NSW GOVERNMENT

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Environmental Impact Statement

December 2020

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131 450

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RMS 20.429
ISBN: 978-1-922463-47-0

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Certification

Submission of environmental impact statement
Prepared under Division 5.2 of the *Environmental Planning and Assessment Act 1979.*

Environmental impact statement prepared by:

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Responsible person:	Alex Wendler Chief Development Officer Infrastructure and Place Transport for NSW 18 Lee Street Chippendale NSW 2008.

Proposed development:

Beaches Link and Gore Hill Freeway Connection

Address of the land on which the infrastructure to which the statement relates:

Land within the North Sydney, Willoughby, Mosman and Northern Beaches local government areas as described within the environmental impact statement.

Description of the infrastructure to which the statement relates:

Construction and operation of the Beaches Link and Gore Hill Freeway Connection, which would comprise two main 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 Wakehurst Parkway at Killarney Heights, and an upgrade of 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).

Environmental impact statement:

An environmental impact statement is attached addressing all matters in accordance with Division 5.2 of the *Environmental Planning and Assessment Act 1979*.

Declaration:	I certify that I have prepared the contents of this environmental impact statement in response to the Secretary's environmental assessment requirements dated 22 April 2020 and the relevant provisions of Schedule 2 of the Environmental Planning and Assessment Regulation 2000. To the best of my knowledge the information contained in the environmental impact statement is not false or misleading.
Signature:	
Name:	Tim Rodham
Date:	4 December 2020

Glossary and abbreviations

Abbreviation	Definition
AADT	Annual average daily traffic
ABLV	Australian bat lyssavirus
ABS	Australian Bureau of Statistics
ACHAR	Aboriginal Cultural Heritage Assessment Report
ACTAQ	Advisory Committee on Tunnel Air Quality
AEP	Annual exceedance probability
AFG	Aboriginal focus group
AFL	Australian Football League
AHD	Australian height datum
AHIMS	Aboriginal Heritage Information Management System
Alluvium	Unconsolidated deposit of gravel, sand or mud formed by water flowing in identifiable channels. Commonly well sorted and stratified.
AM peak	Time period between 8am and 9am
ANZAC	Australian and New Zealand Army Corps
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	*Australian and New Zealand Guidelines for Fresh and Marine Water Quality*
AQIA	Air Quality Impact Assessment
Average recurrence interval (ARI)	The long-term average number of years between the occurrence of a flood larger than the selected event.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARR	Australian rainfall and runoff
AS	Australian standard
ASRIS	Australian Soil Resource Information System
ASSMAC	Acid Sulfate Soils Management Advisory Committee
BDAR	Biodiversity Development Assessment Report
Beaches Link	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 Gore Hill Freeway to Balgowlah and Killarney Heights and including the surface upgrade of Wakehurst Parkway from Seaforth to Frenchs Forest and upgrade and integration works to connect to the Gore Hill Freeway and Reserve Road at Artarmon.
Biodiversity Assessment	Established under section 6.7 of the BC Act to assess impacts on threatened species and threatened ecological communities (TECs), and their habitats, and

Abbreviation	Definition
Method (BAM)	the impact on biodiversity values, where required under the BC Act.
BL	Beaches Link
B-Line	Northern Beaches Bus Rapid Transit
The Blue Book	*Managing Urban Stormwater, Soils and Construction guidelines*, Volumes 1 (Landcom, 2004) and 2 (2008).
BOM	Bureau of Meteorology
BTEX	Benzene, toluene, ethylbenzene and xylene
Burra Charter	*Australia International Council on Monuments and Sites (ICOMOS) Charter for Places of Cultural Significance*
CASA	Civil Aviation Safety Authority
CBD	Central business district
CCTV	Closed circuit television
CEMP	Construction environmental management plan
CEO	Chief Executive Officer
CH_4	Methane
Chart datum	The level of water from which charted depths displayed on a nautical chart are measured.
CO	Carbon monoxide
CO_2	Carbon dioxide
Cofferdam	A temporary enclosure within a body of water that is constructed to allow dewatering of an enclosed area.
Complaint fatigue	An impact that may occur where community perceptions of project complaint management systems result in failure to report concerns about construction impacts. This impact may be compounded where multiple agencies are responsible for issues in the same area where construction of multiple projects occurs.
Construction fatigue	An impact that may be experienced by receivers that are in the vicinity of concurrent or consecutive project construction activities where the activities overlap or have little or no break between the activities of one project, or multiple adjacent projects.
Construction footprint	The total area required to facilitate the construction of the project.
Construction support sites	Parcels of land on which temporary construction-related activities would be carried out.
COVID-19	Coronavirus disease
CPTED	Crime prevention through environmental design
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Cumulative impact	An impact that may occur when impacts from one project interact or overlap with impacts from other projects and potentially result in a larger overall effect

Abbreviation	Definition
	on the environment, businesses or local communities. Cumulative impacts may also occur when projects are constructed consecutively with construction activities occurring over extended periods of time with little to no break in between.
Cut and cover tunnel	Tunnels that are typically constructed at locations where the tunnel alignment does not have enough rock cover to support the construction of traditional driven tunnels.
dB	Decibel
dB(A)	A-weighted decibels
DEC	Department of Environment and Conservation
DECC	Department of Environment and Climate Change
DECCW	Department of Environment Climate Change and Water
Dioxins	Polychlorinated dibenzo-para-dioxins
DIPNR	Department of Infrastructure Planning and Natural Resources
DLWC	Department of Lands and Water Conservation
DPE	Department of Planning and Environment (now known as Department of Planning, Industry and Environment)
DPI	Department of Primary Industries
DPIE	Department of Planning, Industry and Environment
Drawdown	The localised lowering of groundwater levels as a result of water extraction.
Dredging	Excavation carried out underwater or partially underwater.
Driven tunnel	Tunnels excavated using roadheaders.
EES	Environment, Energy and Science Group sitting within the Department of Planning, Industry and Environment
EIA	Environmental impact assessment
EIS	Environmental Impact statement
EMM	Environmental management measure
EMS	Environmental management system
EPA	NSW Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cth)
ESP	Electrostatic precipitator
FDM	Floodplain Development Manual
Floodway	Floodplains that transmit large quantities of water.
Flood fringe	Floodplains that do not play a significant role in either storing or conveying water.

Abbreviation	Definition
Flood storage	Floodplains that store a significant volume of water.
GDE	Groundwater dependent ecosystem
GHF	Gore Hill Freeway
Gore Hill Freeway Connection	Connection and integration works along the existing Gore Hill Freeway and surrounding roads at Artarmon.
GRAL	Graz Langrangian model
GRAMM	Graz Mesoscale model
Groundwater	All waters occurring below the land surface. The upper surface of the soils saturated by groundwater in any particular area is called the water table.
GSP	Gross state product
gy	Gymea landscape group
ha	Hawkesbury landscape group
HEPA	Heads of EPAs Australia and New Zealand
HMAS	Her Majesty's Australian Ship
IAQM	UK Institute of Air Quality Management
IBC	Intermediate bulk containers
ICOMOS	International Council on Monuments and Sites
Immersed tube tunnel	A series of steel tunnel segments placed on top, or within the top layers, of harbour rock and sediment.
IPCC	International Panel on Climate Change
ISCA	Infrastructure Sustainability Council of Australia
ISO	International Organisation for Standardisation
ISQG	*High and Low Interim Sediment Quality Guidelines*
kg	Kilogram
km	Kilometre
km/h	Kilometres per hour
kN	Kilonewtons
ktCO2-e	Kilotonnes of carbon dioxide equivalent
kV	Kilovolt
la	Lambert landscape group
L_{A90}	Noise level exceeded for 90 per cent of the measurement period.
L_{Aeq}	Sound level in decibels equivalent to the total A-weighted sound energy

Abbreviation	Definition
	measured over a stated period of time.
L_{Amax}	Maximum A - weighted sound pressure level.
LALC	Local Aboriginal Land Council
LCZ	Landscape character zone
LED	Light-emitting diode
LEP	Local environmental plan
LGA	Local government area
LoS	Level of service
L/s/km	Litres per second per kilometre
LSPS	Local Strategic Planning Statement
m	Metre
m/s	Metres per second
mm	Millimetres
mm/s	Millimetres per second
m^2	Square metres
m^3	Cubic metres
m^3/s	Cubic metres per second
Mainline tunnel	Tunnels connecting the approved M4-M5 Link at Rozelle to the Warringah Freeway and to the Beaches Link tunnels at Cammeray.
mf	Manmade fill
mg	Milligrams
mg/L	Milligrams per litre
mg/m^3	Milligrams per cubic metre
ML/year	Megalitres per year
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
MVA	Megavolt ampere
NAGD	National Assessment Guidelines for Dredging
NCA	Noise catchment area
NEPC	National Environment Protection Council
NHMRC	National Health and Medical Research Council
NML	Noise management level

Abbreviation	Definition
NO	Nitrogen oxides
NO_2	Nitrous dioxide
NO_x	Nitrogen oxides
NPW	National Parks and Wildlife
NSITP	*North Sydney Integrated Transport Program*
NSW	New South Wales
NTU	Nephelometric turbidity unit
NZS	New Zealand standard
OCP	Organochlorine pesticides
OCSE	Office of the Chief Scientist and Engineer
OEH	Office of Environment and Heritage (now known as the Department of Premier and Cabinet (Heritage) or Heritage NSW)
OLS	Obstruction limitation surface
OPP	Organophosphorus pesticides
PACHCI	Procedure for Aboriginal cultural heritage consultation and investigation
PAD	Potential archaeological deposit
PAH	Polycyclic aromatic hydrocarbons
Palaeochannels	Old river or stream channels which have been filled or buried by younger sediment.
PANS-OPS	Procedures for air navigation systems operations
PCB	Polychlorinated biphenyls
PCT	Plant community type
PCU	Passenger car unit
PFAS	Poly-fluoroalkyl substances
pH	A measure of the degree of acidity or alkalinity expressed on a logarithmic scale of 1-14, on which 1 is most acid, 7 is neutral and 14 is most basic (alkaline).
PIARC	Permanent International Association of Road Congress
Pile	Heavy stake or post installed to support the foundations of a structure.
PM peak	Time period between 5 pm and 6 pm.
$PM_{2.5}$	Particulate matter less than or equal to 2.5 micrometre diameter.
PM_{10}	Particulate matter less than or equal to 10 micrometre diameter.

Abbreviation	Definition
PMF	Probable maximum flood event. The upper limiting value of floods that could reasonably be expected to occur (the result of the most severe combination of meteorological conditions) and defines the extent of flood prone land (ie the floodplain).
POEO Act	*Protection of the Environment Operations Act 1977* (NSW)
Point to point transport	Includes taxis, hire cars, tourist services, rideshare services and other vehicles with 12 seats or less (including the driver) that provide passenger transport services for a fare.
ppm	Parts per million
PVC	Polyvinyl Chloride
RBL	Rated background level
Residual lands	Lots that would be wholly or partially occupied during construction of the project, but would not be required for permanent operational infrastructure or other operational activities (also referred to as surplus lands).
RFS	Rural Fire Service
Rh	Hawkesbury sandstone
RMS	NSW Roads and Maritime Services (now part of Transport for NSW)
Roadheader	An excavation machine that has a rotating, rock-cutting head on the front, mounted to a boom.
Roads and Maritime	NSW Roads and Maritime Services (now part of Transport for NSW)
RSL	Returned & Services League of Australia
RTA	Roads and Transport Authority
Rwa	Ashfield shale
SEPP	State environmental planning policy
SMPM	Sydney Motorway Planning Model
SO_2	Sulphur dioxide
SREP	Sydney regional environmental plan
SSI	State Significant Infrastructure
Standard construction hours	7am to 6pm Monday to Friday, 8am to 1pm Saturday and no construction works on Sundays or public holidays.
STM	Strategic travel model
Substratum acquisition	The acquisition of land below the surface of the ground.
TAFE	Technical and Further Education
TAGG	Transport Authorities Greenhouse Group
TBM	Tunnel boring machine

Abbreviation	Definition
TBT	Tributyltin
TEQ	Toxic equivalence quotient
TfNSW	Transport for NSW
The project	The Beaches Link and Gore Hill Freeway Connection project.
TRH	Total recoverable hydrocarbons
Trough structure	Similar to cut and cover structure, except a cover is not required.
TSP	Total suspended particles
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
UNSW	University of New South Wales
USEPA	United States Environmental Protection Agency
$\mu g/m^3$	Microgram per cubic metre
VENM	Virgin Excavated Natural Material
VIS	Vegetation Information System
VKT	Vehicle kilometres travelled
VOCs	Volatile organic compounds
Warringah Freeway Upgrade	Upgrade and integration works along the existing Warringah Freeway, including infrastructure required for connections to the Beaches Link and Gore Hill Freeway Connection project.
WBCSD	World Council for Sustainable Business Development
Western Harbour Tunnel	A new crossing of Sydney Harbour involving twin motorway tunnels connecting the M4-M5 Link at Rozelle and the existing Warringah Freeway at North Sydney.
WFU	Warringah Freeway Upgrade
WHO	World Health Organisation
WHT	Western Harbour Tunnel
WHTBL	Western Harbour Tunnel and Beaches Link
WQO	NSW water quality objectives
WRI	World Resources Institute
xx	Disturbed landscape group

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Executive summary

transport.nsw.gov.au

DECEMBER 2020

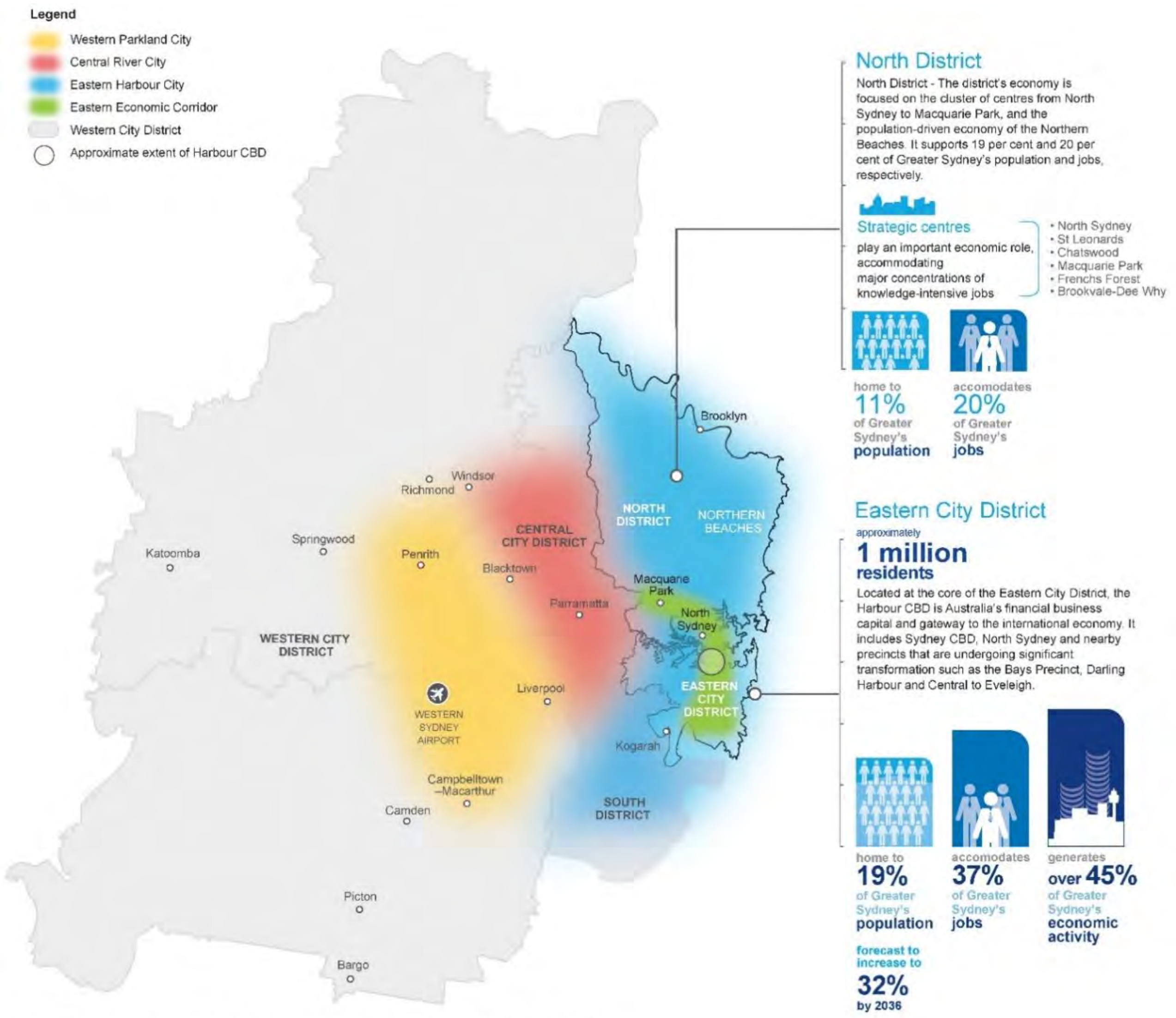
Executive Summary

Beaches Link and Gore Hill Freeway Connection

Strategic context

The population of Sydney is forecast to grow from five million to eight million people over the next 40 years. To accommodate this growth, 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.

The Beaches Link and Gore Hill Freeway Connection project is located within the North District (and the Eastern Economic Corridor) and the Northern Beaches of the Eastern Harbour City region as shown in Figure E-1. The North District supports 11 per cent of the population and 20 per cent of the jobs in Greater Sydney.



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

Figure E-1 Greater Sydney's Eastern City and North districts

Supporting the current needs and future growth of the North District, Eastern Harbour City and Eastern Economic Corridor through an efficient transport network is fundamental to maintaining the liveability, productivity and sustainability of Greater Sydney. Accordingly, the *Greater Sydney Region Plan* was prepared concurrently with the *Future Transport Strategy 2056* (NSW Government, 2018) and the *State Infrastructure Strategy 2018–2038* (Infrastructure NSW, 2018) to align land use, transport and infrastructure outcomes for Greater Sydney.

Project need

The Eastern Harbour City has the largest concentration of jobs in Greater Sydney, accommodates the most productive industries and is home to a highly skilled workforce. Accordingly, the eastern motorway crossings of Sydney Harbour are critical links in Sydney's motorway and arterial road network. These major transport corridors around the Harbour CBD are critical to the performance of the arterial network servicing the Northern Beaches, particularly for north-south trips and are some of the busiest in Greater Sydney and indeed in Australia. Key metrics for the Eastern Harbour City's road transport network are shown in Figure E-2.

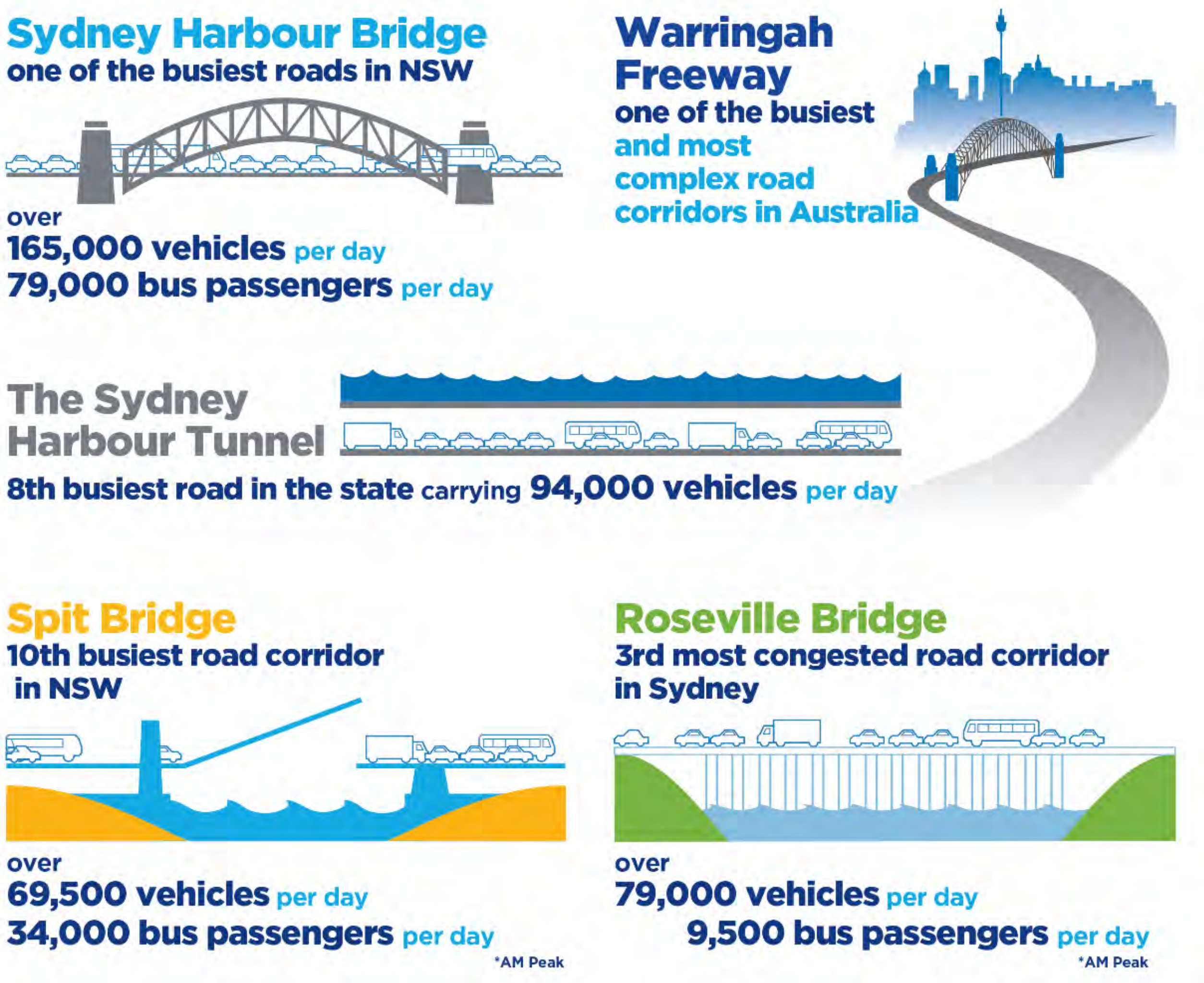


Figure E-2 Key metrics for the Eastern Harbour City's transport network

The high demand and limited capacity on the Sydney Harbour crossings result in delays and unreliable journey times for a significant number of customers who directly rely on these corridors. Furthermore, the limited number of alternate routes for crossing Sydney Harbour makes these corridors critical to the performance of the broader motorway and arterial road network. Network data demonstrates that incidents on the harbour crossings and their approaches can significantly impact journey times for freight, buses and private vehicles travelling north and south on the arterial network servicing the Northern Beaches region, with Spit Road and Military Road particularly affected. The high road demand and limited number of corridors connecting the Northern Beaches means that incidents on these corridors have significant impacts on journey times to and from the region.

As the Northern Beaches is connected to the rest of Greater Sydney by a small number of transport corridors, this contributes to high levels of congestion, long and unreliable journey times and, consequently, poor accessibility to and from the region. Just three road corridors connect the Northern Beaches with the rest of Greater Sydney: Mona Vale Road, Warringah Road and Military Road/Spit Road. All three currently experience high levels of traffic congestion. The region is particularly reliant on the most southerly corridors: Warringah Road via Roseville Bridge and Spit Road/Military Road via Spit Bridge corridors. Currently, these links carry 71 per cent of all inter-regional road journeys to and from the Northern Beaches.

Further to the large traffic volumes and limited alternative routes, a major contributor to congestion around the Harbour CBD is that many of the most critical road corridors – including Military Road, Warringah Road, the Sydney Harbour Bridge, the Sydney Harbour Tunnel, ANZAC Bridge, Western Distributor and the Warringah Freeway – perform both bypass and access functions. The dual function of these corridors is reflected in the high proportion of vehicles that use them to travel to destinations other than Sydney CBD. These conflicting functions, combined with high traffic volumes, result in congestion and poor network performance experienced by freight, public transport and private vehicle users.

Residents on the Northern Beaches rely heavily on private vehicles and public buses for travel (Northern Beaches Council, 2018). Public transport travel times to the Northern Beaches can be long and unreliable, with bus travel times between Mona Vale and the Sydney CBD in excess of 60 minutes during peak periods despite recent improvement due to the B-Line program. By reducing network congestion, the project would result in improved network resilience and reliability, particularly in peak periods, and would make bus routes to and from the Northern Beaches a more attractive transport option, supporting and encouraging a mode shift to public transport. The project would also create the opportunity for new express bus routes to be developed in response to diverse travel demands and future development.

The project is also identified as a priority initiative under Infrastructure Australia's *Australian Infrastructure Plan: The Infrastructure Priority List (*Infrastructure Australia, 2018) for its importance in addressing urban congestion on Sydney's road network, providing cross-harbour connectivity and Northern Beaches connectivity.

Further detail on these transport challenges and their influence on the proposed design for the Beaches Link and Gore Hill Freeway Connection project is provided in Chapter 3.

Project objectives

To ensure the design of the project meets the identified transport needs, the objectives summarised in Figure E-3 have been developed for the Beaches Link and Gore Hill Freeway project.

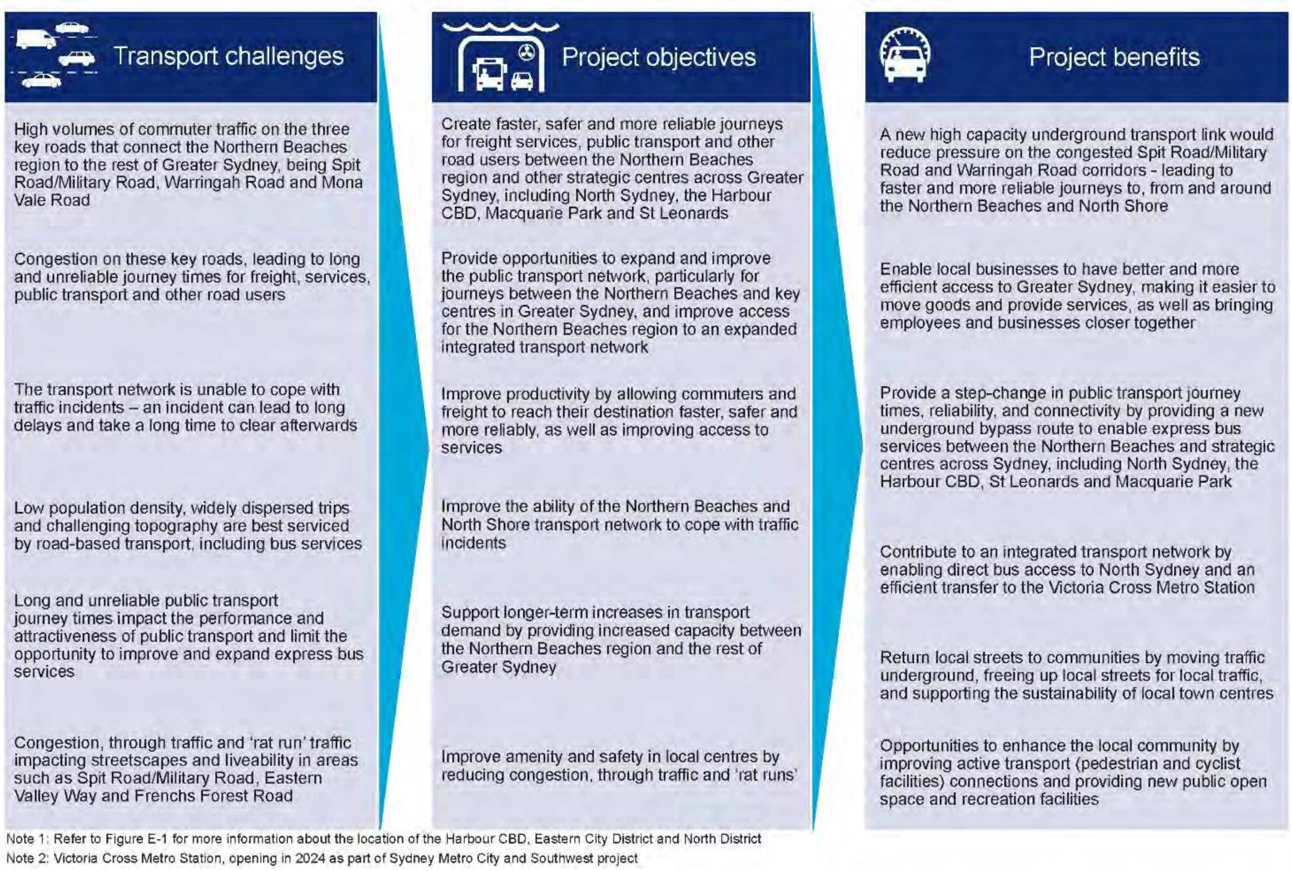


Figure E-3 Project challenges, objectives and benefits

Overview of the Western Harbour Tunnel and Beaches Link program of works

The Western Harbour Tunnel and Beaches Link program of works is a major transport infrastructure program that would make it easier, faster and safer to get around Sydney. As Sydney continues to grow, faster and more reliable trips are essential to reducing congestion and providing new levels of access to jobs, recreation, and services such as schools and hospitals. By creating a western bypass of the Sydney CBD, the Western Harbour Tunnel would take pressure off the Sydney Harbour Bridge, Sydney Harbour Tunnel and ANZAC Bridge; while Beaches Link would create an alternative to the Military Road/Spit Road and Warringah Road corridors to relieve traffic pressure on the North Shore.

The program of works has been designed as part of an integrated transport network, which has a focus on new public transport connections and improved journey times and reliability for buses. It would also provide improvements to walking and cycling routes, providing more active transport options.

The Western Harbour Tunnel and Beaches Link program of works include:

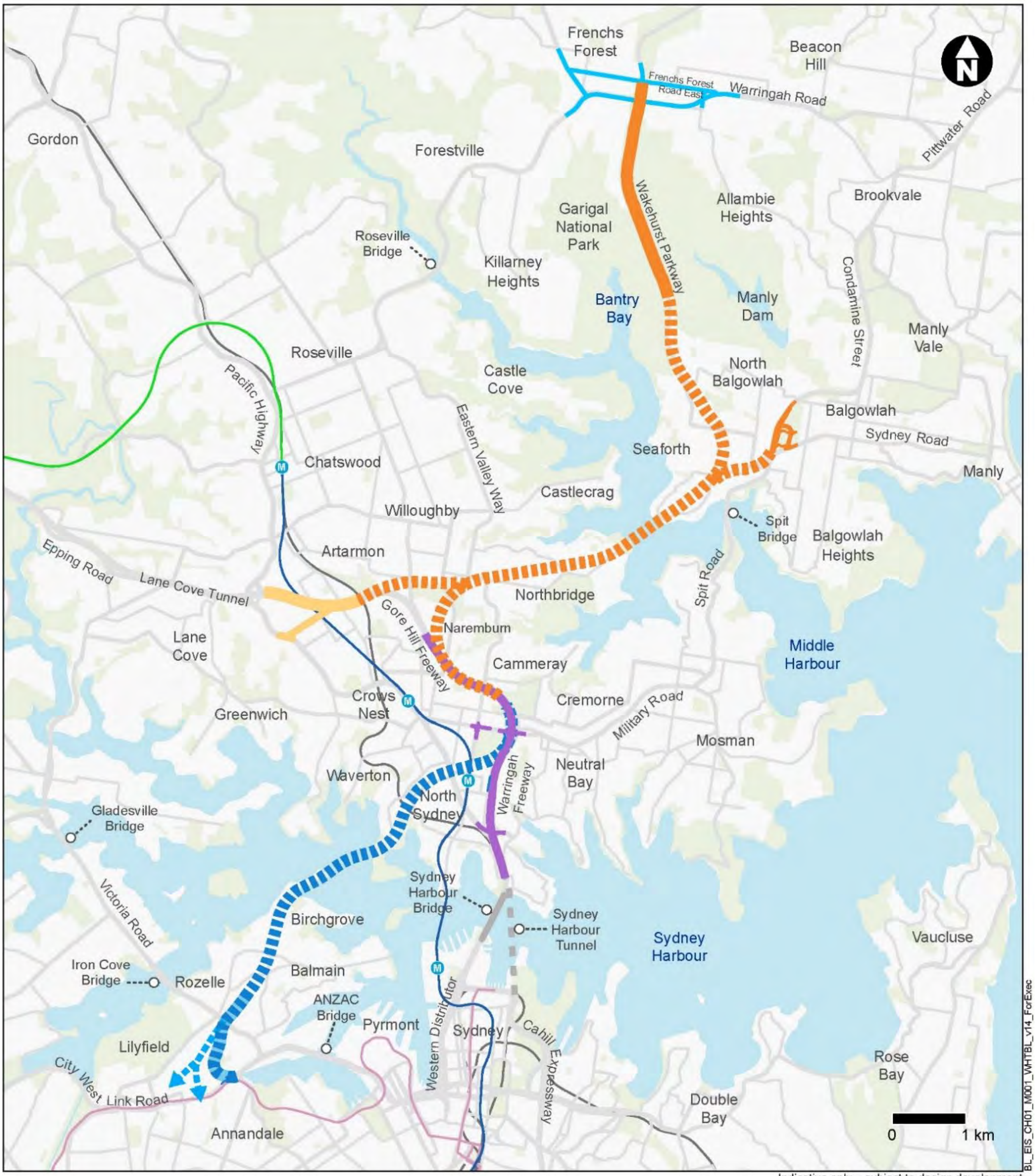
- The Western Harbour Tunnel and Warringah Freeway Upgrade project which comprises a new motorway tunnel connection across Sydney Harbour, and an upgrade of the Warringah Freeway to integrate the new motorway infrastructure with the existing road network and to enable the future connection of the Beaches Link and Gore Hill Freeway Connection project
- The Beaches Link and Gore Hill Freeway Connection project (the project) which comprises a new motorway tunnel connection across Middle Harbour from the Warringah Freeway and Gore Hill Freeway to the Burnt Bridge Creek Deviation at Balgowlah and Wakehurst Parkway at Killarney Heights. The project also includes a surface upgrade of Wakehurst Parkway from Seaforth to Frenchs Forest and upgrade and integration works to connect to the Gore Hill Freeway and Reserve Road at Artarmon.

The components of the Western Harbour Tunnel and Beaches Link program of works are shown in Figure E-4.

The 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 and more reliable travel times for journeys between the strategic centres along the Eastern Economic Corridor of Sydney – an area between Port Botany and north-west that accounts for over 40 per cent of the NSW gross State product. For example, with the combined program of works, journeys from Dee Why to Sydney Kingsford Smith Airport are expected to be 56 minutes faster. Delivering the program of works would also improve the resilience of the motorway network, given that each project provides additional capacity and an alternative to heavily congested existing harbour crossings and their approaches.

The program of works would also provide an opportunity to improve existing, and introduce new, bus services between key employment and education centres, directly and reliably linking the Northern Beaches to strategic centres including North Sydney, the Harbour CBD, St Leonards and Macquarie Park via the motorway network This opportunity would better integrate employment, residential and education centres and provide improved road transport access to a wider range of services and facilities.

The Western Harbour Tunnel and Warringah Freeway Upgrade project and the Beaches Link and Gore Hill Freeway Connection project are subject to separate but coordinated environmental assessment and approval processes.



Indicative only – subject to design development

Legend

Operational features

- Beaches Link
- Gore Hill Freeway Connection
- Western Harbour Tunnel
- Warringah Freeway Upgrade
- M4-M5 Link tunnel fitout and commissioned as part of Western Harbour Tunnel

Connecting projects

- M4-M5 Link connections (indicative)
- Northern Beaches Hospital road upgrade project (Completed 2020)

Other projects

- Sydney Metro City & Southwest (under construction)
- Sydney Metro Northwest

Existing rail network

- Suburban rail/Sydney Trains
- Light rail

Figure E-4 Western Harbour Tunnel and Beaches Link program of works

The Beaches Link and Gore Hill Freeway Connection project

This environmental impact statement relates to the Beaches Link and Gore Hill Freeway Connection project. The project would comprise:

- 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 Wakehurst Parkway at Killarney Heights, and an upgrade of 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).

Key features of the Beaches Link component of the project are shown in Figure E-5 and would include:

- Twin mainline tunnels about 5.6 kilometres long and 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 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 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, Artarmon (about 2.1 kilometres in length).
- An access road connection at Balgowlah between Burnt Bridge Creek Deviation and Sydney Road including the modification of the intersection at Maretimo Street and Sydney Road, Balgowlah
- New and improved public open space and recreation facilities at Balgowlah including utilisation of the new access road for connectivity to the new facilities
- Upgrade and integration works along Wakehurst Parkway at Seaforth, Killarney Heights and Frenchs Forest, through to Frenchs Forest Road East
- New and upgraded active transport infrastructure (pedestrian and cyclist facilities)
- Ventilation outlets and motorway facilities at the Warringah Freeway in Cammeray, the Gore Hill Freeway in Artarmon, Burnt Bridge Creek Deviation in Balgowlah and 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 Wakehurst Parkway in Frenchs Forest
- Other operational infrastructure including groundwater and tunnel drainage management and treatment systems, pavement works, 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 E-1 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 and inclusion of traffic lights of the Dickson Avenue and Pacific Highway intersection
- New and upgraded pedestrian and cyclist facilities
- Other operational infrastructure, including surface drainage and utility infrastructure, signage and lighting, CCTV and other traffic management systems.

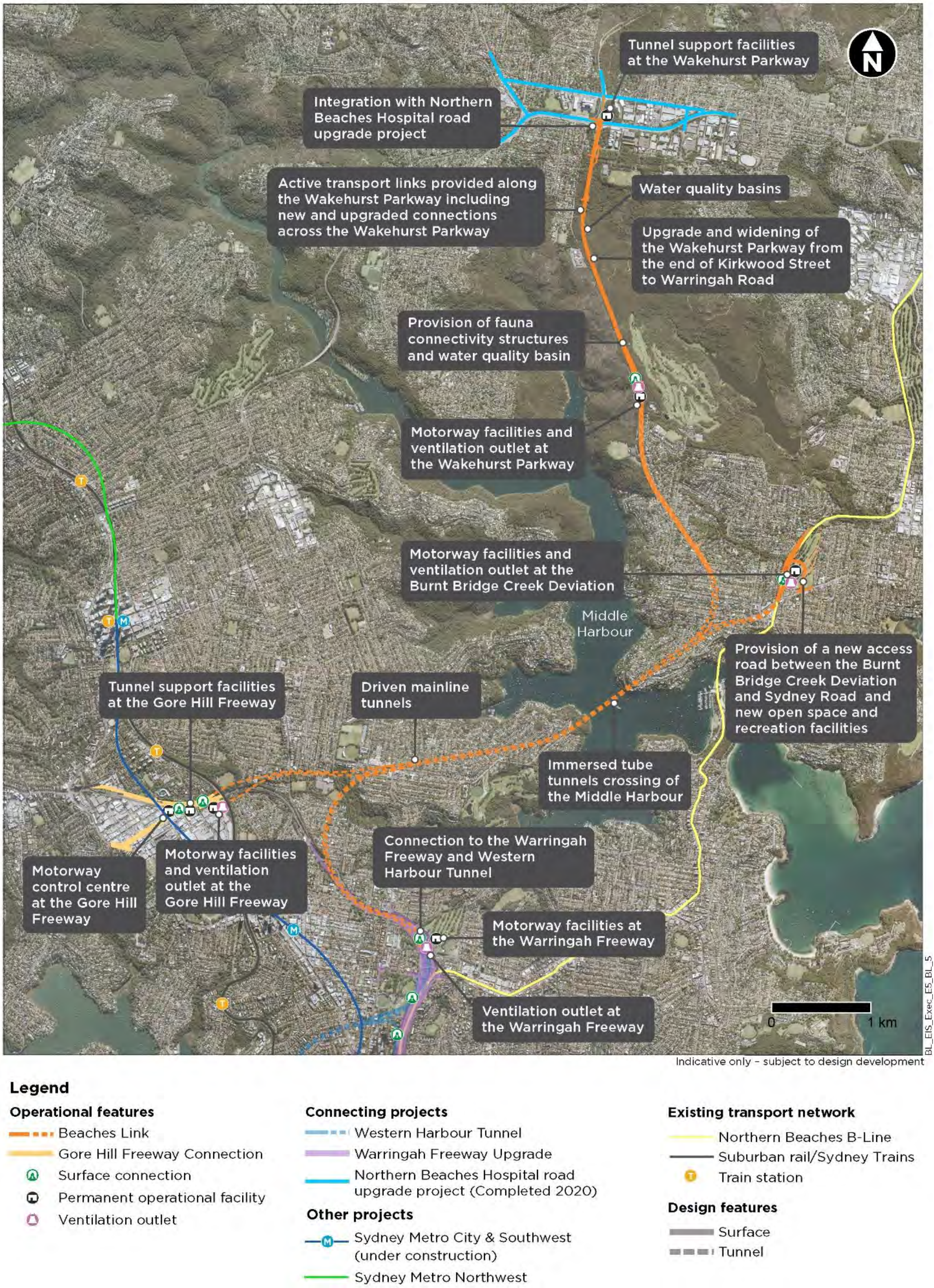


Figure E-5 Key features of the Beaches Link component of the project

Indicative only – subject to design development

Legend

Operational features

- Gore Hill Freeway Connection
- Beaches Link
- Permanent operational facility
- Surface connection
- Ventilation outlet
- Pedestrian / active transport links
- Permanent water quality basin

Existing rail network

- Suburban rail/Sydney Trains

Other projects

- Sydney Metro City & Southwest (under construction)

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

Major transport benefits

The project would provide additional capacity across the Middle Harbour road corridor, relieving congestion on existing key road corridors and providing connections to other key existing and future proposed transport projects. By creating a bypass of both the Spit Bridge/Military Road and the Roseville Bridge/Warringah Road corridors, the project would provide direct access from the Northern Beaches to the Warringah Freeway for fast and reliable access to key commercial and employment centres at North Sydney, the Sydney CBD and beyond. It would also provide a fast, reliable link between the Northern Beaches and other key centres in the north-west including St Leonards and Macquarie Park via the direct Gore Hill Freeway connection.

The project through providing an underground bypass would also provide major benefits to public transport, enabling faster, more reliable and direct peak express services between the Northern Beaches, Harbour CBD, North Sydney, St Leonards, and Macquarie Park. It would also improve travel times and reliability on existing services along key routes such as Military Road, Warringah Road, Pacific Highway, Warringah Freeway and Sydney Harbour Bridge by relieving pressure on surface arterial roads, reducing conflicts between express and multi-stop services allowing multi-stop surface bus routes to operate more efficiently on these corridors.

The project would also deliver improved active transport infrastructure, including a new shared path along Wakehurst Parkway with overpass links to the new Northern Beaches Hospital precinct, and shared user underpasses provided beneath Wakehurst Parkway to provide safe connections from Garigal National Park and Manly Dam Reserve. Additional shared pathways would be provided in and around the new and improved open space recreation facilities at Balgowlah, integrating with existing paths to nearby commercial and community receivers. Realignment and reconstruction of the shared user path along the southern side of the Gore Hill Freeway would also be provided.

Project construction

The construction of the Beaches Link component of the project would include works underground, underwater and at the surface. The majority of the tunnel for the project would be constructed using roadheaders. The combination of the high quality Sydney Sandstone beneath most of the city, and the wide cross section required for road tunnels make this the most efficient and common method for constructing road tunnels in Sydney.

The poorer geological ground conditions at the Middle Harbour crossing requires the use of a different methodology to be adopted for the construction of the harbour crossing. Twin immersed tube tunnels, generally similar to the existing Sydney Harbour Tunnel, have been selected as the preferred solution as it would reduce the risk of deep tunnelling through poor geological ground conditions and deliver the best transport product by providing the lowest possible gradient for surface connections.

This section of the tunnel would be constructed by installing a series of pre-fabricated tunnel units to form the harbour crossing. Due to the profile of the harbour bed, the units would sit both partially within a trench closer to the shore and above the bed of the harbour towards the centre of the crossing. Given the very soft sediments at the bed of Middle Harbour, supporting piles would be required at discrete locations along the immersed tube crossing. A locking fill would be placed around the end sections of the immersed tube tunnels for stability and protection.

The shallow sand bar at the entrance to Middle Harbour prevents the transportation of fully completed tunnel units to the tunnel crossing location. The tunnel units would be partially fabricated outside of Middle Harbour then transported with the assistance of tug boats to a temporary floating immersed tube tunnel casting facility located at Spit West Reserve. The tunnel unit fabrication would be completed at a temporary construction support site at Spit West Reserve and transported by tug boats to a temporary mooring area within Middle Harbour before being placed into their final position.

Temporary cofferdams would be constructed within Middle Harbour off the shoreline at Northbridge and Seaforth. The cofferdams would be used to construct underground connection structures, called interface structures, which are required to connect the immersed tube tunnels to the land tunnels.

Although much of the construction works for the Beaches Link component of the project would be underground, surface works would also be required to support tunnelling activities and to construct the temporary construction support sites, surface connections, surface road upgrades, tunnel portals and operational facilities. Construction activities for the Gore Hill Freeway Connection would generally include surface earthworks, bridgeworks, utility works, tunnel construction of retaining walls, installation of stormwater drainage and pavement construction.

The construction of the Beaches Link and Gore Hill Freeway Connection project would require around 14 temporary construction support sites including tunnelling and tunnelling support sites, civil surface sites, cofferdams, mooring sites, wharf and berthing facilities, laydown areas, parking and workforce amenities. About four of these sites are areas within or adjacent to the existing Gore Hill Freeway corridor. An overview of these sites is provided in Figure E-2.

Tunnel spoil generated by the driven tunnels would be removed from acoustic sheds (designed to minimise noise impacts to the local community) at tunnelling temporary construction support sites. Most of the temporary construction support sites have direct access to the arterial road network, and spoil would generally be removed using trucks.

Most of the material dredged for the immersed tube tunnel crossing would be transported to the existing designated offshore disposal site managed by the Commonwealth Department of Agriculture, Water and the Environment in accordance with the *Environment Protection (Sea Dumping) Act 1981.* This disposal site is over 20 square kilometres in area, about 120 metres deep, and non-dispersive, meaning that material disposed of would stay within the disposal site. The disposal site is currently active and receiving material under permits from other marine maintenance and capital projects. An application for the project to dispose of suitable dredged material at the offshore disposal will be submitted to the Department of Agriculture, Water and the Environment.

Dredged materials not suitable for offshore disposal would be transported by barge to a loadout facility to be made spadable and then loaded onto trucks. The material would be classified according to the NSW Environment Protection Authority's *Waste Classification Guidelines* (NSW EPA, 2014a) and disposed of at a suitably licensed land-based facility.

The construction program presented within the environmental impact statement provides indicative timing only. The final construction program, and commencement of works at each construction site, may vary. Subject to planning approval and procurement, construction of the Beaches Link and Gore Hill Freeway Connection project is currently planned to commence in 2023. On that basis, completion of the main construction would be around the end of 2027 and completion of construction works for the new and improved open space and recreation facilities would be in 2028 – a total construction period of five to six years. Early works and site establishment would be the first works carried out for the project, with substantial construction starting around six months later.

For further details on the construction aspects of the project refer to Chapter 6.

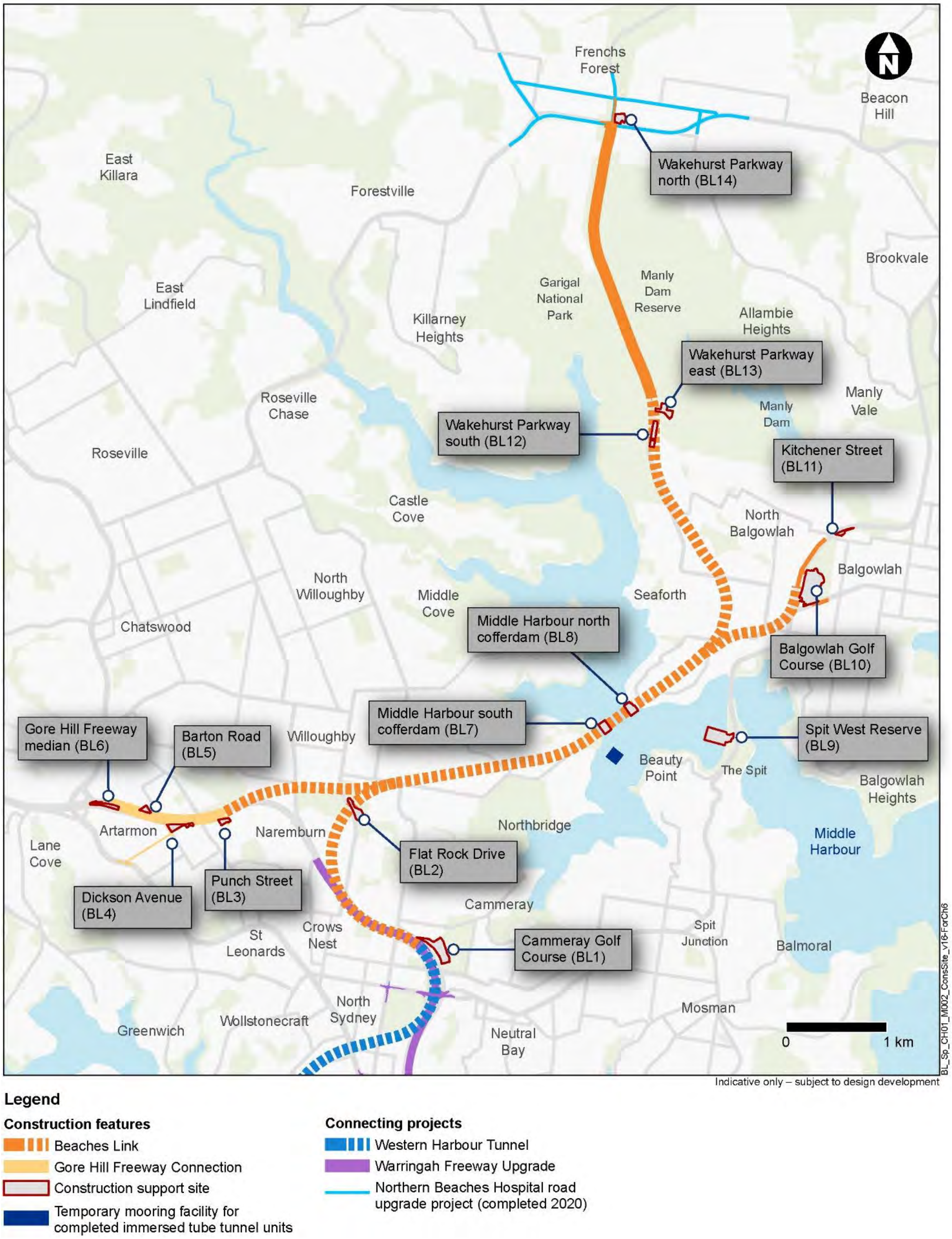


Figure E-2 Overview of the temporary construction support sites

Alternatives considered

The need for additional core motorway capacity at the crossings of Middle and Sydney Harbour was identified as key to development of an appropriate multi-modal Sydney transport network in the *NSW Long Term Transport Master Plan* (Transport for NSW, 2012) and subsequent *Future Transport Strategy 2056* (NSW Government, 2018).

Considering the requirements identified within the *NSW Long Term Transport Master Plan* and the *Future Transport Strategy 2056*, a number of strategic alternatives were considered for delivering the required road capacity at the crossing of Sydney Harbour. The project has undergone extensive evaluation of alternatives from pre-feasibility and strategic investigations through to design development and refinement. The process of developing and assessing project alternatives is outlined in Figure E-3.

The physical and urban geography of the Northern Beaches region presents barriers to the consideration of rail-based solutions in addressing the transport challenges faced by the region. The provision of rail infrastructure is also reliant on the location of and accessibility to high density residential or commercial property in close proximity to the proposed location of stations as well as along its route. Given the high cost of constructing and operating rail infrastructure and the low density nature of the Northern Beaches, it is considered that demand would not be high enough to make investing in a specific or dedicated rail link to the Sydney CBD a viable alternative.

Following identification of a new motorway tunnel as the preferred strategic alternative, a design development process was carried out to determine the most appropriate alignment and construction method to deliver the tunnel. The process for selection of the preferred tunnel alignment and construction methodologies included consideration of ten strategic corridors and over fifteen different combinations of tunnelling methods.

Options were developed and assessed by a multidisciplinary team including design engineers, construction engineers, transport planners and environmental advisors with direct experience in delivering major transport infrastructure in NSW, Australia and internationally.

Following preliminary technical and environmental analysis, five corridor alternatives were shortlisted for a new tunnelled motorway connection between Cammeray, Artarmon, Killarney Heights and Balgowlah (refer to Figure E-4). Selection of the preferred corridor required consideration of various technical, environmental and community factors including:

- Strategic traffic demands and how they define the required connectivity to achieve transport outcomes
- Results of geotechnical, groundwater and contamination investigations
- Topography along the alignment
- Basements and foundations of structures along the routes
- Maritime heritage, biodiversity and marine ecology
- Turbidity and hydrodynamic monitoring and modelling for Middle Harbour
- Opportunities for viable temporary intermediate tunnelling sites that minimise community, environmental and heritage impacts
- Physical and operational interfaces with other major infrastructure (eg Sydney Metro Tunnels, the Warringah Freeway, Northern Beaches Hospital Road Upgrade project)
- Integration with the proposed Western Harbour Tunnel and Warringah Freeway Upgrade project
- Horizontal alignments and waterway crossing methodologies that allow the tunnel to achieve acceptable vertical gradients to achieve the desired transport product, reduce whole of life emissions, operational costs, and improve safety outcomes

- Surface connections and interchanges that integrate with the arterial road network and connect bus routes and public transport nodes
- Interfaces with commercial and recreational maritime traffic
- Construction and operational efficiencies
- Potential impacts on local communities including amenity and connectivity.

The blue corridor was selected as the preferred corridor alternative for the new motorway (refer to Figure E-4). This corridor was selected as it achieves a greater alignment with transport and city-shaping objectives. This reflects the fact that it delivers more direct east-west connectivity relative to the pink corridor, while also providing strong north-south connectivity. This delivers more congestion relief to arterial roads, such as Warringah Road, and also provides the opportunity for new express bus services for customers travelling between the Northern Beaches and strategic centres such as North Sydney, St Leonards and Macquarie Park. The superior east-west connectivity means that the blue option also performs best with respect to productivity objectives. This is a result of enabling greater access to jobs for residents in the Northern Beaches and also the fact that it reduces the cost of business travel.

For further details on the development of the preferred design and the alternatives considered refer to Chapter 4.

Strategic alternatives

- Strategic alternatives assessed included:
  - Do nothing
  - Travel demand management
  - Improvements to the existing arterial road network
  - A new motorway (the project)
  - Improvements to alternative transport modes
- New motorway selected as the preferred strategic alternative

Corridor alternatives

- Five corridor alternatives (pink, purple, green, red and blue) were assessed against:
  - Project objectives
  - Evaluation criteria:
    - Technical criteria
    - Environment and planning criteria
- Blue corridor selected as the preferred corridor alternative (the project)

Further project alternatives development

- Project development work included consideration of the following:
  - Tunnelling method alternatives
  - Connection alternatives to Warringah Freeway
  - Connection alternatives to Gore Hill Freeway
  - Connection alternatives to Wakehurst Parkway
  - Connection alternatives to Balgowlah
  - Ventiltation alternatives
  - Construction support site location alternatives
  - Spoil transport alternatives
  - Tunnelling spoil reuse and disposal alternatives
  - Dredged material management alternatives

The project as described in this environmental impact statement

We are here

Figure E-3 Alternatives development process

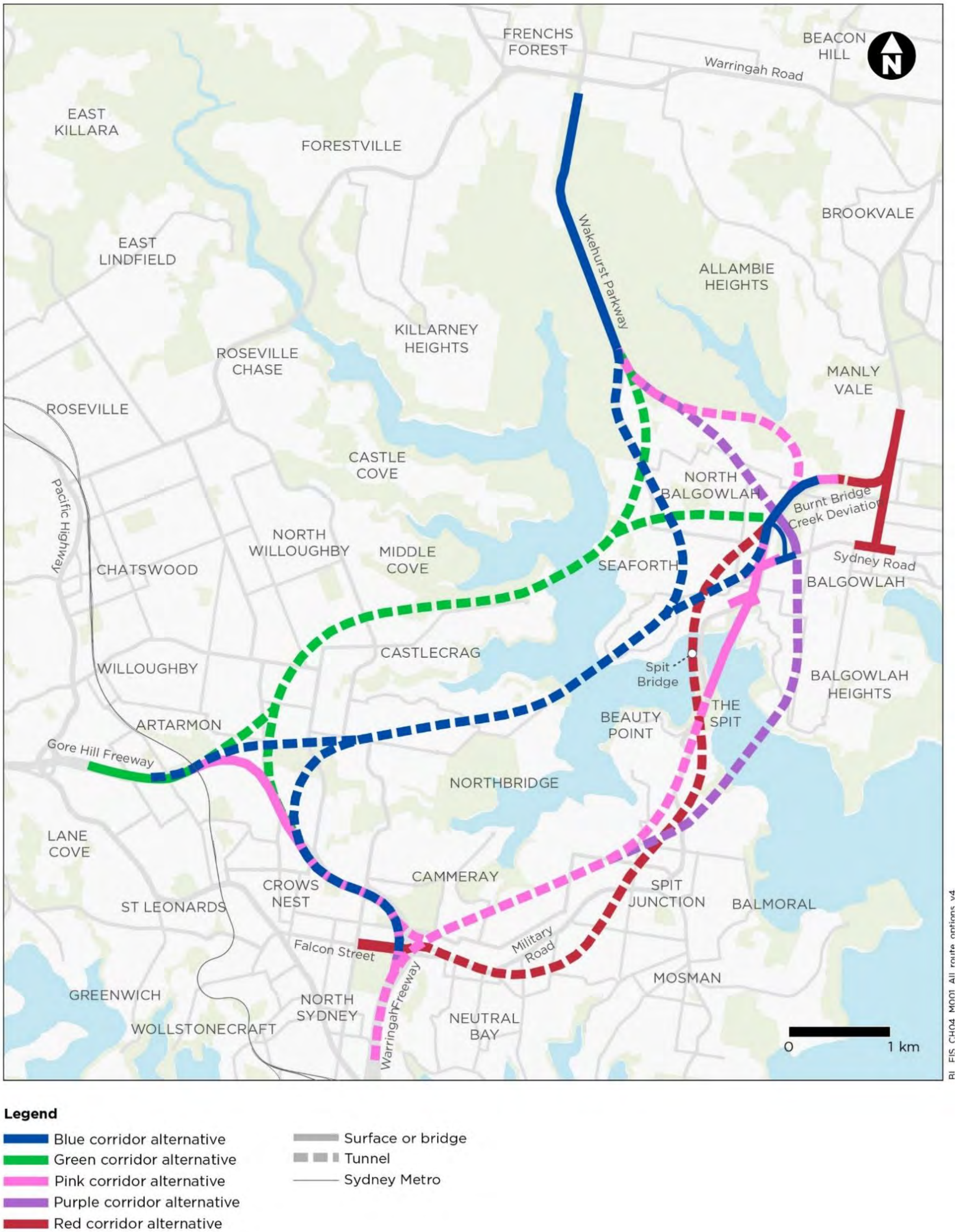


Figure E-4 Shortlisted main corridor alternatives

The proponent

The proponent for the project is Transport for NSW. Transport for NSW is the lead agency of the NSW transport portfolio, with primary responsibility for:

- Transport coordination
- Transport policy and planning
- Transport services
- Transport infrastructure.

Transport for NSW would manage the planning, procurement and delivery of the project.

Planning approval process

Transport for NSW formed the opinion that the construction and operational impacts of the project would require an environmental impact statement. In accordance with clause 1 and clause 14 of Schedule 3 of State Environmental Planning Policy (State and Regional Development) 2011 the project is declared State significant infrastructure. Transport for NSW has also requested the Minister for Planning and Public Spaces to declare the project as critical State significant infrastructure under section 5.13 of the *Environmental Planning and Assessment Act 1979*.

This environmental impact statement is publicly exhibited to provide the community, government agencies and stakeholders with an understanding of what is proposed and to invite comment. Transport for NSW will consider the comments and submit to the Department of Planning, Industry and Environment a submissions report that documents and responds to issues raised during the exhibition period. The Secretary of the Department of Planning, Industry and Environment will then prepare an assessment report for the Minister for Planning and Public Spaces who will then determine whether to grant project approval and specify project conditions.

The assessment and approval process is shown in Figure E-5.

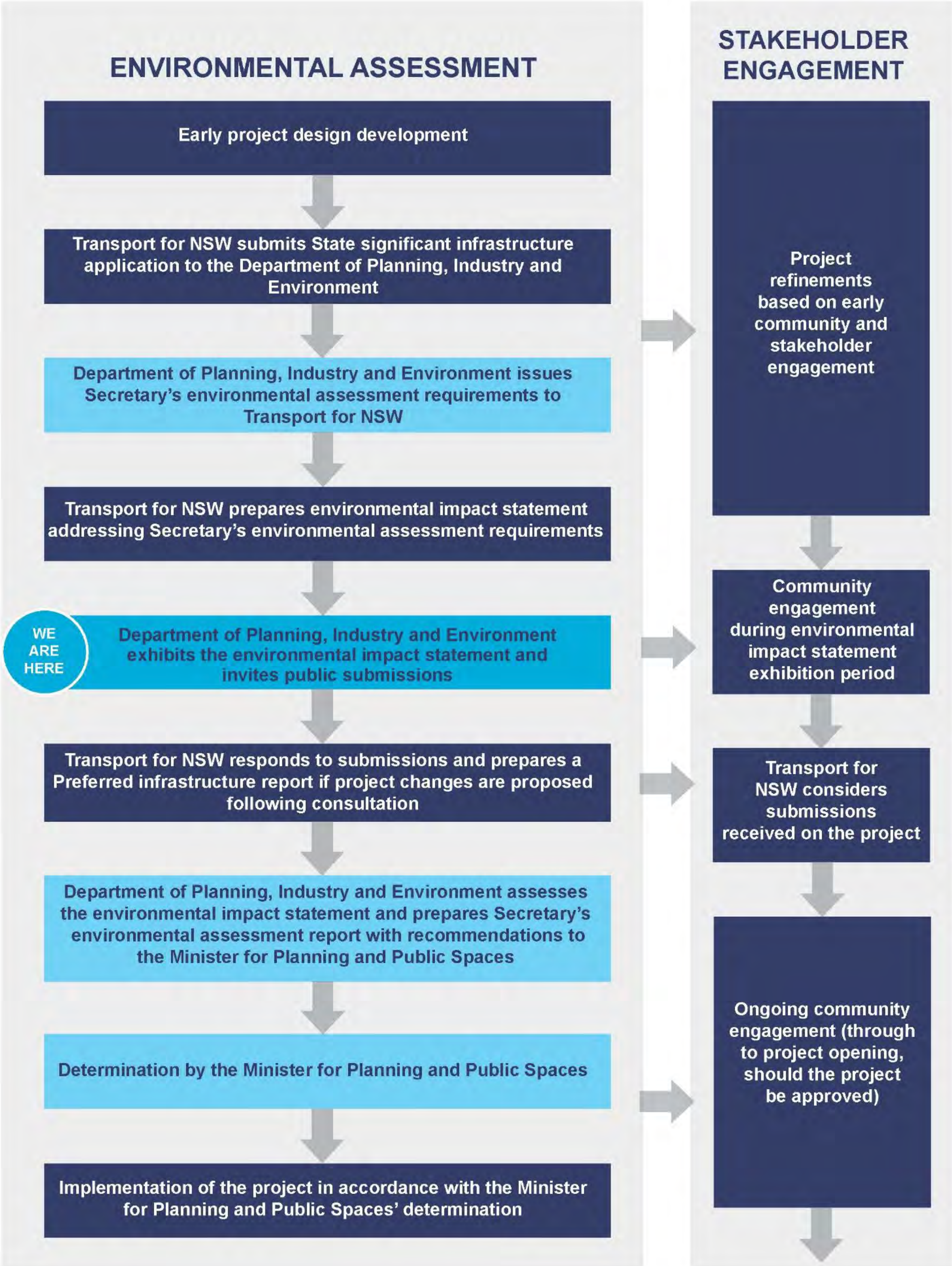


Figure E-5 The assessment and approval process for the project

Environmental assessment

This environmental impact statement has been prepared in accordance with the provisions of Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979*. In particular, it addresses the requirements of the Secretary of the Department of Planning, Industry and Environment. It also includes consideration of the issues raised by the community and stakeholders during the development of the project.

It is inevitable that delivery of a project of this scale within a heavily urbanised environment would have some adverse impacts, particularly during construction. These impacts need to be considered within the context of the overall objectives of the project and the significant transport and other benefits it would provide over the medium to longer term, and for future generations.

Key environmental issues have been considered throughout the design and development process. Consultation has been carried out with affected stakeholders to identify potential impacts at an early stage. Where possible, these would be avoided or appropriate management measures developed. These considerations have resulted in a number of design changes and refinements that have mitigated many of the potential significant impacts.

Some project impacts would be largely temporary and confined to the construction period.

Based on the results of the environmental investigations carried out for this environmental impact statement, it is considered that matters of national environmental significance and the environment of Commonwealth land are not likely to be significantly impacted by the project. Accordingly, Transport for NSW has determined that no referral is required under the *Environment Protection and Biodiversity Act 1999* at this stage.

The following sections provide an overview of the benefits and impacts identified within the environmental assessment.

Traffic and transport

Traffic and transport operational outcomes

Benefits from the project would include:

- Travel time savings and reliability benefits for users of the project, as well as for users of existing key corridors which would benefit from reduced traffic demand including Military Road, Spit Road, Warringah Road, and Eastern Valley Way
- Improved connections to North Sydney and Sydney CBD and new connections to St Leonards and Macquarie Park via the Gore Hill Freeway Connection
- Customers travelling between Frenchs Forest and Macquarie Park would be able to bypass approximately 20 sets of traffic lights by using the Beaches Link tunnel
- Improved travel times and reliability for buses travelling along existing key corridors including Warringah Road, Eastern Valley Way and Military Road
- New opportunities for public transport by providing the opportunity to operate express buses to Sydney CBD, North Sydney and beyond, with potential for direct interchange at North Sydney and St Leonards with Sydney Metro and Sydney Trains
- Better access to jobs and businesses, with direct access to the new Northern Beaches Hospital at Frenchs Forest, and better access to businesses on the Northern Beaches from Greater Sydney
- Substantial improvements in road safety, with reduced traffic demand along key road transport corridors, resulting in a 77 per cent forecast reduction in crashes for vehicles redirected to Beaches Link (equating to a reduction of around 560 crashes per year)

- Major reduction of heavy vehicle traffic on the Spit Road and Military Road corridor by up to 74 per cent
- Additional capacity for outbound traffic crossing Sydney Harbour and leaving the lower North Shore, relieving existing corridors including Military Road and Eastern Valley Way. This is illustrated by substantial improvements in average network speeds and the number of vehicle stops during evening peak periods
- Average travel speeds through the Balgowlah and surrounds study area would increase by up to 72 per cent in the morning peak and 40 per cent in the evening peak. The number of vehicle stops would reduce substantially by up to 57 per cent in the morning peak and 27 per cent in the evening peak
- Greater network resilience due to the provision of new road capacity and connectivity, and reduced rat-run traffic and congestion on existing surface roads including Miller Street (Cammeray), Brook Street (Naremburn), Eastern Valley Way (Northbridge), Frenchs Forest Road (Seaforth) and the Ourimbah Road corridor
- Pedestrian and cyclist facilities would improve the overall active transport network with upgraded infrastructure providing increased connectivity and enhanced safety.

During operation of the project, potential localised impacts would include:

- Changes to access in and around North Sydney would streamline movements around North Sydney CBD but would adjust access for some residents and businesses in the area. Impacts would be minimised by ensuring all properties have reasonable alternative routes to maintain access
- Some instances of localised increases to bus travel times through the North Sydney CBD area.

For further information on operational traffic and transport, refer to Chapter 9 (Operational traffic and transport).

Traffic and transport impacts during construction

The project has been designed to minimise traffic and transport impacts during construction and ensure that traffic movement is maintained. Road closures would be carried out to minimise impacts on the community, particularly during peak periods.

During construction, temporary impacts would include:

- Increased heavy vehicle movements around work sites, and localised increases in traffic volumes and traffic delays
- Temporary, full or partial closures of roads within the Gore Hill Freeway and Artarmon area, Burnt Bridge Creek Deviation and Wakehurst Parkway for short periods of time to carry out key construction activities which are located within the road corridor
- Minor adjustments to some bus stops along the project alignment, and some potential short-term adjustments to bus priority infrastructure on Burnt Bridge Creek Deviation may be required (with minor impacts on bus services)
- Temporary adjustments to shared user paths, pedestrian and cyclist facilities along the project alignment
- Temporary impacts on maritime traffic associated with controlled navigation routes and the partial closures of Middle Harbour for recreational, commercial and government users between Northbridge and Seaforth and adjacent to Spit West Reserve to enable construction works for the immersed tube tunnel.

For further information on construction traffic and transport, refer to Chapter 8 (Construction traffic and transport).

Noise and vibration

Noise and vibration impacts during construction

Proposed temporary construction support sites and activities have been designed to minimise noise and vibration impacts on sensitive receivers. Design considerations to reduce noise and vibration impacts include the proximity of temporary construction support sites to sensitive receivers, construction of acoustic sheds and temporary noise barriers, and positioning of vehicle entrances and exits to allow access directly to and from the arterial road network where possible.

Most of the surface construction for the Beaches Link component of the project would be carried out between 7am and 6pm Monday to Friday and between 8am and 1pm on Saturdays. Tunnelling activities would be carried out 24 hours a day, seven days a week underground, supported by surface-based activities within purpose-built acoustic sheds which would be designed to minimise construction noise impacts for the local community. Spoil haulage from the Beaches Link temporary construction support sites would generally occur between 7am and 6pm Monday to Friday and between 8am and 1pm on Saturdays.

Construction of the Gore Hill Freeway Connection surface road works, and surface works associated with the tunnel connections at Burnt Bridge Creek Deviation at Balgowlah and Wakehurst Parkway at Seaforth/Killarney Heights would require extensive out of hours work, to minimise traffic disruptions and maintain safety for workers and road users and the public.

For the prediction of airborne noise impacts from construction sites, consideration was given to realistic worst case construction activities as required by the Interim Construction Noise Guideline (DECC, 2009a). While the noise levels for the realistic worst case might occur at sensitive receivers during the works, noise levels associated with the typical scenario would occur more frequently.

Key results of construction noise modelling include:

- Airborne noise from the project temporary construction support sites would generally be within the noise management levels with the exception of early works, site establishment (including cofferdam construction), site restoration works and out of hours concrete deliveries, when the noise management levels may be exceeded at some receivers for short periods
- Airborne noise levels from surface road works would generally be within the relevant noise management levels, with the exception of the operation of high noise generating equipment such as rock-hammers or concrete saws or when noisy works occur close to sensitive receivers, and works required outside of standard construction hours. Where airborne noise management levels are exceeded, there would be a requirement to implement reasonable and feasible noise mitigation
- Most of the ground-borne noise generated by roadheader tunnelling would be within the noise management levels. The use of rock-hammers for tunnelling activities has the potential to exceed noise management levels at various locations; however, such activities would be scheduled outside evening and night time periods (where feasible and reasonable) to avoid or reduce ground-borne noise level exceedances on receivers
- Vibration from tunnelling works would be generally within the vibration limits for human disturbance at most receivers. Some receivers have the potential to experience vibration levels above the human comfort criteria when rock-hammers are operating nearby. Several heritage listed structures would be within the vibration minimum working distance for cosmetic damage for an unsound heritage structure during the use of large rock hammers. For these receivers, further assessment would be carried out to determine the susceptibility of the structure to be potentially damaged by vibration, and mitigation measures from the *Construction Noise and Vibration Guideline* (Roads and Maritime, 2016) would be implemented

- Construction road traffic management and vehicle movements associated with the project are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible. The number of maximum noise events from construction traffic that could disturb sleep are not likely to substantially increase, because the maximum number of truck movements generated by the project at night would be small compared to existing truck movements along the proposed haulage routes.

Construction noise and vibration impacts would be managed using reasonable and feasible mitigation and management measures including scheduling of works, noise reduction measures for plant and equipment, and provision of respite periods or offers of alternative accommodation for sensitive receivers if appropriate. Temporary noise barriers or solid hoarding would be used at temporary construction support sites where required to minimise noise impacts on residential receivers.

For further information on construction noise and vibration, refer to Chapter 10 (Construction noise and vibration).

Noise and vibration impacts during operation

The project has been designed to include traffic noise mitigation measures where feasible and reasonable. When the Beaches Link and Gore Hill Freeway Connection are operational the noise assessment indicates that:

- The project is predicted to typically decrease road traffic noise levels at most receiver locations
- Receivers to the east of the Warringah Freeway may experience an increase in maximum noise levels compared to the existing situation. This is due to the widening of the Warringah Freeway resulting in the southbound carriageway moving closer to those receivers
- Receivers to the west and east of the new access road which forms the connection between Burnt Bridge Creek Deviation and Sydney Road may experience an increase in maximum noise levels and the number of events compared to the existing situation without the new access road
- Receivers along the Wakehurst Parkway may experience an increase in maximum noise level events and the number of events compared to the existing situation. This is due to the widening of Wakehurst Parkway resulting in both the northbound and southbound carriageways moving closer to those receivers. The magnitude of maximum noise levels events would increase where lanes (and traffic) moves closer to sensitive receivers.

Appropriate mitigation measures would be confirmed in accordance with the *Noise Mitigation Guideline* (Roads and Maritime Services, 2015b). This would include noise barriers and at-property treatments.

For permanent operational infrastructure (such as the motorway facilities and ventilation outlets, wastewater treatment plants etc), no noise criteria would be exceeded. For further information on operational noise and vibration, refer to Chapter 11 (Operational noise and vibration).

Air quality

Air quality impacts during construction

Air quality modelling has been carried out to assess the potential air quality impacts that construction of the project may generate. Air quality impacts during tunnelling and surface works would typically include dust and the effects of airborne particles on human health and amenity as well as potential odour emissions during handling and management of harbour sediments. Spoil handling within acoustic sheds would minimise dispersion of dust at tunnelling sites. Water carts would be used on surface works to wet down works areas as required to minimise dispersion of dust. A comprehensive range of mitigation measures would be used so that any residual dust and associated human health impacts would be negligible.

Air quality impacts during operation

Extensive air quality modelling has been carried out to assess the project's in-tunnel and ambient air quality outcomes. The predicted total concentrations of pollutants were usually dominated by the existing background contributions.

The tunnel ventilation system would be designed to maintain in-tunnel air quality within applicable criteria for nitrogen dioxide (NO_2), carbon monoxide and visibility for all modelling scenarios including a worst case trip scenario.

The ventilation system would be designed so that there would be no emissions from tunnel portals. All emissions would be via ventilation outlets. Under expected traffic conditions, the predicted contribution of tunnel ventilation outlets to pollutant concentrations at ground level was negligible for all receptors.

For some short-term air quality measures (1-hour NO_2 and 24-hour PM_{10} and $PM_{2.5}$), exceedances of the criteria for ambient air quality in the vicinity of the project are predicted to occur both with and without the project. This is usually due to changes in traffic on surface roads and high background concentrations. Where traffic on roads is expected to reduce due to diversion to the tunnels, ambient air quality is expected to improve compared to conditions without the project.

Regarding elevated receptors, for the project's expected traffic levels, there are no adverse impacts predicted at any existing or future buildings up to a height of 30 metres. For potential future buildings above 30 metres in height and within 300 metres of the Gore Hill Freeway ventilation outlet, further assessment of potential air quality impacts may be required at rezoning or development application stage but would not necessarily preclude such development.

The independent NSW Chief Scientist and Engineer has recently released a report in relation to road tunnel air quality. The report found that emissions from well-designed road tunnels cause a negligible change to surrounding air quality, and as such, there is little to no health benefit for surrounding communities in installing filtration and air-treatment systems in such tunnels. Further information is available at www.chiefscientist.nsw.gov.au.

For further information on air quality, refer to Chapter 12 (Air quality).

Human health impacts

As the project would deliver an underground motorway, there would be a redistribution of vehicle emissions associated with a reduction of traffic on surface roads. For much of the community this would result in no change or a small improvement to local air quality (ie reduced concentrations and fewer health impacts); however, for some areas located near key surface roads, a small increase in pollutant concentration may occur. Potential health impacts associated with changes in air quality (specifically nitrogen dioxide (NO_2) and particulates) within the local community have been assessed and are considered to be acceptable.

Concentrations of pollutants from vehicle emissions would be higher within the tunnel (compared to outside the tunnel). With the completion of a number of tunnel projects (approved or proposed), there is the potential for exposures to occur within a network of tunnels over varying periods of time. However, exposure to NO_2 is expected to be well within the current health guidelines.

Congestion inside the tunnels is not considered likely to result in adverse health effects, due to the operation of the tunnel ventilation systems and the temporary nature of the potential exposure. For motorcyclists, there is the potential for higher levels of exposure to NO_2 but these exposures, under normal conditions, are not expected to result in adverse health effects.

The independent NSW Chief Scientist and Engineer has recently released a report in relation to road tunnel air quality. The report found that emissions from well-designed road tunnels cause a negligible change to surrounding air quality, and as such, there is little to no health benefit for surrounding communities in installing filtration and air-treatment systems in such tunnels. Further information is available at www.chiefscientist.nsw.gov.au.

For further information on human health, refer to Chapter 13 (Human health).

Socio-economic impacts

The project would deliver new strategic road links between Sydney's Northern Beaches and the existing motorway network near Artarmon and North Sydney, bypassing the congested Spit Road and Military Road and Warringah Road corridors. The project would provide links to both the Gore Hill Freeway and Warringah Freeway, improving north–south and east–west connectivity for the Northern Beaches region. The project would include the widening of the Wakehurst Parkway between Seaforth and Frenchs Forest to improve access to the strategic Northern Beaches Hospital precinct and areas further north.

When operational, the project would:

- Reduce traffic along key routes including Military Road, Spit Road, Warringah Road, Eastern Valley Way, Brook Street and Miller Street. The project would also improve average travel speeds through the Warringah Freeway and North Sydney area, resulting in:
    - Improved travel times, enhancing the reliability and resilience of the road network across Sydney and improve access to the north, north-west and north-east of Sydney
    - Improved access and connectivity to community services and facilities within the study area for local residents, through travel time savings and improved travel time reliability
- Provide major benefits to public transport, enabling faster, more reliable and direct peak express services between the Northern Beaches, Harbour CBD, North Sydney, St Leonards, and Macquarie Park
- Reduce rat-run traffic and congestion on existing surface roads including Miller Street (Cammeray), Brook Street (Naremburn), Eastern Valley Way (Northbridge), Frenchs Forest Road (Seaforth) and the Ourimbah Road corridor
- Increase the availability of public open space and passive and active recreation facilities for the community and help to address the current shortfall in recreational facilities within the Northern Beaches Council area
- Enable local businesses to have better and more efficient access to Greater Sydney, making it easier to move goods and provide services, as well as bringing employees and businesses closer together
- Improve pedestrian and cyclist accessibility and connectivity of active transport routes, which would bring long-term benefits for community cohesion.

For further information on socio-economics, refer to Chapter 21 (Socio-economics).

Heritage impacts (Non-Aboriginal and Aboriginal)

Transport for NSW is committed to preserving heritage items along the project corridor and minimising project impacts.

There are 73 listed heritage items and four potential heritage items within the study area. These include four items listed on the State Heritage Register (North Sydney Sewer Vent, St Leonards Park, Tarella and the Walter Burley Griffin Incinerator), with the remainder being of local heritage significance. Impact to the items above the tunnel alignment or adjacent to surface work due to indirect impact from settlement, vibration or changed views related to operational facilities such as noise barriers, has predominantly been assessed as being negligible to minor.

Site-specific management measures would also be applied at specific sites that have been identified as being subject to impact due to the activities associated with construction of the project. Archival recording would be completed prior to any work that has the potential to impact upon the following items:

- Cammeray Conservation Park (including Golf Course), Cammeray (to be completed by the Western Harbour Tunnel and Warringah Freeway Upgrade)

- Item 8: Clive Park and Tidal Pool, Northbridge
- Item 10: Balgowlah Golf Course, Balgowlah
- Item 11: Frenchs Bullock Track, Killarney Heights (pending further design development confirming direct impact).

Additionally, where direct impact in the northern section of the Frenchs Bullock Track would occur due to permanent infrastructure, the Bullock Track would be reformed as close as possible to the existing alignment. Where direct impact to the southern section may occur, further detailed survey would be completed prior to construction to confirm the curtilage to determine if this section remains partially intact (noting the curtilage extends into the existing road corridor, based on available spatial data).

For further information on non-Aboriginal heritage, refer to Chapter 14 (Non-Aboriginal heritage).

Eleven Aboriginal cultural places of local significance were identified within the study area. Based on the results of this assessment and in consultation with the Registered Aboriginal Parties:

- One Aboriginal site (45-6-0662) could not be located or its condition confirmed during field work and the Aboriginal Heritage Office has advised that the site was likely covered by gravel/vegetation. The site is considered likely to be within 50 metres of the construction footprint. The site could be indirectly impacted by vibration and settlement
- Five Aboriginal sites (45-6-0655, 45-6-2940, 45-6-3362, 45-6-3361 and 45-6-3363) are located within 50 metres of surface works including two sites that may be subject to indirect impacts associated with vibration and settlement (45-6-0655 and 45-6-2940)
- Five Aboriginal sites (45-6-3032, 45-6-3012, 45-6-0654, 45-6-0996 and 45-6-3599) are located above or within 50 metres of the tunnel alignment and may be subject to indirect impacts associated with vibration and settlement
- Operational impacts are considered to be negligible

Aboriginal cultural heritage impacts will be managed through vibration monitoring at sites listed in the Aboriginal Heritage Information Management System (AHIMS) database and the implementation of additional management measures where exceedances are identified. An Aboriginal heritage interpretation strategy would be included as part of the project urban design and landscape plan.

For further information on Aboriginal heritage, refer to Chapter 15 (Aboriginal heritage).

Biodiversity (terrestrial and marine) impacts

The southern part of the construction footprint and surrounding area is highly modified and disturbed. Much of the vegetation consists of trees and shrubs in landscaped parks and reserves, private residential gardens and road verges. Native vegetation occurs in the northern parts of the construction footprint on either side of the Wakehurst Parkway (Seaforth to Frenchs Forest) and to a lesser extent, next to the Burnt Bridge Creek Deviation (Balgowlah). Construction of the project would require removal of:

- 15.44 hectares of native vegetation and native revegetation of which 1.38 hectares is consistent with the Duffys Forest Ecological Community in the Sydney Basin Bioregion (listed as Endangered under the Biodiversity Conservation Act)
- 5.48 hectares of other vegetation comprising native plantings, exotic plantings, and weeds and exotics.

The project would remove a small number of individuals of threatened flora species and impact on potential habitat for threatened fauna species. Biodiversity offsets for native vegetation would be provided for the project.

There is potential for indirect impacts to groundwater dependent ecosystems due to groundwater drawdown. Appropriate environmental management measures would be implemented to manage potential drawdown impacts to groundwater dependent ecosystems and baseflow reduction impacts.

There is potential for short-term noise impacts on the Grey-headed Flying-fox camp located in the vegetated area between Balgowlah Road and the Burnt Bridge Creek Deviation (about 120 metres from the surface road works at Balgowlah), fauna in the vicinity of the Wakehurst Parkway during excavation activities and Little Penguins that may occur in Middle Harbour on occasion.

Potential direct impacts on threatened marine species in Middle Harbour, such as the Black Rockcod and White's Seahorse, would be low. Potential impacts on marine mammals and marine turtles would also be low.

Potential underwater noise impacts on marine fauna may occur as a result of dredging and piling activities in Middle Harbour. Noise modelling carried out for the project indicates that impacts would largely be limited to the immediate vicinity of piling and dredging activities. Visual monitoring from the harbour surface would be carried out to identify any underwater noise related impacts on fish, and appropriate at source protection measures would be considered, where required.

For further information on biodiversity, refer to Chapter 19 (Biodiversity).

Geology, soils and groundwater impacts

Ground movement would occur as a result of the construction of the project or associated components. Ground movement may occur as a result of removal of existing rock to form the tunnels or from ingress into the tunnels and associated groundwater drawdown. All project components are expected to experience ground surface settlement impacts of over 10 millimetres. The maximum predicted long-term surface settlement is 85 millimetres at Flat Rock Creek Reserve. However this settlement prediction is conservative and likely to be an over-estimate as it has been based on conservative (worst case) groundwater modelling without design measures to limit groundwater inflows into the tunnel. It has been demonstrated through additional modelling that the installation of tunnel lining under Flat Rock Creek area would be effective in reducing the groundwater induced settlement, reducing settlement to 35 millimetres. The final extent of tunnel lining under the Flat Rock Creek area would be determined through additional investigations as part of further design development. A conservative estimate of maximum long-term surface settlement of over 30 millimetres is expected around the Warringah Freeway portal, Burnt Bridge Creek Deviation portal, Wakehurst Parkway portal, and the Balgowlah ventilation tunnel. All other project components are anticipated to be subject to total settlement of between 10 to 30 millimetres or less. Building settlement between 10 to 50 millimetres is considered to equate to a 'slight' degree of severity, with a typical potential impact being cosmetic cracks that can be filled. No buildings along the tunnel alignment were found to be in the 'slight' to 'very severe' severity categories.

Pre-construction building/structure condition surveys would be prepared for properties (and heritage assets) within the zone of influence of tunnel settlement (for example within the 5 millimetre predicted surface settlement contour and within 50 metres of surface works) and within the minimum working distances for cosmetic and structural damage due to vibration. Within three months of the completion of construction activities that have the potential to impact on the subject surface/subsurface structure, a post condition survey would then be offered to property owners of buildings where a pre-construction building condition survey was carried out. Any property damage caused by the project would be rectified. An Independent Property Impact Assessment Panel, comprising geotechnical and engineering experts, would be established prior to the commencement of works to independently verify building condition survey reports, resolve any property damage disputes and establish ongoing settlement and vibration monitoring requirements. The Panel would be independent of both Transport for NSW and property owners.

A reduction in groundwater baseflow due to groundwater drawdown is predicted at potentially connected surface water systems at Flat Rock Creek, Quarry Creek, and Burnt Bridge Creek.

Drawdown of up to five metres is predicted during construction at the Flat Rock Creek/Quarry Creek groundwater dependent ecosystems and up to 12 metres during operation. However, the assessment of baseflow reduction is conservative and is likely to overestimate actual baseflow reduction as impacts have been modelled without consideration of tunnel linings. A scenario was modelled that included lining of about 300 metres of tunnel below Flat Rock Creek Reserve. The predicted water table drawdown at Flat Rock Reserve for the lined tunnel option was up to eight metres less than the drawdown predicted with no tunnel lining. Tunnel linings would be designed and installed as part of the project to reduce operational groundwater inflows into the tunnels and consequently, the predicted baseflow impacts are likely to be much lower than the conservative prediction.

The project is situated adjacent to a number of areas that are considered to have a 'moderate' or 'high' contamination risk. Further investigations of these sites would be required to quantify risk of soil contamination to construction works. These investigations would be carried out before construction activities so that contamination (if present) can be adequately planned for and managed.

Water table drawdown could also result in migration of contaminants. If contaminants were mobilised from areas of environmental interest identified by the project, they would travel towards the tunnel during construction and operation. This would be managed through monitoring the water quality of tunnel inflows and monitoring groundwater levels and water quality at the existing monitoring sites. Contaminants migrating into this section of the tunnel would be collected and treated at the wastewater treatment plants.

Contaminated sediments have been identified within Middle Harbour and offshore at Spit West Reserve. These contaminated sediments would need to be managed where disturbed during construction activities to reduce the exposure risk to workers and environmental receivers. Based on the elutriate test results and the assessed available natural dilution, water quality impacts at the dredging site due to dissolved contaminants would not be expected. Construction methodologies have been developed to remove or suitably reduce the risks from contaminated sediments during construction activities as detailed in Chapter 6 (Construction work) and Chapter 16 (Geology, soils and groundwater).

Hydrodynamics and water quality impacts

Site investigations and hydrodynamic modelling has been completed to assess and refine the construction methodology for works required within Middle Harbour for the immersed tube tunnel. Dredge plume modelling indicates that the dredging would not have a significant impact on marine water quality. Dredging and construction activities for the project are likely to cause localised increases in suspended sediment concentrations, but due to the rapid dispersion in Middle Harbour it is not likely to result in significant water quality impacts. Monitoring during dredging would assess the compliance of the activities associated with the project. Where appropriate, several silt curtains would be installed to mitigate potential impacts on ecologically sensitive areas.

The behaviour of sediment-bound contaminants when re-suspended into the water column has been previously assessed (Geotechnical Assessments, 2015) for other construction projects (Sydney Metro City & Southwest). These assessments have determined that contaminants are likely to remain bound to sediment particles and not be released into the water column. As an additional control, a backhoe dredge with a closed environmental bucket would be used to remove areas of sediments with elevated levels of contaminants. This would reduce the potential for release of contaminated sediments into the water column, and it is therefore unlikely that marine water quality would be significantly impacted by contaminants.

Regarding surface water quality, the assessment shows that baseflow impacts at Flat Rock Creek and Quarry Creek during the operational phase have the potential to be substantial, noting that operational wastewater treatment plant discharges to Flat Rock Creek may offset this impact. However, baseflow impacts have been modelled conservatively without tunnel linings, which is expected to represent an over-estimated result. Tunnel linings would be designed and installed as part of the project to reduce operational groundwater inflows into the tunnels and consequently the baseflow impacts are likely to be lower than predicted. Additional gauge data would be collected to confirm the modelled results during further design development.

For further information on hydrodynamics and water quality, refer to Chapter 17 (Hydrodynamics and water quality).

Land use and property impacts

The project has been designed to minimise the need for property acquisition. The need to reduce these impacts has been balanced with temporary and permanent impacts to areas of open space. For the Beaches Link component of the project, 41 properties would require permanent acquisition and five properties would require temporary lease. Of the 41 properties that would be permanently acquired, 37 would be full acquisitions and four would be partial acquisitions. Eight properties required for the project are already owned by Transport for NSW.

For the Gore Hill Freeway Connection component of the project, five properties would be permanently acquired and two properties would be temporarily leased. Of the five properties to be permanently acquired, four would be full acquisitions and one would be a partial acquisition. Any property acquisitions required for the project would be carried out in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* and the land acquisition reforms announced by the NSW Government in 2016.

Temporary land use changes (loss of open space) would occur during establishment and operation of temporary construction support sites and other construction areas at Flat Rock Reserve, Spit West Reserve, Manly Dam Reserve, Bantry Bay Reservoir and a vacant piece of land owned by Transport for NSW and Willoughby City Council at Artarmon.

Permanent land use changes would occur at:

- Cammeray Golf Course, for widening of the Warringah Freeway and where the motorway facilities would be established within the Cammeray Golf Course next to the Warringah Freeway as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project. The golf course would be reconfigured to ensure it remains operational
- Artarmon Park and commercial properties along Punch Street, Lambs Road and Cleg Street for widening of the Gore Hill Freeway and where motorway facilities would be established
- Balgowlah Golf Course and residential properties along Dudley Street, for widening of the Burnt Bridge Creek Deviation for the tunnel portal and where the motorway facilities would be established
- Bantry Bay Reservoir, Sydney Water site.

When completed, the project would deliver new and improved public open space and recreation facilities at Balgowlah and Bantry Bay Reservoir to improve urban amenity.

At Balgowlah, the project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities. A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities. This consultation would be separate to the consultation for the Beaches Link and Gore Hill Freeway Connection environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting. As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space.

The Bantry Bay Reservoir site would be rehabilitated and revegetated as soon as practicable after construction completion and land that is surplus to Sydney Water's operational requirements would be transferred to the Manly Warringah Memorial State Park.

For further information on land use and property impacts, refer to Chapter 20 (Land use and property).

Cumulative impacts

When completed, the Western Harbour Tunnel and Beaches Link program of works is expected to deliver beneficial cumulative impacts including considerable improvements to travel speeds through sections of the surface road network, increased reliability and a reduction in average journey times.

Adverse cumulative impacts could occur when impacts from the project interact or overlap with impacts from other projects, potentially resulting in a larger overall impact. Cumulative impacts may also occur when projects are constructed consecutively, resulting in construction fatigue for local receivers.

The implementation of environmental management measures for the project would avoid, to the greatest extent possible, cumulative impacts with surrounding development. The project design has carefully considered minimising construction fatigue for the community as far as practical. The intent is to reduce the overall cumulative or consecutive impacts on the community over a longer period. Transport for NSW would continue to collaborate with the relevant teams on nearby projects and work with local councils on any potential cumulative impact of projects that emerge as part of their future planning.

For further information on cumulative impacts, refer to Chapter 27 (Cumulative impacts).

Management of impacts

This environmental impact statement identifies comprehensive environmental management measures to avoid, manage, mitigate, offset and/or monitor impacts during construction and operation of the project. These include best practice construction environmental planning and management techniques, urban design and landscaping treatments and noise mitigation measures. Further mitigation opportunities are likely to be identified during further design development and construction planning and in consultation with communities and relevant stakeholders.

The design, construction and operation of the project would be carried out in accordance with extensive environmental management commitments identified in this environmental impact statement as included in Appendix Y (Compilation of environmental management measures), as well as any additional measures identified in the conditions of approval for the project.

Stakeholder and community engagement

Since the initial project announcement in March 2017, there has been extensive and ongoing community and stakeholder engagement. This has included:

- Toll free community information line
- Project email
- Project website
- Interactive website portal
- Project database to record correspondence relevant to the project, including contact details and issues raised during the life of the project
- Community update newsletters and letters to residents
- Community information sessions, information displays and staffed pop-ups
- Registered stakeholder database email updates

- Stakeholder briefings, meetings, workshops and presentations
- Interest group correspondence including letters and phone calls
- Face-to-face meetings and doorknocks with individual property owners and residents of properties which may be affected by the project
- Advertisements and proactive media articles in the local press
- Letterbox drops
- Media events at key milestones of the project.

The design has been continually refined throughout the community engagement to improve transport, environmental, amenity, community, heritage and sustainability outcomes.

The project team has developed a community and stakeholder engagement program to continue to proactively engage with local communities, key stakeholders and government agencies.

Next steps

Transport for NSW is seeking approval from the Minister for Planning and Public Spaces for the construction and operation of the project. Steps in the process include:

- Exhibition of the environmental impact statement for a minimum of 28 days in accordance with statutory requirements and invitation for the community and stakeholders to make submissions
- Consideration of submissions. Submissions received by the Secretary of Department of Planning, Industry and Environment would be provided to Transport for NSW and any relevant public authorities. Transport for NSW may then be required to prepare and submit:
  - A submissions report, responding to issues raised in the submissions
  - A preferred infrastructure report, outlining any proposed changes to the project to minimise its environmental impacts or to deal with any other issues raised
- Determination of the environmental impact statement. The Minister for Planning and Public Spaces would then make a decision on the project and, if approved, set conditions of approval.

Consultation with the community and stakeholders would continue throughout the further design development and construction phases as required.

The Department of Planning, Industry and Environment will make this environmental impact statement publicly available for a minimum period of 28 days. During the exhibition period, the environmental impact statement will be available for viewing at the following locations:

- Department of Planning, Industry and Environment major project planning portal: www.planningportal.nsw.gov.au/major-projects/projects/on-exhibition
- Transport for NSW interactive project portal: https://nswroads.work/blportal

Due to COVID-19 restrictions, staffed displays and face to face community information sessions of the environmental impact statement are not proposed to occur during the exhibition period. However this requirement will be reviewed if restrictions are eased and safety controls allow. In order to ensure that adequate opportunities are available for the community to ask questions on the content of the environmental impact statement, Transport for NSW will be running virtual information sessions throughout January and February 2021. Transport for NSW will continue to investigate the opportunity for face to face community information sessions provided COVID-19 guidelines allow.

Details of the times and topics for the virtual information sessions, as well as any potential face to face community information sessions, would be provided through our website, email notifications to registered stakeholders, community updates, and advertisements in local and metropolitan media.

During the exhibition period, a project information line (1800 931 189) and email address (whtbl@transport.nsw.gov.au) will be available for the community and stakeholders.

Written submissions can be made to the Secretary of the Department of Planning, Industry and Environment. All submissions received will be placed on the Department of Planning, Industry and Environment website.

Submissions can be made by creating an account at www.planningportal.nsw.gov.au/major-projects/projects/on-exhibition. This allows you to save a submission in progress and stay up to date with the progress of an application.

If you are unable to make a submission online, you can send a physical copy to the Department by post to the Department office address below. Your submission must include:

- Your name and address, at the top of the letter only
- The name of the application and the application number
- A statement on whether you support or object to the proposal
- The reasons why you support or object to the proposal
- A declaration of any reportable political donations made in the previous two years.

Written postal submissions are to be directed to:

Director, Transport Assessments
Department of Planning, Industry and Environment
Application number SSI-8862
Locked Bag 5022
Parramatta NSW 2124

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 1

Introduction

DECEMBER 2020

1 Introduction

This chapter provides an overview of the Beaches Link and Gore Hill Freeway Connection project (the project), including its key features and location.

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), a plan 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 thereby improving transport connectivity with Sydney's Northern Beaches.

The Western Harbour Tunnel and Beaches Link program of works is a major transport infrastructure program that would make it easier, faster and safer to get around Sydney. As Sydney continues to grow, faster and more reliable trips are essential to reducing congestion and providing new levels of access to jobs, recreation, and services such as schools and hospitals. By creating a western bypass of the Sydney CBD, the Western Harbour Tunnel would take pressure off the Sydney Harbour Bridge, Sydney Harbour Tunnel and ANZAC Bridge; while Beaches Link would create an alternative to the Military Road/Spit Road and Warringah Road corridors to relieve traffic pressure on the North Shore. The program of works has been designed as part of an integrated transport network, which has a focus on new public transport connections and improved journey times and reliability for buses.

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 Gore Hill Freeway to Balgowlah and Killarney Heights and including the surface upgrade of Wakehurst Parkway from Seaforth to Frenchs Forest and upgrade and integration works to connect to the Gore Hill Freeway at Artarmon.

The components of the Western Harbour Tunnel and Beaches Link program of works are shown in Figure 1-1.

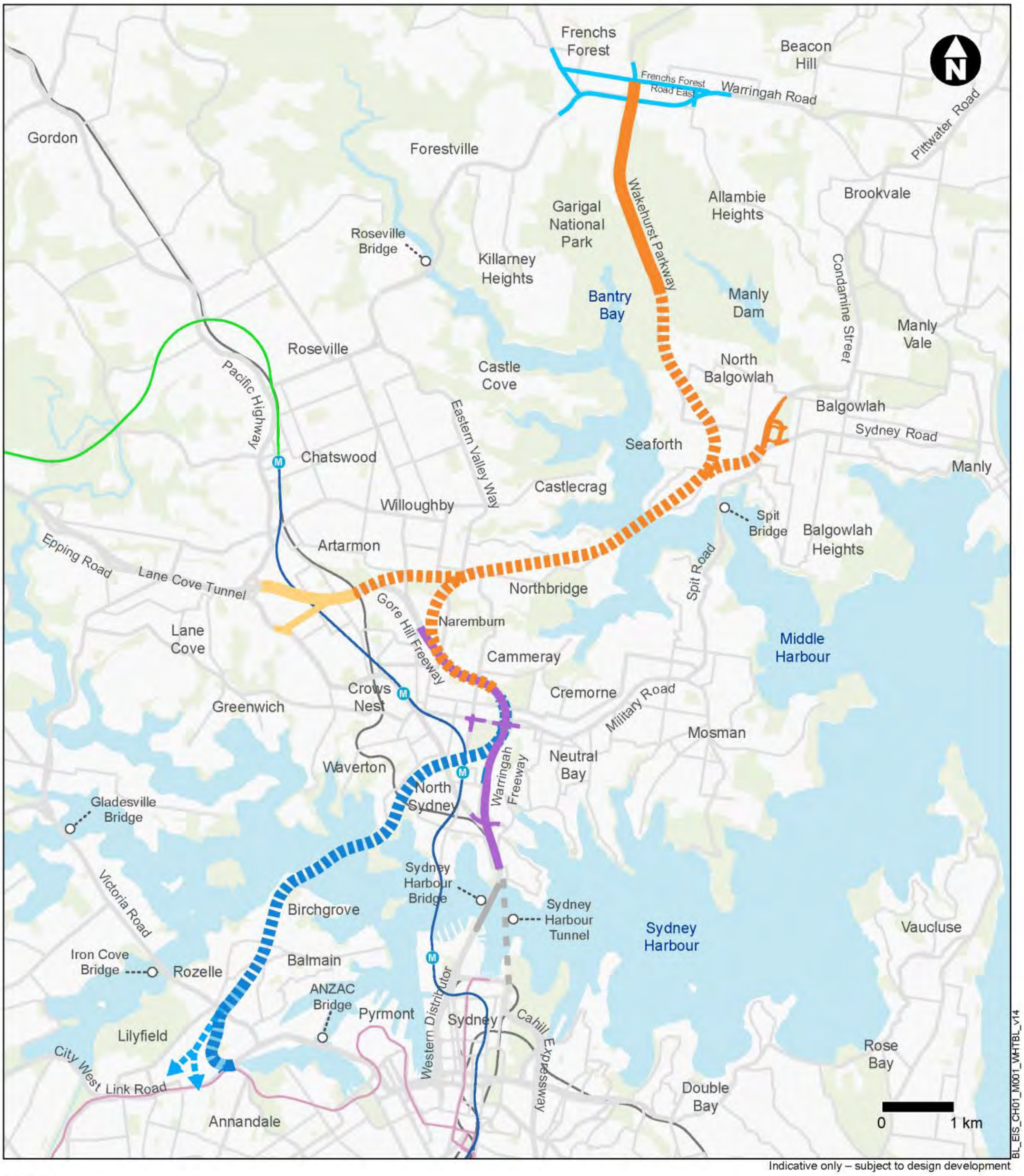
Delivery of the Western Harbour Tunnel and Beaches Link program of works would unlock a range of benefits for freight, public transport and private vehicle users. It would support faster travel times for journeys between the Northern Beaches and areas south, west and north-west of Sydney Harbour. For example, with the combined program of works, journeys from Dee Why to Sydney Kingsford Smith Airport are expected to be 56 minutes faster. 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. These key benefits are discussed further in Chapter 3 (Strategic context and project need).

The project would provide an opportunity to improve travel times on peak express bus services by re-directing bus services from the Northern Beaches through the new motorway to North Sydney, the north west and the Sydney Central Business District (CBD). In addition, it would provide a fast, reliable link between the Northern Beaches and other key centres including St Leonards and Macquarie Park via the direct Gore Hill Freeway connection.

It would also provide an opportunity to introduce new express bus services that would use the new motorway and road connections to deliver increased direct public transport access between strategic centres across the region, reducing reliance on private vehicle travel.

The Western Harbour Tunnel and Warringah Freeway Upgrade project and the Beaches Link and Gore Hill Freeway Connection project are subject to separate and coordinated environmental assessment and approval processes.

This environmental impact statement relates to the Beaches Link and Gore Hill Freeway Connection project.



Legend

Operational features

- Beaches Link
- Gore Hill Freeway Connection
- Western Harbour Tunnel
- Warringah Freeway Upgrade
- M4-M5 Link tunnel fitout and commissioned as part of Western Harbour Tunnel

Connecting projects

- M4-M5 Link connections (indicative)
- Northern Beaches Hospital road upgrade project (Completed 2020)

Other projects

- Sydney Metro City & Southwest (under construction)
- Sydney Metro Northwest

Existing rail network

- Suburban rail/Sydney Trains
- Light rail

Figure 1-1 The Western Harbour Tunnel and Beaches Link program of works

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 Wakehurst Parkway at Killarney Heights, and an upgrade of 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).

The project is an integrated transport solution that would address urban congestion on Sydney's road network. It would take pressure off Spit Bridge and Military Road – improving amenity in Mosman, Cremorne and Neutral Bay and relieving traffic flows on Warringah Road, Roseville and through the suburbs of Willoughby and Northbridge. It would provide direct access from the Northern Beaches to the Warringah Freeway for fast and reliable access to North Sydney, the Sydney CBD and beyond. It would also provide a fast, reliable link between the Northern Beaches and other key centres including St Leonards and Macquarie Park via the direct Gore Hill Freeway connection. For public transport there would be opportunity for express buses within the Beaches Link tunnel, additional express bus services along Military Road and improved connections to the Sydney Trains and new Sydney Metro rail networks.

A detailed discussion of the project benefits is presented in Chapter 3 (Strategic context and project need).

Key features of the Beaches Link component of the project are shown in Figure 1-2 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 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 and improved open space and recreation facilities at Balgowlah
- New and upgraded active transport infrastructure (pedestrian and cyclist facilities)
- 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 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 1-3 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 and inclusion of traffic lights of the Dickson Avenue and Pacific Highway intersection
- New and upgraded active transport infrastructure (pedestrian and cyclist facilities)
- 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). Construction of the project is described in Chapter 6 (Construction work).

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

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. The regional context of the project is shown in Figure 1-1. The local context of the project is shown in Figure 1-2 and Figure 1-3.

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 ramps 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 Purpose of this environmental impact statement

This environmental impact statement has been prepared in accordance with the relevant provisions of the *Environmental Planning and Assessment Act 1979*. It has been prepared to address the environmental assessment requirements issued by the Secretary of the NSW Department of Planning, Industry and Environment (formerly Department of Planning and Environment) on 15 December 2017 and reissued on 22 April 2020, and the relevant provisions of Schedule 2 of the Environmental Planning and Assessment Regulation 2000.

In accordance with Division 5.2 of the *Environmental Planning and Assessment Act 1979*, this environmental impact statement presents an assessment of potential environmental issues identified during the planning and assessment of the project. The assessment considers the area directly or indirectly affected by construction and operation of the project, as relevant to each technical assessment.

This environmental impact statement will be placed on public exhibition, which will provide an opportunity for the community, government agencies and other interested parties to comment on the project. Transport for NSW will consider this feedback and respond to issues raised in a submissions report. The assessment process for the project is discussed further in Chapter 2 (Assessment process).

The Secretary's environmental assessment requirements are detailed in Appendix A, along with a reference to where these have been addressed in this environmental impact statement.

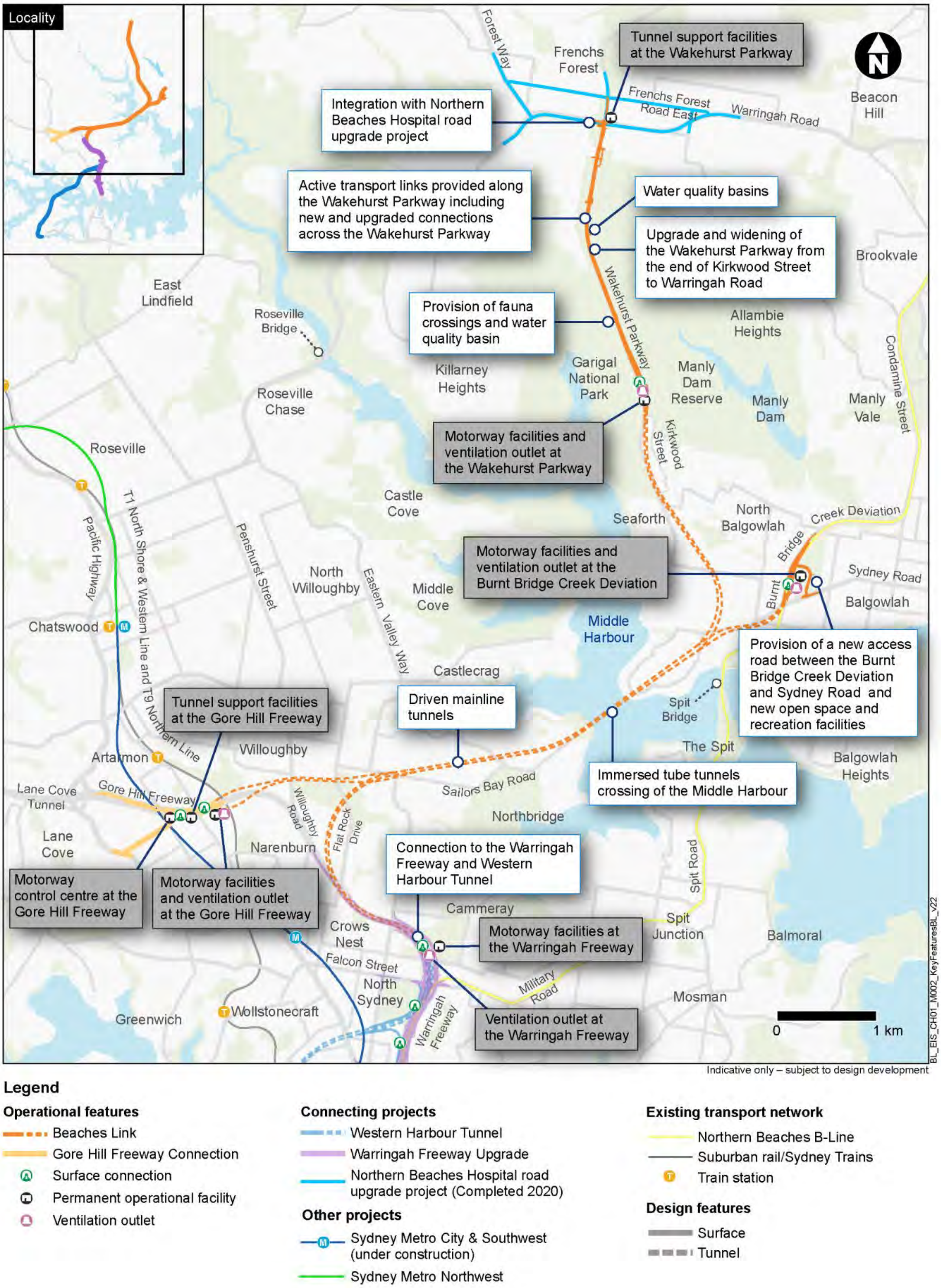


Figure 1-2 Key features of the Beaches Link component of the project

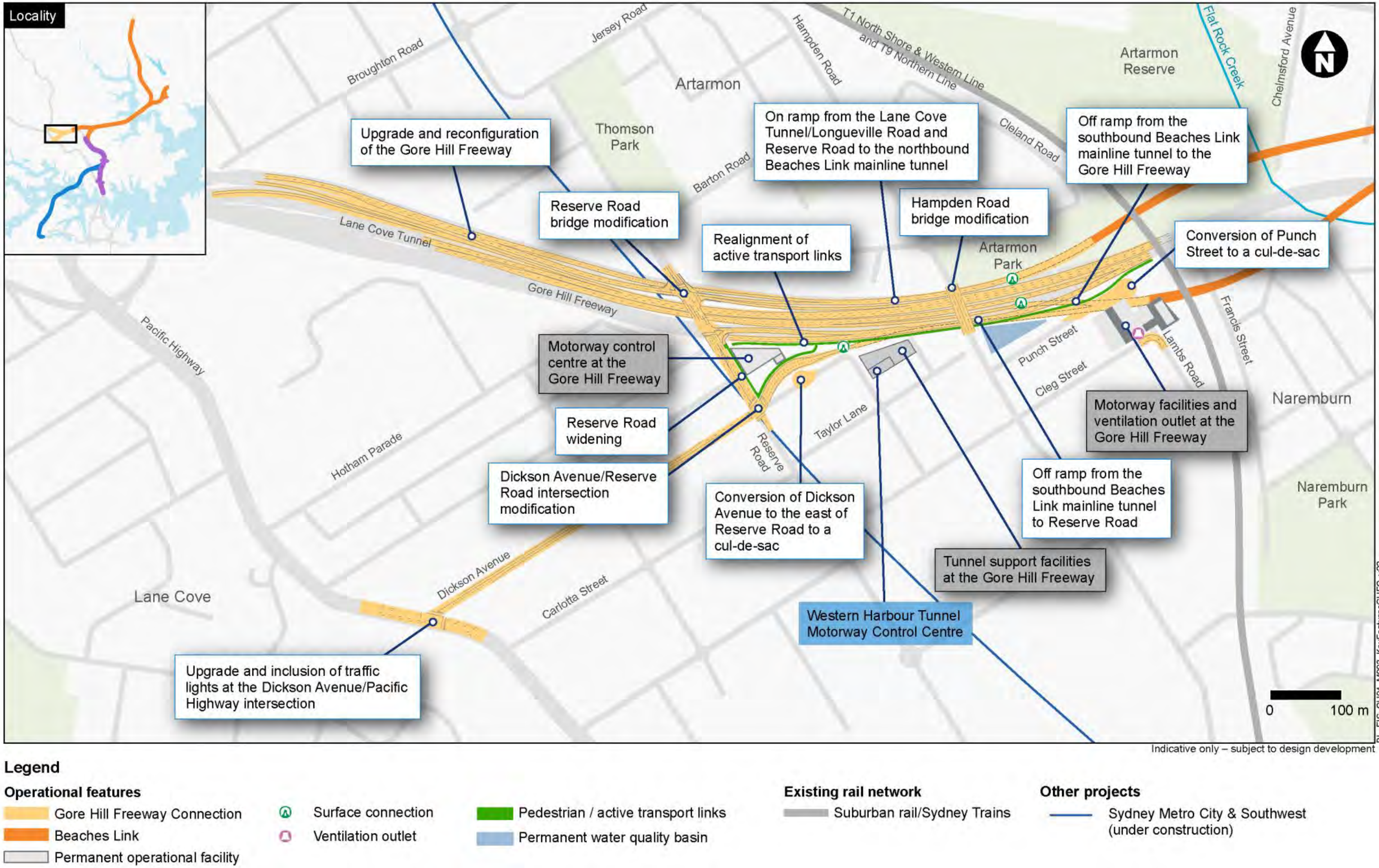


Figure 1-3 Key features of the Gore Hill Freeway component of the project

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 2

Assessment process

transport.nsw.gov.au

DECEMBER 2020

2 Assessment process

This chapter describes the statutory context of the project, including the environmental impact assessment and approval process for the project as well as other relevant environmental planning and statutory approval requirements.

2.1 Assessment and approval framework

2.1.1 Environmental Planning and Assessment Act 1979

The *Environmental Planning and Assessment Act 1979* and the Environmental Planning and Assessment Regulation 2000 are the primary pieces of legislation regulating land use planning and development assessment in NSW. This legislation is supported by a range of environmental planning instruments including State environmental planning policies (SEPPs) and local environmental plans.

Transport for NSW is seeking approval for the Beaches Link and Gore Hill Freeway Connection project as State significant infrastructure under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979*.

Clause 94 of the State Environmental Planning Policy (Infrastructure) 2007 (the Infrastructure SEPP) applies to development for the purpose of a road or road infrastructure facilities and provides that these types of works are development which is permissible without consent. The project is appropriately classified as being for the purpose of a 'road' and a 'road infrastructure facility' under the Infrastructure SEPP.

Clause 14 of the State Environmental Planning Policy (State and Regional Development) 2011 (the State and Regional Development SEPP) declares development as State significant infrastructure if it is permissible without consent and specified in Schedule 3.

Transport for NSW, as the proponent for the project, formed the opinion that the construction and operational impacts of the project would require the preparation of an environmental impact statement, meaning that the project falls within clause 1 of Schedule 3 of the State and Regional Development SEPP, and the project is declared state significant infrastructure. Transport for NSW has also requested that the NSW Minister for Planning and Public Spaces declare the project as critical State significant infrastructure. Section 5.13 of the *Environmental Planning and Assessment Act 1979* provides for the declaration of critical State significant infrastructure by means of an environmental planning instrument. Clause 16 of the State and Regional Development SEPP declares development listed in Schedule 5 to be critical State significant infrastructure.

By reason of section 5.22 of the *Environmental Planning and Assessment Act 1979* the relevant environmental planning instruments that apply to the project are the Infrastructure SEPP and the State and Regional Development SEPP.

The Department of Planning, Industry and Environment (formerly the Department of Planning and Environment) issued the Secretary's environmental assessment requirements for the project on 15 December 2017 and these were reissued on 22 April 2020. A copy of the Secretary's environmental assessment requirements and where they have been addressed in this environmental impact statement is provided in Appendix A (Secretary's environmental assessment requirements checklist).

The assessment and approval process under Division 5.2 of the *Environmental Planning and Assessment Act 1979* is shown in Figure 2-1.

Further information on the assessment process is available on the Department of Planning, Industry and Environment website (www.planning.nsw.gov.au).

