NSW emissions).

Table 3-29 indicates the percentage that the construction and one year of operation emissions would contribute to these targets.

Table 3-29 Contribution to State and national emissions inventories

Source	Project only	Cumulative
State emissions		
Construction	0.55%	1.16%
Operation – 2027	0.03%	0.09%
Operation – 2037	0.04%	0.11%
National emissions		
Construction	0.13%	0.28%
Operation – 2027	0.01%	0.02%
Operation – 2037	0.01%	0.03%

4. References

Climate Change in Australia (CCIA), 2020, *Climate Futures Tool.*

Greater Sydney Commission (2018a), *Greater Sydney Region Plan – A Metropolis of Three Cities*.

Infrastructure Sustainability Council of Australia (ISCA), 2016b, *Infrastructure Sustainability Materials Calculator*.

Intergovernmental Panel on Climate Change (IPCC), 2013, *Fifth Assessment Report.*

National Greenhouse Accounts (NGA), 2017, *NAG factors.*

NSW Government (2018), *Future Transport Strategy 2056.*

Roads and Maritime Services, 2017d, *Tools for Roadside Air Quality.*

Roads and Maritime Services, 2015j, *Technical Guide for Climate Change Adaptation for the State Road Network*

Standards Australia (2013), *AS 5334-2013 Climate change adaptation for settlements and infrastructure – A risk based approach.*

Transport Authorities Greenhouse Group (TAGG), 2013, *Greenhouse Gas Assessment Workbook for Road Projects*.