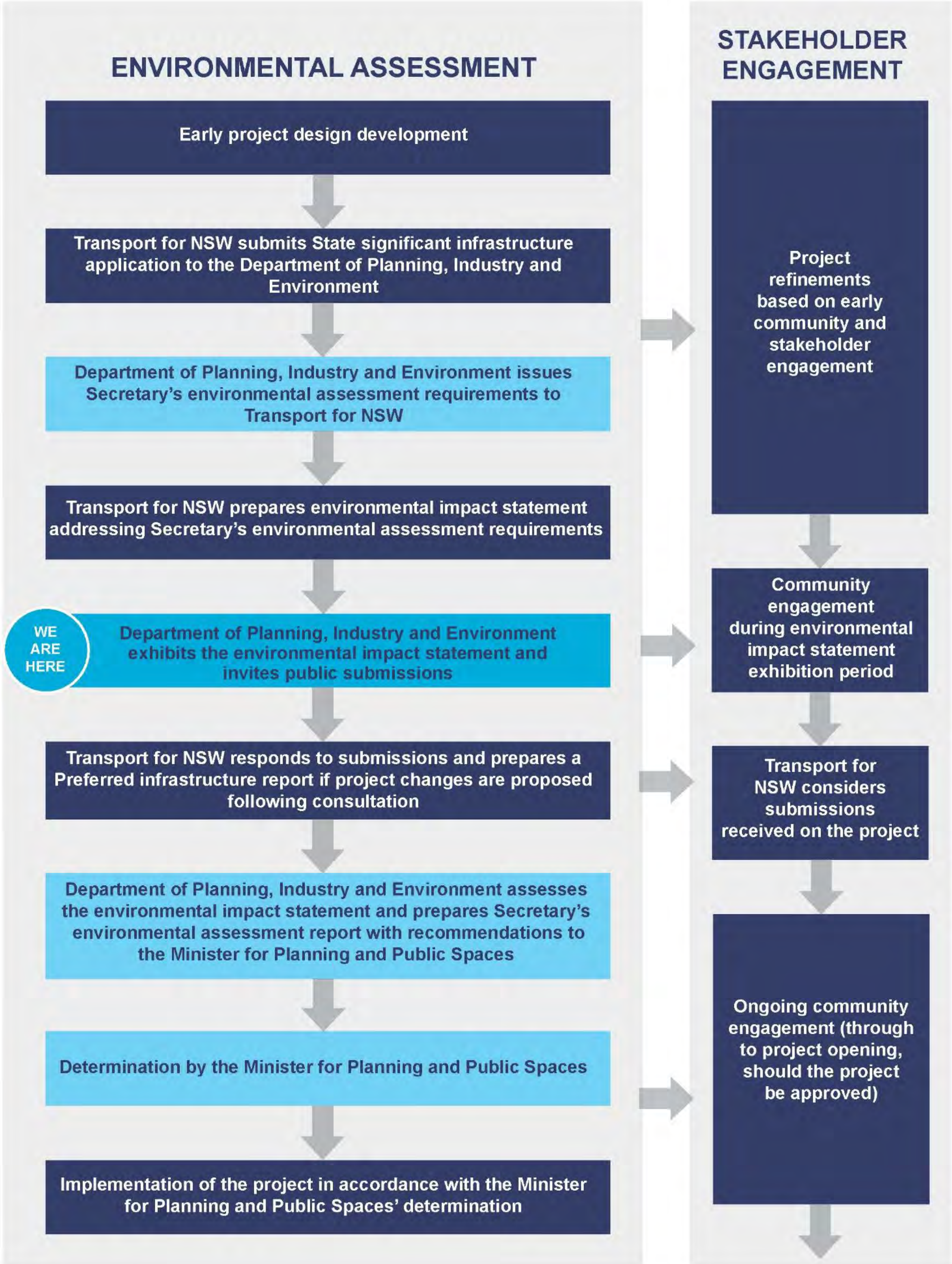


Figure 2-1 The assessment and approval process for the project

2.2 Other legislation

2.2.1 NSW legislation

Key approvals

Approvals under other NSW legislation that may apply to the project include:

- An environment protection licence for road construction and road tunnel emissions under Chapter 3 of the *Protection of the Environment Operations Act 1997*. In accordance with section 5.24 of the *Environmental Planning and Assessment Act 1979*, such a licence cannot be refused for an approved project and is to be substantially consistent with any approval under Division 5.2.

Other relevant legislation

Other NSW legislation that would apply to the project includes:

- The *Aboriginal Land Rights Act 1983* (NSW) was established to return land in NSW to Aboriginal peoples through a process of lodging claim for certain Crown Lands. As such, the management and disposal of Crown Lands is a key issue for Aboriginal Land Councils as it provides a compensatory mechanism for the dispossession of traditional lands from Aboriginal peoples
- The *Land Acquisition (Just Terms Compensation) Act 1991* (NSW), which applies to the acquisition of any land by an Authority of the State which is authorised to acquire the land by compulsory process. Acquisition is discussed in Chapter 5 (Project description) and Chapter 20 (Land use and property)
- The *Contaminated Land Management Act 1997* (NSW) outlines the circumstances in which the notification of the NSW Environmental Protection Authority is required in relation to contamination of land. This is discussed in Chapter 16 (Geology, soils and groundwater)
- The *Heritage Act 1977* (section 146) requires that the Heritage Council be notified if a relic is uncovered during construction and if it is reasonable to believe that the Heritage Council is unaware of the location of the relic. This provision has been incorporated into mitigation measures for the project, summarised in Chapter 28 (Synthesis of the environmental impact statement). Non-Aboriginal heritage is further discussed in Chapter 14 (Non-Aboriginal heritage)
- The *Crown Land Management Act 2016* provides for the ownership, use and management of Crown land in NSW. Ministerial approval is required to grant a 'lease, licence, permit, easement or right of way over a Crown Reserve'. Crown land is further discussed in Chapter 20 (Land use and property)
- The *Local Government Act 1993* includes provisions for leases and permits in respect to works on community land that has not been acquired by the project
- The *Native Title (New South Wales) Act 1994* provides for the recognition of native title in NSW in accordance with the Commonwealth *Native Title Act 1993* (see Section 2.2.2). Native title is further discussed in Chapter 15 (Aboriginal cultural heritage) and Chapter 20 (Land use and property)
- The *Fisheries Management Act 1994* (section 199) aims to manage dredging and reclamation works to conserve marine biodiversity and fish habitats. Under section 199, a public authority is required to give the Minister for Primary Industries written notice of proposed dredging or reclamation work prior to carrying out or authorising the carrying out of such work, and to consider any matters raised by the Minister in response to the notification. Dredging work in Middle Harbour would be required during installation of the immersed tube tunnels for the project

- The *Marine Pollution Act 2012* includes provisions to protect the sea and waters from pollution by oil and other noxious or harmful substances discharged from vessels. The use of marine vessels in the construction of the project would comply with the requirements of this Act and the Marine Pollution Regulation 2014 to prevent marine pollution. Works requiring access by boat or barge are further discussed in Chapter 6 (Construction work) and Chapter 17 (Hydrodynamics and water quality)
- The provisions in the *Marine Safety Act 1998*, Marine Safety Regulation 2016, *Ports and Maritime Administration Act 1995* and Ports and Maritime Administration Regulation 2012 aim to ensure the safe operation of vessels in ports and other waterways in NSW. A number of authorisations, approvals or permits may be required with respect to the placement of any structures in the water in Middle Harbour and/or with respect to obstruction to navigation. Permission of the Harbour Master would be required prior to the disturbance of the bed of the harbour under Part 6D of the Ports and Maritime Administration Regulation 2012. Construction activities within Middle Harbour and potential impacts to navigation are further discussed in Chapter 6 (Construction work) and Chapter 8 (Construction traffic and transport) respectively
- The *Waste Avoidance and Resource Recovery Act 2001* encourages the most efficient use of resources in order to reduce environmental harm in accordance with the principles of ecological sustainable development. Resource use and waste management are further discussed in Chapter 24 (Resource use and waste management)
- The *Sydney Water Act 1994* establishes Sydney Water as a State owned corporation in relation to the supply of water, the provision of sewerage and stormwater drainage systems and the disposal of wastewater in Sydney and other regions. The project would comply with this Act's requirements in relation to connections or impacts to Sydney Water's assets and approval requirements. Water supply utilities management and water supply utilities impacted during construction are further discussed in Chapter 5 (Project description) and Chapter 6 (Construction work).

Approvals not required for State significant infrastructure

A number of approvals are not required for a project approved under section 5.23 of Division 5.2 of the *Environmental Planning and Assessment Act 1979*. Those approvals not required for the project are:

- Permits under sections 201, 205 and 219 of the *Fisheries Management Act 1994*
- Approvals under Part 4 and excavation permits under section 139 of the *Heritage Act 1977*
- Aboriginal heritage permits under section 90 of the *National Parks and Wildlife Act 1974*
- Various approvals under the *Water Management Act 2000*, including water use approvals under section 89, water management work approvals under section 90, and activity approvals (other than aquifer interference approvals) under section 91.

Special dispensations for critical State significant infrastructure

If the project is declared as critical State significant infrastructure, section 5.23(3) of the *Environmental Planning and Assessment Act 1979* precludes the following directions, orders or notices being made to prevent or interfere with the carrying out of the project once approved:

- An interim protection order (within the meaning of the *National Parks and Wildlife Act 1974*)
- An order under Division 1 (Stop work orders) of Part 6A of the *National Parks and Wildlife Act 1974* or Division 7 (Stop work orders) of Part 7A of the *Fisheries Management Act 1994*
- A remediation direction under Division 3 (Remediation directions) of Part 6A of the *National Parks and Wildlife Act 1974*
- An order or direction under Part 11 (Regulatory compliance mechanisms) of the *Biodiversity Conservation Act 2016*

- An environment protection notice under Chapter 4 of the *Protection of the Environment Operations Act 1997*
- An order from a council to demolish or move a building, to repair or make structural alterations to a building, or to do or refrain from doing things under section 124 of the *Local Government Act 1993*.

2.2.2 Commonwealth legislation

Environment Protection and Biodiversity Conservation Act 1999

Under the *Environment Protection and Biodiversity Act 1999* proposed 'actions' that have the potential to significantly impact on matters of national environmental significance, the environment of Commonwealth land, or that are being carried out by a Commonwealth agency must be referred to the Australian Government. If the Australian Minister for the Environment determines that a referred project is a 'controlled action', the approval of that Minister would be required for the project in addition to the NSW Minister for Planning and Public Spaces' approval.

Based on the results of the environmental investigations carried out for this environmental impact statement, it is considered that matters of national environmental significance and the environment of Commonwealth land are not likely to be significantly impacted by the project. Accordingly, Transport for NSW has determined that no referral is required at this stage.

Environment Protection (Sea Dumping) Act 1981

The *Environment Protection (Sea Dumping) Act 1981* aims to regulate permitted sea (offshore) disposal activities to ensure environmental impacts are minimised and prohibit the disposal of harmful waste at sea. Offshore disposal is regulated by permits issued by the Commonwealth Department of Agriculture, Water and the Environment and informed by detailed environmental assessments.

Dredged material associated with the construction of the crossing of Middle Harbour would be eligible for offshore disposal under the Act. This would comprise dredged sediments and rock that are considered suitable for offshore disposal which have been removed during the construction of cofferdams and immersed tube tunnels within Middle Harbour. Transport for NSW will submit an application to the Department of Agriculture, Water and Environment for an offshore disposal permit relating to sediments dredged from Middle Harbour. The application proposes offshore disposal at a designated disposal site, which is located about 10 to 15 kilometres offshore of Sydney Heads. A detailed assessment has been completed and will be submitted to the Department of Agriculture, Water and the Environment, which documents sediments suitable for offshore disposal and details impacts associated with the disposal activity, as required by the permit application process.

Offshore disposal of sediments would be conducted outside NSW and is therefore not regulated under the *Environmental Planning and Assessment Act 1979*. As the offshore disposal grounds, excavation activity and transport to the disposal grounds are regulated by the Department of Agriculture, Water and the Environment, further details of the offshore disposal assessment, contained within the submission to the Department of Agriculture, Water and the Environment, are not included in this environmental impact statement.

Daily maximum construction maritime traffic volumes and routes to navigational channels that lead to Sydney Heads, including barge movements for offshore disposal of suitable dredged sediment and rock, are summarised in Chapter 6 (Construction work) and considered in Chapter 8 (Construction traffic and transport) and Section 5.5 of Appendix F (Technical working paper: Traffic and transport). It is anticipated that six barge movements per day would be required for transportation of dredged sediment and rock to the offshore disposal site.

Measures to manage noise from barges would be included in construction noise and vibration planning to be developed during further design development. Barges would be operated and maintained to comply with the Protection of the Environment Operations (Noise Control)

Regulation 2017, particularly Clauses 37 and 38 of the regulation which require vessels to have properly maintained noise controls. Noise impacts related to the loading and unloading of barges at water-based construction support sites have been considered in Chapter 10 (Construction noise and vibration) and Appendix G (Technical working paper: Noise and vibration).

Sediments that are not suitable for offshore disposal would be brought to land. These sediments would be managed and, if necessary, made suitable for land disposal before being directed to an appropriately licensed waste facility. Further discussion of dredged sediments not suitable for offshore disposal is provided in Chapter 24 (Resource use and waste management).

Native Title Act 1993

The main objective of the *Native Title Act 1993* is to recognise and protect native title. A successful native title claim results in the recognition of the particular rights, interests or uses claimed by the registered party. If a native title claim is recognised under the Act, any actions by Government on that land must be consistent with the claim.

Searches of the register maintained by the National Native Title Tribunal indicate there are no native title claims registered with respect to the land within the project footprint.

Airports Act 1996 and Civil Aviation Act 1986

Under the *Airports Act 1996*, ‘prescribed airspace’ is the airspace above any part of either an obstruction limitation surface (OLS) or procedures for air navigation systems operations (PANS-OPS) surface for Sydney Airport. Approval is required from the Secretary of the Commonwealth Department of Infrastructure, Transport, Regional Development and Communications if the project affects ‘prescribed airspace’, either by a structure physically protruding into the airspace or activities that result in disturbance to the airspace, such as turbulence caused by emissions from a ventilation outlet. Through provisions under the *Civil Aviation Act 1988,* the Civil Aviation Safety Authority can stipulate requirements for the design, construction and operation of new infrastructure that has the potential to influence aviation safety that support the provisions of the *Airports Act 1996*.

The emissions from the ventilation outlet and motorway facilities at the Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway have the potential to affect prescribed airspace.

A plume rise assessment was carried out in accordance with the *CASA Advisory Circular Plume Rise Assessments AC 139-5(1) November 2012* to determine whether plume rise resulting from the operation of these ventilation outlets and motorway facilities would be a controlled activity as defined in section 183 of the *Airports Act 1996*. This assessment considered an expected case, reflective of typical operational conditions of the project, and a capacity case, based on the maximum theoretical airflow that could be discharged from each ventilation outlet. In addition, the assessment also considered the merged ventilation outlets at the Warringah Freeway for the Western Harbour Tunnel and Beaches Link program of works.

The plume extent from the ventilation outlets and motorway facilities would not interfere with the OLS and PANS-OPS surfaces under the expected and capacity case scenarios, except for the ventilation outlet at the Warringah Freeway. For this ventilation outlet, the plume velocities would exceed the OLS under the capacity case when considered in conjunction with the ventilation outlet for the Western Harbour Tunnel at the Warringah Freeway. As such, a plume rise application would be prepared for approval under the *Airports Act 1996* for the ventilation outlet and motorway facilities at the Warringah Freeway where it may constitute a controlled activity.

Further discussion of potential impacts on prescribed airspace is provided in Chapter 23 (Hazards and risks).

2.3 Next steps

As is normally the case for a complex major infrastructure project progressing through an environmental planning and assessment process, the design and construction approach presented in this environmental impact statement is at planning stage and is indicative only. It is subject to refinement once project approval is obtained and the contractor(s) delivering the project have further developed the design and construction methodologies (commonly referred to as detailed design).

Issues raised during exhibition of the environmental impact statement may result in changes to the project design and construction approach, and if so, these would be identified in a preferred infrastructure report (refer to Figure 2-1).

Any refinements to the approved project during the contractor's detailed design would be reviewed for consistency with the approval. This consistency review would be carried out to consider whether the refinement would:

- Result in any of the conditions of approval not being met
- Be consistent with the objectives and operation of the project as described in the environmental impact statement
- Result in a significant change to the approved project
- Result in any potential environmental or social impacts of a greater scale or impact than that considered by the environmental impact statement.

Where design refinements do not meet these criteria, approval for a modification would be sought from the Minister of Planning and Public Spaces in accordance with the requirements of Division 5.2 of the *Environmental Planning and Assessment Act 1979*.

2.3.1 Western Harbour Tunnel and Warringah Freeway Upgrade interface

The project would include a tunnel connection with the Western Harbour Tunnel and a surface connection with the Warringah Freeway Upgrade at Cammeray. The Western Harbour Tunnel and Warringah Freeway Upgrade project is subject to separate planning approval and the environmental impact statement is currently being assessed by the Department of Planning, Industry and Environment.

It is assumed that the Western Harbour Tunnel and Warringah Freeway Upgrade project would commence construction before the Beaches Link and Gore Hill Freeway Connection project. Should timeframes for the Beaches Link and Gore Hill Freeway Connection project be advanced, some elements of the Beaches Link component may be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade works to maximise construction efficiency and minimise impacts in particular areas.

Delivery of any elements of the Beaches Link component as part of the Western Harbour Tunnel and Warringah Freeway Upgrade works would be subject to the conditions of approval for the Beaches Link and Gore Hill Freeway Connection project and the requirements of this environmental impact statement, including relevant environmental management measures provided in Appendix Y (Compilation of Environmental Management Measures) and any other documents incorporated by reference in the approval.

The interface of the Beaches Link project with the Western Harbour Tunnel reflects the arrangement as presented in the environmental impact statement for the Western Harbour Tunnel and Warringah Freeway Upgrade project. The contractor for the Western Harbour Tunnel and Warringah Freeway Upgrade has not yet been appointed and detailed design has not yet been carried out.

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 3

Strategic context and project need

3 Strategic context and project need

This chapter outlines the strategic context and need for the project, taking into account the current and future transport challenges Sydney is facing, and describes the benefits of the project for people across Greater Sydney. It also describes how the project aligns with national and State strategic planning and transport policies.

The Secretary's environmental assessment requirements as they relate to the strategic context and project need, and where in the environmental impact statement these have been addressed, are detailed in Table 3-1.

Table 3-1 Secretary's environmental assessment requirements – Strategic context and project need

Secretary's requirement	Where addressed in EIS
Environmental impact statement	
1. The EIS must include, but not necessarily be limited to, the following: b. a description of the project and all components and activities (including ancillary components and activities) required to construct and operate it, including: - the relationship and/or integration of the project with existing and proposed public and freight transport services	The relationship and integration of the project with existing and proposed public and freight transport services is described in **Section 3.6** and **Section 3.7**. Additional information about the relationship and integration of the project with existing and proposed public and freight transport services is in **Chapter 8** (Construction traffic and transport), **Chapter 9** (Operational traffic and transport) and **Chapter 27** (Cumulative impacts).
c. a statement of the objective(s) of the project	**Section 3.4** states the project objectives.
d. a summary of the strategic need for the project with regard to its State significance and relevant State Government policy	**Section 3.2** outlines the strategic need for the project. References to the project's State significance and relevant State Government policies are provided in **Section 3.7**.

3.1 Sydney's present and future

Greater Sydney is expanding and the NSW Government is working hard to deliver an integrated transport network that meets the community's needs now and into the future. The population of Greater Sydney is forecast to grow from five million to eight million people over the next 40 years. To accommodate this growth, the Greater Sydney Commission's *Greater Sydney Region Plan – A Metropolis of Three Cities* (Greater Sydney Commission, 2018a) envisages a global metropolis of three liveable, productive and sustainable cities. The Beaches Link and Gore Hill Freeway Connection project (the project) would be located in the North District of the Eastern Harbour City - an area of strategic economic importance for Sydney. The cities and districts of the *Greater Sydney Region Plan* and their key metrics are shown in Figure 3-1.

Sydney's key employment and economic areas are clustered along a corridor that runs from Port Botany and Sydney Airport to Macquarie Park; this is known as the Eastern Economic Corridor. The Eastern Economic Corridor contributed two thirds of the NSW economic growth for the 2015/16 financial year (Greater Sydney Commission, 2018b), and provides jobs in a range of knowledge-based sectors including education, financial and other business services, communications, high-tech manufacturing and biotechnology (NSW Government, 2014). The *Greater Sydney Region Plan* is built on a vision of three cities where most residents live within a 30 minute journey of their jobs, education and health facilities, and services.

Supporting the current needs and future growth of the North District, Eastern Harbour City and Eastern Economic Corridor through an efficient transport network is fundamental to maintaining the liveability, productivity and sustainability of Greater Sydney. Accordingly, the *Greater Sydney Region Plan* was prepared concurrently with the *Future Transport Strategy 2056* (NSW Government, 2018) and the *State Infrastructure Strategy 2018–2038* (Infrastructure NSW, 2018) to align land use, transport and infrastructure outcomes for Greater Sydney.

The North District's economy is focused on the cluster of strategic centres along the Eastern Economic Corridor, including North Sydney, St Leonards, Chatswood, Macquarie Park, and centres further north in the district including Frenchs Forest and Brookvale-Dee Why. These centres play an important economic role in supporting the growth of Sydney as a global city.

The North District is home to 886,550 residents (or 19 per cent of Greater Sydney's population), which is forecast to increase by 18 per cent by 2036. The North District accommodates 483,300 jobs (or 20 per cent of Greater Sydney's jobs) (Greater Sydney Commission, 2018b). The highest share of employment in the North District is in knowledge-intensive and professional jobs (35 per cent compared to the Greater Sydney average of 32 per cent) and health and education (21 per cent compared to the Greater Sydney average of 19 per cent) (Greater Sydney Commission, 2018b). These sectors are among the fastest growing in the North District, reinforcing their significance in the North District's economy and, more broadly, to Greater Sydney (Greater Sydney Commission, 2018b).

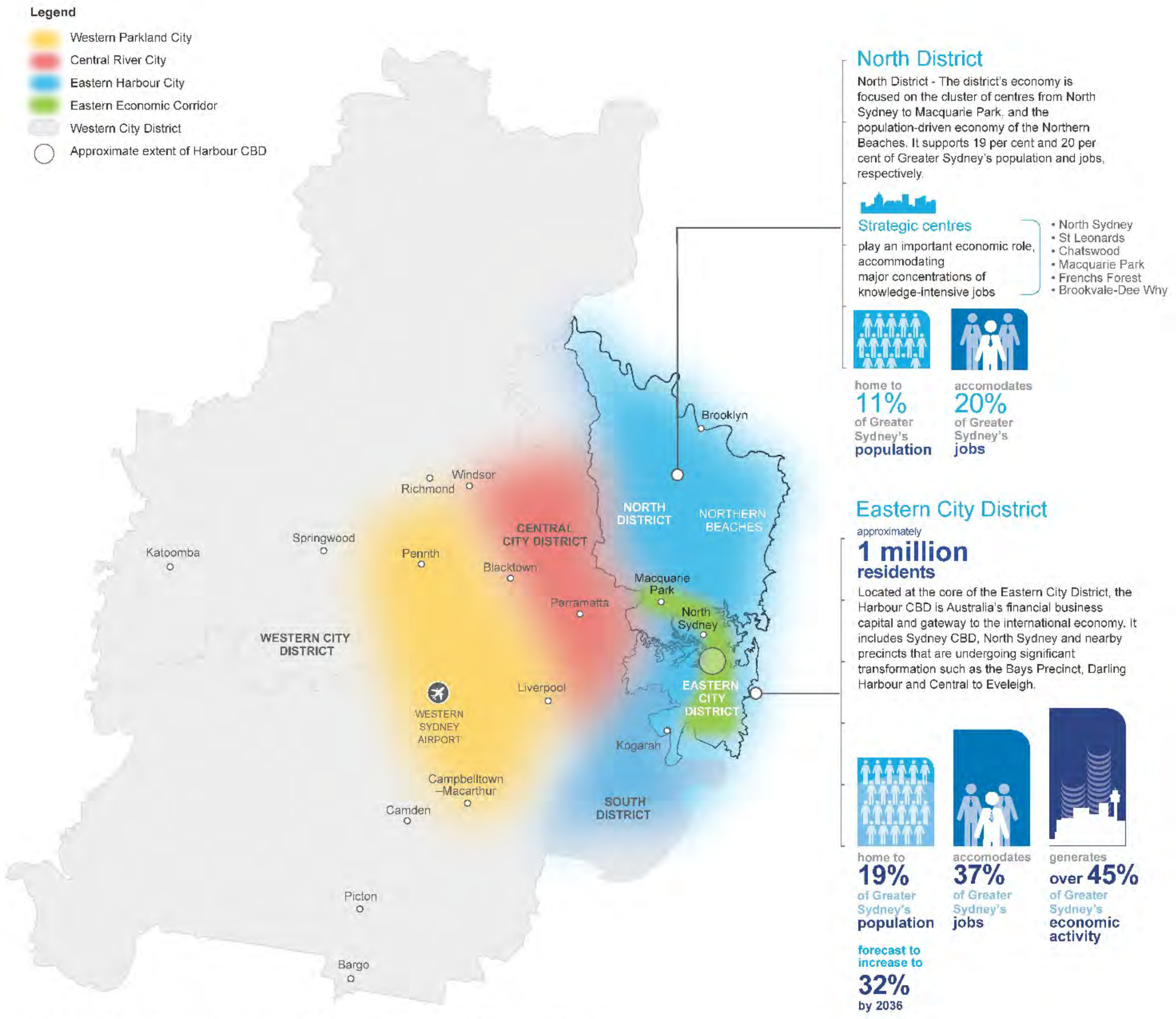
Access between the North District and employment hubs along the Eastern Economic Corridor is primarily provided by private vehicle and bus services using the Military Road/Spit Road (A8) and Warringah Road (A38)/Eastern Valley Way corridors. These arterial links are highly congested and unreliable during peak periods. As a result, a small proportion of jobs within Greater Sydney are accessible to North District residents within 30 minutes by private vehicle or public transport during the morning peak.

The Greater Sydney Commission's *Greater Sydney Region Plan* focuses on concentrating jobs and education facilities around strategic centres. Within the North District, this includes Frenchs Forest, Chatswood, St Leonards and North Sydney. The Greater Sydney Commission lists Frenchs Forest as a key catalyst to attract complementary health services and develop as a major employment hub for the Northern Beaches. This has been supported by the Northern Beaches Hospital road upgrade project, which has improved access to the Northern Beaches Hospital and increased the capacity of the broader road network, particularly along Warringah Road.

The Northern Beaches is the largest population centre within the North District and has a population of about 273,000. Since 1981, annual residential population growth on the Northern Beaches has been below the Greater Sydney average, typically tracking at about one per cent, or half the growth rate of Greater Sydney (Bureau of Transport Statistics, 2016). Jobs growth on the Northern Beaches is also below average relative to other parts of Sydney, with jobs forecast to grow by 0.8 per cent per annum compared to a metropolitan average of 1.1 per cent (excluding the Harbour CBD and Parramatta).

The COVID-19 pandemic is an unprecedented event that has changed the way people work and their travel patterns, while creating some uncertainty about the future of the NSW economy. While it is difficult to fully assess the impact of the event, evidence of Greater Sydney's resilience to such disruptions is already apparent. In Greater Sydney, traffic levels on most roads have returned to those experienced before NSW Government restrictions for COVID-19 were put in place. This indicates a relatively rapid response to the event by the city, and suggests that the movement of people, goods and services and demand for road capacity is returning to conditions similar to those prior to the COVID-19 pandemic. The NSW Government is demonstrating its commitment to supporting the recovery from the COVID-19 pandemic through its guaranteed infrastructure pipeline to drive the creation of jobs and contribute to economic growth. The project is part of this pipeline. While the COVID-19 pandemic (along with other unprecedented events such as bushfires) presents short to medium-term challenges for Sydney (and NSW more broadly), the project has been developed with a long-term view to address the challenges Greater Sydney will face over the next 40 years, and to deliver long-lasting benefits for road users, communities and businesses. As such, the need for the project and other strategic transport projects to meet the demands of a growing population and economy remains critical to ensuring the future success of Sydney.

Additional key strategic planning and policy documents relevant to the project are discussed in Section 3.7.



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

Figure 3-1 Key metrics of Sydney's Eastern City and North District

3.2 The North District's road transport challenge

Freight services, public transport and other road users travelling to and from the Northern Beaches region currently experience some of the slowest and most unreliable journey times across Greater Sydney. The transport challenges for the North District and Northern Beaches region are the product of a number of key issues, summarised below:

- *High traffic volumes and limited capacity at the eastern Sydney Harbour and Middle Harbour crossings, and roads around the Harbour CBD*
  - Network data demonstrates that incidents on the Sydney Harbour crossings and their approaches heavily impact journey times for freight, buses and private vehicles travelling on the arterial network across the Northern Beaches region
  - The limited alternative routes and high demand for the eastern Sydney Harbour and Middle Harbour crossings result in high levels of congestion, and make these cross-harbour corridors critical to the performance of the broader motorway and arterial road network
  - The performance of the road crossings of Sydney Harbour and Middle Harbour are critical to the performance of the arterial network servicing the Northern Beaches (refer to Figure 3-4) – particularly for north-south trips
  - It has long been understood that the benefits of upgrading road capacity to the Northern Beaches region would not be realised without addressing downstream capacity constraints at the Sydney Harbour crossings and beyond.
- *Limited arterial road capacity servicing the Northern Beaches region*
  - The Northern Beaches is connected to the rest of Greater Sydney by a small number of transport corridors. Just three road corridors, including only two Middle Harbour crossings, connect the Northern Beaches with the rest of Greater Sydney:
    - Mona Vale Road (A3)
    - Military Road/Spit Road (A8)
    - Warringah Road (A38)/Eastern Valley Way.

    These three corridors are required to accommodate journeys to and from strategic centres across Greater Sydney, as well as local and intraregional trips, including a large number of bus trips.
  - The Mona Vale Road, Military Road/Spit Road and Warringah Road/Eastern Valley Way road corridors generally operate well over capacity during peak periods. This contributes to high levels of congestion, long and unreliable journey times and, consequently, poor accessibility to and from the region. This poor accessibility hinders daily access for people and goods travelling to, from, and within the region, increasing the time people spend commuting and restricting opportunities for growth in the strategic centres
  - The limited number of corridors connecting the Northern Beaches to the rest of Greater Sydney means that the network is very susceptible to major delays caused by incidents. Network data demonstrates that an incident on one corridor servicing the region can have major impacts on journey times across the broader road network.
- *Low population density across the Northern Beaches region*
  - While the Northern Beaches region is home to a large population, the population density is relatively low. This results in a wide variety of origins and destinations for transport journeys that are not well suited to high-frequency mass transit modes
  - Accordingly, the most appropriate transport modes for the region continue to be road based, including high-quality express bus services such as the B-Line. These modes provide the greatest flexibility to service the diverse trip needs of the dispersed Northern Beaches population

- However, the effectiveness of express bus services will diminish without appropriate improvements to road capacity and travel reliability.

- *Travel time reliability and speed of public transport journeys constrained by a congested road network*
  - The effectiveness and travel time reliability of the public transport network servicing the region is constrained by the capacity of the arterial road network, particularly the Military Road/Spit Road corridor which is the primary bus corridor between the Northern Beaches and Harbour CBD
  - The Military Road/Spit Road corridor also serves as the key corridor for all other road traffic for both interregional journeys between the Northern Beaches and Harbour CBD as well as local trips, resulting in heavy and conflicting road transport demands on this corridor and consequently, poor travel speeds during peak periods.

Further detail on these transport challenges and their influence on the proposed design for the Beaches Link and Gore Hill Freeway Connection project is provided in the following sections of this chapter.

3.2.1 High traffic volumes and limited capacity at the eastern crossings of Sydney Harbour and roads around the Harbour CBD and North District

The Eastern Harbour City has the largest concentration of jobs in Greater Sydney, accommodates the most productive industries and is home to a highly skilled workforce. Accordingly, the eastern motorway crossings of Sydney Harbour and crossings of Middle Harbour are critical links in Sydney's motorway and arterial road network. These major transport corridors around the Harbour CBD are critical to the performance of the arterial network servicing the Northern Beaches, particularly for north-south trips, and are some of the busiest in Greater Sydney and indeed in Australia, including:

- Spit Road/Spit Bridge – a critical connection to and from the Sydney CBD and Northern Beaches, carrying 69,500 vehicles per day and over 34,000 bus passengers per day (Transport for NSW, 2019)[1]
- Warringah Road/Roseville Bridge – a critical connection between employment centres at Chatswood and Macquarie Park and the Northern Beaches, carrying 79,000 vehicles per day and over 9,500 bus passengers per day (Transport for NSW, 2019)[2]
- Sydney Harbour Bridge (Bradfield Highway and Cahill Expressway) – one of the busiest roads in NSW, carrying 165,000 vehicles a day and over 79,000 bus passengers per day (Roads and Maritime, 2017)
- Sydney Harbour Tunnel – the eighth busiest road in NSW, carrying 94,000 vehicles a day (Roads and Maritime, 2017)
- The Warringah Freeway – the busiest road in NSW, carrying over 240,000 vehicles per day and over 100,000 bus passengers per day (Roads and Maritime, 2017)
- Sydney Harbour Bridge railway crossing – an essential link on the Sydney Trains network, accommodating the T1 North Shore and Western Line and T9 Northern Line services (Sydney Trains, 2015)

Key metrics for the Eastern Harbour City's road crossings of Middle Harbour are shown in Figure 3-2.

[1] Note: Existing traffic data sourced prior to the COVID-19 pandemic
[2] Note: Existing traffic data sourced prior to the COVID-19 pandemic

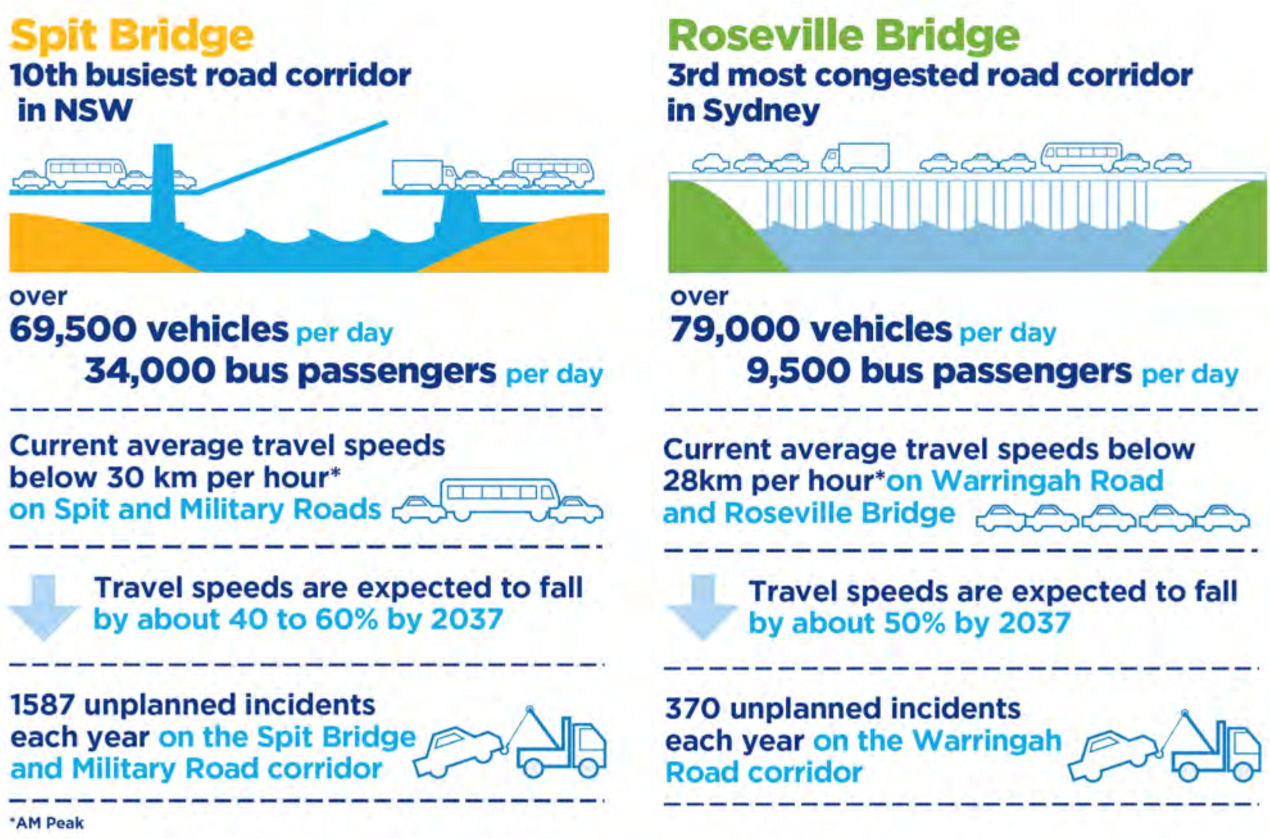


Figure 3-2 Key metrics for the critical Middle Harbour road crossings

The *Australian Infrastructure Audit 2019* (Infrastructure Australia, 2019) listed the Eastern Distributor, Sydney Harbour Bridge, Warringah Freeway and Gore Hill Freeway among Australia's most congested road corridors, generating a congestion cost of $65,000 per day in 2016. If no action is taken, this is forecast to rise to $98,000 per day by 2031, indicating that as congestion on these corridors increases, so too would the costs.

Infrastructure NSW has estimated that the economic risk to growth and productivity posed by traffic congestion in the Eastern City District is about $5 billion a year and is forecast to increase to about $8 billion annually by 2020. Infrastructure NSW has observed that "*without corrective action, congestion will worsen – and the costs to business and the community will escalate – as the city's population grows*" (Infrastructure NSW, 2014).

In addition to the large number of customers who rely on these corridors, the limited capacity and number of alternative routes for crossing Sydney Harbour make these corridors critical to the performance of the broader motorway and arterial road network. Network data demonstrates that incidents on the harbour crossings and their approaches can greatly impact journey times for freight, buses and private vehicles travelling north and south on the arterial network servicing the Northern Beaches region, with Military Road and Spit Road particularly affected.

During 2019, there were 1149 incidents on the Sydney Harbour Bridge and its approaches (including the Warringah Freeway), further impacting journey times for vehicles travelling to and from the North District and Northern Beaches region. Without intervention, the predicted growth in traffic demand over time would result in further increases in journey time delays and deterioration of road travel reliability.

In addition to high traffic volumes, a major contributor to congestion around the Harbour CBD and North District is that many of the most critical road corridors, including the Sydney Harbour Bridge, Sydney Harbour Tunnel, ANZAC Bridge, Western Distributor, Military Road, Spit Road, Warringah Road and Eastern Valley Way, perform both bypass and access functions. The dual function of these corridors is reflected in the high proportion of vehicles that use them to travel to destinations other than the Sydney CBD (see Figure 3-3). This contributes to high levels of congestion as well as poor network outcomes, as bypassing traffic is impacted by congested collector/distributor roads.

Supplementing capacity and reducing the conflict between access and bypass functions for the Sydney Harbour Bridge, Sydney Harbour Tunnel, ANZAC Bridge, Western Distributor, Military Road, Spit Road, Warringah Road and Eastern Valley Way is therefore a key element of the integrated transport network required to support the liveability and productivity of the Eastern Economic Corridor and its connections with international gateways and their surrounds. This is also a key step in supporting and enabling future strategic links, including Beaches Link.

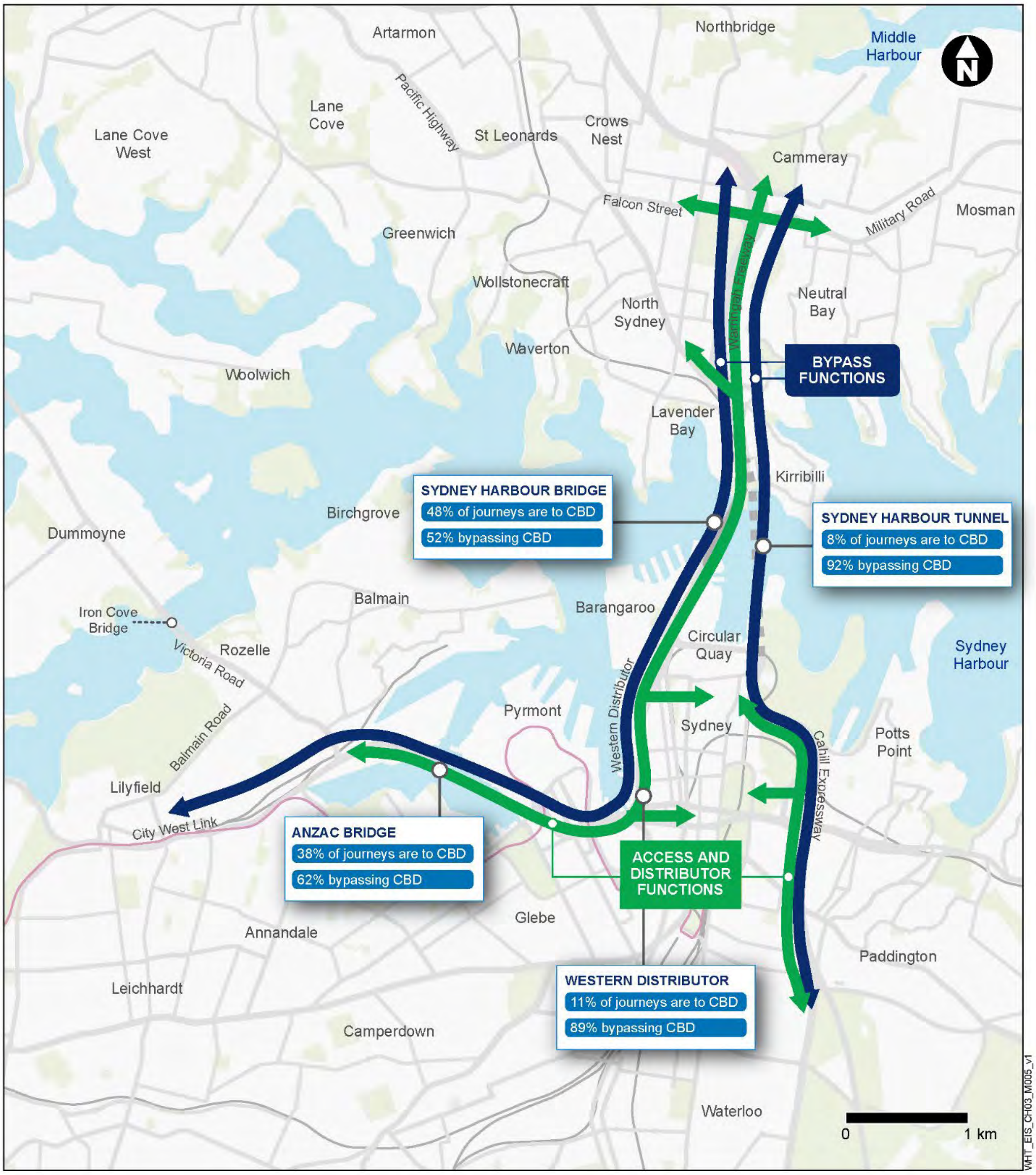


Figure 3-3 Function of critical road corridors around the Harbour CBD

3.2.2 Limited transport corridors connecting the region

The Northern Beaches is connected to the rest of Greater Sydney by a small number of transport corridors, which contributes to high levels of congestion, long and unreliable journey times and, consequently, poor accessibility to and from the region. Just three road corridors connect the Northern Beaches with the rest of Greater Sydney:

- **Mona Vale Road (A3)** is the most northerly road corridor. It is an arterial road from Mona Vale to North Ryde and onward, to the South, Central City and Western City Districts.

  Mona Vale Road carries about 60,000 vehicles per day, with around 4850 vehicles during the morning peak and 4700 vehicles during the afternoon peak, and is used by private vehicles, heavy vehicle freight, light commercial vehicles and several bus routes by both public and private operators connecting Mona Vale with Gordon and Macquarie Park.

- **Warringah Road (A38)** is an east–west part-arterial and part-motorway connection from Brookvale to Chatswood via Frenchs Forest.

  Carrying about 80,000 vehicles per day, including 5850 vehicles during the morning peak and 5800 vehicles during the evening peak, Warringah Road is the third most congested road in Sydney. This route serves private vehicles and freight, including journeys to and from the Harbour CBD via Eastern Valley Way and to Chatswood, Macquarie Park and other centres to the west.

  Given the pressure on the Military Road/Spit Road corridor, Warringah Road also carries vehicles that are making north-south journeys via Eastern Valley Way and using local sub-arterial roads including Willoughby Road, Flat Rock Drive, and Strathallen Avenue to access the Warringah Freeway and North Sydney.

  Warringah Road also carries several bus routes connecting Manly with Chatswood via Brookvale-Dee Why and Frenchs Forest, with about 18 buses traveling on this corridor in the AM peak one hour (Transport for NSW, 2016d). About 9500 bus passengers travel along Warringah Road per day (Transport for NSW, 2019). Planning is underway for a rapid bus system from Dee Why to Chatswood which would benefit from reduced congestion on Warringah Road.

- **Military Road/Spit Road (A8)** is the most southerly road corridor and is a north–south arterial road from Seaforth to North Sydney and the Warringah Freeway. This corridor is the primary route for private vehicles and buses travelling between the Northern Beaches, Harbour CBD and North Sydney.

  Military Road and Spit Road are the seventh and tenth busiest roads, respectively, in NSW in the AM peak, carrying about 70,000 vehicles per day, including about 4250 vehicles during the morning peak and 4750 vehicles in the evening peak.

  A total of 43 bus routes connect the Northern Beaches via the Spit Bridge, with 117 bus movements across the bridge in the AM peak one hour. The number of bus routes increases to 56 on Military Road. The corridor is serviced by the B-Line which would benefit from reduced congestion on the route. About 66,000 bus passengers travel along Military Road per day, with the Spit Bridge remaining a critical connection to and from the Sydney CBD and Northern Beaches, carrying over 34,000 bus passengers per day (Transport for NSW, 2019).

The region is particularly reliant on the most southerly corridors: the Warringah Road via Roseville Bridge and the Military Road/Spit Road via Spit Bridge corridors. Currently, these links carry 71 per cent of all interregional road journeys to and from the Northern Beaches, with traffic volumes forecast to increase by about 10 per cent by 2037 (see Figure 3-4).

Sydney's worst road congestion occurs between Balgowlah and Sydney Harbour through Mosman and Cremorne (Grattan Institute, 2017). The Spit Bridge opens regularly to allow boats to navigate Middle Harbour, resulting in traffic delays. However, even with the bridge down, morning delays on this route are greater and more unpredictable than other routes in Greater Sydney. As a result, Balgowlah commuters to the Sydney CBD need to allow 40 minutes to get to work on time; or 23 minutes longer than the trip would take without traffic (Grattan Institute, 2017).

The *Australian Infrastructure Audit 2015* (Infrastructure Australia, 2015), identified the east–west corridor (Warringah Road between Chatswood and Narraweena) as generating the third highest congestion cost of all road corridors across Sydney, Wollongong and Newcastle. This is based on a delay cost per lane kilometre of $2.18 million. The Audit estimates that by 2031 this will increase to $6.16 million, making it the second-most costly corridor for congestion behind the Warringah Freeway (Infrastructure Australia, 2015).

The heavy reliance on these corridors results in them being highly congested and journeys that rely on them are highly susceptible to delays caused by incidents. Current average travel speeds in the AM peak are below 30 km/h on Military Road and Spit Road. Travel speeds are expected to fall by about 40 to 60 per cent in the southbound direction and about 20 per cent in the northbound direction by 2037. Similarly, average travel speeds for trips on Warringah Road in the westbound direction between Frenchs Forest and North Sydney are expected to drop below 15 km/h in the AM peak (a decrease of about 54 per cent) by 2037.

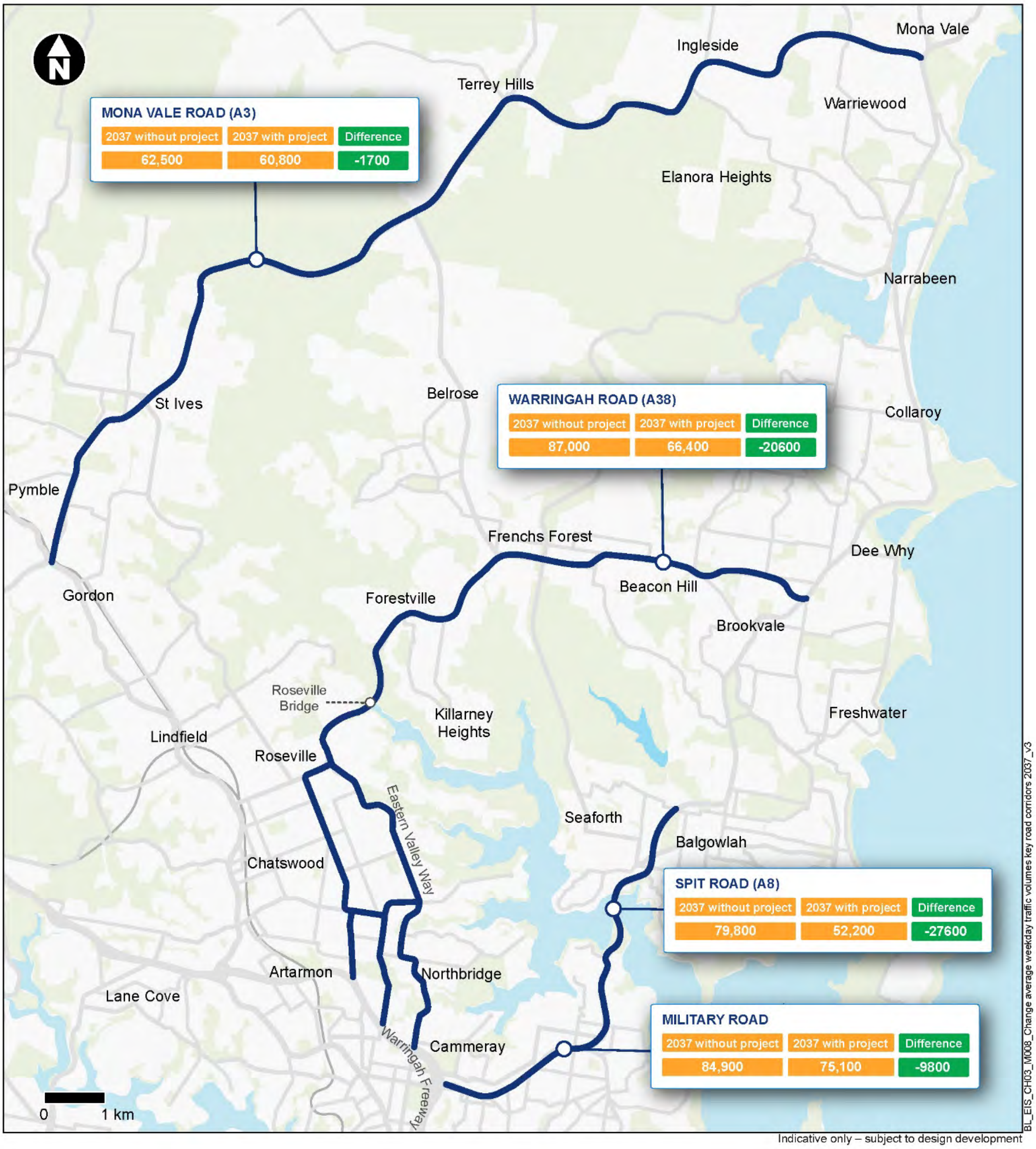


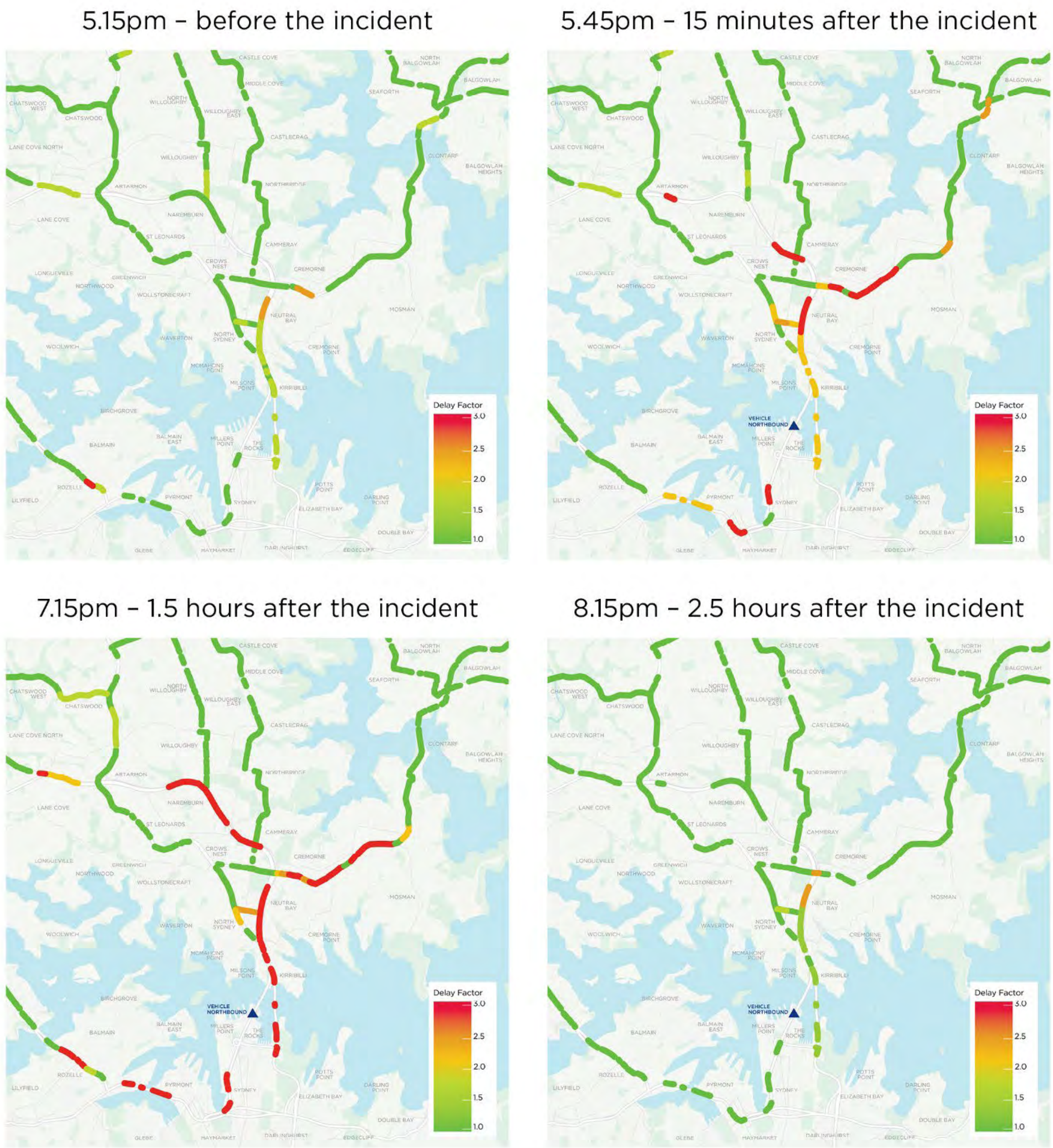
Figure 3-4 Forecast change in weekday traffic volumes average (two-way) in the AM peak on key Northern Beaches corridors by 2037

3.2.3 Low resilience in the transport network connecting the Northern Beaches

The high road demand and limited number of corridors connecting the Northern Beaches means that incidents on these corridors have significant impacts on journey times to and from the region. In 2019, there were 1587 unplanned incidents on the Military Road/Spit Road corridor, and 370 unplanned incidents on Warringah Road.

In 2036, on a network wide level, the lack of network resilience to incidents on the Military Road/Spit Road corridor is estimated to cost $13 million annually. As congestion on this route increases, so too would the costs to the economy of the North District.

The low resilience of the network to incidents is demonstrated by the case study presented in Figure 3-5 which traces the delay impacts of an incident that occurred on the Sydney Harbour Bridge during peak hour in 2016. The incident resulted in the closure of four lanes of the Sydney Harbour Bridge which caused major delays across large parts of the network, including for motorists in the Sydney CBD, the Lane Cove Tunnel on the Eastern Distributor and along Military Road at Mosman. Delays resulting from the incident persisted along the Gore Hill Freeway and Military Road for more than 90 minutes following the incident, with traffic conditions returning to normal about two hours after the incident.



Traffic incident occurring on northbound lane of Sydney Harbour Bridge at 5.30pm

1. Traffic flow 15 minutes before the incident is relatively normal.
2. Traffic flow 15 to 30 minutes after the incident is delayed, with tailbacks developed north of the bridge to the Warringah Freeway and Military Road, and south of the bridge near Western Distributor and ANZAC Bridge.
3. Traffic flow 90 to 105 minutes after the incident, tailbacks continue and worsen north and south of the bridge, extending to Gore Hill Freeway to the north and Victoria Road (at Rozelle) to the south.
4. Traffic flow 2.5 hours after the incident has returned to normal.

Figure 3-5 Delay impacts of an evening incident on Sydney Harbour Bridge

3.2.4 Travel time reliability and speed of public transport journeys constrained by a congested road network

As outlined in the *Northern Beaches Transport Strategy 2038* (Northern Beaches Council, 2018a), residents on the Northern Beaches rely heavily on private vehicles and public buses for travel. With the exception of the Manly ferry, bus transport is the only means of public transport in the region. The travel time reliability and speed of public transport journeys for Northern Beaches bus passengers is strongly linked to the capacity of the road network the buses use and the road network's ability to cope with incidents.

The primary suburban bus routes to and from the Northern Beaches use both the Military Road/Spit Road (A8) and Warringah Road(A38)/Eastern Valley Way corridors to connect with the Harbour CBD and employment centres in Chatswood and Macquarie Park respectively. As outlined in Section 3.2.1, these roads are some of the most utilised bus routes with the Spit Bridge (A8) carrying over 34,000 bus passengers per day, while the Roseville Bridge (A38) carries over 9500 bus passengers per day.

The commencement of the B-Line program in 2017 has successfully improved public transport capacity and journey times to and from the Northern Beaches region, with travel times reduced by about 20 minutes for passengers using the service from Mona Vale to the Sydney CBD during peak periods. Despite these improvements to bus performance, bus travel times between Mona Vale and the Sydney CBD remain in excess of 60 minutes during peak periods. The key constraint in peak periods is the capacity of the Military Road/Spit Road corridor which serves both interregional journeys between the Northern Beaches and Sydney CBD as well as local trips. This places heavy and conflicting road transport demands on the corridor, resulting in poor travel speeds during peak periods. The lack of spare capacity on this corridor also amplifies the impacts of incidents, resulting in poor travel speed reliability.

Buses continue to be the most appropriate public transport mode for the Northern Beaches area given the low population density and subsequently wide variety of origins and destinations for the commuters in the area. Buses provide the ability for flexibility and will be critical in supporting predicted future demand in the area. However, without measures to relieve capacity constraints on the arterial road network, the ongoing success of the B-Line as well as opportunities to implement new express bus services, would be limited in the future as a result of continuing growth in traffic and particularly as express and limited stop services continue to clash with more local bus routes.

There are multiple local and express bus services, contributing to competition for road space and bunching

A key contributor to low bus speeds, particularly in corridors like Military Road/Spit Road, is the high number of buses that also mix with cars and other traffic, competing for limited road space and resulting in increased congestion and lengthy delays. Each day, 43 bus routes traverse the Spit Bridge, with 117 buses crossing it in the period 8am to 9am alone. A further 13 bus routes use Military Road, most carrying passengers to and from Mosman, Cremorne and Neutral Bay.

Bus journey times are unreliable

The journey times for bus services connecting the Northern Beaches to the Sydney CBD are affected by the capacity and conflicts on the existing arterial road network, resulting in some journey times being unreliable. The variability in journey times means that some customers need to incorporate additional time into their schedule, which affects the customer experience and imposes a cost on the productivity of Greater Sydney.

With the streamlining of bus services delivered through the B-Line program, bus service performance and travel time reliability has improved, and bus patronage has increased – with over 2000 weekly services providing enhanced services between Mona Vale and Wynyard. However, for these benefits to be sustained over the long term, investment in additional road capacity through alternative routes or modes for corridors at capacity, is critical to improve the transport performance of the network in this area. To support opportunities for further improvements, including new express services to strategic centres such as North Sydney, Sydney CBD, Macquarie Park and St Leonards, a new motorway standard link is required.

3.3 Congestion impacting urban amenity across the Eastern City and North Districts

In addition to the transport challenges created by the limited arterial roads servicing the North District and Northern Beaches region, the current situation also has urban amenity implications. High through traffic and congestion along the arterial roads servicing the Northern Beaches undermines efforts to improve liveability in several inner urban areas along and next to these routes.

Across the Harbour CBD and Northern Beaches, several parts of the road network perform a 'place' function. This means that, as well as being transport corridors, parts of the road network are destinations in their own right, including for shopping and dining. These places play an important role in supporting the liveability, productivity and sustainability of Greater Sydney, and the transport network has an important role in supporting this objective, as reflected in 'Successful Places' being one of the six NSW-wide outcomes established by the *Future Transport Strategy 2056* (NSW Government, 2018).

The Military Road/Spit Road corridor is one of the busiest and most congested road corridors in NSW. In addition to local trips, about one third (33 per cent) of interregional journeys to and from the Northern Beaches pass through the corridor every day. Through traffic and congestion are a key cause of poor urban amenity along the corridor, impacting areas such as Neutral Bay, The Spit and Mosman. These impacts include restricted parking, reduced pedestrian and cyclist amenity, limited vegetation, and traffic noise and air quality impacts.

Congestion of these corridors also results in broader urban amenity impacts beyond the arterial corridors themselves, with drivers moving to local routes in an attempt to avoid congestion. Transport for NSW customer research carried out in 2017 indicates that 73 per cent of motorway users 'rat-run' to avoid congestion. Improving the core motorway and arterial capacity, resilience and reliability is a key part of the multi-modal transport network required to improve the amenity of local communities and reduce 'rat running'.

3.4 The Western Harbour Tunnel and Beaches Link program of works

The Western Harbour Tunnel and Beaches Link program of works is a major transport infrastructure program that would make it easier, faster and safer to get around Sydney. As Sydney continues to grow, faster and more reliable trips are essential to reducing congestion and providing new levels of access to jobs, recreation, and services such as schools and hospitals. By creating a western bypass of the Sydney CBD, the Western Harbour Tunnel would take pressure off the Sydney Harbour Bridge, Sydney Harbour Tunnel and ANZAC Bridge; while Beaches Link would create an alternative to the Military Road/Spit Road and Warringah Road corridors to relieve traffic pressure on the North Shore.

The program of works has been designed as part of an integrated transport network, with a focus on new public transport connections and improved journey time reliability for buses. It would also provide improvements to walking and cycling routes, providing more shared transport options.

The Western Harbour Tunnel and Warringah Freeway Upgrade project and the Beaches Link and Gore Hill Freeway Connection project are being delivered as separate projects, but have been developed as an integrated program of works known as the Western Harbour Tunnel and Beaches Link program.

The Western Harbour Tunnel and Beaches Link program of works comprises three core elements as illustrated in Figure 3-6.

Figure 3-6 Elements of the Western Harbour Tunnel and Beaches Link program of works

- **Warringah Freeway Upgrade** – An upgrade to about four kilometres of the Warringah Freeway to integrate with the Western Harbour Tunnel and Beaches Link and optimise the way the three harbour crossings will function into the future
- **Western Harbour Tunnel** – A new 6.5 kilometre cross-harbour motorway tunnel linking the Rozelle Interchange to the Warringah Freeway and Beaches Link near North Sydney. This new crossing will change the way people move around Sydney, creating a western bypass of the Sydney CBD, easing pressure on the congested Sydney Harbour Bridge, Sydney Harbour Tunnel and ANZAC Bridge, and enabling the new Beaches Link
- **Beaches Link** – A new seven kilometre motorway tunnel from the Warringah Freeway at Cammeray and the Gore Hill Freeway at Artarmon to Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights, under Middle Harbour. Beaches Link also includes underground connections to and from the Western Harbour Tunnel and widening of the Wakehurst Parkway to two lanes each way between Killarney Heights and Frenchs Forest along with connection and integration works along the existing Gore Hill Freeway and surrounding roads at Artarmon.

In conjunction with the other road, rail, bus and light rail projects outlined in the *Future Transport Strategy 2056* (NSW Government, 2018), the Western Harbour Tunnel and Beaches Link program of works has been developed to meet the current and future transport needs of Sydney. The program of works represents an important step in the long-term development of Greater Sydney's strategic transport network. The program of works has been developed to address critical transport constraints in the motorway and arterial road network, and support the growth of the city and NSW, by improving the capacity, reliability, and journey time performance of the critical cross-harbour transport corridors near the Harbour CBD.

As well as relieving road congestion for freight operators and private vehicle commuters who are affected by limited road capacity to and from the Northern Beaches, the program of works has been designed as part of an integrated transport network with a focus on new public transport connections and improved journey times and journey time reliability for buses to provide major benefits to public transport commuters. This includes opportunities for new express bus services between the Northern Beaches, North Sydney, Sydney CBD, St Leonards and strategic centres to the south west and north west.

To ensure the design for the program of works addresses the transport challenges of the North District and Eastern Harbour City, the following objectives have been developed for the Western Harbour Tunnel and Beaches Link program of works:

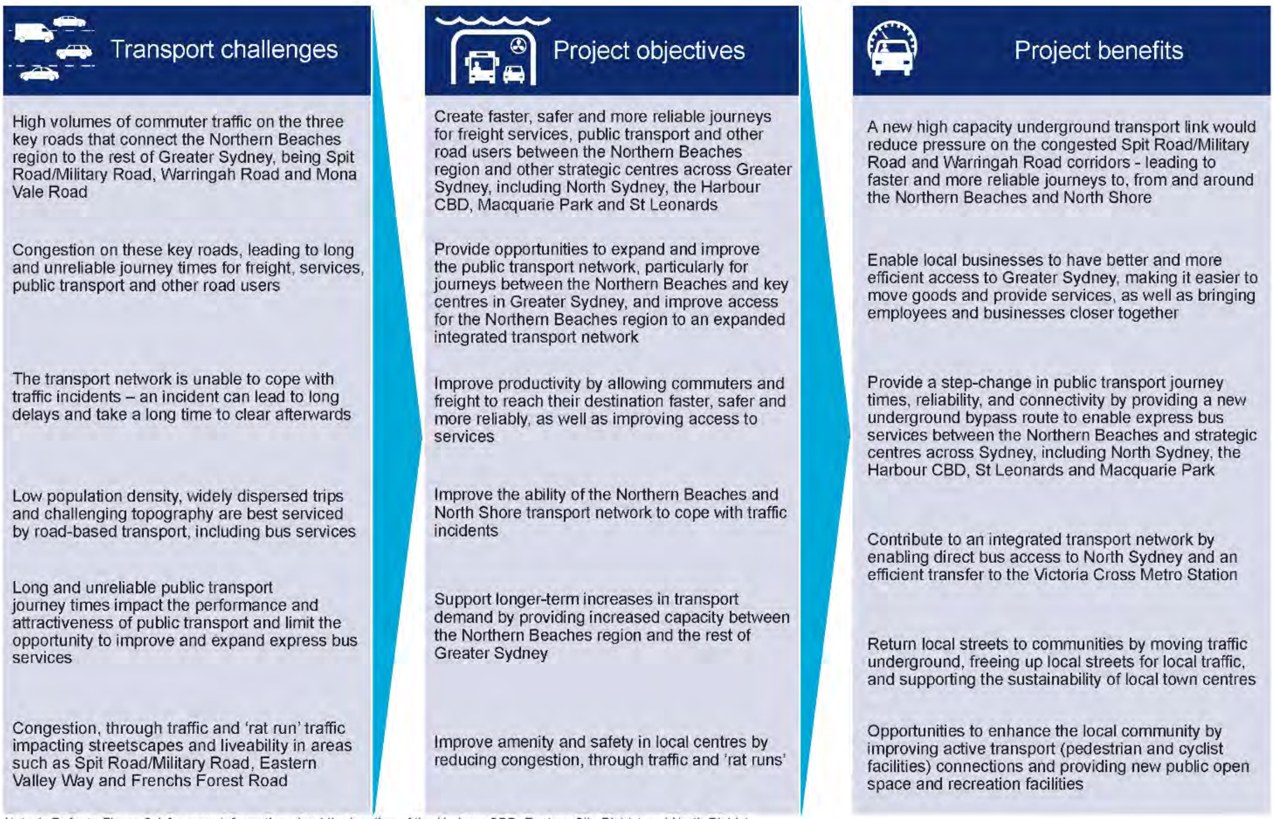
- Reduce congestion on distributor roads around the Harbour CBD, including the Sydney Harbour Bridge, Western Distributor and ANZAC Bridge
- Create faster, safer and more reliable journeys across Sydney Harbour, particularly for traffic bypassing the Harbour CBD to the west
- Improve productivity by allowing commuters and freight to reach their destination faster, safer and more reliably
- Increase the ability for the Harbour CBD road network to cope with traffic incidents

- Reduce travel times, delays and queuing on the Warringah Freeway by improving cross-harbour capacity and reducing merges and weaves, supporting long-term increased demand
- Improve streetscapes, sustainability and liveability across the Eastern City and North Districts by reducing congestion and through traffic in local centres.

The overarching objectives of the program of works translate into the following project specific objectives for the Beaches Link and Gore Hill Freeway Connection project:

- Provide increased capacity on the road network connecting the Northern Beaches region and Greater Sydney by reducing congestion and through traffic on arterial roads
- Create faster, more reliable journey times for freight services, public transport and other road users between the Northern Beaches region and other strategic centres across Greater Sydney, including North Sydney, the Harbour CBD, Macquarie Park and St Leonards
- Provide opportunities to expand and improve public transport journeys between the Northern Beaches and key centres across Greater Sydney, and improve access for the Northern Beaches region to an expanded transport network, including Victoria Cross Metro Station (opening 2024)
- Improve productivity and access to services by facilitating faster and more reliable journey times for commuters and freight to reach their destinations
- Increase the resilience of the Northern Beaches and North Shore road network to traffic incidents
- Improve urban amenity by reducing congestion, through traffic and rat-running on surface corridors.

A summary of the project challenges, corresponding objectives and overall project benefits are shown in Figure 3-7 and discussed in more detail in Section 3.6.



Note 1: Refer to Figure 3-1 for more information about the location of the Harbour CBD, Eastern City District and North District

Note 2: Victoria Cross Metro Station, opening in 2024 as part of Sydney Metro City and Southwest project

Figure 3-7 Project challenges, objectives and benefits

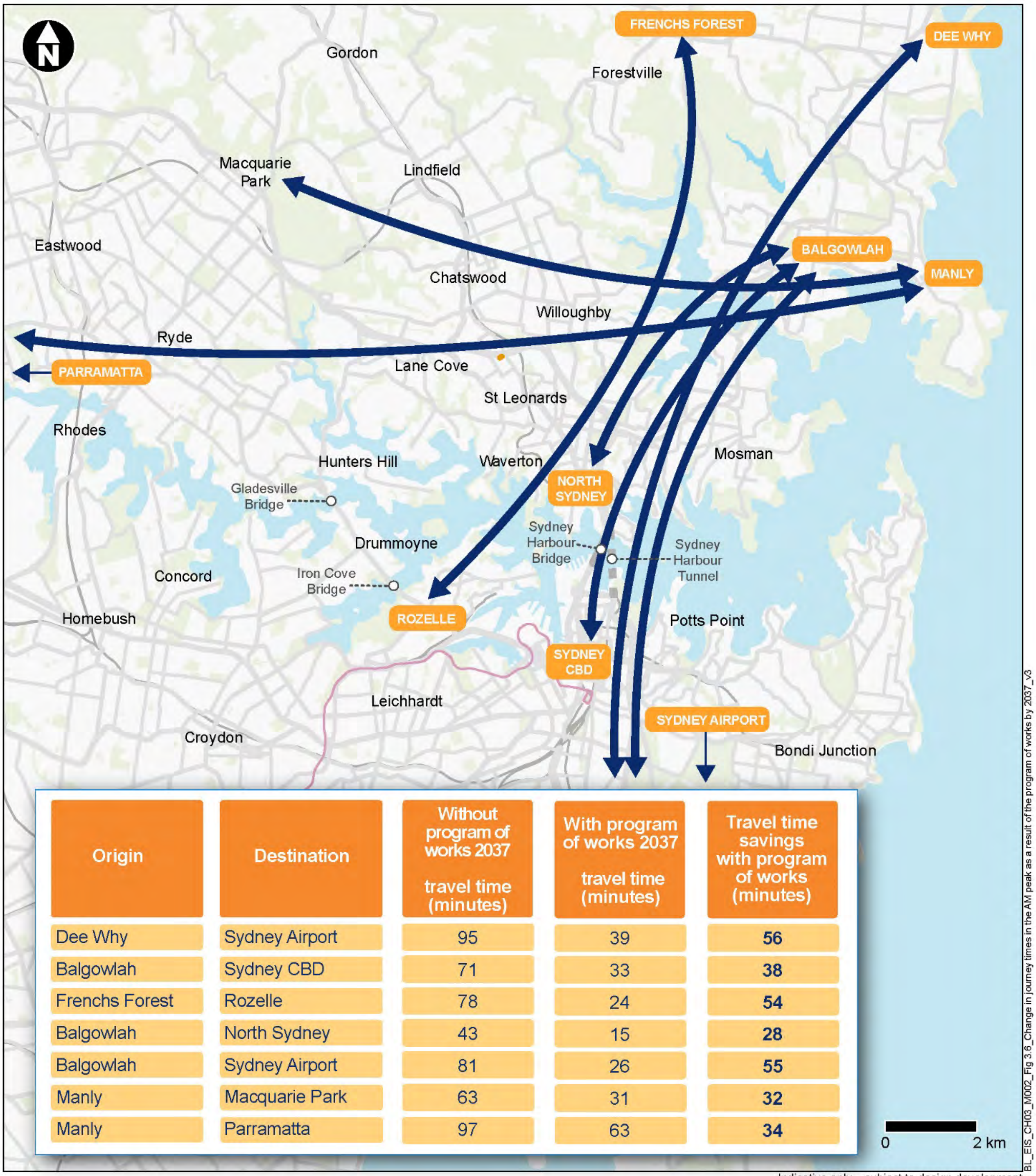
3.5 Key benefits of the Western Harbour Tunnel and Beaches Link program of works

The Western Harbour Tunnel and Beaches Link program of works would deliver new strategic road links for Greater Sydney, improving journey times for freight services, public transport and other road users and alleviating pressure on some of the city's most critical transport corridors. The program of works is designed to improve the capacity, reliability, and journey times on cross-harbour transport corridors near the Harbour CBD and improve connectivity to the Northern Beaches.

Key benefits of the program of works include:

- Delivering a new motorway crossing of Sydney Harbour, taking pressure off critical corridors including the Sydney Harbour Bridge, Sydney Harbour Tunnel, Western Distributor and ANZAC Bridge, and enabling the Beaches Link
- Improving the efficiency and safety of Australia's busiest road, the Warringah Freeway
- Providing a new motorway link between the Northern Beaches and the existing network near North Sydney and Artarmon, bypassing the congested Military Road/Spit Road and Warringah Road/Eastern Valley Way corridors
- Delivering faster and more reliable journey times for freight services, public transport and other road users who rely on the critical cross-harbour road corridors and arterial corridors connecting to the Northern Beaches region
- Increasing the ability for the Harbour CBD arterial road network to cope with traffic incidents by providing additional capacity and an alternative route to the heavily congested existing harbour crossings
- Enabling substantial improvements for public transport customers currently using some of Sydney's busiest road corridors – allowing for quicker and more reliable journey times for express bus services between the Northern Beaches and strategic centres including North Sydney, Sydney CBD, Macquarie Park and St Leonards via the motorway network
- Benefits to users of existing surface corridors by reducing congestion.

The program of works would support faster and more reliable travel times for journeys between the Northern Beaches region and key centres south and west of Sydney Harbour. For example, journeys from Dee Why to Sydney Airport are expected to be 56 minutes faster (total travel time 39 minutes) in the AM peak by 2037 (via the proposed Beaches Link, Western Harbour Tunnel, WestConnex and Sydney Gateway). Other key journey time improvements in the AM peak as a result of the program of works are shown in Figure 3-8.



Origin	Destination	Without program of works 2037 travel time (minutes)	With program of works 2037 travel time (minutes)	Travel time savings with program of works (minutes)
Dee Why	Sydney Airport	95	39	**56**
Balgowlah	Sydney CBD	71	33	**38**
Frenchs Forest	Rozelle	78	24	**54**
Balgowlah	North Sydney	43	15	**28**
Balgowlah	Sydney Airport	81	26	**55**
Manly	Macquarie Park	63	31	**32**
Manly	Parramatta	97	63	**34**

Indicative only – subject to design development

Figure 3-8 Change in journey times in the AM peak as a result of the program of works by 2037

3.6 Key benefits of the Beaches Link and Gore Hill Freeway Connection project

The Beaches Link and Gore Hill Freeway Connection project is a vital part of the overall Western Harbour Tunnel and Beaches Link program of works.

The Northern Beaches and its strategic centres suffer from poor accessibility caused by limited transport capacity connecting the region and the resulting flow on effects for bus performance during peak periods. The project would provide a step-change in journey times and reliability, and resilience for the critical road network servicing the Northern Beaches region. This would deliver considerable benefits for freight services, public transport, and other users of the new and existing links and also enable amenity improvements in areas along and adjacent to the congested surface corridors.

Further detail on some of the key benefits of the project is provided in the following sections. Further information on the consistency of the project outcomes with strategic local, State and Australian Government objectives is provided in Section 3.7.

3.6.1 Reducing pressure on congested road corridors servicing the Northern Beaches and North Shore

The Beaches Link and Gore Hill Freeway Connection project would provide a new underground motorway bypass of the Military Road/Spit Road (A8) and Warringah Road (A38)/Eastern Valley Way corridors. The project would substantially improve journey times and trip reliability for millions of freight vehicles, public transport users and other commuters who rely on these transport links each year.

The project has been designed to provide motorway standard connectivity for both east-west journeys between the Northern Beaches and employment centres such as Chatswood and Macquarie Park, and north-south journeys including to and from the Sydney CBD. This is achieved by providing tunnelled connections to and from the Gore Hill Freeway and Warringah Freeway and the Western Harbour Tunnel. This is key to improving travel times for both north–south and east–west road journeys to and from the Northern Beaches, and alleviating congestion on a number of arterial roads in northern Sydney that are used for these journeys, including Military Road, Spit Road, Warringah Road, Boundary Street, and Eastern Valley Way.

The forecast major reductions in traffic volumes on major arterial routes around northern Sydney that are expected due to the project are shown in Figure 3-9. Analysis of the modelled forecast traffic demands across Middle Harbour with the project in 2037 indicates that:

- Peak period traffic demand on Military Road and Spit Road would decrease as a result of the project, by up to 11 per cent and 33 per cent respectively
- Peak period traffic demand on Warringah Road would decrease as a result of the project by up to 23 per cent
- Peak period traffic demand on Mona Vale Road would decrease by up to eight per cent as a result of the project
- Daily traffic demand on Eastern Valley Way would decrease substantially as a result of the project, by up to 40 per cent.

The overall reduction in traffic on the above surface arterial routes would result in improved travel speeds on these routes as a result of the project by 2037. This would deliver improved journey times for freight services, public transport and other road users that continue to use these routes.

Furthermore, reduced congestion on these surface arterial routes is expected to reduce the attractiveness of rat-running on existing surface roads including Eastern Valley Way, Frenchs Forest Road and Ourimbah Road, reducing traffic through surrounding urban and residential areas.

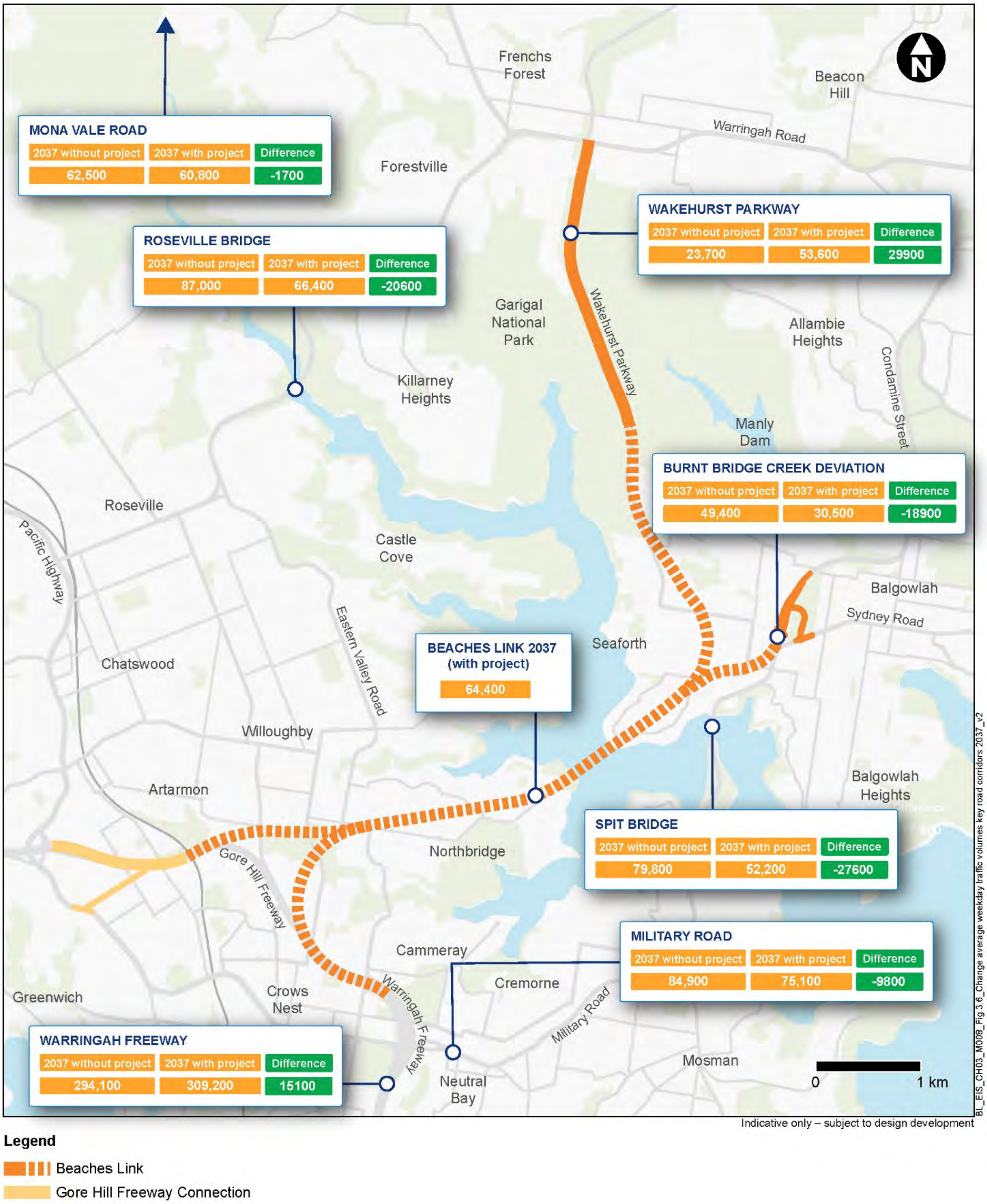


Figure 3-9 Change in average weekday traffic volumes (two-way) on key road corridors by 2037

3.6.2 Creating faster, more reliable journeys for freight services and other road users between the Northern Beaches region and other strategic centres across Greater Sydney

Freight services and private vehicle commuters would benefit from the project through faster and more reliable road journey times between the Northern Beaches region and key centres across Greater Sydney. By connecting the Northern Beaches to the Sydney motorway network, the project would provide faster connections to strategic commercial and industrial centres across Greater Sydney. For example, customers travelling between Frenchs Forest and Macquarie Park would be able to bypass about 20 sets of traffic lights by using the Beaches Link tunnel.

The expected travel time savings for specific journeys in the AM peak are shown in Figure 3-8 which indicates shorter journey times when comparing the 2037 'with program of works' and 'without program of works' cases. Key improvements as a result of the project (in conjunction with the Western Harbour Tunnel and Warringah Freeway Upgrade) would include:

- Journeys from Frenchs Forest to Rozelle would experience a travel time saving of about 31 minutes. This shorter journey time would particularly benefit freight vehicles connecting to the M4-M5 Link at Rozelle
- Journeys to the west, from Manly to Macquarie Park, would experience a travel time saving of about 34 minutes
- Journeys from Balgowlah to North Sydney would experience a travel time saving of about 28 minutes
- Journeys from Dee Why to Kingsford Smith Airport would experience a 27 minute travel time saving.

The above travel time savings would provide the opportunity to investigate new high-quality express bus services to employment centres including Chatswood and Macquarie Park, as well as resulting in improved connectivity to the Sydney Trains network and new Victoria Cross Metro Station at North Sydney.

3.6.3 Creating faster, more reliable travel times and more direct routes for bus journeys between the Northern Beaches, the Harbour CBD and other strategic centres

In addition to the journey time and reliability benefits provided for freight services and private vehicle commuters, the project would unlock considerable improvements for public transport users travelling on some of Sydney's busiest road corridors. The project has been designed to complement and enhance the existing and future public transport network servicing the Northern Beaches region. The project would materially improve the capacity, efficiency and journey time reliability of bus services for the Northern Beaches region and ensure the longer-term success of the B-Line. The project would deliver this by:

- Relieving pressure on surface arterial roads, allowing surface bus routes to operate more efficiently
- Providing an underground bypass route, which would enable express bus services to travel via the tunnel and motorway network to destinations like North Sydney, the Harbour CBD, Macquarie Park and St Leonards, as shown in Figure 3-10. This would result in more rapid and reliable journey times and more direct routes for express bus services, while simultaneously improving the capacity and efficiency of existing surface corridors by reducing conflicts between express and multi-stop services.

The public transport network servicing the Northern Beaches region, including B-Line, is constrained by the performance of the existing surface arterial corridors, particularly the Military Road/Spit Road and Warringah Road/Eastern Valley Way corridors. By relieving pressure on these existing surface arterial road corridors, the project would support the operation of the B-Line as well as local and interregional buses, by improving travel times and travel time reliability on these roads as a result of reduced traffic demand and congestion. Improvements in the capacity of the road network would encourage opportunities for new express bus services, as evidenced by the new rapid bus service from Dee Why to Chatswood which is currently being planned, which would benefit from reduced congestion on the Warringah Road corridor.

By reducing network congestion, and therefore improving network resilience and reliability, particularly in peak periods, the project would make bus routes to and from the Northern Beaches a more attractive transport option, supporting and encouraging a mode shift to public transport. New and improved bus priority infrastructure, dedicated bus bays and shared user underpasses offering access to bus stops that would be provided by the project would also improve efficiency and safety for road users and bus passengers.

By providing a new underground bypass route, the project offers the opportunity for express bus services in the Beaches Link tunnel between the Northern Beaches and strategic centres such as North Sydney, Sydney CBD, Macquarie Park and St Leonards via the new motorway network. These bus services would provide links to strategic stations on the Sydney Trains network, while also facilitating efficient access and interchange with the new Victoria Cross Metro Station at North Sydney, improving connectivity across the broader public transport network. Expansion of express bus services to take advantage of these opportunities would greatly improve the journey times, travel time reliability and connectivity for public transport services both within the Northern Beaches, and between the region and key centres across Greater Sydney.

The potential benefits outlined above only account for the diversion of express bus services to the Beaches Link tunnel and motorway network and improved surface conditions along existing key routes, meaning it is a conservative estimate of the overall public transport benefits and opportunities delivered by the project. It is expected that the bus network could be re-optimised to take advantage of broader opportunities (including provision of new services) unlocked by the project. The project would enable these opportunities for new services to be developed in response to diverse travel demands and future development.

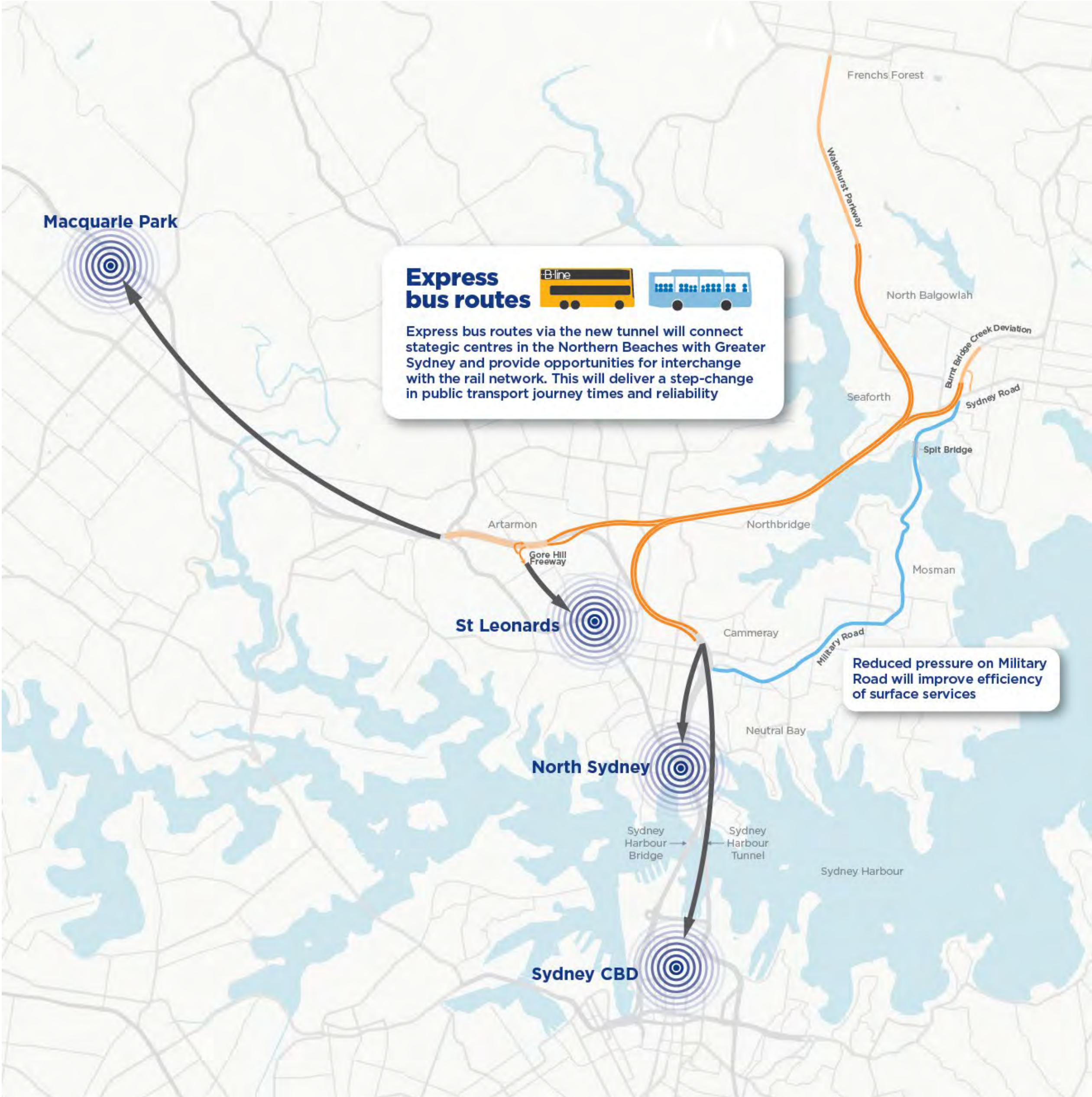


Figure 3-10 Express bus routes and connections to strategic centres

3.6.4 Improving productivity and enabling greater access to jobs and services for northern Sydney businesses and residents

The project would deliver labour supply benefits, including higher employment and better matching of skills and jobs, by improving accessibility. For workers, this is demonstrated by improved accessibility to employment. Once the project is operational, residents of the Northern Beaches and lower North Shore would enjoy improved access to jobs in other parts of Greater Sydney, in particular to jobs in the Harbour CBD and North Sydney CBD.

Given the contribution of the Harbour CBD to New South Wales' gross state product, supporting the future growth and productivity of the Eastern Economic Corridor by enabling greater business-to-business connections would deliver substantial benefits for NSW and the national economy.

Forecast 30-minute catchments by road for strategic centres in the vicinity of the project are provided in Figure 3-11, Figure 3-12 and Figure 3-13. These figures indicate that the project would result in the employment centres of North Sydney and Chatswood being much more accessible for workers residing in the Northern Beaches region, including Manly and Dee Why.

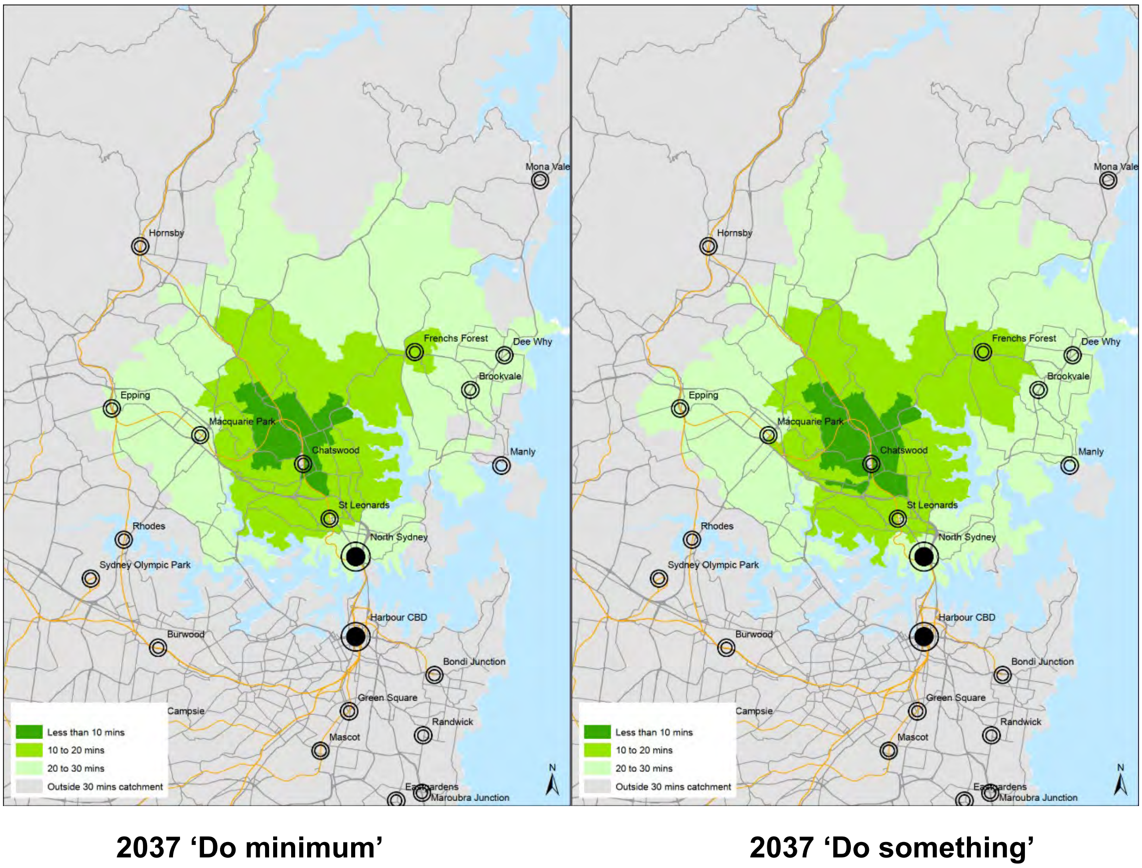


Figure 3-11 Modelled 2037 'Do something' morning peak 30-minute catchment by road from Chatswood

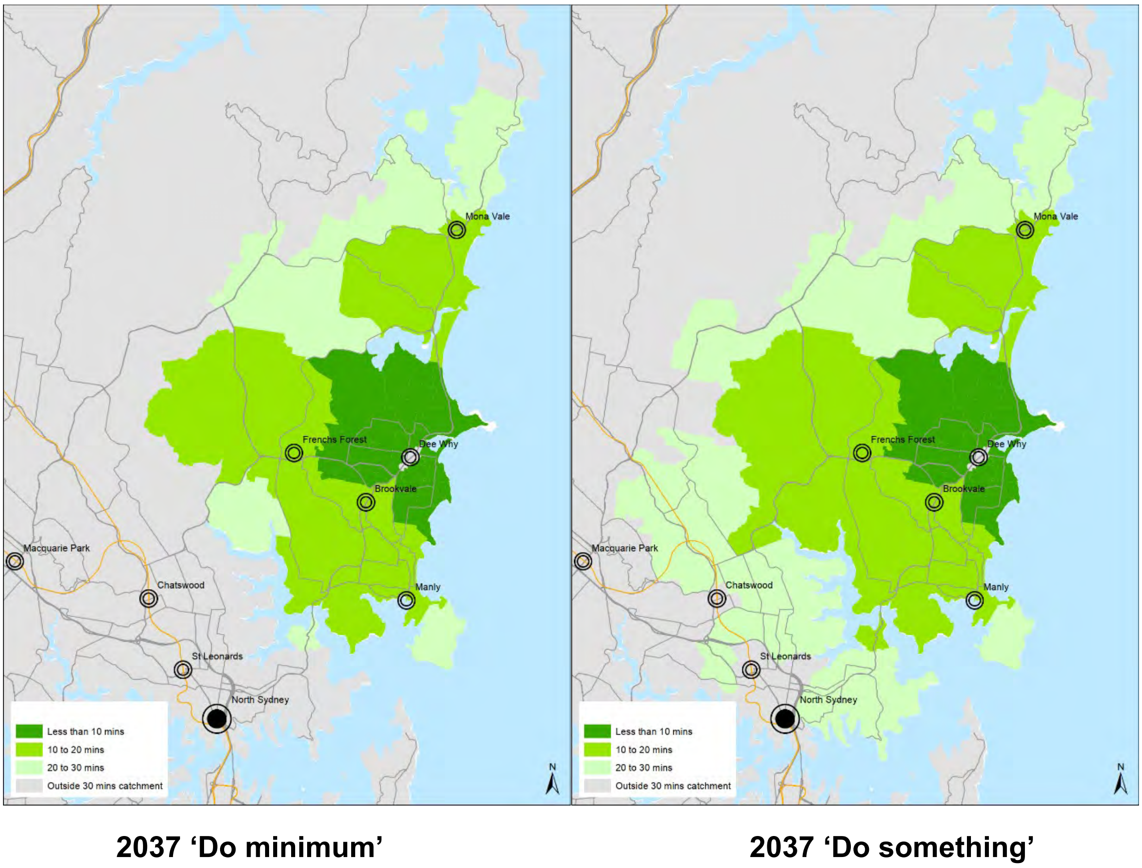
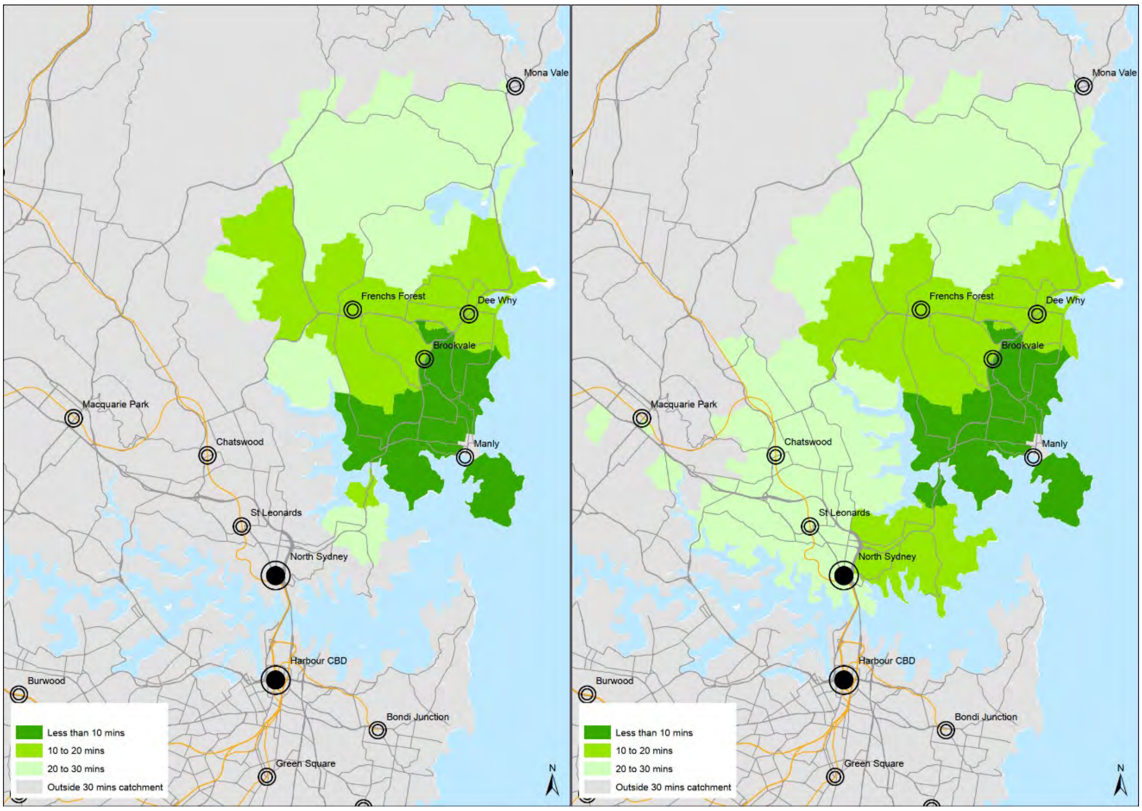


Figure 3-12 Modelled 2037 'Do something' morning peak 30-minute catchment by road from Brookvale-Dee Why



2037 'Do minimum' **2037 'Do something'**

Figure 3-13 Modelled 2037 'Do something' morning peak 30-minute catchment by road from Manly

3.6.5 Increasing the resilience of the Northern Beaches transport network

The limited number of arterial road corridors, such as the Military Road/Spit Road corridor, connecting to the Northern Beaches means that the North District transport network lacks resilience, with incidents on these corridors impacting the performance across the wider transport network.

The project would boost the resilience of the Eastern Harbour City by providing a new underground motorway bypass of the Military Road/Spit Road and Warringah Road/Eastern Valley Way corridors. This would improve the ability of the arterial network servicing the Northern Beaches and North Shore regions to cope with traffic incidents by:

- Substantially increasing capacity
- Providing a new alternate bypass route for many trips currently reliant on the Military Road/Spit Road and Warringah Road/Eastern Valley Way corridors
- Reducing pressure on the existing surface arterial roads, leaving them better placed to accommodate minor incidents without major deterioration or failure.

The resilience benefit resulting from the project is estimated to be $89 million per year (present value). This benefit reflects the travel time and vehicle operating cost savings that would be derived by providing an additional transport route, which would limit the impacts of an incident on the Military Road/Spit Road corridor alone.

3.6.6 Improving urban amenity and safety in local centres

The *Future Transport Strategy 2056* identifies ‘Successful Places’ as one of the six outcomes for NSW and sets out a vision for better balancing ‘movement and place’ needs, particularly in major centres such as the Sydney CBD (NSW Government, 2018). Certain roads in and around the Harbour CBD and Northern Beaches perform important ‘place’ functions, meaning they are destinations in their own right, such as shopping or dining precincts. However, some of these places are adversely affected by amenity issues linked to the performance of the road network, including Military Road and Spit Road (The Spit to Neutral Bay) and some streets in the Sydney CBD.

By providing additional motorway capacity and bypassing communities underground, the project would reduce through traffic volumes in many areas. This would result in reduced noise and improved amenity in these areas. The project would facilitate improvements to urban amenity in the Harbour CBD and Northern Beaches by reducing through traffic in a number of urban areas and by reducing pressure on arterial roads. Specific benefits would include:

- Diversion of through-traffic from Military Road and Spit Road, improving the amenity of local town centres along the corridor, including Mosman, Cremorne and Neutral Bay
- Reduced rat-running on local streets including Ourimbah Road
- Reduced through traffic on Eastern Valley Way and down through Willoughby, Naremburn, Cammeray and Northbridge
- Reduced traffic within Seaforth town centre (due to traffic using the Wakehurst Parkway to access the Spit Bridge).

The project would also provide several new or upgraded shared user paths and underpasses in the Balgowlah, Killarney Heights and Frenchs Forest areas (refer to Chapter 5 (Project description)). These facilities would support safer and easier access for pedestrians and cyclists, helping to encourage increased walking and cycling.

In addition, the project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities at Balgowlah. A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council will take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation will be separate to the consultation for the environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting. As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space. Opportunities for new public open space are discussed further in Chapter 5 (Project description).

3.7 Strategic planning and policy framework

The project has been developed to align with the objectives of a number of strategic plans for transport, freight, and city planning that have been prepared at a national and State level. Table 3-2 provides an overview of relevant strategic plans, policies and strategies and their relationship to the project.

Table 3-2 Strategic planning and policy framework

Policy	Description
Australian Infrastructure Plan	The *Australian Infrastructure Plan: Priorities and Reforms for Our Nation's Future* (Infrastructure Australia, 2016) identifies priority infrastructure investments that Australia needs over the next 15 years. The *Infrastructure Priority List* (Infrastructure Australia, 2018) is a reference point for Australia's most important infrastructure investment needs and currently identifies 100 major infrastructure projects and initiatives. The projects and initiatives have been assessed by Infrastructure Australia for their economic viability, deliverability and strategic compliance with the principles detailed in the *Australian Infrastructure Plan*. The *Infrastructure Priority List* identifies the Western Harbour Tunnel and Beaches Link program of works as a priority initiative in recognition of its importance in addressing urban congestion on Sydney's arterial road network, augmenting critical cross-harbour capacity and Northern Beaches connectivity. This aligns with the Australian Infrastructure Audit's identification of road corridors to the Northern Beaches and across Sydney Harbour as among the top 30 most congested corridors in Australia.
NSW State Priorities	The NSW Government set out 18 State priorities to create a stronger, healthier and safer NSW (NSW Government, 2015). State priorities include improving road travel reliability, with a target of ensuring that 90 per cent of peak travel on key road routes is on time. The project would contribute to achieving a number of these priorities including: • **Encouraging business investment** – by improving east–west and north–south connectivity, and reducing congestion around the Eastern Harbour City, more people would be able to access key employment centres such as Chatswood and Macquarie Park and strategic centres in the Northern Beaches in less time. Freight transport would also benefit from improved cross-harbour connectivity • **Improving road travel reliability** – by delivering travel time savings for freight services, public transport and other road users, and improving the resilience and efficiency of the existing road network • **Reducing road fatalities** – by providing a free-flowing cross-harbour alternative for through traffic, reducing traffic on surface roads and improving traffic flows, which is correlated with a lower number of road incidents.
State Infrastructure Strategy	The *State Infrastructure Strategy 2018-2038* (Infrastructure NSW, 2018) is a 20 year strategy which identifies and prioritises the delivery of critical public infrastructure to drive productivity and economic growth. The *State Infrastructure Strategy 2018-2038* identified the Beaches Link as a near-term priority for the Sydney motorway network to provide an alternative to the Military Road/Spit Road corridor and bypass the Spit Bridge. The NSW Government is committed to commencing work on a new crossing of Middle Harbour. The Beaches Link and Gore Hill Freeway Connection project, as part of the Western Harbour Tunnel and Beaches Link program of works, is the result of that commitment. The *NSW Infrastructure Pipeline* (Infrastructure NSW, 2017) was prepared by Infrastructure NSW to outline infrastructure proposals under development by the NSW Government. This includes the opportunity to develop the Beaches Link and Gore Hill Freeway Connection project.

Policy	Description
Future Transport Strategy 2056	The *Future Transport Strategy 2056* (NSW Government, 2018) builds on the *NSW Long Term Transport Master Plan* (Transport for NSW, 2012a) and sets the 40-year vision, strategic directions and outcomes for customer mobility in NSW. *Future Transport Strategy 2056* identifies the transport challenges that will need to be addressed to support NSW's economic and social performance over the next 20 years and establishes a number of short, medium and long-term actions to address those challenges. These actions provide the overall framework for how the NSW transport system should develop, in terms of services and infrastructure. The *Greater Sydney Services and Infrastructure Plan* forms part of the *Future Transport Strategy 2056*. Building on the state-wide transport outcomes identified in the *Future Transport Strategy2056*, the *Greater Sydney Services and Infrastructure Plan* establishes the specific outcomes that transport customers in Greater Sydney can expect and identifies the policy, service and infrastructure initiatives to achieve these. The *Greater Sydney Services and Infrastructure Plan* identifies the Western Harbour Tunnel and Beaches Link program of works as a committed services and infrastructure initiative and a city shaping transport corridor. In addition, the *Future Transport Strategy 2056* identifies 'Successful Places' as one of the six outcomes for NSW, and sets out a vision for better balancing 'movement and place' needs, particularly in major centres such as the Sydney CBD. The Western Harbour Tunnel and Beaches Link program of works is identified in the *Future Transport Strategy 2056* as a 'Committed' project (within the next ten years, subject to final business case) forming part of the vision for the future strategic road network for Greater Sydney that would support key movements by road, including freight, public transport and private vehicles.
Greater Sydney Region Plan	The *Greater Sydney Region Plan – A Metropolis of Three Cities* (Greater Sydney Commission, 2018a) is built on a vision of three cities where most residents live within 30 minutes of their jobs, education and health facilities, and services. To meet the needs of a growing and changing population, the vision seeks to transform Greater Sydney into a metropolis of three liveable, productive and sustainable cities: the Western Parkland City, Central River City and Eastern Harbour City. The project is located in the Eastern Harbour City and contains Australia's global gateway (Sydney Airport and Port Botany) and financial capital, the Harbour CBD, as its metropolitan centre. One of the key roles of the *Greater Sydney Region Plan* is to provide appropriate infrastructure in the right places to support the continued growth of Greater Sydney. The *Greater Sydney Region Plan* also identifies the importance of investing in and delivering efficient and effective transport systems including road infrastructure that would improve business to business connections and support the 30-minute city vision. Objective 18 of the *Greater Sydney Region Plan* references the Western Harbour Tunnel and Beaches Link program of works as infrastructure that would further improve accessibility from the Northern Beaches to the Harbour CBD and reduce through traffic in the Harbour CBD ensuring the economic strength and global competitiveness of the Harbour CBD. As part of the *Greater Sydney Region Plan*, the Greater Sydney Commission also prepared District Plans which provide a basis for strategic planning at a district level. The District Plan relevant to the project is discussed below.

Policy	Description
North District Plan	The *North District Plan* (Greater Sydney Commission, 2018b) sets out priorities and actions for Greater Sydney's North District, which includes the project-based local government areas of the Northern Beaches, North Sydney and Willoughby. The *North District Plan* addresses issues influencing Greater Sydney to 2056 with one of the overarching priorities for a productive North District including improved access to local jobs, goods and services within 30 minutes. The *North District Plan* includes the Western Harbour Tunnel and Beaches Link program of works as a transport initiative that would provide improved connections and access for the Northern Beaches and North Shore regions.
Directions for a Greater Sydney	*Directions for a Greater Sydney 2017-2056* (Greater Sydney Commission, 2017) aims to better integrate land use and infrastructure in Greater Sydney to accommodate a population that will grow from five to eight million people over the next 40 years. It builds upon the *Greater Sydney Region Plan – A Metropolis of Three Cities* (Greater Sydney Commission, 2018a) and *Towards our Greater Sydney 2056* (Greater Sydney Commission, 2016). The project would support this vision by improving road network performance, resilience and efficiency, enabling sustained growth and productivity across Greater Sydney. The project would also improve access to the strategic centres of North Sydney, Sydney CBD, Macquarie Park and St Leonards, resulting in more people having access to jobs and services.
NSW Freight and Ports Plan	The *NSW Freight and Ports Plan* (Transport for NSW, 2018) supports the *Future Transport Strategy 2056* and provides direction to business and industry for managing and investing in freight into the future. The project in conjunction with the Western Harbour Tunnel and Warringah Freeway Upgrade and M4-M5 Link would benefit the freight industry by providing a western bypass of the Harbour CBD, greatly improving the quality of the freight connection through the Eastern Economic Corridor. The project would address key priority areas in the *NSW Freight and Ports Plan* such as strengthening the freight industry, increasing access for freight across the road and rail network, protecting existing freight precincts and ensuring safe, efficient and suitable freight access would meet the needs of Greater Sydney.

Additional relevant local government strategic plans and their relationship to the project are outlined in Table 3-3.

Table 3-3 Local strategic plans

Policy	Description
North Sydney Integrated Transport Program	The North Sydney Integrated Transport Program (the North Sydney Program) is an ongoing multi-agency collaboration between Transport for NSW, North Sydney Council, Greater Sydney Commission and the Government Architect of NSW, to guide future integrated transport planning and investment in the North Sydney CBD and interconnected areas. Led by Transport for NSW since 2018, it aims to deliver a shared place-based vision for the North Sydney CBD. A key focus of the North Sydney Program is to ensure major projects, such as the Western Harbour Tunnel and Beaches Link program of works, integrate with the North Sydney CBD in a manner that supports the globally connected 'Harbour CBD' and enables delivery of befitting place-based outcomes. Transport for NSW would continue to work with North Sydney Council and key stakeholders through agreed governance structures to investigate options to improve

Policy	Description
	movement and place outcomes within North Sydney, further leveraging the strategic benefits of the program of works. Community consultation would also be carried out. Issues raised by the community would be considered in any final decision to refine the project.
Northern Beaches Council: Towards 2040	*Towards 2040* (Northern Beaches Council, 2020) is Northern Beaches Council's local strategic planning statement which guides planning for the Northern Beaches over the next 20 years. Along with the 20 year vision, *Towards 2040* includes planning priorities and options to guide local land use and planning along with measures of success to determine whether priorities have been achieved. *Towards 2040* aligns with the *North District Plan* and *Greater Sydney Region Plan* and acts as the bridge between strategic land use planning at the district level and local statutory planning. *Towards 2040* outlines the strategic importance that the implementation of the Beaches Link has for the Northern Beaches region and identifies the need for infrastructure to be delivered with predicted employment and housing growth within the Northern Beaches Council area.
Mosman Local Strategic Planning Statement	The *Mosman Local Strategic Planning Statement* (Mosman Council, 2020) (LSPS) sets out Mosman Council's 20-year vision for land use planning in Mosman, along with a suite of planning priorities and actions relating to housing, local centres, infrastructure and the environment. The LSPS identifies reimagining the Military Road/Spit Road corridor to improve function, amenity and accessibility in response to the Western Harbour Tunnel and Beaches Link program of works as a planning priority. The LSPS also acknowledges that poor road capacity on Military and Spit Roads presents a barrier to future growth, limiting future opportunities for Mosman, while noting the Western Harbour Tunnel and Beaches Link program of works would result in traffic reduction along this corridor. The LSPS identifies an action of supporting the construction of the Western Harbour Tunnel and Beaches Link program of works as a key method of achieving the planning priority of ensuring that Mosman is supported by infrastructure.
Military Road Corridor Planning Study	North Sydney Council is currently finalising the preparation of the *Military Road Corridor Planning Study* (North Sydney Council, 2020) in response to strong development interest along Military Road. The project would support the objectives outlined in the *Military Road Corridor Planning Study* through reducing traffic volumes and congestion along the Military Road/Spit Road corridor, enhancing the connectivity and amenity of Military Road.

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 4

Project development and alternatives

4 Project development and alternatives

This chapter describes the alternatives that were considered as part of the project development process and explains the selection of the preferred alternative. The preferred alternatives presented in this chapter are based on technical, environmental and planning considerations. Stakeholder and community considerations which have been incorporated into the project development process are outlined in Chapter 7 (Stakeholder and community engagement). Design refinements for particular elements of the project are also outlined.

The Secretary's environmental assessment requirements as they relate to the project development and alternatives, and where in the environmental impact statement these have been addressed, are detailed in Table 4-1.

Table 4-1 Secretary's environmental assessment requirements – Project development and alternatives

Secretary's requirement	Where addressed in EIS
Environmental impact statement	
1. The EIS must include, but not necessarily be limited to, the following: e. an analysis of any feasible alternatives to the project;	An analysis of strategic alternatives is provided in **Section 4.3**.
f. a description of feasible options within the project, including: - alternative methods considered for the construction of the project, including the tunnels; and - staging of the proposal;	Alternative construction methods are detailed in **Section 4.5.1**. Further detail on staging is included in **Chapter 6** (Construction work).
g. a description of how alternatives to and options within the project were analysed to inform the selection of the preferred alternative/option. The description must contain sufficient detail to enable an understanding of why the preferred alternative to and options(s) within, the project were selected, including: - details of the alternative construction methods that were considered for tunnel construction, particularly those areas spanning Sydney Harbour (Middle) Harbour; - details of the short-listed route and tunnel options considered, and the criteria that was considered in the selection of the preferred route and tunnel design; - the alternative tunnel design and ventilation options considered to meet the air quality criteria for the proposal; and - a justification for the preferred proposal taking into consideration the objects of the *Environmental Planning and Assessment Act 1979;*	The assessment of route alternatives is detailed in **Section 4.4** and construction alternatives in **Section 4.5**. Alternative tunnel construction methods and ventilation system designs considered are discussed in **Section 4.5.1** and **Section 4.5.6** respectively. A description of the benefits of the overall program of works and the justification for the project is provided in **Chapter 3** (Strategic context and project need). Justification for the preferred proposal taking into consideration the objects of the *Environmental Planning and Assessment Act 1979* is presented in **Chapter 28** (Synthesis of the environmental impact statement).

Secretary's requirement	Where addressed in EIS
i. a demonstration of how the project design has been developed to avoid or minimise likely adverse impacts during construction and operation of the project;	Project design development is detailed in **Section 4.4** and **Section 4.5**, and **Chapter 5** (Project description).

4.1 Overview

The project has undergone extensive evaluation of alternatives from pre-feasibility and strategic investigations through to design development and refinement, as outlined in Figure 4-1.

Figure 4-1 Alternatives development process

4.2 Historical context

Middle Harbour is a natural feature fundamental to the liveability and amenity of the Northern Beaches area. However, this waterway has historically presented a substantial challenge to the region's transport network, constraining north-south and east-west journeys to and from the Northern Beaches to limited corridors utilising only two waterway crossings being the Roseville Bridge and the Spit Bridge.

Addressing this transport challenge has been considered since the late 1930s, when a plan for a new road crossing of Middle Harbour, supported by an additional western crossing of Sydney Harbour, was first considered.

While the nature and shape of the city has changed considerably since the 1930s, the fundamental transport challenge for freight services, public transport, and other road users presented by Middle Harbour remains. Advancements in tunnelling technology coupled with the plan for investment in additional crossing capacity at Sydney Harbour have also worked to overcome many of the community and technical challenges associated with the original surface road proposal.

A timeline for the historical development of the Warringah Transport Corridor and additional cross harbour capacity as precursors to the Western Harbour Tunnel and Beaches Link program of works is provided in Figure 4-2.

1924

The (first) Spit Bridge was completed and opened, replacing the existing punt service at Middle Harbour.

1930s

Plans were developed for a new Warringah Transport Corridor, including an additional harbour crossing, to the Northern Beaches.

1948

Plans for the Warringah Transport Corridor were first formally documented as the 'County Road Reservation' in the County of Cumberland Planning Scheme, which was formally adopted by the Cumberland County Council in 1948. This scheme showed a proposed surface road route crossing Middle Harbour at Bluff Head (Northbridge).

1949

In 1949, the Department of Main Roads' *Main Road Development Plan* presented alternative alignments for the Warringah Transport Corridor, one option crossing Middle Harbour at Bluff Head (Northbridge) and another at Sugarloaf Point (Castlecrag). Both options included connectivity between Wakehurst Parkway and the future Burnt Bridge Creek Deviation.

1951

The scheme alignment was prescribed in 1951, dropping the Bluff Head (Northbridge) option in favour of the alignment via Sugarloaf Point (Castlecrag).

1953

The prescribed scheme alignment, as set out in the *Main Road Development Plan*, was later confirmed by the Cumberland County Council's County Road Reservation in 1953, forming part of an inner ring-road extending through a second harbour crossing (Greenwich – Birchgrove).

1960 – 1970

The prescribed scheme was adopted by the planning systems of Warringah, Manly and Willoughby Councils when they were prescribed in 1963, 1968 and 1970 respectively.

1974

The Sydney Area Transportation Study recommended that the Warringah Freeway be part of the long term road network in Sydney.

1977

Following a decision by the State Government (Labour) to drop the proposal to construct an expressway along the Warringah Transport Corridor, the County Road Reservations for the scheme were removed from the planning systems of Warringah, Manly and Willoughby counties in 1977.

1981

The Warringah Transport Corridor Inquiry starts, considering the proposal for the corridor to extend from the Warringah Freeway, across Middle Harbour at Castlecrag, to Seaforth and Balgowlah.

1983

The Commission of Inquiry into the Warringah Transport Corridor found that a new surface road to the Northern Beaches in the identified corridor would result in unacceptable levels of community and environmental impacts. The Inquiry noted that the feasibility of the proposal would be improved by future tunnelling technology alleviating some of the potential environmental and community impacts.

1990 - 2010

Various government proposed feasibility studies were undertaken to widen or duplicate the Spit Bridge or duplicate the Middle Harbour crossing with a tunnel. All these proposals were ultimately not pursued at the time.

2012

The NSW Government's *NSW Long Term Transport Master Plan* (Transport for NSW, 2012) proposed a new harbour crossing to the west of the CBD identifying it as a key 'missing link' in the Sydney motorway network. It also proposed a bus tunnel bypassing Military Road.

2014

Commitments were made in the *NSW State Infrastructure Strategy Update 2014* (Infrastructure NSW, 2014) that the Government would commence work on an additional harbour crossing and would further review and develop Beaches Link.

2015 - 2020

Northern Beaches Hospital road upgrade project is carried out to enhance the road network surrounding the Northern Beaches Hospital at Frenchs Forest. Surface road works along the Wakehurst Parkway would integrate Beaches Link with road network upgrades completed as part of the Northern Beaches Hospital road upgrade project at Frenchs Forest.

2015

Transport for NSW commence development of the B-Line program, to provide more frequent and reliable bus services between the Northern Beaches and Sydney CBD. Beaches Link would provide opportunity for express bus services and reduce pressure on Military Road for existing services.

2015 - 2016

Roads and Maritime carried out preliminary work to establish the viability and high level conceptual design for the Western Harbour Tunnel and Beaches Link program of work.

2016

The draft *North District Plan* (Greater Sydney Commission, 2017b) and draft *Eastern City District Plan* (Greater Sydney Commission, 2017a) released by the Greater Sydney Commission identified the Western Harbour Tunnel and Beaches Link program of works as important initiatives to improve connections and access to and from northern Sydney.

2017

In March 2017, the NSW Government announced the commencement of a community engagement program to inform the development of designs for the Western Harbour Tunnel and Beaches Link program of works, including an additional harbour crossing. Roads and Maritime commences community and stakeholder engagement, preliminary environmental investigations and further design development for the program of works.

2017

The draft *Future Transport 2056 strategy* (NSW Government, 2017) was released which builds on the *NSW Long Term Transport Masterplan*. The Western Harbour Tunnel and Beaches Link program of works is identified in the strategy as a 'Committed' project (ie within the next 0-10 years, subject to final business case).

2018

The *Future Transport Strategy 2056* (NSW Government, 2018), the *NSW State Infrastructure Strategy 2018-2038* (Infrastructure NSW, 2018), the *Greater Sydney Region Plan - A Metropolis of Three Cities* (Greater Sydney Commission, 2018a) and the *North District Plan* (Greater Sydney Commission, 2018b) and the *Eastern City District Plan* (Greater Sydney Commission, 2018c) released. These strategies reference the Western Harbour Tunnel and Beaches Link projects as a transport initiative that will improve connections and accessibility across Sydney.

Figure 4-2 Historical development of additional cross-harbour capacity

4.3 Strategic alternatives

The project aims to provide additional transport capacity across Middle Harbour to improve journey times and journey time reliability for trips between the Northern Beaches and key economic and employment centres. Further information on the strategic context for the project, and the transport needs addressed, is provided in Chapter 3 (Strategic context and project need).

The *NSW Long Term Transport Master Plan* (Transport for NSW, 2012a) and subsequent *Future Transport Strategy 2056* (NSW Government, 2018) set the 40 year vision, strategic directions and outcomes for customer mobility in NSW. These plans identify the transport challenges that would need to be addressed to support NSW's economic and social performance and establish a number of short, medium and long-term actions to address those challenges.

Giving consideration to future land use, population density and transport requirements, both of these strategic plans identified road based transport, including improvements to bus services, as important modes to meet the needs of the Northern Beaches region. Furthermore, the need for additional core motorway capacity at the crossings of Middle Harbour and Sydney Harbour was identified as key to development of an appropriate multi-modal Sydney transport network – and specifically identified the Western Harbour Tunnel and Beaches Link program of works as transport projects required to support the plan.

The Greater Sydney Commission's *Greater Sydney Region Plan – A Metropolis of Three Cities* (Greater Sydney Commission, 2018a) describes the Northern Beaches region as having a very low population growth rate coupled with a low density urban environment. This makes high capacity and high frequency transport options less appropriate for this region. A more appropriate solution is strategic improvement to road based modes, which would also facilitate substantial improvements to express bus service connections between the Northern Beaches and strategic centres including North Sydney, Sydney Central Business District (CBD), Macquarie Park and St Leonards.

Considering the identified requirements of the *NSW Long Term Transport Master Plan* (Transport for NSW, 2012a) and the *Future Transport Strategy 2056* (NSW Government, 2018), a number of strategic alternatives were considered for delivering the required road capacity, as follows:

- Do nothing
- Travel demand management
- Improvements to the existing arterial road network
- A new motorway crossing of Middle Harbour (the project)
- Improvements to alternative transport modes.

These strategic alternatives are described and evaluated in the following sections.

4.3.1 Do nothing

This alternative is to do nothing to the existing crossings of Middle Harbour and the adjoining motorway network and rely on the continued operation of existing transport networks and other transport projects currently proposed to meet future transport demands.

The limited number of existing arterial road connections to the region, including the Military Road/Spit Road, Mona Vale Road and Warringah Road/Eastern Valley Way corridors, currently experience high levels of congestion – particularly during peak periods. This congestion adversely affects travel times, travel time reliability, economic productivity and local amenity.

Excluding the Manly ferry link, bus services are the only mode of public transport for the Northern Beaches region, accounting for about 53 per cent of journeys to the Sydney CBD. However, the performance of bus services to and from the Northern Beaches region, particularly during peak periods, is constrained as a consequence of congestion on the Military Road/Spit Road and Warringah Road/Eastern Valley Way corridors that connect the Northern Beaches to strategic centres across Greater Sydney. The implementation of B-Line services in 2017 has resulted in faster and more reliable journey times between Mona Vale and the Sydney CBD, with travel times reduced by about 20 minutes for passengers using the service during peak periods. Nevertheless, without measures to relieve pressure on the surface arterial road network, the capacity of Military Road/Spit Road would place pressure on the effectiveness of B-Line and other express bus services in the future, while also limiting opportunities to develop new express bus services. Capacity constraints on the Warringah Road/Eastern Valley Way corridor would also place pressure on the effectiveness of a new rapid bus service between Chatswood and Dee Why which is currently being planned. Further detail on these transport challenges is provided in Chapter 3 (Strategic context and project need).

As well as hindering daily access for residents, businesses and public transport users, the capacity and geometry of the limited arterial corridors servicing the Northern Beaches region restricts freight connectivity to the Northern Beaches. Vehicles over 19 metres are currently prohibited from using the Military Road/Spit Road corridor and the eastern portion of Warringah Road. For these larger vehicles, journeys to areas such as Dee Why and Brookvale via Mona Vale Road and Pittwater Road can be up to 20 kilometres longer in each direction than the most direct road route.

The do nothing alternative has been rejected as an undesirable strategic alternative because it would not address the identified project need. For example, future traffic modelling (refer to Chapter 9 (Operational traffic and transport)) indicates that without the project, this alternative would be unable to accommodate forecast growth during the peak periods without substantial and unacceptable delays across the Sydney road network. Without the additional capacity for trips into and out of the Northern Beaches that would be provided by the project, accessibility to and from the Northern Beaches would become substantially restricted in the future. Overall, by 2037 in the do-nothing scenario, traffic growth on the road network would result in travel time increases for road users that would make many nearby strategic centres no longer accessible within a 30 minute trip. For example, trips between Frenchs Forest and Balgowlah and North Sydney which currently take about 30 minutes would increase to 50 minutes and 45 minutes respectively by 2037 in the do nothing scenario. This growth in traffic volumes would also result in longer travel times for public transport, with delays to bus services attributed to increased queuing on key bus route corridors between the Northern Beaches region and the North Sydney and Sydney CBDs. The do nothing alternative would adversely impact on:

- Travel time and travel time reliability for freight services, public transport and other road users
- Public transport performance and connectivity for the region, with limited opportunity to deliver new and improved express bus services
- Amenity and environment for local communities, including air quality, noise, visual and traffic related impacts resulting from traffic congestion
- Economic performance of the region, particularly with regard to ongoing congestion costs and access to jobs and services.

These impacts would result in a reduction in the region’s productivity and amenity, and Sydney’s performance as a global city.

4.3.2 Travel demand management

Travel demand management is a measure that focuses on minimising or avoiding the need to invest in new motorway infrastructure, such as the project, by reducing individual trip lengths, reducing peak traffic volumes and making alternative transport mode options more viable. Demand management initiatives may include:

- Land use planning policies which promote urban consolidation and the establishment of town ‘centres’ to reduce the need for travel. For example, the *NSW Long Term Transport Master Plan* (Transport for NSW, 2012a), *Future Transport Strategy 2056* (NSW Government, 2018), *Greater Sydney Regional Plan: A Metropolis of Three Cities* (Greater Sydney Commission, 2018a) and *Northern Beaches Transport Action Plan* (Transport for NSW, 2016) aim to bring jobs closer to homes and to areas of increasing population, where feasible

- Augmenting existing public transport and integrating urban regeneration around transport nodes
- Implementing policies which restrict parking provisions in new developments to encourage alternative modes of transport
- Road use charges – such as the congestion charging applied for vehicles accessing central London
- Flexible working arrangements to reduce the number of trips during peak hours.

Sydney's population is forecast to grow from five million to eight million people over the next 40 years. Given the current road network servicing the Northern Beaches is already highly congested, even with considerably reduced per-capita travel demand through demand management and improvements to public transport, an expanded road network would be required to accommodate population growth.

Further, to have a major impact on road traffic, travel demand management measures would require considerable changes in social attitudes, travel behaviour and government policy and can take many years to achieve. Travel demand management changes alone are therefore not a viable strategic alternative to the project. They are, however, viewed as complementary initiatives, together with the project, to reduce the level of congestion on Sydney's road network as the city's population grows.

4.3.3 Improvements to the existing arterial road network

Improvements to the existing arterial road network to provide additional transport capacity from the lower North Shore to the Northern Beaches have been considered.

Options to provide additional capacity without major widening schemes have included investigations into various operational changes to the Military Road/Spit Road corridor, including tidal flow, peak period parking restrictions, introduction of bus lanes and T3 lanes and reductions in Spit Bridge opening times. Given the conflicts with existing signalised intersections, such initiatives only provide minor and short-term benefits.

Ways to increase road capacity across Middle Harbour have been considered for many years (refer to Section 4.2). Aside from the challenges associated with augmenting the existing aging structure, increasing capacity across the Spit Bridge would deliver limited benefit to the Military Road/Spit Road corridor without large investment in widening and reprioritisation schemes along the entire corridor from Mosman through to the Warringah Freeway.

The scale of surface solutions required to provide meaningful improved travel times along the existing surface arterial routes would result in unreasonable amounts of land acquisition and environmental and social impact. These works would heavily impact business and communities along the entire route during construction and operation. Users of the existing surface corridors would also be considerably impacted during construction of these upgrades.

Accordingly, substantial new improvements to the existing arterial road network connecting to the Northern Beaches have been rejected as a strategic alternative.

Transport for NSW has an extensive program of upgrades to the existing road infrastructure across Sydney to address congestion and improve travel times. Information on these projects can be found on the Transport for NSW website (https://www.transport.nsw.gov.au/projects/current-projects). These projects are considered complementary because they would improve the capacity of Sydney's existing motorway and arterial road network, but they would not provide the necessary additional transport capacity between the Northern Beaches and other key centres (refer to Chapter 3 (Strategic context and project need) for additional details on this function).

4.3.4 A new motorway crossing of Middle Harbour

Options for a motorway connection to the Northern Beaches requiring a new bridge over Middle Harbour have been discussed since the 1930s when a new surface road corridor was contemplated in the Cumberland Plan. The concept of building a surface motorway was abandoned some 40 years ago, with the principal concerns being the environmental and community impacts of a surface alignment, and the limited benefits offered given the downstream capacity constraint at the Sydney Harbour crossing. At this time, tunnelling technology was not sufficiently advanced to allow a road tunnel to be cost-effectively implemented.

The release of the *NSW Long Term Transport Master Plan* (Transport for NSW, 2012a) and *State Infrastructure Strategy Update 2014* (Infrastructure NSW, 2014) confirmed new motorway crossings of Sydney Harbour and Middle Harbour as transport priorities for the city and State.

In combination with the Western Harbour Tunnel and Warringah Freeway Upgrade project, a new motorway crossing of Middle Harbour would address the project need by:

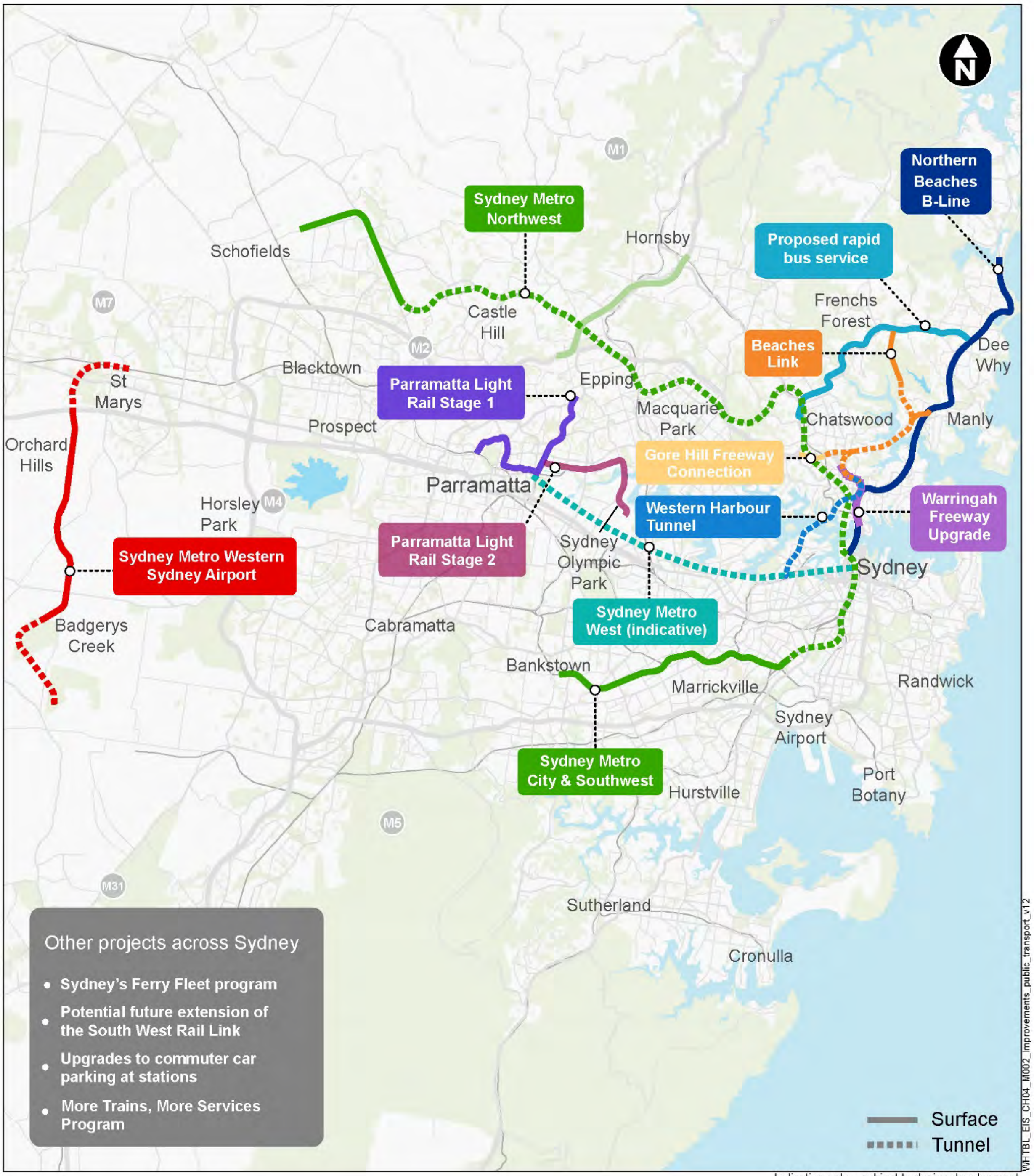
- Providing a new, safer, more efficient and reliable motorway link for freight services, public transport and other road users travelling between the Northern Beaches and strategic centres across Greater Sydney
- Increasing arterial road network capacity between the Northern Beaches region and strategic centres across Greater Sydney by 60 per cent - reducing pressure and congestion on existing arterial routes that run over capacity during peak periods
- Delivering travel time savings and travel time reliability benefits for users of existing surface routes, including freight delivery and bus services, by reducing pressure on surface arterial routes
- Increasing the resilience of the North District transport network to incidents by providing a new alternative motorway standard road corridor between strategic centres
- Creating opportunity for new express bus services between the Northern Beaches region and strategic centres such as North Sydney, Sydney CBD, Macquarie Park and St Leonards via the new motorway – including opportunities for efficient interchange with the new Victoria Cross Metro Station at North Sydney.

4.3.5 Improvements to alternative transport modes

The NSW Government, through Transport for NSW, is currently planning and delivering a series of new and upgraded transport projects and initiatives, consistent with the *Future Transport Strategy 2056* (NSW Government, 2018). The key public transport projects in the Greater Sydney area are shown in Figure 4-3.

Alternative transport modes to the project, and their effectiveness in meeting the project need, are described in the following sections.

Information on these projects can be found on the Transport for NSW website (transport.nsw.gov.au/projects/current-projects).



Indicative only – subject to design development

Legend

Approved

- Sydney Metro
- Northern Beaches B-Line
- Parramatta Light Rail Stage 1

Proposed

- Western Harbour Tunnel
- Warringah Freeway Upgrade
- Beaches Link
- Gore Hill Freeway Connection
- Sydney Metro West
- Parramatta Light Rail Stage 2
- Proposed rapid bus service
- Sydney Metro Western Sydney Airport

Existing heavy and light rail

Figure 4-3 Key public transport projects in the Greater Sydney area

Improvements to the Sydney bus network

Improvements to the Sydney bus network as a strategic alternative to the project include additional bus routes, additional buses on existing routes and bus priority measures.

Buses play a crucial role in Sydney's public transport system. Sydney's bus network currently includes more than 600 routes. For more than 90 per cent of Sydney residents, local bus routes are within 400 metres of home and offer connections to neighbourhood shops and services, major centres and the wider public transport system.

A well planned bus network is the most efficient means of providing public transport in areas where there is a less dense population, meaning that origins and destinations of commuters are more dispersed, as is the case for the Northern Beaches region. Bus services can also be put into service more rapidly and with considerably less infrastructure and disruption than any other type of public transport.

Furthermore, recent advancements in technology have provided the opportunity to develop fully electric buses – reducing noise generation, eliminating at source emissions, and providing a much smoother journey for passengers. Electric buses are already operating on several routes in Sydney's Inner West. The NSW Government plans to introduce additional electric buses in the Inner West, as well as other areas of Greater Sydney over the coming 12 months.

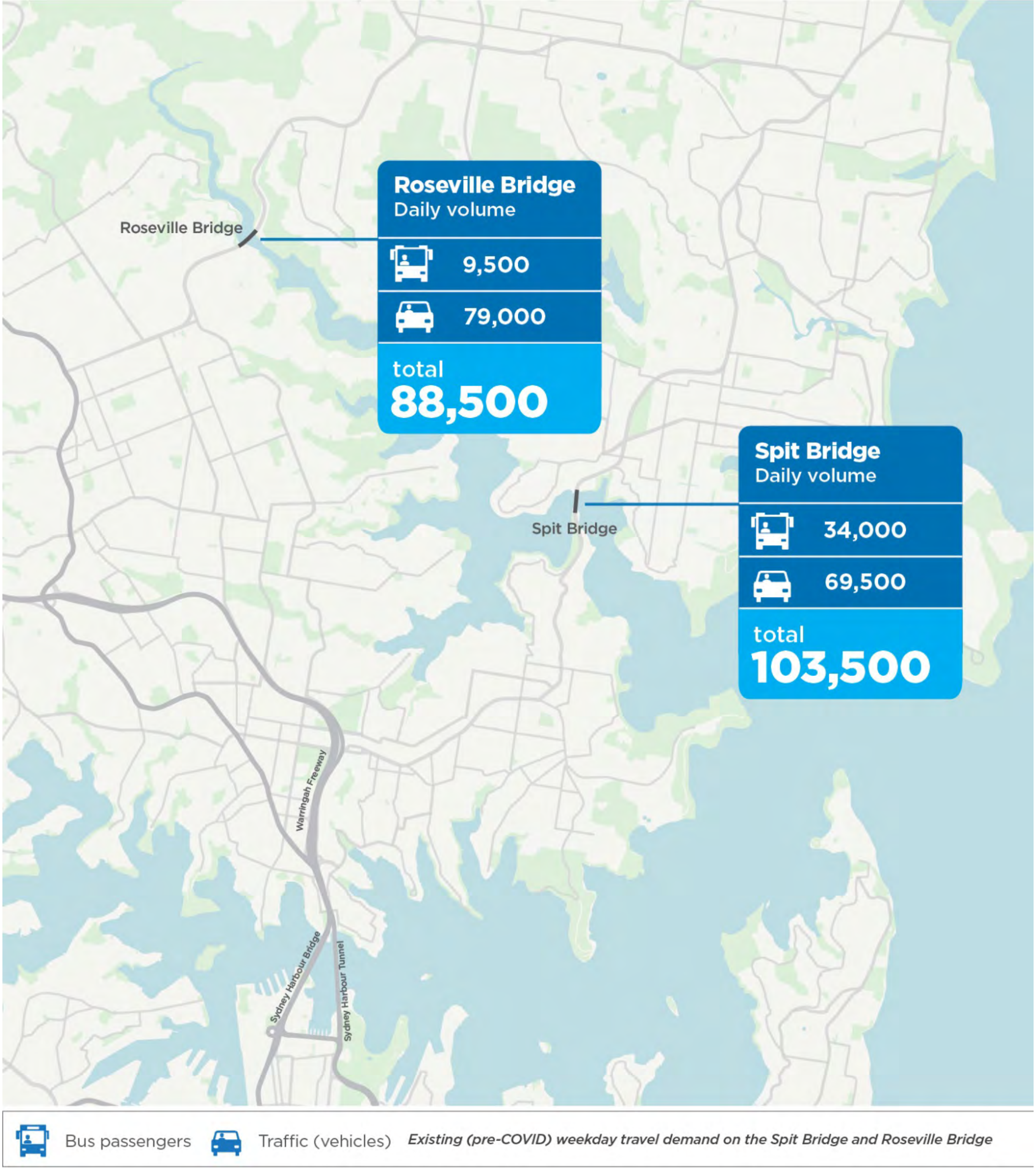


Figure 4-4 Average weekday trips via key transport corridors (existing conditions)

Sydney's Bus Future (Transport for NSW, 2013a) acknowledges that improvements to the bus network are essential to meet changing customer needs, including access to major centres outside the Sydney CBD. *Sydney's Bus Future* aims for seamless connection to other transport modes to deliver the right mix of services. In response to changing passenger needs and an increase in demand, additional services have already been added to the Sydney bus network. However, without measures to improve journey times by increasing the road efficiency or capacity, the addition of more buses to the network can contribute to congestion, making bus services less effective at meeting customer needs.

Sydney's Bus Future proposes major changes to the Sydney bus network to meet current and future demands by providing express service routes to connect major centres along transport routes with mass transit demand. Suburban and local service routes would build on the foundation of these express service routes to improve access to local, neighbourhood destinations. An example of the major changes to the Sydney bus network as a result of *Sydney's Bus Future* is the B-Line program. Its success to date has encouraged the planning of a rapid bus service between Dee Why and Chatswood.

Despite the complementary nature of the aforementioned projects, improved bus services on existing surface corridors alone would not be sufficient to provide the level of additional transport capacity that is required for the Northern Beaches region. The ability for the bus network to provide extra capacity is strictly limited by the capacity of the road network itself – particularly the Military Road/Spit Road and Warringah Road/Eastern Valley Way corridors.

While the B-Line program has been successful in improving capacity and travel times in the short to medium-term, additional road capacity is required to deliver long-term benefits for bus services and unlock the opportunity for new and improved express services between key centres.

Improvements to the rail network

The physical and urban geography of the Northern Beaches region presents barriers to the consideration of rail-based solutions in addressing the transport challenges faced by the region. The hilly, harbour-based Eastern Harbour City with its established urban area and therefore limited available space to develop a rail corridor, means that provision of rail infrastructure would be expensive with a long lead time to development. The topography on either side of Middle Harbour introduces challenges for constructing a tunnel with a gradient that would be acceptable in terms of engineering design and safety for rail infrastructure, with steep elevation changes as well as geology characterised by substantial rock fracturing. The necessity to build deep station boxes for a tunnelled rail link under Middle Harbour was another key consideration when developing the preferred solution. These physical constraints would result in substantial challenges for engineering, with large implications for cost and amenity during construction.

The provision of rail infrastructure is also reliant on the location of and accessibility to high density residential or commercial property close to the proposed location of stations as well as along its route. Given the high cost of constructing and operating rail infrastructure and the low density nature of the Northern Beaches, it is considered that demand would not be high enough to make investing in a specific or dedicated rail link to the Sydney CBD a viable alternative.

Similarly, provision of light rail would entail high capital and operating costs which would require high passenger demand in order to be a viable solution. Due to the low population density and population growth rate for the Northern Beaches region, when considering the distances proposed, light rail would not be considered a suitable mass transit solution. Light rail also performs best when completely separated from other road traffic, so that the introduction of light rail into an already congested road transport network would have the potential to further reduce road capacity where a segregated light rail corridor would replace traffic lanes.

Due to the high cost and long lead time for a heavy or light rail solution, the alternative approach for public transport improvement is to focus on improving the speed and reliability of road based public transport such as bus services – for example, by implementing bus priority measures and developing rapid bus services. Such investment can be delivered as part of a long-term, staged approach to increasing corridor capacity, as and when required, at substantially lower cost than heavy and light rail infrastructure. With a relatively high carrying capacity, rapid or express bus services offer a mass transit solution for bus corridors where a rail based solution is unsuitable. As such, adequate, reliable and efficient public transport using road infrastructure (ie rapid and express bus services) is considered a more suitable and appropriate public transport solution for the area.

The *Northern Beaches Transport Action Plan* (Transport for NSW, 2016), outlined proposed rail initiatives of relevance to the project. These included a second harbour rail crossing as well as a new rail line to the Sydney CBD. Subsequently, this new rail line to the CBD was realised by the Sydney Metro City & Southwest project, which is a 30 kilometre extension of metro rail line from the end of the existing Sydney Metro Northwest terminus at Chatswood. The Sydney Metro City & Southwest project will travel from Chatswood, under Sydney Harbour, through newly established stations in the Sydney CBD through to Bankstown in the south west of the city. The Sydney Metro City & Southwest project will enhance the Sydney rail network and enable it to carry an additional 100,000 people per hour in peak periods, delivering sufficient capacity to serve the city well into the future.

Supplemented by a rapid bus service between Dee Why and Chatswood that is currently being planned, this means more people are likely to travel by rail, helping to reduce the number of buses travelling into the Sydney CBD from locations north of Sydney Harbour. This would also provide increased capacity for buses and cars travelling from the Northern Beaches to the Sydney CBD.

While these projects would contribute to reducing congestion on the existing road network, they would not be sufficient to resolve the existing road network capacity constraints between the lower North Shore and the Northern Beaches. This is due to the complexity of journey patterns and trip purposes within Greater Sydney and the dispersed nature of origin and destination points for an individual journey. This means that roads remain a critical element in the integrated transport network, servicing buses, freight, commercial and many other individual journey needs.

Improvements to the freight rail network would assist with the efficient distribution of freight particularly for freight travelling longer distances. However, a large proportion of Greater Sydney's freight, commercial, and services tasks require distribution of goods and services to customers within the Sydney basin. This requires a diverse and dispersed point-to-point transport system that is most efficiently provided by the road network.

Improvements to the ferry network

Additional ferry services on Sydney Harbour were considered as a strategic alternative to the project. Additional ferry services would provide an improved cross-harbour public transport link and would contribute to relieving congestion on existing cross-harbour road connections. While this would contribute to reducing congestion on the existing road network, it would not resolve the existing cross-harbour road congestion and capacity constraints. This is due to comparatively small number of journeys currently using these crossings that would be transferable to the ferry network.

Improvements to active transport

Improvements to active transport infrastructure (cyclist and pedestrian facilities) that were considered as strategic alternatives to the project included additional cycling and pedestrian routes and facilities as identified in *Sydney's Cycling Future* (Transport for NSW, 2013b) and *Sydney's Walking Future* (Transport for NSW, 2013c).

Sydney's Cycling Future aims to make cycling a safe, convenient and enjoyable transport option for short trips by:

- Investing in separated cycle ways and providing connected bicycle networks to major centres and transport interchanges
- Promoting better use of the existing network
- Engaging with stakeholders across government, councils, developers and bicycle users.

Sydney's Cycling Future aims to increase the mode share of cycling in the Sydney metropolitan area for short trips that can be an easy 20 to 30 minute ride. The strategy aims to improve access between suburbs and major centres, reduce congestion on the road network and increase capacity on the public transport system by investing in connected bike routes within five kilometres of major centres and public transport interchanges. The strategy commits to expanding bike route connectivity within 10 kilometres of major centres in the longer term. The 'Bike and Ride' initiative would make it convenient for customers to cycle to transport hubs, leave their bikes securely locked up and transfer to public transport to continue their journey.

Sydney's Walking Future complements *Sydney's Cycling Future*. The actions set out in *Sydney's Walking Future* propose to make walking the transport choice for quick trips under two kilometres and help people access public transport. Encouraging and enabling more people to make walking trips would ease pressure on public transport, reduce congestion on roads and promote a healthier transport alternative.

As outlined in *Sydney's Cycling Future* and *Sydney's Walking Future*, journeys made by cycling and walking are generally for short trips only, which would not meet the project need of improving existing capacity constraints between the strategic centres across Greater Sydney and the Northern Beaches. For example, it takes about 30 minutes to cycle from Manly Beach to the Spit Bridge at Mosman. Improvements to active transport alone would not cater for the diverse travel demands within the North District that are best met by road infrastructure. Improvements to active transport alone would not be sufficient to support long-term economic growth or enhance the productivity of commercial and freight generating land uses. The active transport network is therefore complementary to other modes of transport as part of an integrated transport solution.

As part of an overarching integrated transport network, the project includes the development of new or improved active transport links in a number of locations, generally associated with surface works for the project. These links would improve connectivity between communities, open space areas, public transport modes and the existing active transport network. This is described in further detail in Chapter 5 (Project description) and Chapter 9 (Operational traffic and transport).

Summary

As detailed in the previous sections, alternative transport modes, including bus, rail, light rail and active transport, could be considered as strategic alternatives to the project. While many of these modes and upgrades are complementary to the project as part of a broader integrated transport network, none would be as effective in providing improvements to journey times and journey time reliability for freight services, public transport and other road users, while improving efficiency and amenity along existing surface road corridors.

The array of journey patterns and trip purposes within Sydney, and the dispersed nature of origin and destination points for an individual journey mean that roads remain a critical element in the integrated transport network, servicing freight, commercial, bus and many other journey needs.

While improvements to the freight rail network would reduce pressure on the core motorway network, Sydney's freight, commercial and services tasks require distribution of goods and services within the Sydney basin, which relies on diverse and dispersed point-to-point transport network that is most efficiently provided by the road network. Providing high-quality motorway links to meet this need is key to growing Sydney's economic prosperity while reducing surface traffic through communities.

Extending the tunnelled motorway network to address capacity, efficiency and reliability issues on critical road corridors would not only provide faster, more efficient and more reliable journeys for users of the network, but would also deliver much broader benefits through reduced congestion on existing local and arterial road networks.

The project would materially improve the functionality and performance of the bus network, providing opportunities for faster and more reliable express bus services to travel via the tunnel and motorway network from the Northern Beaches to strategic centres including North Sydney, the Sydney CBD, Macquarie Park and St Leonards. The design for Beaches Link would also allow for these services to interchange with the new Victoria Cross Metro Station at North Sydney. Furthermore, the use of the Beaches Link tunnel for express bus services would reduce pressure on the Military Road/Spit Road and Warringah Road/Eastern Valley Way bus corridors, allowing for further optimisation of surface services.

The project would improve active transport links through the provision of new and upgraded shared user paths in Artarmon, Balgowlah, Killarney Heights, Seaforth and Frenchs Forest, as well as a number of new shared user underpasses and new shared user and pedestrian bridges which would provide connectivity across the Wakehurst Parkway.

4.3.6 Preferred strategic alternative

When considering the strategic alternatives and complementary projects discussed in previous sections, it was concluded that the construction and operation of a new tunnelled motorway crossing of Middle Harbour (the project) was the preferred solution. This, in combination with the Western Harbour Tunnel, Warringah Freeway Upgrade, and WestConnex network would provide a step-change in transport capacity between the Northern Beaches and strategic centres across Greater Sydney. This would materially improve journey times and journey time reliability for freight services, public transport and other road users on both the new motorway link and bypassed surface routes. Reduced pressure on existing surface routes would also improve the safety, efficiency and amenity of these corridors.

The project is part of a suite of current and future transport initiatives outlined in *Future Transport Strategy 2056* (NSW Government, 2018) that together, would provide the cross-harbour transport capacity required to cater for a diverse array of journeys and future population growth. Further, as discussed in Chapter 3 (Strategic context and project need), a new tunnelled harbour crossing would allow new public transport routes to be developed in response to diverse travel demands and support new social and economic development such as the emerging Northern Beaches Hospital Precinct in Frenchs Forest.

4.4 Corridor alternatives

Following identification of a new tunnelled motorway as the preferred strategic alternative, a design development process was carried out to determine the most appropriate alignment and construction method to deliver the tunnel. This began with consideration of the broad corridors that would best service the road transport demands between the Northern Beaches and strategic centres across Greater Sydney.

The process for selection of the preferred tunnel alignment and construction method included consideration of five strategic corridors and over seven different combinations of tunnelling methods.

Options were developed and assessed by a multidisciplinary team including design engineers, construction engineers, transport planners and environmental advisors with direct experience in delivering major transport infrastructure in NSW, Australia and internationally. Selection of the preferred corridor required consideration of various technical, environmental and community factors including:

- Strategic traffic demands and how they define the required connectivity to achieve transport outcomes
- Physical and operational interfaces with other major infrastructure (eg Sydney Metro, the Warringah Freeway and Northern Beaches Hospital Precinct and associated road upgrades)
- Integration with the proposed Western Harbour Tunnel and Warringah Freeway Upgrade project in the future
- Horizontal alignments and waterway crossing methodologies that allow the tunnel to achieve acceptable vertical gradients to achieve the desired transport product, reduce whole of life emissions, operational costs, and improve safety outcomes
- Surface connections and interchanges that integrate with the arterial road network and connect bus routes and public transport nodes
- Interfaces with commercial and recreational maritime traffic
- Construction and operational efficiencies
- Topography along the alignment
- Potential impacts on local communities including amenity and connectivity
- Results of geotechnical, groundwater and contamination investigations

- Basements and foundations of structures along the routes
- Maritime heritage, biodiversity and marine ecology
- Turbidity and hydrodynamic monitoring and modelling for Middle Harbour.

4.4.1 Description of shortlisted corridor alternatives

Following preliminary technical and environmental analysis, five preferred corridor alternatives were shortlisted for a new tunnelled motorway connection to the Northern Beaches (refer to Table 4-2 and Figure 4-5). The shortlisted corridor alternatives were termed the green, red, purple, pink and blue alternatives.

Table 4-2 Shortlisted corridor alternatives

Corridor alternative	Summary of alternative
Green	• Tunnelled alignment between Burnt Bridge Creek Deviation, Balgowlah and the Gore Hill Freeway, Naremburn – passing beneath Castlecrag • Tunnelled crossing of Middle Harbour between Pickering Point and Sugarloaf Point • Tunnelled ramps to and from the Gore Hill Freeway at Artarmon • Tunnelled ramps to and from the Wakehurst Parkway at Killarney Heights • Wakehurst Parkway upgraded to two lanes in each direction between tunnel connection and Warringah Road interchange, Frenchs Forest • Connectivity: - Signalised connection to and from Burnt Bridge Creek Deviation at Balgowlah - Ramps to and from the Wakehurst Parkway at Killarney Heights - Ramps to and from the Gore Hill Freeway at Artarmon - Ramps to and from the Warringah Freeway at Naremburn.
Red	• Tunnelled alignment broadly following the Military Road/Spit Road corridor • Tunnelled crossing of Middle Harbour located immediately west of Spit Bridge • Connectivity: - Ramps to and from Condamine Street at Manly Vale - Connection to North Sydney and Sydney CBD via signalised intersection at Falcon Street interchange.
Purple	• Tunnelled alignment to the east of the Military Road/Spit Road corridor • Tunnelled crossing of Middle Harbour between Rosherville Reserve and Clontarf • Wakehurst Parkway upgraded to two lanes in each direction between tunnel connection and Warringah Road interchange, Frenchs Forest • Connectivity: - Signalised connection to and from Burnt Bridge Creek Deviation at Balgowlah - Ramps to and from the Wakehurst Parkway at Killarney Heights - Connection to North Sydney and Sydney CBD via signalised interchange at Falcon Street - Tunnelled ramps at Cammeray providing access to and from the Gore Hill Freeway corridor - Underground connections to and from the Western Harbour Tunnel at Neutral

Corridor alternative	Summary of alternative
	Bay/Cammeray.
Pink	• Alignment identified in Strategic Business Case, with surface connection from Burnt Bridge Creek Deviation (with onward tunnel from the Wakehurst Parkway), connecting to a tunnelled alignment broadly following the Military Road/Spit Road corridor • High-level bridge over Middle Harbour east of the existing Spit Bridge • Open trough structure under the Sydney Road/Burnt Bridge Creek Deviation junction • Diamond interchange at the Sydney Road/Burnt Bridge Creek Deviation junction • Tunnelled ramps between Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst parkway at Killarney Heights • The Wakehurst Parkway upgraded to two lanes in each direction between tunnel connection and Warringah Road interchange at Frenchs Forest • Connectivity: - Signalised connection to and from Sydney Road/Burnt Bridge Creek Deviation junction at Balgowlah - Ramps to and from the Wakehurst Parkway at Killarney Heights - Connection to North Sydney and Sydney CBD via signalised interchange at Falcon Street - Tunnelled ramps at Cammeray providing access to and from the Gore Hill Freeway corridor - Tunnelled ramps at North Sydney providing access to and from the Sydney Harbour Bridge - Underground connections to and from the Western Harbour Tunnel at Neutral Bay/Cammeray.
Blue	• Tunnelled alignment between Burnt Bridge Creek Deviation, Balgowlah and the Warringah Freeway at Cammeray – passing beneath Northbridge • Tunnelled crossing of Middle Harbour between Clive Park and Seaforth Bluff • Tunnelled ramps to and from the Gore Hill Freeway at Artarmon and from the Wakehurst Parkway at Killarney Heights • The Wakehurst Parkway upgraded to two lanes in each direction between the tunnel connection and Warringah Road interchange at Frenchs Forest • New access road between Burnt Bridge Creek Deviation and Sydney Road • Connectivity: - Free-flow connection to Burnt Bridge Creek Deviation northbound – signalised connection southbound - Signalised connection to and from Sydney Road (via new access road) - Ramps to and from the Wakehurst Parkway at Killarney Heights - Ramps to and from the Gore Hill Freeway and Reserve Road at Artarmon - Ramps to and from the Warringah Freeway at Cammeray - Underground connections to and from the Western Harbour Tunnel at the Warringah Freeway.

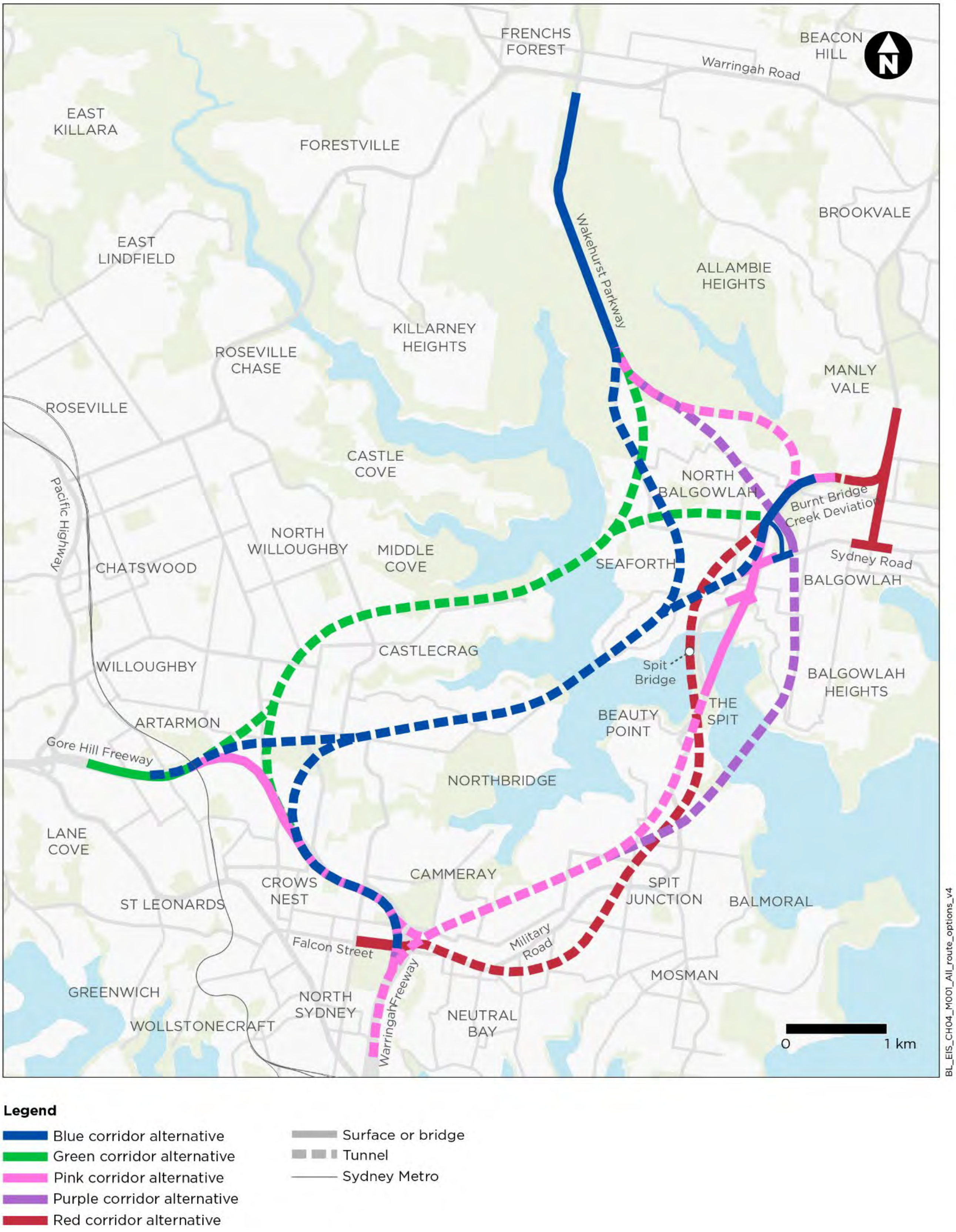


Figure 4-5 Main corridor shortlisted alternatives

4.4.2 Evaluation of corridor alternatives

The five shortlisted corridor alternatives were evaluated by a multidisciplinary team including design engineers, construction engineers, transport planners and environmental advisors to identify the solution that best balanced technical, community and environmental outcomes while meeting the transport objectives. The evaluation criteria used were an expansion of the project objectives with the addition of design and constructability criteria to reflect the more detailed comparison required (Figure 4-6).

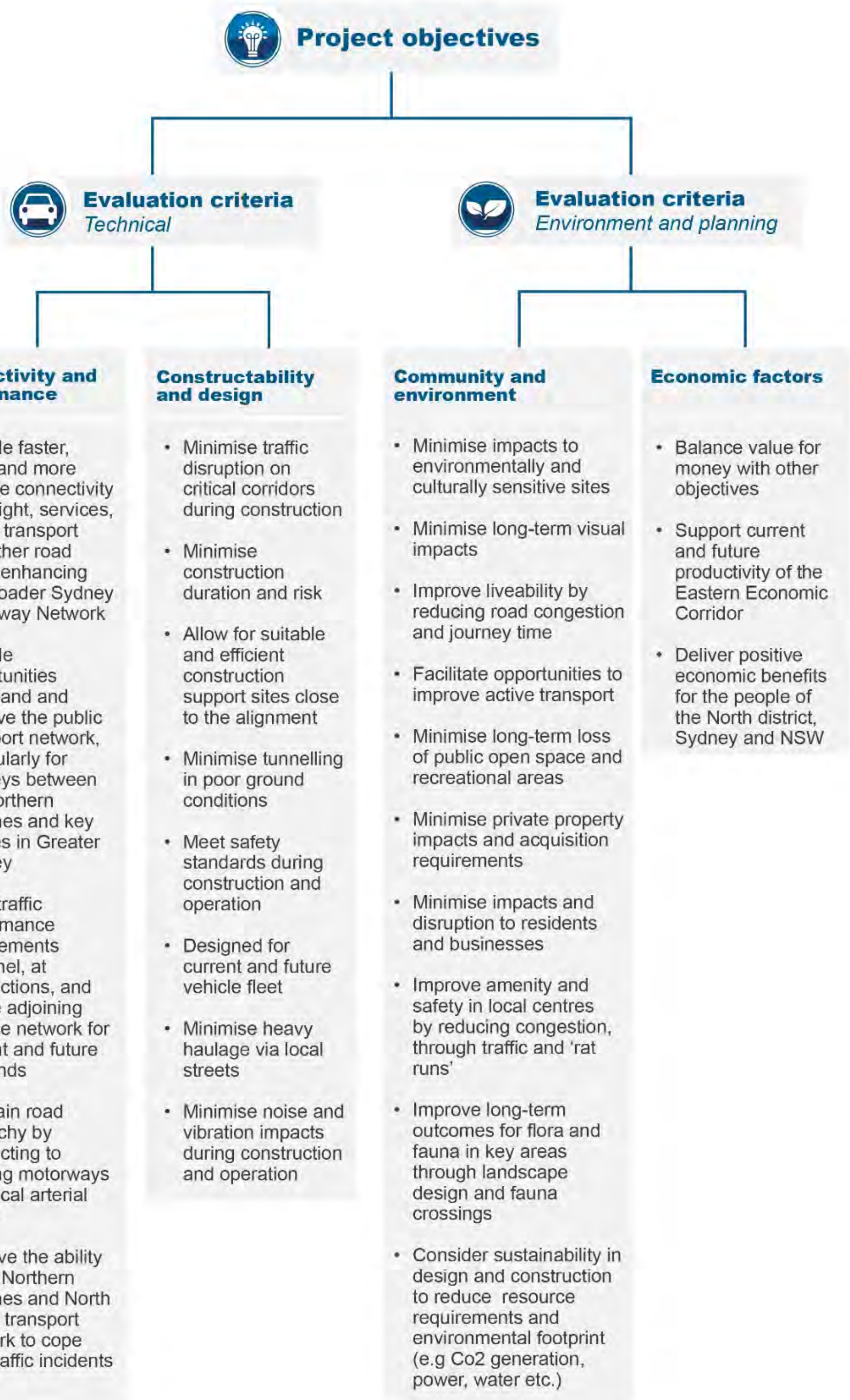


Figure 4-6 Evaluation criteria for corridor alternatives

A summary of the key strengths and weaknesses of each corridor alternative with respect to the evaluation criteria, are shown in Figure 4-7 to Figure 4-13.

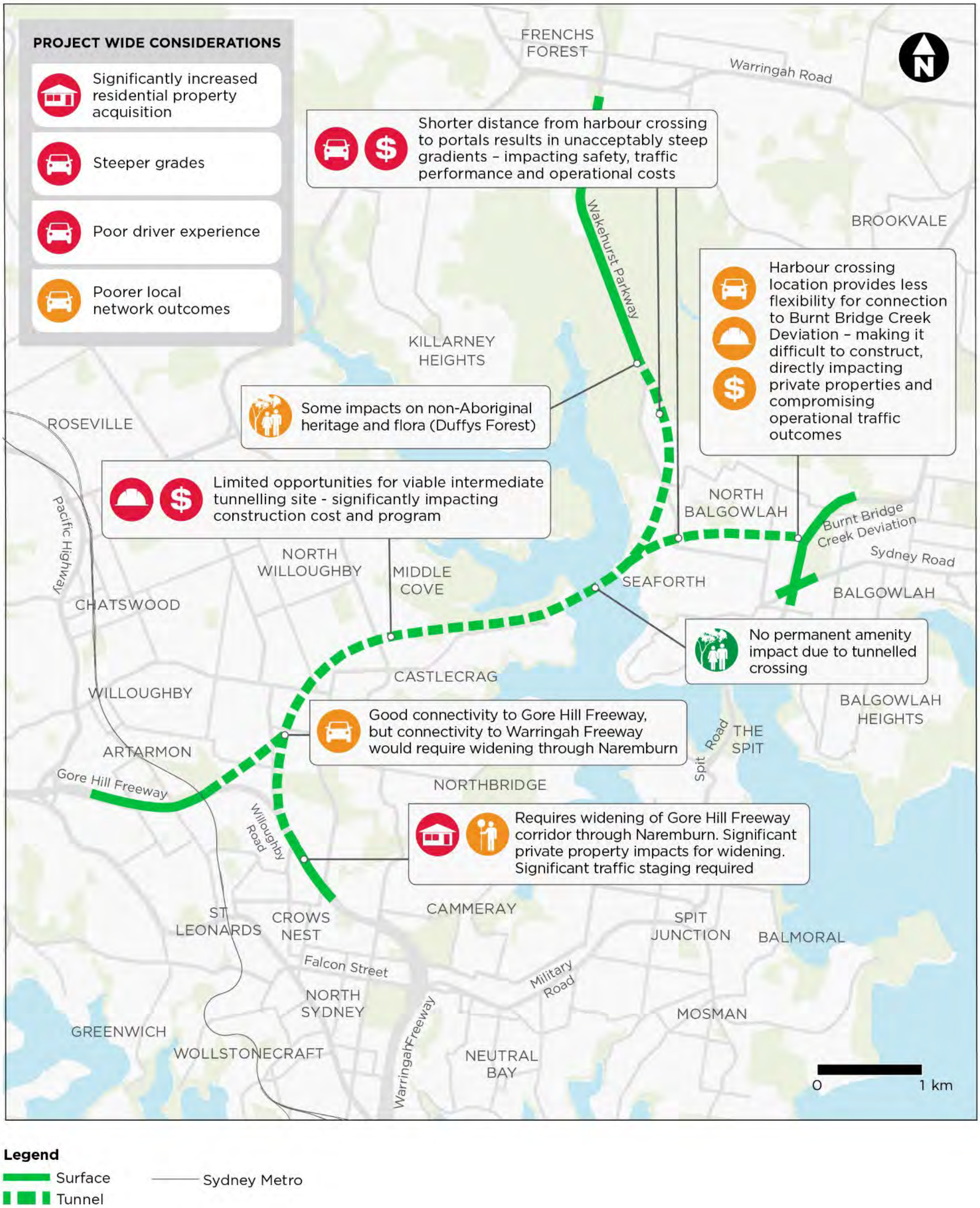


Figure 4-7 Green corridor alternative

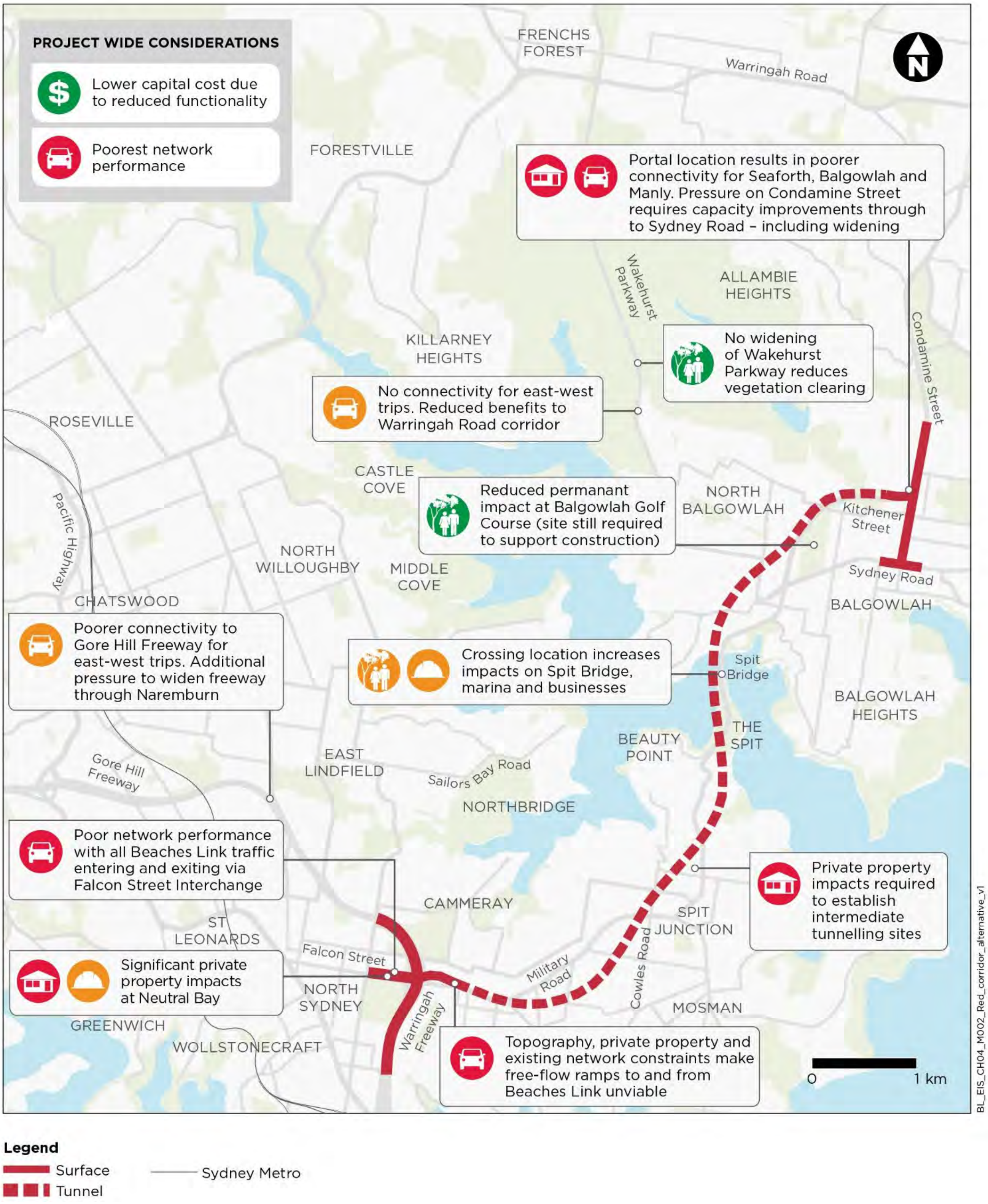


Figure 4-8 Red corridor alternative

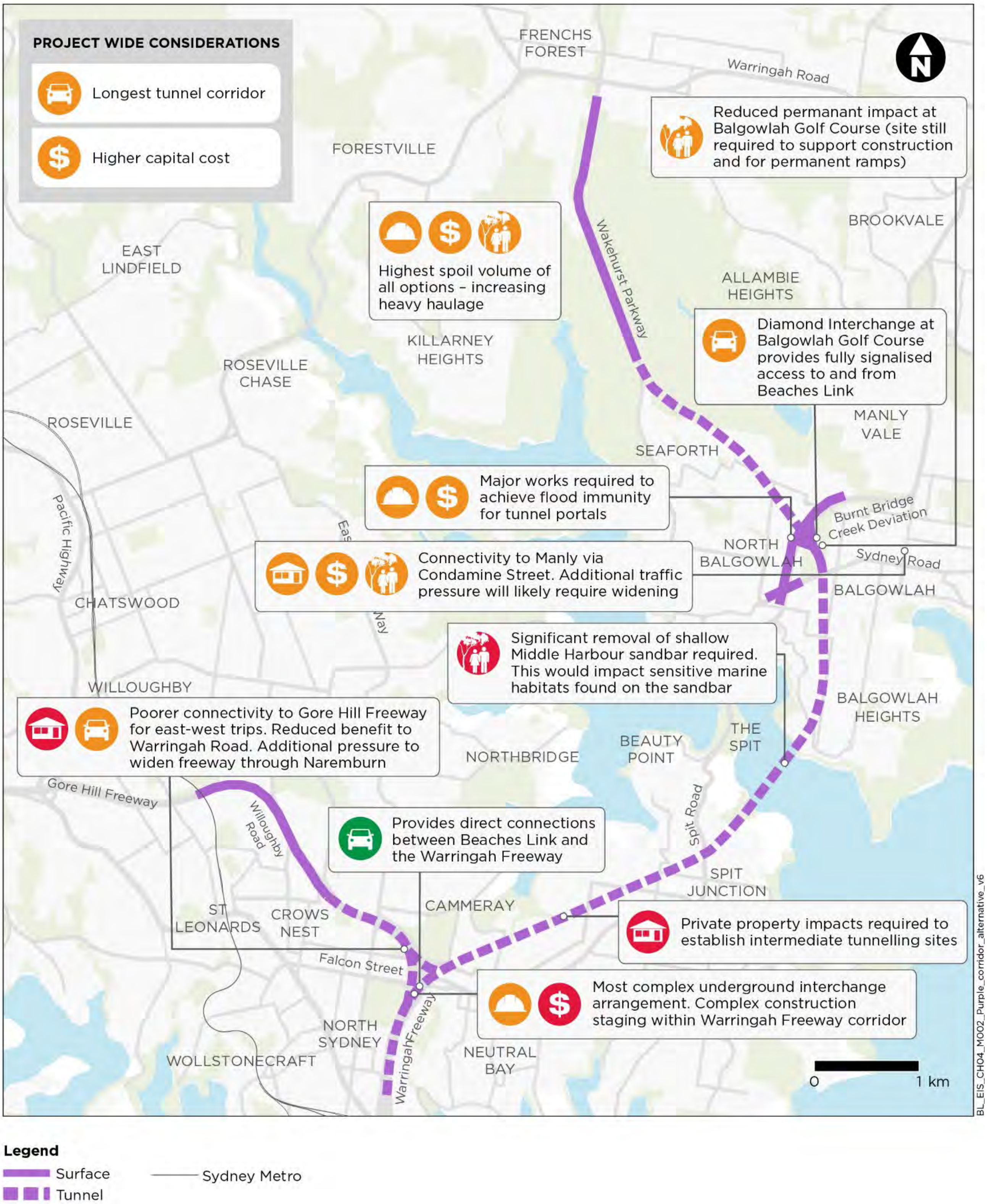


Figure 4-9 Purple corridor alternative

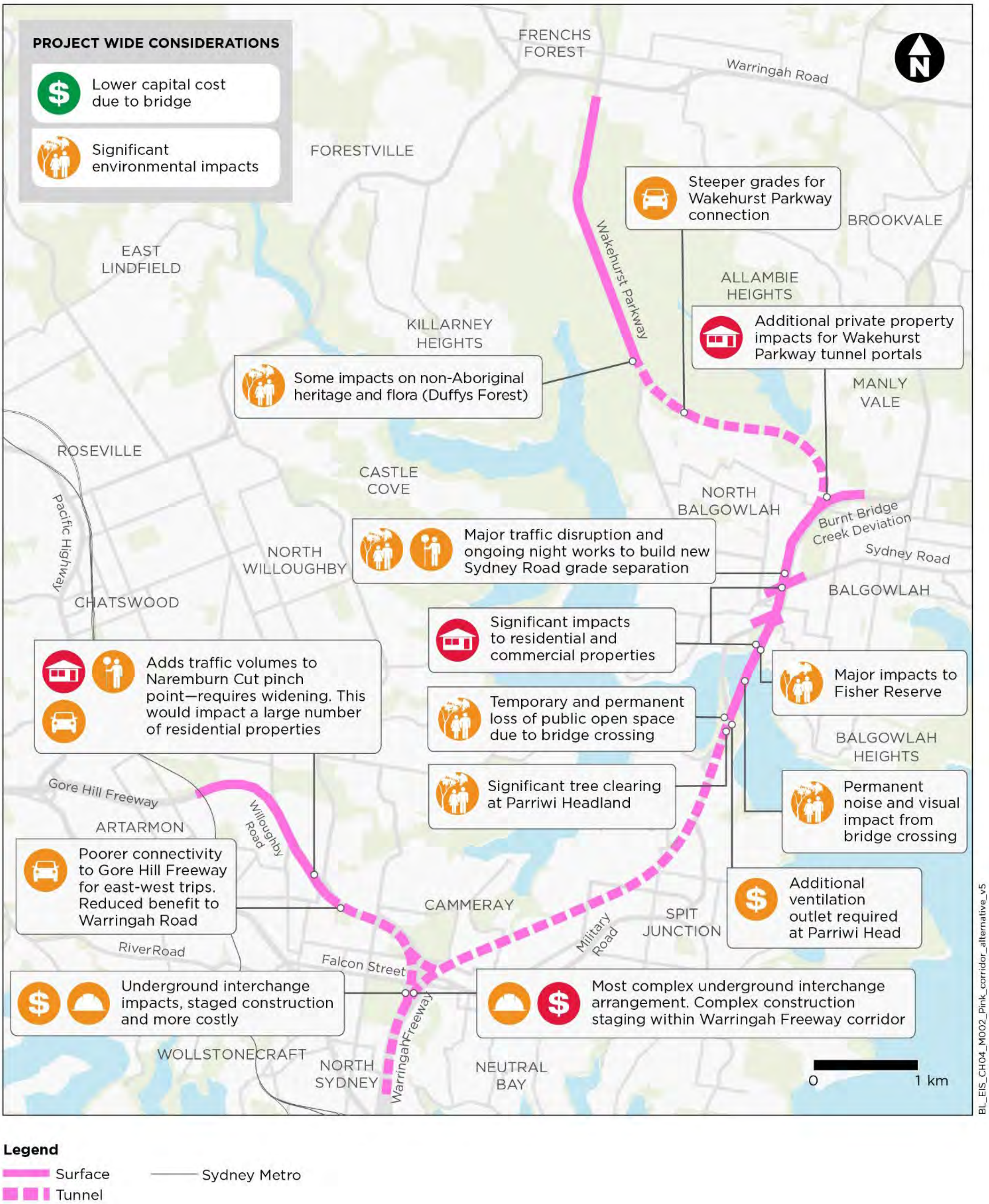


Figure 4-10 Pink corridor alternative

Figure 4-11 Indicative concept design for bridge over Spit Bridge (aerial view) – Pink corridor alternative (image 1)

Figure 4-12 Indicative concept design for bridge over Spit Bridge (aerial view) – Pink corridor alternative (image 2)

Figure 4-13 Blue corridor alternative

A summary of the evaluation of each of the corridor alternatives is outlined below:

- Green corridor – Not shortlisted on the basis of steep grades required to connect to the Wakehurst Parkway and Burnt Bridge Creek Deviation, impacting journey experience and efficiency of the road and the number of residential properties that would need to be acquired
- Red corridor – Not shortlisted on the basis of unacceptable construction impacts associated with construction method across Middle Harbour, traffic management issues associated with Sydney CBD-bound traffic at Falcon Street and widening of Sydney Road as well as private property impacts
- Purple corridor – Not shortlisted on the basis of having a higher capital cost than the other options without offering additional connectivity or constructability benefits. Also has substantial environmental impacts associated with dredging of the Middle Harbour sandbar that would be required to be traversed
- Pink corridor – Shortlisted for further analysis on the basis of having a lower capital cost to a tunnelled crossing of Middle Harbour
- Blue corridor – Shortlisted for further analysis on the basis of providing strong connectivity and also having lower amenity and environmental impacts compared to the other corridor options, including the pink corridor.

4.4.3 Preferred corridor

Both the pink and blue corridor alternatives provide connections to the Wakehurst Parkway and Burnt Bridge Creek Deviation, providing connectivity for residents and businesses in the north and south of the Northern Beaches peninsula. However, the blue corridor alternative has a number of connectivity and network performance advantages relative to the pink corridor, as outlined in the following sections.

Consistency with project objectives

The blue corridor alternative achieves a greater alignment with transport and city-shaping objectives. This reflects the fact that it delivers more direct east-west connectivity relative to the pink corridor alternative, while also providing strong north-south connectivity. This delivers more congestion relief to arterial roads, such as Warringah Road, and also provides the opportunity for new express bus services for customers travelling between the Northern Beaches and strategic centres such as North Sydney, the Sydney CBD, Macquarie Park and St Leonards.

The superior east-west connectivity means that the blue corridor alternative also performs better with respect to productivity objectives. This is a result of enabling greater access to jobs for residents in the Northern Beaches and associated reductions in the cost of business travel.

Connectivity and network performance

The evaluation of how the blue corridor outperforms the pink corridor in regard to connectivity and network performance is as follows:

- More direct connectivity between the Northern Beaches and strategic centres west of North Sydney, including Macquarie Park and St Leonards through an alignment that enables direct ramps to Lane Cove Tunnel and Reserve Road at Artarmon. Journeys between the Northern Beaches and Lane Cove Tunnel would be four kilometres longer each way via the pink corridor alternative – an extra 40 kilometres or 30 minutes travel each week per bus or car commuter
- Alleviating the requirement to widen the Gore Hill Freeway through the Naremburn Cut – a key pinch point on the motorway network. The pink corridor alternative would require widening of this section of motorway as a result of users travelling between Beaches Link and Lane Cove Tunnel needing to travel through the Naremburn Cut. This widening work would present substantial engineering challenges and related community impacts. The blue corridor alternative diverts about 25,500 vehicles per day from this section of motorway relative to the pink corridor alternative

- Enabling a surface interchange at Warringah Freeway rather than an underground interchange (pink corridor alternative), improving legibility for drivers
- Providing a more direct connection between the Wakehurst Parkway and the mainline carriageways under Seaforth, rather than requiring users of the Wakehurst Parkway to first connect to Burnt Bridge Creek Deviation.

Constructability and engineering

The blue corridor alternative also ranks higher overall with respect to constructability and engineering, particularly given it has a smaller construction footprint at Middle Harbour compared to the pink corridor alternative (ie bridge construction). The pink corridor alternative entails less direct construction with respect to the Middle Harbour crossing, as it is a bridge rather than a tunnelled crossing – notwithstanding that it would require major marine works to construct bridge supports with access by water. Construction of an immersed tube tunnel west of Spit Bridge would require passage of steel shell immersed tube tunnel units across the Middle Harbour sandbar and through Spit Bridge. A constructability assessment carried out for the project indicates this is feasible, based on steel shell immersed tube tunnel units being used with final fit out with reinforced concrete being carried out adjacent to Spit West Reserve.

The blue corridor alternative has a number of constructability advantages relative to the pink corridor alternative, including:

- An alignment further west of the Spit Bridge enabling a connection to the Warringah Freeway that alleviates the need for a complex underground interchange within Western Harbour Tunnel. Removing the need for an underground interchange also facilitates staging of Western Harbour Tunnel and Beaches Link
- A tunnelled crossing of Middle Harbour alleviates the requirement to grade separate Beaches Link and Sydney Road north of the Spit Bridge under live traffic. This would be required as part of the pink corridor alternative to facilitate passage of the motorway between the bridge crossing and Burnt Bridge Creek Deviation
- A tunnelled crossing alleviates the requirement to establish substantial work sites on both sides of Middle Harbour to enable bridge construction as part of the pink corridor alternative. The blue corridor alternative would require a work site at Spit West Reserve; however, work would primarily be carried out from the tunnel portal sites.

With respect to grades, the blue corridor alternative achieves about a four per cent mainline and off ramp grade to Burnt Bridge Creek Deviation. A four percent grade is also required for the off ramp connecting the mainline carriageway and the Wakehurst Parkway. The pink corridor alternative necessitates a higher grade of five per cent for the connection to the Wakehurst Parkway.

Community and environment

In terms of community and environmental considerations, the blue corridor alternative performs better than the pink corridor alternative. Of particular note are the greater residential property, heritage, flora and fauna, public open space and visual amenity impacts associated with the pink corridor alternative compared to the blue corridor alternative. The pink corridor alternative would require bridge infrastructure to be installed in Parriwi Park and Fisher Bay Bushland Reserve. These sites are known to contain Littoral Rainforest in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions, which is listed as endangered under the *Biodiversity Conservation Act 2016* and critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999,* and other threatened ecological communities and flora species.

From a community perspective, the pink corridor alternative introduces a visually dominant bridge structure and associated elevated operational noise source that does not currently exist. The blue corridor alternative does not introduce permanent impacts at these sites.

Property

The pink corridor alternative would permanently impact a large number of residential properties, many of which would require acquisition. Residential properties at Clontarf would need to be acquired to allow for construction of the northern bridge abutment and associated cutting, in addition to residences at Sydney Road within the footprint for the grade separated interchange. The connection with Burnt Bridge Creek Deviation would also require permanent acquisition of some of the land occupied by the Balgowlah Golf Course, along with some nearby residential properties.

The blue corridor alternative would impact fewer residential properties than the pink corridor alternative. Residential properties to the east of Burnt Bridge Creek Deviation would need to be acquired to enable construction of tunnel portal structures for the blue corridor alternative, and Balgowlah Golf Course would be permanently closed. At the Wakehurst Parkway connection, both blue and pink corridor alternatives would impact a number of residential properties, although it should be noted that Transport for NSW owns the affected properties. The blue corridor alternative would also impact 12 apartments adjacent to the Cammeray Golf Course due to widening required to connect the Beaches Link portal to the Warringah Freeway. In designing the project, the aim has been to minimise further property impacts by connecting at one of the widest points on the Warringah Freeway. The blue corridor alternative would also require some commercial properties to be acquired at Artarmon as part of the Gore Hill Freeway Connection.

Capital cost

As part of the optioneering process, strategic estimates were prepared for both alignments. Based on these estimates, the P90 Total Outturn Cost of the pink corridor alternative is estimated to be marginally less expensive than the blue corridor alternative.

The key differences in the underlying cost build up for the pink and blue corridor alternatives are as follows:

- Higher construction cost of a tunnel under Middle Harbour (blue corridor alternative) compared to a bridge (pink corridor alternative)
- Higher property impacts of the bridge option (144 residential properties under the pink corridor alternative compared to 54 under the blue corridor alternative).

Given the substantial property, environmental and amenity impacts associated with the pink corridor alternative, it was determined that a decision between either corridor alternative should not be made on the basis of cost difference.

As such, on the basis of its superior performance in these other areas of consideration, the blue corridor alternative was identified as the preferred corridor to be carried forward for further design development, including refinement of interchange options (refer to Section 4.5).

Summary of key advantages of preferred corridor

Key advantages of the blue corridor alternative include:

- Reduced environmental and amenity impacts:
  - The blue corridor alternative would avoid impacts to the areas around Parriwi Park and Fisher Bay Bushland Reserve, where endangered and threatened species have been recorded. Large areas of vegetation would be required to be cleared at these sites to construct the bridge crossing for the pink corridor alternative, and a sizeable portion of these areas would become part of the permanent motorway corridor
  - The blue corridor alternative would avoid major dredging and piling within the Middle Harbour sandbar, which is one of the most sensitive marine habitat areas within Middle Harbour
  - The blue corridor alternative would avoid permanent visual and noise impacts within Middle Harbour

- The blue corridor alternative would avoid major impacts to heavily utilised areas of Middle Harbour, including areas around The Spit, the Spit Bridge and the Middle Harbour Yacht Club.

- Connectivity and network performance:
  - The blue corridor alternative would result in fewer vehicles relying on the section of the Gore Hill Freeway through Naremburn (known as the Naremburn Cut). This reduces pressure on this constrained section of the existing motorway network, reducing the pressure to widen the corridor in an area where widening would present substantial engineering challenges and associated community impacts. This would result from providing a direct connection between Beaches Link and the Lane Cove Tunnel and Reserve Road at Artarmon, which would avoid the need for east–west journeys between these corridors to travel through the Naremburn Cut
  - Journeys between the Northern Beaches and north-west centres including St Leonards, Chatswood and Macquarie Park would be shorter via the blue corridor alternative compared to all others considered, with the exception of the green corridor alternative, which would be equivalent. This would deliver greater congestion relief to key east-west arterial roads, such as Warringah Road, and would also provide the opportunity for new express bus services for passengers travelling between the Northern Beaches and strategic centres such as North Sydney, Sydney CBD, Macquarie Park and St Leonards
  - With the blue corridor alternative, freight services, public transport, and other road users would save an average of 30 minutes travel time per week for journeys between the Northern Beaches and the lower North Shore when compared to the pink, red and purple alternatives – a large time saving, particularly when extrapolated annually across all users making this journey
  - Journeys between the Northern Beaches and North Sydney, the Sydney CBD and centres to the south and south-west would see considerable improvements delivered by the blue corridor alternative. The challenging topography and highly constrained freeway corridor south of Ernest Street at Cammeray mean that providing non-signalised connectivity to and from the Warringah Freeway is a key challenge for all alignment options, which is achieved by the blue corridor alternative
  - The superior connectivity means that the blue option would also perform best with respect to productivity objectives. This would be a result of enabling greater access to jobs for residents in the Northern Beaches and reducing the cost of business travel.

4.5 Further project development

Following identification of the blue corridor alternative as the preferred corridor for the project, further detailed project development work has been carried out, including:

- Extensive community and stakeholder engagement to identify key local issues to be taken into account in the development of the project (refer to Chapter 7 (Stakeholder and community engagement))
- Detailed environmental and other site investigations along the corridor, including desktop and field investigations to obtain additional data and identify further environmental considerations
- Design development and value engineering of multiple options within the blue corridor alignment to ensure benefits are realised, while reducing costs, program, constructability risks and community and environmental impacts where possible. This process also included consideration of community and stakeholder feedback and the outcomes of environmental and other site investigations.

This project development work included detailed consideration of the following, with further detail on these key issues provided in sections 4.5.1 to 4.5.10:

- Tunnelling methodology, both land-based and the preferred harbour crossing method, including alternatives to reduce the extent of dredging in Middle Harbour
- Location and configuration of the surface connections
- Ventilation alternatives, including the ventilation system design and outlet locations
- Temporary construction support site locations, layouts and alternatives
- Spoil transport, reuse and disposal alternatives.

Other factors considered during design development included:

- Detailed construction staging within the Warringah Freeway corridor to minimise disruption and optimise the corridor for future operations
- Construction staging and work methodologies at all surface connection locations to reduce impacts on surrounding communities, the environment, and the transport network
- Integration with and enhancements to existing public transport infrastructure, particularly along the Warringah Freeway corridor
- Opportunities to integrate with, and enhance, walking and cycling routes
- Utilities impacts and relocation requirements
- Minimising interfaces with heritage items
- The opportunity to improve long-term functionality and amenity at Balgowlah post construction by delivering new and improved open space and recreation facilities (subject to further community consultation)
- The opportunity for additional new and improved open space and recreation facilities would also be supplemented post construction by the re-purposing of residual land from the acquisition of Dudley Street private properties used for the Balgowlah Golf Course construction support site (BL10) and staging of the Balgowlah connection portal.

The development and evaluation of detailed components of the preferred corridor included consideration of options against a localised set of criteria that was consistent with the project objectives. These included connectivity, transport network performance, constructability, design, community, environmental, and economic criteria specific to the scope item and area being considered.

4.5.1 Tunnelling method alternatives

The methods used to deliver tunnels at different locations around the world varies greatly, primarily in response to the geology encountered and the cross-section that is required along the alignment. Roadheaders, tunnel boring machines, immersed tube tunnels, cut and cover tunnels, and the drill and blast methods are all used to deliver tunnels in different conditions around the world.

The process for selection of the preferred tunnel alignment and tunnel construction method for the project included the development and evaluation of over seven different combinations of tunnelling methods.

These options were developed and assessed by a multidisciplinary team of design, constructability, and environmental specialists with direct experience in delivering major tunnels in NSW, Australian and international contexts.

The assessment considered various technical and environmental factors including:

- Strategic traffic demands and how the vertical alignment and gradients might impact connectivity and performance

- Results of geotechnical and groundwater investigations
- Maritime heritage investigations
- Biodiversity and marine ecology surveys
- Lessons from domestic and international tunnelling projects with comparable constraints
- Turbidity and hydrodynamic monitoring and modelling of Middle Harbour
- Opportunities for viable temporary intermediate tunnelling sites that minimise impacts on sensitive vegetation, heritage sites, private property, local communities and the functionality of public open space
- Implications for physical and operational interfaces with other major infrastructure (for example Sydney Metro City & Southwest tunnels, the Northside Storage tunnel, the Western Harbour Tunnel and Warringah Freeway Upgrade project and building foundations in Artarmon and Seaforth)
- Horizontal alignments and waterway crossing methods that allow the tunnel to achieve acceptable vertical gradients to achieve the desired transport product, reduce whole of life emissions, operational costs, and improve safety outcomes
- Interfaces with commercial and recreational maritime stakeholders
- Market engagement, including technical engagement with 14 construction contractors
- Construction and operational costs.

The major change in geology beneath Middle Harbour introduces a constructability challenge that is very different to the alignment north and south of the harbour. Compared to the bedrock either side of the harbour, the rock beneath Middle Harbour is characterised by fracturing and is therefore prone to major water ingress under pressure. Given the depth and pressure, this creates a challenging tunnelling environment. Without suitable mitigation measures, major water ingress issues would be likely to arise during construction using a driven or bored tunnelling method. Accordingly, the following sections discuss the methodologies for the harbour crossing and the tunnels north and south of Middle Harbour separately.

Tunnelling north and south of Middle Harbour

Favourable tunnelling conditions are expected north and south of Middle Harbour, with the majority of the tunnel alignment expected to be constructed in high-quality Hawkesbury Sandstone. These geotechnical conditions typically make the use of roadheaders the most efficient and effective tunnelling methodology for delivery of road tunnels. Notwithstanding this, the challenge introduced by the Middle Harbour crossing also led to the consideration of tunnel boring machine construction methods for these segments. Examples of roadheaders and tunnel boring machines are shown in Figure 4-14.

Roadheaders are made up of rotating cutting heads mounted on a boom or similar structure. They are typically used where the rock being tunnelled through is very sound without being too hard. In these conditions roadheaders can be used to efficiently cut away the rock to form a tailored cross-section to match the exact cross-sectional area of the tunnel, minimising spoil generation and internal structure.

When using the roadheader method, multiple roadheaders are typically deployed via intermediate construction support sites along the alignment. This allows the tunnel to be constructed from multiple fronts, typically providing substantially reduced construction durations when compared to tunnelling from a single site.

The roadheader tunnelling method has been the preferred construction technique for all major motorway tunnels in Sydney, with the exception being the existing Sydney Harbour Tunnel, which was delivered mainly using the immersed tube tunnel technique and limited driven tunnelling on the northern approach to the immersed tube tunnel. The favourable Hawkesbury Sandstone geology combined with the requirement for a wide but short cross-section are the key variables that have combined to make roadheaders the most efficient and cost effective method for delivering motorway tunnels in Sydney.

Tunnel boring machines are much larger than roadheaders, and use a circular rotating cutting head that houses many individual cutting tools. Due to the circular cutting head, tunnel boring machines excavate and produce a circular tunnel cross-sectional area.

To allow for tunnelling in many different types of geology, there are many different types of tunnel boring machines. With no one type of machine ideally suited to tunnelling through both rock and soft ground, major changes in geology, such as the transition to the soft sediments found beneath Middle Harbour, or the highly fractured rock below this, would require a different type of tunnel boring machine to the landside tunnels being constructed through Hawkesbury Sandstone.

This is best demonstrated by the construction method adopted for construction of the new Sydney Metro crossing of Sydney Harbour, where the poor geology under Sydney Harbour required a different type of tunnel boring machine to the landside tunnels. Accordingly, the Sydney Metro City & Southwest project used five tunnel boring machines – two north and two south of the harbour to complete tunnelling through rock, with one specialised machine for the crossing of Sydney Harbour. This required the establishment of large shafts at Barangaroo and Blues Point either side of Sydney Harbour to launch, retrieve and support the tunnel boring machine for the harbour crossing.

Figure 4-14 Examples of a roadheader (left) and tunnel boring machine (right)

At about seven metres in diameter, the tunnel cross-section required to deliver a metro rail tunnel is well suited to a small diameter tunnel boring machine. In contrast, at 15.5 metres wide, a modern three lane motorway tunnel requires a wide, but stout cross-section. This does not fit very efficiently into a circular cross-section, meaning that delivering a motorway with a tunnel boring machine requires considerably larger machines than employed on metro rail projects. This means that the tunnel boring machine required to deliver each Beaches Link tunnel would have an area five times that of a machine used to construct the Sydney Metro City & Southwest tunnels.

The indicative cross-sections of the Beaches Link tunnel if roadheaders or tunnel boring machines are used are shown in Figure 4-15. This diagram demonstrates that the cross-section required for a modern motorway does not fit efficiently within the circular cross-section provided by a tunnel boring machine. This geometric challenge creates several practical obstacles to the deployment of tunnel boring machines for the Beaches Link tunnel:

- Large increase in spoil generation, increasing heavy haulage
- Increased structural costs, as the pavement level within the tunnel needs to be raised to the widest point in the cross-section
- Tunnel boring machines 16 metres in diameter and larger are not a common tunnelling solution, increasing construction cost and risk
- Tunnel boring machines are typically not preferred where there are multiple major changes in cross-section or geology. These occur at several locations along the Beaches Link alignment.

This means that roadheaders would still be required to build access tunnels from intermediate sites to construct the caverns where ramps merge and diverge from the tunnels under Northbridge and Seaforth, and at either side of the harbour crossing.

When considering the above, roadheaders emerge as the preferred tunnelling methodology for all tunnelling north and south of the Middle Harbour crossing.

Options to build multi-level roadways within a single cross-section were also considered (for example two lanes above two lanes), but these would require tunnel boring machines with even larger diameters.

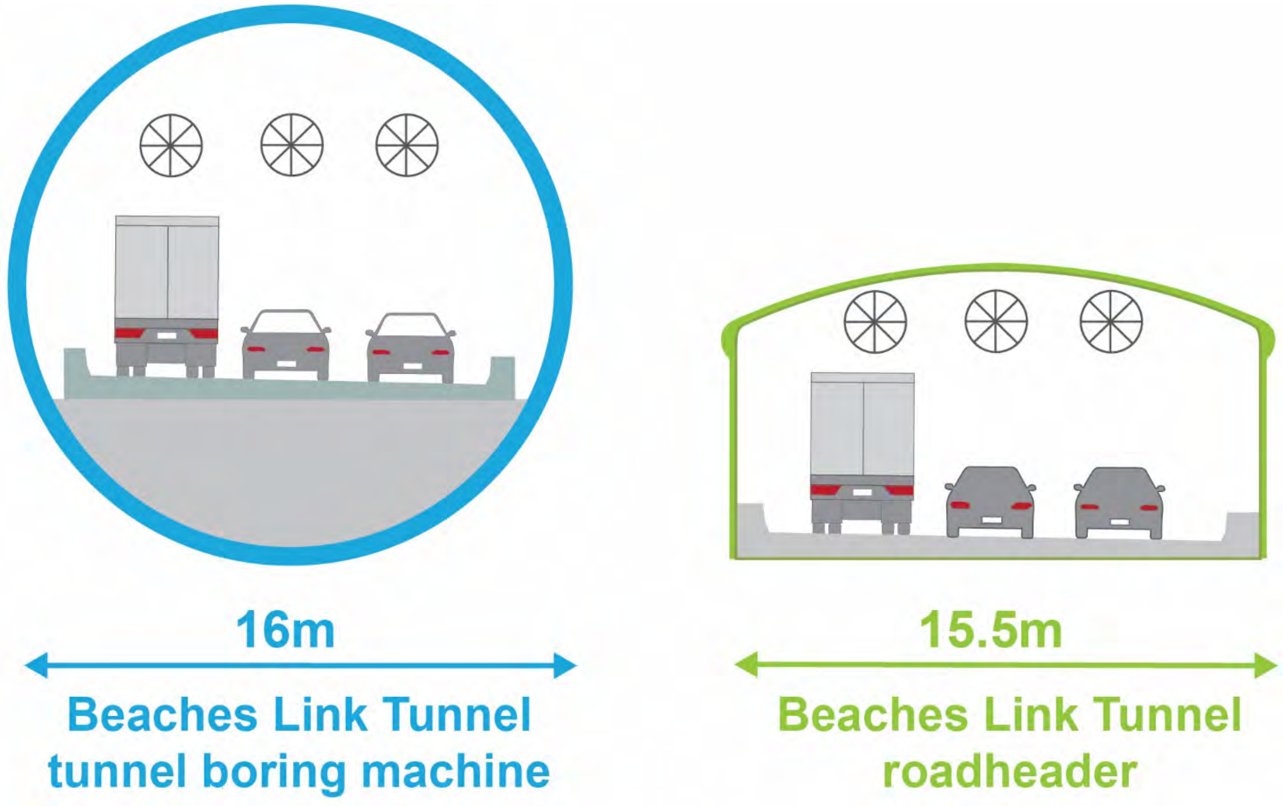


Figure 4-15 Comparison of tunnel cross-sections using a tunnel boring machine and a roadheader

A comparative evaluation of alternative tunnelling methods for tunnelling north and south of Middle Harbour is summarised in Table 4-3.

Table 4-3 Alternative tunnelling methods

Method	Summary of evaluation
Roadheader (preferred method)	**Advantages:** • The technology required is well understood and has been proven to be most efficient and cost-effective for motorways in Sydney's geological conditions • All major motorway tunnels in Sydney to date have been built successfully by roadheader (excluding the Sydney Harbour Tunnel) • Reduced construction risk relative to using a tunnel boring machine for a three lane road tunnel (further details below) • Ability to cut an exact cross-section reduces infrastructure or fill

Method	Summary of evaluation
	required within the tunnel to achieve desired road level • Substantially lower spoil volumes and heavy vehicle movements relative to using a tunnel boring machine • Machines are relatively inexpensive and readily available in the Sydney market • Roadheaders can generally be deployed much faster than tunnel boring machines, due to shorter procurement, establishment and commissioning times. **Disadvantages:** • Tunnelling rate of roadheaders is less than tunnel boring machines when both reach peak production • Depending on the length of tunnel, roadheaders may require intermediate surface construction and access sites.
Tunnel boring machine	**Advantages:** • If the geology and cross-section are consistent, tunnel boring machines can usually construct much longer tunnels with fewer intermediate surface access points • Provides for faster excavation rates than roadheaders when the machine is ideally matched to the project geology and major changes in cross-section or geology along the tunnel are minimised • Provides safer tunnelling conditions in poor ground conditions when compared to roadheaders. **Disadvantages:** • Require larger tunnelling and access sites than roadheaders • Tunnel boring machines are considerably more expensive to procure and operate than roadheaders • The timeframe for procuring, commissioning and launching tunnel boring machines would be much longer than for roadheaders • A three lane motorway cross-section would require tunnel boring machines about 16 metres in diameter. These would be within the top five largest globally. Given that mega diameter machines are uncommon, machines of such size are likely to pose considerably more construction risk than a roadheader solution • Being a circular excavation, tunnel boring machines require much greater over-excavation compared to roadheader construction. This results in substantially increased spoil volumes for the rock tunnelling and associated heavy vehicle hauling or barging and disposal, as well as a need to backfill within the tunnel to build the road level back up • Tunnel boring machines require long stretches of tunnel to outperform roadheaders on a cost and production basis. The maximum drive length for the Beaches Link tunnel would be two kilometres; therefore, there would be minimal efficiencies from using tunnel boring machines • Roadheaders and intermediate sites would still be required to excavate caverns and ramp connections ahead of tunnel boring machine arrival, as tunnel boring machines cannot accommodate these changes in cross-section • Major intermediate sites would be required at the northern and

Method	Summary of evaluation
	southern shorelines of Middle Harbour to retrieve landside machines and launch specialised machines if the project was to select tunnel boring machines that are matched to geology. The sites would need to be large to accommodate tunnel boring machines of the size and type required.

Middle Harbour crossing

While the majority of the tunnelling for the project is expected to be constructed through high-quality Hawkesbury Sandstone, the portion of tunnel crossing Middle Harbour presents particular challenges. These include:

- **Large changes in elevation:** Middle Harbour is a trench formed in bedrock, at its deepest being 60 metres below the water surface and 30 metres below the deepest rock level of the bed of the harbour. The bedrock is covered by up to 30 metres of clay, cobbles and silty sands. The tunnel would rise about 145 metres in elevation to connect from 30 metres below Middle Harbour with the Wakehurst Parkway at 115 metres in elevation. Considering the elevation change between the rock level under the bed of the harbour and the surface road connections at Cammeray, Artarmon, Balgowlah and Killarney Heights, it becomes apparent that the vertical grade of the proposed tunnel would be a key challenge – with gradient having implications for long-term operations of the tunnel in terms of safety and generation of emissions). A tunnel boring machine would be required to travel deep under Middle Harbour and travel underground for a long distance, producing steep tunnel gradients. This would present implications for safety and emission generation
- **Poor geology and rock fracturing at the harbour crossing:** Geotechnical testing has been conducted for the proposed harbour crossing. Unlike the bedrock either side of the harbour, the rock beneath the bed of the harbour is generally highly fractured. Without mitigation measures like forward probing and pre-grouting, this fracture zone is likely to cause major water ingress issues during construction using a driven or bored tunnelling method. This was observed during construction of the Northside Storage Tunnel beneath Middle Harbour in the late 1990s using a tunnel boring machine. These water ingress issues are normally controlled and managed through pre-grouting ahead of tunnelling operations where required and installing appropriate waterproof linings following tunnel excavation. Despite utilising forward grouting on the Northside Storage Tunnel project, the project encountered considerable water ingress during construction due to cracking of grout from initial rock relaxation along with substantial water pressures at depth. Utilisation of this knowledge would allow for a specialist tunnel boring machine to be designed to accommodate this risk in the future. Above the layer of fractured rock are layers ranging from stiff clay through to sand and sediment. Depending on the vertical alignment of the tunnels, they may need to be constructed through rock, through sediment, or a combination of these. Generally tunnelling through sediment is undesirable as it is prone to instability. However, high-quality Hawkesbury Sandstone is very deep beneath the harbour, giving rise to the need to balance between the preference to tunnel through rock and the gradient of the tunnels – with the gradient of the tunnels affecting traffic performance, emission generation, ventilation design, and long-term operational costs for the tunnels
- **Limited intermediate sites:** For most of its alignment, the proposed Beaches Link tunnels would pass beneath the suburbs of Willoughby, Naremburn, Northbridge, Seaforth and Balgowlah, which are characterised by highly urbanised areas with narrow streets. This presents a sizeable challenge to the establishment of viable intermediate tunnelling sites as these would likely require acquisition of a large number of private properties and/or unacceptable haulage routes via narrow local streets. This is a particular challenge when considering the scale of sites required to support large diameter slurry shield or tunnel boring machines for the harbour crossing. Furthermore, the topography means that the Beaches Link tunnels would generally be very deep, meaning that very deep shafts would be required to provide access at intermediate sites. Given the depth of the tunnels, establishment of

intermediate shafts near the harbour would take a long time to construct, and would be very inefficient points for construction access and egress

- **Cross-section:** The cross-section required for a modern three lane motorway crossing of Middle Harbour is about 15.5 metres wide. Given the poor geology (refer to Figure 4-16), this creates a considerable challenge for tunnel boring machines or roadheaders. If using a tunnel boring machine, this would require one of the largest machines of its type ever used in the world – substantially increasing construction cost, engineering and safety risk.

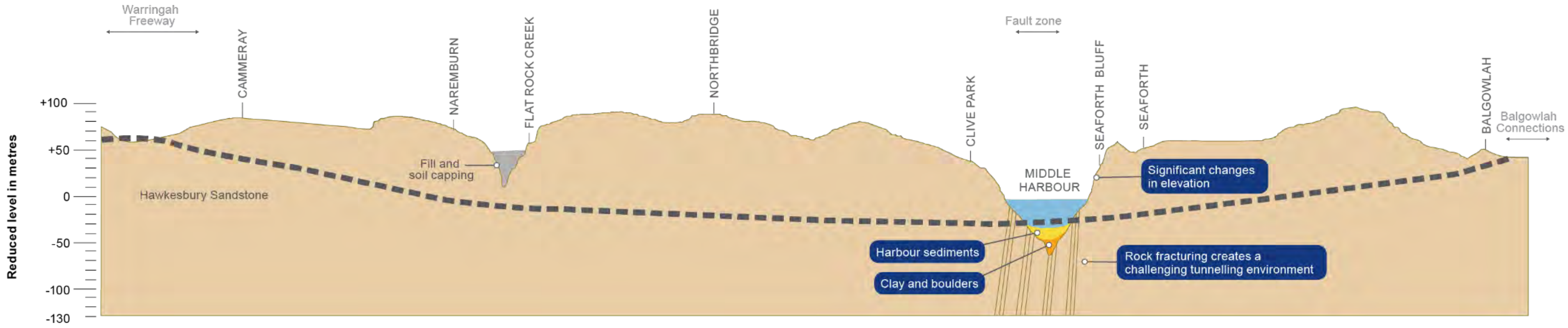


Figure 4-16 Indicative vertical alignment of the mainline and ramp tunnel

Design development for the project included a strong focus on evaluation of potential tunnelling methods for the crossing of Middle Harbour. This analysis was carried out by a multidisciplinary team including design, construction, transport planning, and environmental specialists to ensure a comprehensive analysis. It included the consideration of the roadheader method, specialised slurry shield tunnel boring machines, and an immersed tube tunnel (similar to the existing Sydney Harbour Tunnel).

Roadheader options for the Middle Harbour tunnel crossing were discounted early in the process for the following reasons:

- The tunnel depth required to deliver this method beneath Middle Harbour would compromise the gradients of the mainline tunnel, affecting traffic performance, emissions generation, and construction and operational costs
- The highly fractured geology beneath Middle Harbour, which creates a risk of major water ingress during construction if using the roadheader method.

Although tunnel boring machines are a viable alternative, the diameter and type of machines required for the crossing of Middle Harbour cannot be considered a conventional solution. Depending on the depth of the alignment, the tunnel boring machines required to cross Middle Harbour would need to be very large diameter slurry shield machines, as shown in Figure 4-17.

Slurry shield tunnel boring machines use clay slurry and compressed air to carefully control the pressure at the tunnelling face. This is required to maintain stability ahead of construction of the permanent concrete lining when tunnelling through poor ground conditions, such as those expected beneath Middle Harbour. The pressure at the tunnelling face needs to be carefully controlled as the machine advances to respond to the ground conditions as they vary.

These are highly sophisticated and specialised machines, and have rarely been used for sub-sea tunnelling at the diameter that would be required for the project. Slurry shield tunnel boring machines also require large landside sites, likely needing additional land acquisitions to accommodate these additional facilities which are not required for roadheader tunnelling:

- Segment production and storage
- Clay slurry production and processing.

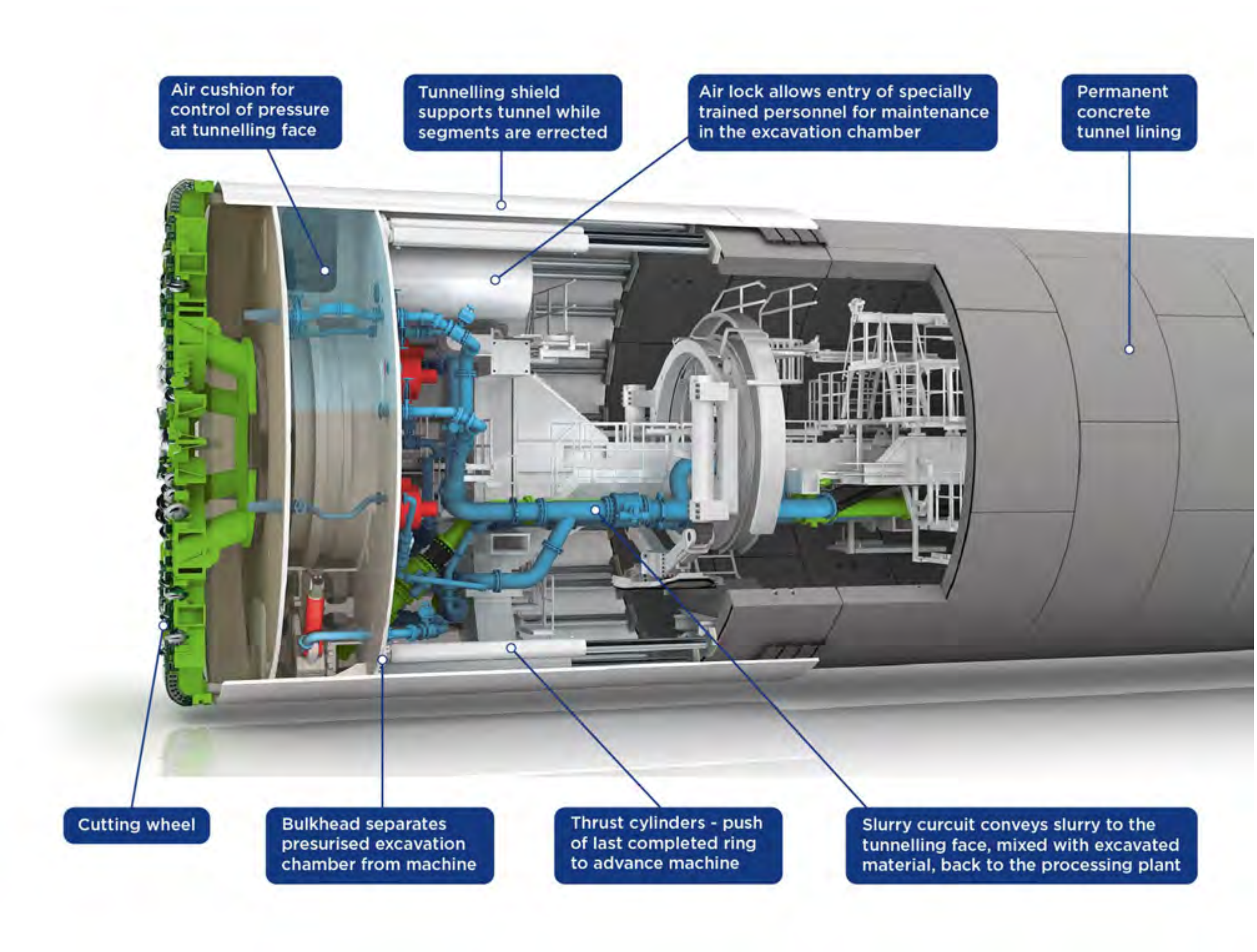


Figure 4-17 Example of a slurry shield tunnel boring machine

An alternative to tunnelling through rock or sediment using roadheaders or tunnel boring machines would be to place precast tunnel units on top, or within, the top layers of harbour rock and sediments. This method is known as an immersed tube tunnel and has been applied to over 150 major road and rail tunnels around the world to overcome similar combinations of geology, topography and cross-sectional challenges, including the existing Sydney Harbour Tunnel.

This alternative would involve excavation of the bed of the harbour and placement of immersed tube tunnel units within the excavated trench of varying depth as shown in Figure 4-18.

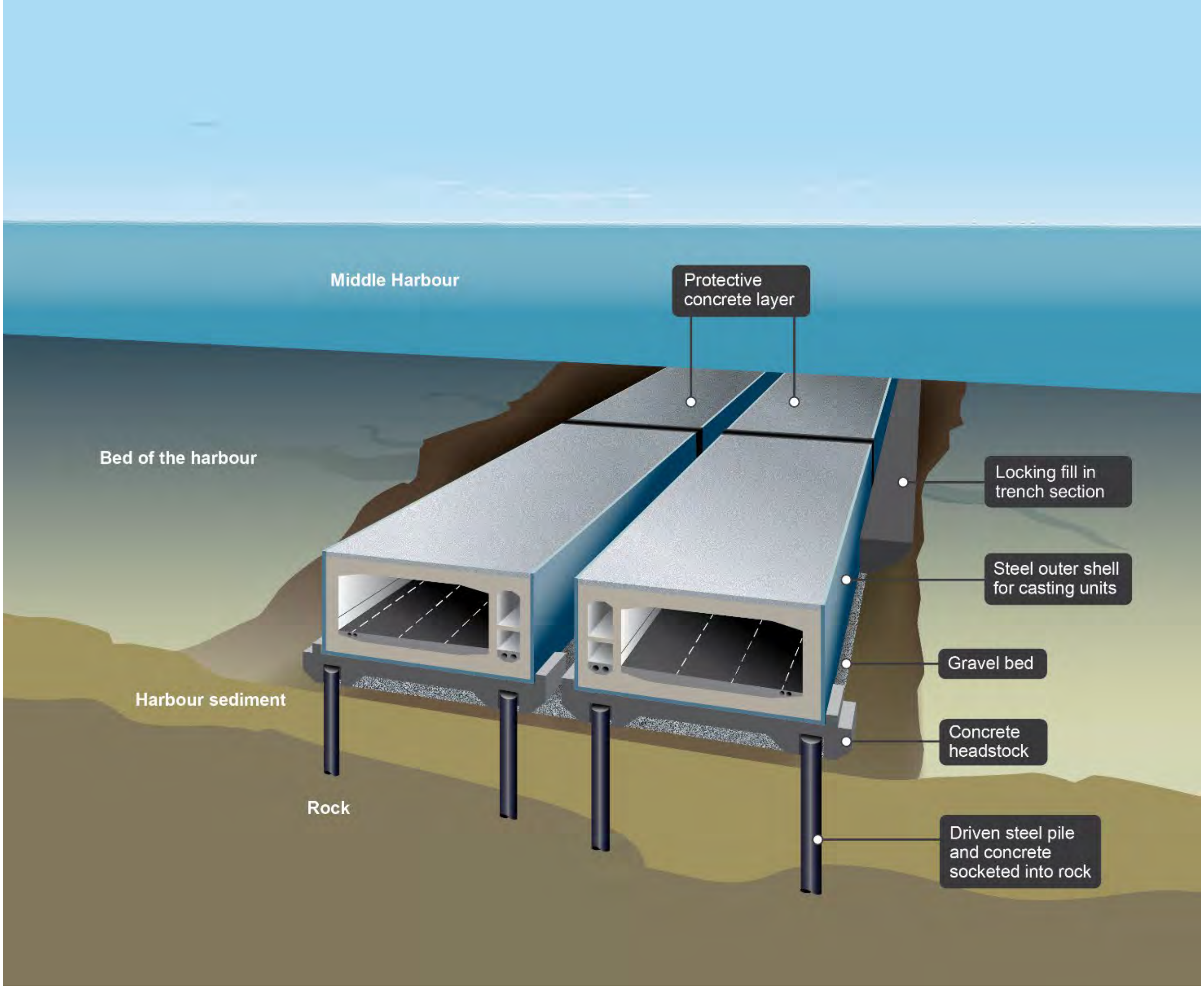


Figure 4-18 Example of an immersed tube tunnel

Figure 4-19 shows the four main options considered for the vertical alignment of the Middle Harbour tunnels:

- A deep driven roadheader tunnel, completely within rock (green)
- A shallower tunnel boring machine tunnel, with parts of the tunnel in softer, weathered rock or sediment (blue and purple)
- An immersed tube tunnel lying on top, or within the top layers, of softer, weathered rock and sediments (grey).

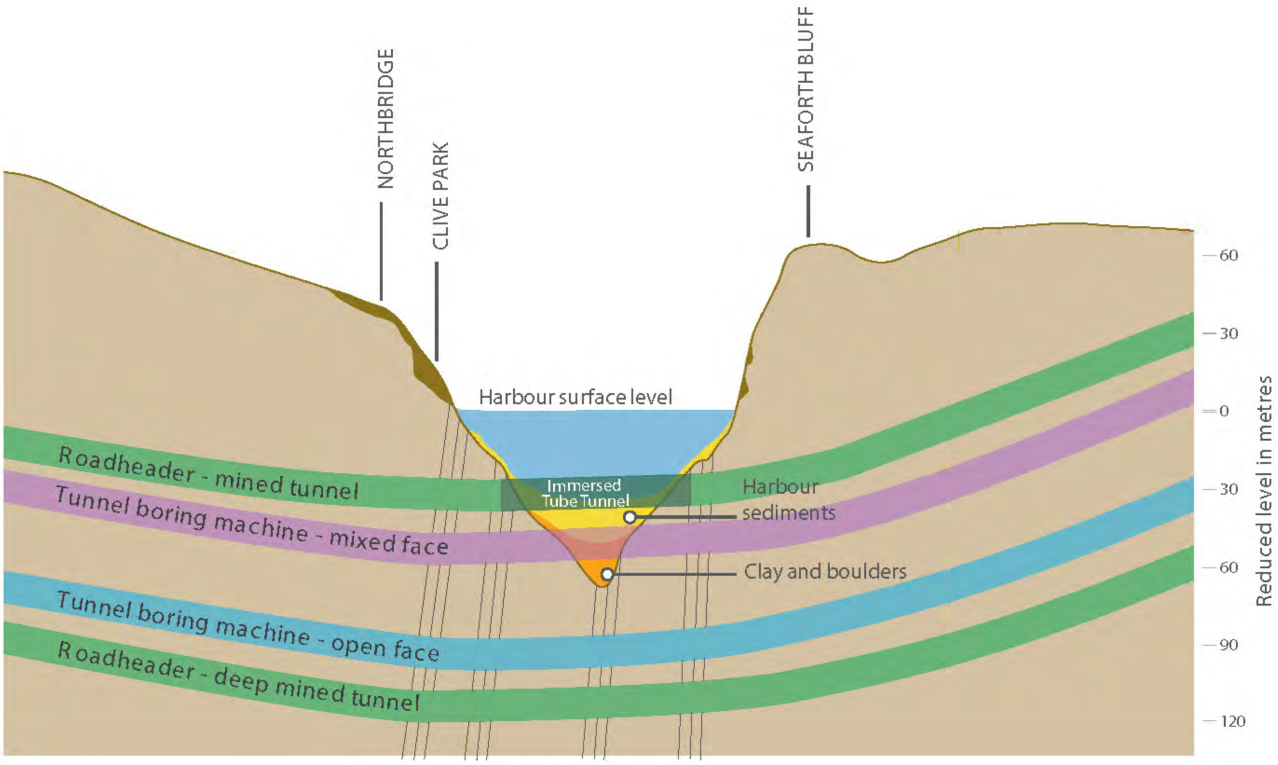


Figure 4-19 Main vertical alignment options for the Middle Harbour tunnels

When considering the performance of each of the potential methodologies against design, constructability, traffic performance, environmental and social criteria, the preferred method for crossing Middle Harbour is via an immersed tube tunnel. The justification for selecting this alternative is summarised in Table 4-4.

Table 4-4 Preferred tunnelling method for the Middle Harbour crossing

Method	Summary of evaluation
Immersed tube tunnel	**Advantages:** • The technology required is proven, having been used on major contemporary infrastructure projects around the world, including the Sydney Harbour Tunnel • Provides the shallowest possible tunnel alignment at the Middle Harbour crossing enabling the best possible gradient and associated performance outcomes (eg safety, vehicle speeds, journey experience, long-term emissions) • Minimises tunnelling risks by reducing exposure to tunnelling through poor geology and reducing the time workers need to spend in high risk tunnelling environments • Lower construction and operational costs when compared to alternative methodologies • Minimises the size of waterside sites when compared to those required to launch, support, and retrieve large diameter tunnel boring machines • Substantially reduces haulage on land when compared to tunnel boring machine solutions • Takes advantage of marine logistics to minimise heavy haulage on roads • The preferred alignment avoids interfaces with substantial sensitive marine ecology at the sand bar at the entrance to Middle Harbour (immersed tube tunnel proposed for the purple corridor alternative). **Disadvantages:**

Method	Summary of evaluation
	• Requires measures to be implemented to prevent migration of material during excavation of sediments, particularly areas with elevated levels of contaminants within the surface layer (about 0.5 metres to one metre) of the bed of Middle Harbour • Interfaces with commercial and recreational maritime traffic during construction.

4.5.2 Warringah Freeway connection alternatives

The Warringah Freeway connection would provide connectivity between Beaches Link, the Western Harbour Tunnel and Gore Hill Freeway. Initially, considerations of possible alternatives for such a connection included an underground interchange option as well as a contemporary surface interchange. Ultimately, the underground interchange was found to be incompatible with the preferred corridor alternative (blue corridor alternative), while also being considered to be cost prohibitive. The underground interchange would require the reconfiguration of the Warringah Freeway corridor for surface infrastructure and portals, given the increase in vehicles that would use the corridor, and some form of connection to the surface for vehicles leaving the Beaches Link tunnel.

As such, a surface connection in the form of a surface interchange, was considered the preferred connection alternative for linking the Beaches Link and Warringah Freeway. However, there were severe limitations for the location for a surface interchange, given the intense land use in the surrounding area and the resulting environmental and community impacts, including property acquisition. Therefore, the preferred alternative for the Warringah Freeway connection has been developed to remain primarily within the existing road corridor.

With this in mind, the consideration of alternatives for the surface connection of Beaches Link and Warringah Freeway included:

- Locations and configurations of ramp connections to and from the Warringah Freeway
- Connections between the Beaches Link and the Western Harbour Tunnel, North Sydney and, more broadly, the Sydney Harbour Bridge (cut and cover or mined-tunnel solutions)
- Minimising environmental, community and property impacts.

Informed by these considerations, it was determined that the preferred connection alternative for the Warringah Freeway would be that the Beaches Link tunnel portals would be located south of the Miller Street overpass within the road corridor. This location would take advantage of the wide road corridor and more sympathetic topography compared to road corridor availability and topography for tunnel portal locations south of Ernest Street. The tunnel portal locations would also enable many of the proposed road connections to largely occur aboveground, thereby avoiding more underground caverns and tunnels. The location would require utilisation of some land currently used by Cammeray Golf Course in order to achieve the optimal staging of the surface connection.

The surface connection would also integrate with the Western Harbour Tunnel and Warringah Freeway Upgrade project, ensuring that the location and extent of ramp connections and portals, as well as the preferred construction methodology, could be optimised between the projects, reducing disruption as much as possible.

4.5.3 Gore Hill Freeway Connection alternatives

The Gore Hill Freeway Connection would provide the strategic east–west link for movements between the Northern Beaches and strategic centres accessed via the Gore Hill Freeway/Lane Cove Tunnel and Reserve Road at Artarmon, including Macquarie Park and St Leonards. Three alternatives have been considered for this connection as shown in Figure 4-20.

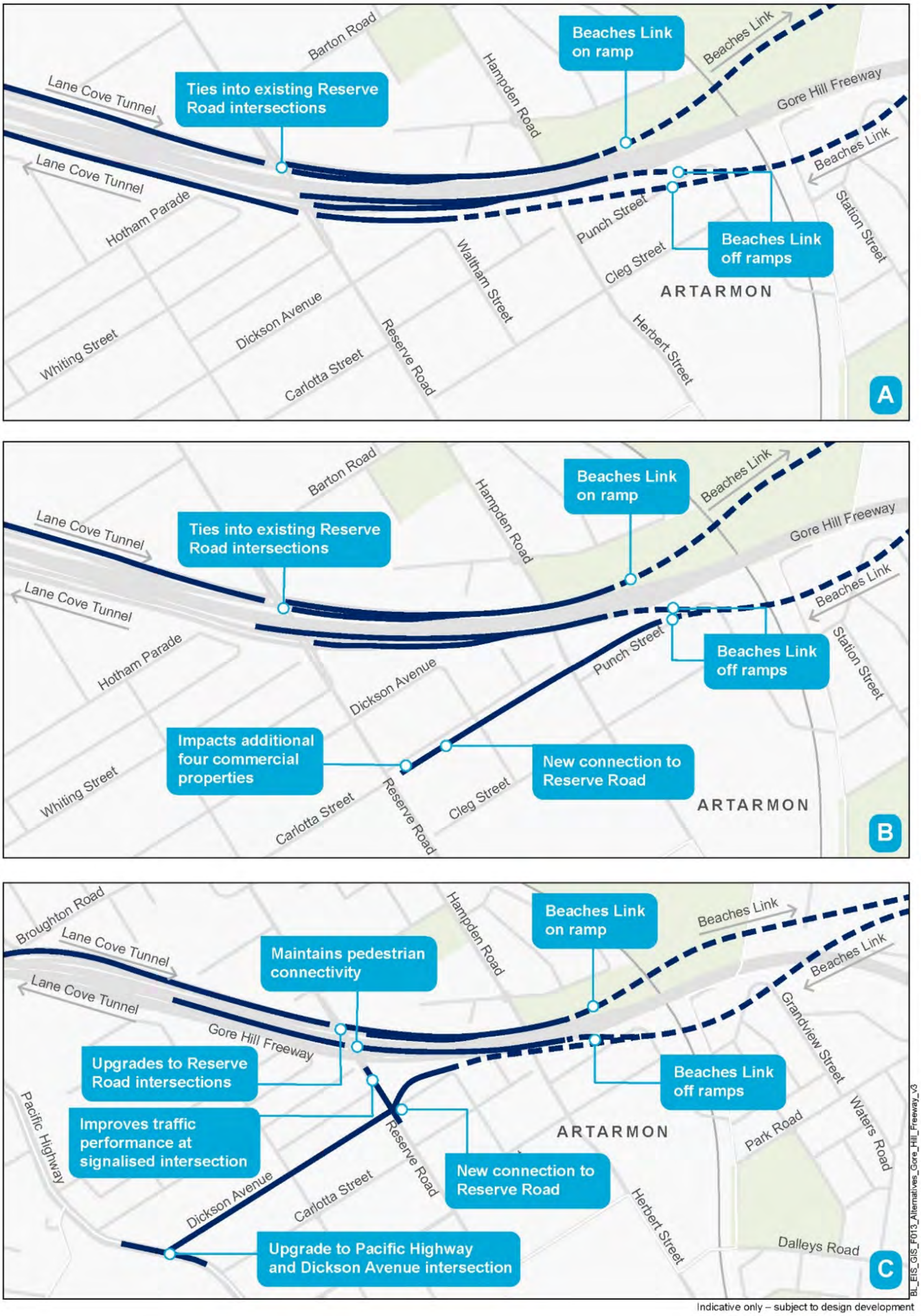


Figure 4-20 Alternatives considered for the Gore Hill Freeway Connection

An overview of the justification for selecting option C (refer to Figure 4-20) as the preferred connection alternative is summarised in Table 4-5.

Table 4-5 Summary of evaluation of Gore Hill Freeway Connection preferred alternative

Evaluation criteria	Reason for preferred alternative (option C)
Connectivity and network performance	• Provides connectivity between Beaches Link and the Gore Hill Freeway/Lane Cove Tunnel, supporting the strategic east–west connectivity to and from the Northern Beaches • Provides connectivity between Beaches Link and Reserve Road, enabling convenient access to and from the Artarmon industrial area, employment centres such as St Leonards and Chatswood, and Royal North Shore Hospital precinct. The direct motorway standard link between Royal North Shore Hospital and the Northern Beaches Hospital Precinct would be an important benefit of Beaches Link • Provides connectivity to Chatswood via Dickson Avenue and the Pacific Highway • Reduces pressure on the Reserve Road interchange compared to options that introduce westbound off ramps into this node.
Constructability and design	• Reduces impacts on the Gore Hill Freeway and Lane Cove Tunnel during construction, given the works would be on both the inside and outside of the existing corridor • Challenges largely relate to the construction of the works under Hampden Road and adjacent to live traffic on the Gore Hill Freeway • Probable maximum flood immunity achieved.
Community and environment	• Minimises impacts on bushland to the north • Minimises impacts to private property, notably residential property acquisition requirements • Major construction sites located to the south of the Gore Hill Freeway in the Artarmon industrial area – reducing exposure to residential receivers.

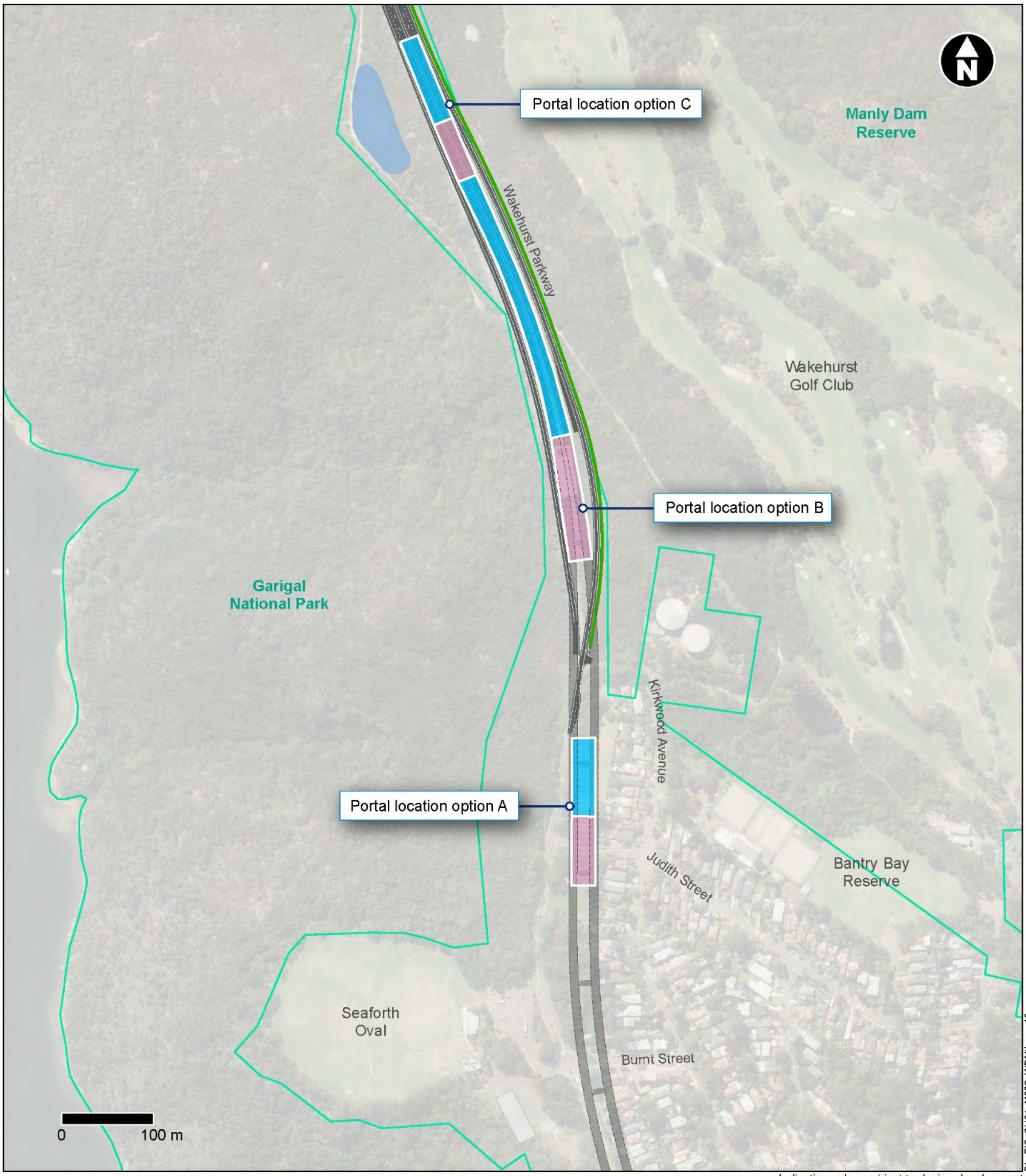
4.5.4 Wakehurst Parkway connection alternatives

Following the unveiling of the *County of Cumberland Planning Scheme* (1948), it was proposed that the Wakehurst Parkway become the main road between the Sydney CBD and the Northern Beaches via a Warringah Freeway extension to Seaforth. The Wakehurst Parkway's intended function as a motorway receiver is reflected in the fact that it is an arterial, limited access road with an 80 km/h posted speed and is located within a road reservation that is about 80 metres wide. The current Wakehurst Parkway corridor is a key arterial road link for the northern and western areas of the Northern Beaches, including Frenchs Forest, Narrabeen and Mona Vale. However, its current utility is diminished by its southern terminus, which links through the Seaforth town centre before connecting to Manly Road/Spit Road/Military Road.

New tunnelled connections to and from the Wakehurst Parkway would provide a strategic link between the Northern Beaches Hospital Precinct and centres in the upper Northern Beaches, and key centres across Greater Sydney. This would greatly improve connectivity for the northern areas of the Northern Beaches and assist in reducing demand for the Warringah Road, Roseville Bridge and Eastern Valley Way corridors.

A range of alternatives have been considered for this connection, including the location of the tunnel portals along the Wakehurst Parkway. Three alternative locations (portal location option A, portal location option B and portal location option C) were considered, as shown in Figure 4-21.

All portal location alternatives were located within the Wakehurst Parkway road corridor, which is much wider than the current road.



Indicative only – subject to design development

Legend

Alternative locations
- Cut and cover
- Trough structure

Operational features
- Surface road
- Pedestrian / active transport links
- Tunnel
- Permanent water quality basin

Natural features
- National parks and reserves

Figure 4-21 Connection alternatives at the Wakehurst Parkway

Following assessment of the options by a multidisciplinary team, portal location option B (refer to Figure 4-21) was selected as the preferred location of the connections to and from the Wakehurst Parkway. The justification for selecting this alternative is summarised in Table 4-6.

Table 4-6 Summary of evaluation of the Wakehurst Parkway connection preferred alternative

Evaluation criteria	Reason for preferred alternative (option B)
Connectivity and network performance	• Portal location option B would provide high-quality connectivity to and from the Wakehurst Parkway within the 80 km/h speed zone, avoiding interfaces between the limited access portion and residential streets • Connectivity to and from the Wakehurst Parkway south of the portals would be maintained but converted to on and off ramps – making the new tunnel connections the main route and downgrading the southern portion of the Wakehurst Parkway which is bypassed • A 'turn around' option was considered to provide access to and from the northern part of Seaforth. This option would involve an underpass near portal location option C and ramps that would allow Seaforth residents to get to and from the tunnels. This option was tested, however the demand was extremely low due to the distance to be travelled combined with the bypass of the southern portion of Wakehurst Parkway and its connection at Balgowlah, making portal location option B more attractive from a travel time perspective.
Constructability and design	• Portal location option B would enable traffic to be diverted around the outside of a central work zone • Portal location option B would result in a reduction of about 450 metres of surface works compared to portal location option A • Portal location option B would include a tunnelling length of 200 metres at a maximum grade of six per cent compared to 750 metres at a maximum grade of six per cent at portal location option A • Portal location option B would require about 450 metres less tunnelling than portal location option C.
Community and environment	• There would be a reduced impact on Duffys Forest endangered ecological community compared to portal location option A • The community impact would be less than at portal location option A, as the tunnel portal would be located further from residential properties • Option B would still require the Option A site area for a temporary construction support site • Access to Seaforth Oval would no longer be impacted during construction • Reduced visual impact and landscape impacts compared to portal location option A • Avoided impacts on Garigal National Park and Manly Dam Reserve.
Economic factors	• Offers economic efficiencies due to reducing the length of tunnel at maximum grade, thus lowering associated costs. These economic efficiencies offset the additional capital cost of increased driven tunnelling for option B.

4.5.5 Balgowlah connection alternatives

The Balgowlah connections would link the Beaches Link tunnels and the eastern area of the Northern Beaches peninsula, including Seaforth, Manly and Brookvale. These suburbs are accessed via Condamine Street and Sydney Road, which both connect to Burnt Bridge Creek Deviation where the Balgowlah connection alternatives have been explored, based on:

- Tunnelled connections to both Burnt Bridge Creek Deviation and Sydney Road (alternatives 1 and 2)
- Tunnelled connections to Burnt Bridge Creek Deviation with a surface connection to Sydney Road via a new access road (alternatives 4a, 4b and 4c)
- Tunnelled connections to Burnt Bridge Creek Deviation with a surface connection via an upgraded Burnt Bridge Creek Deviation to Sydney Road (alternatives 3, 6 and 7)
- Tunnelled connections to Burnt Bridge Creek Deviation with a surface connection to Sydney Road via an upgraded Condamine Street (alternatives 5, 8 and 9).

A summary of the assessment of each of the connection alternatives against the key objectives of the project for the Balgowlah area (as shown in Table 4-7) are outlined below.

Table 4-7 Key objectives of the project for the Balgowlah area

Category	Consideration
Traffic and transport	• Improve key travel times for the region • Improve local traffic performance • Meet predicted strategic demand with connectivity and gradients to deliver a high-quality transport product • Integrate with existing bus lanes to provide for express bus services via Beaches Link • Integrate with the local road network to minimise impacts and optimise performance • Minimise traffic impact to Burnt Bridge Creek Deviation, Condamine Street and Sydney Road during construction • Minimise impacts to existing active transport corridors and identify opportunities for improvements.
Environment and heritage	• Minimise impacts to existing vegetation, particularly intact portions of the Burnt Bridge Creek corridor west of the Burnt Bridge Creek Deviation and east of Kitchener Street • Minimise impacts on Burnt Bridge Creek • Minimise impacts to grey-headed flying fox habitat north of Kitchener Street • Ventilation design and effectiveness to meet Department of Planning, Industry and Environment and NSW Environment Protection Authority requirements.
Community	• Minimise impacts to existing recreation areas • Minimise direct and indirect impacts on sensitive receivers, for example, schools, childcare centres, aged care facilities, etc. • Identify opportunities for amenity improvements both during and after completion (active transport, open space and recreation areas, etc.)

Category	Consideration
	• Minimise direct private property impacts • Minimise indirect private property impacts • Ensure pedestrian safety during construction and operation.
Flooding	• Maintain flood immunity of Beaches Link ramps • Avoid potential increases to flooding in surrounding properties associated with location of Beaches Link infrastructure.
Constructability and engineering	• Designs to meet Australian Standards and Transport for NSW design and safety standards • Access to suitable temporary construction support sites • Minimise construction staging works in busy road corridors • Ensure solution can be constructed and maintained safely and efficiently • Minimise program duration • Minimise haulage via local roads • Minimise interfaces with pedestrians during construction • Minimise exposure to poor geology • Minimise impacts on existing utilities.
Cost	• Ensure a value for money solution, considering both construction and operational costs and risks.

Each alternative was assigned a ranking for each category to identify whether it aligns with the project development considerations, as per the colour coding shown below:

Aligns with project development considerations

Mostly aligns with project development considerations

Partially aligns with project development considerations

Does not align with project development considerations

The proposed reference design (New Access Road option) is used as the base for comparison of alternatives in the following text.

Alternative 1 - Ramps emerging in Sydney Road

Alternative 1 would comprise tunnel ramps emerging within Burnt Bridge Creek Deviation to provide connectivity to and from the Pittwater Road/Condamine Street corridor. Single lane ramps to Sydney Road would provide connectivity for traffic travelling to and from the Manly area.

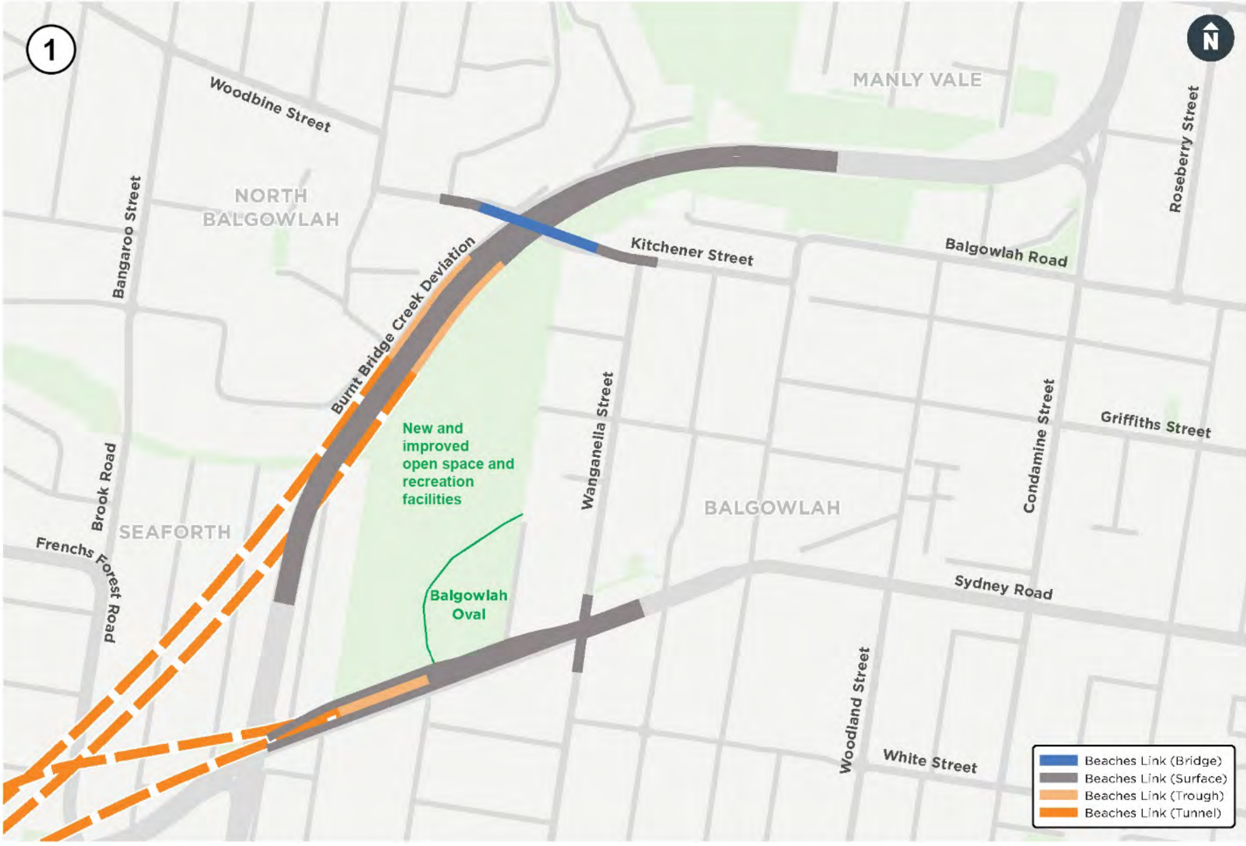


Figure 4-22 Alternative 1 – Ramps emerging in Sydney Road

Table 4-8 Evaluation summary of 'Alternative 1 - Ramps emerging in Sydney Road'

Category	Consideration	Assessment
Traffic and transport	• Poor connectivity to Seaforth/North Balgowlah as east-facing ramps to Sydney Road do not service the catchment west of Burnt Bridge Creek Deviation • Direct tunnel connection to Sydney Road reduces pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection • Reduced traffic signal controls for southbound traffic on Burnt Bridge Creek Deviation • Challenging to integrate tunnel ramps into Sydney Road • Impacts to local access at Pickworth Avenue and Maretimo Street due to emerging tunnel ramps • Lanes from tunnel not able to fully integrate ahead of Wanganella Street intersection. Existing right turn to Wanganalla Street (south) would need to be removed • Existing eastbound queuing capacity at this intersection reduced – likely to impact performance • Major construction staging works within Sydney Road corridor.	

<table>
<tr><th>Category</th><th>Consideration</th><th>Assessment</th></tr>
<tr><td>Environment and heritage</td><td>Requires realignment of Burnt Bridge Creek but this impact would be limited to the portion of the creek previously realigned during original Burnt Bridge Creek Deviation construction and Balgowlah Golf Course construction works.</td><td></td></tr>
<tr><td>Community</td><td>Increased property impacts – 12 residences and businesses impacted along Sydney Road between Burnt Bridge Creek Deviation and Wanganella Street
Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for:
- Burnt Bridge Creek Deviation and Sydney Road staging and widening works
- Tunnel and surface works temporary construction support site
- Motorway facilities
Reduced permanent impacts to golf course; motorway facilities still located on golf course land
Impact to Balgowlah Oval due to widening of Sydney Road
Permanent road infrastructure further away from residents on eastern side of golf course; but closer to residents and schools on Sydney Road
Impact to existing pedestrian bridge over Sydney Road due to road widening and construction of cut and cover ramps in Sydney Road
Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works.</td><td></td></tr>
<tr><td>Flooding</td><td>Increased risk of flooding impacts during construction.</td><td></td></tr>
<tr><td>Constructability and engineering</td><td>Large increase in tunnelling (2.9 kilometres) due to:
- Additional tunnel ramps to Sydney Road not included in the proposed reference design. The length of these ramps is driven by the substantial level difference between Sydney Road and where the Burnt Bridge Creek Deviation ramps dive underground
- Additional tunnelling would also be required to provide ventilation tunnels from the Sydney Road ramps to the Burnt Bridge Creek Deviation motorway facility/ventilation outlet
Increase in tunnelling quantities would necessitate an increased number of roadheaders, increased spoil volumes, and hence increased heavy haulage from this site - over 40,000 truck movements for spoil haulage alone Increased construction complexity and disruptions to local traffic, including major staging within Sydney Road corridor</td><td></td></tr>
</table>

Category	Consideration	Assessment
	• Additional impacts to utilities on Sydney Road. This may result in temporary impacts to local utilities in the area during relocation works.	
Cost	• Increased construction and operational costs due to additional: - Infrastructure and fans required to move air through longer ventilation tunnels, with increased maintenance costs - Major construction staging works within Sydney Road.	●

Alternative 2 - Tunnel loop ramps to Sydney Road

Alternative 2 would comprise tunnel ramps emerging within Burnt Bridge Creek Deviation to provide connectivity to and from the Pittwater Road/Condamine Street corridor. Single lane ramps to Sydney Road would use an underground loop within the Balgowlah Golf Course to connect to a signalised intersection on Sydney Road near Maretimo Street.

Figure 4-23 Alternative 2 - Tunnel loop ramps to Sydney Road

Table 4-9 Evaluation summary of 'Alternative 2 - Tunnel loop ramps to Sydney Road'

Category	Consideration	Assessment
Traffic and transport	• Local network performance as per proposed reference design alternative 4c • Traffic signals for an access road no longer required at Burnt Bridge Creek Deviation.	
Environment and heritage	• Requires realignment of Burnt Bridge Creek but this impact would be limited to the portion of the creek previously realigned during original Burnt Bridge Creek Deviation construction and golf course construction works.	
Community	• Direct private property impacts as per proposed reference design alternative 4c • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: - Burnt Bridge Creek Deviation and Sydney Road staging and widening works - Tunnel and surface works temporary construction support site - Tunnel loop construction works - Motorway facilities • Permanent impacts to the golf course for the loop ramps and motorway facilities • Increased residual land for community use post construction • Balgowlah Oval closed during construction due to loop ramp construction • Permanent road infrastructure further from residents on eastern side of golf course • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works.	
Flooding	• Increased risk of flooding impacts during construction.	
Constructability and engineering	• Large increase in tunnelling (additional 3.3 kilometres) due to: - Additional tunnel ramps to Sydney Road not included in the proposed reference design alternative 4c. The length of these ramps is determined by the substantial level difference between Sydney Road and the location where the Burnt Bridge Creek Deviation ramps dive underground - Additional tunnelling to provide ventilation tunnels from the Sydney Road ramps to the Burnt Bridge Creek Deviation motorway facility/ventilation outlet	

Category	Consideration	Assessment
	• Increase in tunnelling quantities would necessitate an increased number of roadheaders, increased spoil volumes, and hence increased heavy haulage from this site - over 40,000 truck movements for spoil haulage alone.	
Cost	• Increased construction and operational costs due to additional infrastructure and fans required to move air through longer ventilation tunnels, with higher maintenance costs.	●

Alternative 3 - Connection partially controlled by traffic signals at Burnt Bridge Creek Deviation

Alternative 3 would comprise a single set of tunnel ramps to Burnt Bridge Creek Deviation, emerging near Serpentine Crescent. This would provide free-flow connection to and from the tunnel for traffic travelling to and from the Pittwater Road/Condamine Street corridor.

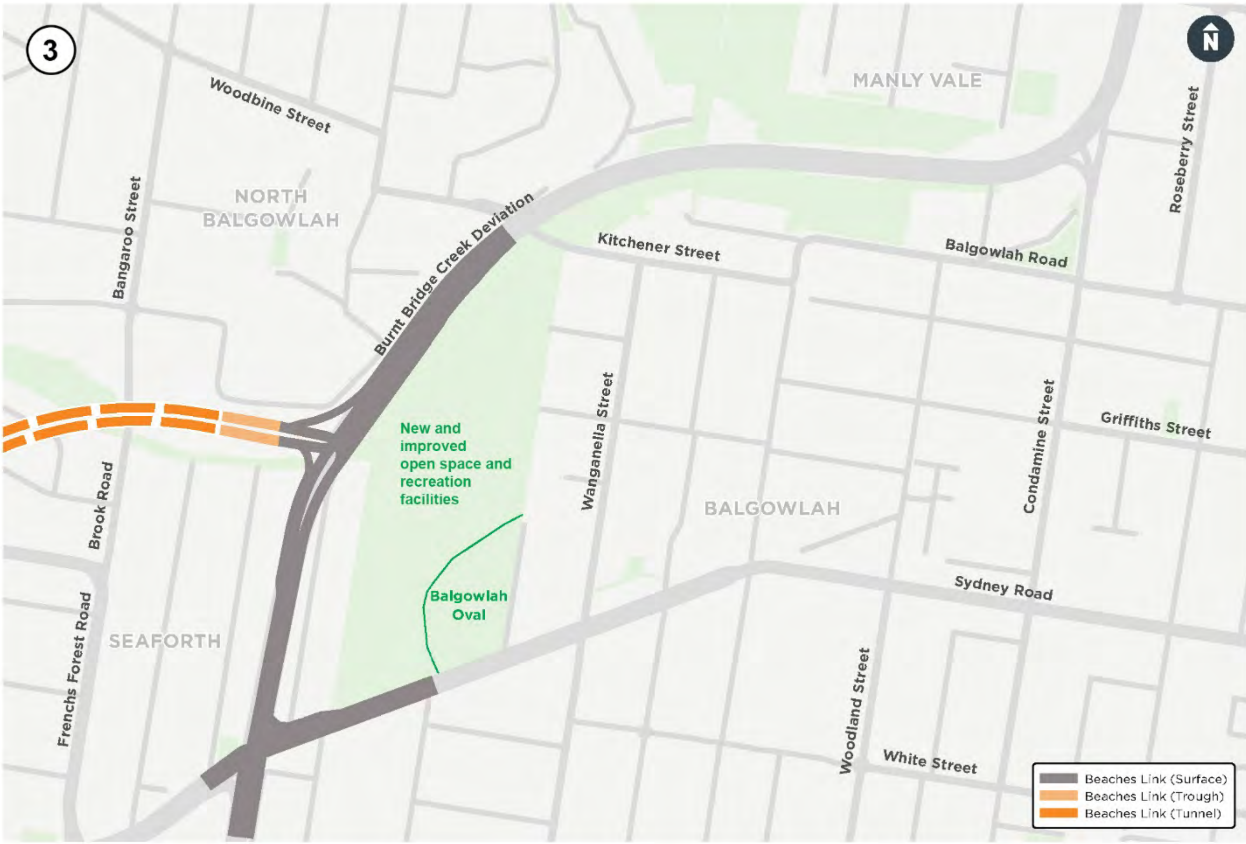


Figure 4-24 Alternative 3 - Connection partially controlled by traffic signals at Burnt Bridge Creek Deviation

Table 4-10 Evaluation summary of 'Alternative 3 - Connection partially controlled by traffic signals at Burnt Bridge Creek Deviation'

Category	Consideration	Assessment
Traffic and transport	• Reduced traffic signal phases for southbound traffic from Burnt Bridge Creek Deviation to the tunnel • Traffic signals for the access road no longer required at the Maretimo Street/Sydney Road intersection • Increased risk of queuing into tunnel due to additional conflicting signalised movements • Poorer local network performance as a result of: - Additional traffic signal phasing to the Sydney Road/Burnt Bridge Creek Deviation/Manly Road intersection to allow for right turn for westbound traffic to Burnt Bridge Creek Deviation (currently not permitted). This would place additional pressure on the performance of this intersection - New traffic signals for northbound surface traffic on Burnt Bridge Creek Deviation (not signalised in proposed reference design alternative 4c).	
Environment and heritage	• Major impacts to the section of Burnt Bridge Creek west of Burnt Bridge Creek Deviation – likely to be redirected into culverts • Additional 13,000 square metres of vegetation clearing along the Burnt Bridge Creek corridor to the west of Burnt Bridge Creek Deviation • Increased tunnel infrastructure in Burnt Bridge Creek floodplain.	
Community	• Permanent road infrastructure located further from residents on eastern side of golf course • Increased property impacts: - 17 additional properties impacted for tunnel ramp construction and intersection upgrade at Sydney Road - Permanent road infrastructure closer to residents on Serpentine Crescent, Hope Street and Kempbridge Avenue and closer to Seaforth Public School • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: - Burnt Bridge Creek Deviation staging and widening works - Tunnel and surface works temporary construction support site • Permanent impacts to Balgowlah Golf Course for the Burnt Bridge Creek Deviation widening • Longer construction program.	

Category	Consideration	Assessment
Flooding	• Increased tunnel infrastructure in Burnt Bridge Creek floodplain to ensure the tunnels are not flooded during major flood events. These measures would be likely to impact flow-path and flood levels on nearby properties • Additional risk of flooding during construction.	
Constructability and engineering	• Complex construction staging resulting in: - Slow productivities due to constrained cut and cover site and tunnel construction access in creek valley - Major disruption to Burnt Bridge Creek Deviation during construction of intersection and cut and cover structure - Risk of flooding during construction due to portal location in creek valley.	
Cost	• Considerably increased construction cost due to: - Increased staging in busy Burnt Bridge Creek Deviation corridor - Increased exposure to flooding risk - Highly constrained construction site.	

Alternative 4a - North facing tunnel ramps to Burnt Bridge Creek Deviation with access road to distribute traffic and provide connection to new open space and recreation facilities

Alternative 4a would comprise a single set of tunnel ramps to Burnt Bridge Creek Deviation, emerging south of Kitchener Street to provide connectivity to and from the Pittwater Road/Condamine Street corridor. Connectivity between the tunnel and Sydney Road corridor would be provided via a surface access road aligned to the eastern boundary of the golf course to distribute traffic across the network. The access road would also provide connection to the new and improved open space and recreation facilities.

Figure 4-25 Alternative 4a - North facing tunnel ramps to Burnt Bridge Creek Deviation with access road to distribute traffic and provide connection to new and improved open space and recreation facilities

Table 4-11 Evaluation summary of 'Alternative 4a - North facing tunnel ramps to Burnt Bridge Creek Deviation with access road to distribute traffic and provide connection to new and improved open space and recreation facilities'

Category	Consideration	Assessment
Traffic and transport	• Access road connection to Sydney Road along eastern boundary improves long-term network performance by: - Reducing pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection and Condamine Street between Burnt Bridge Creek Deviation and Sydney Road - Eliminating traffic weaving inherent in many other options - Improving traffic performance and road safety outcomes • Minimises staging and construction works in Sydney Road corridor • Requires traffic lights for southbound traffic on Burnt Bridge Creek Deviation • Provides connection to the new and improved open space and recreation facilities.	
Environment and heritage	• Requires realignment of Burnt Bridge Creek but this impact would be limited to the portion of the creek previously	

Category	Consideration	Assessment
	realigned during original Burnt Bridge Creek Deviation construction and golf course construction works.	
Community	• Small number (six) of private property acquisitions. Acquisitions on Sydney Road and Serpentine Crescent not required as for several other alternatives • Balgowlah Oval and the pedestrian bridge over Sydney Road remain open during construction • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: - Burnt Bridge Creek Deviation widening works - Tunnel and surface works temporary construction support site - Motorway facilities and access road construction • Opportunity to re-purpose Balgowlah Golf Course as new and improved open space and recreation facilities in a staged manner both during and after construction • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works • Permanent road infrastructure closer to residents near the eastern boundary of the golf course • Permanent noise and visual impacts would require mitigation during operation.	
Flooding	• Increased risk of flooding impacts during construction.	
Constructability and engineering	• Motorway facilities close to the tunnel ramps reduces the length of ventilation tunnels and maximises the efficiency of the system • Less tunnelling and haulage of spoil compared to other alternatives • Minimises construction in the Sydney Road corridor • Minimises construction within the Burnt Bridge Creek Deviation corridor • Relatively low cover tunnelling required under residential properties in Hope Street, increasing settlement risk.	
Cost	• Reduced construction staging in the Sydney Road corridor, reducing construction costs • Reduced scope of local road works required to integrate the project, reducing construction costs.	

Alternative 4b - North facing tunnel ramps to Burnt Bridge Creek Deviation with access road aligned to the golf course's western boundary to distribute traffic and provide connection to the new and improved open space and recreation facilities

Alternative 4b would comprise a single set of tunnel ramps to Burnt Bridge Creek Deviation, emerging south of Kitchener Street to provide connectivity to and from the Pittwater Road/Condamine Street corridor. Connectivity between the tunnel and Sydney Road corridor would be provided via a surface access road to distribute traffic, similar to that outlined for 'Alternative 4a', however differing in alignment as the access road would run parallel to the western boundary of the golf course. The access road would also provide connection to the new and improved open space and recreation facilities.

Compared to alternative 4a, an additional 29 residential properties would be acquired on Dudley Street to facilitate:

- Locating of the temporary construction support site partially near Dudley Street and partially on golf course land
- The opportunity for a staged hand over of new and improved open space and recreation facilities on the eastern side of the new access road
- Additional new open space and recreation facilities on residual land near Dudley Street after construction works are completed.

Figure 4-26 Alternative 4b – North facing tunnel ramps to Burnt Bridge Creek Deviation with access road aligned to the golf course's western boundary to distribute traffic and provide connection to the new and improved open space and recreation facilities

Table 4-12 Evaluation summary of 'Alternative 4b – North facing tunnel ramps to Burnt Bridge Creek Deviation with access road aligned to the golf course's western boundary to distribute traffic and provide connection to the new and improved open space and recreation facilities'

Category	Consideration	Assessment
Traffic and transport	• Access road connection to Sydney Road along eastern boundary improves long-term network performance by: - Reducing pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection and Condamine Street between Burnt Bridge Creek Deviation and Sydney Road - Eliminating traffic weaving inherent in many other options - Improving traffic performance and road safety outcomes • Minimises staging and construction works in Sydney Road corridor • Requires traffic lights for southbound traffic on Burnt Bridge Creek Deviation • Provides connection to the new and improved open space and recreation facilities.	
Environment and heritage	• Requires realignment of Burnt Bridge Creek but this impact would be limited to the portion of the creek previously realigned during original Burnt Bridge Creek Deviation construction and golf course construction works.	
Community	• Additional 29 private property acquisitions compared to alternative 4a • Balgowlah Oval and the pedestrian bridge over Sydney Road remain open during construction • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: - Burnt Bridge Creek Deviation widening works - Tunnel and surface works temporary construction support site - Motorway facilities and access road construction • Opportunity to re-purpose Balgowlah Golf Course as new and improved open space and recreation facilities in a staged manner both during and after construction • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works • Permanent road infrastructure further from residents near the eastern boundary of the golf course • Permanent noise and visual impacts would less require mitigation during operation.	

Category	Consideration	Assessment
Flooding	• Increased risk of flooding impacts during construction.	
Constructability and engineering	• Motorway facilities close to the tunnel ramps reduces the length of ventilation tunnels and maximises the efficiency of the system • Less tunnelling and haulage of spoil compared to other alternatives • Minimises construction in the Sydney Road corridor • Minimises construction within the Burnt Bridge Creek Deviation corridor • Relatively low cover tunnelling required under residential properties in Hope Street, increasing settlement risk.	
Cost	• Reduced construction staging in Sydney Road, reducing construction costs • Reduced scope of local road works required to integrate the project, reducing construction costs.	

Alternative 4c - North facing tunnel ramps to Burnt Bridge Creek Deviation with shortened, centralised access road to distribute traffic and provide connection to the new and improved open space and recreation facilities

Alternative 4c is similar in design and arrangement as alternatives 4a and 4b. Alternative 4c would comprise a single set of tunnel ramps to Burnt Bridge Creek Deviation that would emerge south of Burnt Bridge Creek, rather than further north as in alternatives 4a and 4b. Connectivity to and from Pittwater Road/Condamine Street is maintained. Given the positioning of the tunnel ramps south of Burnt Bridge Creek there would be no requirement to alter the current alignment of the Kitchener Street bridge. Connectivity between the tunnel and the Sydney Road corridor would be provided via a surface access road through the existing Balgowlah Golf Course to distribute traffic demand across the local network and provide connection to the new and improved open space and recreation facilities. The alignment of this surface access road would differ and be notably shorter to alternatives 4a and 4b.

Figure 4-27 Alternative 4c - North facing tunnel ramps to Burnt Bridge Creek Deviation with shortened, centralised access road to distribute traffic and provide connection to the new and improved open space and recreation facilities

Table 4-13 Evaluation summary of 'Alternative 4c – North facing tunnel ramps to Burnt Bridge Creek Deviation with shortened, centralised access road to distribute traffic and provide connection to the new and improved open space and recreation facilities'

Category	Consideration	Assessment
Traffic and transport	• Access road connection to Sydney Road along eastern boundary improves long-term network performance by: - Reducing pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection and Condamine Street between Burnt Bridge Creek Deviation and Sydney Road - Eliminating traffic weaving inherent in many other options - Improving traffic performance and road safety outcomes - Access road is shorter than for alternatives 4a and 4b • Minimises staging and construction works in Sydney Road corridor • Tunnel portal is moved to the south • Requires traffic lights for southbound traffic on Burnt Bridge Creek Deviation • Provides connection to the new and improved open space	

Category	Consideration	Assessment
	and recreation facilities • Longer two lane ramp tunnels to Balgowlah and Wakehurst Parkway connections. Shorter three lane mainline tunnels • Existing Kitchener Street/Myrtle Street traffic arrangements no longer impacted with bridge replacement works eliminated • Extensive utility works and associated local traffic interruptions eliminated in streets west of Burnt Bridge Creek Deviation.	
Environment and heritage	• Requires only minor works to Burnt Bridge Creek and eliminates extensive diversion works within the existing creek, reducing impacts on flora and fauna, including potentially reduced impact on mature trees in the golf course compared to alternatives 4a and 4b • Scope of staged construction within the Burnt Bridge Creek Deviation reduced • Reduced impact likely on grey-headed flying fox habitat north of Kitchener Street bridge compared to alternatives 4a and 4b • Reduced risk of potential impact to Aboriginal heritage due to reduced creek diversion works.	●

Community	• Additional 29 private property acquisitions compared to alternative 4a
	• Balgowlah Oval and the pedestrian bridge over Sydney Road remain open during construction
	• Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for:
	  - Burnt Bridge Creek Deviation widening works
	  - Tunnel and surface works temporary construction support site
	  - Motorway facilities and access road construction
	• Opportunity to re-purpose Balgowlah Golf Course as new and improved open space and recreation facilities in a staged manner both during and after construction
	• Permanent road infrastructure more centrally aligned within the golf course site, reducing potential amenity, noise and vibration impacts when compared to alternatives 4a and 4b
	• Permanent noise and visual impacts would less require mitigation during operation.
		●

Flooding	• Location of tunnel portal reduces risk of flooding impacts during construction and operation.	●
Constructability and	• Overall construction footprint reduced in comparison to alternatives 4a and 4b due to elimination of Kitchener Street	●

Category	Consideration	Assessment
engineering	bridge works • Motorway facilities close to the tunnel ramps reduces the length of ventilation tunnels and maximises the efficiency of the system • Less tunnelling and haulage of spoil compared to other alternatives • Minimises construction in the Sydney Road corridor • Minimises construction within the Burnt Bridge Creek Deviation corridor • Elimination of impacts on multiple utilities required for alternatives 4a and 4b • Relatively low cover tunnelling eliminated under residential properties in Hope Street eliminating settlement and ground–borne noise impacts • Scope of staged construction within the Burnt Bridge Creek Deviation reduced with cut and cover staging works now located close and adjacent to the temporary construction support site at Dudley Street.	
Cost	• Reduced construction staging in Sydney Road corridor, reducing construction costs • Reduced scope of local road works required to integrate the project, reducing construction costs.	

Alternative 5 - North facing tunnel ramps to Burnt Bridge Creek Deviation including Condamine Street upgrade

Alternative 5 would comprise a single set of tunnel ramps to Burnt Bridge Creek Deviation, emerging south of Kitchener Street to provide connectivity to the area. Surface road upgrades to Condamine Street at intersections with Sydney Road and Balgowlah Road would provide surface road access to the tunnel.

Figure 4-28 Alternative 5 - North facing tunnel ramps to Burnt Bridge Creek Deviation including Condamine Street upgrade

Table 4-14 Evaluation summary of 'Alternative 5 - North facing tunnel ramps to Burnt Bridge Creek Deviation including Condamine Street upgrade'

Category	Consideration	Assessment
Traffic and transport	• Widening of Burnt Bridge Creek Deviation into the golf course allows traffic flow to be maintained during construction, as per the proposed reference design alternative 4c • Traffic signals for the access road no longer required on Burnt Bridge Creek Deviation or the Maretimo Street/Sydney Road intersection • Local network impacts and poorer long-term traffic performance, including: - Local traffic impacts concentrated on Kenneth Road and Condamine Street as they become primary access roads for the tunnel - Kitchener Street/Balgowlah Road would be used by traffic attempting to access the tunnel from Seaforth - Potential rat run on local streets, such as Wanganella Street and West Street for traffic accessing Kitchener Street and Balgowlah Road - Existing residential accesses, multiple intersections with	

Category	Consideration	Assessment
	traffic signals and bus stops along the Condamine Street corridor mean capacity of existing lanes would not be realised even with parking removed - Increased demand on these roads is likely to result in poor long-term performance, eroding travel time benefits • Considerably increased traffic volumes on Kitchener Street, Balgowlah Road and Condamine Street would increase impacts on residents and businesses along these corridors.	
Environment and heritage	• Requires realignment of Burnt Bridge Creek but this impact would be limited to the portion of the creek previously realigned during original Burnt Bridge Creek Deviation construction and golf course construction works.	
Community	• Minimises permanent impacts to Balgowlah Golf Course by eliminating 18,000 square metres of impact associated with access road • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: - Burnt Bridge Creek Deviation widening works - Tunnel and surface works temporary construction support site - Motorway facilities construction • Reduced indirect impacts on residents on eastern side of golf course • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works • Increased private property impacts: - Increased demand on Condamine Street would require a road upgrade. This would likely result in removal of parking and property impacts along Condamine Street and Sydney Road to provide turning movements - Properties impacted along Condamine Street and Sydney Road due to intersection upgrades and associated widening in this area.	
Flooding	• Increased risk of flooding impacts during construction.	
Constructability and engineering	• Minimises construction in Sydney Road corridor • Minimises construction within the Burnt Bridge Creek Deviation corridor • Traffic staging for road upgrades on Condamine Street in narrow existing busy road corridor • Less tunnelling and haulage of spoil compared to other	

Category	Consideration	Assessment
	longer driven tunnel options • Motorway facilities close to the tunnel ramps reduces the length of ventilation tunnels and maximises the efficiency of the system.	
Cost	• Additional property and road upgrade costs on Condamine Street and Sydney Road exceed savings of not constructing access road.	●

Alternative 6 - Burnt Bridge Creek Deviation loop interchange

Alternative 6 would comprise two sets of tunnel ramps to Burnt Bridge Creek Deviation to provide connectivity to and from the Pittwater Road/Condamine Street corridor and Sydney Road east and west. The south facing ramps would be in a loop arrangement to transition to and from the tunnel within the Balgowlah Golf Course site.

Figure 4-29 Alternative 6 - Burnt Bridge Creek Deviation loop interchange

Table 4-15 Evaluation summary of 'Alternative 6 - Burnt Bridge Creek Deviation loop interchange'

Category	Consideration	Assessment
Traffic and transport	• Undesirable road geometry: - Tight radius tunnel loops (potentially a major road safety hazard) at the exit and entry from an 80 km/h road (Burnt Bridge Creek Deviation and Beaches Link tunnels) - Road design and safety standards generally suggest this design should be avoided as it increases the risk of accidents, including heavy vehicle rollovers - Northbound tunnel includes a decision point for drivers very close to the exit of the tight radius curve (east or west on Sydney Road) • Traffic signals for the access road no longer required on Burnt Bridge Creek Deviation or the Maretimo Street/Sydney Road intersection • Poorer local network performance: - The proximity of southern ramp to the Sydney Road intersection would create a weave – degrading the performance of this intersection - Requires additional phase for traffic signals to the Sydney Road intersection to allow for right turn to Burnt Bridge Creek Deviation (currently not permitted). This would place additional pressure on the performance of this intersection.	
Environment and heritage	• Requires realignment of Burnt Bridge Creek but this impact is limited to portion of creek previously realigned during original Burnt Bridge Creek Deviation construction and golf course construction works • Increased tunnel infrastructure in Burnt Bridge Creek floodplain.	
Community	• Permanent road infrastructure located further from residents living near the golf course, however the main access ramp would be closer to some residents on the eastern boundary • Increased property impacts, with 13 properties impacted to facilitate south-facing ramps and upgrade of Sydney Road intersection • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: - Burnt Bridge Creek Deviation staging - Tunnel and surface works temporary construction support site - Motorway facilities • Permanent impacts to the golf course site, including: - Burnt Bridge Creek Deviation widening	

Category	Consideration	Assessment
	- Trough structures for loop ramps - Motorway facilities. • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works	
Flooding	• Increased risk of flooding during construction and operation.	
Constructability and engineering	• Substantial increase in tunnelling (additional 635 metres and two additional caverns) for the additional south-facing tunnel ramps not included in the proposed reference design alternative 4c • Increased volumes of heavy haulage from tunnelling • Increased staging in Burnt Bridge Creek Deviation corridor for the additional set of tunnel ramps and bridge structure • Surface works in Burnt Bridge Creek Deviation corridor would be increased to bring multiple ramps to surface • Increased tunnel infrastructure in Burnt Bridge Creek floodplain to ensure the tunnels are not flooded in major flood events. These measures would be likely to impact flow-paths and flood levels on nearby properties during operational phase • Additional risk of flooding during construction.	
Cost	• Considerably higher construction cost due to increased: - Tunnelling complexity - Staging in busy Burnt Bridge Creek Deviation corridor - Exposure to flooding risk.	

Alternative 7 - North and south facing tunnel ramps to Burnt Bridge Creek Deviation

Alternative 7 was suggested as an alternative through community consultation. This alternative would comprises two sets of tunnel ramps to Burnt Bridge Creek Deviation to connect to and from the Pittwater Road/Condamine Street corridor and Sydney Road.

Figure 4-30 Alternative 7 - North and south facing tunnel ramps to Burnt Bridge Creek Deviation

Table 4-16 Evaluation summary of 'Alternative 7 - North and south facing tunnel ramps to Burnt Bridge Creek Deviation'

Category	Consideration	Assessment
Traffic and transport	• Traffic signals for the access road no longer required on Burnt Bridge Creek Deviation or the Maretimo Street/Sydney Road intersection • Poor local network performance due to: - Proximity of northern ramps to Condamine Street intersection creating weave issues and removal of the right-turn movement to Condamine Street south. This would likely place additional pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection to allow for right turn for westbound traffic to Burnt Bridge Creek Deviation (currently not permitted). This would place additional pressure on the performance of this intersection - Increased risk of queuing into tunnel compared to the proposed reference design alternative 4c, which avoids access road signals and is about one kilometre from Condamine Street intersection • Increased heavy haulage due to increased number of roadheaders, spoil volumes and tunnelling.	

Category	Consideration	Assessment
Environment and heritage	• Increased impacts to Burnt Bridge Creek with an additional 300 metres of Burnt Bridge Creek to be realigned • Large increase in vegetation clearing required. Additional 13,000 square metres of vegetation clearing, including in the area behind Kitchener Street identified as grey-headed flying-fox habitat.	
Community	• Permanent road infrastructure further from residents near the eastern boundary of golf course • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: - Burnt Bridge Creek Deviation staging - Tunnel and surface works construction • Permanent impacts to the golf course site due to Burnt Bridge Creek Deviation widening • Reduced permanent impacts to the existing open space at Balgowlah Golf Course by 18,000 square metres due to removal of access road and motorway facilities • Greater private property impacts, with the acquisition of an additional 20 properties: - At Burnt Bridge Creek Deviation/Sydney Road intersection and Dudley Street to allow for intersection augmentation - Along Kitchener Street and Balgowlah Road to allow for creek realignment and construction of north-facing tunnel ramps.	
Flooding	• North-facing tunnel ramps in Burnt Bridge Creek floodplain: - Places tunnels and surface widening in worst affected area of Burnt Bridge Creek floodplain - Would require substantial infrastructure to ensure the tunnels are not flooded during major flood events. These measures are likely to impact flow-paths and flood levels on nearby properties • Additional risk of inundation during construction.	
Constructability and engineering	• Substantial increase in tunnelling (additional 1.9 kilometres, three additional caverns and 400 metres of ventilation tunnel) due to: - Additional tunnel south-facing ramps not included in the proposed reference design alternative 4c - Additional tunnelling to provide ventilation tunnels from the north-facing ramps to the Burnt Bridge Creek Deviation motorway facility - Increased truck haulage due to increased tunnelling and spoil – over 23,000 truck movements for spoil haulage	

Category	Consideration	Assessment
	alone. • Increased staging in Burnt Bridge Creek Deviation corridor for the: - Additional set of tunnel ramps - Cut and cover structures across Burnt Bridge Creek Deviation which are complex to build north of Kitchener Street in a significant flood zone with limited area for staging creek diversion works • Length of surface works in Burnt Bridge Creek Deviation corridor greatly increased.	
Cost	• Considerably greater construction cost due to increased: - Tunnelling - Increased staging in the busy Burnt Bridge Creek Deviation corridor - Exposure to flooding risk in the most affected area of the floodplain during construction and operational phases.	●

Alternative 8 - North facing tunnel ramps and surface ramps to Kitchener Street

Alternative 8 was suggested as an alternative through community consultation and would comprise a single tunnel ramp to Burnt Bridge Creek Deviation, emerging south of Kitchener Street to provide connectivity to and from the Pittwater Road/Condamine Street corridor. A separate set of ramps to the Kitchener Street bridge would provide access to North Balgowlah, Seaforth and Balgowlah Road/Condamine Street for access to Sydney Road.

Figure 4-31 Alternative 8 - North facing tunnel ramps and surface ramps to Kitchener Street

Table 4-17 Evaluation summary of 'Alternative 8 - North facing tunnel ramps and surface ramps to Kitchener Street'

Category	Consideration	Assessment
Traffic and transport	• Traffic signals for the access road no longer required on Burnt Bridge Creek Deviation or the Maretimo Street/Sydney Road intersection • Poor local network performance due to: - Proximity of northern ramps to Condamine Street intersection creating weave issues and removal of the right-turn movement to Condamine Street south. This would likely place additional pressure on Sydney Road and Kenneth Road intersections - Requires additional traffic signal phasing for the Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection to allow for right turn westbound traffic to Burnt Bridge Creek Deviation (currently not permitted). This would place additional pressure on the performance of this intersection • Local traffic impacts would be concentrated on Kitchener Street, and Balgowlah Road would become a sub arterial road with increased demand on Kitchener Street, Balgowlah Road and Condamine Street, reducing travel time benefits	

Category	Consideration	Assessment
	and impacting residents and businesses • Increased risk of queuing into tunnel compared to the proposed reference design alternative 4c, which avoids access road signals and is about one kilometre from Condamine Street.	
Environment and heritage	• Additional 350 metres of Burnt Bridge Creek to be realigned north of Kitchener Street • Additional 13,000 square metres of vegetation clearing, including in the area behind Kitchener Street identified as grey-headed flying-fox habitat.	
Community	• Motorway ramps to Kitchener Street would result in increased traffic noise being generated at a higher elevation in this area • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works • Permanent road infrastructure further from residents near to the eastern boundary of golf course • Reduced permanent impacts to the existing open space at the golf course by 18,000 square metres due to removal of access road and motorway facilities • Greater private property impacts, with the acquisition of more than 20 additional properties: - At Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection and Dudley Street to allow for intersection upgrade - Along Kitchener Street and Balgowlah Road to allow for creek realignment and construction of north-facing tunnel ramps • Kitchener Street, Balgowlah Road and Condamine Street would need to be upgraded resulting in the removal of parking and property impacts • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: - Burnt Bridge Creek Deviation staging - Tunnel and surface works temporary construction support site - Motorway facilities • Permanent impacts to the golf course site due to Burnt Bridge Creek Deviation widening.	
Flooding	• North-facing tunnel ramps in Burnt Bridge Creek floodplain: - Places tunnels and surface widening in worst affected areas of the floodplain	

Category	Consideration	Assessment
	- Would require substantial infrastructure to ensure the tunnels are not flooded during major flood events. These measures are likely to impact flow-paths and flood levels on nearby properties • Additional risk of inundation during construction.	
Constructability and engineering	• Motorway facilities close to tunnel ramps • Increased staging in Burnt Bridge Creek Deviation corridor for the: - Additional set of surface ramps to the new Kitchener Street Bridge - Complex cut and cover structures across the Burnt Bridge Creek Deviation • Length of surface works in Burnt Bridge Creek Deviation corridor substantially increased.	
Cost	• Greater construction cost due to increased: - Staging in busy Burnt Bridge Creek Deviation corridor - Exposure to flooding risk.	

Alternative 9 - North facing tunnel ramps to Burnt Bridge Creek Deviation with dual U-turn overpass facility

Alternative 9 was suggested as an alternative through community consultation. This alternative would comprise tunnel ramps emerging within Burnt Bridge Creek Deviation to provide connectivity to and from the Pittwater Road/Condamine Street corridor, with a U-turn overpass over Burnt Bridge Creek Deviation, north of Kitchener Street. The U-turn overpass would provide movements to and from the tunnel portal and the suburbs of Seaforth, North Balgowlah and Balgowlah.

Figure 4-32 Alternative 9 - North facing tunnel ramps to Burnt Bridge Creek Deviation with dual U-turn overpass facility

Table 4-18 Evaluation summary of 'Alternative 9 - North facing tunnel ramps to Burnt Bridge Creek Deviation with dual U-turn overpass facility'

Category	Consideration	Assessment
Traffic and transport	• Traffic signals for an access road no longer required on Burnt Bridge Creek Deviation or at the Maretimo Street/Sydney Road intersection • Poor local network performance: - Condamine Street would be a much shorter route for traffic coming from Manly via Sydney Road under this option (1780 metres compared to 3200 metres via the proposed U-turn) - This would increase traffic pressure on Condamine Street, triggering the need for substantial surface works to integrate into the local network • Increased traffic impacts during construction due to additional staging and temporary works within the Burnt Bridge Creek Deviation corridor for the new U-turn facility and upgraded Burnt Bridge Creek Deviation/Condamine Street intersection.	
Environment and heritage	• Increase in vegetation clearing. Additional 13,000 square metres of vegetation clearing, including in the area behind	

Category	Consideration	Assessment
	Kitchener Street identified as grey-headed flying-fox habitat • Increased visual impact associated with two elevated structures • Noise and light generation from traffic on elevated structures.	
Community	• Reduces permanent impacts to the existing open space at the golf course • Increased property impacts: - Alternative places substantial additional pressure on Condamine Street. Large number of additional private property acquisitions, including multiple large commercial properties, would be required to facilitate the upgrade of Condamine Street to accommodate additional Manly-bound traffic - Additional permanent project footprint north of Kitchener Street • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: - Burnt Bridge Creek Deviation widening - Tunnel and surface works temporary construction support site - Motorway facilities.	
Flooding	• Tunnel portals constructed clear of the worst affected flood zone, but large ramp structure in flood plain would impact flows and require mitigation.	
Constructability and engineering	• Substantial additional construction within Burnt Bridge Creek Deviation corridor to build multiple ramps and overpasses.	
Cost	• Considerably greater construction cost due to: - Substantial additional upgrades at Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection for additional turn lanes, the Burnt Bridge Creek Deviation/Condamine Street new overpass and Sydney Road/Condamine Street turning lanes - Increased staging within the busy Burnt Bridge Creek Deviation corridor.	

Preferred alternative

An overall summary table comparing the connection alternatives to Balgowlah described above is presented in Figure 4-33.

Project development considerations	Balgowlah connection alternatives										
	Ramps emerging in Sydney Road (1)	Tunnel loop ramps to Sydney Road (2)	Connection partially controlled by traffic signals at BBCD (3)	North facing tunnel ramps to BBCD with east access road to distribute traffic (4a)	North facing tunnel ramps to BBCD with west access road to distribute traffic (4b)	North facing tunnel ramps to BBCD with shorter access road to distribute traffic (4c)	North facing tunnel ramps to BBCD including Condamine Street upgrade (5)	BBCD loop interchange (6)	North and south facing ramps to BBCD (7)	North facing tunnel ramps and surface ramps to Kitchener Street (8)	North facing tunnel ramps to BBCD with dual U-turn overpass facility (9)
Traffic and transport	Partially aligns	Aligns	Mostly aligns	Aligns	Aligns	Aligns	Partially aligns	Mostly aligns	Mostly aligns	Partially aligns	Partially aligns
Environment and heritage	Mostly aligns	Mostly aligns	Partially aligns	Mostly aligns	Mostly aligns	Aligns	Aligns	Mostly aligns	Partially aligns	Mostly aligns	Partially aligns
Community	Mostly aligns	Mostly aligns	Partially aligns	Partially aligns	Partially aligns	Mostly aligns	Partially aligns	Partially aligns	Partially aligns	Partially aligns	Partially aligns
Flooding	Mostly aligns	Mostly aligns	Partially aligns	Mostly aligns	Mostly aligns	Aligns	Mostly aligns	Mostly aligns	Partially aligns	Mostly aligns	Partially aligns
Constructability and engineering	Partially aligns	Partially aligns	Mostly aligns	Mostly aligns	Mostly aligns	Mostly aligns	Partially aligns	Partially aligns	Partially aligns	Mostly aligns	Partially aligns
Cost	Partially aligns	Partially aligns	Partially aligns	Mostly aligns	Mostly aligns	Mostly aligns	Partially aligns	Partially aligns	Does not align	Partially aligns	Partially aligns

Note: BBCD = Burnt Bridge Creek Deviation

- Aligns with project development considerations
- Mostly aligns with project development considerations
- Partially aligns with project development considerations
- Does not align with project development considerations

Figure 4-33 Balgowlah connection alternatives – project development considerations

Based on the assigned ratings and overall scores, the preferred alternative for the Balgowlah connection is the access road alternative 4c. The justification for selecting this alternative is summarised in Table 4-19.

Table 4-19 Summary of evaluation of Balgowlah connection preferred alternative

Evaluation criteria	Reason for preferred alternative
Traffic and transport	• Access road connection to Sydney Road improves long-term network performance by: - Reducing pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection and Condamine Street between Burnt Bridge Creek Deviation and Sydney Road - Eliminating traffic weaving inherent in many other options - Improving traffic performance and road safety outcomes - Access road is shorter than for alternatives 4a and 4b • Provides connection to the new open space and recreation facilities • Minimises construction in Sydney Road corridor • Requires traffic lights for southbound traffic on Burnt Bridge Creek Deviation and new access road/Sydney Road/Maretimo Street intersection • Shorter operational access road compared to alternatives 4a and 4b • Longer two lane ramp tunnels to Balgowlah and Wakehurst Parkway connections. Shorter three lane mainline tunnels compared to alternatives 4a and 4b • Extensive utility works and associated local traffic interruptions greatly reduced in streets west of Burnt Bridge Creek Deviation.
Environment and heritage	• Requires only localised adjustment to Burnt Bridge Creek and eliminates extensive diversion works within the existing creek, reducing impacts on flora and fauna, including potentially reduced impact on mature trees in the golf course precinct compared to alternatives 4a and 4b • Scope of staged construction within the Burnt Bridge Creek Deviation reduced • Reduced impact likely on grey-headed flying fox habitat north of Kitchener Street bridge compared to alternatives 4a and 4b • Reduced risk of potential impact to Aboriginal heritage with reduced creek diversion works.
Community	• Substantial increase to private property impacts compared to alternative 4a. Large portion of Dudley Street subject to property acquisitions (same as for alternative 4b) • Acquisitions on Sydney Road and Serpentine Crescent not required as for several other alternatives • Reduced substratum acquisitions under residential properties in Seaforth compared to alternatives 4a and 4b • Existing Kitchener Street/Myrtle Street local traffic arrangements no longer impacted with bridge replacement works eliminated • New and improved open space and recreation facilities, including (subject to

<table>
<tr><th>Evaluation criteria</th><th>Reason for preferred alternative</th></tr>
<tr><td></td><td>further consultation):
- Land not required for the construction or operation of the project would be progressively re-purposed and handed over to Northern Beaches Council for the community
- Potential for new and improved open space and recreation facilities in residual land primarily to the east and north of the new access road, to be available for use earlier than alternative 4a
• Along with a shorter access road, permanent road infrastructure is more centrally aligned within the golf course site, reducing potential amenity, noise and vibration impacts when compared to alternatives 4a and 4b.</td></tr>
<tr><td>Flooding</td><td>• Location of cut and cover tunnel portal moved to the south away from floodplain therefore reducing potential flooding impacts during construction and operation.</td></tr>
<tr><td>Construction and engineering</td><td>• Overall construction footprint reduced in comparison to alternatives 4a and 4b due to elimination of Kitchener Street bridge works
• Less tunnelling and haulage of spoil compared to several other options with direct tunnel access to Sydney Road or additional south facing ramps on Burnt Bridge Creek Deviation
• Appropriately sized temporary construction support site with arterial road access, allowing the project to be delivered efficiently, reducing construction duration along with allowing repurposed new and improved open space and recreation facilities to be available earlier than for alternatives 4a and 4b
• Minimises construction in the Sydney Road corridor
• Scope of staged construction works within the Burnt Bridge Creek Deviation reduced with cut and cover portal moved to the south and now located close and adjacent to the temporary construction support site at Dudley Street/Balgowlah Golf Course
• Greatly reduces impacts on multiple utilities required for alternatives 4a and 4b
• Relatively low cover tunnelling eliminated under residential properties in Hope Street, eliminating settlement risk and ground-borne noise risk.</td></tr>
<tr><td>Cost</td><td>• Reduced construction staging in busy road corridors, reducing construction costs
• Reduced scope of local road works required to integrate project, reducing construction costs.</td></tr>
</table>

4.5.6 Ventilation alternatives

Ventilation system design

Tunnel ventilation systems must continuously, reliably and efficiently provide a safe environment for tunnel users and communities surrounding the infrastructure. The basic objectives of tunnel ventilation systems are to:

- Maintain in-tunnel air quality
- Avoid portal emissions
- Manage smoke during fire incidents.

Most tunnels in NSW are unidirectional, meaning that traffic travels in one direction only within the tunnel. Usually two tunnels are constructed side by side (for example, the Lane Cove Tunnel), or one on top of the other (for example, the Eastern Distributor), to enable traffic to travel in both directions.

On an open roadway, vehicle emissions are diluted and dispersed by natural surface air flows. However, in a tunnel, mechanical ventilation can be required to ensure that air quality standards are maintained. This is achieved by providing fresh air to, and removing exhaust air from, the tunnel. The requirements for tunnel ventilation are determined by the vehicle emissions in the tunnel and the limits of pollutant levels set by regulatory authorities. Air quality is managed by ensuring that the volume of fresh air coming into the tunnel adequately dilutes emissions.

The movement of vehicles through a tunnel drives air flow, called the 'piston-effect', drawing fresh air in through the tunnel entrance, diluting the vehicle exhaust emissions. In short tunnels up to about one kilometre long, air flow resulting from the piston effect of the vehicles may be adequate to manage in-tunnel air quality.

In longer tunnels, the flow of fresh air can be supplemented by ventilation facilities which remove exhaust air and/or supply additional fresh air. The need for these features is dependent on tunnel size and length, and the number and mix of vehicles using the tunnel. Fans may also be required when the piston effect is insufficient to maintain adequate air flow, such as during periods of low traffic or congested traffic conditions.

Elevated ventilation outlets are used for longer tunnels in urban areas in Australia to disperse tunnel air at a height that ensures compliance with ambient air quality criteria.

There are four broad types of road tunnel ventilation systems, and each of these was considered for application to the project:

- Natural ventilation
- Longitudinal ventilation
- Transverse ventilation
- Semi-transverse ventilation.

A number of alternatives for design of the ventilation system were considered. The advantages and disadvantages of the various systems are described below and shown in Figure 4-34.

Natural ventilation

Road tunnels with natural ventilation rely on vehicle movements, prevailing winds and differences in air pressure between the tunnel portals to move air through the tunnels without the assistance of mechanical ventilation (for example, through the use of fans). In the case of unidirectional naturally ventilated tunnels, the piston effect generated by traffic using the tunnels also assists in the movement of air. Because naturally ventilated tunnels do not have mechanical ventilation outlets, all air from within the tunnels is emitted via the tunnel portals.

Natural ventilation is only acceptable for use in relatively short tunnels (that is less than one kilometre). This is because, without the assistance of mechanical ventilation, vehicle emissions can build up within the tunnels leading to unacceptable in-tunnel air quality under some traffic scenarios. Emergency smoke management considerations may also dictate a mechanical solution. Natural ventilation would not achieve acceptable in-tunnel air quality under low vehicle speed conditions or during emergencies and is therefore not a viable ventilation design for the project.

Longitudinal ventilation

The simplest form of ventilation for road tunnels is longitudinal ventilation, in which fresh air is drawn in at the entry portal and passes out through the exit portal with the flow of traffic. For longer tunnels, during normal operating conditions, most air would be forced through the tunnels by the movement of vehicles (the piston effect) and jet fans would be used to assist with the movement of tunnel air, to maintain acceptable in-tunnel air quality. The air pressure inside the exit portals would be maintained below atmospheric pressure to avoid the release of tunnel air from the portals. This air is then exhausted through an elevated ventilation outlet to maximise dispersion. All road tunnels longer than one kilometre built in Australia in the last 20 years have been designed and operated with longitudinal ventilation systems. This includes the recently completed NorthConnex, New M4 and M8 tunnels and the M4-M5 Link tunnels currently under construction.

Transverse ventilation

Another way to ensure adequate dilution of emissions is to provide fresh air inlets along the length of the tunnel along one side, with outlets on the opposite side. This system requires two ducts to be constructed along the length of the tunnel: one for the fresh air supply and one for the exhaust air. Transverse ventilation has been used in the past when vehicle emissions produced greater levels of pollutants than they do today. A transverse ventilation system is more expensive to construct because of the additional ducts that need to be excavated for each tunnel. This type of system is less effective than a longitudinal system for controlling smoke in the tunnel in case of a fire. It is also more energy intensive as more power is consumed to manage air flows.

Semi-transverse ventilation

Semi-transverse ventilation combines both longitudinal and transverse ventilation. Fresh air can be supplied through the portals and be continuously exhausted through a duct along the length of the tunnel. Alternatively, fresh air can be supplied through a duct and exhausted through the portals.

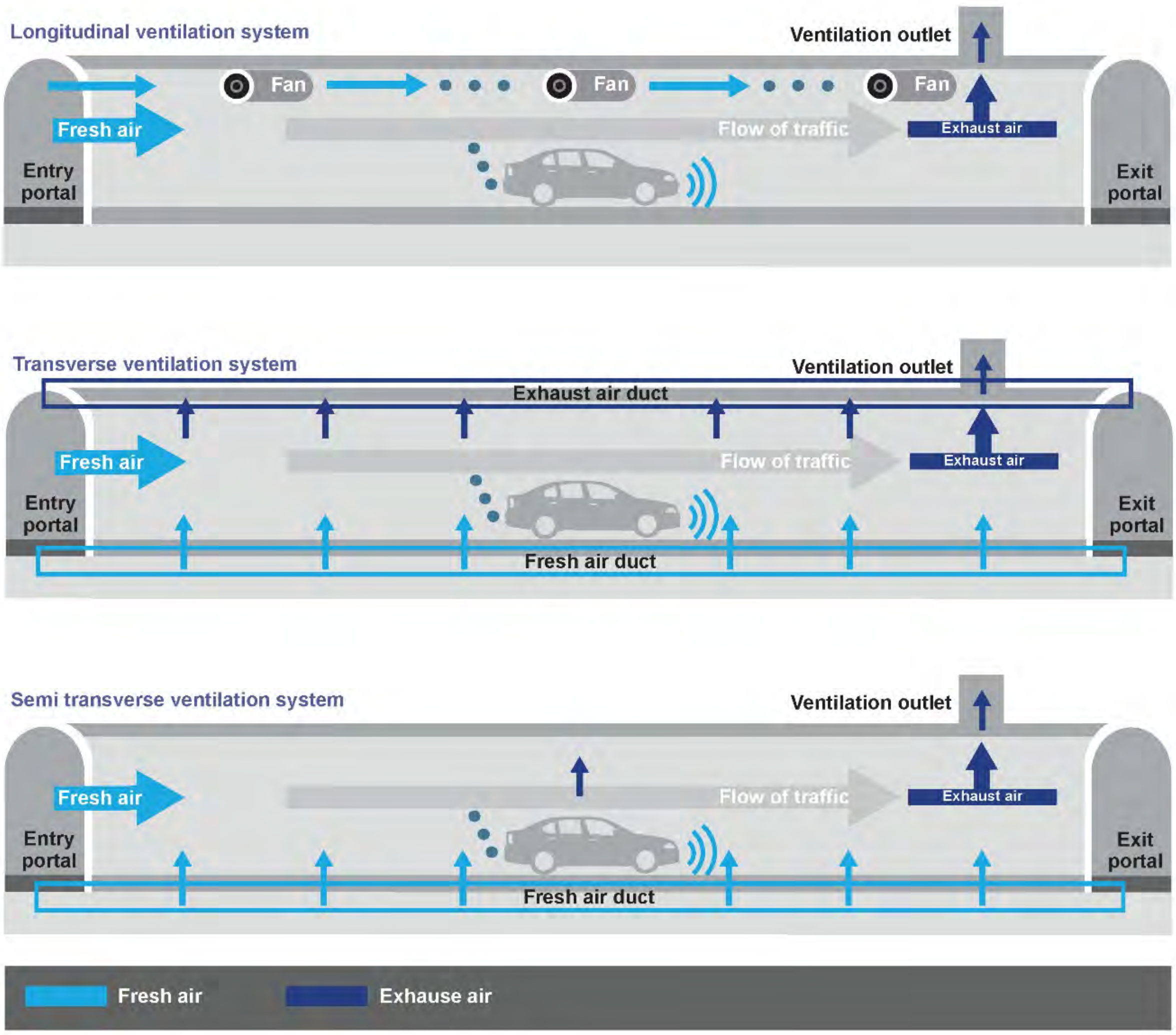


Figure 4-34 Ventilation system design alternatives

Preferred alternative

The development of cleaner vehicles in response to cleaner fuel and emissions standards has led to a substantial reduction in vehicle emissions over the past 20 years. Where longitudinal ventilation was once not suitable for long tunnels, due to the need to supply large volumes of fresh air to dilute vehicle emissions, a well-designed longitudinal ventilation system can maintain acceptable air quality in long tunnels and is considered the most efficient and effective tunnel ventilation system (Advisory Committee on Tunnel Air Quality (ACTAQ), 2019).

Although all three mechanical ventilation systems described above could be designed to meet in-tunnel air quality criteria, a longitudinal system with elevated ventilation outlets has been selected as the preferred option for the project as it is:

- Able to ensure emissions are dispersed and diluted so that there is minimal or no effect on ambient air quality
- Considered to be more effective for the management of smoke in the tunnel in the event of a fire
- Able to meet the requirement to avoid portal emissions
- Less costly to construct and operate than transverse systems.

The effectiveness of elevated ventilation outlets in dispersing emissions is well established. Chapter 12 (Air quality) presents the air quality assessments for both in-tunnel and external air quality. An overview of the ventilation system design and operation is provided in Chapter 5 (Project description).

Consideration of air filtration at the ventilation outlets

Only a small proportion of road tunnels around the world are fitted with air treatment systems. It has been shown that control of pollutants at the source is significantly more effective in improving local and regional air quality (ACTAQ, 2019; NHMRC, 2008a). Control measures include minimising road gradients, increasing tunnel height and providing a large tunnel cross-sectional area. The tunnel ventilation system for the project would be designed with appropriate levels of conservatism and redundancy to ensure compliance with air quality goals and limits.

No in-tunnel filtration system is proposed for the project because the modelling carried out demonstrates that the ventilation system would be effective in ensuring compliance with the in-tunnel air quality criteria. The inclusion of tunnel filtration was evaluated and found not to provide any material benefit to air quality or community health, as discussed in Chapter 12 (Air quality).

The inclusion of filtration would result in no material change in air quality in the surrounding community when compared to the current project ventilation system and outlet design. Any predicted changes in the concentration of pollutants would be largely driven by changes in the surface road traffic.

The independent NSW Chief Scientist and Engineer also released a report in relation to road tunnel air quality. The report found that emissions from well-designed road tunnels cause a negligible change to surrounding air quality, and as such, there is little to no health benefit for surrounding communities in installing filtration and air-treatment systems in such tunnels. Further information is available at www.chiefscientist.nsw.gov.au.

Ventilation outlet locations

The contribution of the ventilation outlets is negligible for the expected traffic scenarios. This outcome can be achieved at nearly any location through appropriate outlet design. Therefore, the main factors when considering the location of the ventilation facilities and outlets were maintaining in-tunnel air quality, maximising operational efficiency and minimising surface disturbance.

Vehicles travelling through the tunnels create a piston effect which draws air in the direction of travel. As a result, the most efficient location for a ventilation outlet is above or adjacent to tunnel portal locations (that is, near the exit portals of the tunnel in Cammeray, Artarmon, Balgowlah and Killarney Heights). This minimises the length of tunnel where the air flow must be forced, by jet fans within the tunnels against traffic flow back to the ventilation point. The reduced use of tunnel ventilation fans also increases the performance of the tunnels and reduces operational power consumption, thereby reducing the operational costs of the project and enhancing the sustainability outcomes.

The proposed ventilation outlets for the project would be located at Warringah Freeway at Cammeray, Gore Hill Freeway at Artarmon, Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights. The ventilation outlet locations at Artarmon, Balgowlah and Killarney Heights were driven by the locations of the tunnel portals and the motorway facilities. For the ventilation outlet at Cammeray, the Warringah Freeway corridor was identified as the preferred location for the ventilation outlet. This location would provide the following key advantages:

- It would minimise the total project footprint, noting alternatives would require additional property acquisition external to the existing road corridor
- It would be immediately above the tunnel, with associated efficiencies.

Refer to Chapter 5 (Project description) for an overview of the key features of the project, including the location of the ventilation outlets, which are shown in Figure 5-1 to Figure 5-7.

4.5.7 Temporary construction support site location alternatives

In addition to the surface disturbance areas required for the operation of the project, a number of temporary construction support sites would be required along the project corridor. The temporary construction support sites would be needed to support both tunnelling and surface works.

Temporary construction support sites would accommodate construction activities such as construction material and equipment storage and staging areas, spoil handling, component casting facilities, worker amenities and car parking.

In addition to the construction requirements, environmental investigations and community and stakeholder feedback were used to inform the identification and configurations of appropriate temporary construction support sites. The primary driver for the location of these sites was the objective of minimising environmental and community impacts, while being suitably located to facilitate the construction activities of the project.

Key factors applied to identification of potential temporary construction support sites included:

- Locating the temporary construction support sites as close as possible to project construction areas
- Avoiding sensitive environments and community locations where possible
- Avoiding material impacts on heritage sites or items
- Maximising opportunities for direct access to motorways and arterial roads or water transport opportunities for construction traffic, and avoiding the need to use local residential streets if possible
- Minimising direct and indirect property impacts and acquisition requirements, particularly in residential areas.

Where the identified temporary construction support sites could not meet the criteria listed above, additional specific mitigation measures were identified to manage impacts associated with their use. Details of temporary construction support sites are provided in Chapter 6 (Construction work) of this environmental impact statement.

Two temporary construction support sites in particular have been subject to more detailed alternative evaluation. These are the:

- Wakehurst Parkway tunnel temporary construction support site at Seaforth/Killarney Heights
- Flat Rock Drive tunnel temporary construction support site at Willoughby/Northbridge.

Wakehurst Parkway tunnel temporary construction support site

Initial planning for this temporary construction support site was associated with the initial preferred connection to and from the Wakehurst Parkway at portal location option A (refer to Section 4.5.4) with the temporary construction support site located at Seaforth Oval overflow carpark area on the western side of the Wakehurst Parkway.

Further community consultation and design development determined the selection of portal location option B as the preferred location of the tunnel portal and connections to and from the Wakehurst Parkway (refer to Section 4.5.4). A preferred temporary construction support site location was then selected on Sydney Water property on Kirkwood Street on the eastern side of the Wakehurst Parkway.

The eastern option was identified as the preferred location for this temporary construction support site, as it:

- Avoids impact to the operation of Seaforth Oval
- Minimises potential impacts on the nearby community precinct
- Uses land owned by the NSW Government

- Allows tunnelling to occur in both a northerly and southerly direction (reducing construction duration).

This site is referred to in Chapter 6 (Construction work) as the Wakehurst Parkway east construction support site (BL13).

Flat Rock Drive tunnel temporary construction support site

For tunnelling in the area from Naremburn to Middle Harbour, two tunnelling sites would be the preferred strategy for tunnelling logistics. This would be the preference for the safety of construction workers, to maximise the efficiency of tunnelling and to limit project costs. Due to the highly urbanised nature of the suburbs between Naremburn and Middle Harbour, and the depth of the tunnel through this area, limited viable intermediate tunnelling sites were considered to be suitable for the project. Due to these limiting factors, although not ideal for tunnelling construction efficiencies, only one tunnelling site has been proposed between Naremburn and Middle Harbour.. With no intermediate tunnelling site be provided between Naremburn and Middle Harbour, all tunnelling for this area is proposed to be completed from Flat Rock Drive. This would result in the longest one-way drive carried out for a motorway tunnel in Hawkesbury Sandstone, additional cost and an increase in the intensity and duration of construction activities.

Multiple sites were considered, and two sites were shortlisted as options to support tunnel construction from Flat Rock Drive:

- On the Flat Rock baseball diamond located on the western side of Flat Rock Drive
- Within part of Flat Rock Reserve on the eastern side of Flat Rock Drive in land that was revegetated post 1998.

Other alternative sites as well as potential additional intermediate tunnelling sites to improve tunnelling efficiency were considered unfavourable as they would have required haulage of spoil on local streets (some of which are narrow), caused local amenity impacts and resulted in the acquisition of a substantial number of private residential and/or commercial properties.

The Flat Rock Reserve option was identified as the preferred location for this tunnel temporary construction support site, primarily because it avoids direct impacts to the local operational recreation facilities of Willoughby Recreation Centre, netball courts, the baseball diamond and other recreation spaces on the western side of Flat Rock Drive, which are in high demand for local community use.

Additionally, the preferred site would provide direct arterial road access, avoiding haulage through local streets and town centres and direct impacts to private properties. The size of the preferred site would allow the construction of an access decline and the ability to tunnel in three different directions, reducing the number of required intermediate tunnelling sites.

The Flat Rock Reserve site includes native vegetation which will be impacted, however the majority of this vegetation has been established relatively recently as part of the progressive rehabilitation of a former landfill over the last twenty years. This site is referred to in Chapter 6 (Construction work) as the Flat Rock Drive construction support site (BL2).

4.5.8 Spoil transport alternatives

Most of the spoil generated by major transport infrastructure projects currently under delivery and development would be Virgin Excavated Natural Material (VENM). VENM is considered a desirable material for clean fill in development sites and major earthworks projects across Greater Sydney.

Securing spoil disposal sites to meet production throughout construction and during bad weather is critical to the delivery program of tunnelling projects. Most reuse arrangements are directly negotiated between construction contractors and councils or private developers – with major projects often using many sites to optimise haulage and cost.

Tunnel spoil generated from major projects in Sydney is generally transported via road due to the majority of reuse sites being within the Sydney basin and the desire to minimise double handling of material.

Options to reduce impacts of spoil haulage on the surface road network were considered during development of the project. The spoil transportation strategy for the project includes road haulage from all sites.

In addition to the mitigation measures adopted within the proposed construction strategy, additional options to reduce spoil haulage impacts have been considered, including rail or barge as outlined below.

Rail

Freight rail was considered as a mode of spoil transport that may offer the opportunity to move large volumes of material and reduce the number of heavy vehicle movements on the Greater Sydney road network. However, when considering the location of the project and associated temporary construction support sites, this method presents the following issues:

- The material would need to be at least double and, most likely, triple handled. Trucks would be required to move material from temporary construction support sites to a suitable train loading facility, and from the rail terminus to the final disposal location. This would greatly undermine the benefits of any such arrangement, as heavy vehicles are typically on the motorway network shortly after leaving the proposed tunnelling temporary construction support sites. Analysis of haulage to potential train loading facilities concluded that heavy haulage distances on non-motorways would actually increase if this option was adopted
- There are few spare timeslots for freight trains on the Sydney rail network, which presents a considerable construction risk. If the material cannot be reliably moved, large spoil storage facilities would be required to ensure tunnelling operations are not interrupted
- Infrastructure upgrades would be necessary to develop an appropriate train loading facility to receive the material.

Barge

As with rail, the main benefit of barge transport is the ability to move large volumes of spoil, while reducing the number of heavy vehicle movements on the wider road network.

Barges would be used for the transport of material excavated from Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8), and for deliveries and staff transport to the cofferdam sites. Barges would also be used for the transport of dredge material from the Middle Harbour crossing to the offshore disposal site (further detailed in Section 4.5.10).

However, beyond this, use of barges for handling spoil presents a number of issues, including:

- As none of the Beaches Link tunnelling sites are located adjacent to the harbour or a navigable waterway, the use of barges would require tunnel spoil to be trucked to a harbourside transfer site where it would need to be transferred to barges
- The material would need to be double (or possibly triple) handled, as trucks would be required to move material to a harbourside barge loading facility, possibly through local streets and from the barge to its final disposal location
- Infrastructure upgrades would potentially be required to allow the barge loading facility to receive the material
- Given the requirement to haul material from tunnelling sites to the harbour and from the final barge point to the disposal site, this option is unlikely to materially decrease heavy haulage impacts.

Truck

Spoil removal using trucks would involve transporting material from the construction sites directly to its final destination and would occur primarily via the arterial road network. However, as trucks would be limited to transporting relatively small volumes of spoil (about 25 to 30 tonnes per truck), a large number of truck movements would be required. The use of trucks would streamline the handling of spoil as minimal double or triple handling would be required, but would result in a higher number of trucks on the road. Transport by other transport options (rail and barge) would still require trucks to move material to or from the loading facility and, potentially, to the final destination.

Preferred alternative

A combination of mostly trucks and some barging for Middle Harbour dredging operations is the preferred spoil transport option for the project. With the major temporary construction support sites for Beaches Link all located close to the arterial road network, this solution minimises impacts on the local road network while delivering an efficient and value for money spoil transport solution.

Chapter 6 (Construction work) provides a summary of heavy vehicle movements, including spoil related haulage.

4.5.9 Tunnelling spoil reuse and disposal alternatives

As described in Chapter 24 (Resource use and waste management), spoil would be beneficially reused as part of the project before alternative spoil disposal options, such as other infrastructure or development projects, would be pursued.

Most of the spoil generated by the project would be VENM, which is considered a desirable material for clean fill in development sites and major earthworks projects across Greater Sydney. Generally, VENM is not disposed of at licenced landfills, primarily due to the high cost of doing so in comparison to reuse at development sites. It is proposed that such material generated from the construction works at Balgowlah Golf Course would partly remain on site and be reused to create a landform to support its re-purposing as new and improved open space and recreation facilities.

Residual spoil waste which cannot be reused or recycled would be disposed of at a suitably licensed landfill or waste management facility. Potential opportunities for reuse of spoil within the project include use for the formation of embankments and earth mound noise barriers, site rehabilitation and landscaping, road upgrades and infill for temporary tunnel access declines.

Alternative and/or additional spoil reuse options may be identified by the construction contractor as the project progresses.

Determination of the final destination(s) for spoil from construction of the project would be made during further design development and may include more than one disposal site.

4.5.10 Dredged and excavated harbour bed material management alternative

The project would require material to be dredged and excavated from Middle Harbour to allow for the construction of the immersed tube tunnel crossing between Northbridge and Seaforth. A number of options for the disposal and reuse of these dredged and excavated materials have been considered as part of the development of the project, including:

- Land disposal at a licensed waste management facility
- Offshore disposal.

A summary of the alternatives considered for the disposal and reuse of these materials is provided below.

Land disposal at a licenced waste management facility

Disposal of all dredged and excavated materials from Middle Harbour only to a licensed waste management facility would require:

- Dewatering to a spadable condition prior to disposal, potentially requiring mixing of the material with additives to alter the consistency of the material, enabling it to be transferred to land. Dewatering may require large areas of land, depending on the quantity of material, which may result in additional property acquisition, large and noisy machinery and potential impacts to nearby receivers
- Large volumes of marine vessel movements to transfer dredged and excavated materials to a loadout facility for treatment
- Large volumes of heavy vehicle movements to transfer material (once spadable) to a licensed waste management facility.

Disposal of this material at a licensed waste management facility would likely be at a landfill and would therefore require the use of landfill space. Given the potential environmental impacts associated with the disposal off all dredged and excavated material to a licensed waste management facility, this option was not considered feasible.

However, it is expected that a relatively small amount of material dredged and excavated from Middle Harbour as part of the project may not be suitable for offshore disposal. The reuse of this material is not an option and, given the small amount of material, disposal at a licensed waste management facility is considered an appropriate option.

Offshore disposal

Transport for NSW will submit an application for offshore disposal of suitable dredged and excavated materials from Middle Harbour to the Australian Government Department of Agriculture, Water and the Environment. Offshore disposal is regularly used by marine excavation projects in NSW, with licenced disposal grounds in operation off Sydney Harbour and Newcastle. These sites have been carefully selected by the Australian Government to provide suitable disposal grounds for dredge and marine excavation material and minimise impacts on sensitive marine ecology. The proposed designated offshore disposal site is located about 10 to 15 kilometres offshore of Sydney Heads. The site is over 20 square-kilometres in area and is a non-dispersive ground, meaning that material placed within the area generally does not migrate from that area.

Material disposed of at the designated offshore disposal site (in accordance with legislative requirements) would comprise sediments and rock removed from Middle Harbour during the construction of the Middle Harbour south (BL7) and Middle Harbour north (BL8) cofferdams, and dredged sediment and rock material removed from Middle Harbour as part of the construction of the immersed tube tunnels.

Disposal of suitable dredged and excavated materials at the designated offshore disposal site would:

- Avoid disposal of spoil to land-based sites
- Avoid additional heavy vehicle movements on the road network
- Minimise some environmental impacts such as noise, odour and dust at sensitive receivers, by avoiding the need to carry out treatment, dewatering and land-based transport of all dredged and excavated material
- Avoid the creation of a sizeable waste stream on land.

Material would be required to satisfy the requirements of the *National Assessment Guidelines for Dredging* (Department of Environment, Water, Heritage and the Arts, 2009) before being considered suitable for disposal at the designated offshore disposal site.

Preferred dredged and excavated materials management option

The preferred option for the disposal and/or reuse of dredged and excavated materials is a combination of mostly offshore disposal and some disposal at a licensed land based waste facility. To minimise the potential environmental impacts associated with the disposal and reuse of dredged material, where dredged material complies with the *Environment Protection (Sea Dumping) Act 1981*, it would be disposed of at the designated offshore disposal site. Where material is not suitable for offshore disposal, it would be barged to a loadout facility for treatment to be made spadable and then loaded onto trucks and disposed of at a suitably licensed land-based facility (at a location yet to be determined), and classified according to the NSW Environment Protection Authority's *Waste Classification Guidelines.*

Chapter 6 (Construction work) provides a summary of heavy vehicle and vessel movements relating to the transport of dredged and excavated materials to land for disposal at a licensed waste management facility. Chapter 24 (Resource use and waste management) details the indicative quantities of material requiring disposal at a licensed waste management facility and suitable for disposal at the designated offshore disposal site.

Offshore disposal of dredged and excavated materials would be conducted outside NSW and is therefore not regulated under the *Environmental Planning and Assessment Act 1979* or considered further in this environmental impact statement. Daily maximum construction maritime traffic volumes and routes to navigational channels that lead to Sydney Heads, including barge movements for offshore disposal of suitable dredged and excavated materials, are summarised in Chapter 6 (Construction work) and considered in Chapter 8 (Construction traffic and transport) and Section 5.5 of Appendix F (Technical working paper: Traffic and transport). Noise impacts related to the use of barges at water-based temporary construction support sites have been considered in Chapter 10 (Construction noise and vibration) and Appendix G (Technical working paper: Noise and vibration).

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 5

Project description

5 Project description

This chapter describes the project, including the route alignment, project footprint, main project elements, operational facilities and environmental controls.

The project design presented in this environmental impact assessment would continue to be refined during further design development, and where relevant, respond to feedback from the community and other stakeholders during public display.

The Secretary's environmental assessment requirements as they relate to the project description, and where in the environmental impact statement these have been addressed, are detailed in Table 5-1. Environmental controls to manage potential impacts are discussed in Section 5.2.11 and Section 5.3.8. Further environmental management measures are provided in Appendix Y (Compilation of environmental management measures).

Table 5-1 Secretary's environmental assessment requirements – Project Description

Secretary's requirement	Where addressed in EIS
Environmental impact statement	
1. The EIS must include, but not necessarily be limited to, the following: b) a description of the project and all components and activities (including ancillary components and activities) required to construct and operate it, including: – the proposed route;	**Section 5.1, Section 5.2** and **Section 5.3** describe the proposed route.
– design of the tunnels, interchanges (inclusive of tunnel portals and entry and exit ramps), road user, pedestrian and cyclist facilities, and lighting;	**Section 5.1, Section 5.2** and **Section 5.3** describe the design of the tunnels, including tunnel-to-tunnel connections and entry and exit ramps as well as road user, pedestrian and cyclist facilities, lighting and other operational ancillary infrastructure.
– surface road upgrade works, including road widening, intersection treatment and grade separation works, property access, parking, pedestrian and cyclist facilities (including appropriate locations for overbridges) and public transport facilities;	**Section 5.2** and **Section 5.3** describe the surface road works and surface connections as well as pedestrian, cyclist and public transport facilities. **Chapter 6** (Construction work), Section 6.5 describes the construction method for surface road works and associated infrastructure, including bridgeworks, active transport infrastructure, lighting and other operational ancillary infrastructure. **Chapter 8** (Construction traffic and transport), **Chapter 9** (Operational traffic and transport) and **Chapter 20** (Land use and property) discuss property access.
– ancillary infrastructure and operational facilities, such as operational and maintenance facilities, ventilation structures and systems, and fire and emergency services and infrastructure for the proposal, including (if required)	**Section 5.2.7** and **Section 5.3.4** describe operational facilities and ancillary infrastructure. **Chapter 6** (Construction work), Section 6.8 describes the temporary construction support sites required to construct the project, while Section 6.4.6 outlines detail on the construction

Secretary's requirement	Where addressed in EIS
additional infrastructure (such as tolling infrastructure);	of operational facilities and ancillary infrastructure.
– location and operational requirements of construction ancillary facilities and access;	**Section 5.2** and **Section 5.3** describe operational facilities and ancillary infrastructure. **Chapter 6** (Construction work), Section 6.8.2 describes the location and hours of construction at each of the temporary construction support sites and their respective access arrangements.
– land use changes as a result of the proposal and the acquisition of privately owned, Council and Crown lands, and impacts to Council and Crown lands; and	**Chapter 20** (Land use and property), Section 20.4 discusses land use changes (including acquisition and impacts to local council and Crown lands).
– the relationship and/or integration of the project with existing and proposed public and freight transport services;	**Chapter 3** (Strategic context and project need) and **Chapter 8** (Construction traffic and transport) discuss the relationship and/or integration of the project with existing public and freight transport services. Additional information about the relationship and/or integration of the project with existing and proposed public and freight transport services is provided in **Chapter 9** (Operational traffic and transport) and **Chapter 27** (Cumulative impacts).

5.1 Project overview

The Beaches Link and Gore Hill Freeway Connection project (the project) forms a core component of the broader Western Harbour Tunnel and Beaches Link program of works. The program of works would unlock substantial travel time savings and journey time reliability for freight services, public transport and other road users travelling between the Northern Beaches region and strategic centres across Sydney. The Western Harbour Tunnel and Warringah Freeway Upgrade project is subject to separate environmental assessment and approval.

The project would deliver new strategic road links between the Northern Beaches and the existing motorway network near Artarmon and North Sydney, bypassing the congested Military Road/Spit Road and Warringah Road/Eastern Valley Way corridors. The project would provide links to both the Lane Cove Tunnel and Warringah Freeway, improving north–south and east–west connectivity for the Northern Beaches region. The project would also include the widening of the Wakehurst Parkway between Killarney Heights and Frenchs Forest to improve access to this strategic centre and areas further north.

A whole alignment overview of the Beaches Link and Gore Hill Freeway Connection project is shown in Figure 1-2 of Chapter 1 (Introduction).

The project is shown in Figure 5-1 to Figure 5-9 and would comprise:

- Twin tolled motorway tunnels connecting the Warringah Freeway at Cammeray and Gore Hill Freeway at Artarmon to the Burnt Bridge Creek Deviation at Balgowlah and Wakehurst Parkway at Killarney Heights
- An upgrade of the Wakehurst Parkway to two lanes in each direction between the tunnel portals at Killarney Heights and the intersection with Warringah Road at Frenchs Forest linking to the Northern Beaches Hospital road upgrade project
- A new access road between the Burnt Bridge Creek Deviation and Sydney Road at Balgowlah, providing direct connectivity to Beaches Link from key catchments along Sydney Road east

and west, improving local network performance and providing direct local access to the new and improved open space and recreation facilities at Balgowlah

- Connection and integration works along the existing Gore Hill Freeway and surrounding roads at Artarmon.

The Gore Hill Freeway Connection may be staged and delivered separately to the Beaches Link component of the project if this yields improved construction efficiency and reduced disruption along the Gore Hill Freeway and Warringah Freeway corridors. For this reason, the Gore Hill Freeway Connection has been assessed and designed as a potentially separable component of the project.

For the purpose of the assessment of environmental impacts of the project, impacts from the project as a whole (ie the Beaches Link and Gore Hill Freeway Connection) have been identified and assessed. However, where possible, these impacts have been separated to identify impacts that would result from each component of the project. To account for possible staging, identification is made of those impacts that would result from each component of the project and the applicable environmental management measures.

Similarly, should the construction timeframes for Beaches Link be advanced, although unlikely, there may be an opportunity to operate it before the Western Harbour Tunnel is operational. Under this scenario, the Warringah Freeway Upgrade would need to be constructed and operational to facilitate Beaches Link connections to the Warringah Freeway at Cammeray. As such, for the purpose of assessing potential operational impacts of the project, the Warringah Freeway Upgrade (without Western Harbour Tunnel) is assumed to be delivered.

Project elements that would be constructed to safeguard delivery of tunnel-to-tunnel connections for the Western Harbour Tunnel and Warringah Freeway Upgrade project to the Beaches Link mainline tunnel (irrespective of construction program) are described in Section 5.2.4.

5.1.1 Beaches Link

Key features of the Beaches Link component of the project are summarised in Table 5-2 and detailed in the following sections. These key features are shown in Figure 5-1 to Figure 5-9.

Table 5-2 Key features of the Beaches Link component

Key project component	Summary
Tunnels	The tunnels would comprise a mainline tunnel (about 5.6 kilometres in length) in each direction, together with entry and exit ramp tunnels to connections at the surface. • The mainline tunnels comprise three lanes of traffic in each direction connecting Cammeray to ramp tunnels under Naremburn, Northbridge and Seaforth. Each ramp tunnel comprises twin two lane tunnels: • Eastbound and westbound connections between the mainline tunnel under Seaforth and the surface at 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, Artarmon (about 2.1 kilometres in length).

Key project component	Summary
	The tunnels comprise mostly driven tunnels, except for the crossing of Middle Harbour between Northbridge and Seaforth which would be twin, three lane immersed tube tunnels.
Tunnel-to-tunnel connections	The Beaches Link mainline tunnels would connect to the single-lane stub tunnels constructed beneath Cammeray as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project, providing direct connections to and from the proposed Western Harbour Tunnel and onward to the M4-M5 Link at Rozelle.
Surface connections and road works	Surface road works would be required to connect the Beaches Link mainline and ramp tunnels to surface roads and integrate these new connections with the surface road network. The following surface connections would be provided to the Warringah Freeway at Cammeray: • A connection from the southbound mainline tunnel to the Warringah Freeway at Cammeray would provide access to the North Sydney area, the Sydney Harbour Bridge and the Cahill Expressway (via the Warringah Freeway) • A connection from the Warringah Freeway at Cammeray to the northbound mainline tunnel would provide access from the North Sydney area and the Sydney Harbour Bridge (via the Warringah Freeway). Some elements of the Beaches Link connection to the Warringah Freeway would be delivered by the Western Harbour Tunnel and Warringah Freeway Upgrade project to improve construction efficiency and reduce ongoing construction in the Warringah Freeway corridor (refer to Chapter 6 (Construction work)). The following surface connections would be provided at the Gore Hill Freeway at Artarmon: • An on ramp from the Gore Hill Freeway would provide connectivity from the Lane Cove Tunnel, Reserve Road and Epping Road/Longueville Road to the Beaches Link northbound mainline tunnel under Northbridge • An off ramp from the southbound mainline tunnel under Northbridge would provide connectivity to both the Lane Cove Tunnel and Reserve Road. The following surface connections and road works would be provided at the Burnt Bridge Creek Deviation at Balgowlah: • Upgrade and integration work along and around Burnt Bridge Creek Deviation and Sydney Road • A new access road between the Burnt Bridge Creek Deviation and Sydney Road at Balgowlah, to provide access to the Beaches Link and to the new and improved open space and recreation facilities • A connection from the eastbound ramp tunnel to Burnt Bridge Creek Deviation would provide access on to northbound Condamine Street, and to eastbound Sydney Road (via the new access road) • A connection from southbound Burnt Bridge Creek Deviation to the westbound ramp tunnel would provide access from southbound Condamine Street, and from westbound Sydney Road (via the new access road).

Key project component	Summary
	The following surface connections and road works would be provided to the Wakehurst Parkway at Seaforth, Killarney Heights, and Frenchs Forest: • An on ramp would connect from the Wakehurst Parkway at Killarney Heights to the southbound mainline tunnel under Seaforth • An off ramp would connect from the northbound mainline tunnel to the Wakehurst Parkway at Killarney Heights • Upgrade and integration work along the Wakehurst Parkway, at Killarney Heights and Frenchs Forest, through to Frenchs Forest Road East and Frenchs Forest Road West.

Operational facilities and ancillary infrastructure	Operational facilities and ancillary infrastructure provided by the project would include:
	• Motorway facilities and ventilation outlets, and ventilation tunnels to connect traffic tunnels to motorway facilities, at:
	  - Warringah Freeway, Cammeray. Ventilation tunnels would connect the southbound mainline and ramp tunnels to the ventilation outlet at Cammeray. The ventilation outlet at the Warringah Freeway would be constructed as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project, with fitout and the ventilation tunnel connection of this structure completed by the project (refer to Chapter 6 (Construction work))
	  - Gore Hill Freeway, Artarmon. Ventilation tunnels would connect the westbound ramp tunnels to the ventilation outlet at Gore Hill Freeway at Artarmon
	  - Burnt Bridge Creek Deviation, Balgowlah. Ventilation tunnels would connect the eastbound ramp tunnels to the ventilation outlet at Burnt Bridge Creek Deviation at Balgowlah
	  - Wakehurst Parkway, Killarney Heights. Ventilation tunnels would not be required at the ventilation outlet at Killarney Heights as the outlet would be located above the tunnel portal
	• A motorway control centre at the Gore Hill Freeway
	• Tunnel support facilities at the Gore Hill Freeway and the Wakehurst Parkway, Frenchs Forest
	• Groundwater and tunnel drainage management and treatment systems, including a wastewater treatment plant at the Gore Hill Freeway, Artarmon
	• Signage, tolling, fire and life safety systems, lighting, emergency evacuation and emergency smoke extraction infrastructure
	• Closed Circuit Television (CCTV) and other traffic management systems.

Public and active transport infrastructure	The project would include the following public and active transport infrastructure: • The southbound mainline connection at the Warringah Freeway has been designed to integrate with the Warringah Freeway dedicated bus lane, providing high quality bus access to North Sydney and the Sydney CBD • The northbound mainline tunnel connection at the Warringah Freeway has been designed to provide direct access from Berry Street,

Key project component	Summary
	providing high quality access for buses travelling northbound from the North Sydney CBD and the new Victoria Cross Metro Station at North Sydney • The mainline and ramp tunnels and surface connections have been designed to allow use by buses, including double decker bus services • New and upgraded public and active transport infrastructure would be provided along the Burnt Bridge Creek Deviation and the new access road at Balgowlah • A new shared user path along the Wakehurst Parkway from Seaforth to Frenchs Forest, improving pedestrian and cyclist connectivity between these two areas, and to recreational areas including the Garigal National Park and Manly Dam Reserve • New shared user paths to service the new and improved open space and recreation facilities at Balgowlah. Pedestrians and cyclists would be excluded from the mainline and ramp tunnels.
Other project features	• New and improved open space and recreation facilities at Balgowlah • Landscape treatments • Environmental controls, surface drainage, utilities connections and modifications.

5.1.2 Gore Hill Freeway Connection

Key features of the Gore Hill Freeway Connection component of the project are summarised in Table 5-3 and detailed in the following sections. These key features are shown in Figure 5-2.

Table 5-3 Key features of the Gore Hill Freeway Connection component

Key project component	Summary
Surface road works	The main surface works would comprise: • Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore and Western Line and T9 Northern Line overpass and the Pacific Highway overpass • Modifications to the Reserve Road and Hampden Road bridges • Widening of Reserve Road between the Gore Hill Freeway and south of Dickson Avenue • Modification of the Dickson Avenue/Reserve Road intersection to allow for the Beaches Link off ramp. Minor changes to local roads would include: • Conversion of Dickson Avenue to the east of Reserve Road to a cul-de-sac • Conversion of Punch Street to a cul-de-sac, and removal of the existing connection between Punch Street and Lambs Road • Modifications to the traffic lights of Reserve Road, Artarmon • Upgrade and inclusion of traffic lights at the Dickson Avenue/Pacific Highway intersection and linemarking along Dickson Avenue west of Reserve Road

Key project component	Summary
	• Conversion of the existing eastbound T2 transit lane from the Lane Cove Tunnel to a general traffic link to Beaches Link eastbound and Reserve Road.
Public and active transport infrastructure	The existing shared user path along the southern side of the Gore Hill Freeway would be replaced in areas directly disturbed by the project and connect with the existing active transport network.
Operational ancillary infrastructure	Operational ancillary infrastructure would include: • Signage and lighting • CCTV and other traffic management systems.
Other project features	The project would also include: • Landscape treatments • Environmental controls, surface drainage, utilities connections and modifications.

5.1.3 Preparatory investigations and surveys

The project does not include preliminary works, including surveys, test drilling, test excavations, geotechnical or contamination investigations or other tests, sampling or investigations carried out for the purposes of the reference design or assessment of the project.

These works are currently permitted under separate existing approvals and/or are subject to separate assessment and determination in accordance with *Environmental Planning and Assessment Act 1979*. However, investigation and survey works would continue as part of further design development for the project following approval.

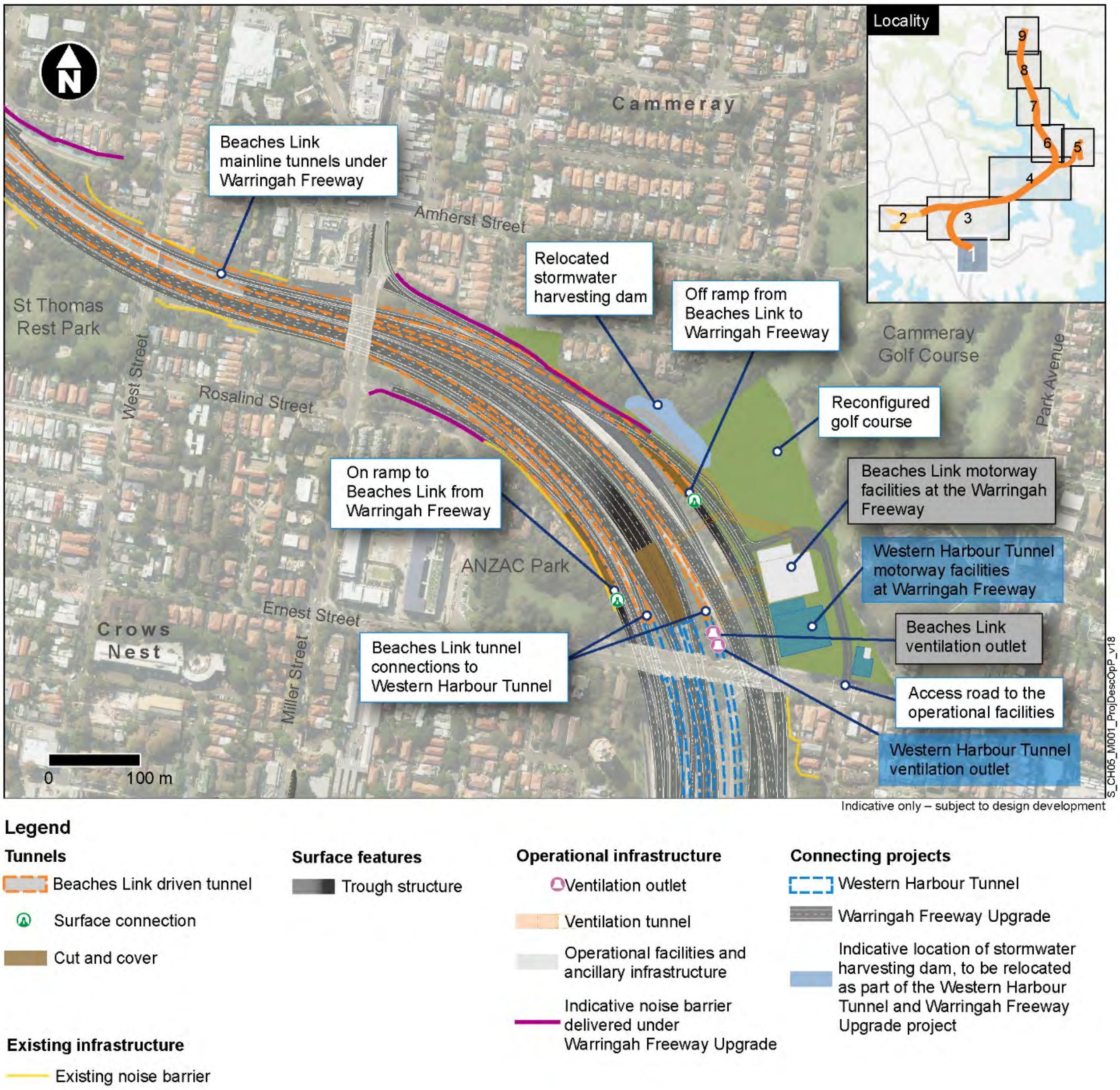
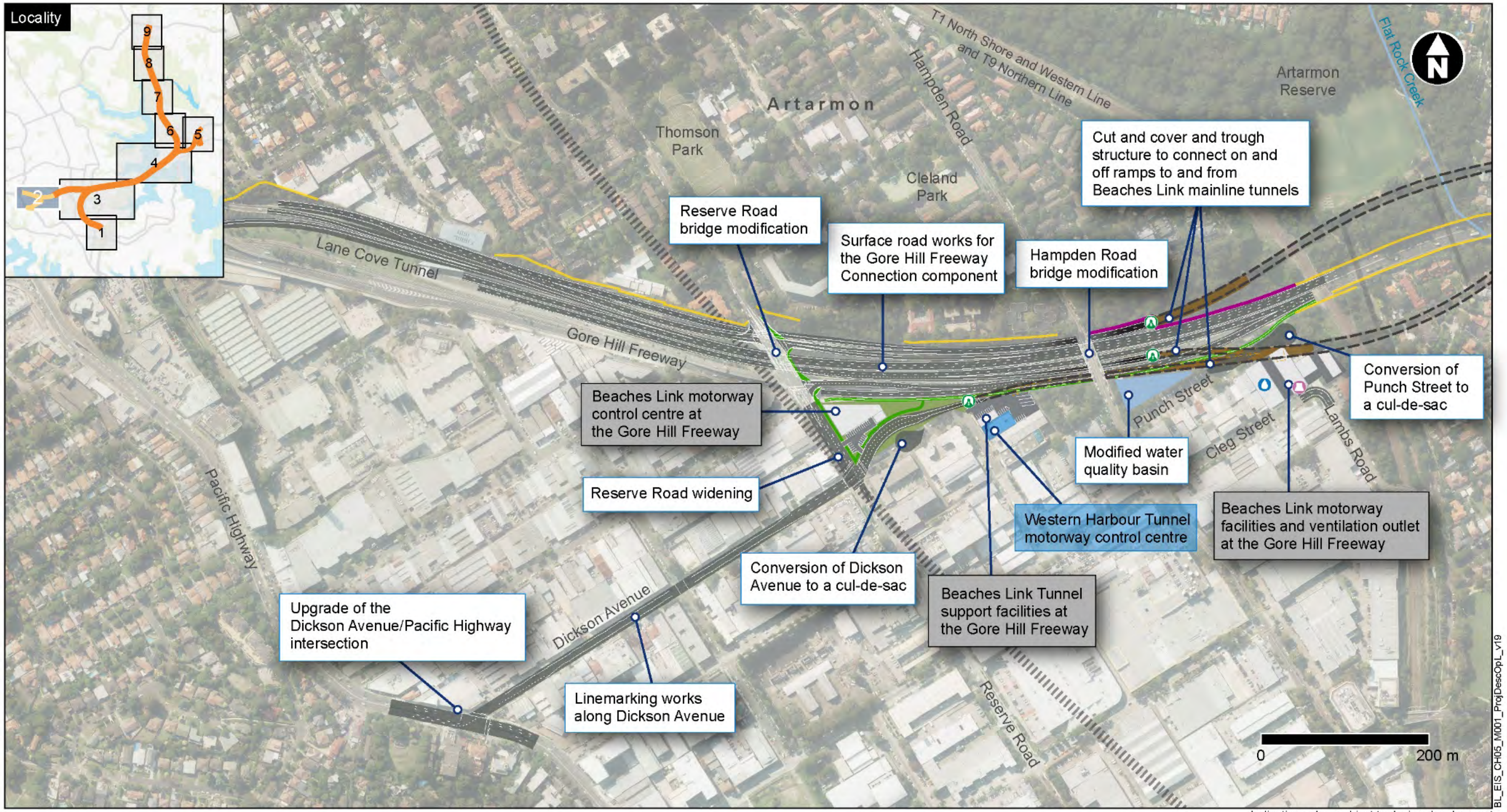


Figure 5-1 Overview of the Beaches Link and Gore Hill Freeway Connection project (map 1)



Indicative only – subject to design development

Legend

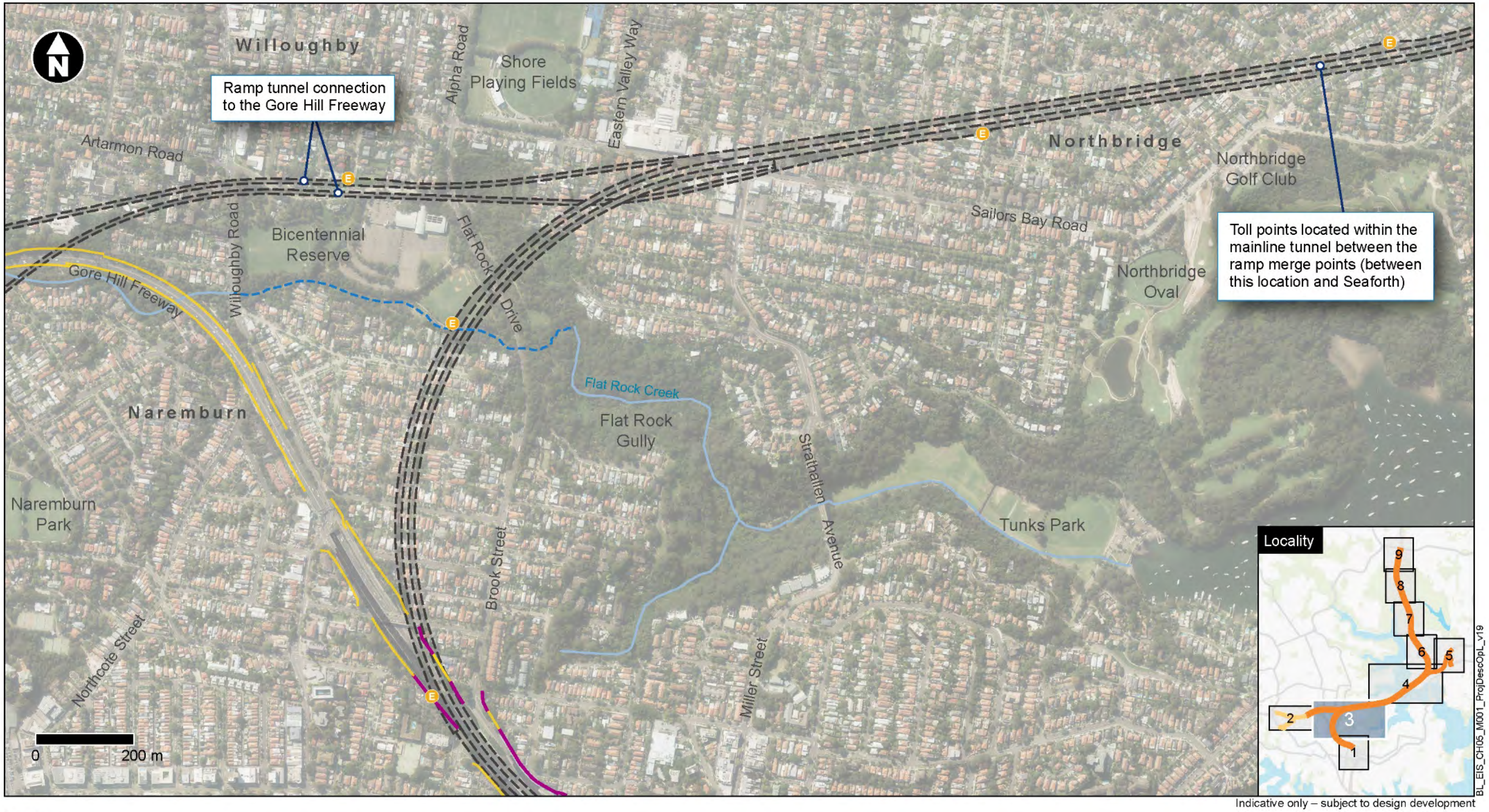
Tunnels
- Beaches Link driven tunnel
- Surface connections
- Cut and cover

Surface features
- Surface road
- Pedestrian / active transport links
- Trough structure

Operational facilities
- Ventilation outlet
- Wastewater treament plant
- Ventilation tunnel
- Operational facilities and ancillary infrastructure
- Indicative new noise barrier

Existing infrastructure
- Existing noise barrier
- Sydney Metro City & Southwest – Chatswood to Sydenham (under construction)

Figure 5-2 Overview of the Beaches Link and Gore Hill Freeway Connection project (map 2)



Legend

Tunnels

Beaches Link driven tunnel

Operational infrastructure

Maintenance and emergency breakdown bays

Indicative noise barrier delivered under Warringah Freeway Upgrade

Connecting projects

Warringah Freeway Upgrade

Existing infrastructure

Existing noise barrier

Flat Rock Creek in underground Box culvert

Figure 5-3 Overview of the Beaches Link and Gore Hill Freeway Connection project (map 3)

Indicative only – subject to design development

Legend

Tunnels

Beaches Link driven tunnel

Immersed tube tunnel

Maintenance and emergency breakdown bays

Figure 5-4 Overview of the Beaches Link and Gore Hill Freeway Connection project (map 4)

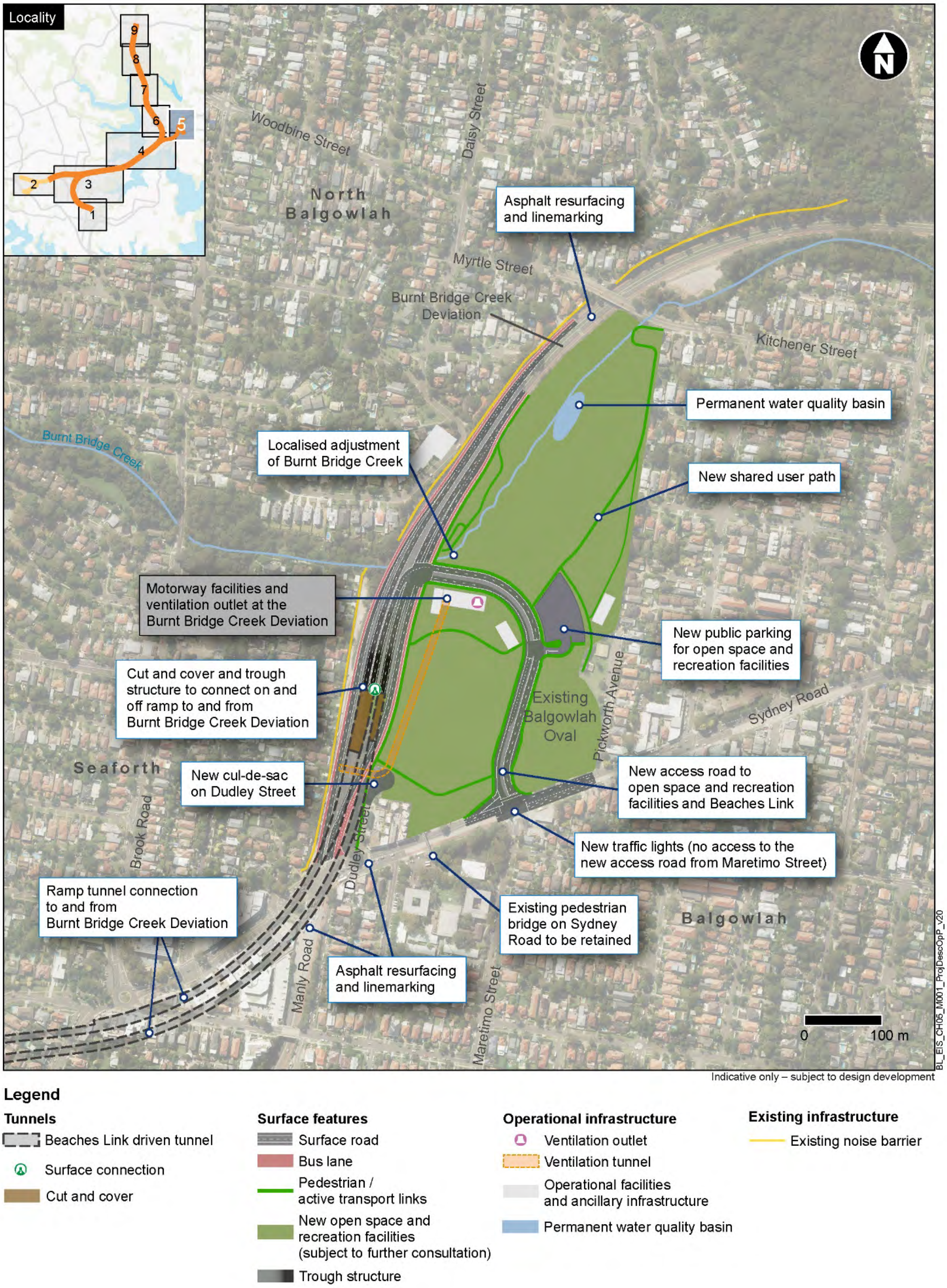
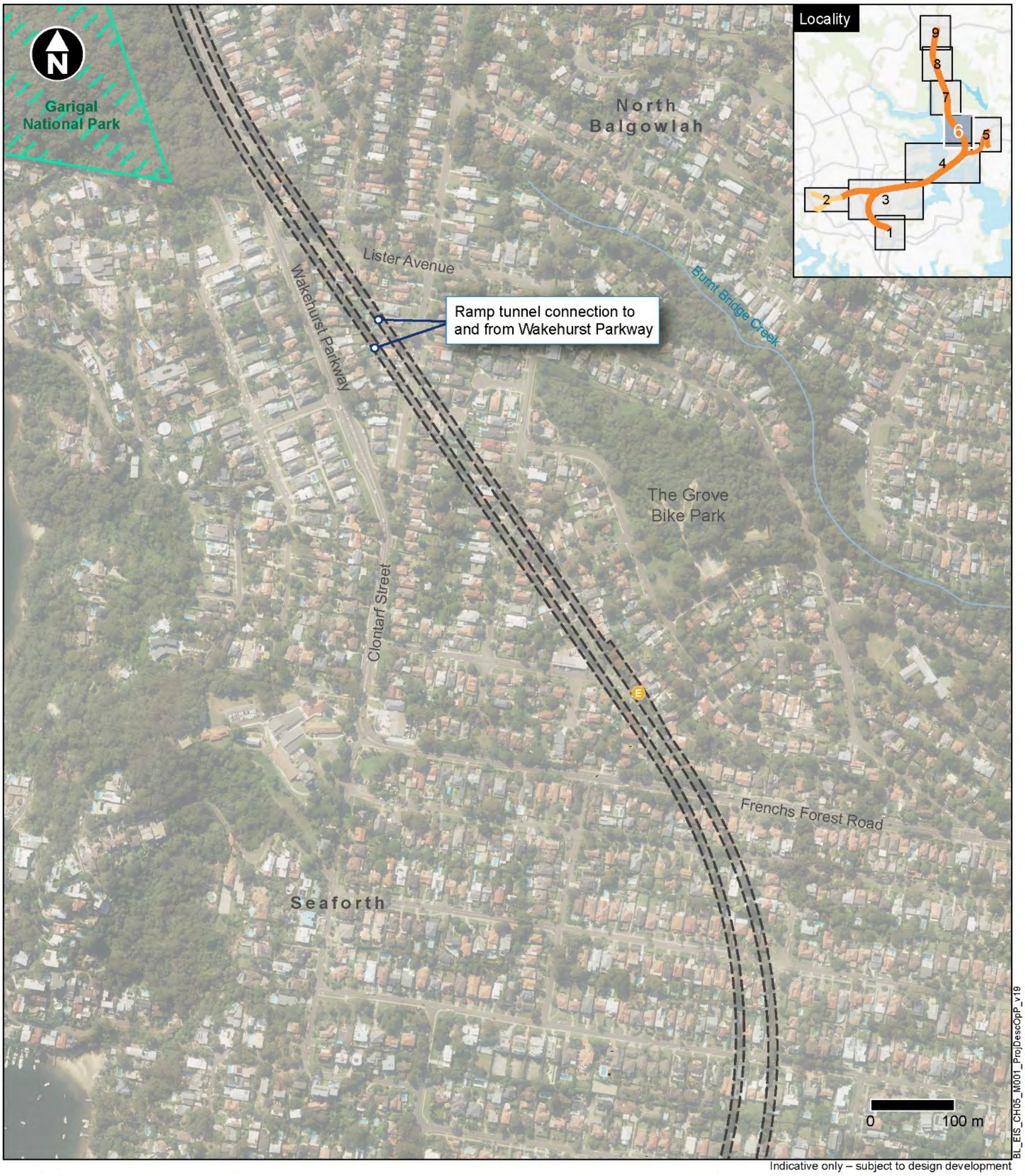


Figure 5-5 Overview of the Beaches Link and Gore Hill Freeway Connection project (map 5)



Legend

Tunnels

Beaches Link driven tunnel

Maintenance and emergency breakdown bays

Natural features

National parks and Reserves

Figure 5-6 Overview of the Beaches Link and Gore Hill Freeway Connection project (map 6)

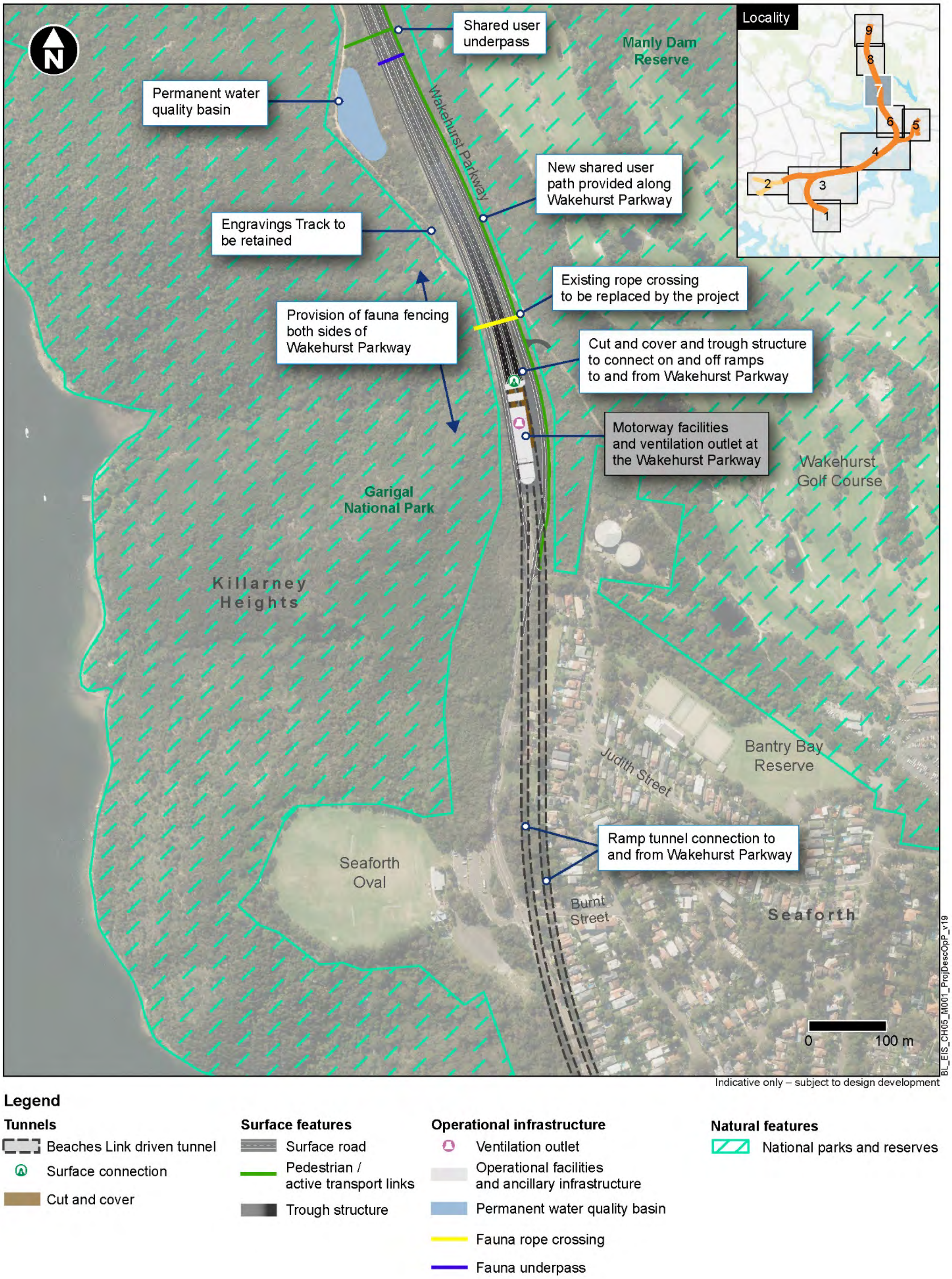
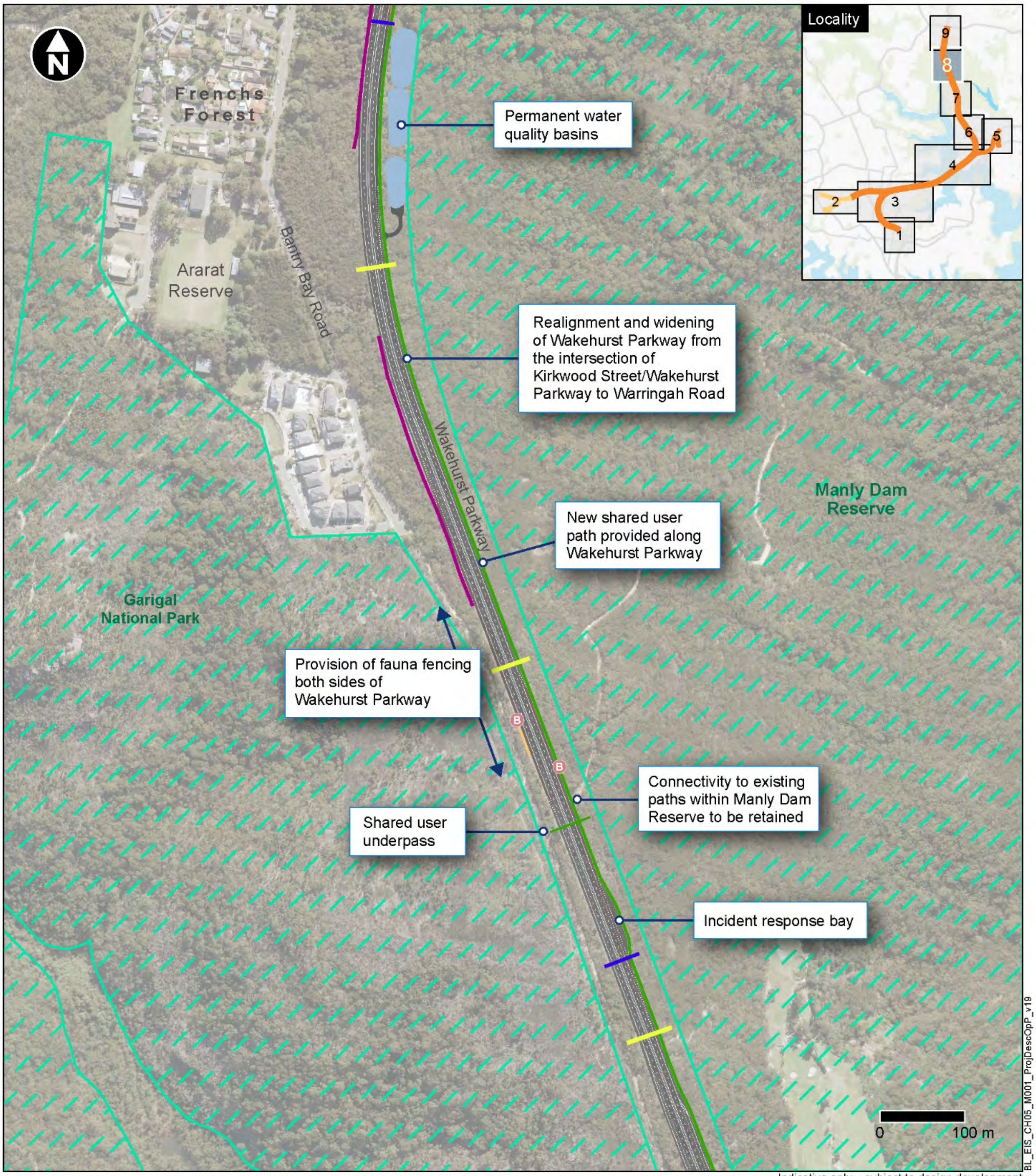


Figure 5-7 Overview of the Beaches Link and Gore Hill Freeway Connection project (map 7)



Indicative only – subject to design development

Legend

Surface features
- Bus stops
- Surface road
- Pedestrian / active transport links

Operational infrastructure
- Fauna rope crossing
- Fauna underpass
- Indicative new noise barrier

Natural features
- National parks and reserves

Figure 5-8 Overview of the Beaches Link and Gore Hill Freeway Connection project (map 8)

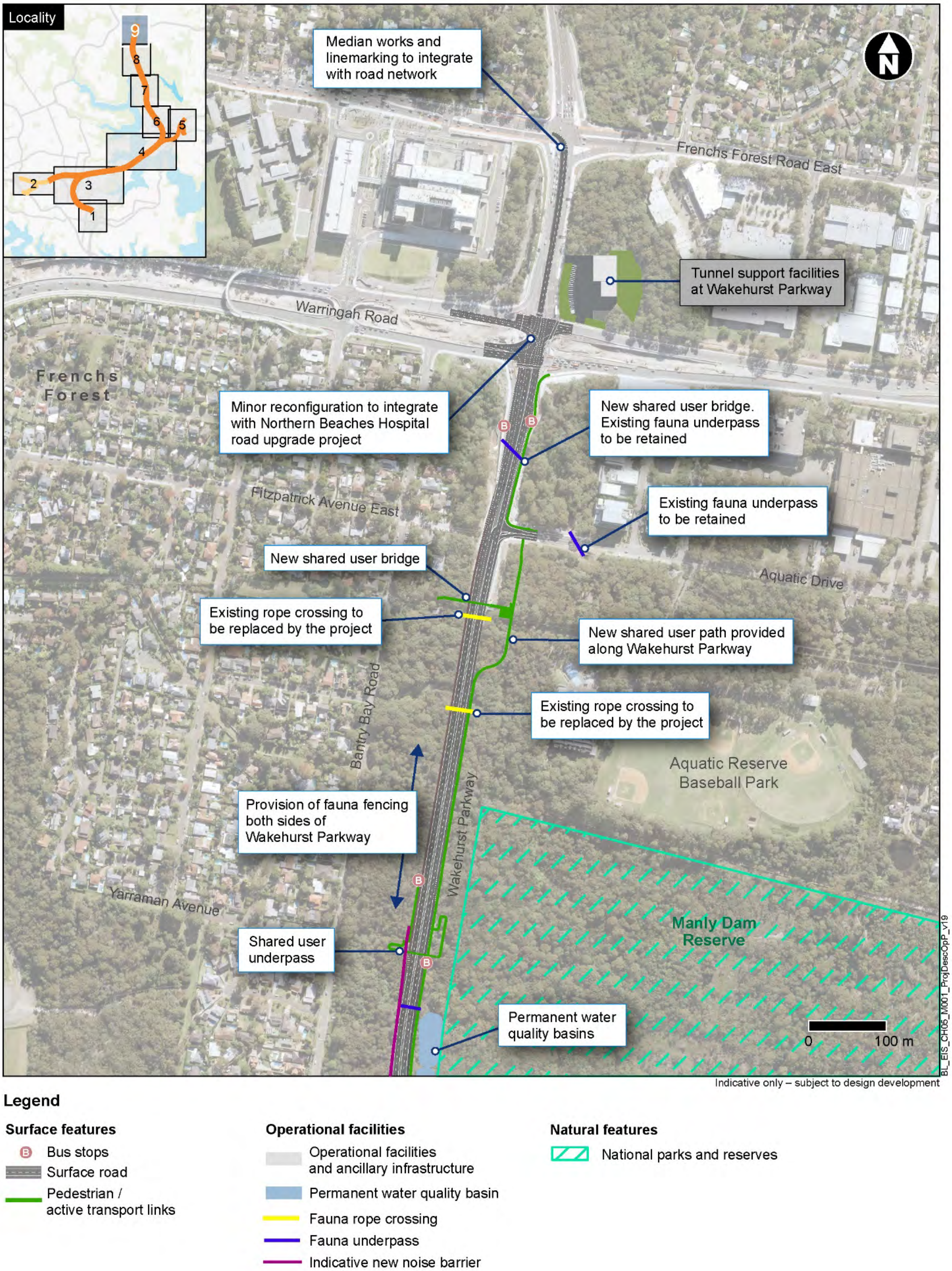


Figure 5-9 Overview of the Beaches Link and Gore Hill Freeway Connection project (map 9)

5.2 Beaches Link

5.2.1 Overview

The Beaches Link component of the project would connect the Western Harbour Tunnel and Warringah Freeway at Cammeray with the Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights. It would also provide an east-west connection with the Gore Hill Freeway at Artarmon. The mainline and ramp tunnels would be mostly driven tunnels, with an immersed tube tunnel crossing of Middle Harbour between Northbridge and Seaforth.

Key operational infrastructure would include:

- A motorway control centre at the Gore Hill Freeway in Artarmon
- Tunnel support facilities at the Gore Hill Freeway in Artarmon and the Wakehurst Parkway in Frenchs Forest
- Ventilation outlets and motorway facilities at the Warringah Freeway in Cammeray, Gore Hill Freeway in Artarmon, Burnt Bridge Creek Deviation in Balgowlah and Wakehurst Parkway in Killarney Heights. Ventilation tunnels would connect traffic tunnels to motorway facilities at the Warringah Freeway, Gore Hill Freeway and Burnt Bridge Creek Deviation.

Surface road works would be required to integrate the new tunnels into the existing road and transport network, including:

- Realignment and upgrade of the Wakehurst Parkway to two lanes in each direction between the tunnel portals at Killarney Heights and the intersection with Warringah Road at Frenchs Forest
- Surface works to connect the Gore Hill Freeway and Reserve Road to the Beaches Link tunnels at Artarmon
- Realignment and widening of the Burnt Bridge Creek Deviation at Balgowlah
- A new access road between the Burnt Bridge Creek Deviation and Sydney Road at Balgowlah, to provide access to the Beaches Link and the new and improved open space and recreation facilities at Balgowlah
- Works to integrate the new Beaches Link tunnels into the Warringah Freeway at Cammeray
- Temporary road works required to provide access to construction sites along the proposed alignment

5.2.2 Alignment

Horizontal alignment

The horizontal alignment of the project is shown in Figure 5-1 to Figure 5-9. The main north-south tunnels would be about 5.6 kilometres long and would connect from the Warringah Freeway at Cammeray to ramp tunnels under Naremburn, Northbridge and Seaforth.

The mainline tunnels would pass beneath the suburbs of Cammeray, Crows Nest, Naremburn, Willoughby, Northbridge and Seaforth. At Seaforth, the mainline tunnels would separate into two ramp tunnels. The eastern ramp tunnel would continue beneath Seaforth and Balgowlah before surfacing at Burnt Bridge Creek Deviation at Balgowlah. The northern ramp tunnel would continue beneath Seaforth before joining the Wakehurst Parkway at Killarney Heights.

Under Northbridge, the mainline tunnels would connect with the Gore Hill Freeway ramp tunnels. The Gore Hill Freeway ramp tunnels would pass beneath the suburbs of Northbridge, Naremburn, Willoughby and Artarmon before surfacing at the Gore Hill Freeway and Reserve Road.

At Cammeray, the mainline tunnels would connect directly with the Western Harbour Tunnel via underground ramp tunnels and the Warringah Freeway via tunnel portals.

Vertical alignment

The vertical alignment of the mainline tunnels and ramp tunnel connections to and from the Warringah Freeway, the Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway are shown in Figure 5-10 to Figure 5-12. As discussed in Chapter 4 (Project development and alternatives), several key factors have influenced the vertical alignment of the project tunnels including:

- Required transport connectivity and network performance
- Geology and geotechnical conditions
- Constructability, design and engineering
- Reducing community and environmental impacts
- The elevation of land on each side of Middle Harbour
- Operational performance and safety
- Limited opportunity for the project tunnels to come to the surface in a highly developed urban environment.

The top of the mainline tunnels would be:

- About 100 metres below ground at their deepest point beneath Northbridge
- Between 16 metres and 22 metres below the water surface of Middle Harbour
- About 75 metres below ground beneath Seaforth.

The mainline and ramp tunnels would rise to the ground surface at the tunnel portals within the Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and the Wakehurst Parkway.

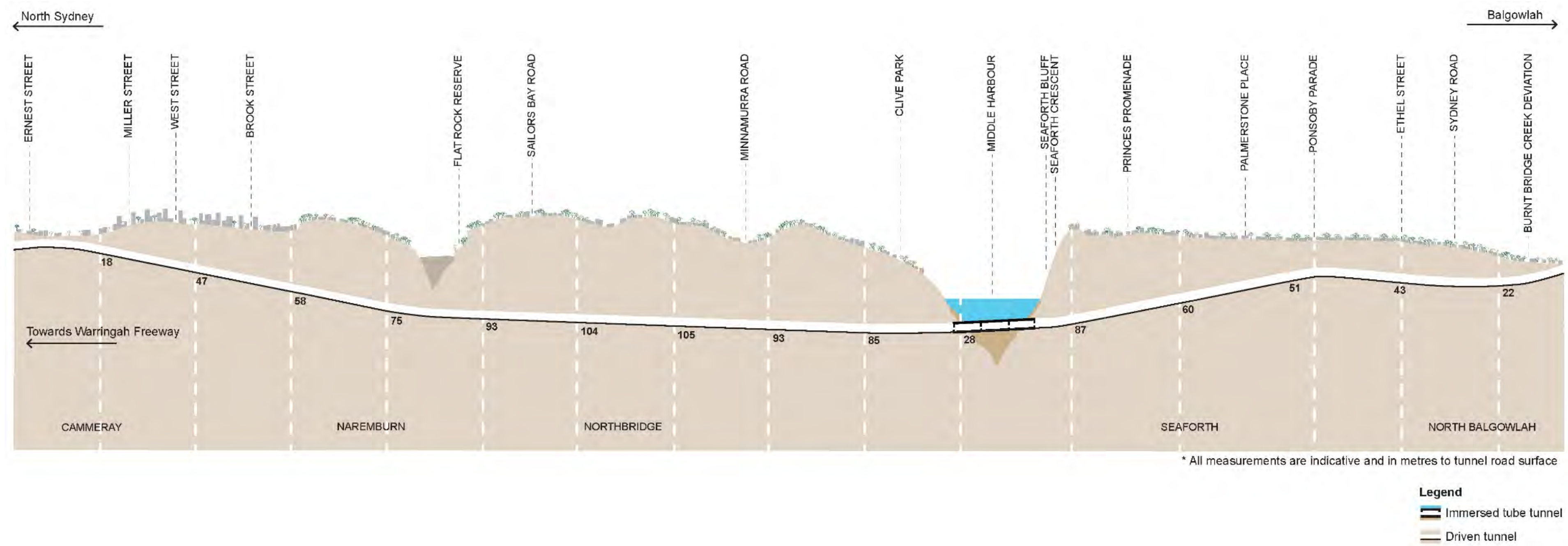


Figure 5-10 Indicative vertical alignment of the mainline tunnels and the ramp tunnel connection to the Burnt Bridge Creek Deviation (Cammeray to Balgowlah)

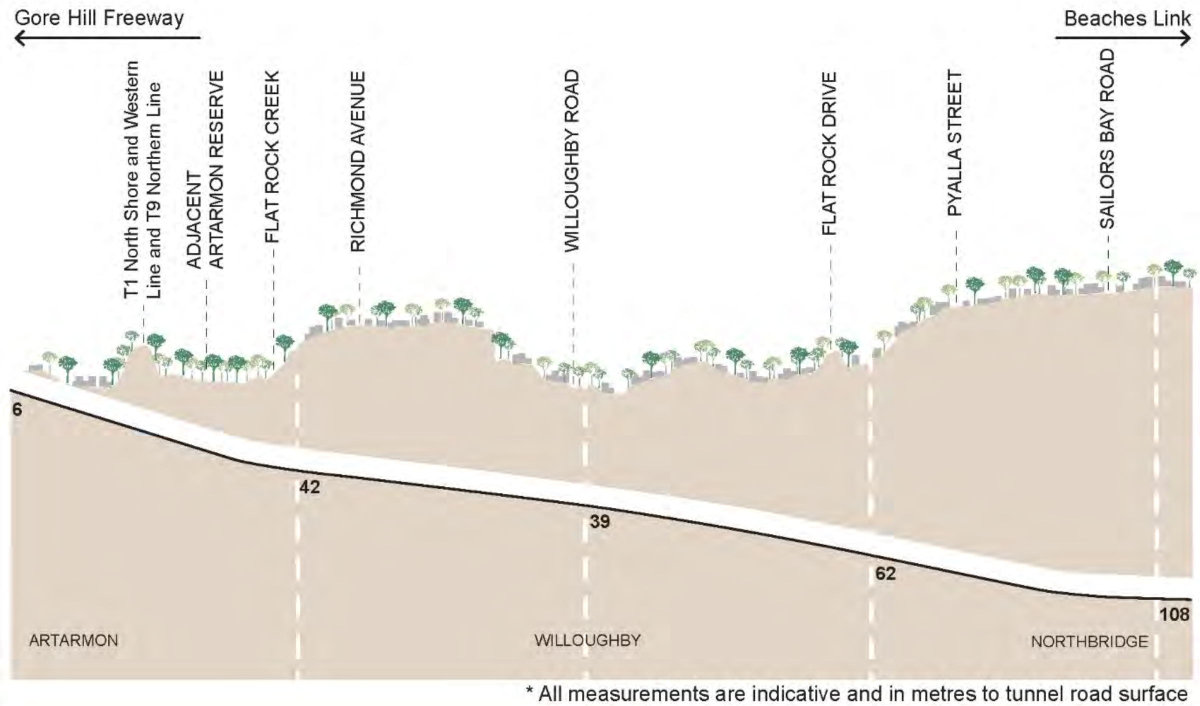


Figure 5-11 Indicative vertical alignment of the ramp tunnel connection to the Gore Hill Freeway

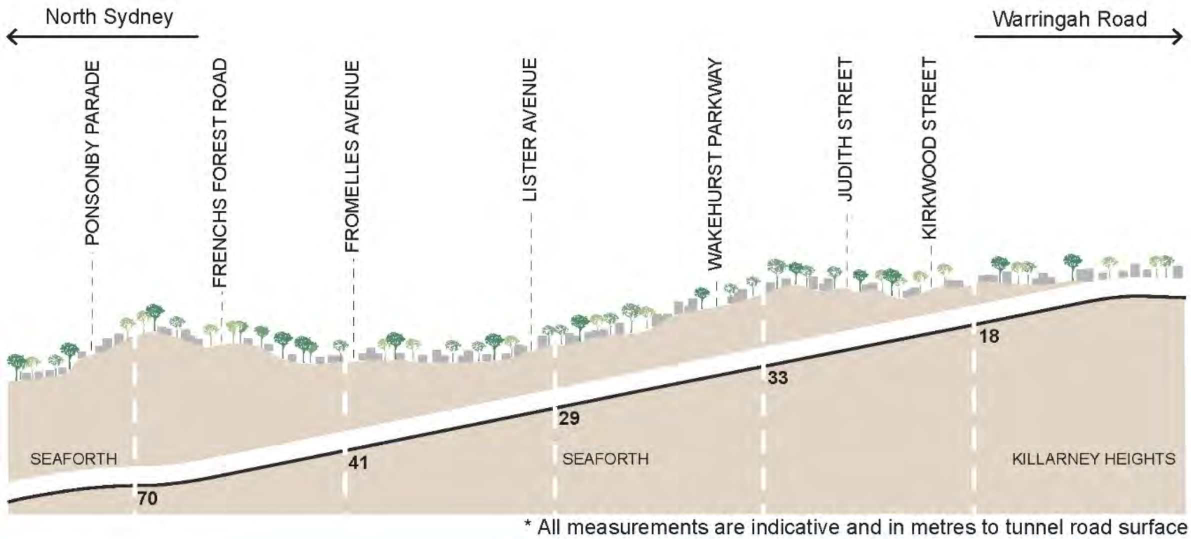


Figure 5-12 Indicative vertical alignment of the ramp tunnel connection to the Wakehurst Parkway

5.2.3 Tunnels

The project would comprise twin tunnels connecting the stub tunnels at Cammeray (constructed as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project) and the Gore Hill Freeway at Artarmon, to Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights. The project would comprise mostly driven tunnels, apart from the crossing of Middle Harbour between Northbridge and Seaforth which would be twin immersed tube tunnels.

The tunnels would provide:

- Three traffic lanes (about 5.6 kilometres in length) in each direction for the mainline tunnels between the Warringah Freeway at Cammeray and the ramp junction under Seaforth
- Two traffic lanes (about 1.2 kilometres in length) in each direction for the ramps that connect from the junction under Seaforth to the Burnt Bridge Creek Deviation at Balgowlah
- Two traffic lanes (about 2.8 kilometres in length) in each direction for the ramps that connect from the junction under Seaforth to the Wakehurst Parkway at Killarney Heights
- Two traffic lanes (about 2.1 kilometres in length) in each direction for the ramps that connect from the junction under Northbridge to the Gore Hill Freeway and Reserve Road at Artarmon.

The posted speed limit on the mainline tunnels would be 80 km/h.

On and off ramps would allow for one or two lanes of traffic, depending on location (refer to Section 5.2.5). The posted speed limit for on and off ramps will vary along their length to match the surface connection they will integrate with to enter and exit the mainline tunnel.

Driven tunnels

The driven tunnels would be located below the surface and would connect with the immersed tube tunnel crossing of Middle Harbour.

An indicative cross-section of the driven mainline tunnels is shown in Figure 5-13.

Driven tunnels would be mainly drained structures. This means a certain amount of groundwater would be allowed to seep through the tunnel walls. The drained tunnels would be designed and managed so that groundwater ingress would be no greater than one litre per second per kilometre on average.

The geology approaching the Middle Harbour crossing may result in higher levels of water ingress into the driven tunnels than encountered on other parts of the alignment. This may require the installation of a waterproof lining or similar treatment at these locations to prevent excessive ingress of water. This type of treatment may also be required at discrete locations along the alignment eg beneath Flat Rock Reserve where because of soil conditions or geological features, there is predicted to be high water ingress into the tunnel. The requirement for, and extent of, lining or similar treatment would be confirmed during further design development.

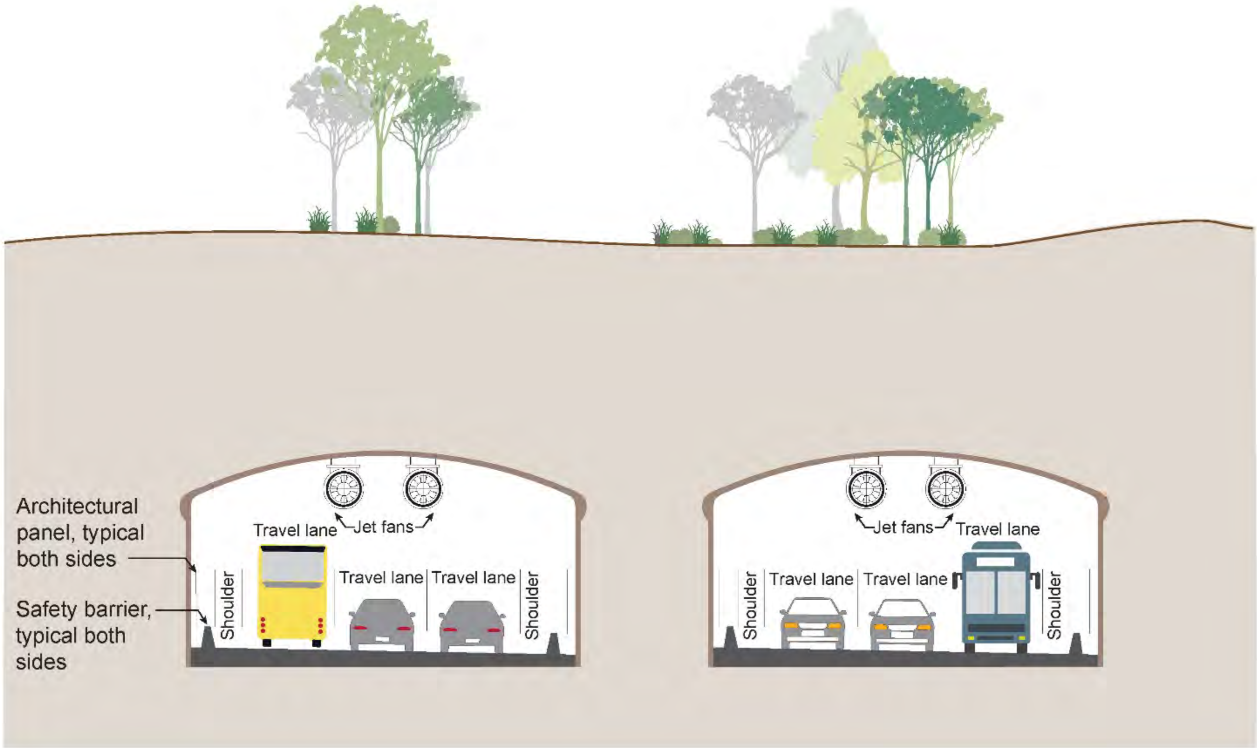


Figure 5-13 Indicative cross-section of the driven mainline tunnels

Immersed tube tunnels

To achieve suitable gradients, the vertical alignment would require the mainline tunnels to pass through rock and soft to very soft sediments forming the bed of Middle Harbour. Given the physical nature of these materials, immersed tube tunnels would be the most appropriate engineering solution to provide a safe, stable and effective method of crossing Middle Harbour.

The immersed tube tunnels would connect to the driven mainline tunnels in Middle Harbour offshore from Clive Park, Northbridge, and Seaforth Bluff, Seaforth.

An indicative long section of the immersed tube tunnel crossing of Middle Harbour is shown in Figure 5-14. Indicative cross-sections of the immersed tube tunnels are shown in Figure 5-15 (end sections) and Figure 5-16 (middle sections).

The immersed tube tunnels would be installed as a series of pre-cast units. Due to the profile of the bed of the harbour, the units would sit both partially within a trench closer to the shore and above the bed of the harbour towards the centre of the crossing. The middle sections would be placed with the tops of the tunnel units being about 9.2 metres above the existing level of the bed of the harbour.

Given the very soft sediments at the bed of Middle Harbour, supporting piles would be required at discrete locations along the immersed tube crossing. A locking fill would be placed around the end sections of the immersed tube tunnels for stability and protection.

The water depth above the immersed tube tunnels would vary between 16 metres and 22 metres, depending on the distance from the shore.

Each immersed tube tunnel would accommodate three traffic lanes in each direction.

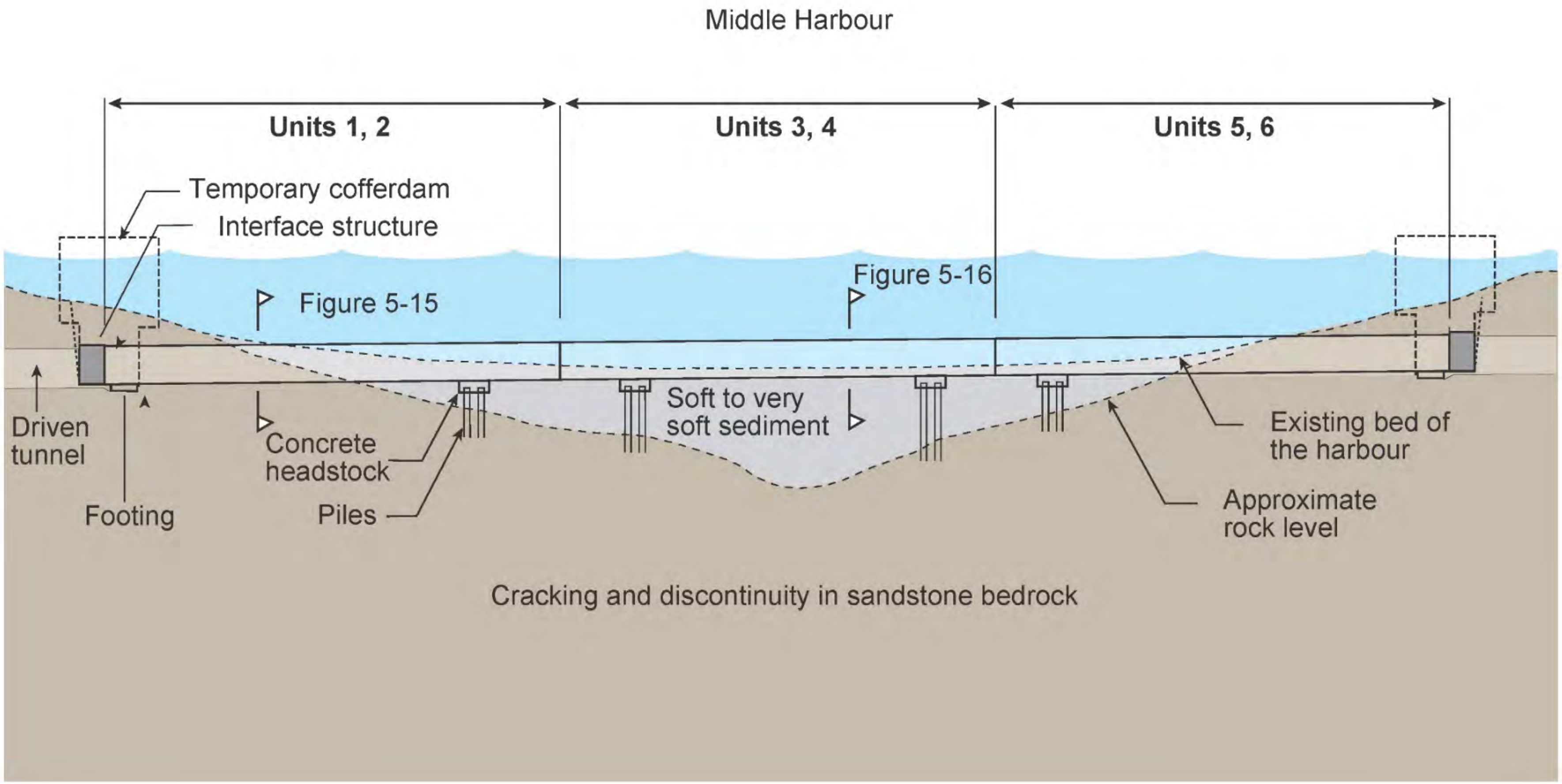


Figure 5-14 Indicative long section of the immersed tube tunnels (Middle Harbour)

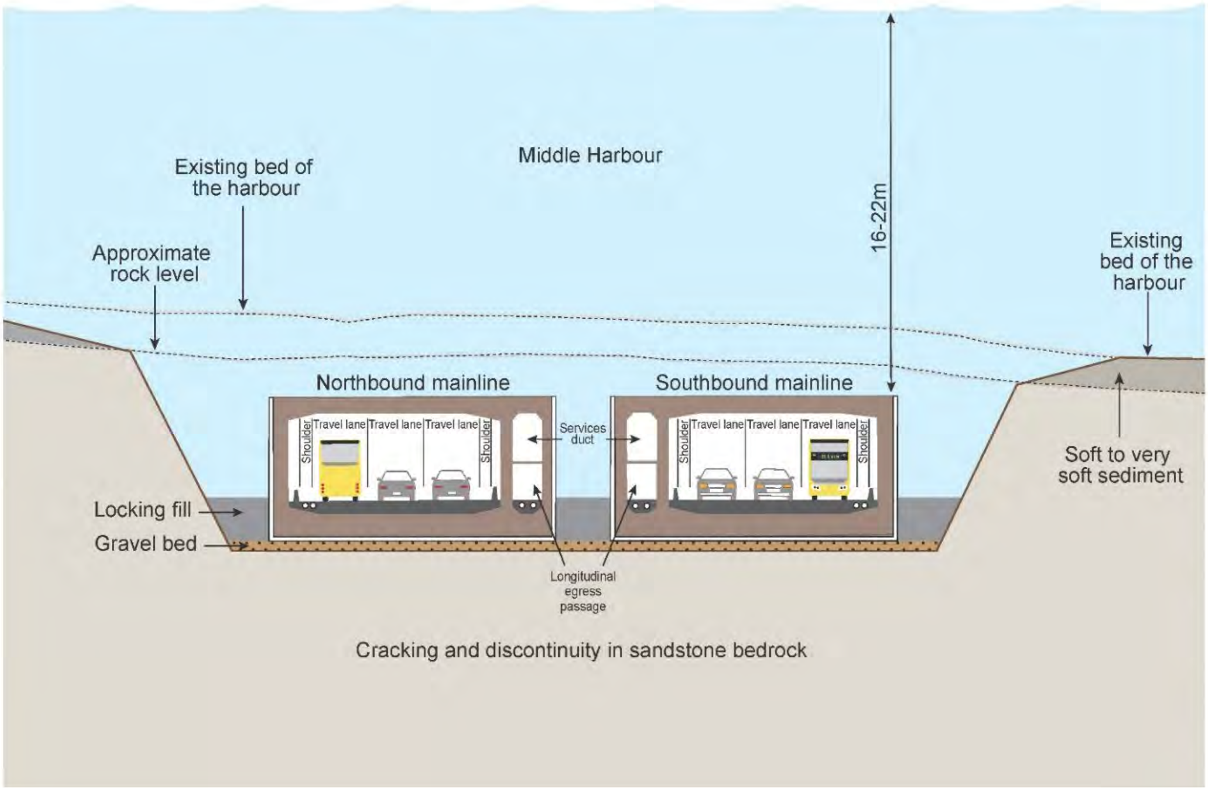


Figure 5-15 Indicative cross-section of the end sections of immersed tube tunnels (Middle Harbour)

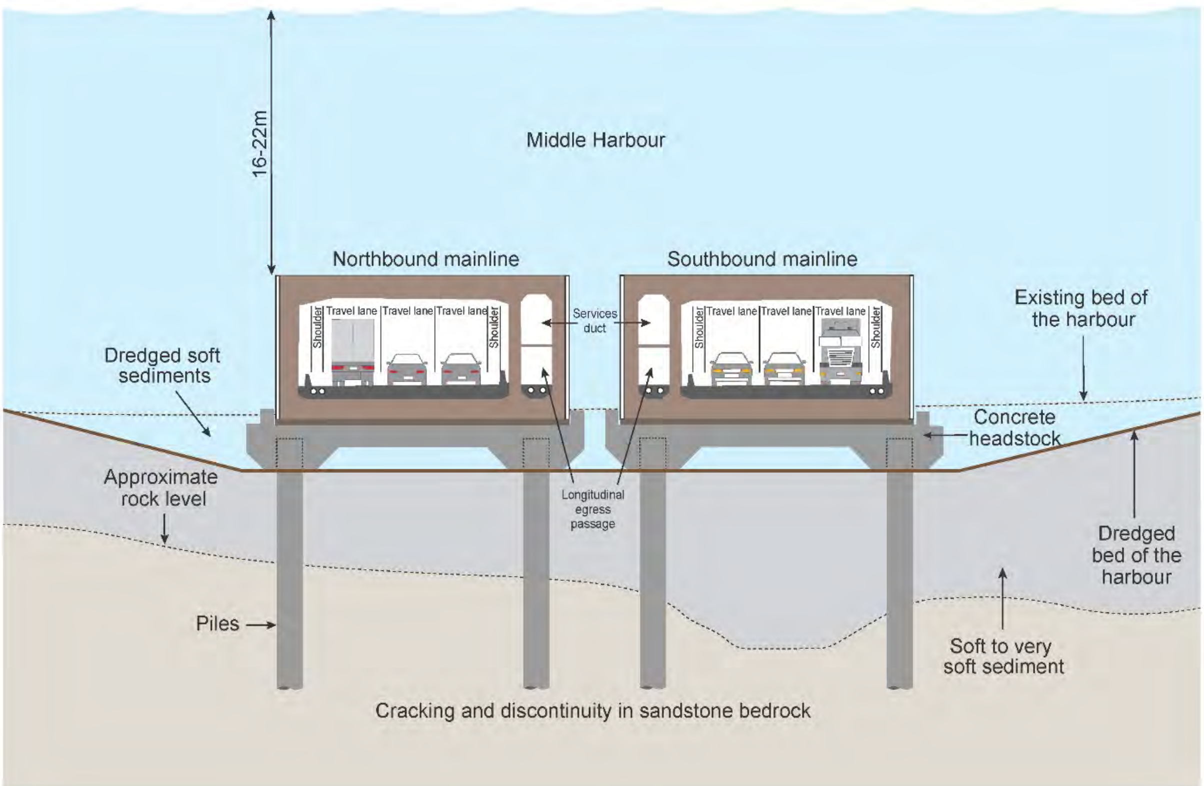


Figure 5-16 Indicative cross-section of the middle sections of immersed tube tunnels (Middle Harbour)

5.2.4 Tunnel-to-tunnel connections

The project would include a tunnel connection between the Western Harbour Tunnel and the Beaches Link component of the project at Cammeray (refer to Figure 5-17). Depending on the relative timing of construction of the mainline tunnels of the Western Harbour Tunnel and Warringah Freeway Upgrade project and the Beaches Link component of the project, the tunnel-to-tunnel connection between the projects may be constructed at or around the same time, or consecutively.

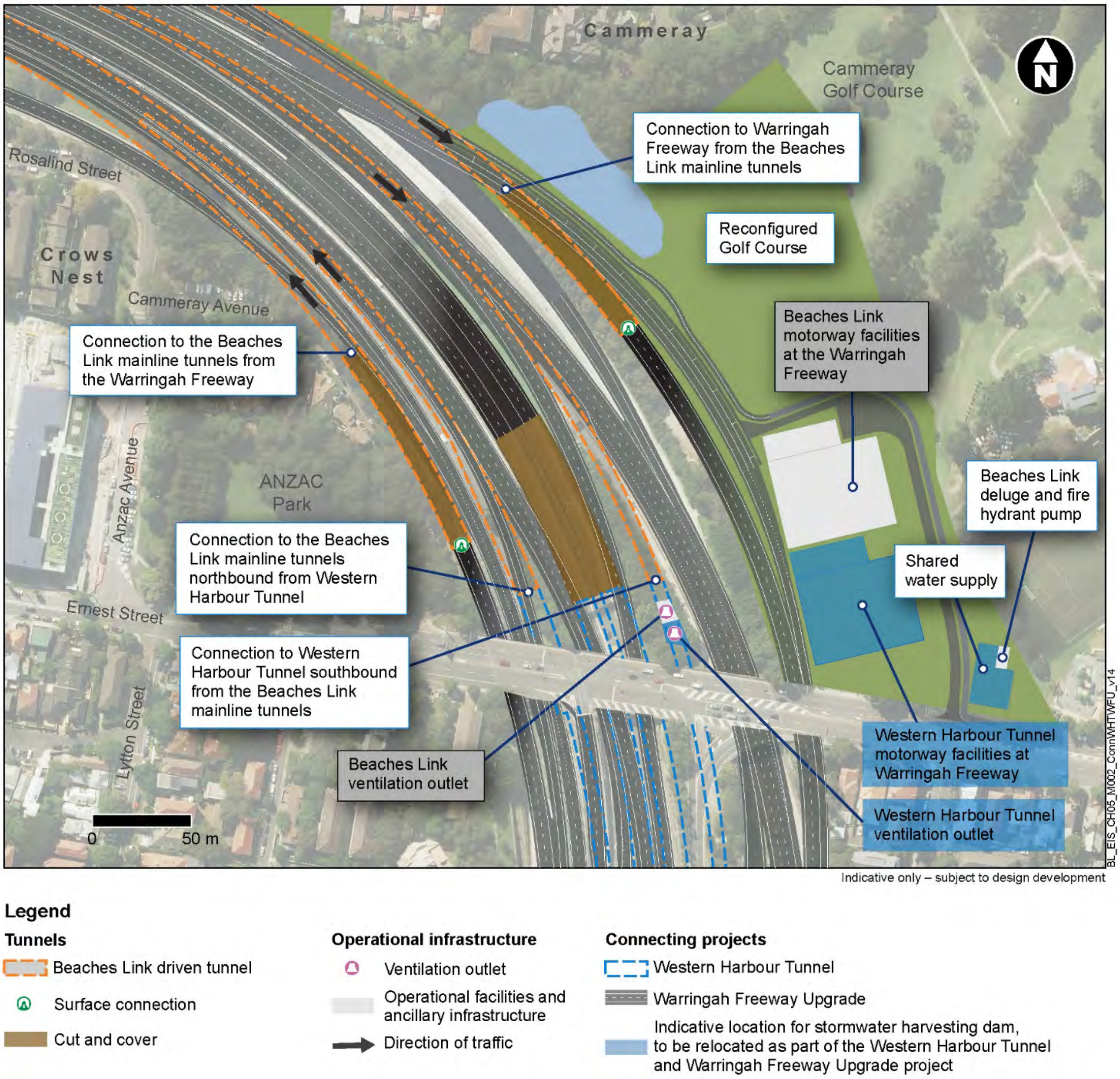


Figure 5-17 Indicative tunnel-to-tunnel connections to the Western Harbour Tunnel and Warringah Freeway Upgrade project tunnel

5.2.5 Surface connections

The tunnels would be connected to the surface road network at the following locations, with connections to and from the:

- Warringah Freeway at Cammeray
- Gore Hill Freeway at Artarmon
- Burnt Bridge Creek Deviation at Balgowlah
- Wakehurst Parkway at Killarney Heights.

Connections from the mainline tunnels to and from the Warringah Freeway

The Beaches Link component of the project would include on and on off ramps that connect the mainline tunnels to the Warringah Freeway. The on and off ramps between the Beaches Link mainline tunnels and the Warringah Freeway would be located around Ernest Street, Cammeray.

Chapter 6 (Construction work) describes the elements of the on and off ramp structures and surface connections that would be delivered by the Warringah Freeway Upgrade.

Connections to and from the Warringah Freeway are shown in Figure 5-17 and would include two lanes connecting from the:

- Warringah Freeway to the northbound mainline tunnel
- Southbound mainline tunnel to the Warringah Freeway.

Connections to and from the Gore Hill Freeway

On and off ramps would connect the mainline tunnels under Northbridge with the Gore Hill Freeway at Artarmon as summarised in Table 5-4 and shown in Figure 5-18.

Table 5-4 Connections to and from the Gore Hill Freeway

Connection	Summary
On ramp from the Lane Cove Tunnel, Longueville Road and Reserve Road to the northbound mainline tunnel	This connection would include two traffic lanes (one carrying traffic from the Lane Cove Tunnel and Epping Road/Longueville Road and one carrying traffic from Reserve Road) with ramp tunnel sections that would be about 2.1 kilometres long. The two traffic lanes would merge to one lane prior to joining the northbound mainline tunnel. Most of the ramp would be a driven tunnel between the T1 North Shore and Western Line and T9 Northern Line and the northbound mainline tunnel. Cut and cover and trough structures would be located to the west of the T1 North Shore and Western Line and T9 Northern Line (refer to Section 5.3). This tunnelled ramp is part of the Beaches Link component of the project.
Off ramp from the southbound mainline tunnel to Reserve Road and the Gore Hill Freeway/Lane Cove Tunnel	This connection would include a single lane diverging from the southbound mainline tunnel, immediately widening to two traffic lanes. The tunnelled section of the ramp would be about two kilometres long. Before connecting to surface at the Gore Hill Freeway, the ramp would divide into two separate ramps to the west of the T1 North Shore and Western Line and T9 Northern Line. One lane would carry traffic to Reserve Road and the other would carry traffic to the Gore Hill Freeway/Lane Cove Tunnel. Most of the ramp would be driven tunnel between the T1 North Shore and Western Line and T9 Northern Line and the northbound mainline tunnel. Cut and cover and trough structures would be located to the west of the T1 North Shore and Western Line and T9 Northern Line (refer to Section 5.3). This tunnelled ramp is part of the Beaches Link component of the project.

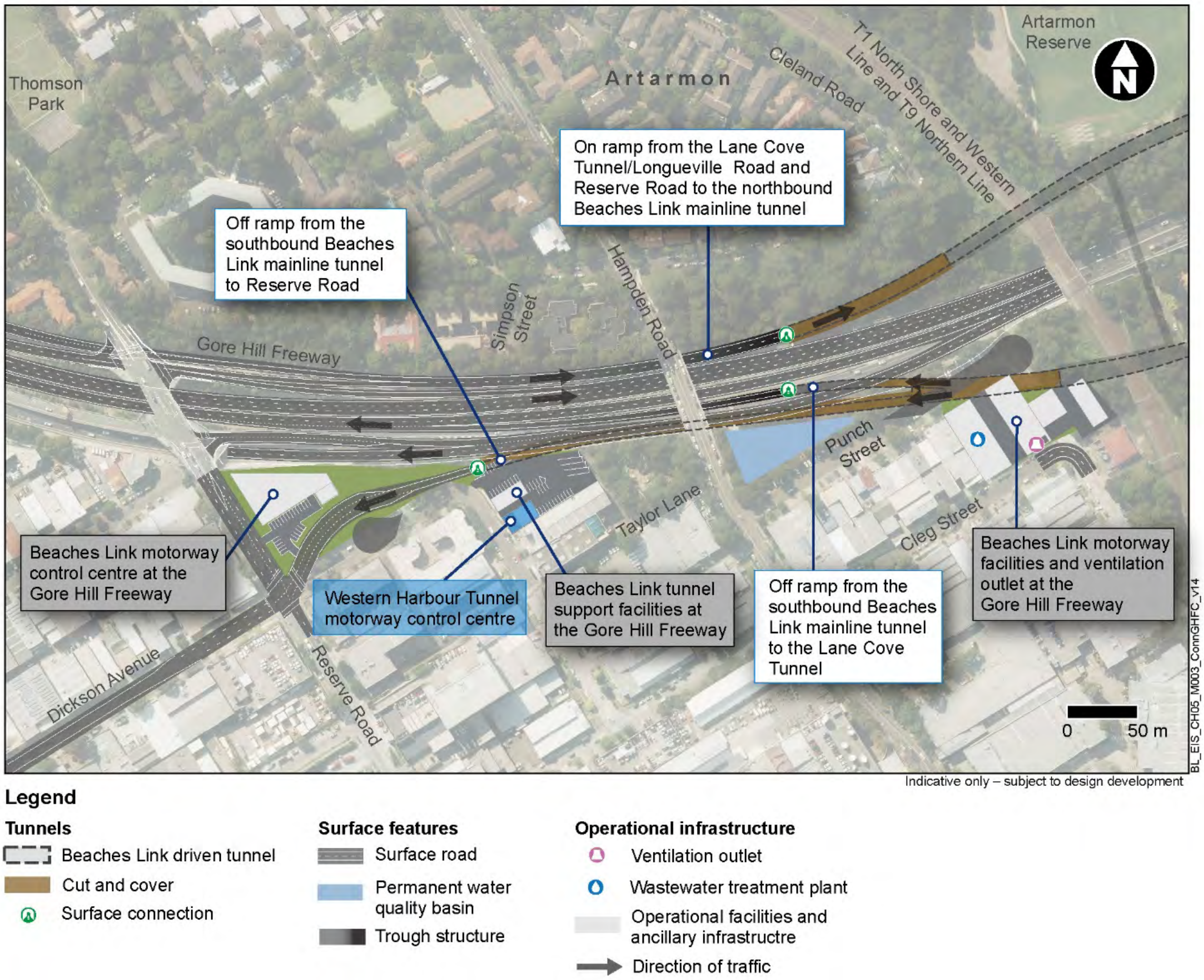


Figure 5-18 Connections to and from the Gore Hill Freeway

Connections to and from the Burnt Bridge Creek Deviation

On and off ramps would connect the mainline tunnels with the Burnt Bridge Creek Deviation at Balgowlah, as summarised in Table 5-5 and shown in Figure 5-19.

Table 5-5 Connections to and from the Burnt Bridge Creek Deviation

Connection	Summary
On ramp from the Burnt Bridge Creek Deviation to the southbound mainline tunnel	This connection would include two traffic lanes, about 1.2 kilometres long. Most of the ramp would be driven tunnel, with cut and cover and trough structures at the Burnt Bridge Creek Deviation.
Off ramp from the northbound mainline tunnel to the Burnt Bridge Creek Deviation	This connection would include two traffic lanes, about 1.2 kilometres long. Most of the ramp would be driven tunnel, with cut and cover and trough structures at the Burnt Bridge Creek Deviation.

Indicative only – subject to design development

Legend

Tunnels
- Beaches Link driven tunnel
- Cut and cover
- Surface connection

Surface features
- Surface road
- Bus lane
- Pedestrian / active transport links
- Trough structure

Operational infrastructure
- Ventilation outlet
- Operational facilities and ancillary infrastructure
- Direction of traffic
- Permanent water quality basin

Figure 5-19 Connections to and from the Burnt Bridge Creek Deviation

Connections to and from the Wakehurst Parkway

On and off ramps would connect the mainline tunnels with the Wakehurst Parkway at Killarney Heights, as summarised in Table 5-6 and shown in Figure 5-20.

Table 5-6 Connections to and from the Wakehurst Parkway

Connection	Summary
On ramp from the Wakehurst Parkway to the southbound mainline tunnel	This connection would include two traffic lanes, about 2.8 kilometres long. Most of the ramp would be driven tunnel, with cut and cover and trough structures at the Wakehurst Parkway north of Kirkwood Street.
Off ramp from the northbound mainline tunnel to the Wakehurst Parkway	This connection would include two traffic lanes, about 2.8 kilometres long. Most of the ramp would be driven tunnel, with cut and cover and trough structures at the Wakehurst Parkway north of Kirkwood Street.

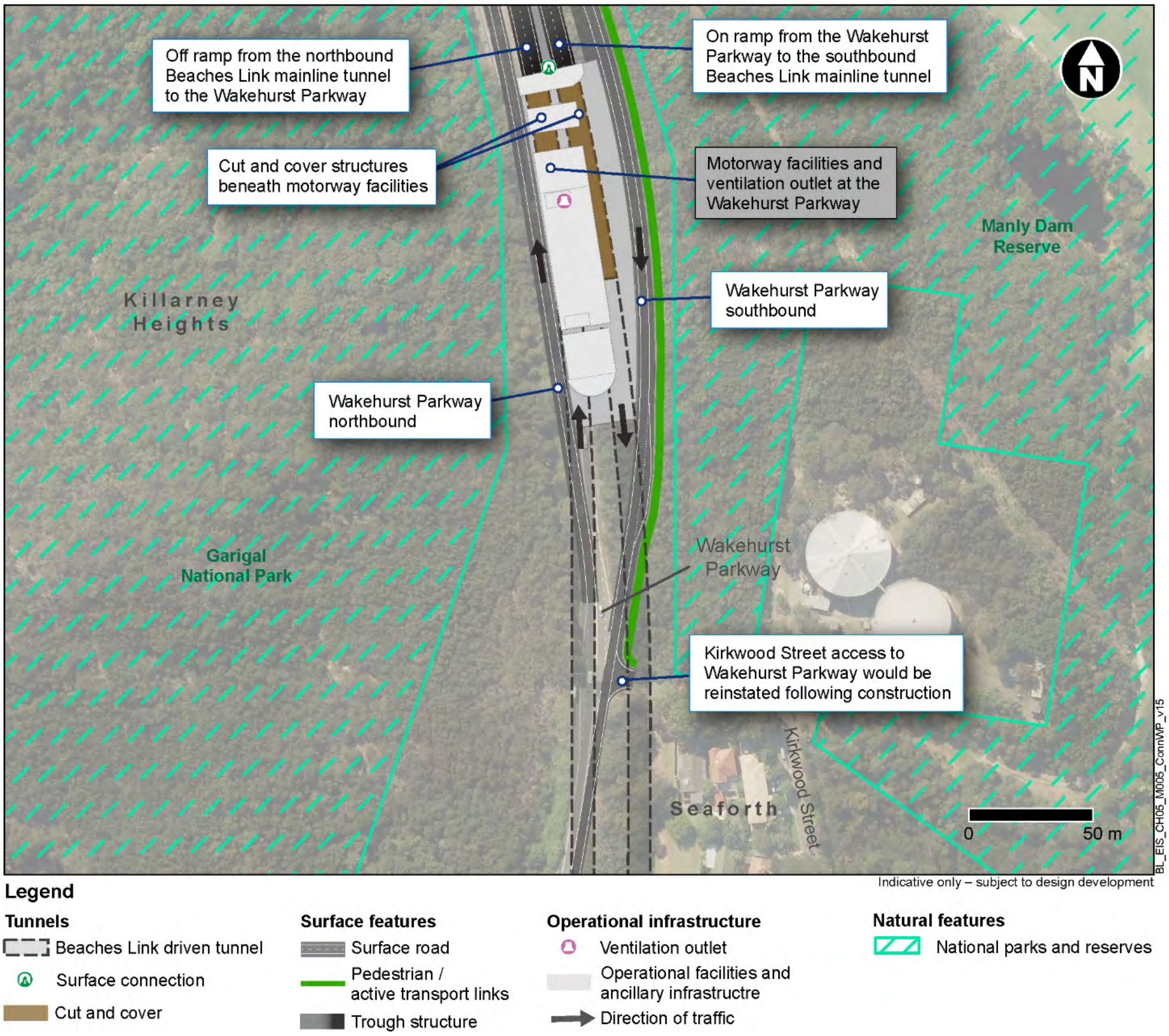


Figure 5-20 Connections to and from the Wakehurst Parkway

5.2.6 Surface road works

Key surface road works that would be carried out as part of the Beaches Link component include:

- Upgrade and integration work along and around the Burnt Bridge Creek Deviation and Sydney Road at Balgowlah, North Balgowlah and Seaforth, including a new access road
- Upgrade and integration work along the Wakehurst Parkway, at Seaforth, Killarney Heights and Frenchs Forest.

Surface road works that would be carried out as part of the Gore Hill Freeway Connection component of the project are detailed in Section 5.3.3.

Surface road works at Balgowlah

Surface road works would be required along and around the Burnt Bridge Creek Deviation, Manly Road and Sydney Road at Balgowlah, North Balgowlah and Seaforth to connect and integrate the project with the surrounding road network. The surface road works would include:

- Realignment and widening of the Burnt Bridge Creek Deviation including cut and cover and trough works east of Hope Street
- Localised adjustment of a small section of Burnt Bridge Creek for road widening and extension of the existing culvert and provision of scour protection
- A new access road which would:
  - Provide connectivity to new car parking facilities at Balgowlah for the new and improved open space and recreation facilities
  - Provide connectivity from the Beaches Link tunnel to and from Sydney Road via a new traffic light intersection on the Burnt Bridge Creek Deviation to a new traffic light intersection at Sydney Road/Maretimo Street
- Minor changes to local roads, including intersection works at Maretimo Street, and localised traffic calming measures, as required
- Retaining walls to support cut rock faces and retain fill embankments
- Relocation of existing utilities impacted by the project at various locations where surface works are required (refer to Section 5.2.9)
- Local access for motorway facilities
- A new cul-de-sac on Dudley Street to align with the new and improved open space and recreation facilities.

Details of the surface road works are summarised in Table 5-7 and shown in Figure 5-21. An indicative cross-section through the Burnt Bridge Creek Deviation and the ramp trough structures is shown in Figure 5-22.

Table 5-7 Surface road works at Balgowlah, North Balgowlah and Seaforth

Key project component	Description
Realignment and widening of the Burnt Bridge Creek Deviation	The Burnt Bridge Creek Deviation would be realigned and widened to allow connection of the ramp tunnels with the surface road network, including: • Surface road works from Sydney Road to around the existing Kitchener Street bridge to reconfigure Burnt Bridge Creek Deviation to integrate with the new Beaches Link tunnel connection • A new traffic light intersection on Burnt Bridge Creek Deviation at the end of the current configuration of Dudley Street to connect to a new

Key project component	Description
	access road through to Sydney Road (see following section in this table for further information on the new access road) • A two lane ramp from the northbound mainline tunnel, widening to four lanes at the surface to provide two free flow lanes for northbound through traffic on the Burnt Bridge Creek Deviation and two right turning traffic lanes into the new access road • Provision of two lanes connecting Burnt Bridge Creek Deviation southbound to the westbound ramp tunnel • Realignment of the Burnt Bridge Creek Deviation (east of Hope Street) around the Beaches Link trough structure to maintain a variable single/twin traffic lanes and single bus lane in each direction following completion of construction. This would require widening of the existing Burnt Bridge Creek Deviation corridor, mainly to the east of the existing alignment in the area of the existing Dudley Street • Median reconstruction, asphalt resurfacing and linemarking works to incorporate adjacent Burnt Bridge Creek Deviation widening works at the intersection of Sydney Road, Burnt Bridge Creek Deviation and Manly Road and further north along Burnt Bridge Creek Deviation.
New access road	A new access road would be constructed at Balgowlah to connect the Burnt Bridge Creek Deviation with Sydney Road. The new access road would allow traffic from the ramp tunnel to access Sydney Road and travel to and from Manly, Balgowlah, North Balgowlah and Seaforth to access Beaches Link. The new road would also provide access for users of the new and improved open space and recreation facilities at Balgowlah. The new access road would include: • Mostly two traffic lanes in each direction, with a posted speed limit of up to 60 km/h • New traffic light intersections at the Burnt Bridge Creek Deviation at the end of the current configuration of Dudley Street and at Sydney Road at the intersection of Maretimo Street • Widening of Sydney Road at the new intersection between the new access road, Sydney Road and Maretimo Street to allow for turning lanes and maintenance of through traffic lanes on Sydney Road. There would be no access between the new access road and Maretimo Street • A driveway off the new access road to access the motorway facilities • A new car park off the access road to provide parking for users of the new open space and recreation facilities • Pedestrian and cyclist facilities along and across the new access road (refer to Section 5.2.8).
Localised adjustment of Burnt Bridge Creek	Due to the widening of the Burnt Bridge Creek Deviation, Burnt Bridge Creek would require localised adjustment to facilitate an extension of the existing box culvert crossing of Burnt Bridge Creek Deviation. Scour protection would also be required at the outlet of the extended culvert. It should be noted that the waterway was previously realigned during construction of Burnt Bridge Creek Deviation in 1982. The localised adjustment would be carried out within the previously modified section of Burnt Bridge Creek.

Key project component	Description
Local road changes	Minor changes to local road conditions would include permanent closure of the northern section of Dudley Street and the creation of a modified cul-de-sac at the southern end of Dudley Street. The design of the cul-de-sac would be refined during further design development and its extent minimised where possible. Traffic calming measures may also be required as part of the project. The final design and location of traffic calming measures would be developed in consultation with Northern Beaches Council.
Retaining walls	Several retaining walls are expected to be required. Each wall would range in length and height to suit the new works and existing surface levels. Finishes would be designed in line with the urban design framework for the project (refer to Appendix V (Technical working paper: Urban design, landscape character and visual impact assessment)).

Indicative only – subject to design development

Legend

Tunnels
- Beaches Link driven tunnel
- Cut and cover
- Surface connection

Surface features
- Surface road
- Bus lane
- Pedestrian / active transport links
- Trough structure

Operational infrastructure
- Ventilation outlet
- Ventilation tunnel
- Operational facilities and ancillary infrastructure
- Permanent water quality basin

Existing infrastructure
- Existing noise barrier

Figure 5-21 Surface road works at Balgowlah

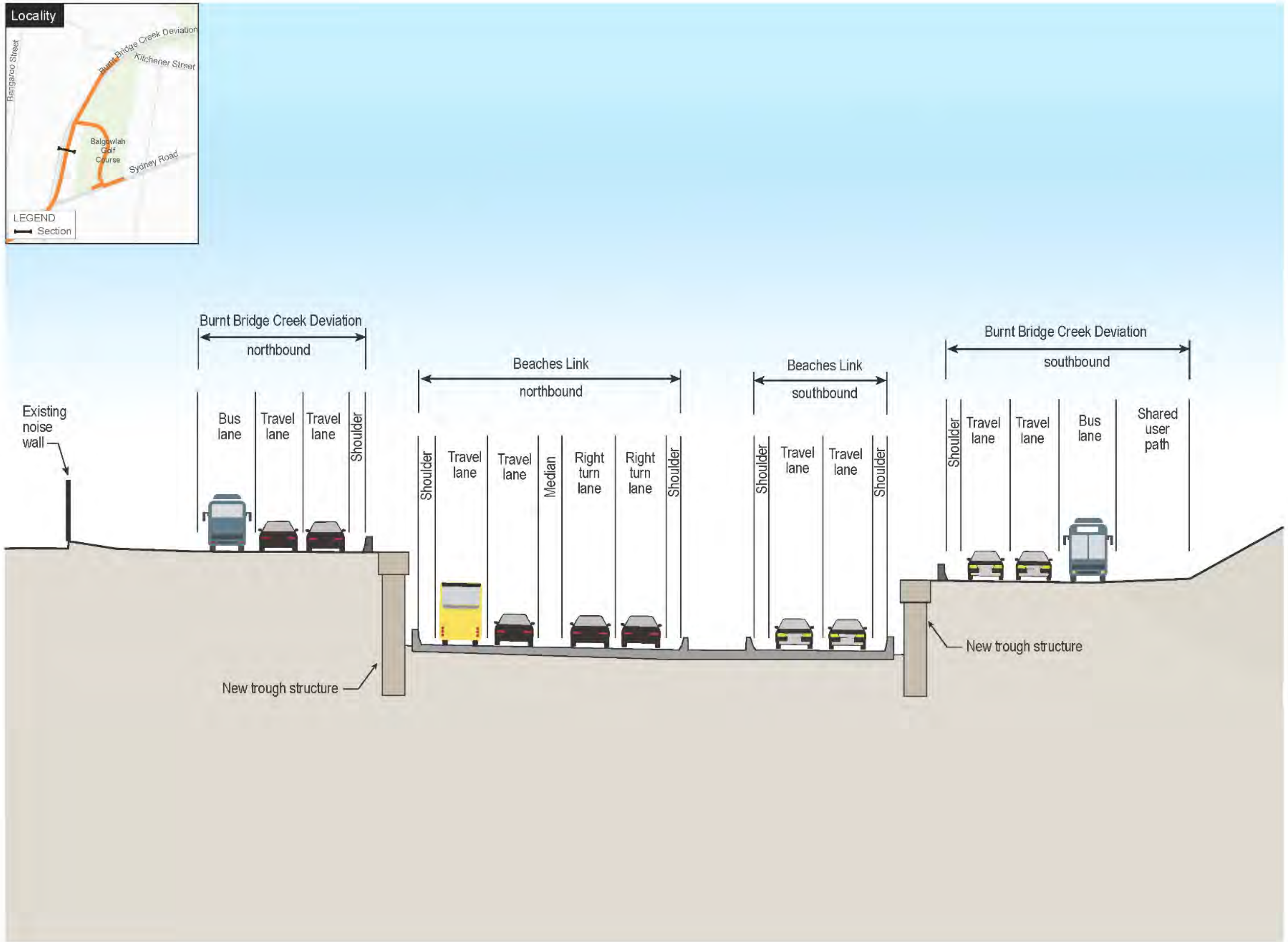


Figure 5-22 Indicative cross-section through the Burnt Bridge Creek Deviation and ramp trough structures

Surface road works at Seaforth, Killarney Heights and Frenchs Forest

Surface road works would be required along the Wakehurst Parkway between Seaforth and Frenchs Forest to connect and integrate the project with the surrounding road network. These works would also integrate the project with road network upgrades completed as part of the Northern Beaches Hospital road upgrade project. Surface road works in these areas would comprise:

- Realignment and upgrade of the Wakehurst Parkway to two lanes in each direction, south of Warringah Road through to the new Beaches Link tunnel portals at Killarney Heights
- Minor changes to the intersections of the Wakehurst Parkway with Kirkwood Street, Fitzpatrick Avenue/Aquatic Drive, Warringah Road and Frenchs Forest Road East and Frenchs Forest Road West.

Details of the surface road works at Seaforth, Killarney Heights and Frenchs Forest are provided in Table 5-8 and shown in Figure 5-23 and Figure 5-24. An indicative cross-section through the Wakehurst Parkway and the ramp trough structures is shown in Figure 5-25.

Table 5-8 Surface road works at Seaforth, Killarney Heights and Frenchs Forest

Key project component	Description
Realignment and widening of the Wakehurst Parkway	The Wakehurst Parkway would be realigned to allow connection of the ramp tunnels with the surface and widened between the ramp trough structure and Warringah Road to provide additional capacity. The surface works would include: • Realignment of the Wakehurst Parkway around the ramp cut and cover and trough structures. The realignment would extend from the intersection with Kirkwood Street at Seaforth, to the merge with traffic lanes connecting to and from the tunnel ramps • Widening of the Wakehurst Parkway from one lane in each direction to two lanes in each direction, from the ramp trough structures to the intersection of the Wakehurst Parkway with Warringah Road, Frenchs Forest • A new shared user path along the Wakehurst Parkway between Seaforth and Frenchs Forest, with new underpasses and connections to existing bus stops, paths and surface trails at key locations (refer to Section 5.2.8) • New and replaced fauna fencing and crossing infrastructure along and across the Wakehurst Parkway (refer to Section 5.2.11) • Retaining walls to support cut or fill embankments. Each wall would range in length and height to suit the new works and existing surface levels. Finishes would be designed in line with the urban design framework for the project (refer to Appendix V (Technical working paper: Urban design, landscape character and visual impact assessment)) • Replacement of the existing pedestrian bridge south of Aquatic Drive with a new shared user bridge structure to suit the road widening works • Driveway access to the motorway facility from the Wakehurst Parkway • Driveway access to the tunnel support facilities at the Wakehurst Parkway in Frenchs Forest via a left in and left out to Warringah Road and a left in and left out to the Wakehurst Parkway.

Key project component	Description
Minor intersection changes	Minor changes would be required to intersections of the Wakehurst Parkway with Kirkwood Street, Fitzpatrick Avenue/Aquatic Drive, Warringah Road and Frenchs Forest Road East and Frenchs Forest Road West to integrate the project with the surface road network. These minor changes would include: • Removal of the right turn movement from the Wakehurst Parkway northbound onto Frenchs Forest Road East • Alterations to linemarking, traffic signals and signage • Adjustments to medians • Asphalt resurfacing.
Water quality basins	Construction of four permanent water quality basins along the Wakehurst Parkway, which would include: • A new water quality basin to the west of the widened Wakehurst Parkway, next to Garigal National Park and about 600 metres north of Kirkwood Street, accessed via the Wakehurst Parkway • Three new water quality basins to the east of the widened Wakehurst Parkway about 800 metres to 900 metres south of the intersection with Warringah Road, accessed via the Wakehurst Parkway.

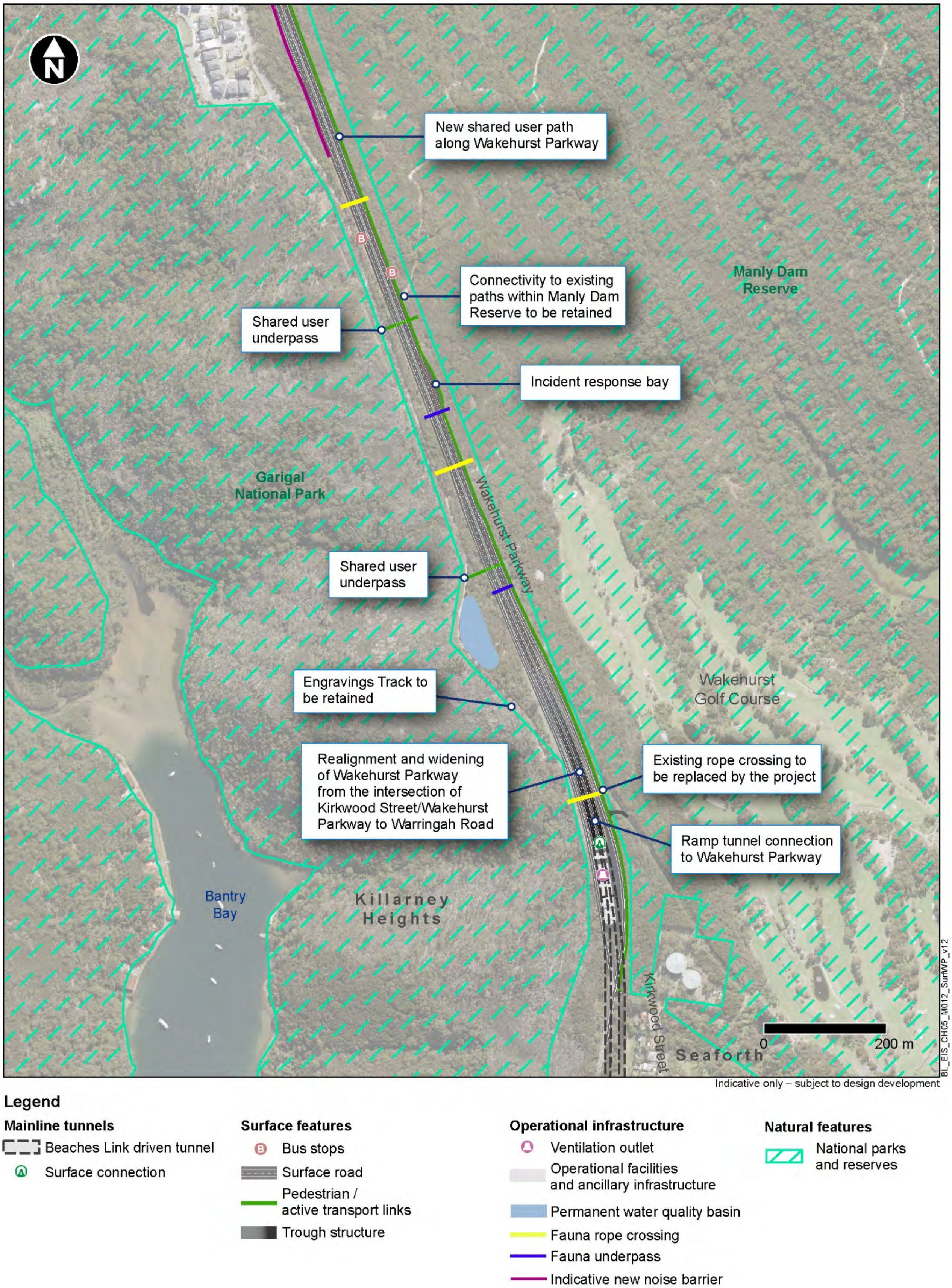


Figure 5-23 Surface road works at Seaforth, Killarney Heights and Frenchs Forest (map 1)

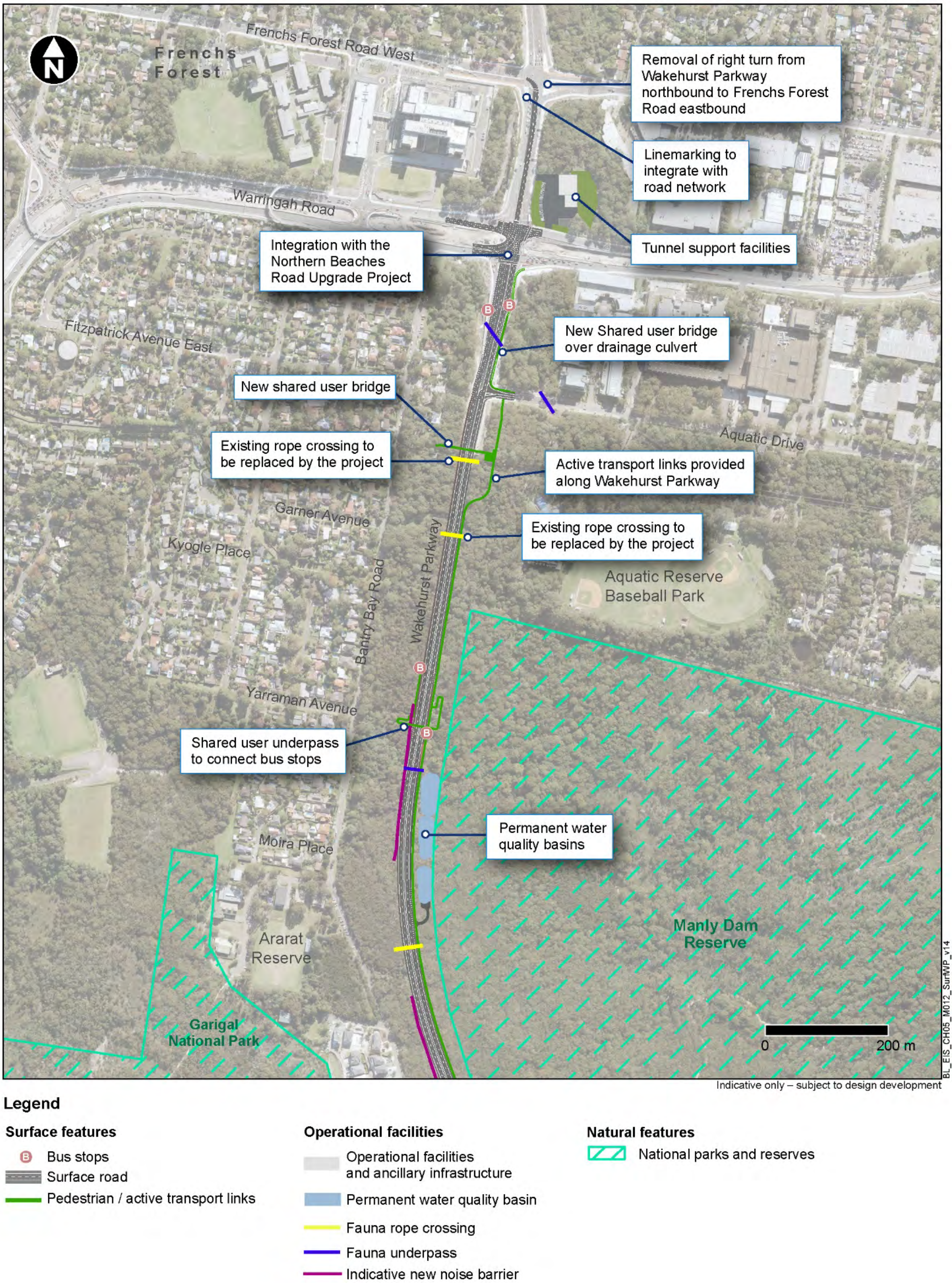


Figure 5-24 Surface road works at Seaforth, Killarney Heights and Frenchs Forest (map 2)

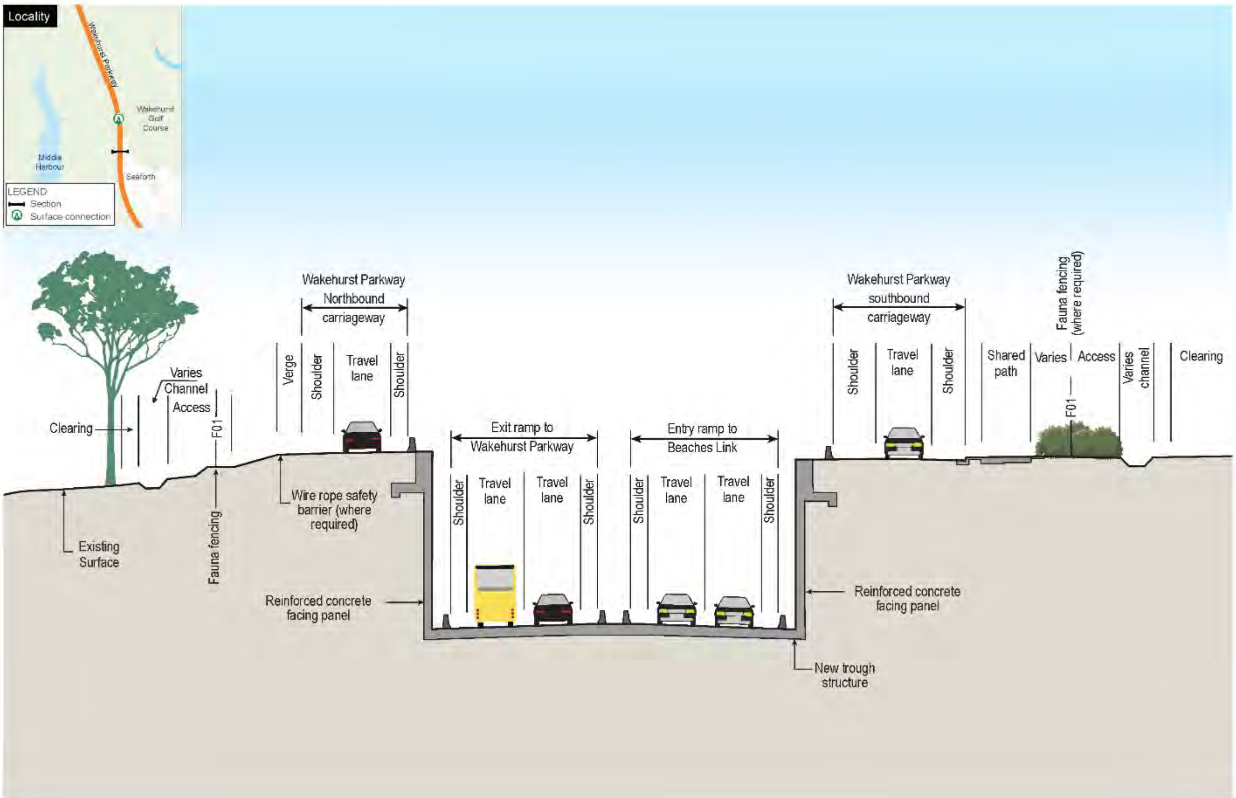


Figure 5-25 Indicative cross-section through the Wakehurst Parkway and ramp trough structure

5.2.7 Operational facilities and ancillary infrastructure

Operational facilities for the Beaches Link component of the project would include:

- Tunnel ventilation systems
- A motorway control centre
- Tunnel support facilities.

Operational ancillary infrastructure for the Beaches Link component of the project would include:

- Fire and life safety systems
- Tunnel drainage and wastewater treatment plant
- Lighting
- Signage, CCTV and other traffic control systems
- Tolling infrastructure
- Emergency breakdown bays
- Electrical substations (discussed in Section 5.2.9).

Tunnel ventilation systems

Tunnel ventilation systems would be installed to ensure in-tunnel air quality is protective of human health and amenity, and to manage fire and smoke in the event of an incident in the tunnels. The tunnel ventilation systems would include:

- Jet fans installed in the ceiling of the tunnels
- Axial fans within the motorway facilities to extract air from the tunnel via ventilation tunnels
- Axial fans within the motorway facilities to supply air to the tunnel via ventilation tunnels
- Ventilation outlets to effectively disperse tunnel air into the atmosphere
- Air quality monitoring systems in the tunnels and ventilation outlets to monitor and control the ventilation system.

The design and operation of the tunnel ventilation systems are detailed in Appendix I (Technical working paper: Air quality).

During normal operating conditions, most air would be forced through the tunnels by the movement of vehicles (the piston effect). Jet fans would be used to assist with the movement of tunnel air, if required, to maintain acceptable in-tunnel air quality.

The design of the ventilation system would ensure zero portal emissions. This would involve using jet fans to draw air back into the tunnel at the exit portals, to be emitted via the ventilation outlets. Tunnel air flow during normal operating conditions is shown in Figure 5-26.

If the tunnels become congested, or in instances of reduced traffic speeds, jet fans would be used to maintain air flow and acceptable in-tunnel air quality.

Air would be removed from the tunnels before it reaches the exit portals, and directed to motorway facilities at the Warringah Freeway (refer to Figure 5-1), Gore Hill Freeway (refer to Figure 5-2), Burnt Bridge Creek Deviation (refer to Figure 5-21) and the Wakehurst Parkway (refer to Figure 5-23).

In the case of a fire, the carriageway on which the incident has occurred would be closed to incoming traffic and traffic downstream of the fire would exit the tunnel. Jet fans would be used to control smoke and fire in the event of an incident in the tunnels, and would propel the smoke downstream and away from the stopped vehicles to the nearest ventilation outlet, or the tunnel portal(s), depending on the location of the fire. The ventilation system would be designed to prevent smoke spreading to adjoining tunnels.

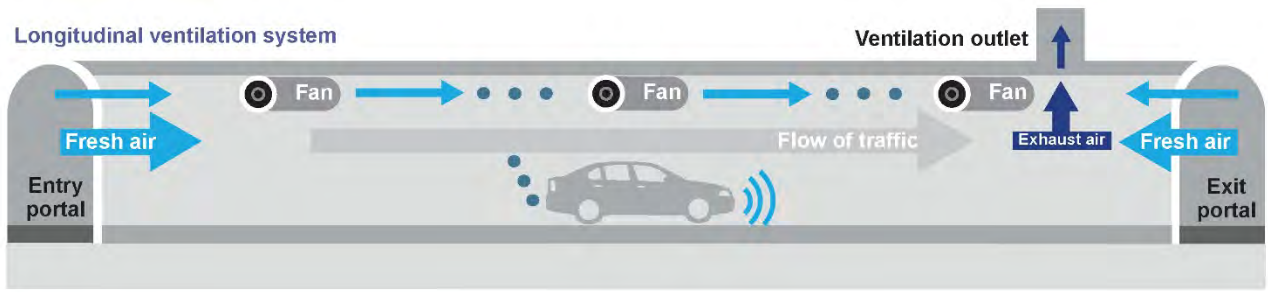


Figure 5-26 Tunnel air flow during normal operating conditions

Motorway control centre

The Beaches Link motorway control centre would be located at the Gore Hill Freeway, within the Artarmon industrial area, as shown in Figure 5-2.

The motorway control centre is anticipated to comprise a double-storey building with an area of about 650 square metres, and an adjoining car park. It would be continuously staffed and used to monitor, and if necessary, respond to, conditions in the tunnels and on surface road connections.

Tunnel support facilities

Tunnel support facilities would be located at the Gore Hill Freeway within the Artarmon industrial area (as shown in Figure 5-2) and next to the intersection of the Wakehurst Parkway and Warringah Road at Frenchs Forest (as shown in Figure 5-27).

The tunnel support facilities would include:

- A maintenance facility
- An incident recovery centre
- Materials storage and management areas.

The sites would be enclosed by high security fencing.

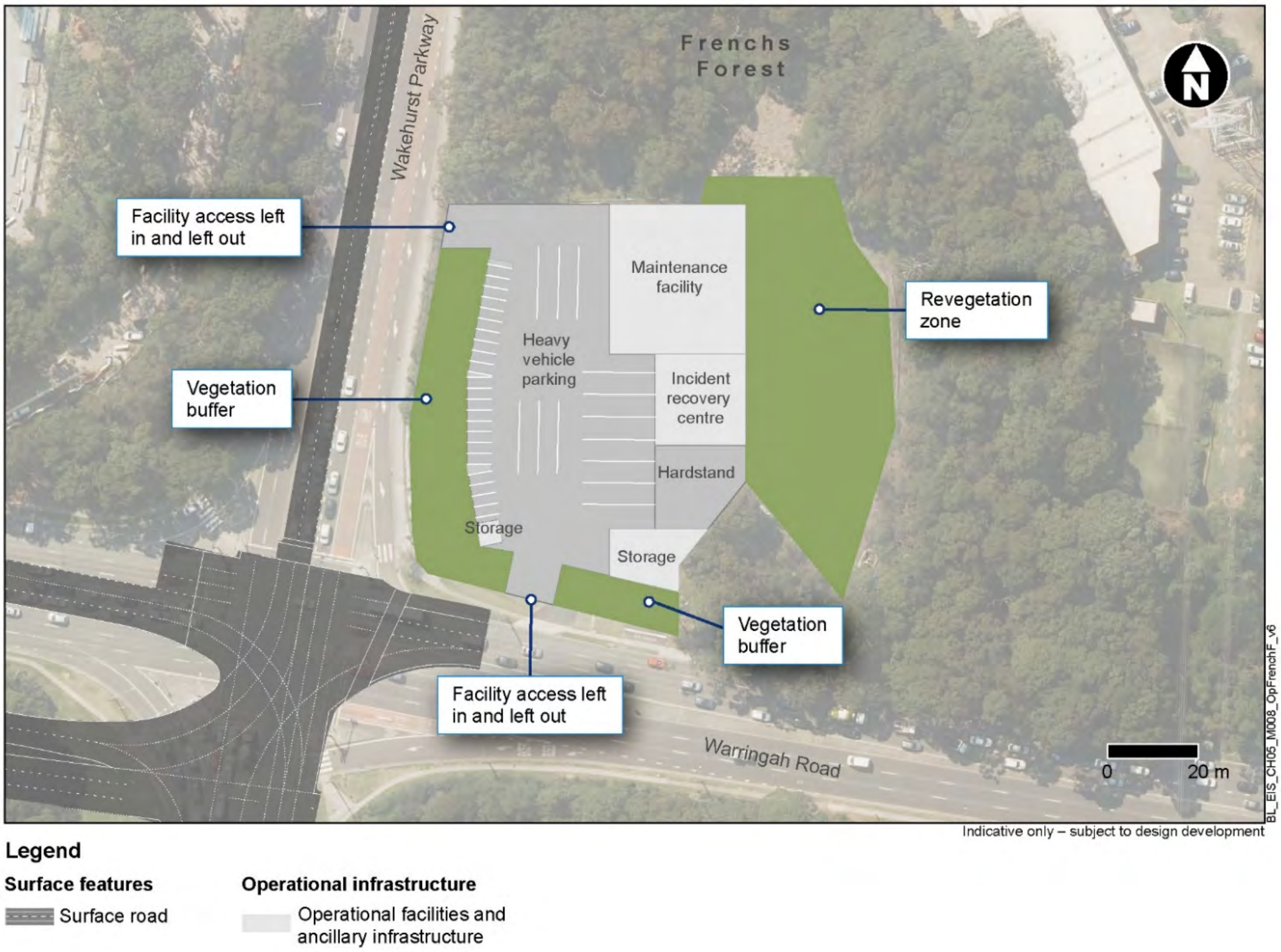


Figure 5-27 Tunnel support facilities at the Wakehurst Parkway in Frenchs Forest

Fire and life safety systems

The tunnels would be fitted with fire and life safety systems consistent with Australian Standard *AS 4825:2011 Tunnel Fire Safety*, applicable Austroads and Transport for NSW guidelines, and the outcomes of consultation with emergency services. Fire and life safety systems would include:

- Fire and incident detection equipment, a CCTV monitoring system, automatic video incident detection system and linear heat detection systems
- Communication systems, public and emergency broadcast services, and motorist emergency telephones
- Fire suppression systems, including a deluge water suppression system, a fire hydrant system, and emergency equipment points containing hydrants, fire hose reels and fire extinguishers

- Emergency lighting, smoke management and power systems
- Pedestrian cross passages between the tunnels, or longitudinal egress passages, to provide safe access or exit in the event of a fire or other emergency
- Tunnel closure systems.

Tunnel drainage and wastewater treatment plant

A drainage and sump system would be installed within the tunnels to collect:

- Groundwater ingress into the tunnels
- Deluge water in the event of an incident or during routine testing of emergency systems
- Washdown water
- Spills and leaks.

Wastewater intercepted by the tunnel drainage systems would be collected at a sump and pumped to the project wastewater treatment plant at the Gore Hill Freeway in Artarmon (refer to Chapter 17 (Hydrodynamics and water quality) for further details of the operational wastewater treatment plant for the project).

The wastewater treatment plant would consist of:

- A balance tank to regulate flows into the plant
- A treatment plant, including clarifier and control room, to treat water prior to discharge into the stormwater drainage system.

To minimise the impact on downstream water quality, the wastewater treatment plant would be designed to treat the wastewater to comply with the *National Water Quality Guidelines* (ANZG (2018) and Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ) water quality guidelines (2000) default trigger values for physical and chemical stressors for estuarine and lowland river ecosystems and the 95 percent species protection levels for toxicants when designing wastewater treatment plants. For toxicants known to bioaccumulate, the 99 percent species protection level will be adopted. Additionally, where required, appropriate tunnel lining design would reduce water inflow into the tunnel thereby minimising the amount of wastewater treatment and disposal required during tunnel operation.

Lighting

Lighting would be provided within the tunnels and along surface roads, consistent with the guidelines published by Austroads and Transport for NSW, as well as the relevant and applicable Australian Standards.

Emergency lighting would also be installed in the tunnels. This would include fixed direction exit signage and illuminated signage. Aviation hazard lighting may be installed on motorway facilities if required as a result of consultation with the Civil Aviation Safety Authority.

Lighting of aboveground operational facilities would be provided, consistent with Australian Standard *AS 4282-2019 Control of Obtrusive Effects of Outdoor Lighting*. Lighting would be designed and installed to ensure safety and security, and to minimise the potential for light spill and nuisance impacts.

Signage, CCTV and other traffic control systems

Traffic, locational, directional, warning and variable message signs would be installed along the length of the project. Signage would be consistent with the requirements of applicable Australian Standards and guidelines published by Austroads and Transport for NSW.

The project would include intelligent transport system technology and traffic control infrastructure including:

- Variable message signs
- Lane use management systems
- Variable speed limit signs
- CCTV and automatic incident detection systems
- Ramp metering infrastructure
- Motorists emergency telephones within breakdown bays
- Vehicle enforcement systems.

Tolling infrastructure

Infrastructure would be installed as part of the project to provide the NSW Government with the option to apply tolls to traffic using the Beaches Link tunnel. Toll gantries would span one or more traffic lanes, depending on location. The toll gantries would be installed with lighting (where required) and electronic tolling units. The toll gantries would indicatively be located inside the tunnels at locations to be determined during further design development, between the ramp merge points between Northbridge and Seaforth, as shown in Figure 5-3 and Figure 5-4.

5.2.8 Public and active transport infrastructure

The Beaches Link component of the project has been designed to be a key piece of the public transport network of the Northern Beaches, allowing for the future provision of express bus connections with North Sydney, the Sydney CBD, Macquarie Park, St Leonards and other key centres across greater Sydney via the motorway network. Accordingly, the Beaches Link tunnels have been designed to allow use by buses, including taller double decker bus services. The tunnel portals at the Warringah Freeway have also been designed to integrate with a new southbound bus lane on the Warringah Freeway (delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project), and provide the opportunity for efficient access and interchange with the new Victoria Cross Metro Station at North Sydney.

Public and active transport infrastructure included within the project would be delivered as part of the surface road connections at Artarmon, Balgowlah, Killarney Heights and Frenchs Forest and as part of the new and improved open space and recreation facilities at Balgowlah. Works at Artarmon would form part of the Gore Hill Freeway Connection component of the project and are detailed separately in Section 5.3.4. Further public and active transport infrastructure would be provided around Cammeray and North Sydney as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

Any new or modified public and active transport associated with the project would satisfy relevant accessibility requirements as per the *Disability Discrimination Act 1992* and the 'crime prevention through environmental design' principles as per Appendix V (Technical working paper: Urban design, landscape character and visual impact assessment).

Pedestrians and cyclists would be excluded from the tunnels.

Public and active transport infrastructure that would be provided at Balgowlah, Seaforth, Killarney Heights and Frenchs Forest is summarised in Table 5-9 and shown in Figure 5-21, Figure 5-23 and Figure 5-24.

Table 5-9 Public and active transport infrastructure of the Beaches Link component

Infrastructure	Summary
Works at Cammeray	
Public transport infrastructure	Beaches Link on and off ramps have been designed to provide for high quality bus access to and from North Sydney (including the new Victoria Cross Metro Station) and the Sydney CBD via upgraded bus infrastructure along the Warringah Freeway, and North Sydney access arrangements to be delivered as part of the Warringah Freeway Upgrade. Bus priority would be provided by allowing buses travelling southbound in the Beaches Link tunnel direct access to a new southbound bus lane on the Warringah Freeway.
Works at Balgowlah	
Public transport infrastructure	A northbound and a southbound bus lane would be maintained along the Burnt Bridge Creek Deviation as part of the realignment and widening of the road. This would be consistent with existing bus provisions in this area, but would benefit from the new Beaches Link tunnels, which would enable express services to bypass the Military Road/Spit Road corridor to access North Sydney, the Sydney CBD, Macquarie Park, St Leonards and other strategic centres.
Active transport infrastructure (final layouts subject to further consultation)	The following pedestrian and cyclist facilities would be provided: • Realignment and reconstruction of the shared user path along the south eastern side of the Burnt Bridge Creek Deviation between the Kitchener Street bridge and Dudley Street. The realigned and reconstructed shared user path would connect with the existing shared user path at Dudley Street and extension of the existing active transport underpass beneath the Burnt Bridge Creek Deviation to the north of Dudley Street • A new shared user path along the eastern side of the new access road between Burnt Bridge Creek Deviation and Sydney Road • New at-grade pedestrian crossings of the new access road adjacent to the: - Intersection with Sydney Road - Intersection with Burnt Bridge Creek Deviation - New public car park within the new and improved open space and recreation facilities at Balgowlah. The existing pedestrian bridge over Sydney Road would be retained. The final layout of the new and improved open space and recreation facilities at Balgowlah, including shared user paths, are subject to further consultation with Northern Beaches Council and the community.
Works at Seaforth, Killarney Heights and Frenchs Forest	
Public transport infrastructure	Four new dedicated bus bays and bus stops would be provided along: • Wakehurst Parkway northbound, near Yarraman Avenue and about 930 metres south of Yarraman Avenue • Wakehurst Parkway southbound, near Yarraman Avenue and about 990 metres south of Yarraman Avenue.

Infrastructure	Summary
	The new bus bays and stops would be integrated with new active transport infrastructure including new underpasses to improve accessibility and user safety.
Active transport infrastructure	The following pedestrian and cyclist facilities would be provided to improve safety: • A new shared user path along the eastern side of the Wakehurst Parkway, from the northern end of Kirkwood Street at Seaforth to the intersection with Warringah Road at Frenchs Forest. The new shared user path includes a new bridge over a drainage culvert and fauna underpass (constructed as part of Northern Beaches Hospital road upgrade project), about 150 metres south of the intersection with Warringah Road • A new shared user underpass beneath the Wakehurst Parkway about 700 metres north of Kirkwood Street to connect Garigal National Park and the Engravings Trail to Manly Dam Reserve • A new shared user underpass beneath the Wakehurst Parkway about 1150 metres north of Kirkwood Street to connect Garigal National Park to Manly Dam Reserve • A new shared user underpass beneath the Wakehurst Parkway about 750 metres south of the intersection with Warringah Road at Frenchs Forest • Replacement of the existing pedestrian bridge across the Wakehurst Parkway, with a new shared user bridge about 350 metres south of Warringah Road at Frenchs Forest.

5.2.9 Utilities

The project would require the installation, relocation, adjustment and/or protection of utilities, particularly within and around surface connections and surface road works (refer to Section 5.2.5 and Section 5.2.6). The Utilities management strategy for the project (refer to Appendix D (Utilities management strategy)) provides a framework for utility installations, relocations, adjustments and protection. The Utilities management strategy provides information in relation to utility installations, relocations and adjustments which are currently:

- Known and proposed within the construction footprint
- Unknown and/or located outside of the construction footprint. The Utilities management strategy provides the framework for how these utility relocations and adjustments would be identified, assessed and managed.

The location of existing utilities and any changes required would be confirmed during further design development of the project in consultation with the relevant utility provider.

The project would also require connection with electricity and water supply networks, as outlined below.

Electricity supply

Electricity would be supplied to, and distributed through, the project via:

- Underground substations along the length of the tunnels
- Aboveground substations that would be co-located with motorway facilities at the Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway.

The aboveground substation at the Wakehurst Parkway at Killarney Heights would be connected to the existing electricity supply network via new conduits installed along the Wakehurst Parkway upgrade works. Subject to further consultation with Ausgrid, it is expected that electricity supply connections would be made with the Warringah sub-transmission substation.

Access for the service provider would be maintained to the existing 132kV cable adjacent to operational facilities at the Gore Hill Freeway.

Water supply

The project would be connected to the mains water supply network to provide water for essential services. Mains water would be used in cases where treated groundwater and rainwater harvesting are of insufficient quality or quantity to fully meet project needs.

During operation, water would be required for:

- Testing and operation of the tunnel deluge water suppression system (which forms part of the fire and life safety system)
- Motorway facilities ablutions
- Landscape irrigation.

The mains water supply network connection requirements, including connection location and design, would be determined in consultation with Sydney Water prior to the start of construction. Connection to water supply infrastructure would be subject to separate assessment and approval.

Water storage tanks to supply the tunnel hydrant and deluge water suppression systems would be located with other operational ancillary infrastructure at Cammeray and Artarmon (refer to Section 5.2.7).

5.2.10 Property acquisition

The project has been designed to minimise land acquisition and limit the severance of private properties. Property impacts are discussed further in Chapter 20 (Land use and property).

The total area and number of properties that would be acquired for the project may change as the project continues to be refined, or in response to changes resulting from the exhibition of the environmental impact statement and conditions of approval that may be applied by the Minister for Planning and Public Spaces.

The project would also involve the subdivision of private and public land. In some cases, whole lots would be acquired to avoid creating small unusable lots. Where a part of any lot is identified as being usable post construction and surplus to operational requirements, or requiring boundary adjustment following the completion of construction, Deposited Plans of subdivision, would be lodged at NSW Land Registry Services.

5.2.11 Environmental controls

The project has been designed to avoid or minimise environmental impacts as detailed in Chapter 4 (Project development and alternatives). Key environmental controls that would be provided as part of the Beaches Link component of the project are summarised in Table 5-10. Environmental controls forming part of the Gore Hill Freeway Connection component of the project are detailed in Section 5.3.8.

Table 5-10 Environmental controls of the Beaches Link component

Infrastructure	Summary
General environmental controls	
Ventilation outlets	A description of the proposed tunnel ventilation system is provided in Section 5.2.7. The tunnel ventilation method adopted for the project is based on a longitudinal ventilation system, where fresh air is typically introduced into the tunnels via the entry portals, extracted prior to the

Infrastructure	Summary
	exit portals and discharged into the atmosphere via the ventilation outlets. This ventilation method delivers and disperses tunnel air high into the atmosphere and avoids impact to ambient air quality around the tunnel portals. The primary motive force for airflow through the tunnel is the vehicle piston effect, which can be supplemented by jet fan operation, typically at lower average traffic speeds, if required. The location of ventilation outlets is considered in Chapter 4 (Project development and alternatives).
Air quality monitoring and management systems	Continuous emission monitoring and ambient air quality monitoring would be carried out during operation of the project to monitor: • In-tunnel air quality • Air quality within ventilation outlets • Ambient air quality at representative locations for a defined period of project operation. Air quality monitoring and ventilation for the project would be coordinated across the broader road network (including the Western Harbour Tunnel and Warringah Freeway Upgrade, and WestConnex network) to ensure: • Air quality remains within specified limits for motorists and road workers • Required airflows can be achieved for safety outcomes in the event of an incident or emergency • Ventilation systems are used efficiently to minimise day-to-day energy usage and cost and to maximise asset life • Airflows required for safety outcomes in the event of an incident can be achieved. Continuous emissions monitoring equipment for key contaminants (nitrogen dioxide and carbon monoxide), visibility and potentially other pollutants would be installed at appropriate locations within tunnels and ventilation outlets to ensure the project is operating within the prescribed emission limits for the project set by the conditions of approval, and the NSW Environment Protection Authority. Periodic manual monitoring of ventilation outlet emissions would also be carried out as required, to validate the accuracy of the continuous emissions monitoring equipment. Continuous ambient air quality monitoring of key contaminants (particulate matter ($PM_{2.5}$ and PM_{10}), oxides of nitrogen (NO and NO_2) and carbon monoxide would also be carried out at representative locations in the vicinity of the ventilation outlets to allow for the review of the predicted air quality outcomes. Monitoring would be in accordance with *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales* (DEC, 2007) or as otherwise agreed with the NSW Environment Protection Authority. Ambient air quality monitoring would occur at least 12 continuous months prior to operation and continue for two years following the commencement of operation. At the conclusion of the two year operational monitoring period, the need for continued use of ambient air quality monitoring stations would be reviewed in consultation with the NSW Environment Protection Authority and the Department of Planning, Industry and Environment.
Environmental controls at Artarmon	

Infrastructure	Summary
Tunnel water drainage and management infrastructure	A wastewater treatment plant would be located at the Gore Hill Freeway in the Artarmon industrial area, to treat stormwater, groundwater, deluge water, or spills collected within the Beaches Link tunnels to comply with ANZECC/ARMCANZ (2000) and ANZG (2018) guidelines before reuse or discharge (refer to Section 5.2.7).
Noise attenuation measures	Noise attenuators would be fitted on axial fans within the motorway facilities.
Surface water drainage and management infrastructure	Key surface water drainage and management that would be provided at Artarmon would include flood walls along the top of the Beaches Link on and off ramp portals to the west of the T1 North Shore and Western Line and T9 Northern Line.
Environmental controls at Balgowlah	
Surface water drainage and management infrastructure	Key surface water drainage and management that would be provided at Balgowlah would include: • A new drainage network at the tunnel portals to minimise the potential for ingress of water • Replacement of existing drainage infrastructure directly affected by surface works where required • Extension of the existing box culvert beneath Burnt Bridge Creek Deviation to the north of Dudley Street • Culverts beneath the new access road to carry drainage from around Sydney Road • A new water quality basin and provision of flood storage capacity • Localised adjustment of a small section of Burnt Bridge Creek (as discussed in Section 5.2.6).
Noise attenuation measures	Noise attenuation measures as part of the project at Balgowlah would include noise attenuators fitted on axial fans within the motorway facilities. No new noise barriers are proposed. The two existing noise barriers on Burnt Bridge Creek Deviation northbound would be maintained at the existing extent and height.
Environmental controls at Seaforth, Killarney Heights and Frenchs Forest	
Surface water drainage and management infrastructure	Key surface water drainage and management that would be provided at Seaforth, Killarney Heights and Frenchs Forest would include: • A new drainage network at the tunnel portals to minimise the potential for ingress of water • Replacement of existing drainage infrastructure directly affected by surface works where required • Extension and replacement where necessary of the six existing cross drainage structures beneath the Wakehurst Parkway • A new water quality basin to the west of the widened Wakehurst Parkway, adjacent to Garigal National Park and about 600 metres north of Kirkwood Street • Three new water quality basins to the east of the widened Wakehurst Parkway about 800 metres to 900 metres south of the intersection with Warringah Road.

Infrastructure	Summary
Noise attenuation measures	Noise attenuation measures as part of the project at Killarney Heights and Frenchs Forest would include two new noise barriers along the northern end of the Wakehurst Parkway in Frenchs Forest, with a nominal height between four and five metres installed where required. The final height and design of the noise barriers would be confirmed during further design development.
Fauna crossings and fencing at the Wakehurst Parkway	New and replacement fauna crossings would be provided over and beneath the Wakehurst Parkway, including: • Two new fauna underpasses about 1000 metres north of Kirkwood Street and 620 metres south of Aquatic Drive. The underpasses would be 1.8 metres high and three metres wide • A separate fauna underpass would be located about 725 metres north of Kirkwood Street • Three new rope crossings about 910 metres and 1370 metres north of Kirkwood Street and 885 metres south of Aquatic Drive • Replacement of the existing fauna rope crossing about 330 metres north of Kirkwood Street • Replacement of two fauna rope crossings about 110 metres and 200 metres south of Aquatic Drive constructed as part of the Northern Beaches Hospital road upgrade project • Retention of the existing fauna underpass north of Aquatic Drive constructed as part of the Northern Beaches Hospital road upgrade project • Fauna fencing as required along the Wakehurst Parkway. Fauna crossings are discussed in more detail in Chapter 19 (Biodiversity) and Appendix S (Technical working paper: Biodiversity development assessment report).

5.2.12 Landscape treatments

Landscape treatments for the project would be consistent with the project urban design framework in Appendix V (Technical working paper: Urban design, landscape character and visual impact assessment). Landscape treatments would be designed and implemented with the aims of:

- Minimising the visual and landscape impacts of the project
- Integrating the project into the surrounding visual catchment
- Improving local and regional amenity
- Maximising the use of endemic species, including consideration of current and future climate conditions
- Providing opportunity for improvements in urban ecology.

Landscape treatments would be provided along and around surface road works, including around tunnel portals and bridges, and around operational ancillary infrastructure. Key features of landscape treatments for the Beaches Link component of the project are summarised in Table 5-11. Landscape treatments for the Gore Hill Freeway Connection component of the project are outlined in Section 5.3.9.

Land used for construction but not required for operational infrastructure would be reinstated as outlined in Chapter 6 (Construction work).

The landscape design for the project would continue to be refined through further design development in line with the principles established in Appendix V (Technical working paper: Urban design, landscape character and visual impact assessment).

Table 5-11 Landscape treatments of the Beaches Link component

Area	Key features of landscape treatments
Cammeray surface works	Landscape treatments around the Cammeray surface works and operational ancillary infrastructure would include: • Restoration of areas disturbed during construction, however reconfiguration of Cammeray Golf Course would be carried out as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project • Screen planting around the motorway facilities at the Warringah Freeway • Landscape planting to assist the integration of the Beaches Link tunnel portals into the surrounding landscape.
Balgowlah surface works	Landscape treatments around the Balgowlah surface works and operational ancillary infrastructure would include (refer to Figure 5-28): • Screening of motorway facilities using landscape planting • Landscape planting to assist the integration of the tunnel portals into the surrounding landscape • Revegetation of minor disturbed area of Burnt Bridge Creek with an appropriate mix of native vegetation • A vegetated screening buffer between residential dwellings along the eastern boundary of the new and improved open space and recreation facilities at Balgowlah.
Seaforth, Killarney Heights and Frenchs Forest surface works	Landscape treatments around the Seaforth, Killarney Heights and Frenchs Forest surface works and operational ancillary infrastructure would include: • Bushland type seeding and planting of appropriate size and scale for restoration of areas disturbed during construction • A vegetated screening buffer around motorway facilities and supporting infrastructure • Bushland type planting of appropriate size and scale above the tunnel portals with an appropriate mix of native vegetation.

5.2.13 New and improved public open space

Balgowlah

The project has identified the potential for residual land at Balgowlah to be re-purposed as new and improved open space and recreation facilities for the community.

A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council will take place to give the community an opportunity to provide input into the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation will be separate to the consultation for the environmental impact statement. This process will start after the environmental impact statement public exhibition period and well in advance of construction starting. As part of this consultation process, a community reference group will be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space.

The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved open space and recreation facilities. Residual land, primarily to the east and north of the new access road, would progressively become available through the construction period, which would facilitate re-purposing it to the new open space and recreation facilities. This would allow it to be handed over progressively for use by the community. The new open space and recreation facilities to the west of the proposed access road, between the access road and Burnt Bridge Creek Deviation, would be constructed and handed over to Northern Beaches Council after completion of the project. Construction of the new and improved open space and recreation facilities is discussed further in Chapter 6 (Construction work).

An indicative layout of the new and improved open space and recreation facilities at Balgowlah is provided in Figure 5-28. This layout is subject to consultation, but as shown could include new cricket nets, playgrounds, soccer fields, amenities blocks, a multi-purpose oval, netball/basketball courts, and general public open space areas and pathways. An access road and centrally located car park would also be provided.

Bantry Bay Reservoir

The project proposes to use an area north of the Bantry Bay Reservoir to enable construction of Beaches Link. This site is currently a non-operational part of the Sydney Water Bantry Bay Reservoir site. As part of the project, Transport for NSW would acquire this parcel of land from Sydney Water. During the construction period, the project would use this site as part of the Wakehurst Parkway east construction support site (BL13) (refer to Chapter 6 (Construction work)). Use of this site would enable construction of the project, while reducing impacts to private property in the Seaforth and Killarney Heights area.

The site would be rehabilitated and revegetated as soon as practicable after construction completion and land that is surplus to Sydney Water's operational requirements would be transferred to the Manly Dam Reserve. This would add about 4000 square metres of new public space to the Manly Dam Reserve.

Indicative only – subject to design development

Legend

Tunnels
- Beaches Link driven tunnel
- Surface connection

Surface features
- Surface road
- Bus lane
- Pedestrian / active transport links
- New open space and recreation facilities (subject to further consultation)
- Trough structure

Operational infrastructure
- Ventilation outlet
- Operational facilities and ancillary infrastructure
- Permanent water quality basin

Indicative open space and recreation facilities
- A Amenity block
- C Cricket nets
- N Netball/ Basketball
- O Open space
- P Playground

Figure 5-28 Indicative Balgowlah new and improved open space and recreation facilities layout

5.3 Gore Hill Freeway Connection

5.3.1 Overview

The Gore Hill Freeway Connection component of the project would connect and integrate the Beaches Link tunnels with the Gore Hill Freeway and Lane Cove Tunnel at Artarmon. This connection would facilitate a more direct and efficient east-west link between the Northern Beaches and key strategic centres in the north west including St Leonards, Macquarie Park and Chatswood, and provide high quality connectivity with the Hills M2 Motorway, the Westlink M7 and NorthConnex.

Key features of the Gore Hill Freeway Connection are shown in Figure 5-1. The Gore Hill Freeway Connection would comprise a series of surface road works to the Gore Hill Freeway and parts of the surrounding surface road network, as shown in Figure 5-29.

5.3.2 Surface connections

Tunnel ramps would connect the mainline tunnels under Northbridge with the Gore Hill Freeway and Reserve Road at Artarmon as outlined in Section 5.2.5. Surface connections between the Beaches Link ramp tunnels and the Gore Hill Freeway are shown in Figure 5-18.

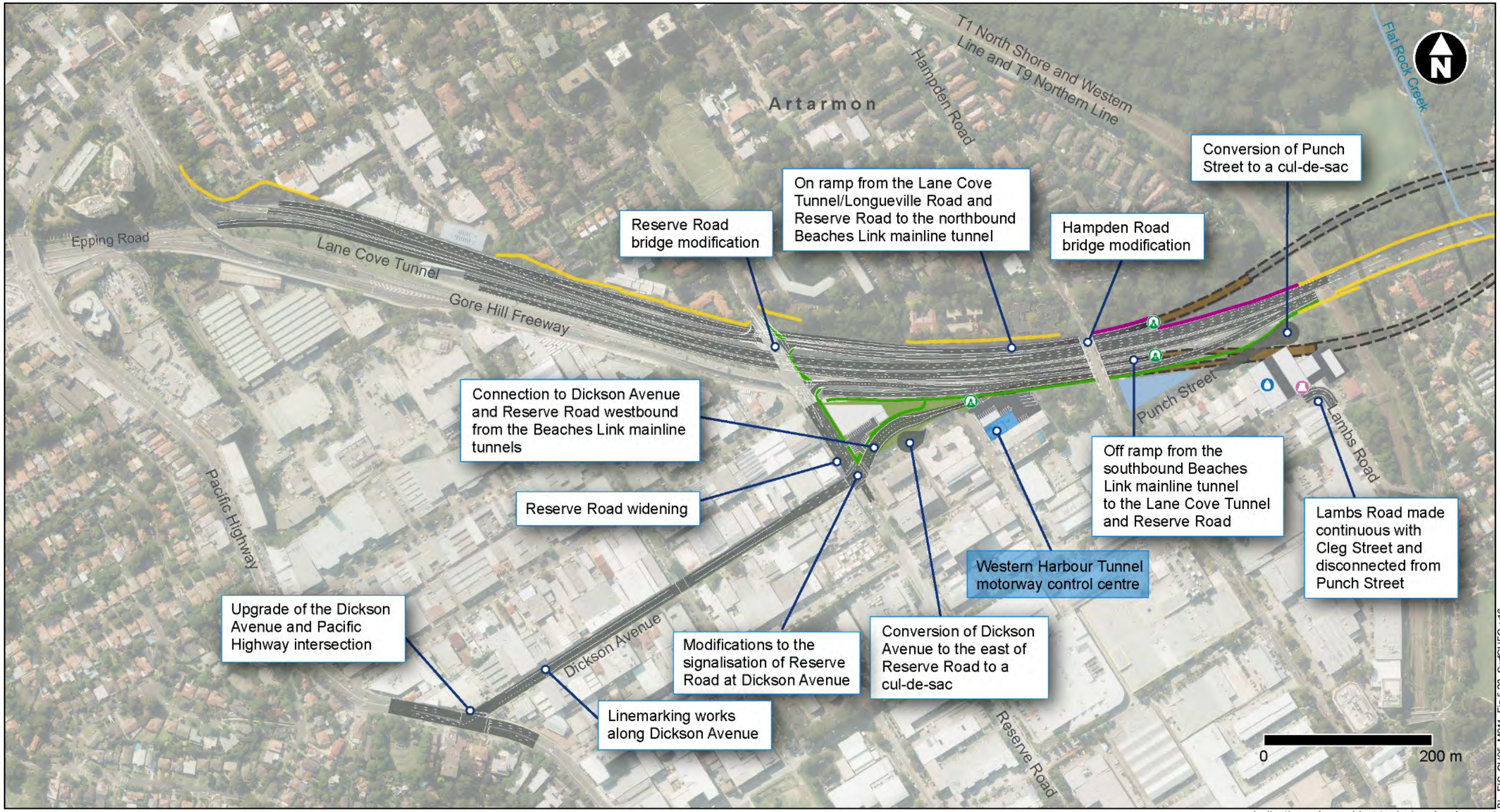
5.3.3 Surface road works

Surface road works forming part of the Gore Hill Freeway Connection would include realignment and adjustment of the existing freeway, and associated changes to the surrounding road network, as summarised in Table 5-12 and shown in Figure 5-29.

Table 5-12 Surface road works of the Gore Hill Freeway Connection component

Key project component	Summary
Realignment and upgrade of the Gore Hill Freeway	The Gore Hill Freeway would be realigned and adjusted, including: • Adjustment and reconfiguration of the Gore Hill Freeway between the T1 North Shore and Western Line and T9 Northern Line and the Pacific Highway to accommodate the Beaches Link tunnel portals and the on and off ramps • Modification of existing lanes from Epping Road/Longueville Road to the Gore Hill Freeway west of Reserve Road to provide connections to the Beaches Link tunnel and Gore Hill Freeway • Realignment of the existing Gore Hill Freeway westbound lanes towards Epping Road/Longueville Road to further south to accommodate the Beaches Link tunnel portals and connection to Reserve Road at Artarmon • Conversion of the existing T2 transit lane on the Gore Hill Freeway to a general traffic lane • Pedestrian and cyclist infrastructure (refer to Section 5.3.5).
Modified and upgraded road bridges	Existing road bridges across the Gore Hill Freeway would be modified, including: • Increasing the capacity of the northbound Reserve Road bridge lanes from two traffic lanes to three lanes. This would require conversion of the existing pedestrian footpath on the eastern side of the existing bridge and construction of a new pedestrian footpath (refer to Section 5.3.5)

Key project component	Summary
	• Partial rebuild of the eastbound (east-facing) on ramp from the Reserve Road bridge connecting to the Gore Hill Freeway and the Beaches Link tunnel • Strengthening works to the foundations of the Hampden Road bridge, including modifications to existing retaining walls and embankments.
Changes to local roads	Minor changes to local roads around the Gore Hill Freeway Connection would include: • Removal of the connection between Dickson Avenue east and Reserve Road, Artarmon, with conversion of Dickson Avenue to the east of Reserve Road to a cul-de-sac • Removal of the connection between Punch Street and Lambs Road, Artarmon, with conversion of Punch Street to a cul-de-sac • Modifications to the Dickson Avenue west/Reserve Road intersection to accommodate the new Beaches Link off ramp • Modifications to the traffic lights of Reserve Road, Artarmon • Upgrade and inclusion of traffic lights at the Dickson Avenue/Pacific Highway intersection and linemarking along Dickson Avenue west of Reserve Road • Integration work along Dickson Avenue between Reserve Road and the Pacific Highway.
Retaining walls	Several existing retaining walls would be modified, and several new retaining walls would be constructed to accommodate changes in surface levels. Each wall would range in length and height to suit the new works and existing surface levels. Finishes would be designed in line with the urban design framework for the project (refer to Appendix V (Technical working paper: Urban design, landscape character and visual impact assessment)).



Indicative only – subject to design development

Legend

Tunnels
- Beaches Link driven tunneltunnel
- Cut and cover
- Surface connections

Surface features
- Surface road
- Pedestrian / active transport links
- Permanent water quality basin

Operational facilities
- Ventilation outlet
- Wastewater treament plant
- Operational facilities and ancillary infrastructure
- Indicative new noise barrier

Existing infrastructure
- Existing noise barrier

Figure 5-29 Surface works of the Gore Hill Freeway Connection component

5.3.4 Operational ancillary infrastructure

Operational ancillary infrastructure forming part of the Gore Hill Freeway Connection component of the project would include:

- Lighting
- Signage and traffic control systems.

Lighting

The Gore Hill Freeway Connection component of the project would be provided with lighting consistent with the guidelines published by Austroads and Transport for NSW as well as the relevant and applicable Australian Standards. Lighting would be designed and installed to ensure safety and security, and to minimise the potential for light spill and nuisance impacts.

Signage, CCTV and traffic control systems

Traffic, locational, directional, warning and variable message signs would be installed along the reconfigured Gore Hill Freeway Connection component of the project. Signage would be consistent with the requirements of applicable Australian Standards and guidelines published by Austroads and Transport for NSW.

The project would include intelligent transport system technology and traffic control infrastructure including:

- Variable message signs
- Vehicle detection sites
- Lane use management systems
- Variable speed limit signs
- CCTV and automatic incident detection systems
- Ramp metering infrastructure
- Motorists emergency telephones within breakdown bays
- Vehicle enforcement systems.

5.3.5 Public and active transport infrastructure

Public and active transport infrastructure that would be provided as part of the Gore Hill Freeway Connection component of the project is summarised in Table 5-13 and shown in Figure 5-29.

Table 5-13 Public and active transport infrastructure of the Gore Hill Freeway Connection component

Infrastructure	Summary
Public transport infrastructure	The configuration of the surface roads and ramps at the Gore Hill Freeway Connection component are designed to enable high quality bus connectivity between the Beaches Link tunnels and St Leonards, Chatswood, and strategic centres to the north west via the Lane Cove Tunnel. Additional surface road public transport infrastructure would not be provided as part of the project.
Active transport infrastructure	The following pedestrian and cyclist facilities would be provided as part of the Gore Hill Freeway Connection component:

Infrastructure	Summary
	• Realignment and reconstruction of the shared user path along the southern side of the Gore Hill Freeway between Reserve Road and the T1 North Shore and Western Line and T9 Northern Line • Replacement of the existing pedestrian footpath along the eastern side of the Reserve Road bridge.

5.3.6 Utilities

The project would require the installation, relocation, adjustment and/or protection of utilities, particularly within and around surface connections and surface road works (refer to Section 5.3.2 and 5.3.3). The Utilities management strategy for the project (refer to Appendix D (Utilities management strategy)) provides a framework for utility installation, relocations, adjustments and protection, including consultation with relevant utility providers. The Utilities management strategy provides information in relation to utility installations, relocations and adjustments which are currently:

- Known and proposed within the construction footprint
- Unknown and/or located outside of the construction footprint. The Utilities management strategy provides the framework for how these utility relocations and adjustments would be identified, assessed and managed.

The location of existing utilities and any changes required would be confirmed during further design development of the project in consultation with the relevant utility provider.

The project would also require connection with electricity and water supply networks.

5.3.7 Property acquisition

The project has been designed to minimise land acquisition and limit the severance of private properties. Property impacts are discussed further in Chapter 20 (Land use and property).

The total area and number of properties that would be acquired for the project may change as the project continues to be refined, or in response to changes resulting from the exhibition of the environmental impact statement and conditions of approval that may be applied by the Minister for Planning and Public Spaces.

The project would also involve the subdivision of private and public land. In some cases, whole lots would be acquired to avoid creating small unusable lots. Where a part of any lot is identified as being usable post construction and surplus to operational requirements, or requiring boundary adjustment following the completion of construction, Deposited Plans of subdivision, would be lodged at NSW Land Registry Services.

5.3.8 Environmental controls

The project has been designed to avoid or minimise environmental impacts, as detailed in Chapter 4 (Project development and alternatives). Key environmental controls that would be provided as part of the Gore Hill Freeway Connection component of the project would include:

- Surface water drainage and management infrastructure
- Noise attenuation measures.

Environmental controls to be provided at Artarmon as part of the Gore Hill Freeway Connection component of the project are summarised in Table 5-14. Environmental controls forming part of the Beaches Link component of the project are detailed in Section 5.2.11.

Table 5-14 Environmental controls of the Gore Hill Freeway Connection component

Infrastructure	Summary
Surface water drainage and management infrastructure	Key surface water drainage and management infrastructure that would be provided at Artarmon would include: • A new drainage network around the Beaches Link on and off ramp portals to minimise the potential for ingress of water • A new drainage line between Reserve Road and Hampden Road at Artarmon, connecting to the existing water quality basin between Punch Street and the Gore Hill Freeway • Extension of the existing water quality basin at Punch Street • Relocation of the existing drainage infrastructure around the Hampden Road bridge • Diversion of existing stormwater drainage infrastructure from around the Beaches Link tunnel on and off ramp portals into Flat Rock Creek, with energy dissipation and scour protection measures provided • Upgrade of the concrete lined drainage line between Punch Street and Flat Rock Creek via Chelmsford Avenue.
Noise attenuation measures	New noise barrier on the northern side of the Gore Hill Freeway east of Hampden Street with a nominal height of five metres. The use of quieter pavements to reduce operational road traffic noise would be further investigated during further design development. Pavements would ultimately be selected by balancing performance, design life, durability, serviceability and noise emissions.

5.3.9 Landscape treatments

Landscape treatments for the Gore Hill Freeway Connection component of the project would be consistent with the project urban design framework in Appendix V (Technical working paper: Urban design, landscape character and visual impact assessment). Landscape treatments would be designed and implemented with the aims of:

- Minimising the visual and landscape impacts of the project
- Integrating the project into the surrounding visual catchment
- Improving local and regional amenity
- Maximising the use of endemic species, including consideration of current and future climate conditions
- Providing opportunity for improvements in urban ecology.

Key features of landscape treatments which would form part of the Gore Hill Freeway Connection component of the project include:

- Restoration of areas disturbed during construction
- Replacement of the existing green edge to the Gore Hill Freeway where feasible
- Screen planting around the motorway facilities and motorway control centre
- Landscape planting to assist the integration of the Beaches Link tunnel portals into the surrounding landscape.

Landscape treatments for the Beaches Link component of the project are outlined in Section 5.2.12.

Land used for construction but not required for operational infrastructure would be reinstated as outlined in Chapter 20 (Land use and property).

The landscape design for the project would continue to be refined through further design development in line with the principles established in Appendix V (Technical working paper: Urban design, landscape character and visual impact assessment).

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 6

Construction work

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6 Construction work

This chapter describes the proposed approach to construction of the project. It outlines the proposed construction program, footprint, methodology, working hours, materials, equipment, traffic management, site access routes, and temporary construction support sites.

The construction works described in this chapter may be refined in response to submissions received during exhibition of this environmental impact statement, to further minimise impacts on the community or environment and/or during further design development and construction planning once a construction contractor has been appointed.

Detailed construction planning would be carried out before construction of the project begins. This would include the identification of specific construction methods and program.

The Secretary's environmental assessment requirements as they relate to construction works, and where in the environmental impact statement these have been addressed, are detailed in Table 6-1.

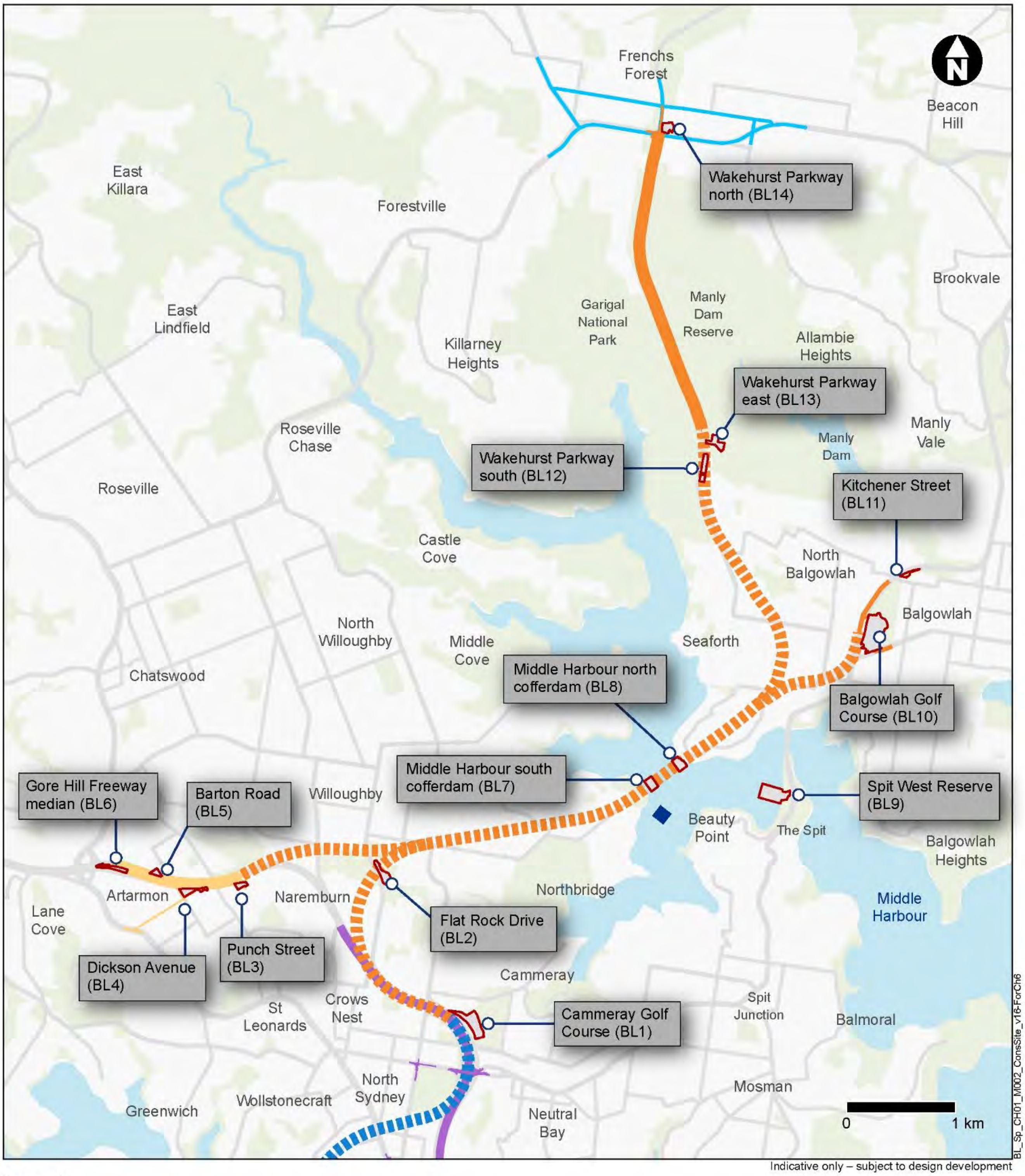
Table 6-1 Secretary's environmental assessment requirements - Construction work

Secretary's requirement	Where addressed in EIS
Environmental impact statement	
1. The EIS must include, but not necessarily be limited to, the following: b. a description of the project and all components and activities (including ancillary components and activities) required to construct and operate it, including: - the proposed route	This chapter describes the key construction activities and shows the temporary construction support sites along the proposed route. **Chapter 5** (Project description), sections 5.1, 5.2 and 5.3, describe the proposed route.
- Design of the tunnels, interchanges (inclusive of tunnel portals and entry and exit ramps), road user, pedestrian and cyclist facilities, and lighting	**Section 6.4** describes the tunnel construction method. **Section 6.5** describes the construction method for surface road works and associated infrastructure. **Chapter 5** (Project description), sections 5.1, 5.2 and 5.3, describe the design of the tunnels, including tunnel-to-tunnel connections and entry and exit ramps as well as road user, pedestrian and cyclist facilities, lighting and other operational ancillary infrastructure.
- Surface road upgrade works, including road widening, intersection treatment and grade separation works, property access, parking, pedestrian facilities (including appropriate locations for overbridges) and public transport facilities	**Chapter 5** (Project description), sections 5.2 and 5.3, describe the surface road works and surface connections as well as pedestrian, cyclist and public transport facilities. **Section 6.5** describes the construction method for surface road works and associated infrastructure, including bridgeworks and pedestrian facilities. **Chapter 8** (Construction traffic and transport), **Chapter 9** (Operational traffic and transport), **Chapter 20** (Land use and property) and

Secretary's requirement	Where addressed in EIS
	Chapter 21 (Socio-economics) discuss property access.
- Ancillary infrastructure and operational facilities, such as operational and maintenance facilities, ventilation structures and systems, and fire and emergency services and infrastructure for the proposal, including (if required) additional infrastructure (such as tolling infrastructure)	**Chapter 5** (Project description), sections 5.2.7 and 5.3.4 describe operational facilities and ancillary infrastructure. **Section 6.8** describes the temporary construction support sites required to construct the project. Construction of operational facilities and ancillary infrastructure is described in **Section 6.4.6**.
- Location and operational requirements of construction ancillary facilities and access	**Chapter 5** (Project description), sections 5.2 and 5.3, describe operational facilities and ancillary infrastructure. The location and hours of construction at each temporary construction support site and their respective access arrangements are described in **Section 6.8.2**.
- Land use changes as a result of the proposal and the acquisition of privately owned, Council and Crown lands, and impacts to Council and Crown lands	Land use changes as a result of the project are described in **Chapter 20** (Land use and property).
- The relationship and/or integration of the project with existing public and freight transport services.	**Chapter 3** (Strategic context and project need) and **Chapter 8** (Construction traffic and transport) discuss the relationship and/or integration of the project with existing public and freight transport services. Additional information about the relationship and/or integration of the project with existing and proposed public and freight transport services is provided in **Chapter 9** (Operational traffic and transport) and **Chapter 27** (Cumulative impacts).

6.1 Overview of construction works

An overview of the temporary construction support sites required for the project is provided in Figure 6-1. Further detail on the key activities to be carried out at each site and typical construction hours for each location is provided in Section 6.8. An overview of the types of construction work required for the project is provided in Table 6-2. Detailed descriptions of each construction activity are also provided in sections 6.3 to 6.7.



Legend

Construction features

- Beaches Link
- Gore Hill Freeway Connection
- Construction support site
- Temporary mooring facility for completed immersed tube tunnel units

Connecting projects

- Western Harbour Tunnel
- Warringah Freeway Upgrade
- Northern Beaches Hospital road upgrade project (completed 2020)

Figure 6-1 Overview of the temporary construction support sites for the project

Table 6-2 Overview of construction works

Component	Typical activities
Early works and site establishment	• Survey work and investigations (including geotechnical) • Property acquisitions and condition surveys • Utilities installation, protection, adjustment and relocation • Land remediation and heritage conservation and/or salvage works (where required) • Temporary relocation of swing moorings, where required • Provision of alternative facilities (swing mooring or marina berth) for users, where required • Installation of site fencing, environmental controls and traffic management controls • Vegetation clearing, earthworks and demolition of structures • Construction of minor access roads and the provision of access where required • Establishment of temporary construction support sites and acoustic sheds, where required.
Construction of the Beaches Link component	• Excavation of tunnel construction access declines • Construction of driven tunnels and surface connections • Construction of cut and cover and trough structures • Cofferdam construction and dredging activities in preparation for the installation of immersed tube tunnels (crossing of Middle Harbour) • Removal of temporary cofferdams • Installation of immersed tube tunnel piled supports and associated concrete headstocks • Casting and installation of immersed tube tunnels • Civil finishing works and tunnel fitout • Construction of operational facilities including: - A motorway control centre within the Artarmon industrial area, next to the Gore Hill Freeway - Motorway facilities and substations at Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway - Fitout of the Beaches Link ventilation outlet at Warringah Freeway. Civil construction of the ventilation outlet would form part of the Western Harbour Tunnel and Warringah Freeway Upgrade project (subject to separate environmental assessment and approval) - A wastewater treatment plant within the industrial area at Artarmon - Tunnel support facilities at Artarmon and Frenchs Forest - Installation of motorway tolling infrastructure (in tunnel).
Surface road works (Beaches Link and Gore	• Traffic staging works to enable access for the road works • Earthworks

Component	Typical activities
Hill Freeway Connection components)	• Bridgeworks • Construction of retaining walls • Construction of cut and cover and trough for connections to and from the Gore Hill Freeway, the Burnt Bridge Creek Deviation and the Wakehurst Parkway • Construction and installation of stormwater and cross drainage • Pavement works and linemarking • Utilities installation and relocation • Localised adjustment of a small section of Burnt Bridge Creek for road widening and existing culvert extension works • Tolling gantries and associated infrastructure • Installation of road furniture, fauna connectivity structure, lighting, signage and noise barriers • Construction of new active transport infrastructure.
New open space and recreation facilities at Balgowlah	• Staged construction of the new and improved open space and recreation facilities • Facilities may include shared user paths, open space areas, amenities, car park, playground, netball courts, soccer field, hockey field and new enlarged AFL/cricket oval.
Testing, commissioning and site rehabilitation	• Testing of plant and equipment • Commissioning of the project • Removal of infrastructure at temporary construction support sites • Backfill of access declines • Landscaping and rehabilitation of disturbed areas • Removal of temporary environmental and traffic controls.

6.2 Construction program

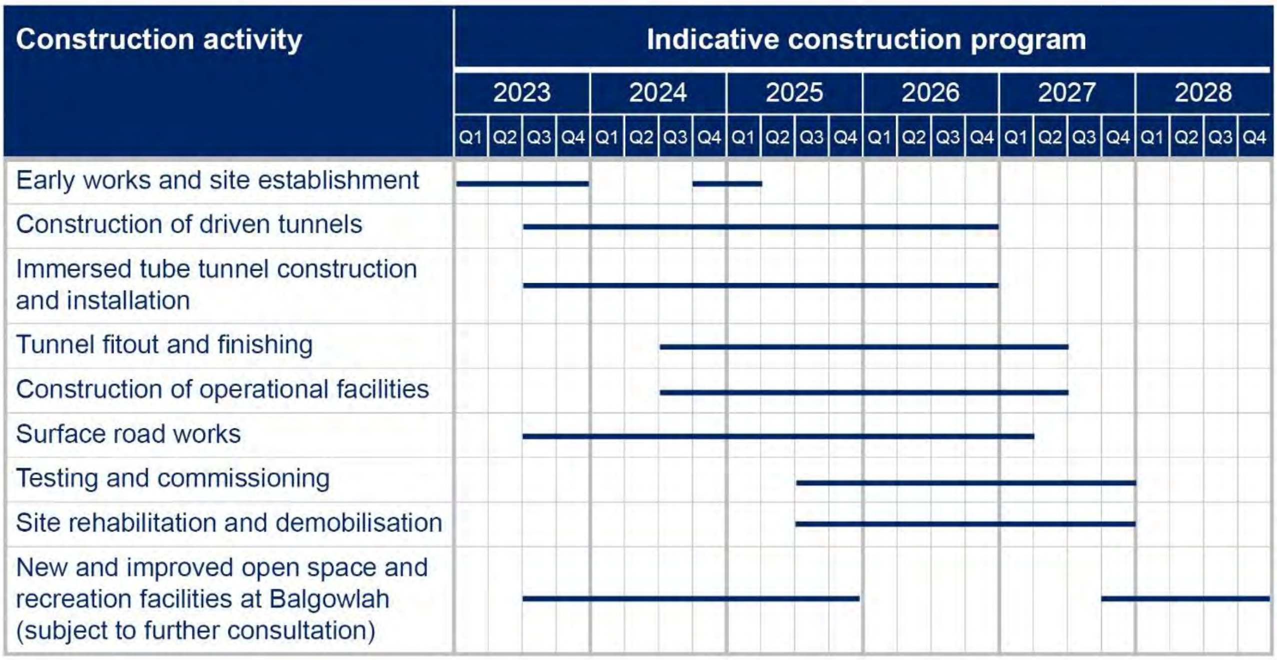
6.2.1 Program overview

The construction program presented within this environmental impact statement provides indicative timing only. The final construction program, and commencement of works at each temporary construction support site, may vary. Subject to planning approval and procurement, construction of the Beaches Link and Gore Hill Freeway Connection project is currently planned to commence in 2023. On that basis, completion of the main construction would be around the end of 2027 and construction works for the new and improved open space and recreation facilities would be completed in 2028 - a total construction period of five to six years. Early works and site establishment would be the first works carried out for the project, with substantial construction starting around six months later.

Construction associated with the Gore Hill Freeway Connection component comprises early works and site establishment, surface works and bridgework activities, which would run concurrently from 2023 to around end 2027.

The indicative construction program of the project, including the Gore Hill Freeway Connection component, is shown in Table 6-3. Construction activities outlined in Table 6-3 may not occur continuously during the time period outlined.

Table 6-3 Beaches Link and Gore Hill Freeway Connection project indicative construction program



The final construction program for the project would depend on future project procurement and packaging decisions. This may include one or multiple construction contractors.

It is assumed that the Western Harbour Tunnel and Warringah Freeway Upgrade project, which is subject to separate assessment and approval, would commence construction before the Beaches Link and Gore Hill Freeway Connection project. Should timeframes for the project be advanced, some elements of the Beaches Link component may be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade works to maximise construction efficiency and minimise impacts in particular areas.

Delivery of any elements of the Beaches Link component as part of the Western Harbour Tunnel and Warringah Freeway Upgrade works would be subject to the conditions of approval for the Beaches Link and Gore Hill Freeway Connection project and the requirements of this environmental impact statement, including relevant environmental management measures provided in Appendix Y (Compilation of environmental management measures) and any other documents incorporated by reference in the approval.

Works could include but may not be limited to cut and cover and trough works at Cammeray, construction of motorway facilities and ventilation tunnels at Warringah Freeway and traffic staging enabling works for the Gore Hill Freeway Connection.

6.3 Early works and site establishment

6.3.1 Early works, preparatory investigations and surveys

Early works, preparatory investigations and surveys for major infrastructure projects are carried out prior to substantial construction to prepare sites to facilitate the main construction activities. Typically, these works are of low environmental impact. Subject to conditions of approval some early works, preparatory investigations and surveys would take place prior to the formal approval of the main works construction management plans, and would include but are not limited to:

- Survey work and investigations including investigative drilling
- Carrying out existing condition surveys of buildings and infrastructure
- Property acquisitions and adjustment works including installation of property fencing

- Further contamination testing and land remediation subject to the recommendations of a remediation action plan (where required)
- Relocation, adjustment and protection of utilities and services affected by the project (utility works would be ongoing during the main works to suit staging of surface works)
- Road work adjustments to facilitate access to various temporary construction support sites
- Carrying out detailed heritage investigations, protections, salvage and/or conservation works (where required)
- Carrying out maritime heritage and submerged Aboriginal site investigations, protections, salvage and/or conservation works (where required)
- Upgrade of Spit Bridge pier protection fenders, including piling (if required, subject to condition survey)
- Temporary relocation of swing moorings from within Middle Harbour as close to their existing position as possible (details on swing moorings requiring temporary relocation are provided in Chapter 8 (Construction traffic and transport))
- Provision of alternative facilities (swing mooring or marina berth) for the users of a small number of fixed jetties below Seaforth Bluff that would have access restricted during construction (details on jetties requiring temporary closure are provided in Chapter 8 (Construction traffic and transport)).

6.3.2 Site establishment

Site establishment would occur prior to the main construction activities commencing. Similar to the early works described above, subject to conditions of approval (and approval of relevant site establishment plans), site establishment activities also include works which are of low environmental impact and could be carried prior to the formal approval of the main works construction management plans. Site establishment would include, but is not limited to:

- Installation of site environmental management controls (including site fencing, exclusion fencing for sensitive areas, noise attenuation measures and erosion and sediment controls)
- Vegetation clearing, chipping and mulching, where required
- Traffic management controls, including adjustments to road signage where required (showing changes to traffic movements and speed limits)
- Construction of minor access roads and provision of access including the temporary relocation of pedestrian and cycle paths and bus stops
- Earthworks to level the temporary construction support sites in preparation for site work and installation of site facilities
- Building structures and/or erection of demountable buildings within temporary construction support sites including temporary site accesses, acoustic sheds and associated access decline acoustic enclosures, where required
- Demolition of existing structures which require removal to enable construction of the project.

6.4 Construction of Beaches Link

Construction of the Beaches Link component would include the following activities:

- Excavation of the tunnel construction access declines
- Construction of driven tunnels
- Construction of cut and cover and trough structures

- Construction of temporary cofferdams in Middle Harbour
- Construction of interface structures between driven tunnel and immersed tube units
- Construction of immersed tube tunnel units
- Dredging to form the trench for installation of immersed tube tunnel units
- Installation of immersed tube tunnel piled supports and associated concrete headstocks
- Installation of immersed tube tunnels for the crossing of Middle Harbour
- Civil finishing and fitout of the tunnels, including drainage, pavement construction, barrier construction, architectural panel installation and other works required to finish the civil works
- Surface works to tie-in to surface roads in Cammeray, Artarmon, Balgowlah, Seaforth, Killarney Heights and Frenchs Forest
- Realignment and upgrade of Wakehurst Parkway between Killarney Heights and Frenchs Forest
- Construction of operational facilities
- Testing and commissioning.

More information on each of these activities is provided in the following sections.

6.4.1 Excavation of tunnel construction access declines

To enable construction of the driven tunnels, construction accesses would need to be created from temporary construction support sites to intersect the tunnel alignment. Tunnel construction accesses can take the form of shafts or declines, depending on constraints and construction context. All of the accesses for construction of the Beaches Link tunnels are currently proposed to be declines.

Excavated access declines would be required at the Cammeray Golf Course (BL1), Flat Rock Drive (BL2), Punch Street (BL3), Balgowlah Golf Course (BL10) and Wakehurst Parkway east (BL13) construction support sites.

The access decline provides access for workers, equipment, material supply, and spoil removal, and would be big enough for construction vehicles, including roadheaders, concrete trucks, spoil removal trucks and other equipment to drive in and out of the tunnel. The temporary tunnel ventilation and services such as compressed air, potable water and drainage return lines would also be installed through the access decline.

The access decline would typically be sized to allow for two-way vehicular traffic and a separated walkway for construction workers. An example of an access decline is shown in Figure 6-2.

While the majority of these tunnel declines would be driven tunnels, trough structures are required where these declines reach the surface. These trough structures are ultimately enclosed within the acoustic shed or covered with their own acoustic enclosure.

The access declines at Cammeray Golf Course (BL1) (partial), Flat Rock Drive (BL2), Punch Street (BL3), Balgowlah Golf Course (BL10) and Wakehurst Parkway east (BL13) construction support sites would be backfilled at the completion of construction. Part of the access decline at Cammeray Golf Course construction support site (BL1) would be used for a permanent ventilation tunnel connecting to the motorway facilities at this location.

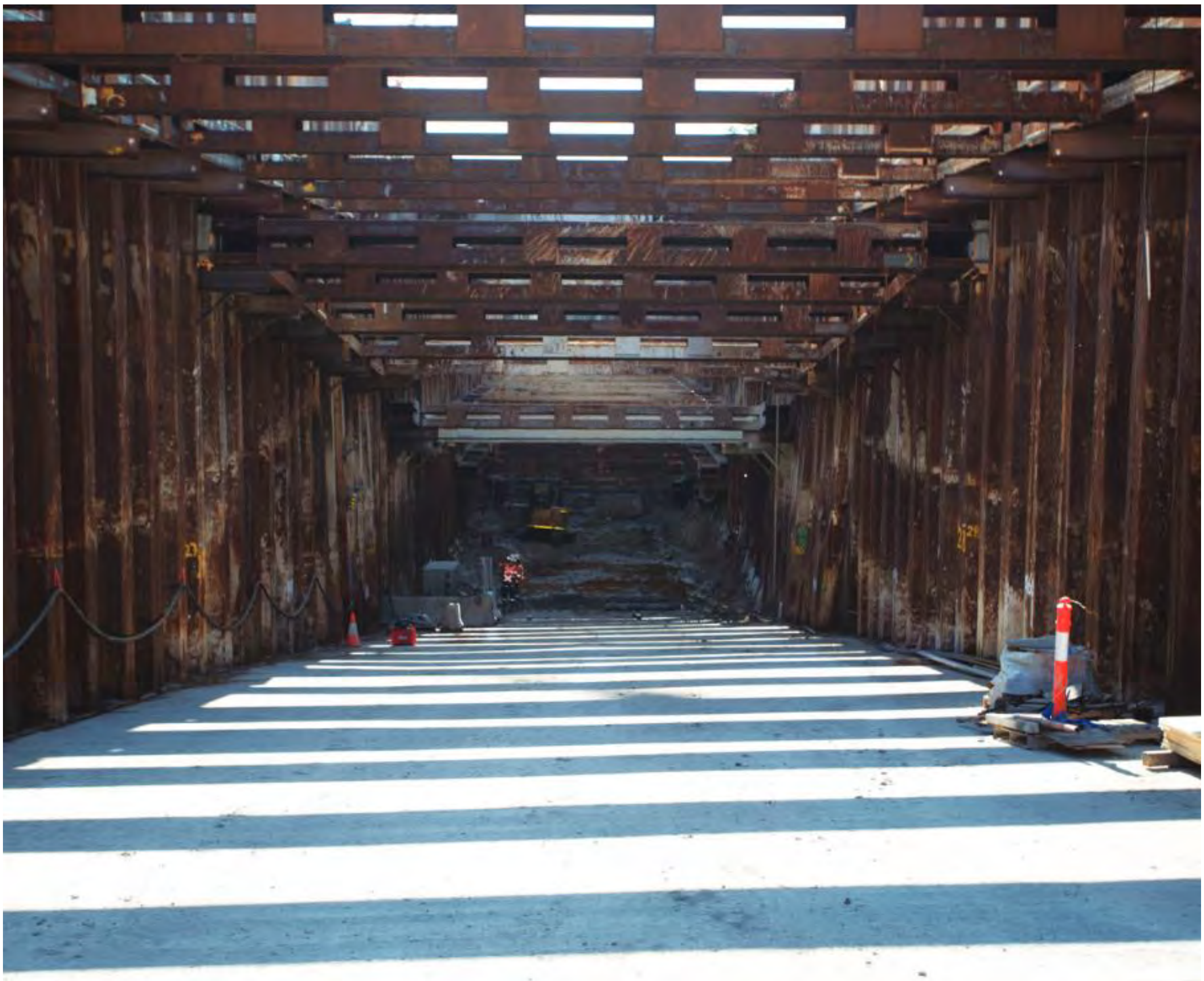


Figure 6-2 Example tunnel access decline

Acoustic sheds

An acoustic shed is an enclosed noise mitigation structure constructed over access declines that access the tunnel for construction. Noisy works required to support out of hours tunnelling, including spoil handling, would take place within the acoustic shed, reducing impacts on nearby receivers. Acoustic sheds would be designed with consideration of the activities that would occur within them and the noise management levels applicable at nearby receivers. They would also be designed to accommodate stockpiled tunnel spoil within the shed thereby removing the requirement for spoil haulage outside of standard hours. An example of an acoustic shed is shown in Figure 6-3.

Figure 6-3 Example from within an acoustic shed constructed for the New M4 tunnels

6.4.2 Construction of driven tunnels

The project would involve the construction of two mainline tunnels, as well as on and off ramps, cross passages and ventilation tunnels. The majority of this tunnelling work is expected to be carried out in Hawkesbury sandstone using electrically powered machines known as roadheaders.

A roadheader is an excavation machine that has a rotating, rock-cutting head on the front, mounted to a boom. When the underground rock is cut using a roadheader, a loading device typically transfers the rock onto a conveyor belt which runs the spoil onto haulage trucks. An example of a roadheader working underground to construct the New M4 tunnels is shown in Figure 6-4.

Ground support for tunnels excavated using roadheaders would typically consist of cement grouted rock anchors and/or rock bolts and shotcreting as shown in Figure 6-5. In areas which require control of higher levels of groundwater ingress or to accommodate poorer geology, the permanent tunnel lining would include a thicker reinforced concrete lining and waterproofing membrane. Ground support would be installed progressively following tunnel excavation.

In addition to the mainline tunnels and on and off ramp tunnels, cross passages would be excavated between the tunnels at intervals to facilitate emergency egress. These cross passages would be excavated using smaller roadheaders, rock hammers, rock saws or controlled blasting.

Figure 6-4 Example of a roadheader in the New M4 tunnels loading tunnel spoil into a spoil haulage truck

Figure 6-5 Example of tunnel shotcreting

It is anticipated that tunnel excavation would be carried out using a number of roadheaders, supported from multiple temporary construction support sites, including:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Balgowlah Golf Course (BL10)
- Wakehurst Parkway east (BL13).

Each of these temporary construction support sites would require additional surface infrastructure to support tunnel construction, such as acoustic sheds, workshops, material and equipment storage areas, heavy and light vehicle parking areas, air intake facilities to supply air for workers, power and water supply, temporary construction wastewater treatment plants, and worker amenities.

Temporary construction wastewater treatment plants would be designed to treat wastewater generated from tunnel construction activities and groundwater inflow during construction (refer to Chapter 17 (Hydrodynamics and water quality) for more detail).

Rock hammering (see Figure 6-6) and rock saws may be used in some areas for excavation of the tunnels, cross passages and areas of sandstone within the cut and cover and trough structures.

Figure 6-6 Example of rock hammering

Controlled underground blasting may also be used to improve the efficiency of excavation activities and shorten the overall excavation program. Areas likely to require controlled blasting would be confirmed during detailed construction planning. Refer to Chapter 10 (Construction noise and vibration) for further information on the management of blasting impacts from the project.

6.4.3 Construction of cut and cover and trough structures

Cut and cover tunnels would typically be constructed at locations where the tunnel alignment connects to and from the surface and does not have enough rock cover or quality of rock cover for construction using roadheaders. Cut and cover is a tunnel excavation methodology that generally involves excavating downwards from the surface of the ground, and installing a tunnel structure including a base, walls and a roof. Once the roof is in place, the structure is either used for permanent surface roads or covered over with soil and revegetated. These structures can also be constructed by installing the walls and roof and subsequently excavating out the material below from underneath the roof.

Cut and cover structures typically transition to open trough structures which connect to and from the surface (see Figure 6-7). Construction of trough structures is similar to cut and cover, except a roof is not installed (see Figure 6-8).

Figure 6-7 New M4 tunnel cut and cover structures

Figure 6-8 Trough structure for New M4 tunnel ramp at Haberfield

Cut and cover tunnels and trough structures are anticipated to be constructed at the following locations:

- The Beaches Link connections to the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project
- The eastbound on ramp from the Gore Hill Freeway to Beaches Link
- The westbound off ramps from Beaches Link to both the Gore Hill Freeway and Reserve Road
- The Wakehurst Parkway on and off ramps
- The Burnt Bridge Creek Deviation on and off ramps.

The Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project would provide the structural works for the cut and cover and trough structures for the Beaches Link ramps to and from the Warringah Freeway. This would allow maximum use of the road corridor by the Warringah Freeway Upgrade contractor and minimise disruption. The structural works would largely comprise the construction of the ‘roof’ and supporting piles for these structures. The construction impacts of these works have been assessed in the Western Harbour Tunnel and Warringah Freeway Upgrade environmental impact statement (Transport for NSW, 2020b).

The excavation and fitout (including pavement works to tie-in to the Warringah Freeway Upgrade) of the trough and cut and cover structures connecting Beaches Link mainline tunnels and the Warringah Freeway would be carried out as part of the Beaches Link component of this project.

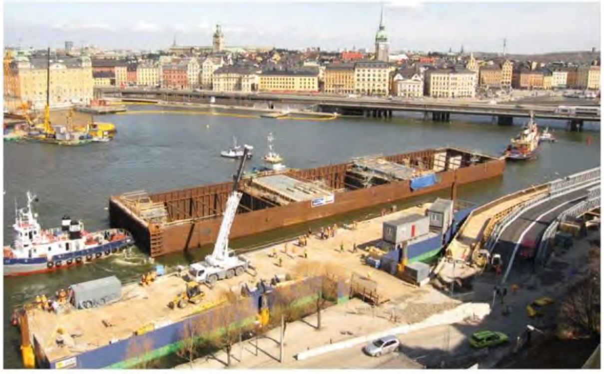
6.4.4 Construction process for immersed tube tunnels

An overview of the construction process for the immersed tube tunnel crossing of Middle Harbour is shown in Figure 6-9 and Figure 6-10. During the construction process, temporary anchors for plant associated with marine works would be required to ensure stability and safety.

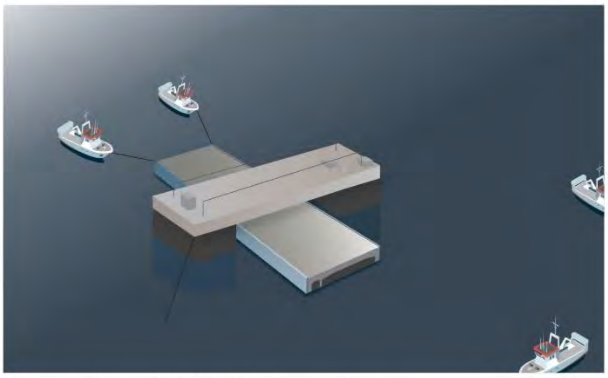
Figure 6-9 Indicative construction process for the immersed tube tunnels

Transport of steel shell units through Spit Bridge.

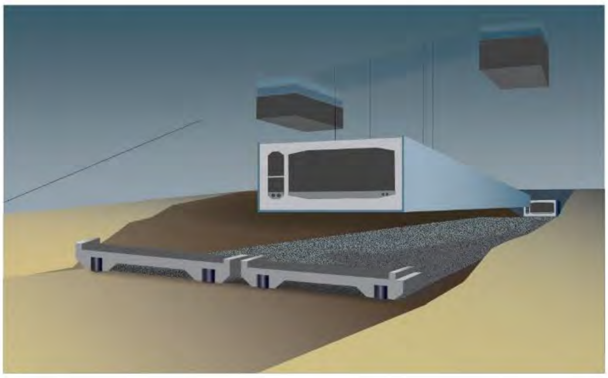
Steel shell unit arrives at Spit West Reserve construction support site (BL9) casting facility.



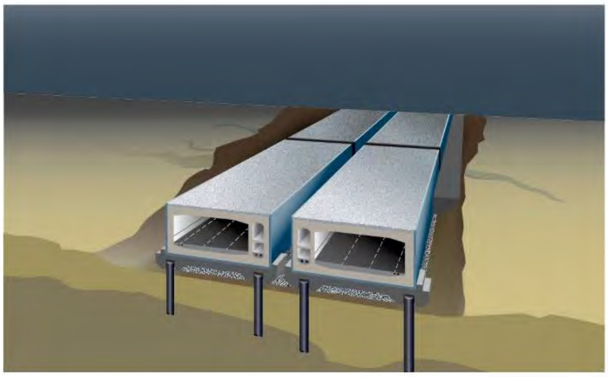
Floating steel shell unit arriving at casting facility for concrete construction. *



Transport completed unit to immersion site.



Immersion of completed tunnel units.



Completed units partially within a trench with locking fill.

*Note: Example of a casting facility for the Soderstrom Tunnel, Stockholm (TunnelTalk, 2013)

Figure 6-10 Indicative construction sequence for the immersed tube tunnels

Cofferdam construction

A cofferdam is a temporary enclosure within a body of water that is constructed to allow dewatering of an enclosed area. The purpose of the cofferdams is to create a relatively dry environment to allow the construction of the interface structures which would connect the driven tunnel and the immersed tube tunnels at each end of the Middle Harbour crossing.

Two temporary cofferdams would be constructed to facilitate construction of the concrete interface structures to enable the connection of the immersed tube tunnels to the driven tunnels off the shoreline at Northbridge and Seaforth. The cofferdams would be about 63 metres wide and 25 metres long. The location and indicative layout of the Middle Harbour cofferdams are shown in Figure 6-36. The cofferdams would be supported (with labour, plant, materials) from both the Spit

West Reserve construction support site (BL9) and Balgowlah Golf Course construction support site (BL10).

The method for the construction of the cofferdams within Middle Harbour is summarised below:

- Ground treatment – before the construction of the cofferdam can occur, the upper layer of the bed of the harbour would be injected with a permanent grouting material to improve its strength and make relatively water-tight. Ground treatment would be carried out by drilling holes into the bed of the harbour. These holes would then be injected with grout by a grouting machine located on a flat top barge. An example of a flat top barge is shown in Figure 6-12
- Piling – the cofferdam structure would be made up of a series of interlocking, tubular piles. Each pile would be driven into the underlying sandstone within the areas that were subject to ground treatment. Piling would take place from a flat top barge (or similar barge) using a crane fitted with a hydraulic vibrating hammer, offshore pile driving hammer and/or a similar piece of construction equipment
- Dewatering and installation of structural support – once all piles have been installed, the water level within the cofferdam would be progressively lowered (dewatered). Structural steel supports would be installed within the cofferdams from a flat top barge so that the cofferdams remain structurally sound.

The construction sequence for the cofferdam and interface structure is provided in Figure 6-11.

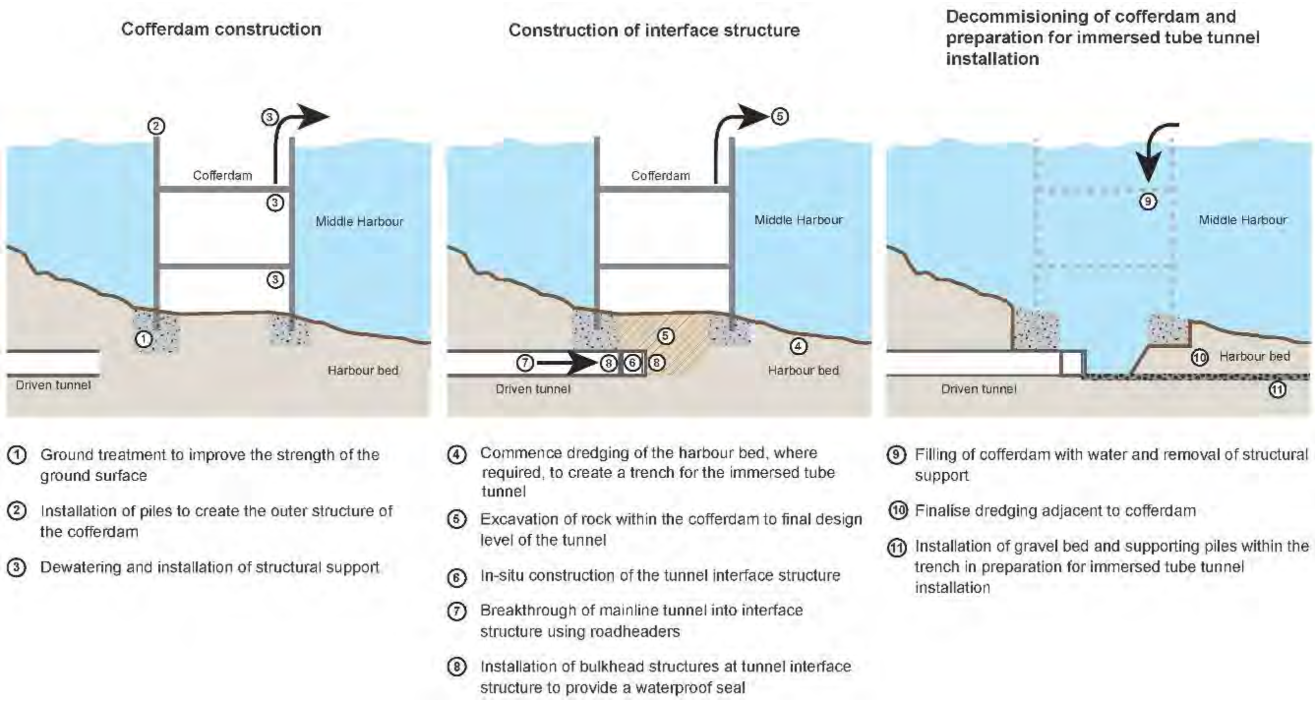


Figure 6-11 Indicative process for constructing cofferdams and interface structures

Figure 6-12 Example of a flat top barge

Construction of the interface structures within the cofferdams

The immersed tube tunnels would be connected to the mainline driven tunnels by an interface structure, which would be built within the cofferdams. The interface structure is essentially a structural adaptor between the driven tunnel cross section and the rectangular immersed tube tunnel cross section. Construction of the interface structures within the cofferdams would require excavation of overlying soft sediments and rock from within the cofferdam.

Excavation works within the cofferdams would be carried out using excavators that would be lowered into the cofferdam. The excavators would use both buckets, hydraulic hammers and steel cutter blades where required, to load out soft sediments and fracture and load out the underlying rock. To facilitate fracturing of the rock, some pre-cutting may be required using a large steel cutting blade fitted to the excavator. The sediment and fractured rock would be loaded into bins within the cofferdam, and lifted out by a crane, which would be located on the cofferdam work platform. An application for offshore disposal of dredged material will be submitted to the Australian Government Department of Agriculture, Water and the Environment. It is proposed that suitable dredged material would be loaded in a hopper barge and transported to the designated offshore disposal site (refer to Chapter 24 (Resource use and waste management) for further information). Any material not suitable for offshore disposal would be barged to a loadout facility for treatment to be made spadable and then loaded onto trucks and disposed of at a licensed land-based facility.

Construction of the interface structure would be supported by work barges that would be moored at the cofferdams for the duration of construction works (refer to Section 6.8.2 for location of cofferdams). A ferry barge would be used to transport the construction materials and plant, and smaller boats would transfer the workforce, from the Spit West Reserve construction support site (BL9) for the construction of the interface structure.

Decommissioning of cofferdams

Following completion of the interface structures, the cofferdams would be refilled with seawater pumped from Middle Harbour. As the cofferdams are filled with water, the structural support within the cofferdams would be removed. Once the water levels inside the cofferdams match the water level outside, the tubular piles would be removed, and the marine environment rehabilitated, where required. Where the tubular piles remain fixed in the bed of the harbour, they would be cut off at the harbour bed level and the marine environment rehabilitated where required.

Dredging

The construction of the immersed tube tunnels would require dredging of the bed of the harbour to create a trench for the installation of the immersed tube tunnels.

Dredging depths would range from 10 metres below the existing bed of the harbour near to the cofferdams, reducing to the existing bed level of the harbour at the mid-harbour section. Most of the mid-harbour section of the immersed tube tunnels would be located on the existing bed of the harbour and would not require substantial dredging. The tunnel trench beyond the mid-harbour section, would be designed to provide a solid foundation for placement of the immersed tube tunnel units.

The immersed tube tunnel units would need to be installed on a piled foundation in the mid-harbour section, due to the very soft marine sediments of lower strength which occur in Middle Harbour.

The method of dredging would depend on the material being dredged and would be carried out for the project using a combination of methods (refer to Table 6-4).

During dredging operations, floating silt curtains would be used to minimise impacts on the surrounding marine environment. Silt curtains are designed and installed to restrict and contain suspended sediments which can be spread into the water column during dredging operations. Dredging operations would be carried out within a localised floating silt curtain enclosure to a depth of two to three metres (sometimes referred to as a 'moon pool'). Additional containment of suspended sediments would be provided by installation of large enclosed silt curtains extending to a depth of 10 to 12 metres enclosing the broader dredging site. An additional shallow silt curtain would also be installed where required next to any nearshore ecologically sensitive areas to provide additional protection.

Dredging of the sand bar at the entrance to Middle Harbour would not be required. Transport of dredged material, marine construction equipment and steel shell immersed tube tunnel units would be planned to use high tide periods to allow safe travel over this relatively shallow area.

Table 6-4 Dredging methods for installation of the immersed tube tunnels

Type of material to be dredged	Type of dredge to be used	Description
Soft sediments not suitable for offshore disposal (anticipated to be the top 0.5 – 1.0 metre of the bed of the harbour, subject to further testing (refer to Chapter 16 (Geology, soils and groundwater)))	Backhoe dredge with a closed environmental clamshell	A backhoe dredge consists of a hydraulic excavator that is fixed to a pontoon or work barge (refer to Figure 6-13). A closed environmental clamshell is a closed bucket which is used to minimise the spread of excavated material into the water column (refer to Figure 6-14). This material would be loaded directly into nearby self-propelled split hopper barges (with no overflow allowed). Once fully loaded, the vessel would transport the dredged material to a load out facility. This material would be made spadable, loaded onto trucks and then disposed of at a suitable land-based licensed facility.

Type of material to be dredged	Type of dredge to be used	Description
Soft sediments suitable for offshore disposal	Backhoe dredge with a closed environmental clamshell	A closed environmental clamshell would be used for the removal of soft clay, silt or silty sand material. Dredged material would be loaded directly into nearby self-propelled split hopper barges (with no overflow allowed). Once fully loaded, the vessel would transport and dispose of the dredged material at the designated offshore disposal site.
Rock layer suitable for offshore disposal	Backhoe dredge with a set of drum cutters or steel cutting blade and a standard open bucket	The underlying soft rock would be removed using a backhoe dredge with standard open bucket. The underlying hard rock would be crushed with a very large backhoe dredge fitted with a set of rotating drum cutters on a boom (instead of a bucket) (refer to Figure 6-15). The drum cutter would be lowered by the backhoe dredger to crush the rock into small fragments. The fragmented rock would be removed by a backhoe dredge fitted with a standard open bucket. The backhoe dredge would then load the fragmented rock into the self-propelled split hopper barges (with no overflows) for transport and disposal of the dredged material at the designated offshore disposal site. To facilitate crushing of the rock, some pre-cutting of the harder rock may be required using a large steel cutting blade fitted to the backhoe dredge.

Figure 6-13 Example of backhoe dredger with an open bucket (Royal Haskoning DHV, 2020)

Figure 6-14 Example of an excavator fitted with a closed environmental clamshell loading into a hopper barge (Source: supplied by Royal Haskoning DHV, 2020)

Figure 6-15 Example of drum cutters which can be used in a marine situation

Installation of the gravel bed

The immersed tube tunnel trench would be lined with gravel to a depth of about 0.8 metres. The gravel bed would be installed using a pontoon with a fall pipe which levels the gravel materials supplied via a conveyor belt from a barge moored against the pontoon.

Installation of immersed tube tunnel units on support piles

Immersed tube tunnel units would need to be placed on supporting piles due to the soft marine sediments on the bed of the Middle Harbour. Installation of the piles would be carried out using similar sized equipment to the cofferdam construction. The piles would be tubular steel liners, vibrated through the upper sediments and screwed into the underlying rock. The piles would then be filled with reinforced concrete after reaching their final depth. The piles would be cut off to level and a concrete headstock would be cast below water on top of the piles. Alternatively, a pre-cast concrete headstock may be placed on the installed piles and locked in place.

Construction of the immersed tube tunnel units

The immersed tube tunnels would be about 340 metres in overall length and would each consist of three individual units for each carriageway (six units in total). Refer to Figure 6-16 for an example of an immersed tube tunnel casting facility and Figure 6-17 for an example of a completed immersed tube tunnel unit.

The steel shell immersed tube tunnel units would be transported by sea from a location outside of Middle Harbour (either on a barge or directly towed by a tug) to the Spit West Reserve construction support site (BL9) to be completed. Works to complete the units at the Spit West Reserve construction support site (BL9) would include installation of internal formwork and reinforcement, pouring of concrete in stages to form the permanent immersed tube structure. The cast concrete units would then have fitout works completed prior to immersion. An additional concrete layer would be provided to protect the top of the completed tunnel units from marine activities during operation, including falling or dragging anchors.

Once the casting and fitout of the immersed tube tunnel units is complete, the units would be towed by tug boats to the temporary mooring location east of Clive Park in Middle Harbour (refer to Figure 6-26). The temporary mooring location would enable storage of the first four completed immersed tube tunnel units prior to installation. The final two completed units would be towed directly to the immersion site.

Figure 6-16 Example of a casting facility for the Soderstrom Tunnel, Stockholm (Source: TunnelTalk, 2013)

Figure 6-17 Example of completed immersed tube tunnel unit for the Amsterdam Metro moored ahead of installation (Source: ITA, n.d.)

Immersion of tube tunnels

The immersion of the immersed tube tunnel units would be carried out using pontoons (refer to Figure 6-18). Temporary anchors would be placed prior to the immersion process to position the tunnel units (refer to Figure 6-19).

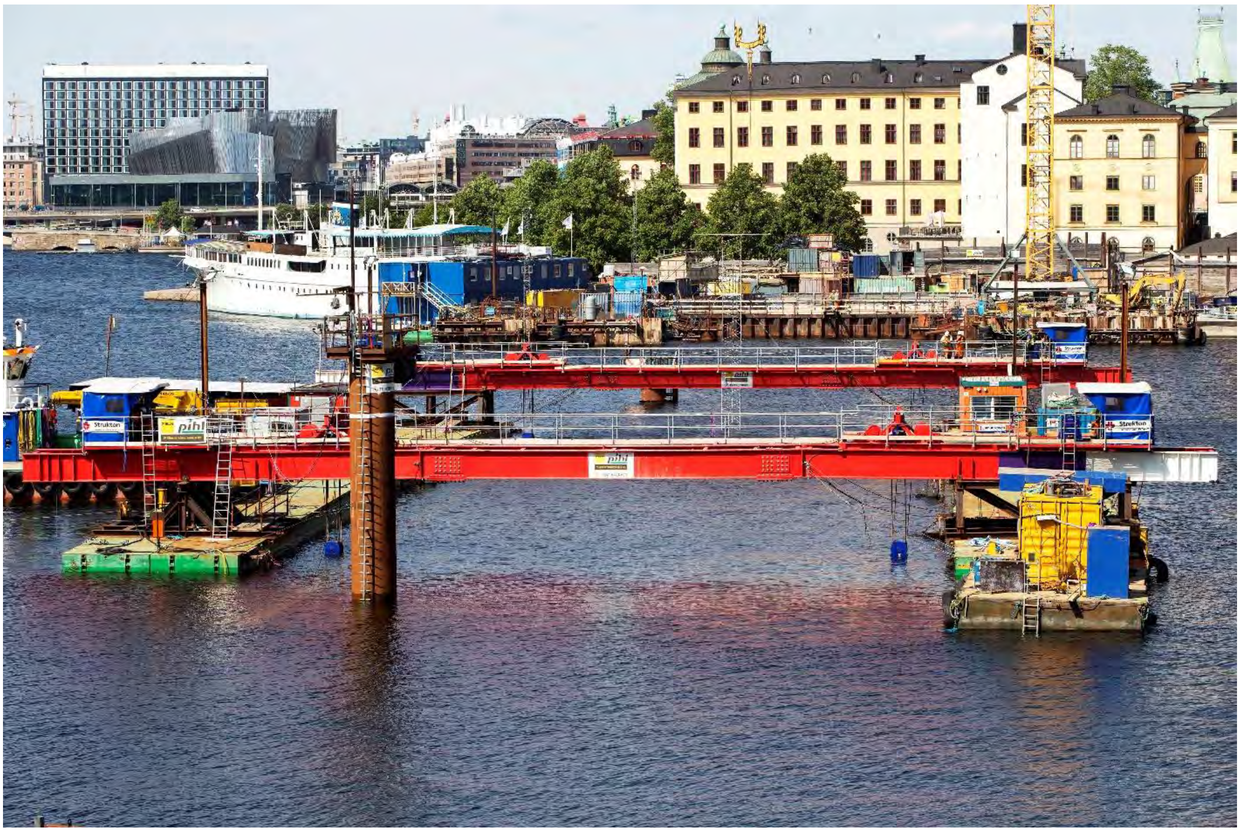


Figure 6-18 Example of immersed tube tunnel unit being immersed for the Soderstrom tunnel in Stockholm (Source: provided by Strukton)

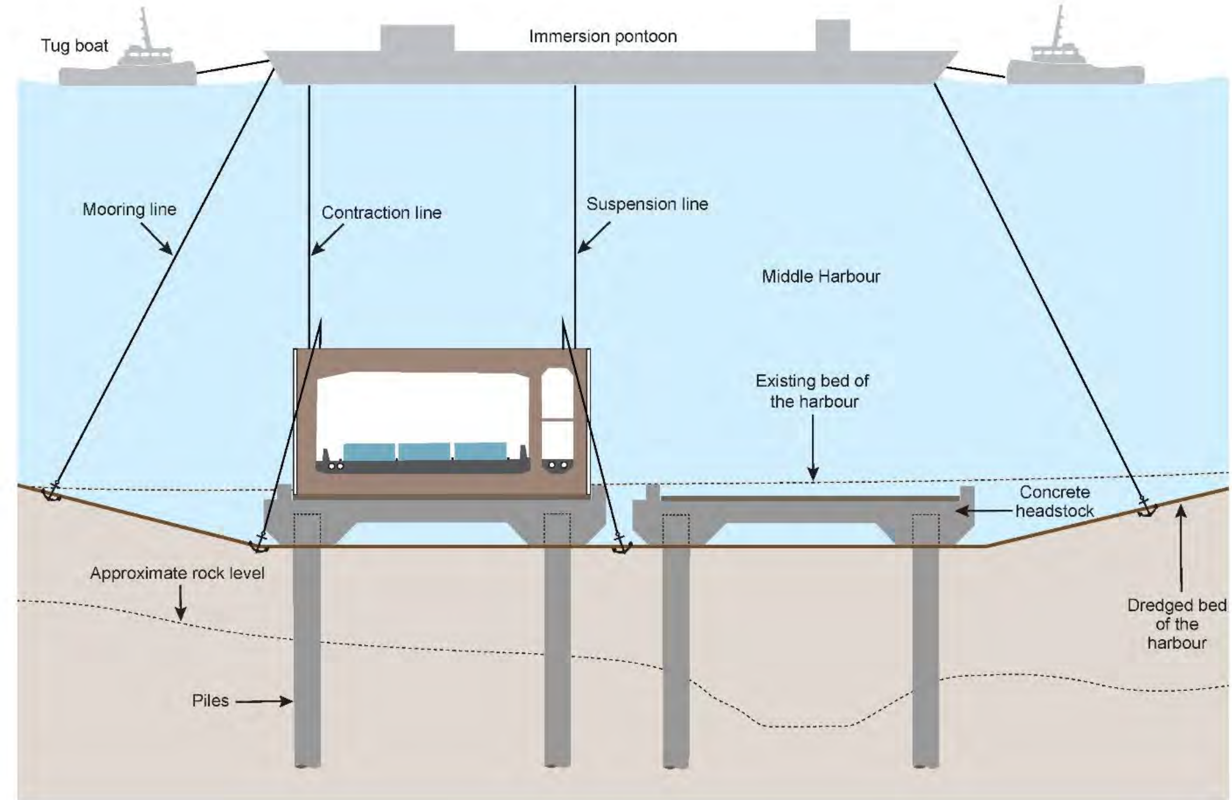


Figure 6-19 Positioning of immersed tube tunnel units in Middle Harbour

Immersion would be carried out by pumping water into temporary ballast tanks within the immersed tube tunnel unit. The water ballast tank would be used to control the buoyancy (ie the amount they float) and balance of each unit. A guidance system would be installed on the pontoon deck to guide the immersed tube tunnel unit to the previous immersed unit and/or to the interface structure.

The immersed tube tunnel units would be installed both on supporting piles and within a trench. The middle third of the tunnel would be installed on supporting piles and would sit generally just above the nominally dredged bed of the harbour. The northern and southern thirds of the tunnel would be installed within a trench of varying depth.

Once the immersed tube tunnel units have been placed into their final location in the section within the trench, locking fill would be placed between the sides of the tunnel units and the trench wall to provide initial stability and to prevent it from moving.

Immersed tube tunnel units placed on supporting piles would be founded securely on concrete headstocks installed on the supporting piles.

Following immersion of each unit, and connection to the either the interface structure or an adjacent tunnel unit, the immersion joint would be dewatered and steel bulkhead barriers at the connected end safely removed. Construction workers would then be able to gain access to the unit through the mainline tunnel to complete fit out works within the units. Concrete pavement would be cast within the immersed tube tunnel unit to replace the weight provided by the temporary ballast tanks, allowing them to be removed.

This configuration is shown schematically in Figure 6-20.

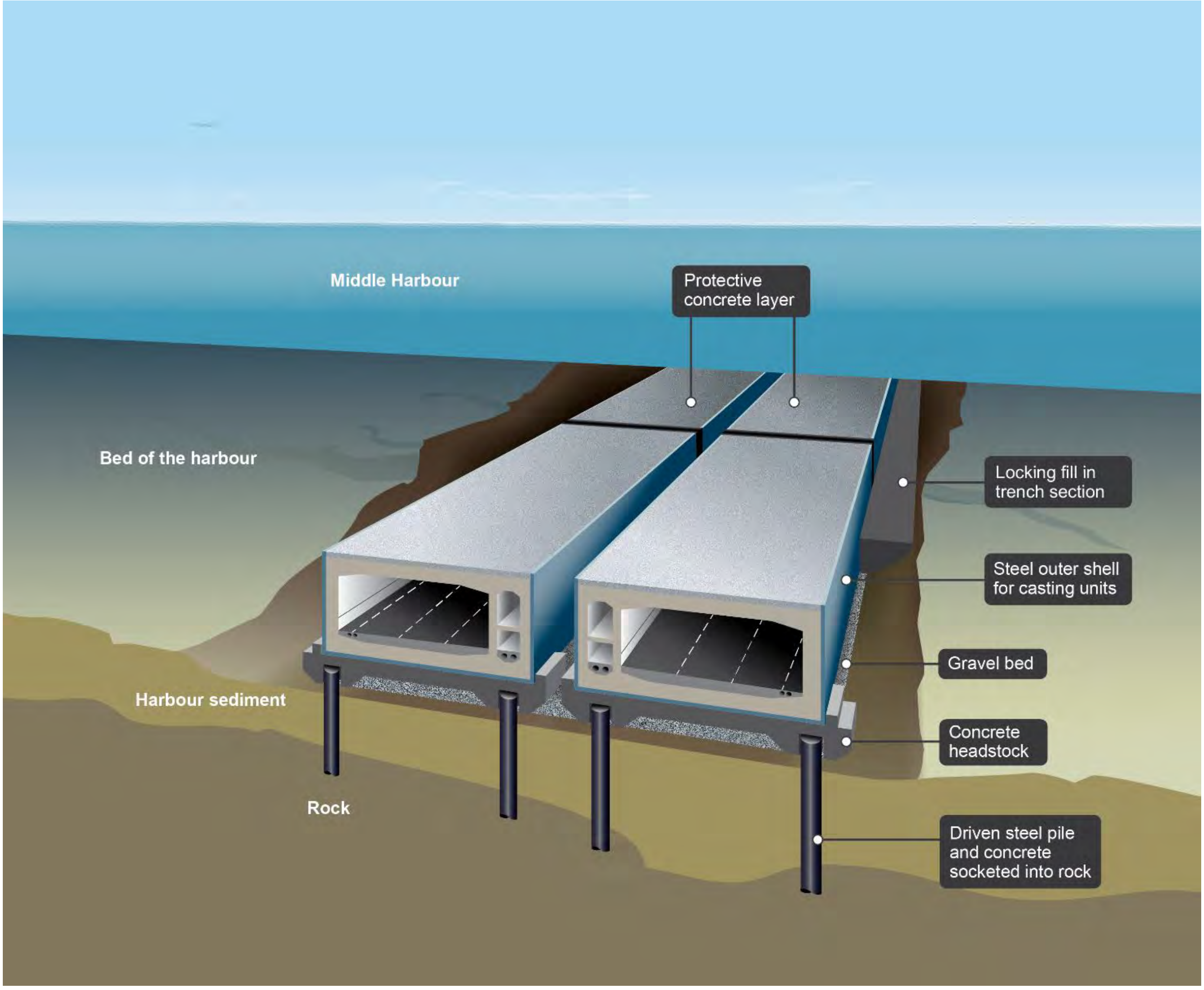
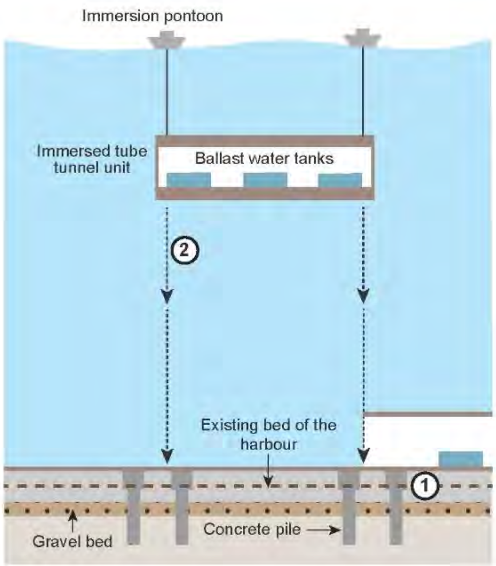


Figure 6-20 Example of an immersed tube tunnel

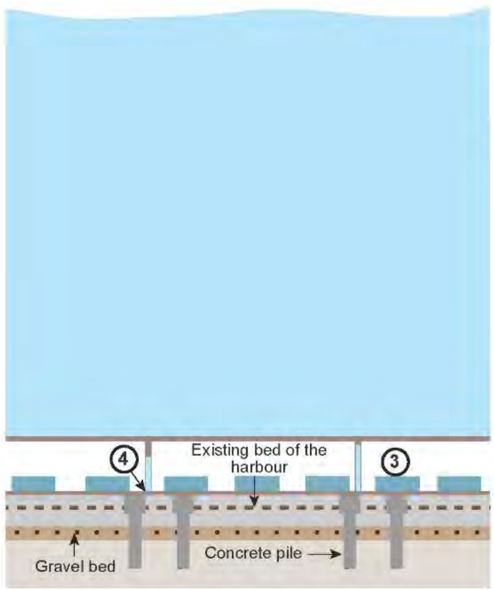
A typical immersion process for one immersed tube tunnel unit would take 24 to 48 hours. Partial harbour closures in the vicinity of the site would be required while each unit is immersed. Full harbour closures may be required during immersion of the two middle units.

The installation sequence for the immersed tube tunnels is shown in Figure 6-21.



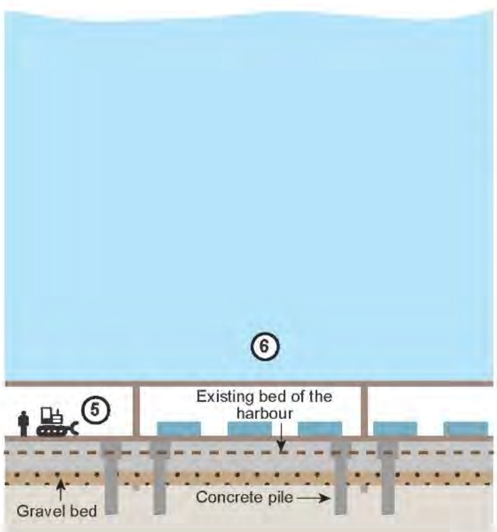
Immersion of tube tunnel units

1. Installation of gravel bed and/or supporting piles
2. Immersion of immersed tube tunnel element against previous element



Connection and dewatering of immersed tube tunnel units

3. Connection of immersed tube tunnel unit with interface structure or adjacent immersed tube tunnel unit and installation of waterproof joint between units/structures
4. Dewatering of immersion joint



Fitout and finishing works

5. Removal of water ballast tanks, ballast concrete and fitout
6. Placement of backfill between tunnel units and the tunnel trench to close any voids

Figure 6-21 Indicative immersed tube tunnel installation sequence

6.4.5 Tunnel fitout and finishing works

On completion of the tunnelling works, a variety of fitout and finishing works would be required. Fitout refers to the construction works that need to be carried out after excavation of the tunnels.

Fitout and finishing works to be completed within the Beaches Link tunnels are described in Table 6-5.

Table 6-5 Tunnel fitout and finishing works

Construction activity	Description
Service conduits	Trenches would be constructed along the inner wall of the mainline and ramp tunnels under the shoulder of the roadway using a saw mounted on an excavator. Rock would be broken up by an excavator with a hydraulic hammer and loaded out for disposal. Conduits would then be installed within the trench, and the trench then backfilled to cover the conduits.
Roadway drainage	Trenches would be constructed in the same way as the service conduits but positioned on the low side of the road pavement where water runoff would be directed during operation. Drainage pipes would be placed within the trench and held in place, and the trench would then be backfilled with concrete.
Pavement works	Continuously reinforced concrete pavement would be installed within the tunnels.
Traffic barriers	Traffic barriers would be constructed from concrete using a specialised barrier placement machine or alternative hand placement methods where the machine is unable to access that location.
Mechanical and electrical infrastructure	The mechanical and electrical infrastructure would include the installation of: • Tunnel lighting and surveillance cameras • Operations management and traffic management equipment • Toll points within the mainline tunnels • Cross passages and equipment rooms, including lighting, power, exit lights and signage • Emergency and surveillance systems • Fire systems and protection equipment • Underground pump stations • Ventilation system, jet fans and support frames • Cabling including high voltage and low voltage cables, power supply cables from substations, power and control cables from jet fans to substations and communications cables • Substation equipment.
Finishing works	Finishing works within the tunnels would include: • Testing and commissioning all equipment and systems • Installation of architectural wall panels above the concrete traffic barriers • Painting sections of the tunnels as required • Linemarking • Signage.

6.4.6 Construction of operational facilities and ancillary infrastructure

Permanent operational infrastructure would be required for the ongoing management and operation of the project. Operational infrastructure would be located at Cammeray, Artarmon, Balgowlah, Killarney Heights and Frenchs Forest. The construction methods employed for operational facilities and ancillary infrastructure are summarised in Table 6-6.

Table 6-6 Construction of operational facilities and ancillary infrastructure

Operational facilities	Construction method
Tunnel ventilation systems	Construction of the tunnel ventilation systems would involve: • Excavation and fitout of the ventilation tunnels to connect the ventilation outlet to the mainline or ramp tunnels (where required) • Construction and fitout of the Beaches Link motorway facilities buildings at the Warringah Freeway, the Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway • Connections to utilities, including sewerage, power, potable water and stormwater • Construction of car parking, hardstand areas, and access to the public road network • Fitout of the ventilation outlets • Internal fitout of plant areas, equipment installation and commissioning. The civil construction of the Beaches Link ventilation outlet at the Warringah Freeway would be carried out as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project, which is subject to separate environmental assessment and approval. As such, only fitout and commissioning works for this particular ventilation outlet would be carried out as part of this project. All other ventilation outlets for the project would be constructed as part of the Beaches Link and Gore Hill Freeway Connection project.
Motorway control centre	Construction of the motorway control centre at Artarmon would include: • Demolition of existing structures • Connections to utilities, including sewerage, power, potable water and stormwater • Excavation, footing and base slab installation • Construction of concrete columns, deck and roof • Enclosure of the building • Construction of car parking, hardstand areas, and access to the public road network • Internal fitout of control rooms, computer rooms, offices and workshop and associated staff amenities • Security fencing.

Operational facilities	Construction method
Tunnel support facilities	Construction of the tunnel support facilities at Artarmon and Frenchs Forest would include: • Demolition of existing structures • Connections to utilities, including sewerage, power, potable water and stormwater • Excavation, footing and base slab installation • Construction of columns and deck to the first floor • Construction of columns to support the roof • Cladding of the building • Internal fitout of control rooms, computer rooms, offices and workshop and associated staff amenities • Construction of car parking, hardstand areas, and access to the public road network • Security fencing.
Operational wastewater treatment plant	The operational wastewater treatment plant would be constructed at Artarmon using prefabricated components which would be assembled on site as follows: • Mechanical assembly of operational wastewater treatment plant components, including rising main and discharge pipework • Complete electrical connections between the operational wastewater treatment plant components and incoming power supply • Commission the operational wastewater treatment plant • Connection of the wastewater treatment plant to the local stormwater network for the discharge of treated wastewater.
Substations	The substations area located adjacent to the motorway facilities at the Warringah Freeway, the Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway would be constructed using prefabricated components where feasible.

6.5 Surface road works

Surface road works are required to connect and integrate the new tunnels with the existing road network. The main areas of surface road works for the project include:

- Integration works to connect the new tunnels into the Warringah Freeway
- Upgrade and integration works along the Gore Hill Freeway
- Upgrade and integration works at Balgowlah
- Upgrade and integration works along Wakehurst Parkway, between Seaforth and Frenchs Forest.

This would also include new and upgraded public and active transport infrastructure at Artarmon, Balgowlah, Killarney Heights and Frenchs Forest.

The construction of the surface road works would typically involve the following activities:

- Traffic staging works to enable access for the surface road works
- Demolition of existing kerbs, structures and pavements

- Utility relocation works to suit staging of surface works
- Earthworks
- Bridgeworks at Artarmon and Frenchs Forest
- Construction of retaining walls, noise barriers, traffic barriers and flood walls
- Stormwater drainage
- Road pavement works
- Signage and linemarking
- Installation of new and modification of existing, lighting and lighting structures
- Fauna connectivity structures
- Surface finishing works.

These activities are described in detail in the following sections with utility relocation works detailed in Appendix D (Utilities management strategy).

6.5.1 Earthworks

Earthworks would be required for the surface works of the project including:

- The tunnel portals at Warringah Freeway, Gore Hill Freeway, Wakehurst Parkway and Burnt Bridge Creek Deviation
- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore and Western Line and T9 Northern Line and the Pacific Highway
- Widening of Burnt Bridge Creek Deviation
- Realignment and upgrading of Wakehurst Parkway between Seaforth and Frenchs Forest
- Construction of the new access road at Balgowlah to connect the tunnel portals to Sydney Road and provide access to the new and improved open space and recreation facilities
- The staged construction of the new and improved open space and recreation facilities at Balgowlah
- Local road works at Artarmon, Balgowlah, Seaforth and Frenchs Forest in the vicinity of surface road works.

Earthworks would include bulk excavation, excavation for new pavement or pavement widening, and placement and compaction of general fill and select fill. Excavation work would be carried out using excavators and bulldozers.

Where earthworks are required, excavated material would be loaded directly into trucks and removed from site or unloaded and compacted directly into new fill areas or stockpiled for future reuse on the project.

It is expected that excavated material would consist of a combination of:

- Virgin excavated natural material
- Roadbuilding materials from within existing road corridors, such as concrete, roadbase and asphalt.

Material required for filling and compaction works would typically be imported to temporary construction support sites and/or the construction footprint as this material is required to have specific engineering properties. Tunnelling spoil would be used as fill material if it is available at the time required for surface earthworks. Earthworks in sections of Wakehurst Parkway would potentially be constructed as local cut to fill operations utilising locally sourced materials for reuse where it is practical. This is likely to involve stockpiling to ensure locally sourced materials could be utilised on site at the appropriate times rather than needing to be transported off site as spoil or to site from other sources.

Fill material imported to site would typically be placed directly from trucks and would be spread with a grader and/or excavator and compacted using vibratory rollers. Where fill material cannot be placed directly from trucks, stockpile areas would be established within temporary construction support sites and/or the construction footprint as required. Watercarts would be used to add moisture to aid compaction and control the generation of dust.

It is anticipated that sections of Wakehurst Parkway may require controlled blasting during bulk earthworks as an alternative to ripping or hammering of rock so as to minimise the duration of this activity. Controlled blasts would not take place during peak hour traffic periods, on Sundays or public holidays. Traffic control measures related to blasting are detailed in Section 6.9.2. Refer to Chapter 10 (Construction noise and vibration) for further information on the management of blasting impacts from the project.

During the earthworks identified above, a number of erosion and sediment controls would be required to mitigate and manage potential erosion and sedimentation impacts from the project, including impacts to water quality. Temporary sediment basins would be used in catchments where the erosion hazard exceeds 150 cubic metres/year (200 tonnes/year) of soil loss. The final location and size of all sediment basins would be determined during further design development and construction planning. Alternative erosion and sediment control measures would be implemented in locations where sediment basins cannot be provided because of site, soil and drainage constraints to constructing large scale sediment basins. For these catchments, smaller sediment basins, sediment sumps, mulch bunds, sediment fences or combinations of these would be used. However, to manage potential associated risks, these catchments would also be subject to enhanced erosion control measures and best management practice, such as limiting the size of disturbed land at any one time and ensuring disturbed areas are re-landscaped progressively. Refer to Chapter 17 (Hydrodynamics and water quality) for further information on the management of potential erosion and sedimentation impacts from the project.

6.5.2 Bridgeworks

Bridgeworks required for the project include:

- Modification of the existing Reserve Road bridge and Hampden Road bridge in Artarmon
- Replacement and upgrade of the existing pedestrian bridge across Wakehurst Parkway, south of Aquatic Drive
- Construction of a new shared user bridge over an existing combined fauna underpass/drainage culvert south of Warringah Road at Frenchs Forest.

Typical bridge construction methods are described in Table 6-7. Chapter 5 (Project description) provides more information on the types of new, modified and relocated bridges.

Table 6-7 Bridge construction methods

Bridgeworks	Construction method
Bridge modification works at Artarmon	Reserve Road bridge and Hampden Road bridge would generally remain operational during construction but may require lane closures or short-term closures. Modification of Reserve Road bridge would involve: • Traffic staging works to enable access for the bridge modification works • Relocation of utilities as required • Existing bridge lane closures as required • Existing bridge barriers removed down to the existing bridge deck slab

Bridgeworks	Construction method
	• Existing asphalt removed from the bridge deck • New pre-cast sections positioned with the use of cranes and fixed to the bridge deck • Asphalt applied to the bridge deck to form the roadway surface • Installation of any required barriers, drainage infrastructure, throw screens • Signage, linemarking and lighting adjustments • Footpaths periodically closed to allow for reinstalment of utilities within the bridge prior to reopening. Works at Hampden Road bridge are generally limited to the underside of the bridge at the two abutments. Surface works at Hampden Road bridge would involve piling behind and strengthening of the existing northern abutment.
Replacement and upgrade of the existing pedestrian bridge across Wakehurst Parkway and construction of a new shared user bridge over drainage culvert south of Warringah Road	Replacement of the existing pedestrian bridge and construction of the new shared user bridge would generally include: • Relocation of utilities as required • Construction of the substructure, likely to be cast in-situ concrete in the following sequence: - Piling works, such as bored piles - Pile cap construction including localised excavation around the piles - Abutment construction including localised excavation around the piles - Pier or column construction • Headstock construction • Construction of the new superstructure (including the new bridge deck), likely to be through the placement of pre-cast concrete segments • New pre-cast sections positioned with the use of cranes • Construction of access ramps and integration of these with the surface path network • Installation of any required handrails, drainage infrastructure, throw screens • Demolition of the existing bridge. The new replacement shared user bridge would be constructed just to the north of the existing bridge so the existing bridge can remain operational during construction of the replacement bridge.

6.5.3 Retaining walls

Retaining walls would be required at Cammeray, Artarmon, Balgowlah, Killarney Heights and Frenchs Forest.

The type of retaining wall required would depend on the location and the ground conditions and would be determined during further design development. The choice of retaining wall would consider the urban design principles and objectives developed for the project (Appendix V (Technical working paper: Urban design, landscape character and visual impact assessment)). The types of retaining walls used on the project could include:

- Piled retaining wall – generally used in areas where the face of the retaining wall is within an area that has been excavated or is to be excavated
- Reinforced soil wall – used where retaining walls would be constructed in areas of fill
- L-shape retaining wall – used where retaining walls would be constructed in areas of fill and are lower in height or where reinforced soil walls are not suitable for structural and/or geometric reasons
- Soil nail retaining wall – used in areas with stable ground conditions where the cut is reinforced with ground anchors and the cut face is stabilised using shotcrete.

The method for constructing retaining walls would vary depending on the type of wall required but could include:

- Excavation
- Piling, installation of concrete footings, provision of structural support (ie rock anchors or soil nails)
- Shotcreting
- Drainage at the base or behind the retaining wall
- Installation of either pre-cast or cast in-situ panels or segments
- Backfilling the retaining walls
- Safety railings
- Planting and architectural finishes (where required).

6.5.4 Stormwater drainage

The project would require construction of new drainage infrastructure and alterations to existing drainage infrastructure, including:

- Construction of new pits, pipes, culverts and associated outlet structures for the surface roads
- Alterations to existing drainage infrastructure to suit new road alignments on existing surface roads including Sydney Road at Balgowlah
- Alterations to the existing drainage infrastructure in the vicinity of tunnel connections to the Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway
- Localised adjustment of a small section Burnt Bridge Creek and provision of scour protection adjacent the downstream side of the culvert extension
- Construction of stormwater basins and associated outlet structures along Wakehurst Parkway.

Stormwater drainage would generally consist of pre-cast concrete pipes or culverts which would be placed in trenches and then backfilled with select material that meets engineering specifications. Where pipes and culverts need to be installed under existing roadways, underboring or pipejacking may be used to avoid the need to trench across live traffic lanes, where this work cannot be feasibly carried out in stages across existing carriageways. In this instance, a pit would be excavated to one side of the roadway, and the drainage pipes installed by drilling horizontally underneath the roadway.

During construction of new drainage infrastructure and alterations to existing drainage infrastructure, there may be a need to carry out temporary drainage works. This could include temporary diversions and drainage line crossings to enable earthworks and for installation of culverts. Temporary diversions and drainage line crossings would be managed to avoid impact on any sensitive receiving environments, including any changes to flow conditions. Depending on local site conditions, temporary diversions may also be required to extend outside the construction footprint to ensure appropriate connection to existing drainage lines and ensure flow conditions are maintained or impacts minimised where possible.

Due to establishment of the Flat Rock Drive construction support site (BL2), there would also be a need to carry out box culvert drainage works associated with an aboveground constructed drainage line of Flat Rock Creek. This would include construction of a culvert and minor redirection of the drainage line at this location (refer to Figure 6-31).

Scour protection measures would be installed downstream of culverts and disturbed drainage line/creek banks to avoid erosion of the watercourse. Depending on local site conditions, scour protection and/or drainage work may be required to extend outside the construction footprint to ensure appropriate connection to existing waterways and/or drainage lines and ensure hydrologic conditions are maintained or impacts minimised where possible.

Indicative construction methods for permanent stormwater drainage are outlined in Table 6-8.

Table 6-8 Indicative stormwater drainage construction methods

Drainage type	Construction method
Drainage pipes	• Excavation of a trench in the existing ground surface • Installation of pre-cast concrete pipes placed in sections onto a bedding layer • Placement and compaction of select material around the pipes using hand-propelled compaction equipment, such as rammers or vibrating plates.
Installation of drainage pits and lids	• Excavation of pit location • Installation of pre-cast concrete pits, or casting the pit in-situ • Connection of pipes into concrete pits, which would be backfilled similar to the drainage pipes • Lids and inlets would be installed onto the pits and later incorporated into the kerbs and slabs • Installation of associated outlet structures.
Construction of box culverts	• Excavation of a trench in the existing ground surface • Concrete casting of culvert base slab in-situ • Installation of pre-cast culvert units • Backfilling, where required, using select material around the culverts and hand-propelled compaction equipment, such as rammers or vibrating plates • Installation of associated outlet structures.
Installation of flood walls	• Excavation of a foundation for the floodwall • Pour concrete foundation • Form, reinforce and pour concrete floodwall in panel sections.
Localised adjustment of a small section Burnt Bridge Creek and scour protection	• Localised diversion and protection of existing waterway • Excavation works including lowering and regrading of the creek channel to the required depth • Installation of box culvert base slab • Installation of box culvert units and redirect waterway into new box culvert • Backfill of installed box culvert units • Placement of scour protection • Landscaping and rehabilitation of the localised creek area.

6.5.5 Road pavement works

In areas where existing road pavements would be realigned and/or widened, pavements would be constructed to consist of similar pavement types to the existing road, and to meet Transport for NSW design standards.

Construction of areas of new surface roads would consist of both flexible and rigid pavements. Flexible pavements generally comprise the installation of an upper asphalt base layer (including an asphalt wearing course), placed on a granular or concrete sub-base. Installation of the sub-base pavement layer would involve the placement of material using trucks, excavators and graders, and compacted by vibratory rollers. A bitumen seal would be sprayed onto this layer of material, and aggregate would then be spread and rolled on top of the sprayed bitumen to create a waterproof seal.

Asphalt would be laid on top of the bitumen seal. Hot asphalt material would be transported to site in trucks from an off-site batching plant. Asphalt would be unloaded into paving machines, which would spread the asphalt to the required thickness. The asphalt surface would then be compacted by vibrating rollers and allowed to cool.

Rigid pavements generally comprise a concrete base (this may also include an asphalt wearing course), placed on a granular sub-base or concrete sub-base. The base or sub-base could be constructed using concrete pavers or they could be formed, with fixed forms set at the required pavement levels. Reinforcement would also be placed if required by the design. The concrete would be poured directly from agitator trucks into the concrete paver or into the forms.

Existing road pavements would be modified to integrate with the project where required. This may require milling and resurfacing of the existing pavements to tie-in with new road surfaces. These works are often required to be carried out at night when traffic numbers are reduced to enable the required lane closures.

Shared user path and cycleway pavements would be constructed to consist of similar pavement types to the existing paths, and to meet Transport for NSW design standards

Construction of the three shared user underpasses beneath the Wakehurst Parkway would be staged as part of the surface road works along the Wakehurst Parkway with further planning to include the potential of early access to one or more of the new underpasses. Controlled shared user access across Wakehurst Parkway would be limited but still available at all times with final access to all three underpasses available at the completion of construction works.

The extension of the existing shared user underpass beneath the Burnt Bridge Creek Deviation at Burnt Bridge Creek would be staged to maintain access at all times. Subject to final planning for staging of these works, short term detours may be required due to construction access restrictions.

6.5.6 Fauna connectivity structures

Three new fauna underpasses would be constructed along the Wakehurst Parkway as shown in Figure 6-28 and Figure 6-29. Fauna underpasses would be constructed using inverted U-shaped pre-cast concrete units placed on a cast concrete base slab. Following placement of the pre-cast units, the underpasses would be backfilled to the required new roadway level with select backfill material. An example of a fauna underpass is shown in Figure 6-22.

Additionally, three new fauna rope canopy bridges would be constructed about 910 metres and 1370 metres north of Kirkwood Street and 885 metres south of Aquatic Drive along Wakehurst Parkway. Three existing fauna rope canopy bridges would also be replaced by the project due to the widening of the Wakehurst Parkway. One of the fauna rope canopy bridges is located about 330 metres north of Kirkwood Street and the other two are located about 110 metres and 200 metres south of Aquatic Drive which were constructed as part of the Northern Beaches Hospital road upgrade project. Refer to Chapter 19 (Biodiversity) for further information on the management of biodiversity impacts from the project including measures to maintain the function of the existing fauna underpass on the Wakehurst Parkway north of Aquatic Drive during construction.

Figure 6-22 Example of a fauna underpass (Pacific Highway Upgrade, Woolgoolga to Ballina upgrade)

6.5.7 Surface finishing works

Surface finishing works would be carried out progressively during construction as areas are near completion and would include:

- Linemarking of new road pavement
- Installation of directional signage and other roadside furniture
- Final landscape treatments and rehabilitation works
- Local commercial and residential property adjustments required due to surface road changes
- Local road traffic calming measures.

6.6 New open space and recreation facilities at Balgowlah

A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input to the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation would be separate to the consultation for the Beaches Link and Gore Hill Freeway Connection environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting. As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space. The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities.

Construction of the new and improved open space and recreation facilities at Balgowlah would be delivered progressively. Commencement of the staged works for the new open space and recreation facilities would be subject to completion of the consultation process described above.

Residual land, primarily to the east and north of the new access road, would progressively become available through the construction period, which would facilitate re-purposing it to the new open space and recreation facilities. This would allow it to be handed over progressively for use by the community. The new open space and recreation facilities to the west of the proposed access road, between the access road and Burnt Bridge Creek Deviation, would be constructed after completion of the project and then handed over to Northern Beaches Council.

An indicative layout of the new and improved open space and recreation facilities at Balgowlah is provided in Figure 5-28 of Chapter 5 (Project description).

6.7 Testing, commissioning and demobilisation

Testing and commissioning works would be carried out towards the completion of construction to validate the correct operation and integration of tunnel systems prior to road opening.

Site clean-up and demobilisation works would be carried out once construction activities have been completed at that location. This would include:

- Site demobilisation and rehabilitation of temporary construction support sites
- Post construction condition surveys
- Removal of construction-related signage
- Removal of construction-related environmental controls and traffic management infrastructure. In some instances, controls will remain in place until the environment has stabilised (eg vegetation is established).

Residual land refers to those lots that would be wholly or partially occupied during construction of the project but would not be required for operational infrastructure or other operational activities. Where land is leased for construction of the project, reinstatement and rehabilitation of the land would be carried out as part of demobilisation works, in consultation with and to meet the requirements of the relevant landowner.

Any future development of residual land would be subject to separate assessment and approval in accordance with the *Environmental Planning and Assessment Act 1979*. Additional detail about residual land not required following construction of the project is provided in Chapter 20 (Land use and property).

6.8 Construction footprint and temporary construction support sites

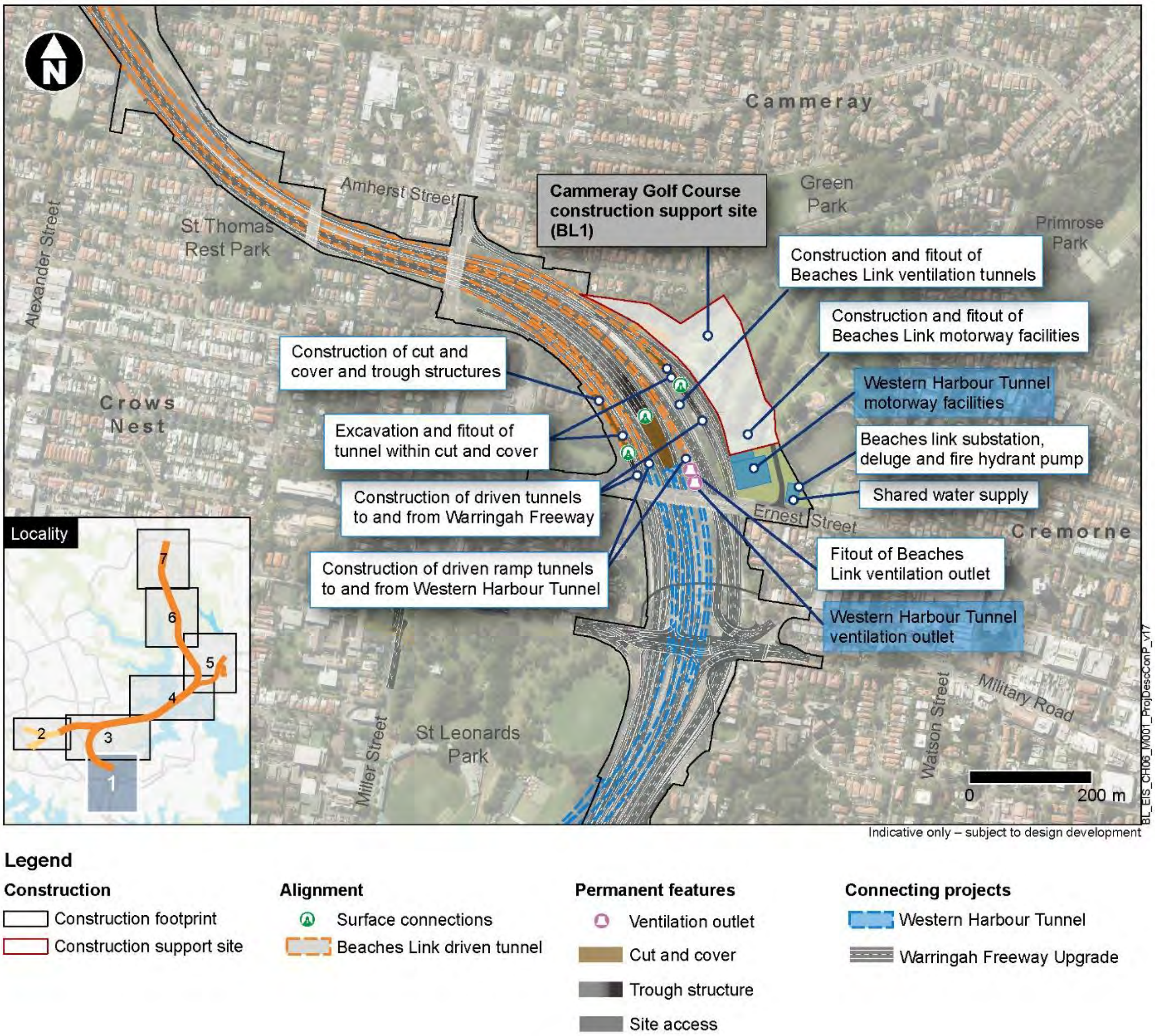
6.8.1 Construction footprint

The total area required for construction of the project is referred to as the construction footprint. The construction footprint consists of the anticipated area needed for the project and includes temporary construction support sites and additional areas where work would be required to construct the project. Temporary construction support sites required for the project are discussed in Section 6.8.2.

While a substantial amount of the work for the project would occur underground, temporary construction support sites on the surface would be required to support underground construction activities and to support and construct the surface connections, tunnel portals, surface road works including the realignment and upgrade of the Wakehurst Parkway, active transport facilities (pedestrian and cyclist facilities) and operational facilities.

Apart from the motorway facilities, cut and cover structures, trough structures and tunnelling works in Cammeray, the construction footprint shown on the Warringah Freeway would consist of low impact activities such as traffic control and management, line marking and staged surface roadworks tie in works, and utility and cable works required to connect to the Western Harbour Tunnel and Warringah Freeway Upgrade project and other local roads.

An overview of construction activities and the construction footprint is shown in Figure 6-23 to Figure 6-29.



Note: The Beaches Link construction footprint shown on Warringah Freeway within this area extends to include construction activities that would be associated with traffic control and management, line marking, tie-in works and utility and cable works.

Figure 6-23 Overview of construction activities and construction footprint (map 1)

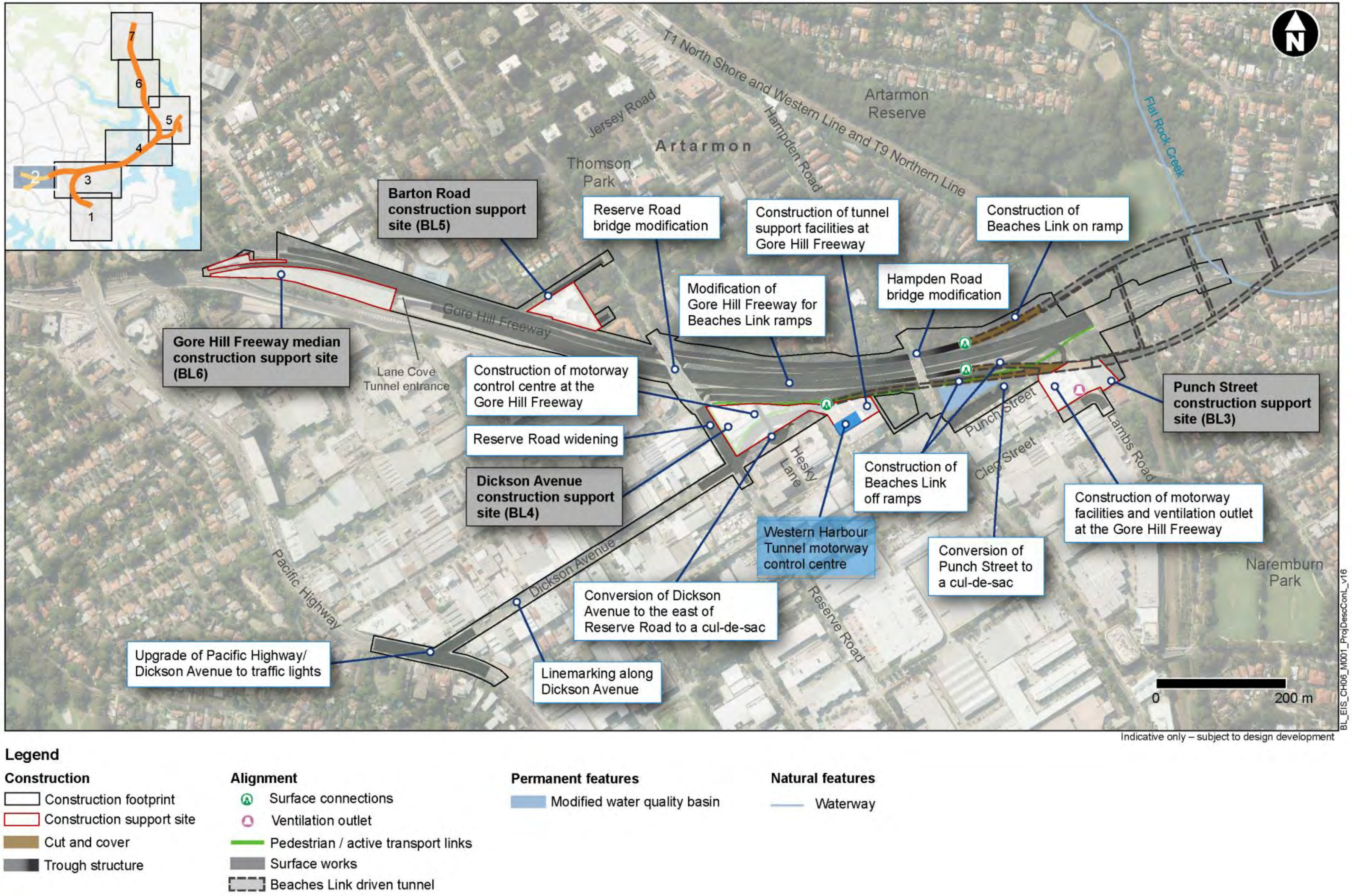
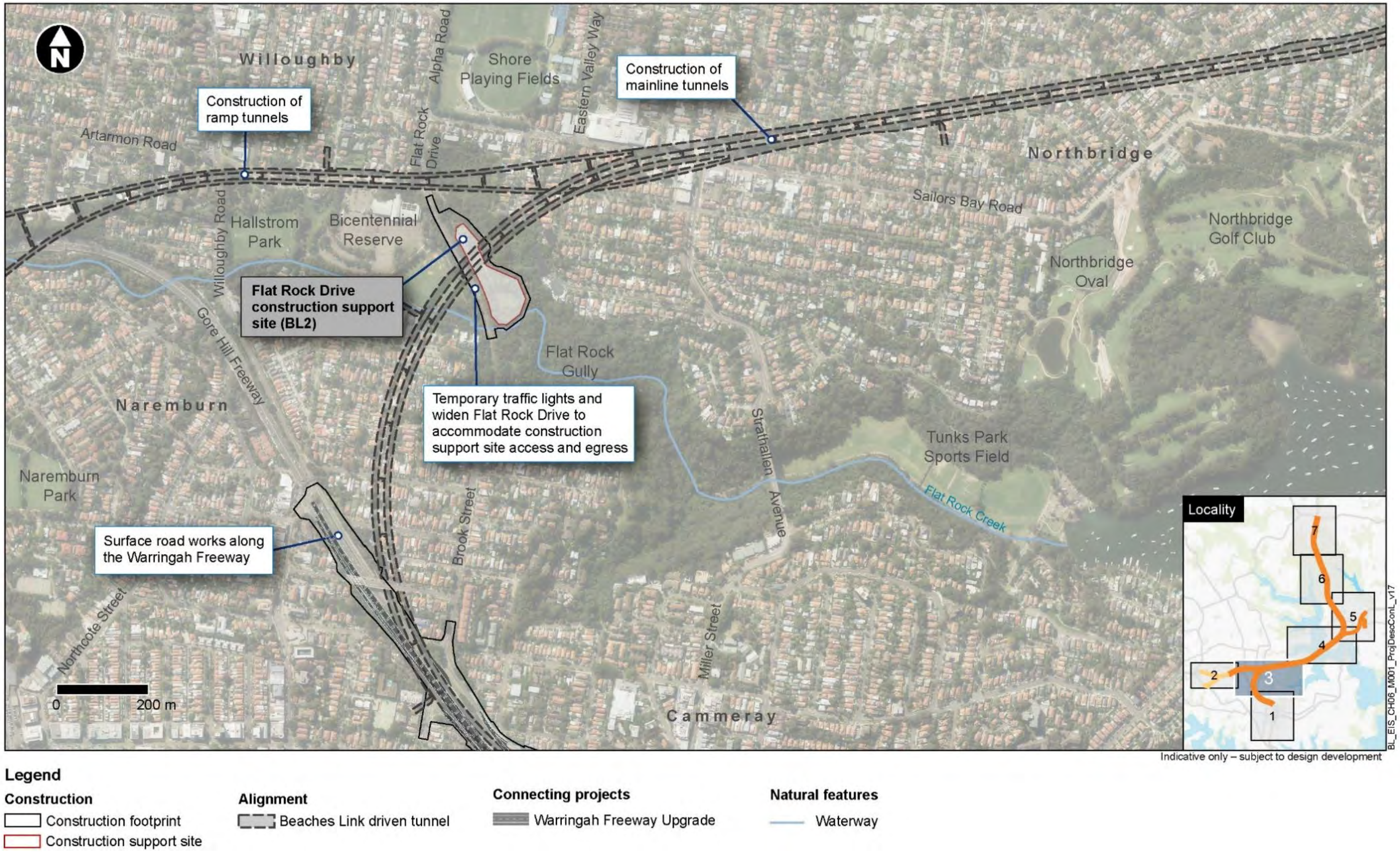
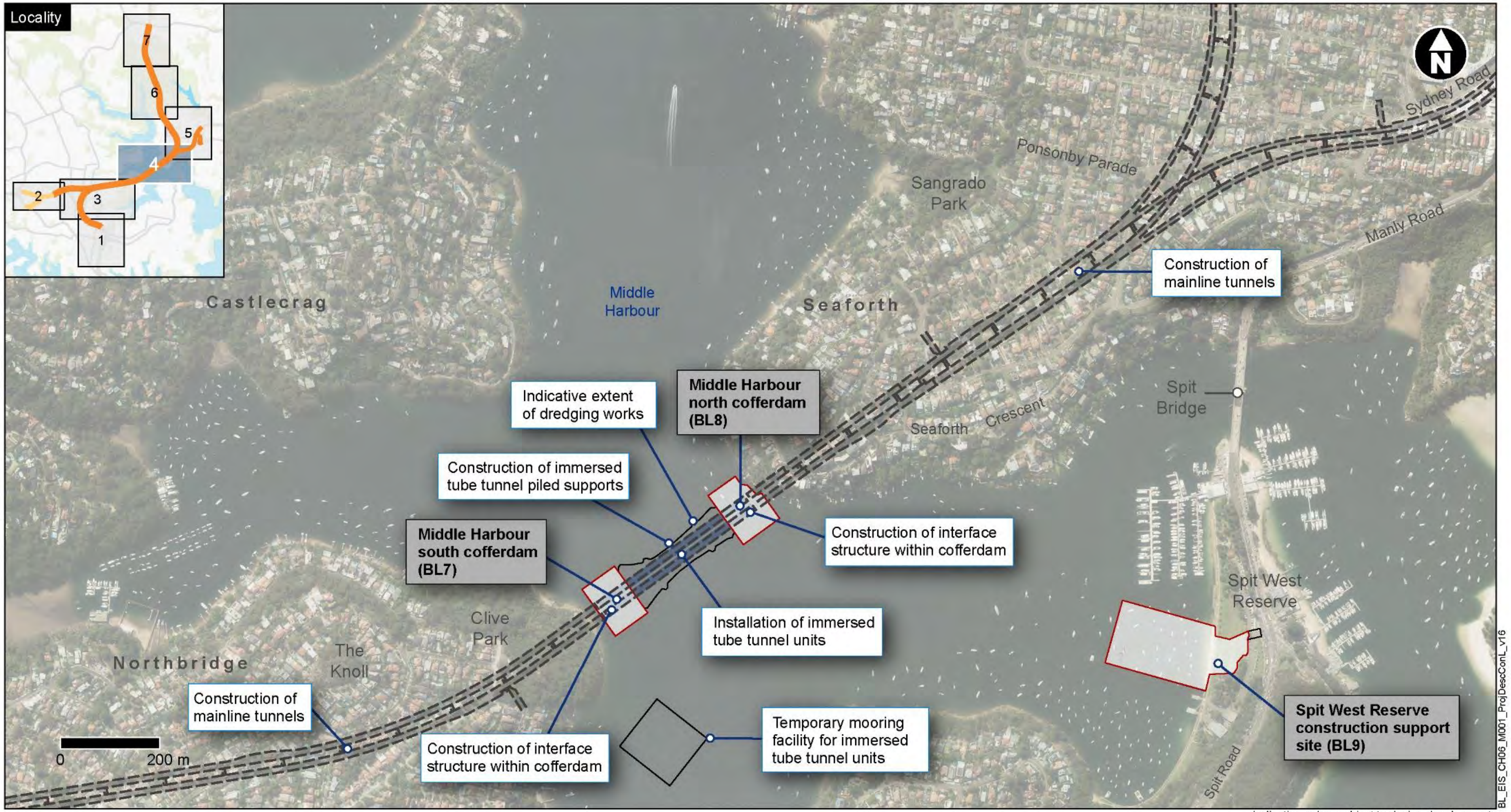


Figure 6-24 Overview of construction activities and construction footprint (map 2)



Note: The Beaches Link construction footprint shown on Warringah Freeway within this area extends to include construction activities that would be associated with traffic control and management, line marking, tie-in works and utility and cable works.

Figure 6-25 Overview of construction activities and construction footprint (map 3)



Indicative only – subject to design development

Legend

Construction

Construction footprint

Construction support site

Alignment

Beaches Link driven tunnel

Immersed tube tunnel

Figure 6-26 Overview of construction activities and construction footprint (map 4)

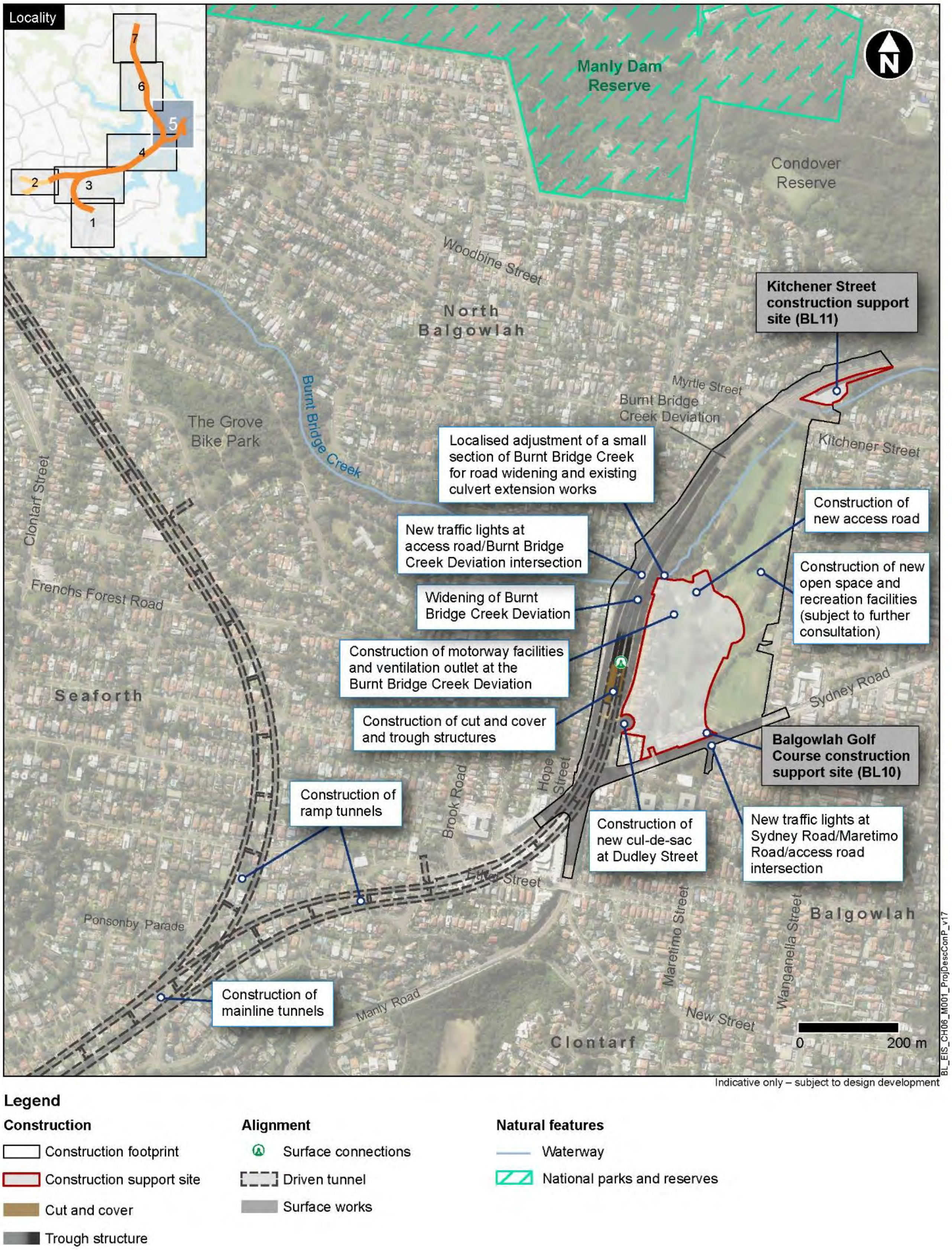


Figure 6-27 Overview of construction activities and construction footprint (map 5)

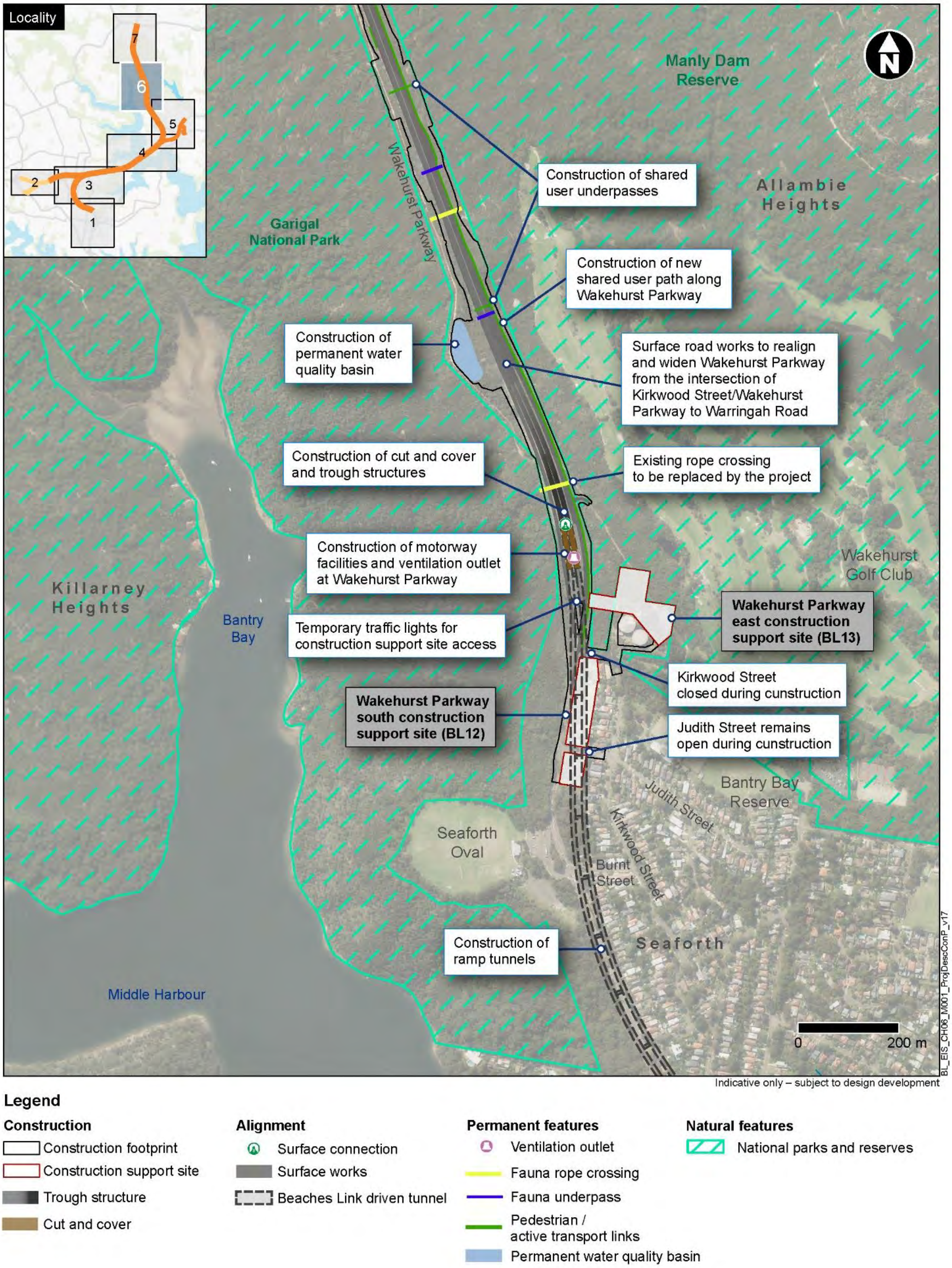
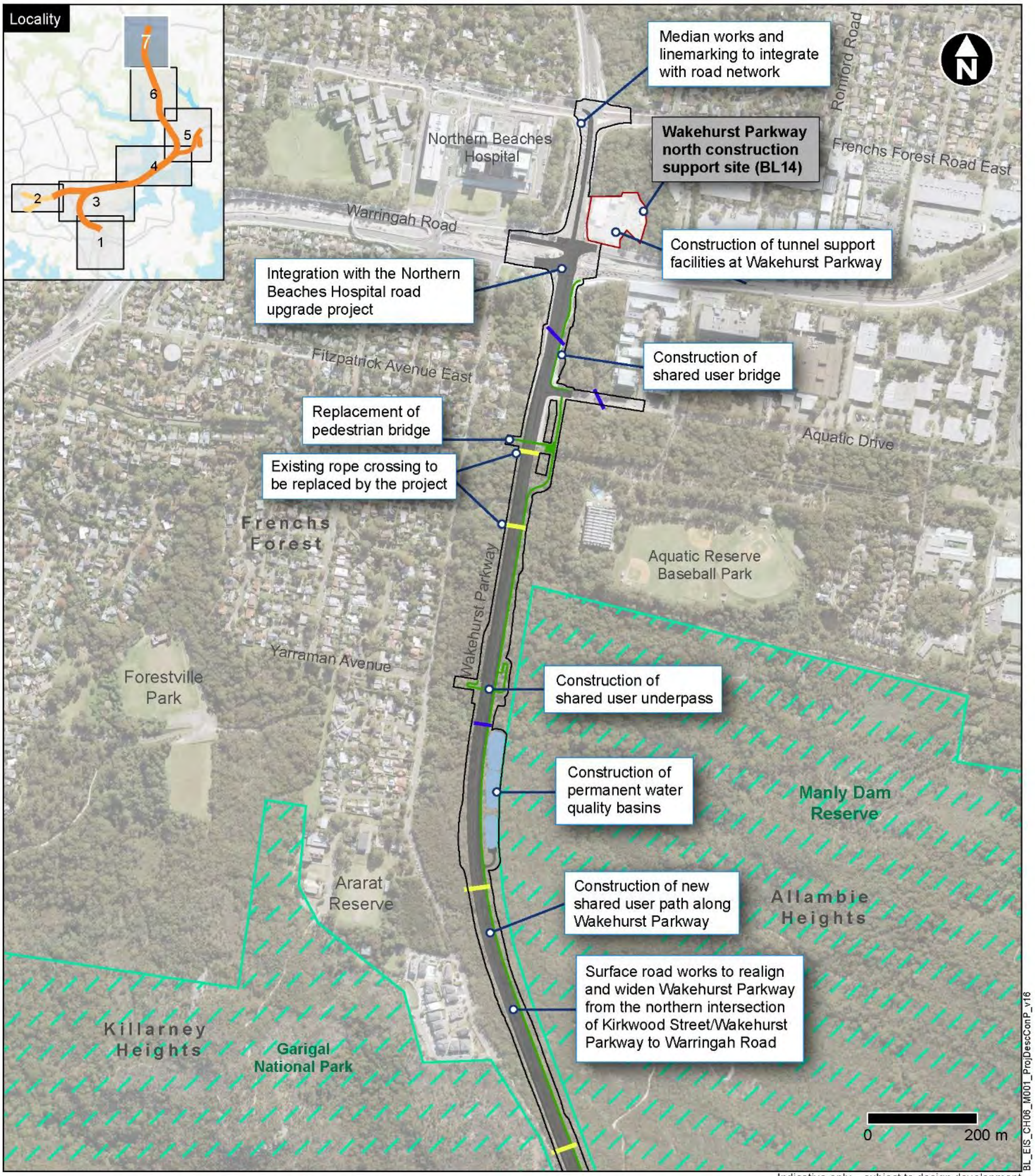


Figure 6-28 Overview of construction activities and construction footprint (map 6)



Indicative only – subject to design development

Legend

Construction
- Construction footprint
- Construction support site

Alignment
- Surface works

Permanent features
- Fauna rope crossing
- Fauna underpass
- Pedestrian / active transport links
- Permanent water quality basin

Natural features
- National parks and reserves

Figure 6-29 Overview of construction activities and construction footprint (map 7)

6.8.2 Beaches Link and Gore Hill Freeway Connection temporary construction support sites

Temporary construction support sites for the project would include tunnelling and tunnelling support sites, surface civil sites, cofferdams, mooring sites, wharf and berthing facilities, construction storage (laydown) areas, parking and workforce amenities.

All temporary construction support sites would have appropriate boundary fencing. This would be typical construction hoarding or security fencing. Where required, temporary noise barriers would be installed on the site boundary. Indicative locations are shown on the temporary construction support site figures (Figure 6-30 to Figure 6-42).

To support operation of the sites, power, potable water supply and suitable connection for stormwater and sewerage discharge would be required (discussed in Section 6.9.4).

Construction hours at temporary construction support sites would vary depending on the type of construction activity being carried out. Proposed hours for each temporary construction support site are outlined in the following sections and construction work hours associated with specific activities are detailed in Section 6.9.1.

The following sections describe the proposed temporary construction support sites and their anticipated functions/uses during construction.

Cammeray Golf Course (BL1)

A summary of the key features of the Cammeray Golf Course construction support site (BL1) is included in Table 6-9. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-30. An indicative program for construction activities is provided in Table 6-10.

Table 6-9 Key features of the Cammeray Golf Course construction support site (BL1)

Key feature	Summary
Site area	27,600 m^2
Site description	Located within the north-west portion of the Cammeray Golf Course. The site is bound by the Cammeray Golf Course to the north, Cammeray Golf Course and Cammeray Park to the east, Warringah Freeway to the west and Ernest Street to the south. Residential properties are located to the north on Warringa Road and Morden Street and to the south across Ernest Street.
Key activities	This site would be used for the construction and fitout of motorway facilities at the Warringah Freeway and would provide tunnel and construction support for the Beaches Link component of the project. The site would initially be established as a temporary construction support site for the Western Harbour Tunnel and Warringah Freeway Upgrade project and was assessed as part of the environmental impact statement for Western Harbour Tunnel and Warringah Freeway Upgrade (Transport for NSW, 2020b). The site has been designed and developed to minimise impacts to the golf course, and allow for a reconfigured nine-hole golf course to operate throughout construction and operation. Key activities that would occur on, or be supported by this site would include: • Site reconfigured for Beaches Link project works including construction and operation of temporary site facilities, including

Key feature	Summary
	an acoustic shed, workshop, wastewater treatment facility, air intake, staff offices and amenities, pavements and car parking • Excavation of a tunnelling access decline connecting to a modified ventilation tunnel • Excavation of driven mainline tunnels from Cammeray towards Naremburn • Excavation of shafts and ventilation tunnels for the ventilation outlet and motorway facilities at the Warringah Freeway • Construction and fitout of the Beaches Link motorway facilities and fitout of the ventilation outlet structure at the Warringah Freeway (the ventilation outlet civil works would be constructed as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project) • Construction support for the Beaches Link cut and cover and trough structures and their connection to the Warringah Freeway • Construction of the substation and operational support facilities • Treatment of wastewater from tunnelling activities • Excavation, handling and stockpiling of tunnel spoil • Utility works associated with surface works • Tunnel civil and mechanical and electrical fitout • Backfill access decline • Testing, commissioning and site rehabilitation.
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Tunnel construction and fitout would be carried out up to 24 hours per day, seven days per week either within an acoustic shed or underground. Night time deliveries would be required to support the tunnelling activities.
Access arrangements	Access in and out of the site would be primarily via Warringah Freeway around the location of the existing bus layover area at Cammeray. A secondary access would be provided at Ernest Street.

Note: Leasing and acquisition at this site would be carried out as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

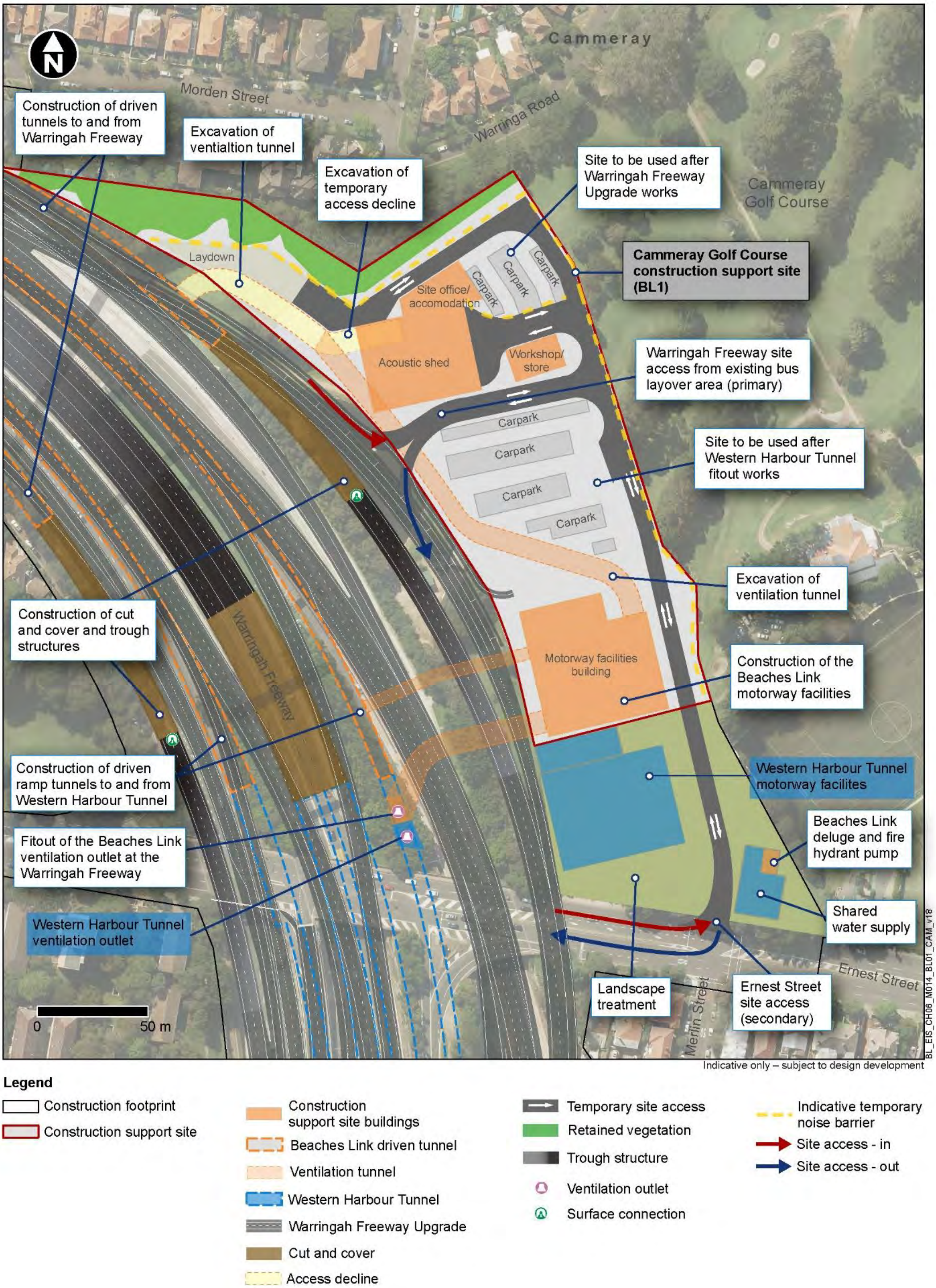


Figure 6-30 Indicative layout - Cammeray Golf Course construction support site (BL1)

Table 6-10 Cammeray Golf Course construction support site (BL1) indicative construction program

Construction activity	Indicative construction program															
	2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment																
Construction of tunnel access decline																
Tunnel construction																
Construction of cut and cover and trough structures																
Fitout of cut and cover and trough structures																
Tunnel fitout and finishing																
Construction of motorway facilities and fitout of ventilation outlet (civil works constructed by Western Harbour Tunnel and Warringah Freeway Upgrade project)																
Testing, commissioning and site rehabilitation																

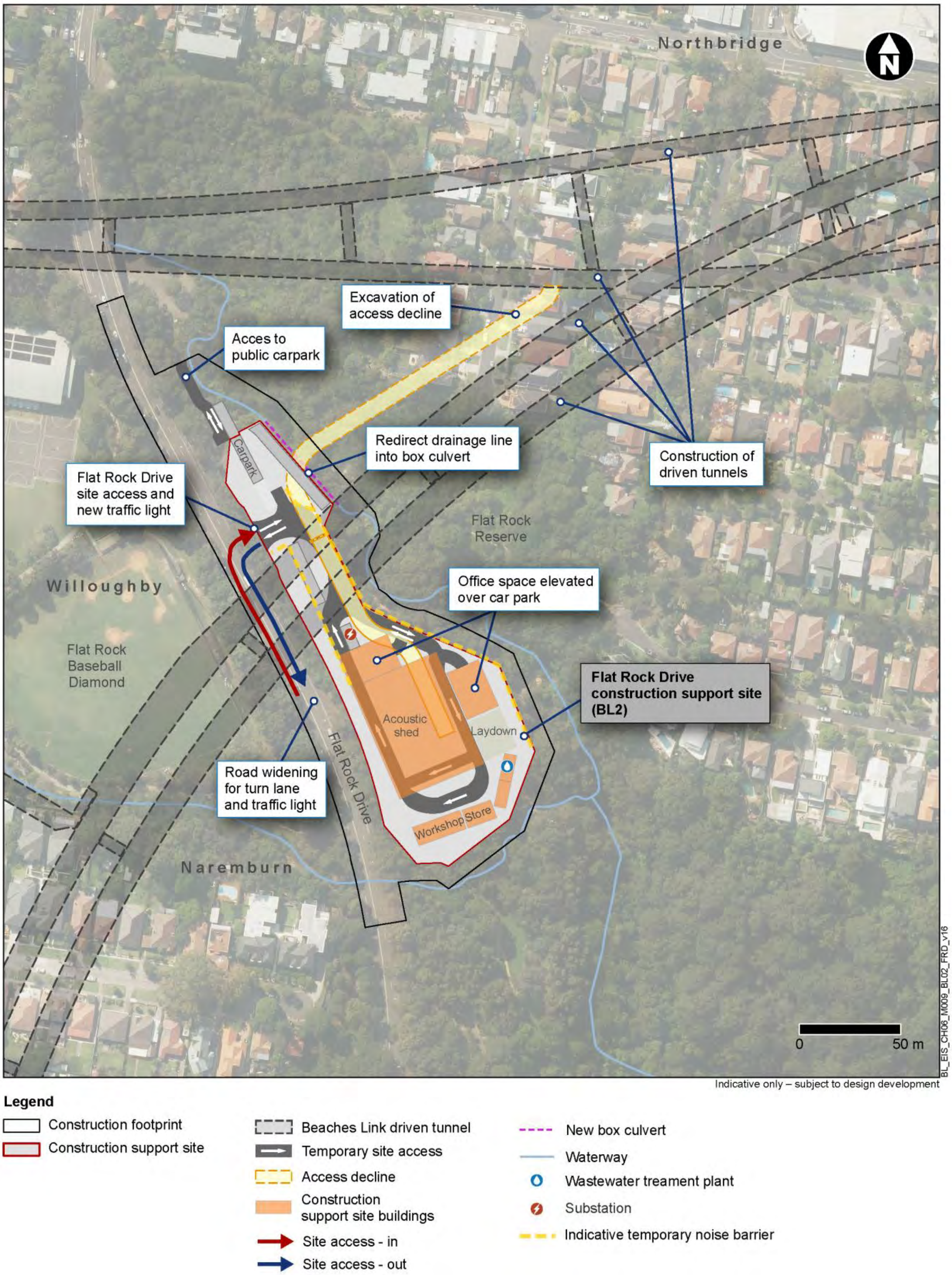
Flat Rock Drive (BL2)

A summary of the key features of the Flat Rock Drive construction support site (BL2) is included in Table 6-11. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-31. An indicative program for construction activities is provided in Table 6-12.

Table 6-11 Key features of the Flat Rock Drive construction support site (BL2)

Key feature	Summary
Site area	11,760 m^2
Site description	Located in Flat Rock Reserve, on the eastern side of Flat Rock Drive, opposite to the Flat Rock Baseball Diamond in Northbridge. This site was chosen to avoid direct impact on nearby residential or commercial properties, the Flat Rock Baseball Diamond, or the Willoughby Leisure Centre indoor facilities, netball courts or car park. It also provides direct access to and from the site via a main road, avoiding the need to use local roads for site access. The temporary construction support site is located on a revegetated former landfill site. Potentially contaminated materials disturbed during site establishment and access decline construction would be subject to further investigation, remediation and/or management. All identified contaminated materials would be managed during construction with the implementation of environmental management measures detailed Chapter 16 (Geology, soils and groundwater) and in accordance with the

Key feature	Summary
	Guideline for the Management of Contamination (Roads and Maritime Services, 2013a).
Key activities	This would be a tunnel support site. Key activities that would occur on, or be supported by, this site would include: • Support site works including the temporary diversion of existing shared user paths and walking tracks, clearing and grubbing, topsoil stripping, bulk earthworks, management of potentially contaminated waste, retaining structures to reshape and regrade existing reserve • Construction and operation of temporary site facilities, including an acoustic shed, temporary noise barriers, workshop, wastewater treatment facility, air intake, staff offices and amenities, pavements and car parking • Installation of a culvert in an existing aboveground watercourse within the northern extent of Flat Rock Reserve along the north eastern boundary of the site • Excavation of an access decline to the main tunnel alignment (via the westbound ramp tunnel connection at the Gore Hill Freeway) • Excavation of the main tunnel alignment towards both Cammeray and Middle Harbour and excavation of ramp tunnels toward Artarmon • Treatment of wastewater from tunnelling activities • Support for tunnel excavation works • Support for tunnel fitout and finishing works • Utility works associated with surface works • Excavation, handling and stockpiling of tunnel spoil • Backfill of access decline • Testing, commissioning and site rehabilitation.
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Tunnel construction and fitout would be carried out up to 24 hours per day, seven days per week either within an acoustic shed or underground. Night time deliveries would be required to support the tunnelling activities.
Access arrangements	Access in and out of the site would be via a temporary signalised intersection at Flat Rock Drive. Local surface works for road widening, shared user path and utility adjustments would be required on Flat Rock Drive to establish a traffic light intersection and turning lane. Road widening works would be carried out on the eastern side of Flat Rock Drive.



Note: The waterway includes a constructed surface creek, above ground concrete lined stormwater channels, a naturalised bedrock channel and an underground box culvert. Flat Rock Creek is within a box culvert from Willoughby Road to a point 150m east of Flat Rock Drive. Further detail on Flat Rock Creek characteristics is provided in Chapter 17 (Hydrodynamics and water quality) (refer to Figure 17-2).

Figure 6-31 Indicative layout - Flat Rock Drive construction support site (BL2)

Table 6-12 Flat Rock Drive construction support site (BL2) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment	■	■																		
Construction of tunnel access decline			■																	
Tunnel construction				■	■	■	■	■	■	■	■	■	■	■	■	■				
Tunnel fitout									■	■	■	■	■	■	■	■	■	■		
Testing, commissioning and site rehabilitation																■	■	■	■	■

Punch Street (BL3)

A summary of the key features of the Punch Street construction support site (BL3) is included in Table 6-13. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-32. An indicative program for construction activities is provided in Table 6-14.

Table 6-13 Key features of the Punch Street construction support site (BL3)

Key feature	Summary
Site area	4800 m^2
Site description	Located within the Artarmon industrial area, next to the T1 North Shore and Western Line and T9 Northern Line rail corridor, on the southern side of the Gore Hill Freeway. The western portion of the site is currently occupied by industrial buildings and the eastern portion is vegetated.
Key activities	This would be a tunnel support and project management site for Beaches Link. Key activities that would occur on, or be supported by this site would include: • Demolition of existing structures • Construction and operation of temporary site facilities, including an acoustic shed, temporary noise barrier, workshop, wastewater treatment facility, air intake, staff offices and amenities • Excavation of an access decline • Excavation of ramp tunnels and cross passages from the Gore Hill Freeway Artarmon to the mainline tunnels under Northbridge • Treatment of wastewater from tunnelling activities • Support for tunnel fitout and finishing works • Utility works associated with surface works including existing 132kV utility support works over cut and cover. Access for the service provider would be maintained throughout construction • Excavation, handling and stockpiling of tunnel spoil

Key feature	Summary
	• Construction of permanent operational facilities, including motorway facilities • Backfill access decline • Testing, commissioning and site rehabilitation.
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Tunnel construction and fitout would be carried out up to 24 hours per day, seven days per week either within an acoustic shed or underground. Night time deliveries would be required to support the tunnelling activities.
Access arrangements	Access into the site would be via Reserve Road and Cleg Street, and out of the site via Punch Street. An alternative heavy goods vehicle exit would be constructed and staged with the cut and cover works to connect directly to the Gore Hill Freeway westbound.

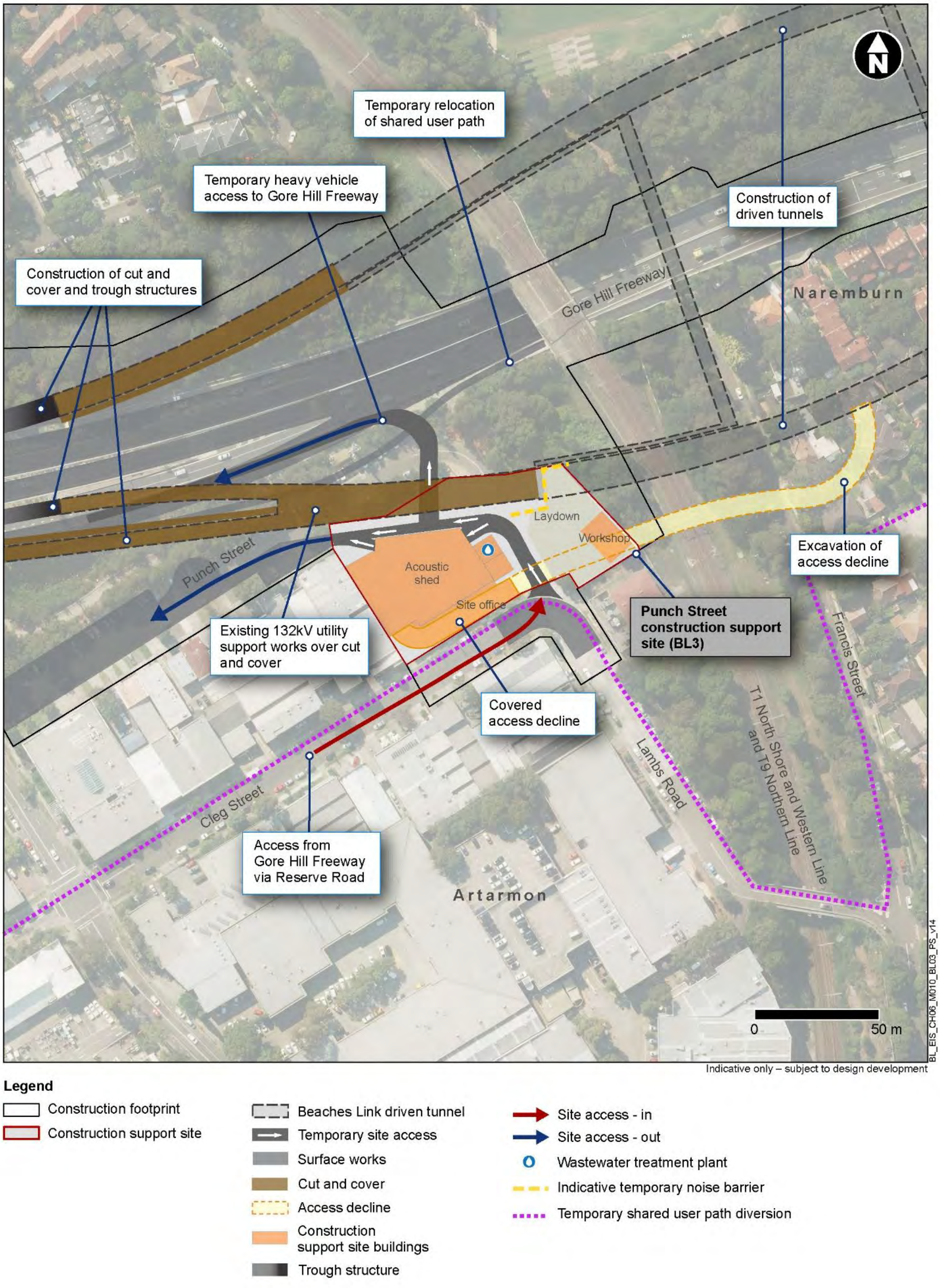


Figure 6-32 Indicative layout - Punch Street construction support site (BL3)

Table 6-14 Punch Street construction support site (BL3) indicative construction program

Construction activity	Indicative construction program															
	2023				2024				2025				2026			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment	—	—														
Excavation of tunnel access decline			—													
Tunnel construction				—	—	—	—	—	—	—	—					
Tunnel fitout									—	—	—	—	—			
Construction of operational facilities							—	—	—	—	—	—	—			
Testing, commissioning and site rehabilitation											—	—	—	—	—	

Dickson Avenue (BL4)

A summary of the key features of the Dickson Avenue construction support site (BL4) is included in Table 6-15. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-33. An indicative program for construction activities is provided in Table 6-16.

Table 6-15 Key features of the Dickson Avenue construction support site (BL4)

Key feature	Summary
Site area	9900 m^2
Site description	Located within the Artarmon industrial area, between Reserve Road, Dickson Avenue and Waltham Street, on the southern side of the Gore Hill Freeway. The site is currently occupied by industrial buildings and the Freeway Hotel. It is noted that an area in the eastern part of this site (off Waltham Street) would be occupied by the Western Harbour Tunnel motorway control centre (delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project). The area allocated for the Western Harbour Tunnel motorway control centre is not currently proposed for use by the project for construction activities.
Key activities	The site would support construction activities for both the Beaches Link and Gore Hill Freeway Connection components of the project. The site would initially involve support site works including: • Demolition of existing structures • Construction and operation of temporary site facilities, including laydown areas, staff offices and amenities, pavements and car parking. For the Beaches Link construction works, the site would be used for supplementary support for tunnelling activities that occur from the Punch Street construction support site (BL3) and construction of operational facilities. For the Gore Hill Freeway Connection construction works the site would be used as a project management site and used for equipment laydown, car parking for construction workers and temporary site office buildings. Once most of the surface and tunnelling works have been completed, the temporary construction

Key feature	Summary
	support site would be rearranged to allow for construction of permanent infrastructure (ie the off ramp trough structures and surface works to Reserve Road, the motorway control centre and the tunnel support facility).
Hours of construction	General site activities, including construction of the motorway control centre and tunnel support facilities and most surface works, would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday and no construction works on Sundays or public holidays). Some construction activities (eg some more complex and constrained surface works and utility adjustments) supported by this site would require out of hours work due to site access restrictions and constraints presented by existing traffic staging requirements. This would require periods throughout the construction program where works at this site would occur outside of standard construction hours.
Access arrangements	Access in and out of the site would be via Dickson Avenue/Reserve Road.

Figure 6-33 Indicative layout - Dickson Avenue construction support site (BL4)

Table 6-16 Dickson Avenue construction support site (BL4) indicative construction program

Construction activity	Indicative construction program															
	2023				2024				2025				2026			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Beaches Link construction works																
Early works and site establishment																
Additional tunnel support at Punch Street																
Construction of operational facilities																
Testing and commissioning																
Gore Hill Freeway Connection construction works																
Early works and site establishment																
Construction of Gore Hill Freeway surface works and bridge modifications																
Construction of the off ramp trough and surface works to Reserve Road																
Site rehabilitation																

Barton Road (BL5)

A summary of the key features of the Barton Road construction support site (BL5) is included in Table 6-17. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-34. An indicative program for construction activities is provided in Table 6-18.

Table 6-17 Key features of the Barton Road construction support site (BL5)

Key feature	Summary
Site area	3830 m^2
Site description	Located on the northern side of Gore Hill Freeway, between Butchers Lane and Barton Road.
Key activities	Used for equipment laydown facilities, car parking for construction workers and temporary site office buildings associated with the Gore Hill Freeway Connection works.
Hours of construction	General site activities, including most surface works, would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday and no construction works on Sundays or public holidays). Some construction activities (eg some more complex and constrained surface works and utility adjustments) supported by this site would require out of hours work due to site access restrictions and constraints presented by existing traffic staging requirements. This would require periods throughout the construction program where works at this site would occur outside of standard construction hours.

Key feature	Summary
Access arrangements	Access in and out of the site would be via Barton Road and Butchers Lane, via Reserve Road.

Figure 6-34 Indicative layout - Barton Road construction support site (BL5)

Table 6-18 Barton Road construction support site (BL5) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment			■	■																
Construction support for surface works					■	■	■	■	■	■	■	■	■	■	■	■				
Site restoration and demobilisation																	■	■		

Gore Hill Freeway median (BL6)

A summary of the key features of the Gore Hill Freeway median construction support site (BL6) is included in Table 6-19. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-35. An indicative program for construction activities is provided in Table 6-20.

Table 6-19 Key features of the Gore Hill Freeway median construction support site (BL6)

Key feature	Summary
Site area	7700 m^2
Site description	Located within the Gore Hill Freeway road corridor on top of the Lane Cove Tunnel portal. The site is currently a grassed area with scattered juvenile and mature trees.
Key activities	Used for equipment laydown facilities associated with the Gore Hill Freeway Connection works.
Hours of construction	General site activities, including most surface works, would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday and no construction works on Sundays or public holidays). Some construction activities (eg some more complex and constrained surface works and utility adjustments) supported by this site would require out of hours work due to site access restrictions and constraints presented by existing traffic staging requirements. This would require periods throughout the construction program where works at this site would occur outside of standard construction hours.
Access arrangements	Access into the site would be primarily via Gore Hill Freeway, a secondary access would be provided via Epping Road. Access out of the site would be via Gore Hill Freeway (eastbound).

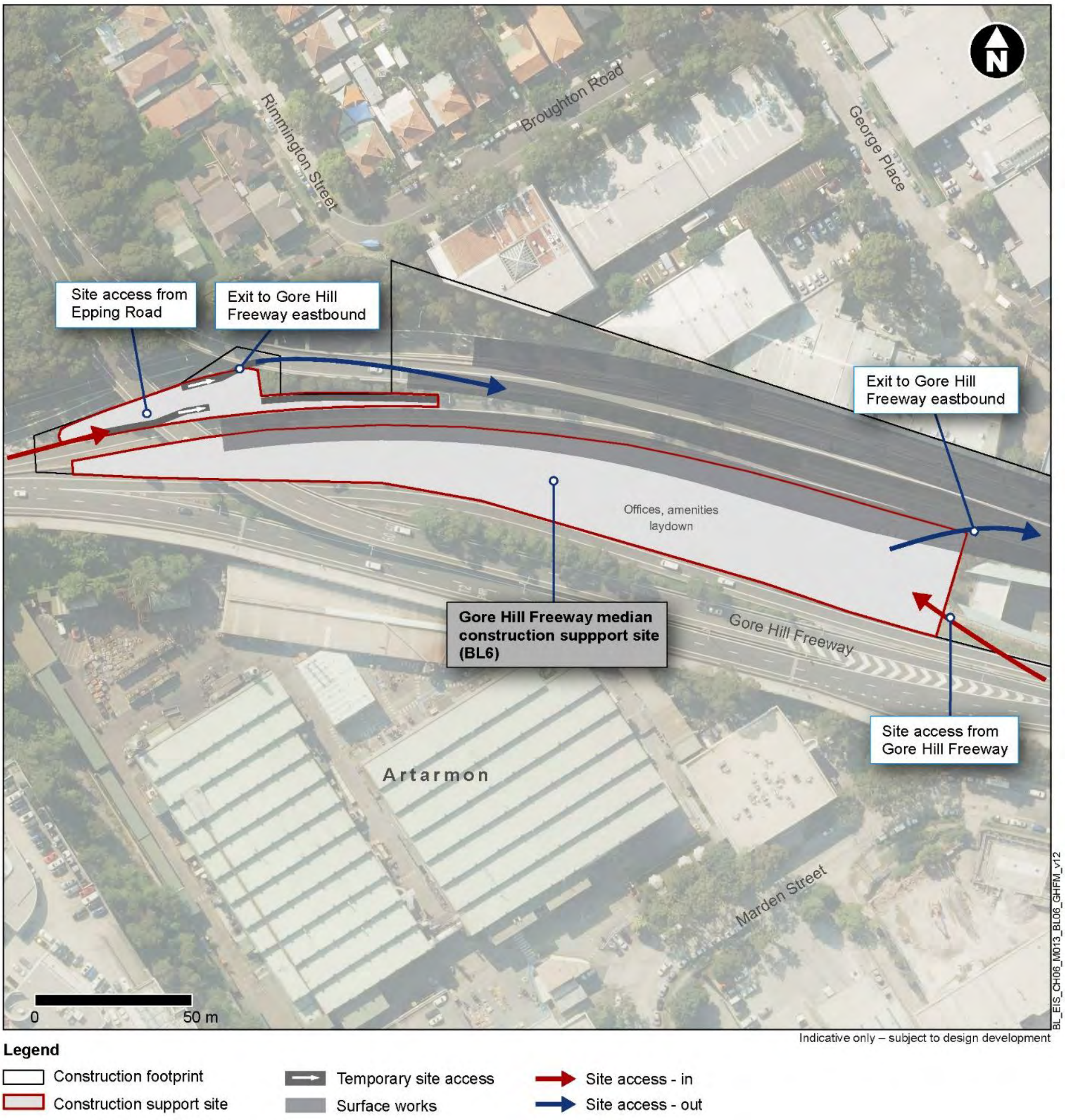


Figure 6-35 Indicative layout - Gore Hill Freeway median construction support site (BL6)

Table 6-20 Gore Hill Freeway median construction support site (BL6) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment																				
Construction support for surface works																				
Site restoration and demobilisation																				

Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8)

A summary of the key features of the Middle Harbour cofferdams (BL7 and BL8) is included in Table 6-21. An indicative layout for the cofferdams is shown in Figure 6-36. An indicative program for construction activities is provided in Table 6-22. Marine transport routes are shown in Figure 6-36.

Table 6-21 Key features of the Middle Harbour cofferdam construction support sites (BL7 and BL8)

Key feature	Summary
Site area	9200 m^2 (BL7) and 9900 m^2 (BL8)
Site description	Temporary cofferdams would be constructed at each end of the Middle Harbour crossing and within the harbour off the shore at Northbridge to the south and Seaforth to the north. Access would be from Spit West Reserve construction support site (BL9).
Key activities	The cofferdams would facilitate construction of the interface structures which connect the driven mainline tunnels and the immersed tube tunnel units. Key activities that would occur on, or be supported by, these sites would include: • Temporary relocation of about 10 moorings below Seaforth Bluff • Construction of temporary cofferdam structure, including ground treatment, piling, dewatering, installation of structural steel supports and excavation • Construction of interface structure (connection between the driven tunnels and the immersed tube tunnels, refer to Section 6.5.4) within the cofferdams • Construction support from the water, including the use of a work barge (such as a flat top barge as shown in Figure 6-12, and barge movements for transfer of dredged material, deliveries and staff transport • Construction of immersed tube tunnel piled supports • Removal of cofferdam structure and site rehabilitation. Alternative facilities (swing mooring or marina berth) would be provided nearby for the users of the three fixed jetties below Seaforth Bluff that would have access restricted during construction.

Key feature	Summary
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Rock hammering, piling and dredging would be carried out during standard construction hours only. However, certain activities may be carried out up to 24 hours per day, seven days per week. This would include dewatering of cofferdams. Some transport by barge to the designated offshore disposal site may take place outside standard construction hours. It is noted that weekends are typically the busiest period for recreation including recreational boating, and this would be considered during detailed construction planning stages to minimise impacts to recreational activities and residents.

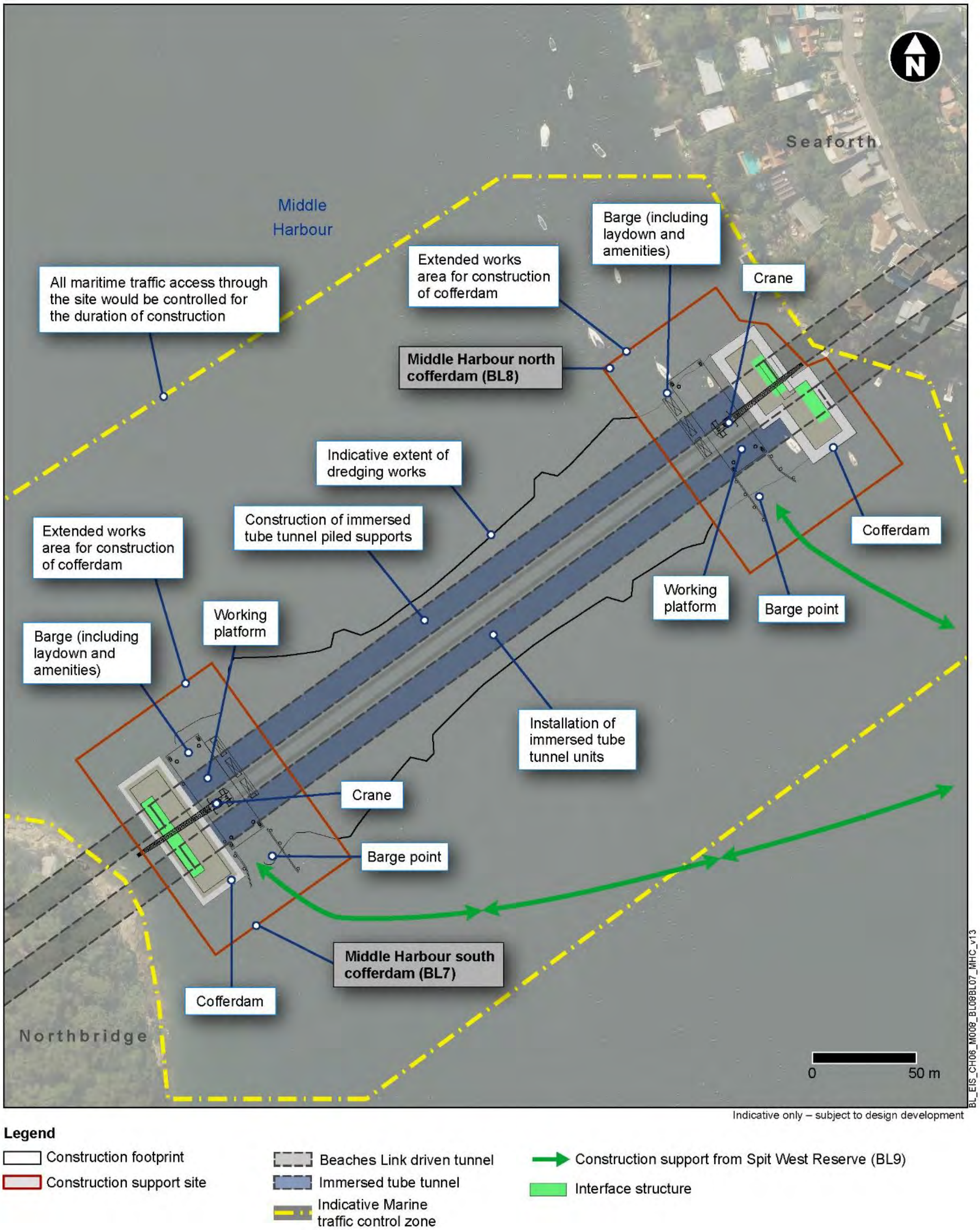


Figure 6-36 Indicative layout – Middle Harbour cofferdams (BL7 and BL8)

Table 6-22 Middle Harbour cofferdams (BL7 and BL8) and other activities indicative construction program

Construction activity	Indicative construction program															
	2023				2024				2025				2026			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment	■	■														
Installation of temporary cofferdam structures			■	■	■	■	■	■	■							
Construction of pile moorings between Beauty Point and Clive Park				■	■											
Construction of immersed tube tunnel pile supports					■	■	■									
Excavation of soft sediment and rock within cofferdams							■	■	■	■						
Construction of interface structures										■	■	■				
Reinstatement works to cofferdam areas												■	■			
Dredging of trench for the immersed tube tunnels									■	■	■	■	■			
Installation of immersed tube tunnel units														■	■	■

Spit West Reserve (BL9)

A summary of the key features of the Spit West Reserve construction support site (BL9) is included in Table 6-23. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-37. An indicative program for construction activities is provided in Table 6-24. Marine transport routes are shown in Figure 6-43.

Table 6-23 Key features of the Spit West Reserve construction support site (BL9)

Key feature	Summary
Site area	26,000 m^2 (water area) and 4500 m^2 (land area)
Site description	Located primarily in the water west of Spit West Reserve, with a small adjoining land-based site. The land-based site is currently a public recreational space. However, a section of the land-based site has been recently used to support construction of the Northern Beaches B-Line infrastructure.
Key activities	The temporary construction support site will include a land-based support site facility in Spit West Reserve including car park, access road, laydown area and shed. The proposed support site works would include construction of a temporary floating immersed tube tunnel casting facility that would be connected to Spit West Reserve by two temporary fixed jetties.

Key feature	Summary
	The floating facility and fixed jetties will require the installation of temporary piling and associated marine structures. The casting facility would provide space for two immersed tube tunnel units to be cast concurrently. The site would also provide support for: • Middle Harbour cofferdams • Interface structures • Immersed tube tunnel unit support piles • Dredging works • Immersed tube tunnel immersion • Immersed tube tunnel granular backfill placement • Site rehabilitation. A mooring location would be provided in Middle Harbour to the west of the Spit West Reserve site to temporarily moor the immersed tube tunnel units prior to immersion. The mooring location would provide space for four immersed tube tunnel units. The proposed mooring location is shown in Figure 6-43. The Spit West Reserve construction support site (BL9) would require the relocation of about 45 moorings in Middle Harbour for about two years. In an effort to minimise impacts to traffic during peak periods and consideration of the limited construction footprint, the construction workforce would be transported to the site by a bus from the Balgowlah Golf Course construction support site (BL10), where required. Following the completion of construction works, both the marine and land-based sites would be rehabilitated and landscaped.
Hours of construction	General site activities would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). Where possible concrete pours would be scheduled to take place within standard construction hours; however, the process of casting the tunnel elements may require some works outside of standard construction hours. Support works (immersion and installation) for the immersed tube tunnel installation would be required on six occasions for continuous periods lasting between 24 to 48 hours for each unit.
Access arrangements	Access in and out of the site would be via Spit Road. Barge access would also service this site.

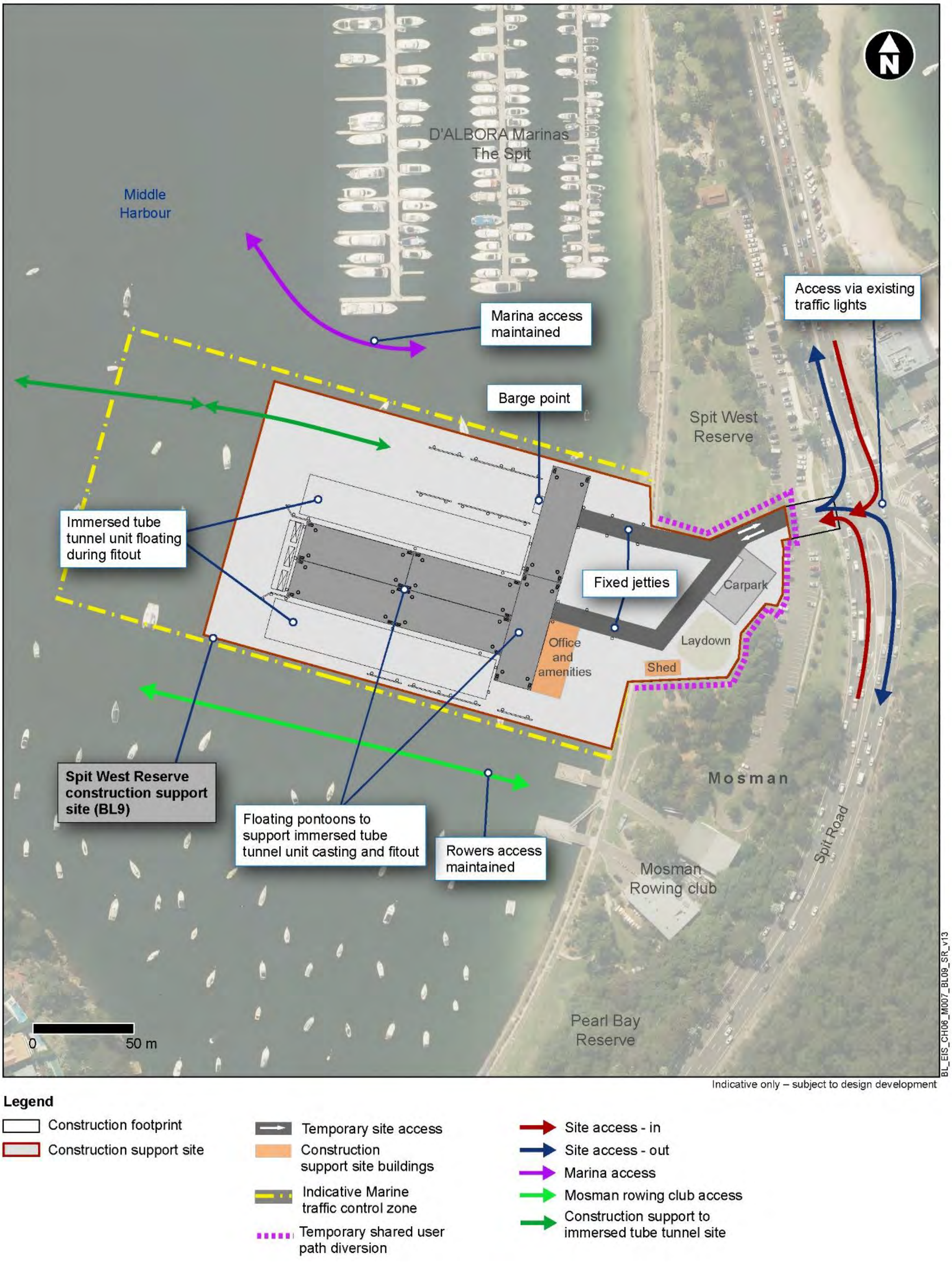
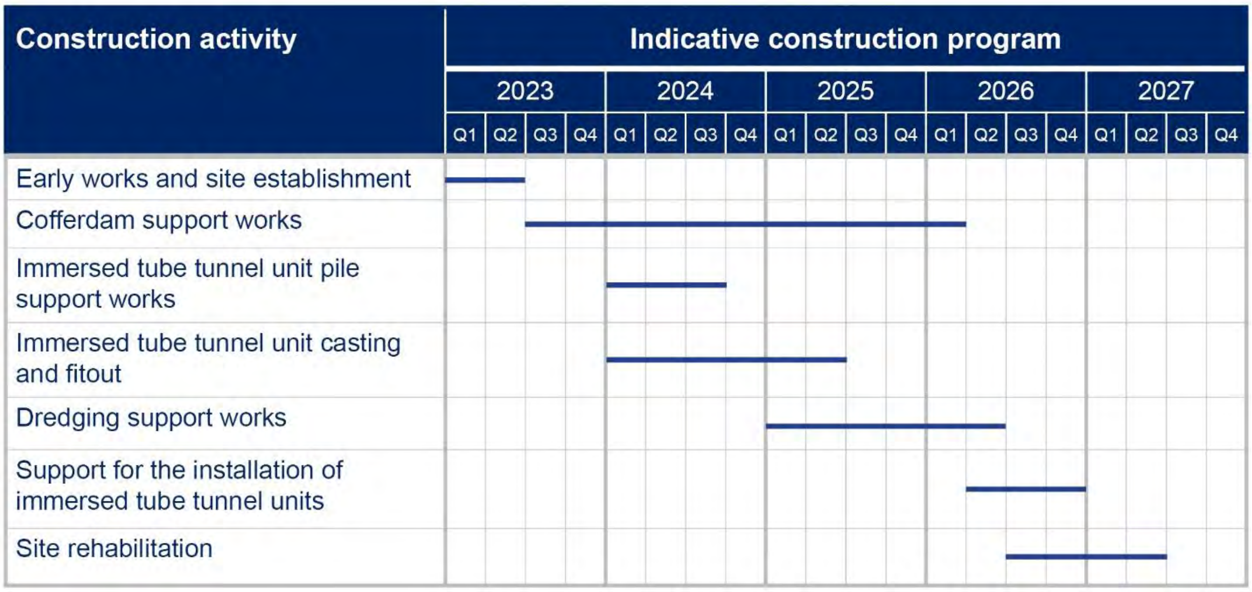


Figure 6-37 Indicative layout – Spit West Reserve construction support site (BL9)

Table 6-24 Spit West Reserve construction support site (BL9) indicative construction program



Balgowlah Golf Course (BL10)

A summary of the key features of the Balgowlah Golf Course construction support site (BL10) is included in Table 6-25. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-38. An indicative program for construction activities is provided in Table 6-26.

Table 6-25 Key features of the Balgowlah Golf Course construction support site (BL10)

Key feature	Summary
Site area	74,250 m^2
Site description	Located partially within Balgowlah Golf Course and on privately owned lots on Dudley Street.
Key activities	This would be a tunnel support site, surface works support site and project management site. Key activities that would occur on, or be supported by this site would include: • Demolition of existing structures • Construction and operation of temporary construction facilities, including an acoustic shed, temporary noise barriers, workshops, wastewater treatment facility, air intake, staff offices and amenities, pavements and car parking and concrete batch plant • Localised adjustment of a small section of Burnt Bridge Creek for road widening and existing culvert extension works • Construction of new and improved open space and recreation facilities (refer to Section 6.6 and Chapter 5 (Project description) for further detail). Construction would be staged and the final layout would subject to a dedicated consultation process with the community and jointly led by Transport for NSW and Northern Beaches Council

Key feature	Summary
	• Excavation of an access decline to the ramp tunnel alignment • Excavation of the tunnels and cross passages under Seaforth between Balgowlah and Middle Harbour • Treatment of wastewater from tunnelling activities • Excavation, handling and stockpiling of tunnel spoil • Support for tunnel fitout (driven and immersed tube tunnels) and finishing works • Utility works associated with surface works, the temporary construction site, and permanent operational infrastructure • Support for cut and cover works, trough works, surface works and road widening works at Burnt Bridge Creek Deviation and Sydney Road • Construction of a new access road between Burnt Bridge Creek Deviation and Sydney Road to provide connectivity between the project and Sydney Road and service future users of the new and improved open space and recreation facilities. This would include construction of new traffic lights at both the new Sydney Road and Burnt Bridge Creek Deviation intersections. A car park would also be constructed for users of the open space and recreation facilities • Construction of permanent operational facilities, including a ventilation outlet and motorway facilities • Additional support for construction of the immersed tube tunnels at the Spit West Reserve construction support site (BL9) • Construction of new active transport links through the new and improved open space and recreation facilities and along the widened section of Burnt Bridge Creek Deviation • Backfill of access decline • Testing, commissioning and site rehabilitation.
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Limited out of hours work would be required to stage traffic lanes during surface works construction, to minimise disruption to the road network and to ensure safety of road users, construction personnel and the public, and for delivery of oversized equipment. Tunnel construction and fitout would be carried out up to 24 hours per day, seven days per week either within an acoustic shed or underground. Night time deliveries would be required to support the tunnelling activities.
Access arrangements	Access in and out of the site would be via Burnt Bridge Creek Deviation and Sydney Road.

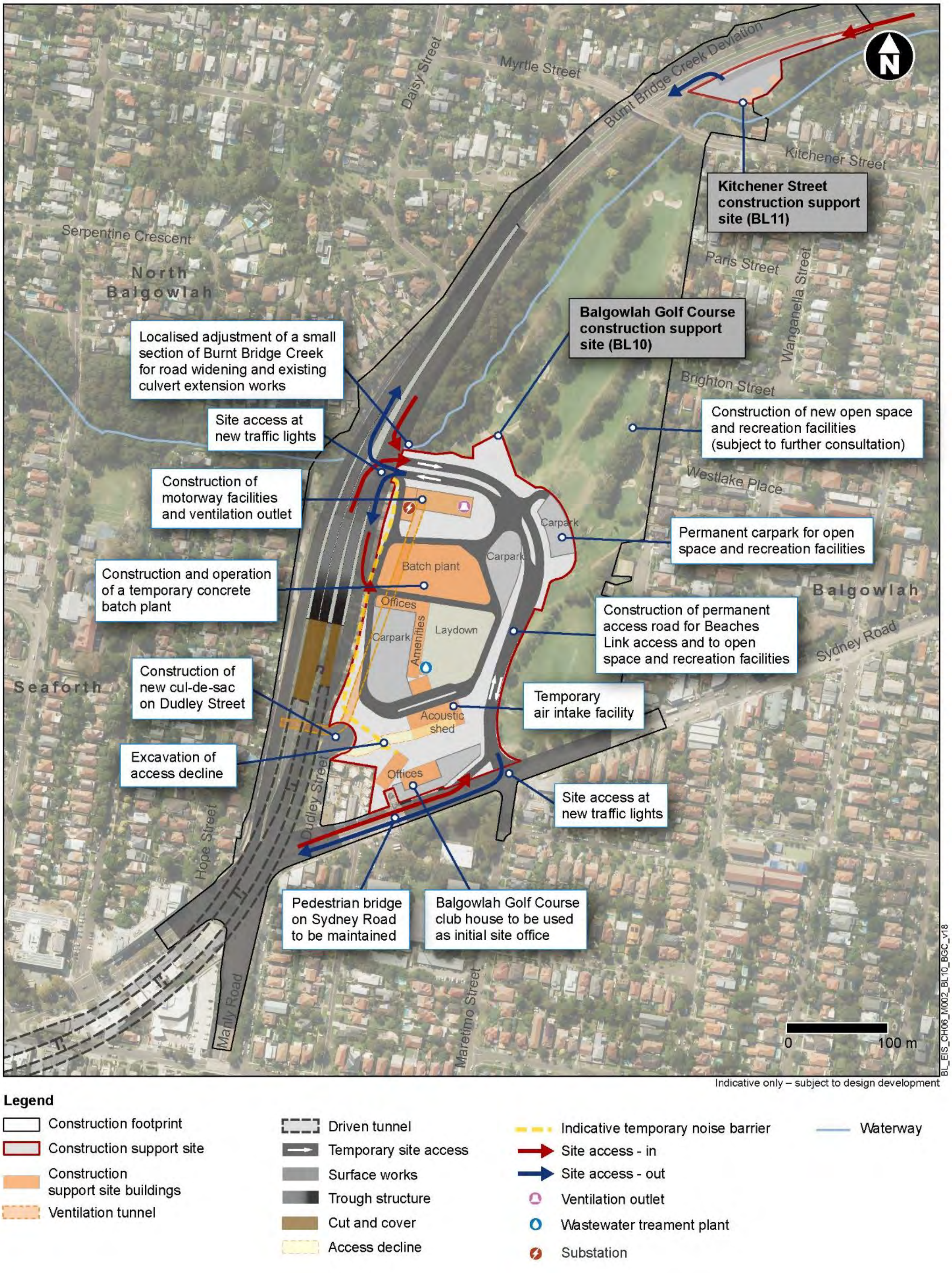
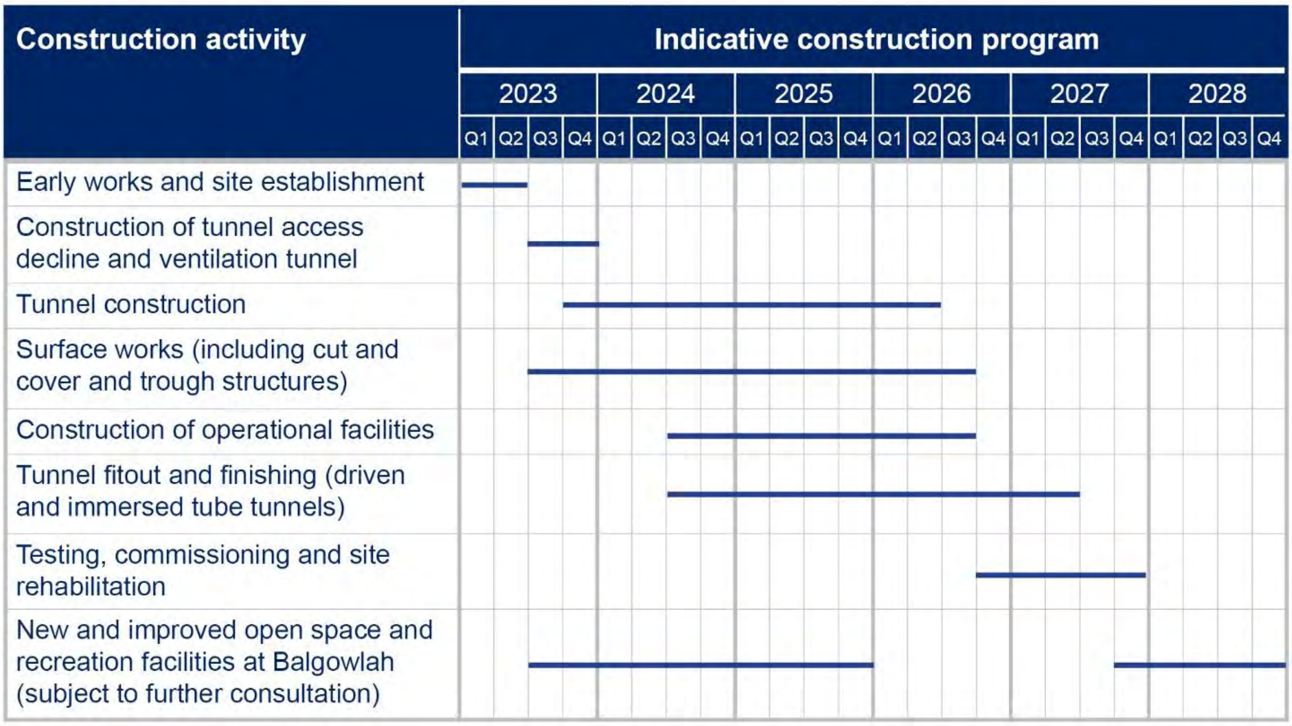


Figure 6-38 Indicative layout – Balgowlah Golf Course construction support site (BL10)

Table 6-26 Balgowlah Golf Course construction support site (BL10) indicative construction program



Kitchener Street (BL11)

A summary of the key features of the Kitchener Street construction support site (BL11) is included in Table 6-27. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-39. An indicative program for construction activities is provided in Table 6-28.

Table 6-27 Key features of the Kitchener Street construction support site (BL11)

Key feature	Summary
Site area	5400 m^2
Site description	Located next to Burnt Bridge Creek Deviation directly north of Kitchener Street bridge. The site is currently unoccupied and largely comprises cleared gravel space bordered by mature trees and shrubs. An adjacent property at 36 Kitchener Street is owned by Transport for NSW and is intended to be used by the project as a site office and amenities. The property is included within the construction footprint and should it be used as a site office, an access road would be provided to connect to the construction support site shown in Figure 6-38. This would be confirmed during further design development.
Key activities	The site would support the surface road works and utility relocation works along Burnt Bridge Creek Deviation.

Key feature	Summary
Hours of construction	General site activities would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays.
Access arrangements	Access in and out of the site would be via the existing southbound lanes of Burnt Bridge Creek Deviation. Limited access for light vehicles would be via Kitchener Street.

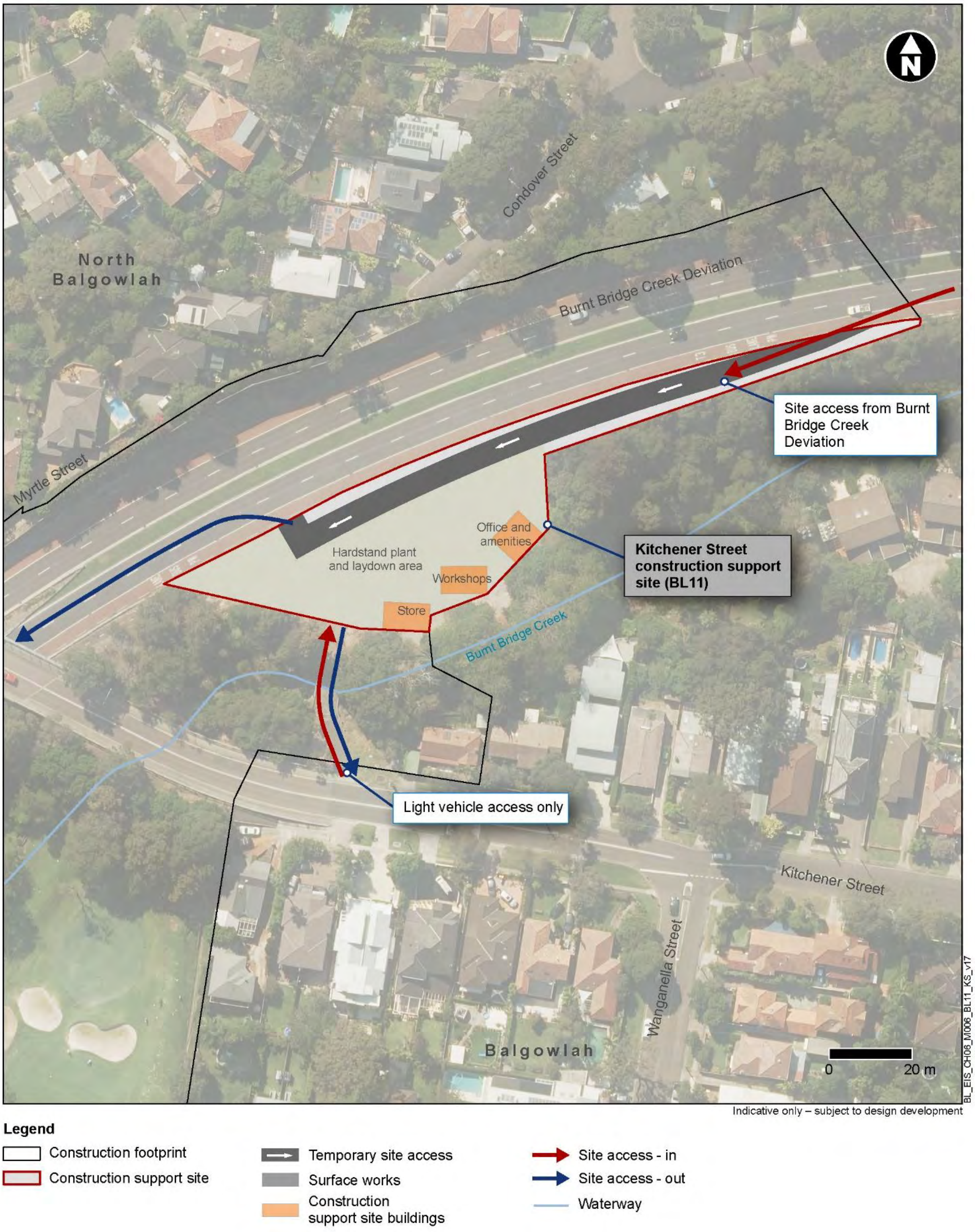
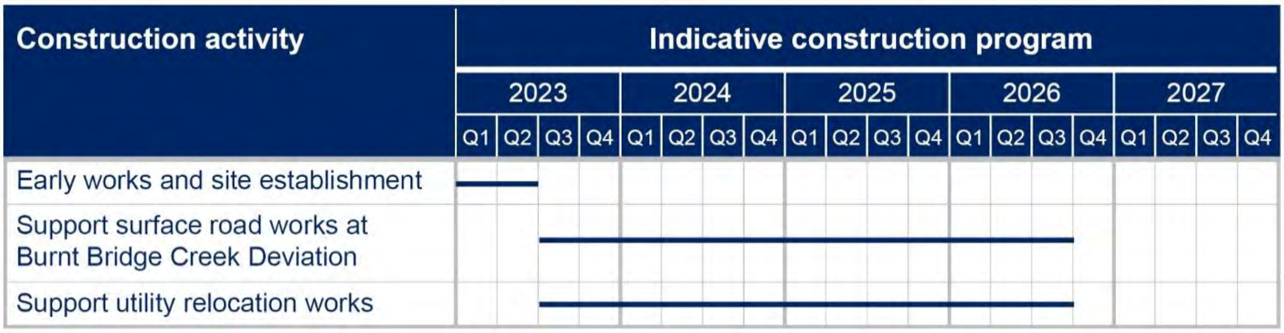


Figure 6-39 Indicative layout – Kitchener Street construction support site (BL11)

Table 6-28 Kitchener Street construction support site (BL11) indicative construction program



Wakehurst Parkway south (BL12)

A summary of the key features of the Wakehurst Parkway south construction support site (BL12) is included in Table 6-29. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-40. An indicative program for construction activities is provided in Table 6-30.

Table 6-29 Key features of the Wakehurst Parkway south construction support site (BL12)

Key feature	Summary
Site area	10,200 m^2
Site description	Located on the eastern side of Wakehurst Parkway just south of Judith Street and Kirkwood Street at Seaforth.
Key activities	Key activities that would occur on, or be supported by, this site would include: • Support site works including clearing and grubbing, topsoil stripping, bulk earthworks, minor retaining structures to reshape and regrade existing site • Construction and operation of temporary site facilities, including a workshops, staff offices and amenities, pavements and car parking • Support the upgrade of Wakehurst Parkway and also the construction of the cut and cover tunnel and trough and motorway facilities at Wakehurst Parkway • Supplementary office support for tunnelling works at Wakehurst Parkway east construction support site (BL13).
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Occasional works outside of standard hours to support traffic staging and switches on the Wakehurst Parkway and intersection modifications during site establishment may be required.
Access arrangements	Access in and out of the site would be via Judith Street and Kirkwood Street directly to the Wakehurst Parkway.

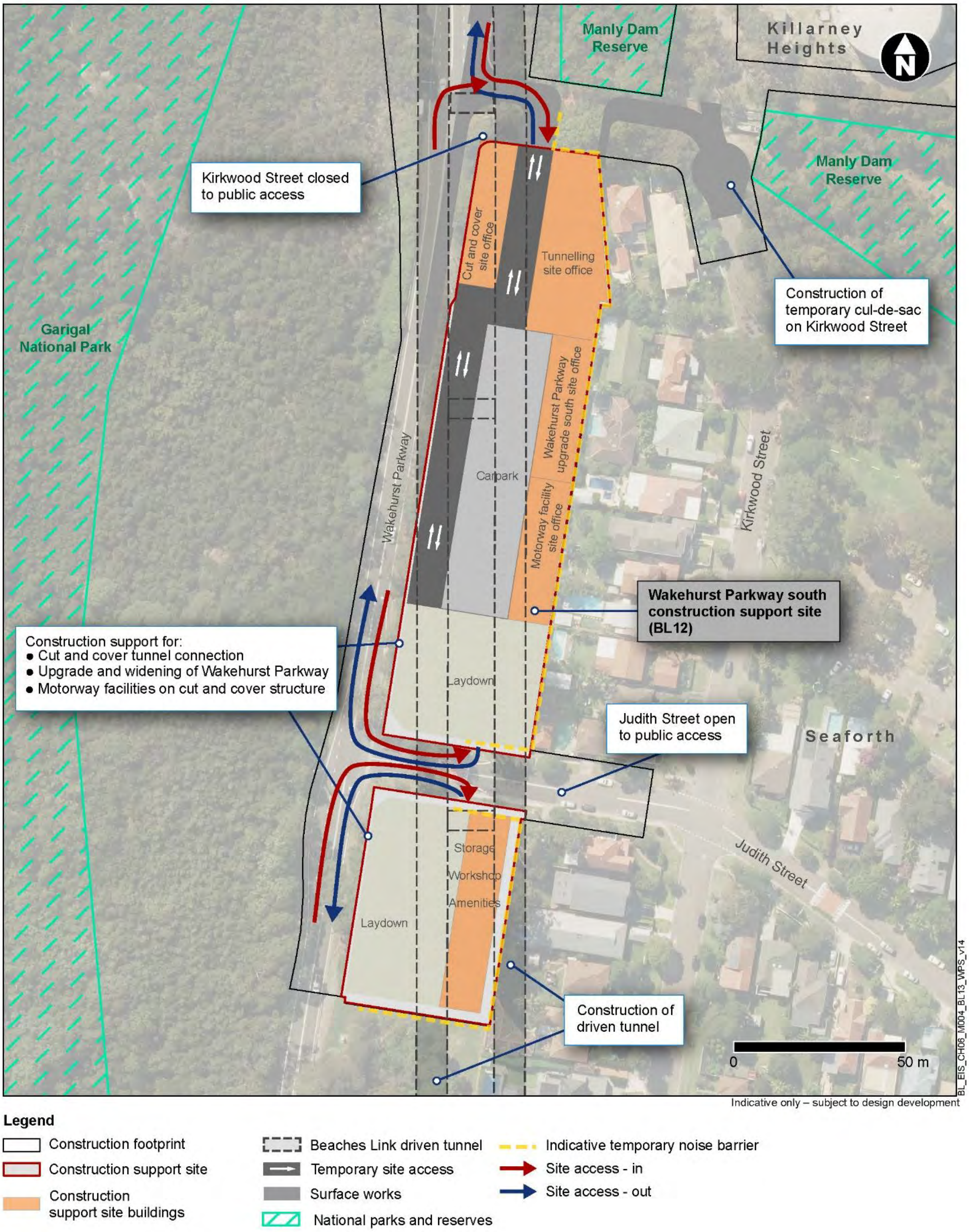


Figure 6-40 Indicative layout – Wakehurst Parkway south construction support site (BL12)

Table 6-30 Wakehurst Parkway south construction support site (BL12) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment	—	—																		
Surface road works support			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
Cut and cover and trough support			—	—	—	—	—	—	—											
Motorway facilities support										—	—	—	—	—	—	—				
Testing, commissioning and site rehabilitation																—	—	—	—	

Wakehurst Parkway east (BL13)

A summary of the key features of the Wakehurst Parkway east construction support site (BL13) is included in Table 6-31. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-41. An indicative program for construction activities is provided in Table 6-32.

Table 6-31 Key features of the Wakehurst Parkway east construction support site (BL13)

Key feature	Summary
Site area	11,000 m^2
Site description	Located on the eastern side of Wakehurst Parkway, on land within Sydney Water's Bantry Bay Reservoir site, next to the Wakehurst Parkway Golf Course. The site is mostly level and includes vegetated areas that would be cleared as part of the site establishment works. Sydney Water facility operations and the on-site Telstra tower would remain operational for the duration of the construction activities on the site. Existing driveways and services crossings would be upgraded as required to suit access for heavy vehicles.
Key activities	The Wakehurst Parkway east construction support site (BL13) would be a tunnel support site and project management site. The site would be used for the construction of Beaches Link tunnelled ramps between the Wakehurst Parkway and the mainline tunnels beneath Seaforth. Key activities that would occur on, or be supported by this site would include: • Support site works including clearing and grubbing, topsoil stripping, bulk earthworks, minor retaining structures to reshape and regrade existing site • Construction and operation of temporary construction facilities, including an acoustic shed, temporary noise barrier, workshop, wastewater treatment facility, air intake and staff offices and amenities, pavements and car parking • Excavation of an access decline • Construction of the Wakehurst Parkway tunnel ramps to mainline tunnels at Seaforth

Key feature	Summary
	• Treatment of wastewater from tunnelling activities • Support for tunnel fitout and finishing works • Utility works associated with surface works, the temporary construction site, and permanent operational infrastructure • Excavation, handling and stockpiling of tunnel spoil • Backfill of access decline • Testing, commissioning and site rehabilitation.
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Tunnel construction and fitout would be carried out up to 24 hours per day, seven days per week either within an acoustic shed or underground. Night time deliveries would be required to support the tunnelling activities.
Access arrangements	Access in and out of the site would be via a new temporary connection to the Wakehurst Parkway.

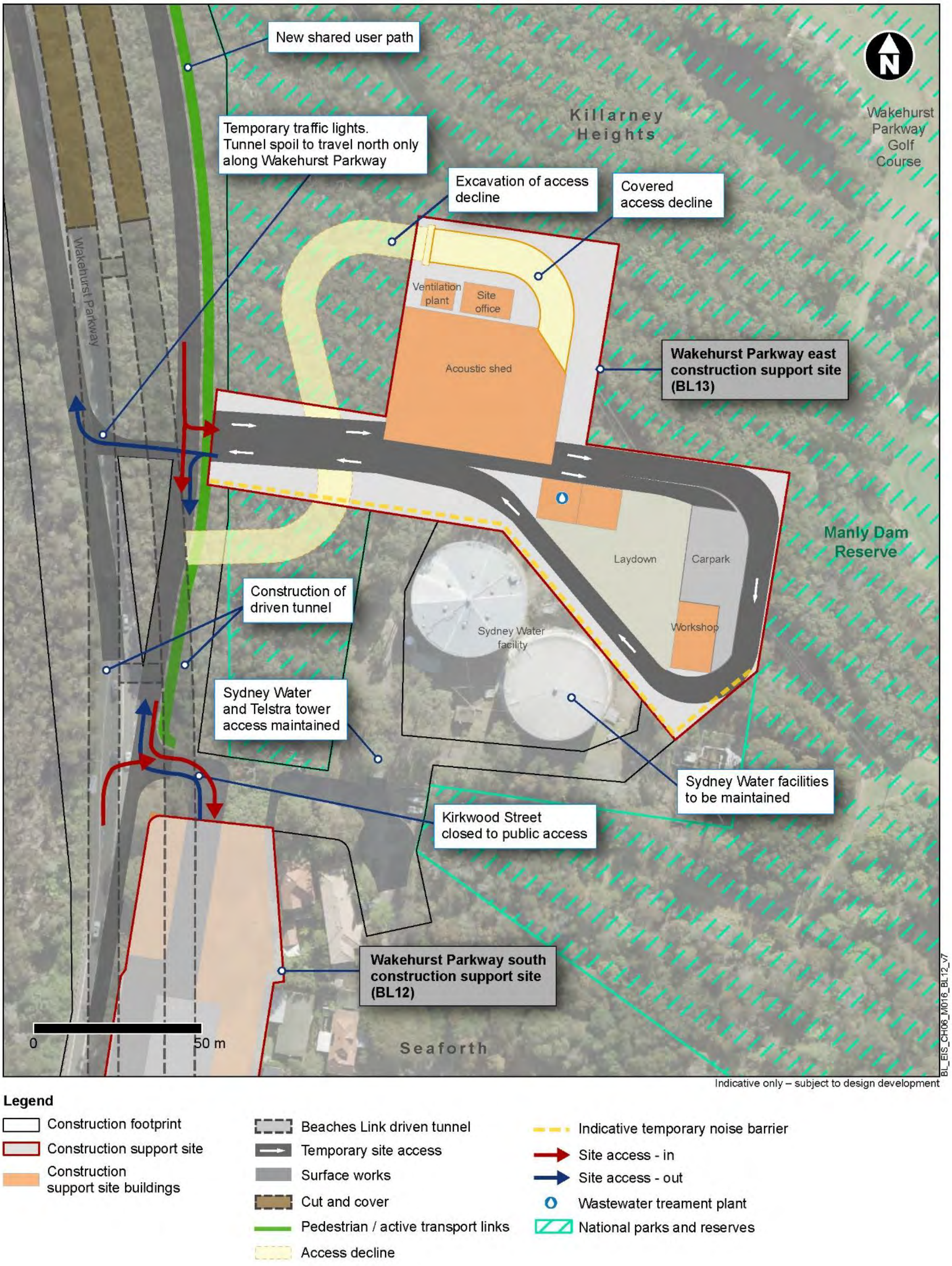
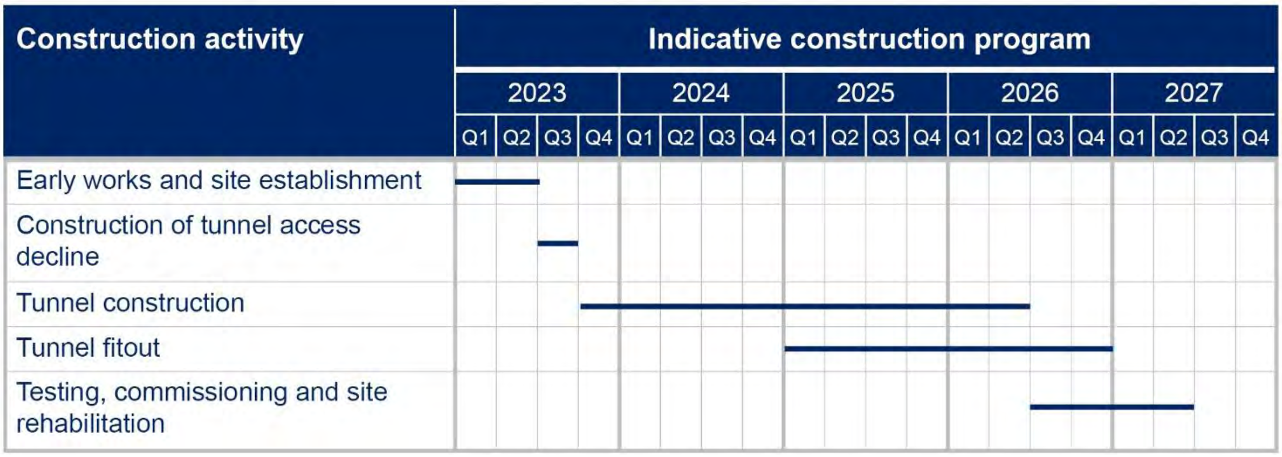


Figure 6-41 Indicative layout – Wakehurst Parkway east construction support site (BL13)

Table 6-32 Wakehurst Parkway east construction support site (BL13) indicative construction program



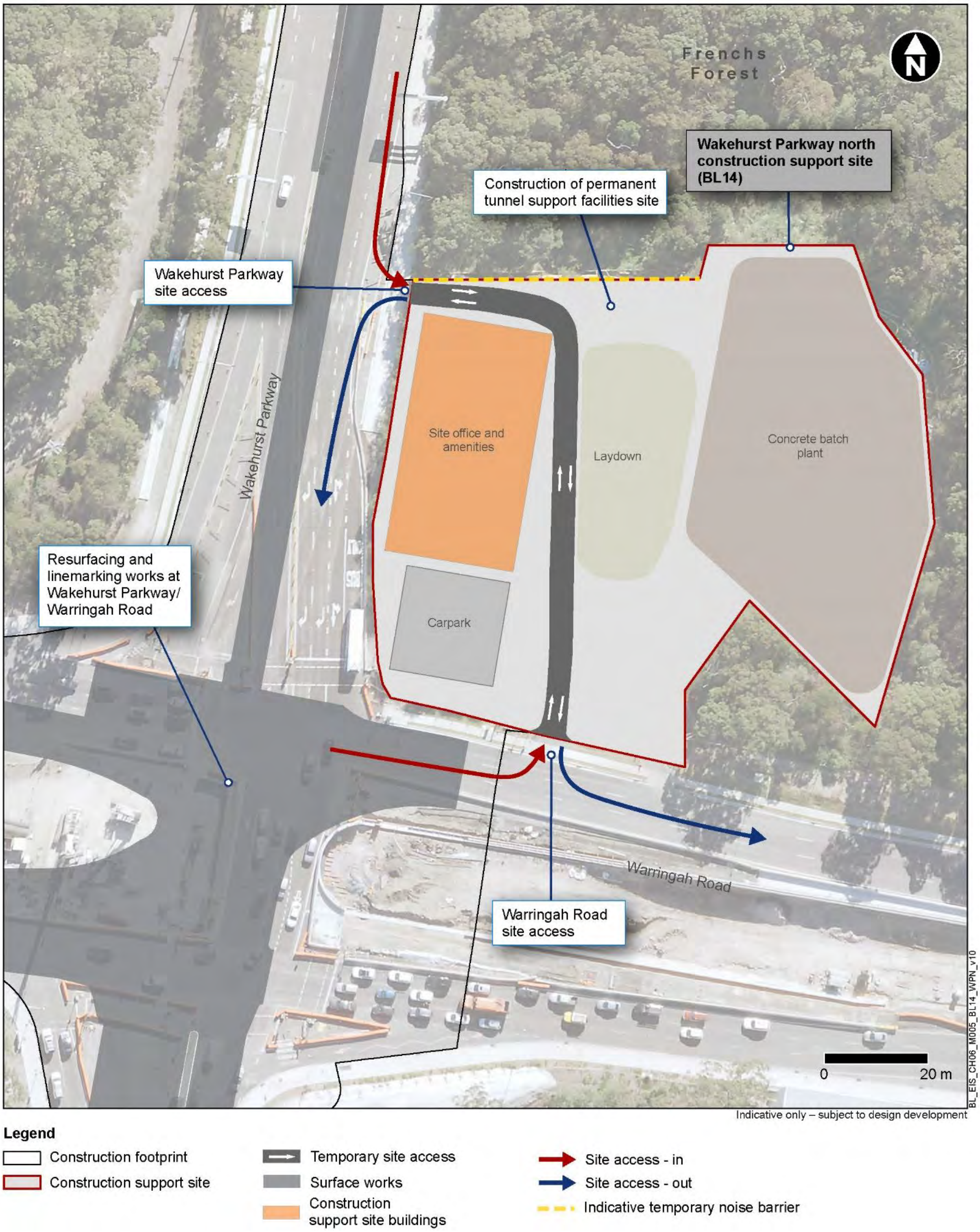
Wakehurst Parkway north (BL14)

A summary of the key features of the Wakehurst Parkway north construction support site (BL14) is included in Table 6-33. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-42. An indicative program for construction activities is provided in Table 6-34.

Table 6-33 Key features of the Wakehurst Parkway north construction support site (BL14)

Key feature	Summary
Site area	8400 m^2
Site description	The Wakehurst Parkway north construction support site (BL14) would be located on the north-east corner of the intersection between Wakehurst Parkway and Warringah Road at Frenchs Forest. The same site was used as the main construction support site for the Northern Beaches Hospital road upgrade project, which was completed in August 2020. Revegetation works were carried out within the Northern Beaches Hospital road upgrade project's main construction support site as part of decommissioning. This included planting with species consistent with the Duffys Forest endangered ecological community within the eastern section of the decommissioned construction support site. During site establishment of the Wakehurst Parkway north construction support site (BL14), this revegetated area would remain fenced off and protected from disturbance. Due to the timing of these recent revegetation works, the current site layout of Wakehurst Parkway north construction support site (BL14) does not show the revegetation area. During further design development and construction planning, the temporary construction support site layout would be refined to show the revegetation area, and ensure it is avoided and protected during construction.

Key feature	Summary
Key activities	Key activities that would occur on, or be supported by this site would include: • Construction and operation of temporary construction facilities, including a temporary noise barrier, workshop, staff offices and amenities, pavements and car parking and concrete batch plant • Construction works for Wakehurst Parkway surface road works, minor intersection works at Wakehurst Parkway/Warringah Road and Wakehurst Parkway/Frenchs Forest Road East and construction of the permanent tunnel support facilities.
Hours of construction	General site activities would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday and no construction works on Sundays or public holidays). Occasional night time deliveries to the site may be required. This site would support occasional night staging works that are necessary for upgrading Wakehurst Parkway between Seaforth and Warringah Road at Frenchs Forest.
Access arrangements	Access in and out of the site would be via Warringah Road. Access from the site would also be provided onto Wakehurst Parkway.



Note: The indicative layout does not show the revegetation area associated with the recent demobilisation of the Northern Beaches Hospital road upgrade project. During further design development and construction planning, the temporary construction support site layout would be refined to ensure the revegetated area is avoided and protected.

Figure 6-42 Indicative layout – Wakehurst Parkway north construction support site (BL14)

Table 6-34 Wakehurst Parkway north construction support site (BL14) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment	■	■																		
Surface road works			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
Construction of operational facilities											■	■	■	■	■	■	■	■		
Testing, commissioning and site rehabilitation																	■	■	■	■

6.9 Construction management and resources

6.9.1 Construction workforce and hours

Construction workforce

The project would be expected to support up to 7500 full time equivalent jobs (direct employment) during the five to six years of construction. About 2350 full time equivalent jobs (2000 for Beaches Link and 350 for the Gore Hill Freeway Connection) would be expected to be supported during peak construction.

Construction work hours

Construction work hours required for the project would generally fall within the following categories:

- Early works and site establishment
- Tunnelling, tunnelling support and underground activities
- Construction traffic for material supply and spoil movement
- Surface construction activities (not covered by the other categories)
- Blasting and rock breaking
- Other activities.

The proposed construction hours for various construction activities are provided in Table 6-35. Standard construction hours from the *NSW Interim Construction Noise Guideline* (DECC, 2009a) are:

- 7am to 6pm Monday to Friday
- 8am to 1pm Saturday
- No construction works on Sundays or public holidays.

Recent planning approval conditions for State significant infrastructure projects have included an extension to standard construction hours on Saturdays, allowing certain activities to be carried out until 6pm. This approval condition has been provided on other major infrastructure projects such as Sydney Gateway, M6 Motorway (Stage 1) and WestConnex M4-M5 Link. Should the project construction contractor elect to use this additional allowance on Saturdays to shorten the construction program and reduce the overall duration of impacts to amenity, site specific construction noise and vibration impact statements prepared for the project will assess any associated noise impacts and adopt appropriate noise mitigation measures accordingly.

Out of hours works would be carried out in specific circumstances at any time, subject to individual requirements for safety and public infrastructure operational reasons (ie to minimise traffic disruptions). Specific management measures would be developed for each relevant activity or group of activities to manage potential impacts on sensitive receivers (refer to Chapter 10 (Construction noise and vibration) for further details on management of out of hours work). This would include use of respite periods.

Table 6-36 to Table 6-38 provides the proposed out of hours work, locations and an indicative duration of the work outside standard construction hours required. The indicative duration may change as the further construction planning.

Indicative timeframes for construction activities are provided in Table 6-35. The proposed construction hours at each of the temporary construction support sites are summarised in Section 6.8.

Table 6-35 Proposed construction hours

Activity	Construction hours	Comments or exceptions
Early works and site establishment	Standard construction hours and works outside of standard construction hours	Works that require lane occupancy or are immediately adjacent to live traffic would be required outside of standard construction hours to minimise impacts to road users and for the safety of both construction personnel and the public.
Tunnelling, tunnelling support and underground activities		
Underground tunnel excavation and tunnel fitout	Up to 24 hours per day, seven days per week	Tunnelling using roadheaders would occur 24 hours per day, seven days a week, due to each excavation cycle taking around eight to 10 hours (dependent on geological conditions). Once complete, newly excavated sections need to be supported immediately to ensure the tunnel is stable and minimise any potential ground movement. This work cannot be completed entirely during a work shift in standard construction hours. Some other tunnel excavation activities using rock hammers might also need to occur outside standard construction hours for the above reasons.
Surface-based support of underground tunnelling, activities and tunnel fitout	Up to 24 hours per day, seven days per week	Surface-based activities at temporary construction support sites are typically required to support underground tunnelling and tunnel fitout. The support activities would need to occur 24 hours per day, seven days per week when tunnelling and tunnel fitout are occurring. Spoil handling outside of standard construction hours at the surface would be carried out within acoustic sheds at tunnel temporary construction support sites.
Dewatering of cofferdams during construction and filling	Standard construction hours and outside	Dewatering required to create a relatively dry and safe environment to allow the construction of the interface structures.

Activity	Construction hours	Comments or exceptions
of cofferdams during removal	standard construction hours	Pump operation is not expected to generate noise in excess of the applicable noise management level at any sensitive receiver.
Dredging and excavation of the bed of the harbour, and barge movements for associated marine spoil transportation	Standard construction hours	Dredging works would be carried out during daytime hours. Some transport by barge to the designated offshore disposal site may take place outside standard construction hours.
Piling works in Middle Harbour	Standard construction hours	Required for construction of the cofferdams and at the temporary mooring facility east of Clive Park in Middle Harbour. Impact piling in Middle Harbour would only take place one to two hours per day or five to six hours on a single day per week.
Barge movements for transport of immersed tube tunnel units	Standard construction hours and works outside of standard construction hours, for discrete periods	Barges to transport immersed tube tunnel units from the casting facility at the Spit West Reserve construction support site (BL9) to a temporary mooring east of Clive Park in Middle Harbour.
Immersed tube tunnel installation	Standard construction hours and works outside of standard construction hours, for discrete periods	Carried out during closures of Middle Harbour at the crossing location. Likely four partial closures (for outer units) and two full closures (for middle units), each for a continuous period for around 24 to 48 hours.
Fabrication of tunnel tube units	Standard construction hours and works outside standard construction hours for discrete periods	Fabrication of concrete tunnel units would typically occur during standard construction hours. However, some concrete pours might need to continue into the evening period where required to ensure appropriate concrete curing and the structural integrity of the fabricated concrete unit.
Construction traffic for material supply and spoil removal		
Construction traffic for material deliveries and spoil removal	Standard construction hours	Spoil haulage would be carried out during standard construction hours. Some deliveries to and from the temporary construction support sites would be required outside of standard construction hours.

Activity	Construction hours	Comments or exceptions
Surface construction activities		
Cut and cover, trough structures and bridgeworks	Standard construction hours and works outside of standard construction hours	These works would generally be scheduled during standard construction hours wherever feasible and reasonable. Works that require lane occupancy or are immediately adjacent to or above live traffic areas (eg bridge demolition and girder lifts) would be required outside standard construction hours to minimise potential disruption to the road network and to minimise potential safety risks to road users, construction personnel and the public
Demolition and surface construction activities including major surface road upgrades (including major traffic switches), infrastructure construction and utility relocations.	Standard construction hours and works outside of standard construction hours	Non-disruptive (low noise intensive) preparatory work, repairs or maintenance that does not generate noise in excess of the applicable noise management level at any sensitive receiver would be carried out outside standard construction hours. Works that require lane occupancy, are immediately adjacent to live traffic or involve substantial changes to lane configurations and traffic management arrangements would be carried out outside of standard construction hours to minimise impacts to road users as well as to ensure the safety of both construction personnel and the public. Key locations include: • Warringah Freeway • Gore Hill Freeway • Pacific Highway (near Dickson Avenue at Artarmon) • Flat Rock Drive • Burnt Bridge Creek Deviation and Sydney Road.

Activity	Construction hours	Comments or exceptions
Blasting and rock breaking		
Controlled blasting (underground and surface based along Wakehurst Parkway)	9am to 5pm Monday to Friday 9am to 1pm Saturdays No blasting on Sundays or public holidays	Controlled blasting may be used for cross passage excavation and bench removal in mainline and ramp tunnels, and excavation and surface works along Wakehurst Parkway (refer to Section 10.6.15). Controlled blasting might also be adopted along Wakehurst Parkway to minimise the duration over which traditional excavation methods for rock (eg rock hammers) would be required.
Rock breaking and other high impact noise activities	Standard construction hours, and outside of standard construction hours	Respite periods described in *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016) would be provided and scheduled. Rock breaking and other high impact noise activities that require lane occupancy or are immediately adjacent to live traffic would be required outside of standard construction hours to minimise impacts to road users as well as to ensure the safety of both construction personnel and the public
Other activities		
Minor activities	At any time	Includes activities that do not generate noise in excess of the applicable noise management level at any noise sensitive receiver.
Works that require road occupancy licences	At any time (typically outside standard construction hours)	Works on busy roads typically must occur under a road occupancy licence issued by the Transport Management Centre. Road occupancy licences specify the allowable working hours and typically require the road works to occur outside standard construction hours when traffic volumes are low. Road occupancy licences can also require works to occur over multiple consecutive nights.
Activities authorised by an environment protection licence	As specified in the environment protection licence (can include works outside standard construction hours)	Construction activities would be managed as required by an environment protection licence issued by the NSW Environment Protection Authority.
Emergency or directed activities	At any time	Activities carried out if required to prevent an imminent injury, loss of life or environmental damage.

Table 6-36 Surface road works – works outside standard construction hours

Work area	Indicative duration	Indicative percentage of work days on which work outside standard construction hours required
Warringah Freeway surface road works and associated use of Cammeray Golf Course construction support site (BL1)	1 year 6 months	10%
Gore Hill Freeway Connection surface road works and associated use of Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6) construction support sites	4 years	10%
Upgrade of Pacific Highway/Dickson Avenue intersection and surface road works and associated use of Dickson Avenue construction support site (BL4)	3 months	30%
Balgowlah surface road works and associated use of Balgowlah Golf Course construction support site (BL10)	3 years	10%
Wakehurst Parkway surface road works and associated use of Wakehurst Parkway south (BL12) and Wakehurst Parkway north (BL14) construction support sites	3 years 3 months	10%
Widening of Flat Rock Drive and associated use of Flat Rock Drive construction support site (BL2)	6 months	30%
Create site access for Wakehurst Parkway east construction support (BL13) and road/intersection modification during site establishment	6 months	10%

Table 6-37 Middle Harbour crossing – works outside standard construction hours

Activity	Indicative duration	Indicative works outside standard construction hours
Dewater cofferdams	1 year 9 months	Continuous pump operation is required during initial dewatering of each cofferdam and then as required once dewatered.
Cast and fitout of immersed tube tunnel units at Spit West Reserve construction support site (BL9)	1 year 6 months	Occasional concrete pours would extend into evening period depending on technical and quality requirements.
Installation of immersed tube tunnel units and associated use Spit West Reserve construction support site (BL9)	9 months	One continual work period of around 48 hours is required for the immersion of each of the six tunnel units. Use of Spit West Reserve construction support site (BL9) outside standard construction hours would be required to provide support each time.
Decommissioning and refill of cofferdams	6 months	Continuous pump operation during to refill of each cofferdam is required prior to commencement of cofferdam removal.

Table 6-38 Surface-based support of underground tunnelling and tunnel fitout activities outside standard construction hours

Temporary construction support site	Indicative duration	Indicative works outside standard construction hours
Cammeray golf course construction support site (BL1)	2 years	Low noise impact activities 24 hours per day, seven days a week while underground tunnel activities are occurring.
Flat Rock Drive construction support site (BL2)	3 years 9 months	Low noise impact activities 24 hours per day, seven days a week during underground tunnel activities are occurring.
Punch Street construction support site (BL3)	2. years 6 months	Low noise impact activities 24 hours per day, seven days a week during underground tunnel activities are occurring.
Balgowlah Golf Course construction support site (BL10)	3 years 9 months	Low noise impact activities 24 hours per day, seven days a week during underground tunnel activities are occurring.
Wakehurst Parkway east (BL13) construction support site	3 years 3 months	Low noise impact activities 24 hours per day, seven days a week during underground tunnel activities are occurring.

6.9.2 Traffic management and access

Road transport

The construction of the project would be subject to comprehensive traffic management measures to ensure the ongoing functionality of surrounding roads, and the safety of members of the public, motorists and construction personnel.

A number of stages of traffic management and traffic switches would be required around the tunnel connections and for Wakehurst Parkway surface road works to facilitate the construction of the on and off ramps and tie-ins to arterial and local roads. Traffic staging at the Gore Hill Freeway Connection would be fundamental to enable access for surface works to be carried out and is likely to require works outside of standard construction hours. Signage would be installed for road closures or detours, where required, to facilitate traffic movement.

Controlled blasting may be required along sections of the Wakehurst Parkway. Controlled blasts would not take place during peak hour traffic periods and not on Sundays or public holidays. Traffic near the area would be stopped while the controlled blast is initiated and delays of up to 10 minutes may be experienced. Traffic control measures and advanced signage would be in place to notify vehicles using Wakehurst Parkway of any proposed controlled blasting.

The project would also necessitate the temporary alteration of pedestrian and cyclist facilities, although alternative access arrangements would be implemented around construction sites and access points. Appropriate detour routes would be established, utilising existing cycle routes and paths where feasible.

The proposed access points to and from the temporary construction support sites are described in Section 6.8 and shown in figures for each temporary construction support site. Where possible, site access points have been configured to provide access directly to and from arterial roads.

Over-size and over-mass vehicles would be required for the delivery and removal of large plant and equipment on discrete occasions. There would be a higher proportion of these movements during site establishment and site closure, as large plant and equipment (such as roadheaders) are moved to and from site respectively.

Peak construction daily light vehicle and heavy vehicle numbers associated with spoil and waste removal, material deliveries and arrival and departure of construction works are summarised in Table 6-39.

Potential traffic and transport impacts from the construction of the project, and measures which address these impacts, is provided in Chapter 8 (Construction traffic and transport).

Table 6-39 Peak construction vehicle movement and access

Site	Proposed access route	Daily heavy vehicle movements[1]	Daily light vehicle movements	Construction vehicle movements during AM peak hours (6am to 10am)		Construction vehicle movements during PM peak hours (3pm to 7pm)	
				Heavy vehicles	Light vehicles	Heavy vehicles	Light vehicles
Cammeray Golf Course (BL1)	Warringah Freeway Ernest Street	275	305	72	99	73	142
Flat Rock Drive (BL2)	Flat Rock Drive	545	355	145	165	146	136
Punch Street (BL3)	Cleg Street Punch Street Gore Hill Freeway	370	580	110	222	87	203
Dickson Avenue (BL4)	Dickson Avenue	90	500	40	160	8	132
Barton Road (BL5)	Reserve Road	35	120	5	45	10	45
Gore Hill Freeway median (BL6)	Gore Hill Freeway Epping Road	10	100	2	20	0	21
Spit West Reserve (BL9)	Spit Road	220	200	60	71	60	86
Balgowlah Golf Course (BL10)	Burnt Bridge Creek Deviation Sydney Road	495	1195	149	429	119	460
Kitchener Street (BL11)	Burnt Bridge Creek Deviation	10	65	2	27	2	25
Wakehurst Parkway south (BL12)	Judith Street Kirkwood Street	15	285	6	119	1	102

Site	Proposed access route	Daily heavy vehicle movements[1]	Daily light vehicle movements	Construction vehicle movements during AM peak hours (6am to 10am)		Construction vehicle movements during PM peak hours (3pm to 7pm)	
				Heavy vehicles	Light vehicles	Heavy vehicles	Light vehicles
Wakehurst Parkway east (BL13)	Wakehurst Parkway	275	305	72	99	73	142
Wakehurst Parkway north (BL14)	Warringah Road Wakehurst Parkway	95	180	29	58	26	52

Note 1: Vehicle movements are each way (ie a heavy/light vehicle arriving at a site and leaving a site counts as two movements).

Construction workforce car parking

A portion of the project's labour force would be required to drive and park at temporary construction support sites. The numbers of construction personnel requiring parking would vary over the duration of the construction program.

Due to the generally constrained nature of temporary construction support sites, only limited car parking for construction workers would be available on site. Car parking areas would be provided at the following temporary construction support sites:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Dickson Avenue (BL4)
- Barton Road (BL5)
- Spit West Reserve (BL9)
- Balgowlah Golf Course (BL10)
- Kitchener Street (BL11)
- Wakehurst Parkway south (BL12)
- Wakehurst Parkway east (BL13)
- Wakehurst Parkway north (BL14).

The number of car parking spaces at the above temporary construction support sites would be determined during construction planning. Shuttle bus transfers between temporary construction support sites would also be provided, where required.

The construction workforce would be encouraged to use public transport (except where construction personnel are required to travel to site with construction-related tools and equipment). The public transport provisions available near the project to provide access to temporary construction support sites include:

- Military Road/Spit Road, the Pacific Highway, Epping Road, Eastern Valley Way, Frenchs Forest Road, Warringah Road and Condamine Street/Pittwater Road are key bus corridors near the project with multiple bus routes that would provide access to temporary construction support sites along the project
- Artarmon Station and North Sydney Station on the Sydney Trains suburban train network would provide access to construction sites around Artarmon and Cammeray respectively.

Measures to manage any potential parking impacts during construction are discussed in Chapter 8 (Construction traffic and transport).

Property access

At locations where temporary and/or permanent road closures are required, access to properties would be maintained or alternative arrangements made in agreement with the affected stakeholder(s). For further details on property impacts refer to Chapter 20 (Land use and property).

Marine transport

Marine construction vessels would be required during construction. Figure 6-43 shows the main routes which would be used during construction. Table 6-40 details the indicative type and number of marine transport and construction vessels likely to be used during construction. Refer to Chapter 8 (Construction traffic and transport) for discussion on maritime navigation during construction.

Table 6-40 Marine-based construction vessel movements

Site	Indicative vessel movements per day at peak
Between Spit West Reserve construction support site (BL9) and Middle Harbour south (BL7) and Middle Harbour north (BL8) cofferdams	• Twelve small boats movements for transporting construction workforce • Four barge movements for support of cofferdam dredging, piling and tube tunnel immersion • Three barge movements for disposal of dredged material to sea • 48 barge movements for concrete deliveries.

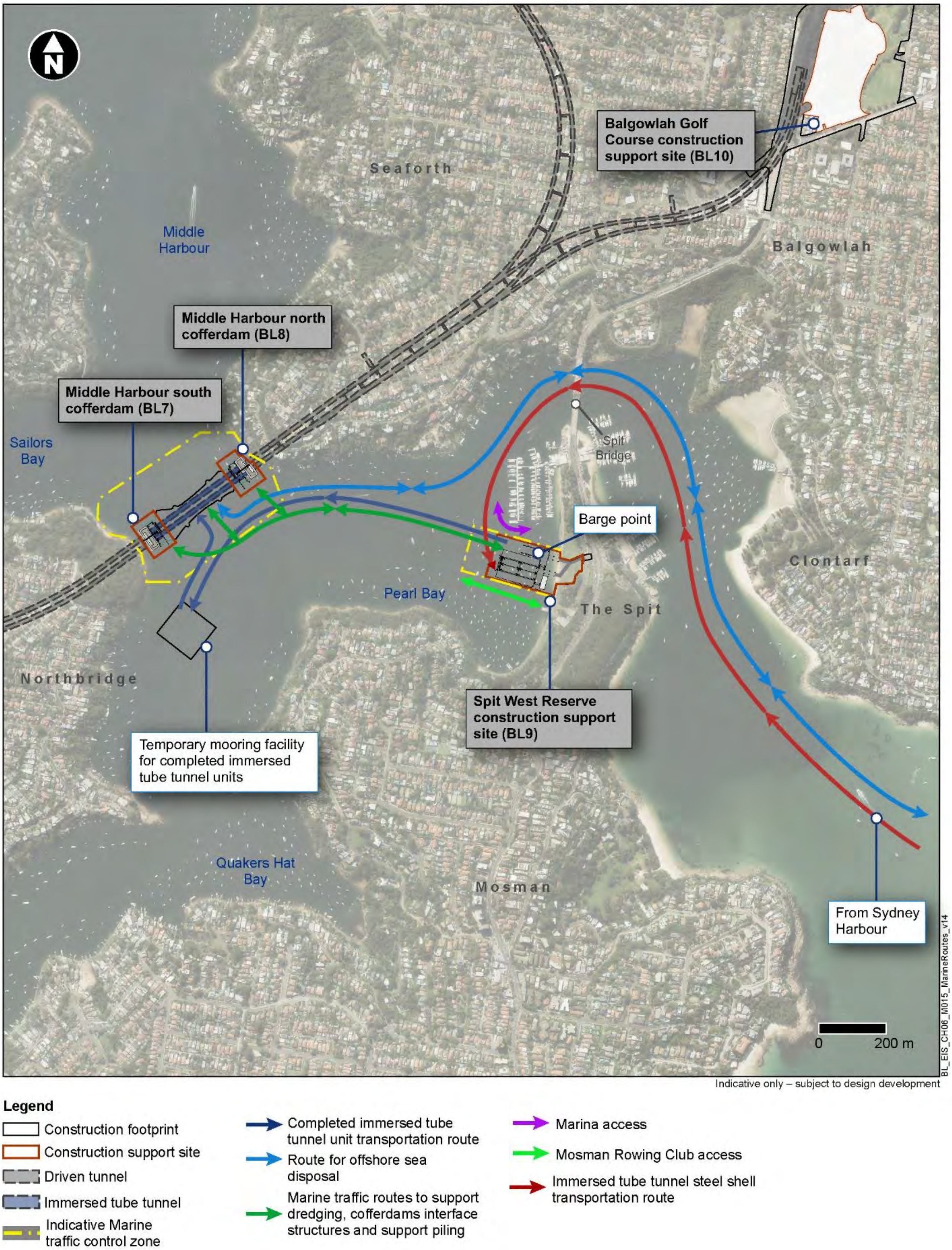


Figure 6-43 Marine transport and construction vessel routes in Middle Harbour

6.9.3 Construction plant and equipment

The plant and equipment listed in Table 6-41 are likely to be used during construction of the project. The final list of plant and equipment required for each construction activity would depend on the final construction methodology developed by the construction contractor.

Table 6-41 Indicative construction plant and equipment

Plant and equipment	Early works	Site establishment	Construction of driven tunnels	Installation of immersed tube tunnels	Construction of operational facilities	Tunnel fitout and finishing works	Surface road works	Testing, commissioning and demobilisation
Vacuum truck	X						X	
Grader, excavator, excavator with rock hammer	X	X	X	X	X		X	
Bulldozer		X					X	
Backhoe, bobcat, front end loader	X	X	X		X	X	X	X
Chainsaw[1]		X					X	
Grinder, mulcher[1]		X					X	X
Forklift		X	X			X		
Elevated work platform, scissor lift		X		X	X	X	X	X
Light tower[2]				X			X	
Mobile crane[2]	X	X	X	X	X	X	X	X
Light vehicle	X	X	X	X	X	X	X	X
Dump truck, cement delivery truck, concrete agitator	X	X	X	X	X	X	X	X
Truck	X	X	X		X	X	X	X
Linemarking truck		X					X	
Pavement laying machine		X				X	X	
Vibratory roller, compactor		X					X	
Power generator				X	X	X	X	X
Compressor		X	X	X	X		X	
Jackhammer[1]				X		X	X	
Rock crusher[1]							X	

Plant and equipment	Early works	Site establishment	Construction of driven tunnels	Installation of immersed tube tunnels	Construction of operational facilities	Tunnel fitout and finishing works	Surface road works	Testing, commissioning and demobilisation
Concrete saw[1]	X					X	X	
Concrete pump, concrete vibrator		X	X	X	X	X	X	
Concrete batch plant			X	X	X	X	X	
Hand tools, welding equipment	X	X	X	X	X	X	X	X
Piling rig (bored)[1]		X	X		X		X	
Piling rig (impact)[1]				X			X	
Drilling machine (diesel)			X					
Pneumatic hammer/vibrator[1]			X			X		
Shotcrete rig			X				X	
Air track drilling rig[1]			X				X	
Roadheader			X					
Dust scrubber			X					
Ventilation fan		X	X					
Water cart		X				X	X	X
Road sweeper			X			X	X	X
Barge, small boat, tugboat			X	X				
Flat top barge				X				
Mooring pontoon				X				
Dredging equipment				X				

Note 1: Refers to high noise generating equipment

Note 2: Refers to plant and equipment likely to generate a visual impact

6.9.4 Construction resources and waste management

Construction resource use

Construction would require various resources and materials. The main construction materials required would include:

- General fill and select fill for earthworks (sourced from within the project cutting and from tunnel spoil where the material is available and of suitable quality)
- Pavement materials, cement, concrete and steel reinforcement

- Materials for lining drainage channels
- Aggregate used for concrete and asphalt
- Water
- Pre-cast concrete including pipes, culvert segments, bridge elements, retaining wall elements and roadside barriers
- Structural steel
- Plastics used for drainage, piping and conduits
- Pre-fabricated steel and road furniture units
- Wood for use in formwork and other temporary structures.

Construction material would generally be sourced from off-site suppliers. Where reasonable and feasible, local sources of construction materials would be preferred to minimise haulage distances.

Indicative quantities of the main sources of materials required for construction are provided in Chapter 24 (Resource use and waste management).

Construction power requirements

Power supply would be required during the construction works at the majority of temporary construction support sites. In particular, high voltage power would be required at the tunnel support sites. Prior to the connection of mains power supply to the tunnel support sites, roadheaders may be powered by diesel generators.

The power supply for each site would be sourced from outside the project area. The power supply requirements for temporary construction support sites is described in Chapter 24 (Resource use and waste management). Potential supply source, supply route and power demand is described in Appendix D (Utilities management strategy).

Construction water requirements

Tunnelling works would require substantial volumes of water for excavation and would generate wastewater requiring treatment and disposal.

Construction water supply would also be required for tunnel connection construction and surface activities, including earthworks, concreting, building construction and dust suppression. Additional information about construction water requirements is provided in Chapter 24 (Resource use and waste management).

Suitable connections for water discharge from wastewater treatment plants at temporary construction support sites would be required at:

- Cammeray Golf Course (BL1) – to Willoughby Creek
- Flat Rock Drive (BL2) – to a drainage pit on Flat Rock Drive then to Flat Rock Creek
- Punch Street (BL3) – to Flat Rock Creek near Station Street at Artarmon
- Balgowlah Golf Course (BL10) – to Burnt Bridge Creek
- Wakehurst Parkway east (BL13) – to a drainage channel to be formed at the eastern section of the site (which would drain towards a Wakehurst Golf course dam for reuse by the golf course).

Further details are provided in Chapter 17 (Hydrodynamics and water quality).

Spoil and waste management

The project is estimated to generate a substantial volume of spoil from tunnelling, surface works, and dredging operations. Spoil generation and dredged material from each temporary construction support site is provided in Chapter 24 (Resource use and waste management).

Excess spoil that cannot be reused within the project would require offsite disposal. The final destination(s) for excess spoil from construction of the project would be planned prior to construction commencing.

The majority of the spoil generated by the project would be virgin excavated natural material (VENM) – typically consisting of crushed sandstone and shale. VENM is generally considered a desirable material for clean and stable fill in development sites and major earthworks projects across Greater Sydney. Recent examples include the use of crushed sandstone from Sydney Metro to construct runway pavements for the new Western Sydney Airport, and reuse of crushed sandstone from the WestConnex tunnels for numerous development projects.

An application for offshore disposal of suitable dredged material will be submitted to the Australian Government Department of the Agriculture, Water and the Environment under the *Environment Protection (Sea Dumping) Act 1981*. It is proposed that suitable dredged material would be transported by barge and disposed of at a designated offshore disposal site (in accordance with legislative requirements). These sites have been carefully selected by the Commonwealth to provide suitable disposal grounds for dredge material and minimise impacts on sensitive marine ecology. The designated offshore disposal site is over 20 square-kilometres in area and is a non-dispersive ground, meaning that material placed within the area generally does not migrate from that area. Any material not suitable for offshore disposal would be barged to a loadout facility for treatment to be made spadable and then loaded onto trucks and disposed of at a suitably licensed land-based facility and classified according to the NSW Environment Protection Authority's *Waste Classification Guidelines* (NSW EPA, 2014a).

Any contaminated material disturbed during construction would be separated from uncontaminated material on site to prevent cross contamination. Contaminated material would be encapsulated on site where appropriate, and in accordance with relevant regulatory requirements. Any material that is not suitable for encapsulation would be loaded into sealed and covered trucks for disposal at a suitably licensed facility. Further site investigations during the further design development and construction planning phases would inform contamination management including determining where encapsulation is appropriate. Other waste streams which would be generated during construction include:

- Demolition waste from existing structures and properties
- General construction waste such as concrete, steel and timber formwork off-cuts
- Vegetation waste from clearing and grubbing
- Plant and vehicle maintenance waste such as oils and lubricants
- General office waste such as paper, cardboard, plastics and food waste
- Sewage waste.

Further details are provided in Chapter 24 (Resource use and waste management) including potential opportunities for reuse.

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 7

Stakeholder and community engagement

7 Stakeholder and community engagement

This chapter provides an overview of the stakeholder and community engagement activities carried out during the project's development and during the preparation of this environmental impact statement. An overview of engagement and consultation tools which would be used to support the public exhibition of this environmental impact statement and during delivery of the project is also provided.

The Secretary's environmental assessment requirements as they relate to stakeholder and community engagement, and where in the environmental impact statement they have been addressed, are detailed in Table 7-1.

Table 7-1 Secretary's environmental assessment requirements – Stakeholder and community engagement

Secretary's requirement	Where addressed in EIS
Consultation	
1. The project must be informed by consultation, including with relevant local, State and Commonwealth government agencies (including the Harbour Master where disturbance of seabeds, shipping channel closures or marine movement of materials/spoil are proposed), infrastructure and service providers, special interest groups (including Local Aboriginal Land Councils, Aboriginal stakeholders, and pedestrian and bicycle user groups), affected landowners, businesses and the community.	A summary of consultation carried out to date is provided in **Section 7.1** and **Section 7.2**. A summary of feedback received is provided in **Section 7.3**. A summary of project refinements in response to feedback is provided in **Section 7.4**. Project refinements have also been considered in **Chapter 5** (Project description).
2. The Proponent must document the consultation process, and demonstrate how the program has responded to the inputs received.	The consultation process is documented in **Section 7.1** and **Section 7.2**. A summary of the feedback received and how the feedback has been addressed is provided in **Section 7.3**. A summary of project refinements in response to feedback is also provided in **Section 7.4**. Project refinements have also been considered in **Chapter 5** (Project description).
3. The Proponent must describe the timing and type of community consultation proposed during the design and delivery of the project, the mechanisms for community feedback, the mechanisms for keeping the community informed, and procedures for complaints handling and resolution.	The engagement timeline is provided in **Section 7.1.2**. Ongoing and future engagement for the project is outlined in **Section 7.5**. A detailed Community communication strategy would be developed and implemented during delivery of the project. This would be based on the community consultation framework provided in **Appendix E** (Community consultation framework). Mechanisms for distributing information and seeking feedback, and procedures for complaints handling and resolution are provided in

Secretary's requirement	Where addressed in EIS
	Appendix E (Community consultation framework).
4. The Proponent must assess the potential for complaint fatigue to occur during construction of the project and describe how mitigation measures, complaint handling procedures and community consultation mechanisms will mitigate complaint fatigue. The assessment must consider the cumulative impacts from the program and other major projects in the area.	The potential for complaint fatigue to occur and proposed mitigation measures are described in **Section 7.5**. Complaint handling procedures are outlined in **Appendix E** (Community consultation framework). Potential cumulative impacts from the project are considered in **Chapter 27** (Cumulative impacts).
Socio-economic, Land Use and Property	
6. A draft Community Consultation Framework must be prepared identifying relevant stakeholders, procedures for distributing information and receiving/responding to feedback and procedures for resolving stakeholder and community complaints during construction and operation. Key issues that must be addressed in the draft Framework include, but are not limited to: a. traffic management (including property access, pedestrian access); b. landscaping/urban design matters; c. construction activities including out of hours work; and d. noise and vibration mitigation and management.	A Community consultation framework is provided in **Appendix E**. The content of the framework is summarised in **Section 7.5**.

7.1 Engagement and consultation process

Consultation forms a key component of engagement. For the purpose of this document, the definitions of consultation and engagement are provided in Table 7-2**Error! Reference source not found.**, in line with International Association of Public Participation definitions.

Table 7-2 Engagement and consultation definitions

Term	Definition
Engagement	In this document, engagement refers to any type of interaction with the community or stakeholders and is also used to refer to the community and stakeholder engagement program holistically. Engagement includes communication, consultation, notification and education.
Consultation	In this document, consultation refers to the level of engagement of a specific activity. Specifically where the term consultation has been used, this describes the process where the aim of the engagement is to obtain public and community feedback on a matter and use this information for project development.

7.1.1 Engagement objectives and strategy

The engagement process aims to provide opportunities for community and stakeholder involvement throughout all phases of the project. To achieve this, the following engagement objectives have been applied:

- Provide clear, consistent and timely information about the project to stakeholders and the community
- Provide communications in a variety of mediums
- Promote and raise awareness of the project and engagement activities being carried out
- Foster and develop positive and meaningful relationships with stakeholders and the community
- Identify opportunities for community and stakeholder groups to be proactively involved in the project
- Collaborate with the community and stakeholders to help shape the design of the project at each key development phase
- Address and respond to community and stakeholder issues raised in a timely and transparent manner
- Use lessons learnt from other major infrastructure projects to improve on community and stakeholder engagement
- Meet the statutory requirements for consultation under the *Environment Planning and Assessment Act 1979*
- Meet the Secretary's environmental assessment requirements.

Community and stakeholder engagement has been an integral component in the development of the project and the Western Harbour Tunnel and Beaches Link program of works more widely. The engagement process has proactively informed and engaged stakeholders and community members during project development. This approach aimed to increase public understanding of the project, encourage participation in the development process, and promote the benefits of the project to local communities and stakeholders. The project has benefited from the input of local knowledge, insight, experience, goals and priorities and learnings from other major infrastructure projects, which has helped to identify issues, potential mitigation strategies and opportunities to improve project outcomes.

7.1.2 Engagement timeline

Engagement for the Beaches Link and Gore Hill Freeway Connection project was carried out by Transport for NSW as part of the engagement process for the wider Western Harbour Tunnel and Beaches Link program of works. Engagement with key government and other project stakeholders, including Port Authority of NSW, Sydney Metro, Infrastructure NSW, Greater Sydney Operations (including Transport Management Centre and Sydney Coordination Office) (within Transport for NSW) and Northern Beaches B-Line, has occurred since early 2016 to help shape the design and plan investigations. Engagement with the community and broader stakeholders commenced in March 2017 and has continued through to the preparation of this environmental impact statement.

Community and stakeholder engagement has been carried out in accordance with the Secretary's environmental assessment requirements. A summary of the community and stakeholder engagement process and timeline for the project is shown in Figure 7-1.

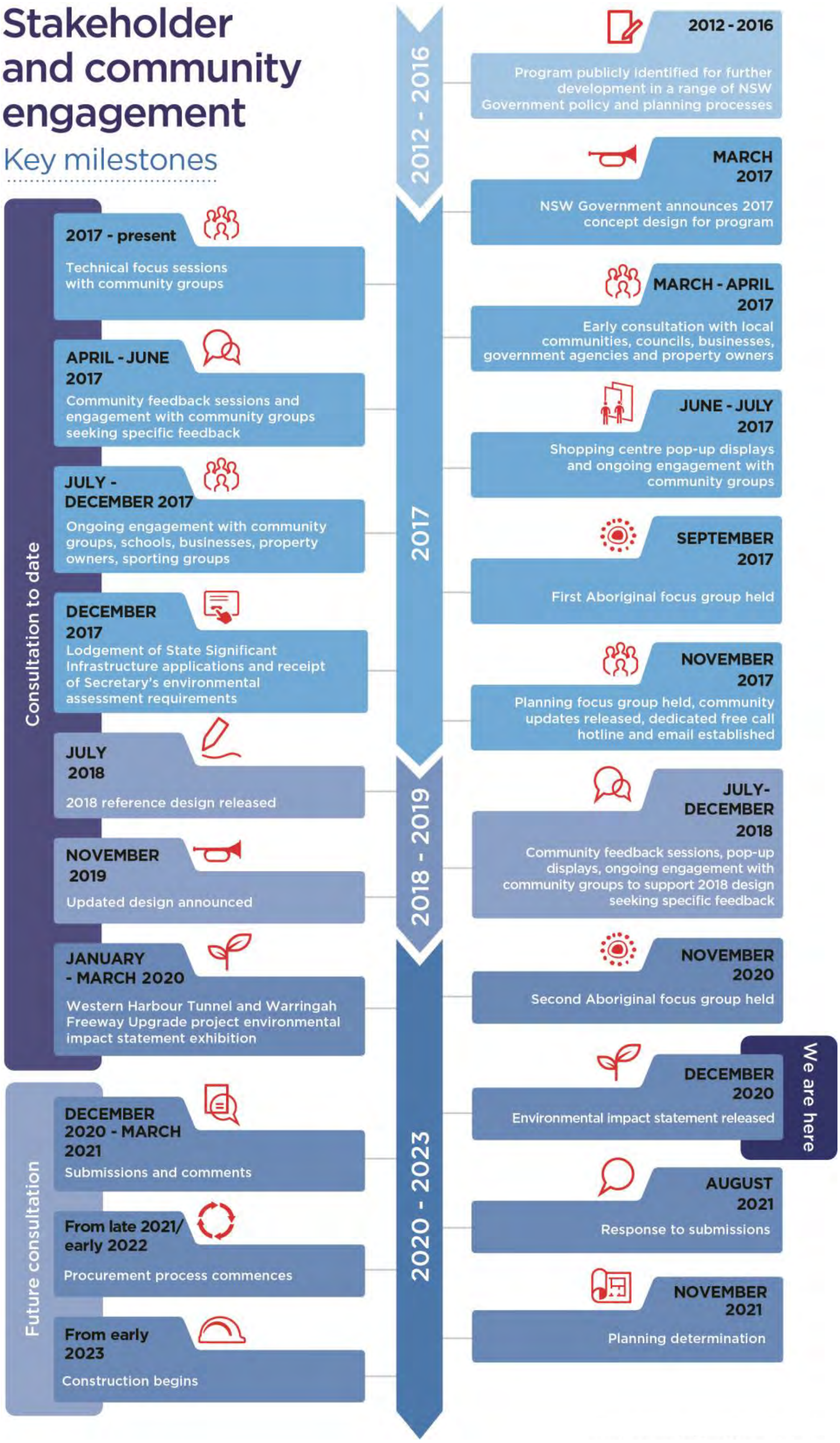


Figure 7-1 Beaches Link and Gore Hill Freeway Connection project community and stakeholder engagement process

7.1.3 Stakeholders

Stakeholders were identified through consideration of the project's potential direct and indirect impacts and from records of previous correspondence with relevant government bodies, business groups and community groups. Engagement has included ongoing liaison and consultation with the following stakeholder groups:

- Government Ministers and elected representatives
- Australian and NSW government agencies
- Local councils
- Property owners and residents along and near the alignment
- Members of the community
- Community service providers
- Business and industry groups
- Education, health and sporting facilities along or near the alignment
- Local precinct committees and/or resident action groups
- Marine stakeholders and waterway users
- Aboriginal groups and the Metropolitan Local Aboriginal Land Council (LALC)
- Pedestrians and cyclists
- Service and utility providers.

7.1.4 Engagement and consultation tools

A variety of two-way consultation and communication tools have been used to provide information to the community, providing a range of opportunities for the community to be consulted and involved throughout the project's development.

Communication and consultation tools established for the project include:

- Toll free community information line (1800 931 189)
- Project email (whtbl@transport.nsw.gov.au (previously whtbl@rms.nsw.gov.au))
- Project website (nswroads.work/whtbl)
- Interactive project portal (nswroads.work/blportal)
- Project database to record correspondence relevant to the project, including contact details and issues raised during the life of the project
- Community update newsletters, fact sheets, and letters to residents
- Guide to the environmental impact statement
- Community information sessions including virtual information sessions, information displays and staffed displays at local shopping centres
- Registered stakeholder database email updates
- Stakeholder briefings, meetings, workshops, and presentations
- Interest group correspondence including letters and phone calls
- Face-to-face meetings and doorknocks with individual property owners and residents of properties which may be affected by the project

- Advertisements and proactive media articles in the local press
- Letterbox drops
- Translating and Interpreting services for Culturally and Linguistically Diverse (CALD) communities (131 450)
- Media events at key milestones of the project.

These tools would be used to support the public exhibition of this environmental impact statement and during further design development and delivery of the project (subject to COVID-19 requirements).

Due to COVID-19 restrictions, staffed displays and face to face community information sessions of the environmental impact statement are not proposed to occur during the exhibition period. However this requirement will be reviewed if restrictions are eased and safety controls allow. In order to ensure that adequate opportunities are available for the community to ask questions on the content of the environmental impact statement, Transport for NSW will be running virtual information sessions throughout January and February 2021. Transport for NSW will continue to investigate the opportunity for face to face community information sessions provided COVID-19 guidelines allow.

Details of the times and topics for the virtual information sessions, as well as any potential face to face community information sessions, would be provided through the project website, email notifications to registered stakeholders, community updates, and advertisements in local and metropolitan media.

7.2 Engagement activities to date

An extensive community engagement process has been carried out for the project before exhibition of the environmental impact statement. This has included two rounds of formal public consultation for the Western Harbour Tunnel and Beaches Link program of works:

- Between April and June 2017 following the announcement of the concept design
- Between July and December 2018 following the publishing of the proposed reference design.

Between 29 January and 30 March 2020, the Department of Planning, Industry and Environment placed the Western Harbour Tunnel and Warringah Freeway Upgrade project environmental impact statement on public exhibition for feedback. As part of this process, various community engagement activities were carried out. Although the purpose of the engagement was to support the Western Harbour Tunnel and Warringah Freeway Upgrade project, community enquiries about the Beaches Link project were also responded to by members of the project team.

In addition to these formal engagement periods, engagement and consultation with stakeholders has been ongoing throughout the project's development, with the project team holding numerous workshops and meetings with councils, community groups and other stakeholders. The following provides a summary of engagement activities carried out to date.

7.2.1 Australian, NSW and local government agencies

Engagement and consultation has been carried out with key Australian, NSW and local government agencies as summarised in

Table 7-3. Feedback on specific environmental, technical and socio-economic matters provided by government stakeholders has informed the design development of the Beaches Link and Gore Hill Freeway Connection project.

Table 7-3 Consultation with Australian, NSW and local government agencies

Stakeholder	Timeframe	Engagement topics/activities
Other divisions of Transport for NSW (eg Sydney Trains)	2016 – present	• Various project updates to different functional areas across the Transport cluster to maintain coordinated planning across projects and operations • Northern Beaches B-Line and bus service coordination and future network planning post completion of the Western Harbour Tunnel and Beaches Link program of works • Consultation with Greater Sydney Operations (including Transport Management Centre and Sydney Coordination Office) in carrying out site investigations • Planning sessions with Greater Sydney Operations (including Transport Management Centre and Sydney Coordination Office) to plan traffic management during construction and operation • Site visit to the Traffic Management Centre to discuss and observe existing operation of the Warringah Freeway, the Sydney Harbour Bridge, Warringah Road, Military Road and other critical road links to understand how key adjoining transport corridors perform during peak traffic demand periods • North Sydney public transport integration and transport planning • Transport integration working group • North Sydney Integrated Transport Program working group • Health, safety and environmental briefings • Marine construction overview to understand implications for marine traffic • T1 North Shore and Western Line and T9 Northern Line underground interface.
Sydney Metro	2016 – present	• Sydney Metro City & Southwest tunnel design and construction coordination • North Sydney public transport integration and precinct planning.
Department of Planning, Industry and Environment (Crown Lands)	2017 – present	• General project overview and updates.
Metropolitan LALC	2017 – present	• Regular meetings and correspondence to provide project briefings and seek feedback • Correspondence with CEO, Metropolitan LALC, regarding location of sites in Artarmon, Northbridge, Wakehurst Parkway and Balgowlah • Involvement of site officers in archaeological surveys and field surveys

Stakeholder	Timeframe	Engagement topics/activities
		• Involvement of site officers in survey, recording and condition assessment of cultural heritage close to the construction footprint, including site adjacent to the Wakehurst Parkway.
Australian Government Department of Agriculture, Water and the Environment	2017 – present	• General project overview and updates • Consultation regarding the potential for offshore disposal of dredged material at the designated offshore disposal site • Development of testing plans and permit applications.
Australian Government Department of Infrastructure, Transport, Regional Development and Communications	2017	• General project overview and update.
Infrastructure Australia	2017 – present	• General project overview and updates.
Department of Planning, Industry and Environment (Planning and Assessment)	2017 – present	• General project overview and updates • Warringah Freeway and Gore Hill Freeway concept overview presentation • Frenchs Forest precinct planning and transport integration • Planning focus session on lodgement of State Significant Infrastructure application • Western Harbour Tunnel and Beaches Link program of works site tour to understand design and key challenges • Western Harbour Tunnel and Beaches Link program of works construction methodology, noise, vibration and spoil management presentation.
Greater Sydney Commission	2017 – present	• Multiple project overview and update meetings • North Sydney precinct and transport planning sessions • Frenchs Forest precinct planning • Land use and employment assumptions for design development.
Government Architect NSW	2017 – present	• Project overviews and updates • North Sydney Integrated Transport Program working group • Reference Design Urban Design review panel.
Port Authority of NSW	2017 – present	• Regular project updates and briefings • Stakeholder sessions prior to geotechnical investigations in Sydney Harbour and Middle Harbour • Simulation with Sydney Harbour Pilots undertaken at Brisbane Smartship facility for transporting immersed

Stakeholder	Timeframe	Engagement topics/activities
		tube tunnel units into Middle Harbour and through the Spit Bridge • Development of Harbour Master's conditions for proposed dredging, cofferdams, immersed tube tunnel construction and general marine logistics within Sydney Harbour and Middle Harbour • Planning focus meeting on lodgement of State Significant Infrastructure application.
NSW Urban Growth (now Infrastructure NSW from July 2019)	2016 – present	• Project overviews and updates • Planning focus meeting on lodgement of State Significant Infrastructure application.
NSW Small Business Commissioner	2018	• Project briefing/update.
Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources)	2017 – present	• General project overview and updates • Agency briefings on terrestrial biodiversity, freshwater and contamination, marine water (hydrodynamics and dredging) • Marine ecology survey and water quality testing • Consultation for the development of the project application for offshore disposal of dredged material • Planning focus meeting on lodgement of State Significant Infrastructure application.
NSW Environment Protection Authority (EPA)	2017 – present	• General project overview and updates • Marine ecology survey and water quality testing • Planning focus meeting on lodgement of State Significant Infrastructure application • Western Harbour Tunnel and Beaches Link program of works construction methodology, noise, vibration and spoil management presentation • Consultation for the development of the project application for offshore disposal of dredged material • Briefing to the Advisory Committee on Tunnel Air Quality (ACTAQ). Members of the committee were provided the air quality technical report and health impact assessment for review and comment.
Infrastructure NSW	2016 – present	• Multiple project overview and update sessions • Multiple reviews by Infrastructure NSW on various aspects on the design and construction aspects of the project • Review of environmental and community impacts, mitigation and assessment process • Planning focus meeting on lodgement of State Significant Infrastructure submission.
NSW National Parks and Wildlife Services	2017	• Planning focus meeting on lodgement of State Significant Infrastructure application.

Stakeholder	Timeframe	Engagement topics/activities
Department of Premier and Cabinet (Environment, Energy and Science)	2016 – present	• Multiple project overview and update sessions • Planning focus meeting on lodgement of State Significant Infrastructure application • Agency briefings on terrestrial biodiversity, freshwater and contamination, marine water (hydrodynamics and dredging).
Department of Premier and Cabinet (Heritage)	2017	• Planning focus meeting on lodgement of State Significant Infrastructure application • Agency briefings on Aboriginal heritage and non-Aboriginal heritage.
NSW Treasury	2016 – present	• Multiple project overview and update sessions • Planning focus meeting on lodgement of State Significant Infrastructure application • Regular engagement via Western Harbour Tunnel and Beaches Link program of works steering committees.
Sydney Harbour Federation Trust	2017	• Planning focus meeting on lodgement of State Significant Infrastructure application.
Ministry of Health	2017 – present	• Planning focus meeting on lodgement of State Significant Infrastructure application • Project update during environmental impact statement development • Briefing to the Advisory Committee on Tunnel Air Quality. Members of the committee were provided the air quality technical report and health impact assessment for review and comment.
NSW Chief Scientist & Engineer	2017 – present	• Project overview and update session • Planning focus meeting on lodgement of State Significant Infrastructure application • Joint public consultation on approach to Western Harbour Tunnel and Beaches Link air quality and ventilation outlet locations • Briefing to the Advisory Committee on Tunnel Air Quality. Members of the committee were provided the air quality technical report and health impact assessment for review and comment.
Northern Beaches Council	2017 – present	• Project briefings and updates, including briefings on geotechnical investigations, project design, potential project impacts and temporary construction support sites, noise, air quality, future land use after the project is complete and the development of the environmental impact statement • Discussion of feedback from the local community • Planning focus meeting on lodgement of State Significant Infrastructure application.

Stakeholder	Timeframe	Engagement topics/activities
Willoughby City Council	2017 – present	• Project updates on geotechnical work planning, potential project impacts, temporary construction support sites, noise, air quality, future land use after the project is complete and the development of the environmental impact statement • Discussion of feedback from the local community • Planning focus meeting on lodgement of State Significant Infrastructure application.
Mosman Council	2017 – present	• Project updates on the project design, potential project impacts and temporary construction support sites, noise, air quality, and the development of the environmental impact statement • Planning focus meeting on lodgement of State Significant Infrastructure application.
Lane Cove Council	2017 – present	• Project updates on the development of the design, construction methodology, active transport connections, motorway facilities, ventilation outlets, tunnel entry and exit points, spoil transport, tunnel depth and alignment, potential community impacts, air quality, and the development of the environmental impact statement • Planning focus meeting on lodgement of State Significant Infrastructure application.
North Sydney Council	2017 – present	• Updates on tunnel design, project justification, urban design, community engagement process, public transport integration, ventilation outlet locations, air quality and monitoring, potential impacts to Cammeray Golf Course, active transport and pedestrian connections, opportunities and potential impacts to the North Sydney area, and the development of the environmental impact statement • North Sydney Integrated Transport Program working group • North Sydney urban design workshops to discuss potential impacts and proposed mitigation measures – particularly at and around temporary construction support sites and permanent facilities • Planning focus meeting on lodgement of State Significant Infrastructure application.
City of Sydney Council	2017	• General project overview and update.

7.2.2 Utility providers

Engagement and consultation has been carried out with utility providers through activities including briefings, meetings and ongoing technical engagement. These activities provided:

- An overview of the Western Harbour Tunnel and Beaches Link program of works including the proposed design and construction method
- Discussions about the possible impact on utility assets
- Discussion and development of potential relocation and protection strategies
- An opportunity to provide feedback and discuss any issues or concerns.

Providers that have been engaging with the Beaches Link and Gore Hill Freeway Connection project team include:

- Ausgrid
- Jemena
- Telstra
- Sydney Water.

Feedback from these utility providers has informed the design for utility relocation and/or protection, where applicable.

7.2.3 Aboriginal stakeholders

Consultation with Aboriginal stakeholders was carried out in accordance with requirements outlined in Chapter 15 (Aboriginal cultural heritage) of this environmental impact statement.

Table 7-4 provides a summary of engagement and consultation activities carried out. Refer to Appendix L (Technical working paper: Aboriginal cultural heritage assessment report) for further details on Aboriginal stakeholder engagement.

Table 7-4 Consultation with Aboriginal stakeholders

Stakeholder	Summary
National Native Title Tribunal	Contacted to identify any registered native title claimants of native title holders for the options assessment area. No registered native title claimants were identified in relation to the study area.
Aboriginal site officers	Aboriginal site officers nominated by the Metropolitan LALC were present for archaeological surveys, recording and condition assessment of cultural heritage.
• Department of Premier and Cabinet (Heritage) • NSW Aboriginal Land Council • Metropolitan LALC • Aboriginal Heritage Office • Registrar appointed under the *Aboriginal Land Rights Act 1983* • National Native Title Tribunal	Organisations were written to during June and July 2017 seeking the details of Aboriginal people who may have an interest in the project and who may hold cultural knowledge about objects and places in the study area.

Stakeholder	Summary
• Native Title Services Corporation Limited • Northern Beaches Council • North Sydney Council.	
Aboriginal Focus Group	Identified Aboriginal stakeholders (registered Aboriginal parties) were contacted by letter and advertisement and invited to attend focus group meetings to discuss the project and received comment on the draft archaeological survey methodology. The first Aboriginal Focus Group was held in September 2017. A second Aboriginal Focus Group was held in November 2020 to outline the findings of the Aboriginal cultural heritage assessment and seek feedback from registered Aboriginal parties.

7.2.4 Business stakeholders

A business survey was carried out to gain a better understanding of the main issues, perceptions and concerns of businesses in regard to construction and operation of the project. Surveys were conducted during a three-week period in November 2017 in nine local centres that may be susceptible to direct or indirect effects of construction and/or operation. Businesses were approached at random within these local centres, with every effort made to survey a range of business types across the study area. The results of the business survey are provided Appendix U (Technical working paper: Socio-economic assessment) and discussed in Chapter 21 (Socio-economics).

Local business owners also attended community information sessions. Further engagement with business stakeholders would be carried out during the environmental impact statement exhibition period, this may include door knocking and letter box drops (subject to COVID-19 requirements and with social distancing and other safety measures implemented as required).

7.2.5 Directly impacted landowners and residents

In March 2017, property owners affected by the concept design were notified. In July 2018, property owners affected by the proposed reference design were notified. In November 2019, property owners affected by the updated access road design at Balgowlah were notified and assigned a Personal Manager Acquisition. Residential property owners were provided the opportunity to start the acquisition process (at owner discretion). Further engagement would be carried out with affected property owners as the project progresses.

All acquisition required for the project is carried out in a manner consistent with the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW) (Just Terms Act), the *Land Acquisition Information Guide* and the land acquisition reforms announced by the NSW Government in 2016.

Transport for NSW has appointed a Personal Manager Acquisition to help land owners who may be affected by acquisition for the project. The Personal Manager Acquisition is in regular contact with these individuals to provide updates on the project and respond to questions and queries. Should acquisition for the project be confirmed for a particular property, the Personal Manager Acquisition would work with the affected land owners and residents to offer assistance and support throughout the acquisition and relocation process (refer to Chapter 20 (Land use and property)).

7.2.6 Community

Western Harbour Tunnel and Beaches Link program of works engagement

Community engagement was carried out for the whole Western Harbour Tunnel and Beaches Link program of works by Transport for NSW (formerly Roads and Maritime). The following section describes the community feedback received during the 2017 and 2018 consultation periods for the program of works, in addition to engagement carried out with a number of community and interest groups.

2017 concept design

In March 2017, the NSW Government announced the Western Harbour Tunnel and Beaches Link program of works design. Feedback on the concept design was invited between 16 March 2017 and 31 July 2017, supported by community engagement activities summarised in Table 7-5.

Table 7-5 2017 concept design – community engagement activities

Activity	Details
General program information and feedback channels	
Program website	nswroads.work/whtbl (previously rms.nsw.gov.au/whtbl).
Program email address	Over 700 emails were sent to the program email account: whtbl@transport.nsw.gov.au (previously motorwaydevelopment@rms.nsw.gov.au).
Program 1800 number	Over 1000 telephone calls were received via the program information line: 1800 789 297.
Letterbox drops	More than 330,000 program fact sheets and community feedback session information flyers delivered.
Online community engagement map	More than 1700 comments posted on specific topics by members of the community.
Subscribers to program updates	Over 2300 subscribers to receive ongoing program updates.
Ministerial	About 90 customer enquiries issued as ministerial inquiries.
Hosted events	
Community Feedback Sessions attended by program team and technical specialists	Sixteen sessions attended by more than 2100 people at the following locations: • Mosman Club (two sessions) • McMahons Point Community Centre (two sessions) • Chatswood Club (two sessions) • Balmain Town Hall (two sessions) • Manly-Warringah Leagues Club (two sessions) • Northbridge Bowling Club (two sessions) • North Sydney Oval Function Centre (two sessions) • Seaforth Community Centre (one session) • Fred Hutley Hall, North Sydney Council Chambers (one session).
Pop up information displays	Twelve displays in major shopping centres attended by more than 800 people including: • Birkenhead Point Shopping Centre (two sessions)

Activity	Details
	• Warringah Mall (four sessions) • Balgowlah Stockland (two sessions) • Chatswood Westfield (four sessions).
Direct engagement with individual stakeholders	
Meetings with residents and stakeholders	More than 25 meetings were attended by more than 1000 people.
Door knocks	More than 1500 residences.
Notifications of investigation work	
Marine geotechnical notifications	More than 170 notifications to properties in the vicinity of the proposed harbour crossings.
Land based geotechnical notifications	More than 5500 notifications and more than 1200 door knocks.
Noise monitoring installation notifications	More than 590 notifications and more than 470 door knocks.
Air quality monitoring station installations	More than 50 notifications and more than 40 door knocks.
Media	
Newspaper advertisements	89 half page advertisements, placed in the local media in the weeks preceding the community feedback sessions.
Media releases	One media release was issued by the NSW Government to coincide with the announcements of the preferred corridor and start of field investigation works.
Facebook	More than 169,000 people reached through two direct program related Facebook posts on the NSW Roads Facebook page, as well as a broadly targeted Facebook advertising campaign.

2018 proposed reference design

In July 2018, the NSW Government announced the proposed reference design for the Western Harbour Tunnel and Beaches Link program of works. Feedback on the proposed reference design was invited between 26 July 2018 and 1 December 2018, supported by community engagement activities summarised in Table 7-6.

Feedback from this period helped to inform the design which has been included in this environmental impact statement. A summary of this feedback and where it has been addressed is provided in Table 7-8.

Table 7-6 2018 proposed reference design – community engagement activities

Activity	Detail
General program information and feedback channels	
Program website	nswroads.work/whtbl (previously rms.nsw.gov.au/whtbl).
Program email address	Around 2320 emails were sent to the program email account: whtbl@transport.nsw.gov.au (previously whtbl@rms.nsw.gov.au).

Activity	Detail
Program 1800 number	More than 300 telephone calls were received via the program information line: 1800 931 189.
Letterbox drops	About 400,000 program fact sheets and community feedback session information flyers delivered.
Online community engagement map	More than 4000 comments posted on specific topics by members of the community (https://www.rms.nsw.gov.au/projects/western-harbour-tunnel-beaches-link/consultation-map-bl.html).
Feedback forms	More than 530 written feedback forms received at community sessions.
Subscribers to program updates	Over 3300 subscribers to receive ongoing program updates.
Ministerial	Over 90 customer enquiries issued as ministerial inquiries.
Hosted events	
Community Feedback Sessions attended by program team and technical specialists	Twenty sessions attended by more than 2600 people at the following locations: • Balgowlah Club Totem (one session) • Balgowlah Golf Club (one session) • Crows Nest Centre (two sessions) • Mosman RSL (two sessions) • Fred Hutley Hall, North Sydney Council Chambers (two sessions) • Waverton Bowling Club (two sessions) • Balgowlah RSL (three sessions) • Manly Warringah Leagues Club (two sessions) • Balmain Town Hall (two sessions) • Northbridge Golf Club (two sessions) • Cammeray Golf Club (one session).
Pop up information displays	Six displays in major shopping centres attended by more than 590 people including: • Birkenhead Point Outlet Centre (three sessions) • Balgowlah Stockland (three sessions).
Direct engagement with individual stakeholders	
Stakeholder meetings	More than 88 meetings were held with local precinct committees, schools and associated Parents & Citizens (P&C) Associations, resident groups, special interest groups, sporting associations, Government agencies and local councils.
Door knocks	More than 3890 residences.
Notifications of investigation work	
Land based geotechnical notifications	More than 132 notifications and more than 20 doorknocks.
Media	
Newspaper advertisements	Eighteen half page advertisements, placed in the local media in the weeks preceding the community feedback sessions.

Activity	Detail
Media releases	One media release was issued by the NSW Government to coincide with the announcements of the further developed design.

2019 project updated design

In November 2019, the NSW Government announced an updated design for the Beaches Link and Gore Hill Freeway Connection project.

The community were advised of the preferred temporary construction support sites at Wakehurst Parkway east (BL13) and Flat Rock Drive (BL2), an updated design of the Balgowlah access road (noting the Balgowlah access road has since evolved to that presented in this environmental impact statement) and the updated timing for the Beaches Link and Gore Hill Freeway Connection project environmental impact statement.

Community updates were uploaded onto the project website and distributed to 46,500 properties along the Beaches Link alignment and suburb specific fact sheets were created to update the community about design changes in their area. The fact sheets focussed on Balgowlah, Cammeray, Willoughby, Seaforth and Frenchs Forest.

In addition, an email was sent to 2592 subscribers, informing them of the changes and linking them to the community update on the website.

2020 Western Harbour Tunnel and Warringah Freeway Upgrade project environmental impact statement public exhibition

As stated in Section 7.2, during the display period of the Western Harbour Tunnel and Warringah Freeway Upgrade project environmental impact statement between 29 January and 30 March 2020, general questions around the design, project alignment, project timelines and impacts of the Beaches Link and Gore Hill Freeway Connection project were asked by community members. A dedicated technical expert from the Beaches Link and Gore Hill Freeway Connection project team attended the information sessions in order to respond to these questions.

Submissions made on the Western Harbour Tunnel and Warringah Freeway Upgrade project environmental impact statement that related to the Beaches Link and Gore Hill Freeway project were considered in the preparation of this environmental impact statement.

Community and interest groups

Engagement and consultation has been carried out with a number of community and interest groups through activities such as briefings, meetings, presentations and workshops. These activities provided:

- An overview of the Western Harbour Tunnel and Beaches Link program of works, including the proposed design and construction method
- Information on potential impacts during construction and operation including air quality, noise and vibration, traffic and transport, biodiversity, and maritime issues
- Further detail on options considered and their advantages and disadvantages
- The opportunity to provide feedback and discuss any issues or concerns
- The opportunity to present community options for analysis by the technical and environmental team.

Engagement and consultation has occurred with the following community and interest groups:

- Artarmon Progress Association
- Naremburn Progress Association
- Northbridge Progress Association

- Federation of Willoughby Progress Associations
- North Sydney Precinct Committees
- Plateau Precinct (Cammeray)
- Waverton Precinct Committee
- Waverton Progress Association
- Willoughby Progress Association
- Willoughby South Progress Association
- Wollstonecraft Precinct Committee
- Crows Nest Rotary Club
- North Sydney Rotary Club
- Mosman Rotary Club
- Northbridge Rotary Club
- Marist College North Shore
- North Sydney Boys High School
- Seaforth Primary School and P&C
- Northern Beaches Secondary College Balgowlah Boys Campus
- St Cecilia's Catholic Primary School
- St Mary’s Primary School
- Anzac Park Public School
- Anzac Park Public School P&C Association
- Cammeray Public School
- Cammeray Public School P&C Association
- Monte Sant' Angelo Mercy College
- Wenona School
- Balgowlah Golf Club
- Cammeray Golf Club
- Seaforth Residents Group
- Serpentine Crescent Residents Group
- Balgowlah Residents Group
- Dudley Street residents
- Seaforth Football Club
- Northbridge Sailing Club
- The Greens North Sydney
- Save Manly Dam Catchment Committee.

7.3 Feedback received

Feedback and issues identified during the engagement program by stakeholders and the community have informed the environmental assessment and the ongoing development of the project. A summary of these issues and where they have been addressed is provided in the following section.

7.3.1 Summary of feedback received

Feedback received was recorded and considered during the preparation of this environmental impact statement and throughout the development of the project.

Table 7-7 provides a summary of the feedback topics and number of comments received during the 2017 and 2018 engagement periods for the Western Harbour Tunnel and Beaches Link program of works, and where this has been considered in the environmental impact statement for the Beaches Link and Gore Hill Freeway Connection project.

Table 7-7 Summary of stakeholder and community feedback

Feedback topic	Number of comments 2017	Number of comments 2018	Environmental impact statement reference
Air quality impacts, location and operation of tunnel ventilation system, potential impact on health	1068	4729	Air quality impacts are assessed in Chapter 12 (Air quality) Location and operation of tunnel ventilation outlets and motorway facilities is described in Chapter 5 (Project description) and Appendix H (Technical working paper: Air quality) Assessment of potential human health impact is provided in Chapter 13 (Human health) and Appendix I (Technical working paper: Health impact assessment)
Design – tunnel entry and exit portals, alignment, road connections, depth, project description, suggested design changes, motorway features	928	1566	Chapter 4 (Project development and alternatives), Chapter 5 (Project description) and this chapter in Section 7.4
Transport mode, public transport alternatives, network integration, connectivity, integration with other key projects and proposed infrastructure (eg Northern Beaches B-Line, Sydney Metro)	547	1974	Chapter 3 (Strategic context and project need) Chapter 4 (Project development and alternatives) Chapter 5 (Project description) Chapter 8 (Construction traffic and transport), Chapter 9 (Operational traffic and transport) and Appendix F (Technical working paper: Traffic and transport)

Feedback topic	Number of comments 2017	Number of comments 2018	Environmental impact statement reference
Potential property impact on directly and indirectly affected properties, including property value and potential increase in urban density, property condition surveys, property access, property acquisition	501	1756	Chapter 20 (Land use and property) and Appendix U (Technical working paper: Socio-economic assessment)
Construction impact, location of temporary construction support sites, impact of temporary construction support sites, hours of work, night work, spoil transport, cumulative impacts, light spill	383	3475	Chapter 6 (Construction work)
Potential impact on local streets, rat runs, local road safety, construction traffic, impact on parking spaces, congestion, road network performance, local road connections, increased traffic, cumulative traffic impact, travel time	398	4023	Chapter 8 (Construction traffic and transport), Chapter 9 (Operational traffic and transport) and Appendix F (Technical working paper: Traffic and transport) Chapter 27 (Cumulative impacts)
Traffic modelling	273	312	Chapter 8 (Construction traffic and transport), Chapter 9 (Operational traffic and transport) and Appendix F (Technical working paper: Traffic and transport)
Satisfaction with engagement	151	86	This chapter provides an overview of the engagement and consultation process feedback received
Impact on fauna, flora, vegetation, green spaces, National Parks	177	1676	Chapter 19 (Biodiversity) and Appendix S (Technical working paper: Biodiversity development assessment report)
Need for land bridges and open space	1	2175	Chapter 22 (Urban design and visual amenity)
Drainage and flooding	2	133	Chapter 18 (Flooding) and Appendix R (Technical working paper: Flooding)
Project cost, cost benefit ratio and tolling	97	437	A description of tolling infrastructure is provided in Chapter 5 (Project description). Tolling cost modelling is not subject to this environmental impact assessment

Feedback topic	Number of comments 2017	Number of comments 2018	Environmental impact statement reference
Support for project	89	184	This chapter provides an overview of the engagement and consultation process feedback received
Dissatisfaction with engagement process, need for further project detail, consideration of different ways to engage with the community and stakeholders including different mediums	81	232	Consultation has been adapted as the project progresses. The project has endeavoured to provide information in a variety of different mediums for stakeholders as detailed in this chapter
Noise impact, construction noise, cumulative noise impact, road traffic noise changes, noise walls, noise monitoring	73	2646	Chapter 10 (Construction noise and vibration), Chapter 11 (Operational noise and vibration) and Appendix G (Technical working paper: Noise and vibration)
Cycling, cycleway facilities, active transport	61	336	Chapter 8 (Construction traffic and Transport), Chapter 9 (Operational traffic and transport) and Appendix F (Technical working paper: Traffic and transport)
Oppose project	59	2243	This chapter provides an overview of the engagement and consultation process and feedback received
Visual amenity, visual impact of temporary/permanent structures, overshadowing, urban design	21	306	Chapter 22 (Urban design and visual amenity), Chapter 21 (Socio-economics) and Appendix U (Technical working paper: Socio-economic assessment)
EIS process and project approval	18	58	Chapter 2 (Assessment process)
Aboriginal and non-Aboriginal heritage	14	486	Chapter 15 (Aboriginal cultural heritage), Appendix L (Technical working paper: Aboriginal cultural heritage assessment report), Chapter 14 (Non-Aboriginal heritage) and Appendix J (Technical working paper: Non-Aboriginal heritage)
Impact on community amenity during construction/operation, neighbourhood character, local business impact	8	39	Chapter 21 (Socio-economics) and Appendix U (Technical working paper: Socio-economic assessment)
Project timing	6	80	Chapter 5 (Project description) and Chapter 6 (Construction work)

7.3.2 Issues raised by government agencies and local government

A list of government stakeholders consulted and details on engagement activities and topics is provided in Section 7.2.1. Feedback from government stakeholders has informed the design development of the Beaches Link and Gore Hill Freeway Connection project and is addressed throughout the chapters of this environmental impact statement.

7.3.3 Issues raised by the community

All questions, comments and issues raised by the community have been recorded in the project's database. Feedback received during both consultation periods has been considered and addressed as part of the environmental assessment and, wherever possible, has been incorporated into the design.

Feedback from the 2017 consultation period was addressed in the Beaches Link and Gore Hill Freeway Connection scoping report (Roads and Maritime Services, 2017c), submitted to Department of Planning, Industry and Environment in October 2017. This feedback informed the development of the proposed reference design, as discussed further in Section 7.4.

Feedback from the 2018 consultation period, including key issues raised by community members, stakeholder interest groups and local businesses are provided in Table 7-8. To consolidate the feedback received by the community, feedback has been grouped by issue category and summarised where appropriate. This table also provides the Transport for NSW response and/or the reference to where this feedback has been addressed in this document.

7.3.4 Issues raised by Aboriginal stakeholders

Feedback from Aboriginal stakeholders, including key issues, and how they have been addressed are provided in Chapter 15 (Aboriginal cultural heritage) and Appendix L (Technical working paper: Aboriginal cultural heritage assessment report). Feedback from the Aboriginal Focus Group sessions is provided in Annexure A of Appendix L (Technical working paper: Aboriginal cultural heritage assessment report).

Table 7-8 Issues raised by the community

Issue category	Issue raised	Response to issue and where addressed
Strategic justification and project need	Project viability studies, including the business case, should be released to public.	An overview of the strategic context and project need are provided in Chapter 3 (Strategic context and project need). An overview of the development process and options considered are provided in Chapter 4 (Project development and alternatives).
	Requested more information on whether increased private vehicle road capacity would impact the future development of the North District and Northern Beaches employment centres.	The project would provide increased capacity, connectivity, resilience, and result in a decrease in travel time between employment centres. This is anticipated to have a positive impact and encourage future development in the business centres. Refer to Chapter 9 (Operational traffic and transport) and Appendix F (Technical working paper: Traffic and transport) for further information. The potential social and economic impacts of the project are considered and assessed in Chapter 21 (Socio-economics).
Project development and alternatives	Further investigations into other transport mode options should have been carried out prior to choosing a road option.	An overview of the strategic context and project need are provided in Chapter 3 (Strategic context and project need). An overview of the development process and options considered are provided in Chapter 4 (Project development and alternatives).
	Preference for public transport over motorways. Project should be replaced by a metro or heavy rail. Consideration should be given to a dual rail/road.	The project (as part of the broader Western Harbour Tunnel and Beaches Link program of works) has been planned as part of an integrated transport network to meet the diverse travel and transport needs of Sydney. This includes a well-developed road, rail, bus, ferry, walking and cycling network. An overview of the strategic context and project need are provided in Chapter 3 (Strategic context and project need). The project has been designed to provide high quality access for express bus services expected to travel via the proposed Beaches Link tunnels in

Issue category	Issue raised	Response to issue and where addressed
		the future – providing a significant improvement in public transport travel times and reliability. The project has also been designed to provide significant improvement in existing public transport route travel times by reducing congestion on existing arterial roads. In addition, the Western Harbour Tunnel and Warringah Freeway Upgrade project would provide significant improvements to the efficiency and connectivity of the southbound bus lane on the Warringah Freeway from Miller Street to Sydney Harbour Bridge and direct access to North Sydney to enable interchange with the new Sydney Metro and Sydney Trains. The core capacity improvement offered by the Western Harbour Tunnel and Warringah Freeway project is key to enabling the proposed Beaches Link and Gore Hill Freeway Connection project and the associated significant change in connectivity and reliability for the northern transport network. More information on public and active transport connections can be found in Chapter 3 (Strategic context and project need) and Chapter 5 (Project description). An overview of the development process and alternatives is provided in Chapter 4 (Project development and alternatives). Public transport is also addressed in Chapter 9 (Operational traffic and transport).
	Concerns about toll prices.	A description of tolling infrastructure is provided in Chapter 5 (Project description). The potential social and economic impacts of the project are considered and assessed in Chapter 21 (Socio-economics). Tolling cost modelling is not subject to this environmental impact assessment.

Issue category	Issue raised	Response to issue and where addressed
Tunnel design	Potential impacts to property due to tunnel depth.	Pre-construction building/structure condition surveys would be offered and prepared for properties (where the offer is accepted by the owner) within the zone of influence of tunnel settlement (where the degree of severity has been assessed as 'slight' or above and within the minimum working distances for cosmetic and structural damage due to vibration) prior to the commencement of tunnelling and vibration intensive activities in the vicinity with the potential to affect the building/structure. This survey provides a clear record of the property's condition prior to works starting. Post-construction building condition surveys would be offered to property owners of buildings for which a pre-construction building condition survey was carried out. Where the project is deemed the cause of building and/or property damage, the damage would be repaired at no cost to the property owner. An Independent Property Impact Assessment Panel, comprising geotechnical and engineering experts, would be established prior to the commencement of works to independently verify building condition survey reports, resolve any property damage disputes and establish ongoing settlement monitoring requirements. Potential impacts to property due to tunnel depth is considered and assessed in Chapter 16 (Geology, soils and groundwater).
Construction	Proximity of temporary construction support sites to homes, businesses and schools. Objections to the proposed site locations.	Proposed temporary construction support sites have been selected to support safe and efficient construction. Key factors applied to identification of potential temporary construction support sites include: • Locate the temporary construction support sites as close as possible to the tunnels or surface works they support to minimise unnecessary tunnelling or heavy vehicle movements • Avoid sensitive environments and community locations where possible • Avoid material impacts to heritage sites or items

Issue category	Issue raised	Response to issue and where addressed
		• Maximise opportunities for direct access to motorways and arterial roads or water transport opportunities for construction traffic, and avoid the need to use local residential streets if possible • Minimise direct and indirect property impacts and acquisitions, particularly in residential areas. More information on the sites can be found in Chapter 6 (Construction work).
	Impacts to ambulance and patient transport and access to the Northern Beaches Hospital during construction.	The realignment and upgrade of the Wakehurst Parkway would be staged to maintain traffic at all times. Works in the hospital precinct area would mainly be pavement works and linemarking works.
	Potential hours of operation and impacts of construction activities carried out up to 24 hours per day seven days a week.	Above ground civil construction work such as spoil haulage would, where feasible, generally be carried out between the following standard construction hours: • 7am to 6pm Monday to Friday • 8am to 1pm Saturday • Generally, no work on Sundays or public holidays. Activities that support tunnelling works and fitout, including above ground work supporting underground activities such as spoil handling, may need to occur 24 hours per day, up to seven days per week. Tunnel excavation and spoil handling outside of standard construction hours would be carried out within acoustic sheds at temporary construction support sites that would support tunnel excavation. For works undertaken outside of standard hours, the potentially affected community would be notified in advance. More information can be found in Chapter 6 (Construction work).

Issue category	Issue raised	Response to issue and where addressed
	Duration of construction work and potential for long program delays.	Significant effort has been invested in understanding the key construction activities, their durations, key delay risks and mitigation strategies. More information can be found in Chapter 6 (Construction work).
	Future use of temporary construction support sites including proposed rehabilitation and/or use during operation.	Proposed temporary construction support sites and would be returned at completion of works to the community as open space, wherever possible. Rehabilitation of temporary construction support sites would be carried out with relevant landowners, the local council and community. A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input to the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation would be separate to the consultation for the Beaches Link and Gore Hill Freeway Connection environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting. As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space. The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities. Residual land, primarily to the east and north of the new access road, would progressively become available through the construction period, which would facilitate re-purposing it to the new open space and recreation facilities. This would allow it to be handed over progressively for use by the community. The new open space and recreation facilities to the west of the proposed access road, between the access road and Burnt

Issue category	Issue raised	Response to issue and where addressed
		Bridge Creek Deviation, would be constructed after completion of the project and then handed over to Northern Beaches Council. More information can be found in Chapter 5 (Project description) and Chapter 6 (Construction work).
Consultation process	Inadequate consultation and dissatisfaction with the process.	This chapter provides an overview of the communication and engagement activities carried out to date, and engagement and communication tools which would be used to support the public exhibition of this environmental impact statement and during project delivery. Communication tools and activities for informing and consulting with stakeholders would continue to be flexible, to suit the nature and scale of each stakeholder's interests and issues, and to reflect any restrictions on face to face engagement pending any COVID-19 requirements in place during the life of the project. A detailed Community communication strategy would be developed prior to the start of construction pending project approval. This would be based on the framework developed and included in Appendix E (Community consultation framework).
	Lack of transparency and community involvement as part of the early project development.	
	Timing and inadequacy of available project information and distribution.	
	Lack of trust in the validity of the information provided.	
	Dissatisfaction with project team response timeframes.	
	Accessibility, location selection and timing of community information sessions.	
Air quality	Effectiveness of the proposed tunnel ventilation system.	The independent NSW Chief Scientist and Engineer has released a report (ACTAQ, 2018b) in relation to road tunnel air quality. The report found that emissions from well-designed road tunnels cause a negligible change to surrounding air quality, and as such, there is little to no health benefit for
	Locations of ventilation outlets.	

Issue category	Issue raised	Response to issue and where addressed
	Proximity of ventilation outlets to sensitive receivers including schools and recreational facilities.	surrounding communities in installing filtration and air treatment systems in such tunnels. Further information is available at www.chiefscientist.nsw.gov.au and nswroads.work/airquality. Ventilation outlet locations have been carefully selected to make sure they operate efficiently and there would be minimal changes to local air quality. The air quality assessment has demonstrated that the emissions from the project's ventilation outlets would have a negligible impact on existing ambient pollutant concentrations and would pose a very low risk to human health. In this context, there is no basis to justify the cost and energy use associated with installation and operation of filtration systems. The ventilation systems for Beaches Link would be built strictly in compliance with any conditions specified in the Department of Planning, Industry, and Environment's planning approval, and would be operated to comply with the terms of the Environment Protection Licence to be issued by the NSW Environment Protection Authority. A description of the ventilation systems and facilities is provided in Chapter 5 (Project description), Chapter 12 (Air quality) and Appendix H (Technical working paper: Air quality).
	Air quality impacts would be more around the ventilation outlets and portals than at other locations.	
	Concern five kilometres of tunnel would then place five kilometres "worth" of emissions into a single local area.	
	Cumulative air quality impacts when multiple ventilation outlets were present in a single area/suburb.	
	Preference for the ventilation system to include filtration.	
	Multiple citations of use of ventilation outlets overseas and suggestion this is best and standard practice.	
	Health implications to residents and children's schools due to the proximity of unfiltered ventilation outlets to Lambs Road and Clegg Street.	

Issue category	Issue raised	Response to issue and where addressed
	Potential impacts during construction including exposure to emissions and carcinogens produced from processing of sandstone and granite producing silica dust.	Potential construction air quality impacts are considered and assessed in Chapter 12 (Air quality) and Appendix H (Technical working paper: Air quality).
	Potential air quality impacts as the result of road widening.	
	Impacts from contaminants and dust from construction work and spoil haulage.	
	Request for accurate on-going air quality monitoring.	Ongoing air quality monitoring would occur during both construction and operation. Refer to Chapter 12 (Air quality) for further information.
	Climate change impacts.	Chapter 26 (Climate change and greenhouse gas) assesses the potential impacts of climate change on the project, and greenhouse gas emissions generated by the construction and operation of the project.
Operational traffic	New motorway would result in increased traffic on local streets and key arterial routes.	Potential operational traffic and transport impacts have been assessed and considered in Chapter 9 (Operational traffic and transport) and in Appendix F (Technical working paper: Traffic and transport).
	New motorway would create new rat runs.	
	Increased vehicles on local streets trying to access the new portals.	
	Increased commuter traffic creating parking needs in local street which cannot accommodate the demand.	

Issue category	Issue raised	Response to issue and where addressed
	Project will encourage the use of private vehicles for longer trips.	Refer to Appendix F (Technical working paper: Traffic and transport) for an assessment of likely induced traffic due to the project.
	Requested details on the potential for the program to deliver long term traffic reduction benefits for Military Road and whether a local road improvements program will be delivered as part of the program.	Traffic modelling has indicated that there would be traffic reductions on alternative routes like Military Road, Warringah Road and Eastern Valley Way due to the Western Harbour Tunnel and Beaches Link program of works. As part of the Beaches Link and Gore Hill Freeway Connection project, adjustments would not be made to Military Road; however, the project would provide the opportunity for agencies (eg councils and Transport for NSW network management teams) to consider other opportunities for local road improvements. Operational traffic impacts and benefits are outlined in Chapter 9 (Operational traffic and transport) and in Appendix F (Technical working paper: Traffic and transport).
Construction traffic	Increased traffic on local streets around temporary construction support sites.	Temporary construction support sites have been selected to provide direct access to the arterial road network, dedicated parking for construction workers (where possible) and would keep trucks and vehicles off local streets during construction, wherever possible. During construction, the main priority is to maintain the safety of the public in and around the sites and the immediate areas adjacent to the sites. Vehicle access to and from temporary construction support sites would be managed to maintain pedestrian, cyclist and motorist safety. Assessment of construction traffic impacts including potential benefits is provided in Chapter 8 (Construction traffic and transport) and in Appendix F (Technical working paper: Traffic and transport).
	Increased traffic around Eastern Valley Way and Edinburgh Road, Willoughby.	
	Disruptions to Northbridge residents due to congestion on Flat Rock Drive, Alpha Road, Brook Street, Sailors Bay Road, Eastern Valley Way and Strathallen Avenue.	
	Reduced safety on local streets as the result of increased heavy vehicles.	

Issue category	Issue raised	Response to issue and where addressed
	Access to construction areas from residential roads and residents impacted along truck haulage routes.	
	Loss of residential parking on local streets as the result of project staff parking.	
	Increased rat running down local streets by both construction staff and community avoiding areas under construction.	
	Reduced road safety around schools as the result of increased heavy vehicle traffic. Particularly in areas where children are required to cross roads alone and during peak periods including drop off and collections.	
	Heavy vehicle use of narrow local streets and impacts to adjacent residents.	
	Rat runs at Woodbine Street, North Balgowlah to connect to the access road due to no Wakehurst Parkway access when tunnel is operational.	
	Traffic flow impacts for Sydney Road.	

Issue category	Issue raised	Response to issue and where addressed
Public transport	Potential impacts to bus routes during construction and operation.	Assessment of potential impacts to public transport is provided in Chapter 8 (Construction traffic and transport), Chapter 9 (Operational traffic and transport) and in Appendix F (Technical working paper: Traffic and transport).
	Preference for dedicated express bus lanes in current road infrastructure.	Public transport is addressed in Chapter 9 (Operational traffic and transport). An overview of the strategic context and project need is provided in Chapter 3 (Strategic context and project need).
Noise and vibration	Potential damage to property as a result of tunnelling activities. Potential damage to property as the result of underground blasting activities. Conservation of heritage homes and potential for cosmetic damage as a result of tunnelling activities, underground blasting and heavy vehicle movements.	Minimum working distances for vibration intensive construction activities and vibration monitoring would be implemented where applicable to manage potential vibration impacts to property during construction. Ground movement impacts would be managed through predictive settlement models, building condition surveys (including for heritage assets) and the establishment of an Independent Property Impact Assessment Panel. Pre-construction building/structure condition surveys would be offered and prepared for properties (where the offer is accepted by the owner) within the zone of influence of tunnel settlement (where the degree of severity has been assessed as 'slight' or above and within the minimum working distances for cosmetic and structural damage due to vibration) prior to the commencement of tunnelling and vibration intensive activities in the vicinity with the potential to affect the building/structure. This survey provides a clear record of the property's condition prior to works starting. Post-construction building condition surveys would be offered to property owners of buildings for which a pre-construction building condition survey was carried out. Where the project is deemed the cause of building and/or property damage, the damage would be repaired at no cost to the property owner.

Issue category	Issue raised	Response to issue and where addressed
		The Independent Property Impact Assessment Panel, comprising geotechnical and engineering experts, would be established prior to the commencement of works to independently verify building condition survey reports, resolve any property damage disputes and establish ongoing settlement monitoring requirements. Refer to Chapter 10 (Construction noise and vibration), Appendix G (Technical working paper: Noise and vibration) and Chapter 16 (Geology, groundwater and soils) for further information.
	Noise during construction activities.	Potential noise impacts are considered and assessed in Chapter 10 (Construction noise and vibration) and Appendix G (Technical working paper: Noise and vibration).
	Noise as the result of 24 hour tunnelling activities.	Potential noise and vibration impacts from tunnelling activities are considered and assessed in Chapter 10 (Construction noise and vibration) and Appendix G (Technical working paper: Noise and vibration).
	Vibration issues as the result of tunnelling activities.	
	Hours of work and potential noise impacts.	Ongoing engagement would be carried out with schools about the timing and duration of construction work and management of potential impacts. Where possible additional mitigation measures would be implemented to further reduce impacts. Proposed hours of work are discussed in Chapter 6 (Construction work). Potential construction noise impacts are considered and assessed in Chapter 10 (Construction noise and vibration) and Appendix G (Technical working paper: Noise and vibration).
	Duration of activities and subsequent duration of noise impacts.	
	Potential impacts of noise at sensitive receivers like schools during peak exam periods.	
	Noise impacts during construction.	

Issue category	Issue raised	Response to issue and where addressed
	Noise from heavy vehicle traffic.	Heavy vehicle traffic is considered as part of the noise assessment and is addressed in Chapter 10 (Construction noise and vibration) and Appendix G (Technical working paper: Noise and vibration).
	Low frequency noise and vibration during construction and operation.	Potential noise and vibrations impacts are considered and assessed in Chapter 10 (Construction noise and vibration), Chapter 11 (Operational noise and vibration) and Appendix G (Technical working paper: Noise and vibration).
	Potential noise impacts as a result of road widening.	Potential noise impacts during construction are considered and assessed in Chapter 10 (Construction noise and vibration) and Appendix G (Technical working paper: Noise and vibration).
Open space	Loss of open space during construction for recreational and leisure activities.	Potential social and economic issues are considered and assessed in Chapter 21 (Socio-economics). Also refer to Chapter 22 (Urban design and visual amenity).
	Closure of Manly Dam mountain bike trail.	The realignment and upgrade of the Wakehurst Parkway would be staged with existing walking and bike trails to remain operational. Some minor diversions of these would be required from time to time during staging of works to ensure safe passage of the public through the project. Refer to Chapter 8 (Construction traffic and transport), Chapter 9 (Operational traffic and transport) and Appendix F (Technical working paper: Traffic and transport) for an assessment on impacts to active transport due to both construction and operation.
	Adequate design options to include active transport options.	The project has been planned as part of an integrated transport network to meet the diverse travel and transport needs of Sydney. This includes a well-developed road, rail, bus, ferry, walking and cycling network.

Issue category	Issue raised	Response to issue and where addressed
		An overview of the strategic context and project need are provided in Chapter 3 (Strategic context and project need). Assessment of potential impacts to active transport is provided in Chapter 9 (Operational traffic and transport) and in Appendix F (Technical working paper: Traffic and transport).
	Increased population to the Peninsula that is considered to be already over-developed with a need for more sporting facilities and parking.	The project has the opportunity to enhance and/or add to the amount of public open space, and recreation facilities and associated parking through potential re-purposing works at Balgowlah, Seaforth/Killarney Heights and Flat Rock Reserve. The final design of the re-purposing of open space would be determined in collaboration with the relevant council and through further community consultation.
	Reduction of Artarmon Park at the end of the construction.	The project would require the permanent acquisition of a portion of land at Artarmon Park adjacent to the Gore Hill Freeway to accommodate road infrastructure associated with the Gore Hill Freeway Connection component. This would not impact the ongoing use or functioning of the park and its facilities.
	Students from Northern Beaches Secondary College Balgowlah Boys Campus cannot access the oval.	Works associated with the project at Balgowlah Golf Course, including the surface connections at Balgowlah, would be staged to maintain safe access to Balgowlah Oval for the public, including students, clubs and scouts would continue to have access. Some minor temporary diversions of the existing access arrangements would be required from time to time during staging works to provide safe passage of the public through the project. The existing pedestrian bridge across Sydney Road adjacent to the high school is expected to remain in place and remain operational at all times.
	Clubs and Scouts from the Balgowlah Scout Hall could not access open space.	

Issue category	Issue raised	Response to issue and where addressed
	Lack of active transport from Artarmon Park to Artarmon Reserve.	The cycle network in the Gore Hill Freeway and Artarmon area consists of a mix of off-road shared user paths and on-road cycle routes on local and collector roads. Refer to Chapter 8 (Construction traffic and transport), Chapter 9 (Operational traffic and transport) and Appendix F (Technical working paper: Traffic and transport) for an assessment on impacts to active transport due to both construction and operation.
	Closure of the Balgowlah Golf Course and acquisition of Dudley Street properties.	Acquisition of Crown land at Balgowlah Golf Course would result in closure of the golf course. The project has been designed to optimise opportunities for the re-purposing of the remaining Crown land into new open space and recreation facilities. Final designs would be determined in conjunction with the Northern Beaches Council and through further community consultation. A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input to the final layout of the new open space and recreation facilities at Balgowlah. This consultation would be separate to the consultation for the Beaches Link and Gore Hill Freeway Connection environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting. As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space. The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities. Further information regarding future opportunities for re-purposing of the remaining Crown land is provided in the Chapter 20 (Land use and property).

Issue category	Issue raised	Response to issue and where addressed
		All acquisition required for the project is carried out in a manner consistent with the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW) (Just Terms Act), the *Land Acquisition Information Guide* and the land acquisition reforms announced by the NSW Government in 2016. Transport for NSW has appointed a Personal Manager Acquisition to help land owners who may be affected by acquisition for the project. The Personal Manager Acquisition is in regular contact with these individuals to provide updates on the project and respond to questions and queries. Refer to Chapter 20 (Land use and property) for further information.
Visual amenity	Loss of amenity to Clive Park and the Northbridge Baths.	Temporary construction support sites, including at Spit West Reserve (BL9) and the Middle Harbour cofferdams (BL7 and BL8), would be temporary and would be developed to minimise visual impacts for adjacent receivers where feasible and reasonable. Refer to Chapter 22 (Urban design and visual amenity) for further information.
	Design and visual amenity of the ventilation outlets.	A description of ventilation systems and facilities is provided in Chapter 5 (Project description). Consideration and assessment of urban design and visual amenity is provided in Chapter 22 (Urban design and visual amenity).
	Light pollution from compounds and work during construction.	Site lighting would be designed to minimise glare issues and light spillage into adjoining properties. Refer to Chapter 22 (Urban design and visual amenity) for further information.
	Visual impacts for residents living adjacent to construction compounds.	Hoardings and temporary noise walls would be erected to provide visual screening where appropriate. Refer to Chapter 22 (Urban design and visual amenity) for further information.

Issue category	Issue raised	Response to issue and where addressed
	Visual impacts of the noise attenuation sheds on adjacent residents.	Acoustic sheds would be designed to be visually recessive and to minimise potential overshadowing impacts where possible. Refer to Chapter 22 (Urban design and visual amenity) for further information.
	Permanent loss of amenity.	Potential visual amenity impacts are considered and assessed in Chapter 22 (Urban design and visual amenity).
Flora and fauna (on land)	Potential impacts to threatened species such as the Powerful Owl and the Eastern Pygmy Possum due to Wakehurst Parkway widening.	Vegetation removal along Wakehurst Parkway would be timed to avoid the winter breeding period for the Eastern Pygmy-possum (May to July), where feasible and reasonable. Refer to Chapter 19 (Biodiversity) and Appendix S (Biodiversity development assessment report) for further information on potential impacts to threatened species including the Powerful Owl and Eastern Pygmy Possum.
	Impacts on mature trees currently within the Balgowlah Golf Course and on Burnt Bridge Creek Deviation.	Final works to be carried out within Balgowlah Golf Course including adjacent to the existing Burnt Bridge Creek would be subject to further design development. Development of the final layout of the new open space and recreation facilities would be undertaken in conjunction with the Northern Beaches Council and through further community consultation. Every effort would be made to retain mature trees, however the dedicated consultation process would determine the final layout and this would influence decisions regarding vegetation. More information on vegetation removal and potential impacts can be found in Appendix W (Technical working paper: Arboricultural impact assessment).

Issue category	Issue raised	Response to issue and where addressed
	Loss of tree cover at Artarmon Park and the assurance of offset vegetation and mature trees.	The project has endeavoured to limit vegetation removal wherever possible and replanting would be carried out as part of rehabilitation work. Transport for NSW would work with Willoughby Council to develop a plan for the rehabilitation of Artarmon Park where the area may have been impacted by excavation works adjacent to the Gore Hill Freeway Connection component. More information on vegetation removal and potential impacts can be found in Appendix W (Technical working paper: Arboricultural impact assessment).
	Desire for fauna crossings at Wakehurst Parkway.	Fauna crossings along Wakehurst Parkway have been included in the design. Refer to Chapter 5 (Project description) for further information.
Flora and fauna (marine)	Damage to marine environments.	Design development for the project included a strong focus on evaluation of potential tunnelling methods for the crossing of Middle Harbour. This analysis was carried out by a multidisciplinary team including design, construction, transport planning, and environmental specialists to ensure a comprehensive analysis. An immersed tube tunnel has been selected as the preferred tunnelling method for the Middle Harbour crossing. The dredging methodology has been designed to minimise impacts on the marine environment and is detailed in Chapter 6 (Construction work). This includes use of appropriate environmental controls to minimise the risk of sediment and contaminants within the sediments being mobilised into the water. These measures reflect best environmental practice to reduce the water quality impacts of dredging and would result in an overall reduction in the extent and intensity of the dredge plumes. There are precedents for successful and environmentally sensitive dredging and immersed tube tunnel construction in sensitive marine environments, like that found at the Middle Harbour crossing, with
	Potential impacts to the marine environment including effects to tidal flows and disturbance of toxic sediments.	
	Environmental impacts to seagrass beds, mangroves and other species affected by tidal and sediment changes and seabed or increased run off.	

Issue category	Issue raised	Response to issue and where addressed
		appropriate technology and methodologies available. Industry experts with direct experience in such work have been engaged for the project to develop the appropriate methodology, equipment and controls. Detailed studies and modelling have been carried out as part of the Western Harbour Tunnel and Beaches Link program of works to understand the harbour's tides, currents, water quality, and marine ecology, along with extensive testing of the sediments at the location of the proposed harbour crossing. Consultation has taken place with technical, marine ecology and human health experts, as well as drawing on knowledge of Sydney Harbour obtained during previous projects. For further information refer to: • Chapter 16 (Geology, groundwater and soils) • Chapter 17 (Hydrodynamics and water quality) • Chapter 19 (Biodiversity) and Appendix T (Technical working paper: Marine ecology).
Hazards and waste	Run off of hazardous materials.	Management and treatment of wastewater discharge is discussed in Chapter 17 (Hydrodynamics and water quality). Management of spoil, including management of potential runoff from stockpiles, is discussed in Chapter 24 (Resource use and waste management).
	Impacts of dumping soil.	The project design has taken into account the principles of the resource management hierarchy as defined in the *Waste Avoidance and Resource Recovery Act 2001.* For further details on the management of waste disposal refer to Chapter 24 (Resource use and waste management).
Social amenity	Reduction in property values as the result of construction activities including noise, pollution	Property values are driven by a range of economic, social and amenity factors, for example housing supply and demand, interest rates, economic

Issue category	Issue raised	Response to issue and where addressed
	concerns, dust, presence of tunnels underneath homes, the proximity of ventilation outlets and tunnel ramps, increased traffic and parking issues. Loss of open space would result in reduction of property prices.	growth, local amenity and accessibility to such things as employment and social infrastructure. It is likely that broader external factors would influence property values more than perceived or actual impacts resulting from the project. Furthermore, improvements to transport access, reduced travel times and reduced congestion on surface arterial roads delivered by the project are likely to improve liability in many areas. Refer to Chapter 21 (Socio-economics) and Appendix U (Technical working paper: Socio-economic assessment) for further information.
	Impacts to social amenity because of construction vehicles in nearby residential streets.	Temporary construction support sites have been selected to provide direct access to the arterial road network, dedicated parking for construction workers (where possible) and to keep trucks and light vehicles off local streets during construction wherever possible. Construction workers would be encouraged to use public transport wherever possible and demand for construction personnel parking would be managed with shuttle buses where appropriate. Potential traffic impacts are considered and assessed in Chapter 8 (Construction Traffic and transport). Also refer to Chapter 21 (Socio-economics) for information on potential impacts on socio-economic issues.
Cumulative impacts	Cumulative construction traffic impacts as the result of multiple projects active in the area. Potential for construction fatigue as a result of ongoing construction activities.	Multi-party engagement and cooperation would be established prior to construction to maximise the opportunities for all contributors to work together to minimise adverse impacts or enhance benefits of multiple projects occurring concurrently or consecutively. Potential cumulative construction impacts are assessed and considered in Chapter 27 (Cumulative impacts). For further details, also refer to: • Chapter 6 (Construction work) • Traffic and transport: Chapter 8 (Construction traffic and transport) and Appendix F (Technical working paper: Traffic and transport)

Issue category	Issue raised	Response to issue and where addressed
		• Noise and vibration: Chapter 10 (Construction noise and vibration) and Appendix G (Technical working paper: Noise and vibration) • Air quality: Chapter 12 (Air quality) and Appendix H (Technical working paper: Air quality) • Human health: Chapter 13 (Human health) and Appendix I (Technical working paper: Health impact assessment) • Chapter 19 (Biodiversity) • Chapter 21 (Socio-economics).
Heritage	Impacts to local Aboriginal sites.	Assessment of potential impacts to Aboriginal heritage is provided in Chapter 15 (Aboriginal heritage) and Appendix L (Aboriginal cultural heritage assessment report).
Health	General concerns about health as the result of air quality. Potential adverse impacts to health as the result of existing medical conditions like asthma and allergies. Exposure to silica dust from spoil transport.	During construction, the priority would be to ensure public health and safety. Potential air quality impacts would be managed through standard construction air quality mitigation and management measures, which would include dust suppression measures, selection of construction equipment and/or materials handling techniques that minimise dust generation, minimisation of exposed areas during construction and monitoring activities. Emissions from plant and equipment would be minor and localised. Assessment of construction and operational air quality impacts is provided in Chapter 12 (Air quality) and Appendix H (Technical working paper: Air quality). Potential impacts to health are addressed in Chapter 13 (Human health).

Issue category	Issue raised	Response to issue and where addressed
	Health concerns and risks around contaminated harbour spoil.	Design development for the project included a strong focus on evaluation of potential tunnelling methods for the crossing of Middle Harbour. This analysis was carried out by a multidisciplinary team including design, construction, transport planning, and environmental specialists to ensure a comprehensive analysis. An immersed tube tunnel has been selected as the preferred tunnelling method for the Middle Harbour crossing. The dredging methodology has been designed to minimise impacts on the marine environment and is detailed in Chapter 6 (Construction work). This includes use of appropriate environmental controls to minimise the risk of sediment and contaminants within the sediments being mobilised into the water. These measures reflect best environmental practice to reduce the water quality impacts of dredging and would result in an overall reduction in the extent and intensity of the dredge plumes. There are precedents for successful and environmentally sensitive dredging and immersed tube tunnel construction in sensitive marine environments, like that found at the Middle Harbour crossing, with appropriate technology and methodologies available. Industry experts with direct experience in such work have been engaged for the project to develop the appropriate methodology, equipment and controls. For further information refer to: • Chapter 16 (Geology, groundwater and soils) • Chapter 17 (Hydrodynamics and water quality).

Issue category	Issue raised	Response to issue and where addressed
	Potential impacts to health of stakeholder using sporting facilities adjacent to temporary construction support sites.	A comprehensive and robust environmental assessment has been carried out for the project which assesses the potential risks to health and safety as a result of the project. Assessment of construction and operational air quality impacts is provided in Chapter 12 (Air quality) and Appendix H (Technical working paper: Air quality). Potential impacts to health are addressed in Chapter 13 (Human health).
	Potential increases in population, and associated issues, in the Northern Beaches due to increased access due to the Western Harbour Tunnel and Beaches Link program of works.	The potential social and economic impacts of the project are considered and assessed in Chapter 21 (Socio-economics). Also refer to Chapter 9 (Operational traffic and transport) and Chapter 13 (Human health).

7.4 Summary of project refinements in response to feedback

A summary of how community and stakeholder feedback has been incorporated into the project is provided in Table 7-9 below.

Table 7-9 Design refinements – considerations in response to feedback

Stakeholder and community feedback	Response
Ventilation outlets should be located to minimise community concerns, environmental and property impact.	Permanent ventilation outlets would be placed in the Warringah Freeway corridor allowing the motorway facilities for Western Harbour Tunnel and Beaches Link to be co-located, simplifying long-term operational and maintenance activities and allowing for design synergies and reduced property impact. The air quality assessment has demonstrated that operation of the ventilation outlets for the project would have a negligible impact on existing ambient pollutant concentrations and would pose a very low risk to human health. Chapter 4 (Project development and alternatives) details the alternative tunnel design and ventilation options considered to meet the air quality criteria for the project.
Concerns regarding proximity of connections to and from the Wakehurst Parkway to houses and Seaforth Oval, including: • Tunnel portal locations • Ventilation outlet located near residential streets.	The proposed tunnel portal including motorway facility and ventilation outlet would be located about 500 metres north of Seaforth Oval on Wakehurst Parkway, compared to the initial design location west of Kirkwood Street in 2017. Further project development has reduced private property impacts by relocating the temporary construction support site from the Seaforth Oval overflow carpark to the Sydney Water site north of Kirkwood Street (Wakehurst parkway east construction support site (BL13)). With respect to the connections to and from the Wakehurst Parkway, temporary construction support facilities are now located wholly within Transport for NSW and Sydney Water owned land. The connection to and from the Wakehurst Parkway north of Kirkwood Street was adopted which moved the portal, motorway facility and ventilation outlet north of residential properties. The relocated portal also allowed for ramp tunnel grades to be reduced therefore resulting in improved operational efficiencies. Reduced impacts to Duffys Forest endangered ecological community within Transport for NSW land associated with the original option of a temporary construction support site for tunnelling adjacent to Seaforth Oval. Refer to Chapter 4 (Project development and alternatives) for further details.
Options for alternative construction methodologies, temporary construction support sites, and routes to minimise the project impact.	The current proposed construction methodologies for the project have been developed in conjunction with a team of national and international experts with direct experience in the design and construction of major infrastructure within urban environments. These methods have considered the following key factors:

Stakeholder and community feedback	Response
	• Ability to deliver the required project scope and connectivity • Minimise environmental impacts • Minimise impacts to communities • Ensure safety for construction workers and the public • Minimise the time and cost risks associated with construction • Maximise value for money • Maximise efficiency of construction and future operations of the asset to minimise energy use and operational costs. Proposed temporary construction support sites have been selected to support safe and efficient construction. Key factors applied to identification of potential temporary construction support sites include: • Locate the temporary construction support sites as close as possible to the tunnels or surface works they support to minimise unnecessary tunnelling or heavy vehicle movements • Avoid sensitive environments and community locations where possible • Avoid material impacts to heritage sites or items • Maximise opportunities for direct access to motorways and arterial roads or water transport opportunities for construction traffic, and avoid the need to use local residential streets if possible • Minimise direct and indirect property impacts and acquisitions, particularly in residential areas • Impacts to the functionality of open space. Two temporary construction support sites in particular have been subject to more detailed alternative evaluation: • Wakehurst Parkway east construction support site (BL13) • Flat Rock Drive construction support site (BL2) Refer to Chapter 4 (Project development and alternatives) and Chapter 6 (Construction work) for further information.
Concerns about potential changes to local roads, including rat-runs through local streets to access the tunnels.	Potential rat-running would be addressed further through consultation with relevant councils and may include the implementation of traffic calming measures in local streets (refer to Chapter 9 (Operational traffic and transport)).
Concern Seaforth Oval sports field would be directly impacted by construction. Concern about construction traffic on local streets and around the oval.	Temporary construction support sites have been chosen and would be designed to minimise local impacts. The Wakehurst Parkway east construction support site (BL13) for tunnelling has been relocated away from the Seaforth Oval carpark and is located at the rear of the Sydney Water Bantry Bay water tanks and north of Kirkwood Street (see Wakehurst Parkway east construction support site (BL13) in Chapter 6 (Construction work)). The relocated temporary construction support site would reduce potential impacts on Seaforth Oval and the Seaforth local community.

Stakeholder and community feedback	Response
	Additionally, construction traffic carrying tunnel spoil would head north (not south) on Wakehurst Parkway from Wakehurst Parkway east (BL13) construction support site and avoid any potential impact to the Seaforth shopping precinct along Sydney Road.
Desire for safe and accessible active transport and connections to existing cycle and walking trails, including the desire to keep shared user path under Burnt Bridge Creek Deviation.	The project would improve safe and accessible active transport and connections by providing new dedicated shared user paths along Wakehurst Parkway, including new underpasses to connect existing trails of Garigal National Park and Manly Dam Reserve. The shared user path crossing Burnt Bridge Creek Deviation would be maintained throughout and after construction.
Preference for tunnel ramps and construction to use Balgowlah Golf Course rather than impacting homes, Burnt Bridge Creek bushland or Seaforth Public School (west of Burnt Bridge Creek Deviation).	The modified surface connections at Balgowlah detailed in Chapter 5 (Project description) have been made to reduce community, bushland and private property impacts. The proposed tunnel alignment has been changed so that the tunnel ramps would be located in the centre of Burnt Bridge Creek Deviation. The revised tunnel alignment would also avoid impacts on private properties and minimise impacts to bushland west of Burnt Bridge Creek Deviation. Part of the Balgowlah Golf Course would be used for a temporary construction support site and permanent facilities including a ventilation outlet and new access road, which would mean: • Reduced construction impact on local residences and Seaforth Public School • Less disruption to traffic and buses • Opportunity to re-purpose the Balgowlah Golf Course as new open space and recreation facilities to improve amenity and help manage the growing shortfall in recreational space in the area, in line with Northern Beaches Council objectives. The final design of the re-purposing works would be determined in conjunction with Northern Beaches Council and through further community consultation.
Concern about a ventilation outlet to be located in the Burnt Bridge Creek 'valley'.	The design of the ventilation systems, including ventilation outlet locations, has been carefully developed to make sure they operate efficiently and there would be minimal changes to local air quality. The proposed ventilation outlet would be located near the tunnel ramps, in the Balgowlah Golf Course precinct. Operation of these facilities would be carried out in accordance with strict guidelines and would be monitored closely by the relevant authorities. Refer to Chapter 12 (Air quality), Appendix H (Technical working paper: Air quality), Chapter 13 (Human health) and Appendix I (Technical working paper: Health impact assessment) for details on operational impacts and management measures in relation to ventilation outlets.

Stakeholder and community feedback	Response
Concern about queuing of vehicles going in and out of the tunnel ramps and traffic impacts on local roads.	Improved design of connections to Condamine Street and a new access road to Sydney Road would provide improved access outcomes and reduced congestion for the local road network. Refer to Chapter 9 (Operational traffic and transport) for further details on operational impacts.
Desire to avoid Artarmon Reserve sports field	There would be no temporary construction support site located at Artarmon Reserve or direct impact to Artarmon Reserve sports field.
Desire to avoid the homes to the north of Gore Hill Freeway	No residential properties would be acquired in this area.
Preference to locate the ventilation outlet to the south of Gore Hill Freeway in industrial area	The proposed ventilation outlet would be located in the Artarmon industrial area, south of Gore Hill Freeway. Refer to Chapter 12 (Air quality), Appendix H (Technical working paper: Air quality), Chapter 13 (Human health) and Appendix I (Technical working paper: Health impact assessment) for details on operational impacts and management measures in relation to ventilation outlets.
Concerns about the clearing of bushland adjacent to Gore Hill Freeway	The project has avoided impact to Artarmon Reserve through redesign and by further widening to the south. Widening to the north would require vegetation removal in Artarmon Park. The final extent of removal would be assessed during further design development and detailed construction planning, and further reduced where feasible and reasonable. Appendix W (Technical working paper: Arboricultural impact assessment) provides a preliminary assessment of trees that could be retained subject to further design development and construction planning.
Desire to be able to access both the Western Harbour Tunnel and Beaches Link from Artarmon.	Access to Beaches Link via Gore Hill Freeway and Reserve Road and access to Western Harbour Tunnel provided via Gore Hill Freeway.
Concern regarding proximity to schools in the Cammeray and North Sydney area, in particular in relation to ventilation outlets.	The design of the ventilation systems, including ventilation outlet locations, has been carefully developed to make sure they operate efficiently and there would be minimal changes to local air quality. The air quality assessment has demonstrated that the emissions from the ventilation outlets of the project have a negligible impact on existing ambient pollutant concentrations and would pose a very low risk to human health. Operation of these facilities would be carried out in accordance with strict guidelines and would be monitored closely by the relevant authorities. Refer to Chapter 12 (Air quality), Appendix H (Technical working paper: Air quality), Chapter 13 (Human health), Appendix I (Technical working paper: Health impact assessment), Chapter 10 (Construction noise and vibration) and Appendix G (Technical working paper: Noise and vibration) for details on construction management measures.

7.5 Future engagement

A Community consultation framework (Appendix E) has been prepared to guide the planning and delivery of communication and stakeholder engagement activities across the project.

The objective of ongoing communication and stakeholder engagement program for the project, guided by the Community consultation framework, is to provide the community with:

- Accurate and accessible information about the processes and activities associated with the project
- Information in a timely manner
- Appropriate avenues for providing comment or raising concerns, and to ensure the community is aware of the avenues
- A high level of responsiveness to community feedback and concerns throughout development and delivery of the project.

The Community consultation framework informs the delivery of the communication and stakeholder engagement in line with the requirements of the Secretary's environmental assessment requirements. The framework addresses key issues of concern to the community, including:

- Enquiries and complaints handling procedures
- Monitoring, reporting and evaluation procedures
- Mechanisms for distributing information and seeking feedback
- Specific issues management including:
  - Traffic management (including property access and pedestrian access)
  - Landscaping and urban design matters
  - Construction activities including out of hours work
  - Noise and vibration mitigation and management.

7.5.1 Submissions report

Following exhibition of this environmental impact statement, the Secretary would provide copies of submissions from the community and stakeholders to Transport for NSW as the proponent. Transport for NSW would then prepare a submissions report to respond to the feedback received in submissions. The Secretary may also require Transport for NSW to prepare a preferred infrastructure report to outline any proposed changes to the project. This report may be made publicly available if significant changes to the project are proposed.

The Secretary would prepare an assessment report and provide it to the Minister for Planning and Public Spaces, who would then decide whether to approve the project and, if approved, identify a set of conditions of approval for Transport for NSW to adhere to during construction and operation of the project.

Community involvement would continue as part of the project's construction, should the project be approved. A construction contractor would be engaged to carry out further design development and construction. Together with the proponent, the construction contractor would be responsible for communication and engagement and a detailed communication and engagement strategy would be developed and implemented. This would be based on the framework provided in Appendix E (Community consultation framework).

Community liaison would also continue during the operation phase of the project. A communication plan would be developed to support maintenance and operations of the motorway as a key part of the operational environmental management plan framework.

7.5.2 Managing consultation fatigue

The extent and impacts of consultation fatigue would be assessed by:

- Identifying potentially impacted stakeholders and community members by both previous/current projects and the project
- Analysing the type, extent and timing of consultation, for both this project and other projects, that has been/would be received by these community members
- Determining whether consultation for the project is likely to result in overload or disinterest for community members.

The community relations team would continue to work with the project teams for other major projects and developments in the area to identify those persons or organisations who may be susceptible to consultation fatigue.

The community relations team would work to develop an integrated approach to contacting persons or organisations which may experience consultation fatigue and would determine which communication mechanisms stakeholders prefer.

7.5.3 Managing construction fatigue

The extent and impact of construction fatigue would be assessed by:

- Identifying where the project would have sustained impacts to stakeholders or community members
- Identifying whether the project would result in similar or overlapping impacts with other projects, to the same stakeholders or community members
- Analysing whether the project would increase the magnitude and intensity of overlapping impacts on any stakeholders or community members
- Analysing the extension of duration of impacts for stakeholders or community members.

A preliminary assessment was completed to identify areas where the project would potentially have sustained impacts to stakeholders or community members who may be susceptible to construction fatigue. Project activities which could lead to construction fatigue, potentially impacted groups, and a summary of management measures proposed to address these issues is provided in Chapter 27 (Cumulative impacts).

During construction of the project, the community relations team would build a working relationship with the project teams for other major projects to identify stakeholders or community members who may be susceptible to construction fatigue. The community relations team would ensure the expectations of these stakeholders or community members are managed for the project.

7.5.4 Managing complaint fatigue

The extent and impact of complaint fatigue would be assessed by:

- Identifying regular complainants from previous and current projects close to the temporary construction support sites
- Analysing the cause and solution to each complaint
- Determining whether the project would result in similar or overlapping impacts with other projects, which are likely to result in a complaint.

A complaints management system would be implemented for the duration of construction. This would include the recording of complaints and how the complaint has been addressed (within a complaints register). Complainants would be contacted within 24 hours to follow up and respond to their complaint. A Community Complaints Commissioner (an independent specialist) would oversee the system and follow up on any complaint where the public is not satisfied with the response.

The community relations team would build a working relationship with the project teams for other major projects and developments which would be under construction at the same time as the project to identify stakeholders and community members who may be susceptible to complaint fatigue.

Transport for NSW would ensure a number of different complaint mechanisms are provided to cater to different needs and preferences. Complaint management tools for the project are outlined in Appendix E (Community consultation framework).

7.5.5 Interface management

The community relations team would work closely with other government agencies to ensure the various State Government and local government projects are releasing and/or consulting on projects in collaboration with each other and to reduce consultation and construction fatigue in local communities.

At present there is a formal group, the Intergovernmental Working Group – Northern Beaches/Mosman, which meets regularly to manage potential cumulative impacts. The group consists of engagement leads from agencies which have an interface around the Northern Beaches/Mosman precinct. Attendance at meetings varies depending on the work and activities being carried out at the time and includes:

- Mosman Council
- Northern Beaches Council
- Manly MP office
- Pittwater MP office
- Transport for NSW.

Additional coordination groups would be developed as required.

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 8

Construction traffic and transport

8 Construction traffic and transport

This chapter considers the potential traffic and transport impacts from the construction of the Beaches Link and Gore Hill Freeway Connection and identifies measures which address these impacts. Potential operational traffic and transport impacts are discussed in Chapter 9 (Operational traffic and transport).

A detailed traffic and transport assessment has been carried out for the project and is included in Appendix F (Technical working paper: Traffic and transport).

The Secretary's environmental assessment requirements as they relate to construction traffic and transport, and where in the environmental impact statement these have been addressed, are detailed in Table 8-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to construction traffic and transport are included in Section 8.5.

Table 8-1 Secretary's environmental assessment requirements – construction traffic and transport

Secretary's environmental assessment requirements	Where addressed
Traffic and Transport	
1. The Proponent must assess construction transport and traffic (vehicle, marine, pedestrian and cyclists) impacts, including, but not necessarily limited to: a. a considered approach to route identification and scheduling of marine and land transport movements, particularly outside standard construction hours;	Construction traffic routes are assessed in **Section 8.4**. Construction traffic movements are shown in **Chapter 6** (Construction work).
b. the number, frequency and size of construction related vehicles (passenger, marine, commercial and heavy vehicles, including spoil management movements);	Information on construction traffic movements is presented in **Chapter 6** (Construction work). **Section 6.8** outlines number, frequency and size of construction vehicles.
c. construction worker parking;	Construction worker parking is assessed in **Section 8.4**. Temporary construction support site layouts, including provision of construction worker parking, are presented in **Chapter 6** (Construction work).
d. the nature of existing traffic (types and number of movements) on construction access routes (including consideration of peak traffic times and sensitive road users and parking arrangements;	The nature of existing traffic is detailed in **Section 8.3**. The assessment of potential traffic impacts during construction are detailed in **Section 8.4**.

Secretary's environmental assessment requirements	Where addressed
e. access constraints and impacts on public transport, pedestrians and cyclists;	Access constraints and impacts on public transport, pedestrians and cyclists is described in **Section 8.4**.
f. how construction of the project affects the capacity of, and the need to close, divert or otherwise reconfigure elements of, the road, cycle and pedestrian network;	Impacts during construction on the road, cycle and pedestrian networks are detailed in **Section 8.4**.
g. details of how construction and scheduling of works are to be coordinated in regard to public events and cumulative traffic impacts resulting from concurrent work on the project and other major projects, under or preparing for or commencing construction in the vicinity of the proposal;	Coordination regarding public events and recreational activities is discussed in **Section 8.4.8** and **Section 8.5**. Cumulative construction impacts are discussed in **Section 8.4.6**.
h. alternatives to road transport of construction spoil including marine and rail options as well as potential re-use in existing land reclamation areas or in association with Resource Recovery Exceptions (if obtained from the EPA) to minimise traffic impacts on the road network;	Impacts from transportation of dredged material are discussed in **Section 8.4.3**. Potential reuse of spoil is addressed in **Chapter 24** (Resource use and waste management). Alternatives to road transport of construction spoil including marine and rail options are discussed in **Chapter 4** (Project development and alternatives).
i. the likely risks of the project to public safety, paying particular attention to pedestrian safety and users of Middle Harbour; and	The assessment of potential traffic impacts during construction for pedestrians and users of Middle Harbour are detailed in **Section 8.4**. **Chapter 23** (Hazard and risk) (**Section 23.2** and **Section 23.3**) assess the interactions between maritime traffic and tunnel infrastructure.
j. impacts to water based traffic on Middle Harbour.	Impacts to water based traffic and shipping channels during construction are discussed in **Section 8.4.3**.

8.1 Strategic transport planning context

Details regarding the project's compatibility with key Australian Government and State strategic planning and transport policies are provided in Chapter 3 (Strategic context and project need). Specific transport strategies relevant to operation of the project are discussed in Chapter 9 (Operational traffic and transport).

8.2 Assessment methodology

8.2.1 Overview

The assessment methodology for construction traffic and transport impacts considered five core components:

- Road traffic
- Local roads and parking
- Public transport
- Pedestrian and cyclists (active transport)
- Maritime traffic.

The method and outputs of assessment for each of these components are summarised in Table 8-2. The construction traffic and transport assessment conservatively focused on the impacts during peak construction activities to reflect the greatest potential impact of the project. For example, the quantitative assessment of road network performance is for the highest potential construction site traffic generation per hour. These peak construction activities are likely to be short in duration and would only occur for a small proportion of the overall construction program. Typical site traffic generated per hour would therefore generally be lower than the peak site traffic numbers assessed.

Table 8-2 Overview of approach to the construction traffic and transport assessment

Project impacts	Method of assessment	Assessment output
Road traffic	Analysis of road network performance during construction based on strategic traffic forecasting and modelling of the worst case construction traffic scenario.	Quantitative assessment of road network performance with and without the project.
Local roads and parking	Analysis of changes to local road access arrangements, loss of parking spaces and availability of comparable alternative parking in nearby locations. The analysis considers both temporary impacts (ie during construction) and permanent impacts.	Qualitative assessment of local road changes. Estimate of number of lost parking spaces. Qualitative assessment of the impact of parking overflow to parking in nearby locations.
Public transport	Analysis of changes to public transport routes and stops, and service timeliness and efficiency during construction.	Qualitative assessment of impacts on public transport performance (increase or decrease in travel times).
Pedestrians and cyclists (active transport)	Analysis of temporary changes to shared user paths, cycle ways, footpaths and pedestrian crossings.	Qualitative assessment of impacts on pedestrian and cycling networks and accessibility.

Project impacts	Method of assessment	Assessment output
Maritime traffic	Analysis of proposed use of the waterway including the number, type, frequency and duration of marine construction traffic. Simulation of marine vessels and transport of immersed tube tunnel elements.	Qualitative assessment of impacts on existing waterway navigation and commercial and recreational usage. Simulation report showing the paths of marine vessels and the area required for the transport of immersed tube tunnel elements in Middle Harbour.

The assessment methodology for road traffic is described in more detail below.

8.2.2 Road traffic assessment methodology

The potential construction impacts of the project on road network performance were assessed through strategic traffic demand forecasting and traffic modelling. The assessment included modelling, which enabled existing and future traffic and transport conditions and road network performance to be characterised during construction of the project. An overview of the transport modelling methodology used in the assessment of the project is provided in Figure 8-1.

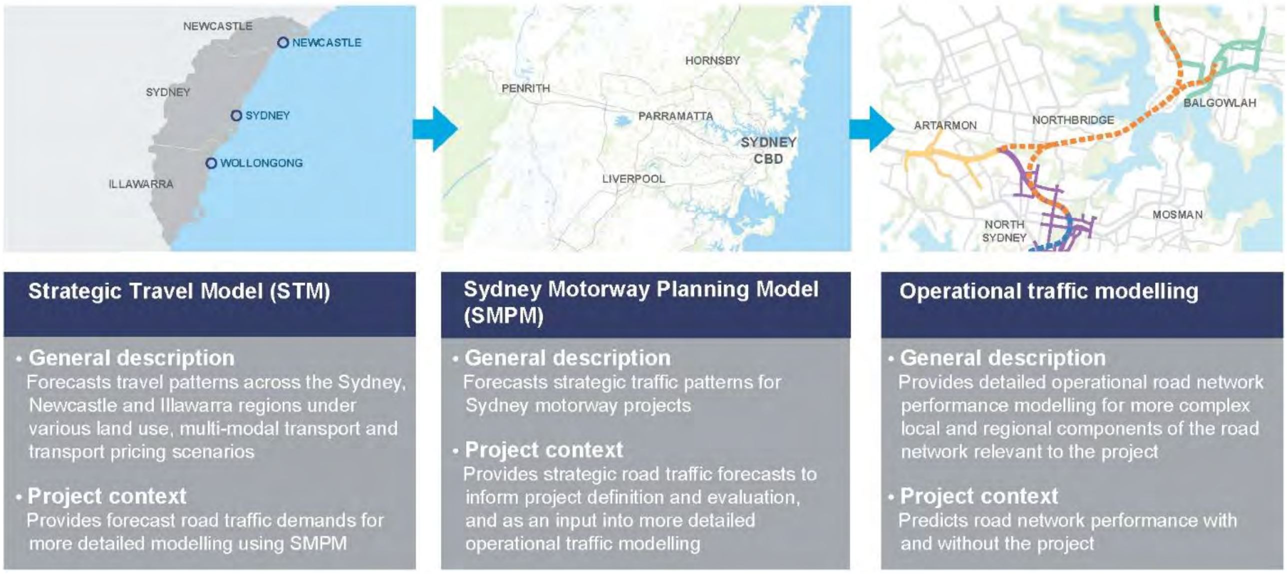


Figure 8-1 Overview of transport modelling approach

Construction traffic modelling scenarios

Construction modelling was based on construction traffic routes to and from the various temporary construction support sites. Based on the planned construction activities, the worst case construction traffic scenario was assumed to occur during the peak period of spoil removal from tunnel construction and associated surface works during 2024.

Models were developed for the AM peak (between 7am and 9am on a normal working weekday) and PM peak (between 4pm and 6pm on a normal working weekday) to assess the future performance of the road network during construction. Forecast traffic growth was taken from the Sydney Motorway Planning Model (SMPM) to derive background traffic demand. The SMPM, developed and operated by Transport for NSW, provides a platform to understand changes in future traffic patterns under different land use, transport infrastructure and pricing scenarios.

Construction traffic was then added to the background traffic. This was based on the proposed construction methodology as described in Chapter 6 (Construction work) including vehicle types, volumes and construction traffic routes. The performance of the roads and intersections in the vicinity of the temporary construction support sites was then calculated.

The scenarios modelled to assess the impacts of construction on the road network are listed in Table 8-3. In addition, key intersections were modelled based on 2016 travel demands to characterise existing intersection performance. The SMPM model forecasts travel demands in five year increments (ie 2016, 2021, etc). The 2016 baseline year represents transport network conditions available at the time of assessment. Ongoing and continuous traffic surveys carried out by Transport for NSW indicate that the 2016 baseline year is appropriate for modelling purposes as there is little material difference between 2016 and existing (2020) traffic conditions in the project area.

Specific intersections were assessed if they would form part of a construction traffic route and the increase in construction vehicles due to the project would be greater than 50 vehicles per hour (ie the vehicle contribution was significant enough to warrant modelling).

Table 8-3 Construction traffic modelling scenarios

Model year	Without project	With project	Modelling scenario	Description
2024	✓		Base case 2024	The existing road network with no new projects or upgrades.
2024		✓	Construction 2024	Peak tunnelling and associated surface works for the project. The current road network with construction traffic movements for the project. No new projects or upgrades are included.
2024		✓	Cumulative construction 2024	Peak construction year for the Western Harbour Tunnel and Beaches Link program of works. The current road network with construction traffic movements for the project and the Western Harbour Tunnel and Warringah Freeway Upgrade project. No new projects or upgrades are included.

8.2.3 Assessment criteria

The criteria used to assess road network performance were as follows:

- At an intersection level, showing changes to traffic flow (expressed in vehicles per hour), average delay (expressed in seconds per vehicle), level of service (as defined in the *Guide to Traffic Generating Developments Version 2.2* (RTA, 2002)) and degree of saturation (expressed as the ratio of traffic volumes at an intersection to its overall capacity (V/C ratio))
- At a midblock level, showing changes on traffic volumes, volume to capacity ratio (ratio of traffic volumes at a midblock road to its overall capacity) and level of service (as defined in the *Guide to Traffic Generating Developments Version 2.2* (RTA, 2002))
- At a network level for cumulative assessments, showing changes to overall traffic demand and average speeds within the modelled areas, travel times along key routes, and changes to stopping frequencies.

8.2.4 Intersection and midblock level of service

Level of service (LoS) is a measure to describe the operational conditions and efficiency of a road or intersection. The definition of level of service generally outlines the operating conditions in terms of speed and travel time, freedom to manoeuvre, traffic interruptions, comfort and convenience, and road safety. It is a qualitative measure describing operational conditions within a roadway or intersection, as perceived by motorists and passengers. Average delay is commonly used to assess the operational performance of intersections, with level of service used as an index.

The performance of roads can also be defined by the midblock level of service. The midblock level of service is based on the degree of saturation, which is the ratio between traffic volumes and the road capacity (V/C ratio). Satisfactory operations usually occur with a degree of saturation below 0.9. As degree of saturation approaches one, both queue length and delays increase rapidly. The level of service for freeways and motorways is calculated from vehicle density, which is the traffic volume divided by the average passenger car speed. Density is measured in passenger car units (PCU) per kilometre per lane. Passenger car units account for the amount of road space various vehicle types use. Heavy vehicles and buses use more road space than cars or light commercial vehicles and therefore have a passenger car unit greater than one.

A description of the level of service scale for intersection and midblock performance is shown in Table 8-4. There are six levels of service; labelled LoS A to LoS F. LoS A represents the best operating conditions and LoS F the poorest operating conditions. For the purposes of this assessment, LoS E and LoS F are considered unsatisfactory.

Table 8-4 Level of service criteria for intersection and midblock performance

LoS	Intersection criteria	Mid-block criteria
A	Good operation	A condition of free flow in which individual drivers are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to manoeuvre within the traffic stream is extremely high, and the general level of comfort and convenience provided is excellent.
B	Good with acceptable delays and spare capacity	In the zone of stable flow where drivers still have reasonable freedom to select their desired speed and to manoeuvre within the traffic stream. The general level of comfort and convenience is a little less than with LoS A.
C	Satisfactory	In the zone of stable flow, but most drivers are restricted to some extent in their freedom to select their desired speed and to manoeuvre within the traffic stream. The general level of comfort and convenience declines noticeably at this level.
D	Operating near capacity	Close to the limit of stable flow and approaching unstable flow. All drivers are severely restricted in their freedom to select their desired speed and to manoeuvre within the traffic stream. The general level of comfort and convenience is poor, and small increases in traffic flow would generally cause operational problems.
E	Unsatisfactory. At capacity. At traffic lights, incidents would cause delays. Roundabouts require other control mode.	Traffic volumes are at or close to capacity and there is virtually no freedom to select desired speeds or to manoeuvre within the traffic stream. Flow is unstable and minor disturbances within the traffic stream would cause breakdown.
F	Unsatisfactory. Extra capacity required.	In the zone of forced flow, where the amount of traffic approaching a point exceeds that which can pass it. Flow breakdown occurs, and queuing and delays result.

Source: Roads and Traffic Authority (2002) Guide to Traffic Generating Developments and Austroads.

8.3 Existing environment

The existing traffic and transport environment for the project within the context of the broader road network is outlined below, along with more detailed analysis across the following local areas:

- Warringah Freeway and surrounds
- Gore Hill Freeway and Artarmon
- Northbridge to Seaforth (Middle Harbour crossing)
- Balgowlah and surrounds
- Frenchs Forest and surrounds.

8.3.1 Broader road network

Travel times and speed along key corridors

A summary of 2016 travel times and average speeds for trips for key road corridors between destinations in the Northern Beaches and lower North Shore of Sydney in the AM peak (between 7am and 9am on a normal working weekday) and PM peak (between 4pm and 6pm on a normal working weekday) is provided in Figure 8-2 and Figure 8-3. These centres are connected by motorways and major arterials with posted speeds of between 50 and 80 km/h. Typical operating speeds during peak periods are shown to be in the range of 20 to 40 km/h, indicating these corridors are operating at capacity resulting in congestion and delays.

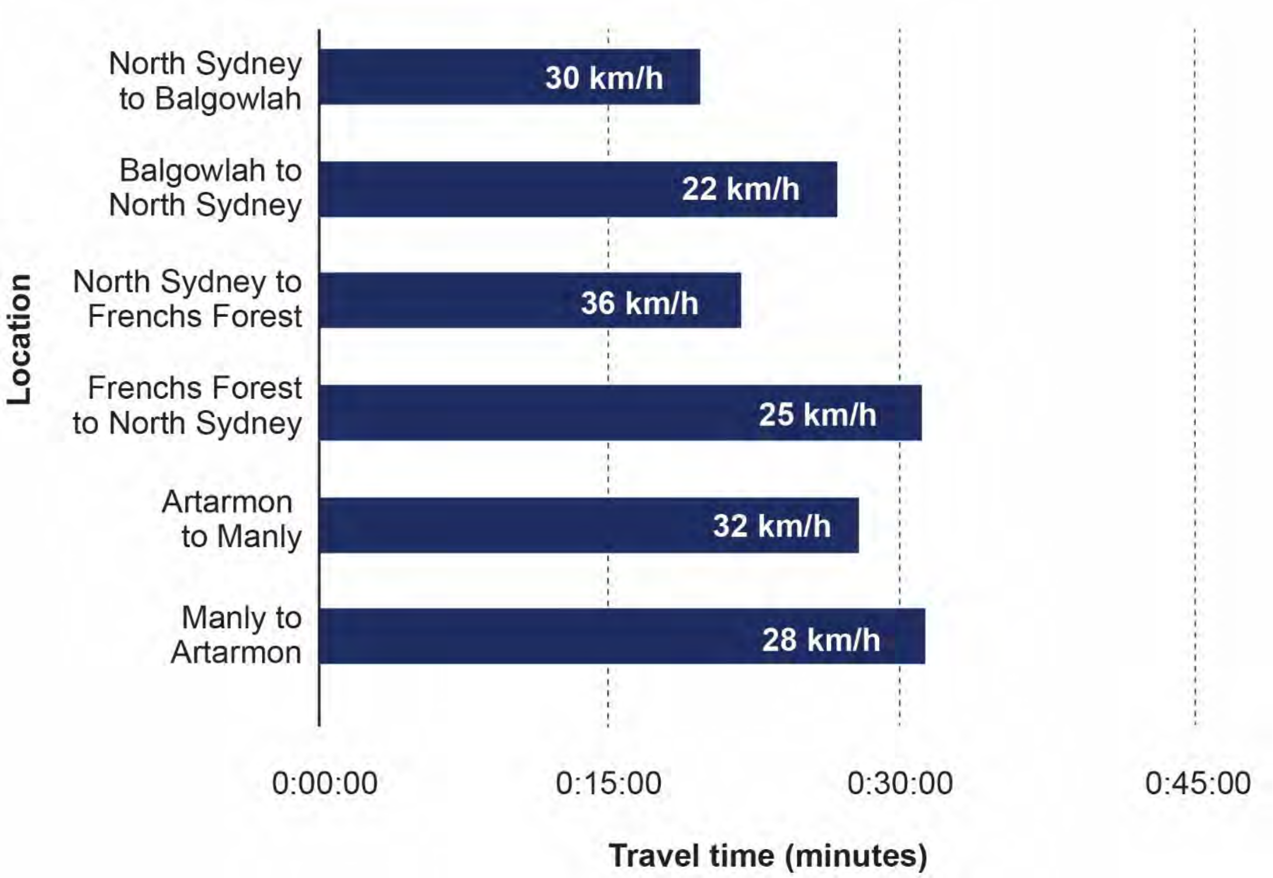


Figure 8-2 2016 AM peak travel times and average speeds along key corridors

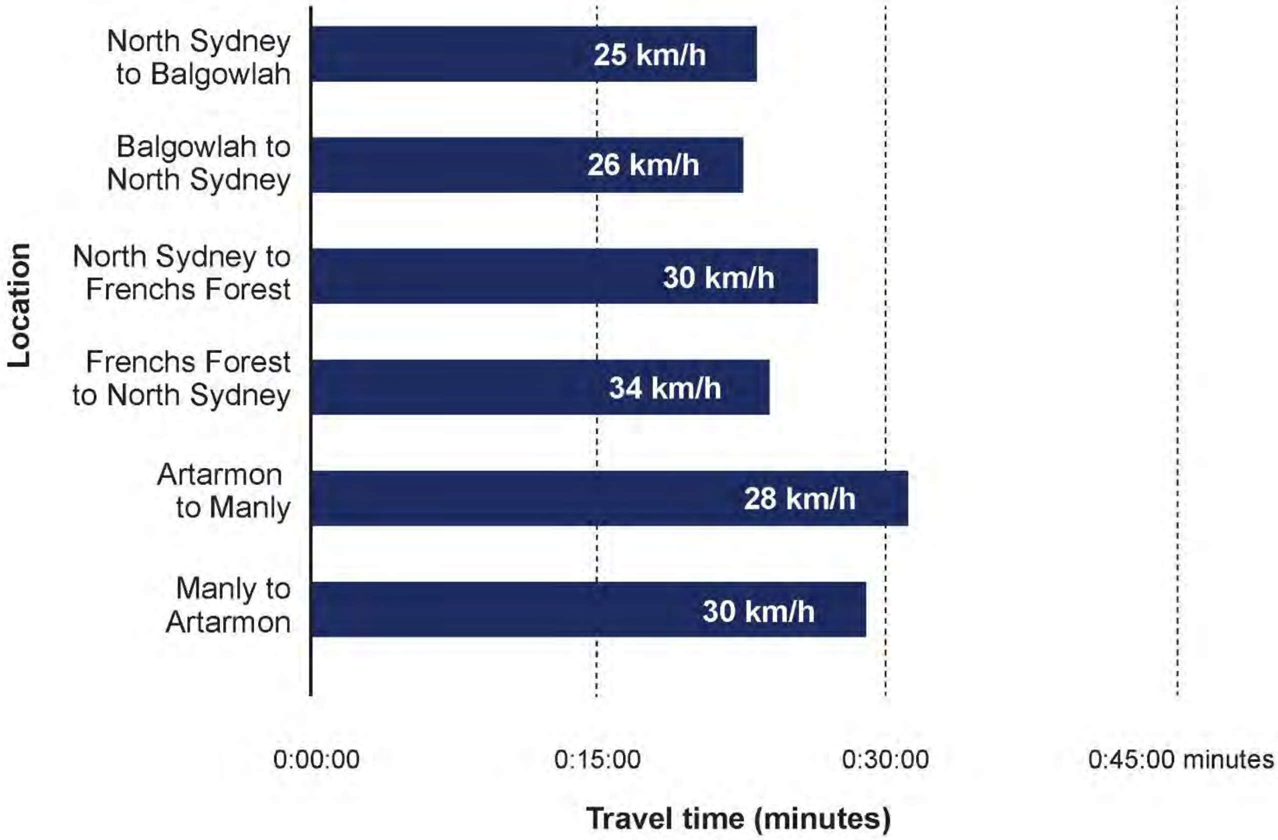


Figure 8-3 2016 PM peak travel times and average speeds along key corridors

Heavy vehicles and freight

Spit Road/Military Road and Warringah Road are both arterial commuter corridors and the movement of heavy vehicles along these roads is limited by capacity constraints and congestion, particularly during peak periods. Further, Spit Road and Military Road have access restrictions for large articulated trucks (ie B-Doubles and other Higher Mass Limit vehicles are not permitted). As such, access to the Northern Beaches for B-Doubles is currently limited to Mona Vale Road and Warringah Road.

The largest proportion of truck movements into and out of the Northern Beaches peninsula in 2016 occurred via Mona Vale Road, likely due to lower congestion and its proximity to the M1 Sydney Newcastle Motorway and industrial areas in Mona Vale, Warriewood, Belrose and Terrey Hills.

While Mona Vale Road carries much higher volumes of heavy vehicles compared to Spit Road/ Military Road and Warringah Road, the poor standard of the road, particularly through Terrey Hills and Mona Vale, likely contributed to two fatal crashes over the past 10 years. It is noted that the NSW Government is upgrading Mona Vale Road from two to four lanes between Terrey Hills and Mona Vale. The upgrade is being carried out in two stages to provide customers with a better travelling experience and to improve safety and traffic flow. Works have commenced and are anticipated to be completed in 2022.

8.3.2 Warringah Freeway and surrounds

Description

Transport network

The existing transport network within the Warringah Freeway and surrounds area is shown in Figure 8-4 and includes the suburbs of Cammeray, Neutral Bay, North Sydney, Naremburn and Waverton.

Traffic volumes and patterns

A summary of existing peak hour traffic volumes for Warringah Freeway and surrounds in the AM peak (between 7am and 9am on a normal working weekday) and PM peak (between 4pm and 6pm on a normal working weekday) is provided in Table 8-5.

Table 8-5 Existing (2016) peak hour traffic volumes – Warringah Freeway and surrounds

Road	Direction	AM peak		PM peak	
		Volume (vehicles)	Heavy vehicle percentage	Volume (vehicles)	Heavy vehicle percentage
Warringah Freeway and surrounds					
Pacific Highway south of Walker Street	Northbound	2100	4%	1410	11%
	Southbound	380	13%	580	6%
Pacific Highway south of Bay Road	Northbound	690	8%	800	7%
	Southbound	1100	7%	950	3%
Bay Road west of Pacific Highway	Eastbound	230	2%	260	1%
	Westbound	380	4%	280	2%
Berry Street east of Walker Street	Eastbound	1650	7%	2390	4%
	Westbound	-	-	-	-
Falcon Street east of Miller Street	Eastbound	1250	2%	1350	6%
	Westbound	1170	6%	1110	5%
Ridge Street east of Miller Street	Eastbound	330	5%	130	2%
	Westbound	160	9%	260	4%
Miller Street north of Ernest Street	Northbound	470	6%	730	8%
	Southbound	1050	4%	1060	3%
Ernest Street east of Miller Street	Eastbound	1070	4%	1380	4%
	Westbound	1050	1%	870	2%
Ernest Street west of Merlin Street	Eastbound	650	3%	2000	1%
	Westbound	2070	1%	990	1%
Blue Street south of Pacific Highway	Northbound	330	3%	500	1%
	Southbound	290	3%	220	1%

Road	Direction	AM peak		PM peak	
		Volume (vehicles)	Heavy vehicle percentage	Volume (vehicles)	Heavy vehicle percentage
Arthur Street north of Pacific Highway	Northbound	800	2%	610	1%
	Southbound	-	-	-	-
Alfred Street north of Mount Street	Northbound	40	9%	30	0%
	Southbound	1420	1%	730	3%
Falcon Street west of Merlin Street	Eastbound	2330	7%	2910	5%
	Westbound	3140	6%	2110	8%
Walker Street north of Pacific Highway	Northbound	830	3%	650	2%
	Southbound	290	2%	360	3%
Brook Street south of Merrenburn Avenue	Northbound	720	9%	1660	2%
	Southbound	2070	2%	1020	6%

Public transport network

The Warringah Freeway and surrounds area is readily accessible via public transport.

Heavy rail services are provided at Milsons Point, North Sydney, Waverton and Wollstonecraft railway stations, which are located on the T1 North Shore and Western Line and T9 Northern Line. A new station as part of Sydney Metro City & Southwest is under construction in North Sydney (Victoria Cross station) and is expected to be operational in 2024.

The Warringah Freeway and surrounds area is a major thoroughfare for buses including services operating along the Warringah Freeway, Military Road, Miller Street and the Pacific Highway.

The area is also serviced by ferry, with ferry wharves located at McMahons Point, Milsons Point, Kirribilli, North Sydney, Neutral Bay and Kurraba Point.

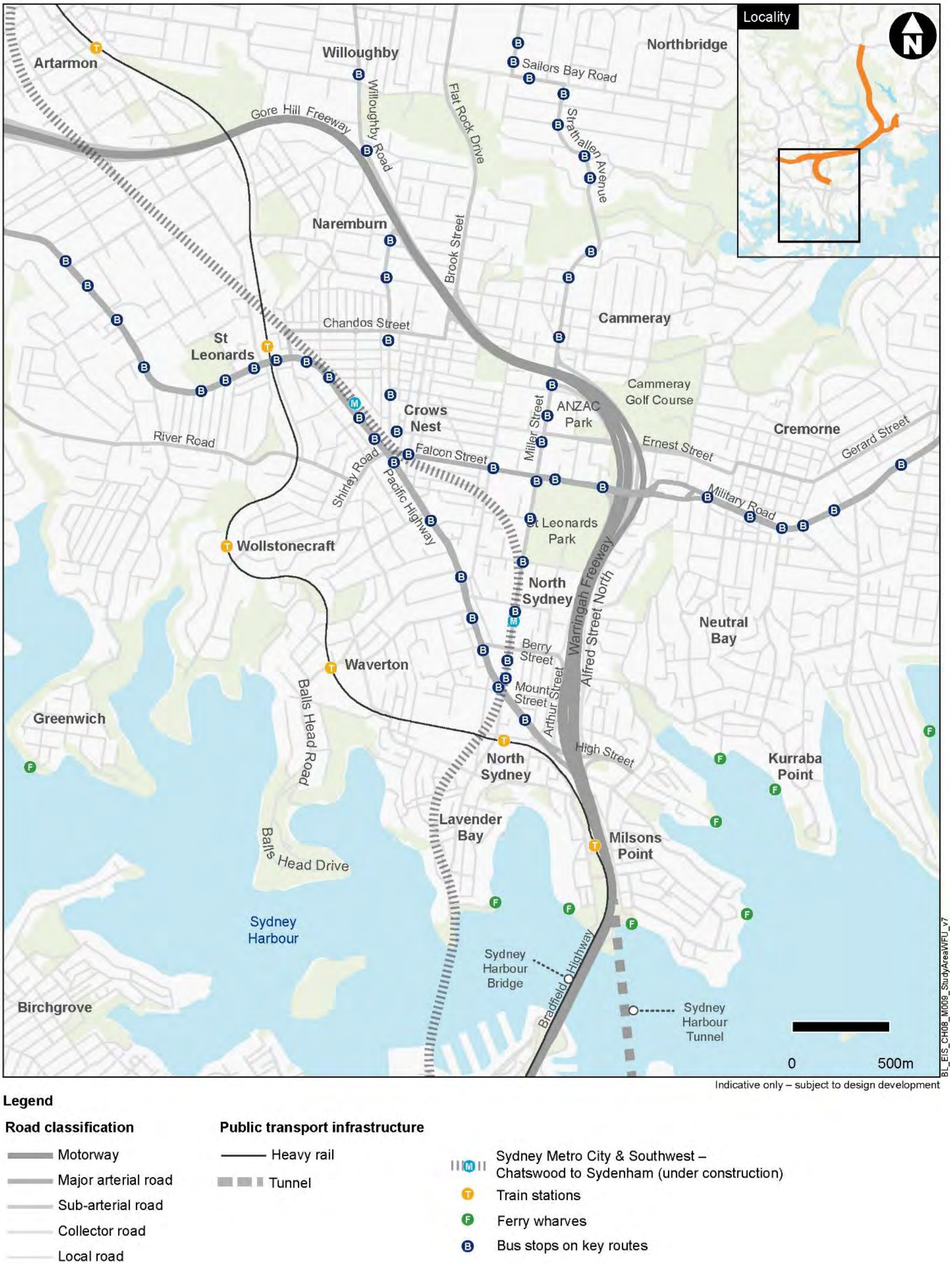


Figure 8-4 Transport network within the Warringah Freeway and surrounds area

Active transport network

The pedestrian network in the Warringah Freeway and surrounds area is well developed, with footpaths along most roads and controlled crossings at signalised intersections. Pedestrians are prohibited from walking along the Warringah Freeway. Significant pedestrian activity associated with retail and commercial activities occurs within the North Sydney CBD, including in the vicinity of several schools located west of the Pacific Highway and along Miller Street. Balls Head Reserve and other parks and reserves in the area are also associated with high levels of pedestrian activity.

The cycle network in the Warringah Freeway and surrounds area consists mostly of on-road cycle routes on local, collector and sub-arterial roads.

The Warringah Freeway presents a significant barrier to east–west movements for pedestrians and cyclists, with crossings available at select locations. Based on pedestrian and cyclist surveys carried out for the project, Mount Street was identified as the most used crossing for pedestrians due to its proximity to North Sydney CBD, while West Street was the most used crossing for cyclists. The Falcon Street underpass was identified as being under-utilised by pedestrians and cyclists during the week and on weekends.

Existing road performance

Road network performance

The Warringah Freeway is the busiest section of motorway in NSW. Congestion and delays are highest during the AM peak period, particularly for southbound traffic with queues extending as far north as the Miller Street interchange. During the PM peak, queuing and congestion is frequently observed on the northbound off ramp to Falcon Street eastbound.

Queuing and congestion are also frequently observed on connecting roads within the North Sydney CBD area, to the west of the Warringah Freeway.

Intersection performance

Modelled intersection performance under 2016 travel demands is provided in Table 8-6. The assessment indicates that the following intersections perform at an unsatisfactory level of service (LoS E or F) during the AM peak:

- Mount Street and Arthur Street
- High Street and Clark Road
- High Street and Alfred Street North.

The assessment also indicates that the Miller Street and Falcon Street intersection performs at an unsatisfactory level of service during the PM peak.

The intersection of Mount Street and Arthur Street is the primary western access to the Warringah Freeway, where traffic heading to the Sydney Harbour Bridge (Bradfield Highway) and Cahill Expressway lanes converges from Berry Street and Pacific Highway during the AM peak.

The intersection of Clark Road and High Street is the primary eastern access to the Sydney Harbour Bridge Cahill Expressway lane where traffic from Kirribilli and Neutral Bay converge. Queues from the intersection of High Street and Alfred Street North occasionally extend back through this intersection.

Table 8-6 Modelled intersection performance in the Warringah Freeway and surrounds area (AM and PM peaks in 2016)

Intersection	AM peak (8am-9am) – LoS (average delay in seconds)	PM peak (5pm-6pm) – LoS (average delay in seconds)
Willoughby Road/Gore Hill Freeway interchange	A (11)	B (20)
Brook Street/Warringah Freeway on ramp	C (31)	B (16)
Brook Street/Warringah Freeway off ramp	C (30)	B (22)
Brook Street/Merrenburn Avenue	C (31)	A (12)
Amherst Street/West Street	A (6)	A (10)
Amherst Street/Miller Street	B (19)	B (15)
Miller Street/Warringah Freeway on ramp	A (<5)	A (6)
Miller Street/Warringah Freeway off ramp	A (13)	A (13)
Miller Street/Ernest Street	C (34)	C (31)
Miller Street/Falcon Street	C (35)	**E (69)**
Ernest Street/Warringah Freeway on ramp	A (<5)	B (15)
Ernest Street/Warringah Freeway off ramp (off ramp in PM, on ramp in AM)	A (<5)	B (18)
Falcon Street/Warringah Freeway ramps (off ramp in PM, on ramp in AM)	C (38)	D (46)
Watson Street/Military Road	B (16)	C (29)
Military Road/Ben Boyd Road	A (13)	B (20)
Falcon Street/Merlin Street	B (17)	C (38)
Berry Street/Walker Street	C (32)	D (50)
Berry Street/Miller Street	C (30)	B (27)
Mount Street/Arthur Street	**F (84)**	C (32)
Mount Street/Walker Street	D (43)	C (31)
Pacific Highway/High Street/Arthur Street	D (53)	B (19)
Pacific Highway/Walker Street/Blue Street	D (53)	D (48)
Pacific Highway/Miller Street/Mount Street	D (52)	C (41)
Pacific Highway/Berry Street	A (9)	A (11)
Pacific Highway/Bay Road	B (21)	B (14)

Intersection	AM peak (8am-9am) – LoS (average delay in seconds)	PM peak (5pm-6pm) – LoS (average delay in seconds)
Miller Street/McLaren Street	B (24)	B (17)
Miller Street/Ridge Street	C (39)	B (26)
Miller Street/Carlow Street	B (14)	C (29)
High Street/Clark Road	F (>100)	C (36)
High Street/Alfred Street North	E (60)	B (18)
Mount Street/Alfred Street North	B (24)	A (11)
Ernest Street/Ben Boyd Road	A (11)	B (16)
Pedestrian crossing at Military Road	A (<5)	B (20)

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

8.3.3 Gore Hill Freeway and Artarmon

Description

Transport network

The existing transport network within the Gore Hill Freeway and Artarmon area is shown in Figure 8-5 and includes the suburbs of Artarmon, Crows Nest, St Leonards, Cammeray, Lane Cove, Naremburn and Willoughby.

Traffic volumes and patterns

A summary of existing peak hour traffic volumes for the Gore Hill Freeway and Artarmon area in the AM peak (between 7am and 9am on a normal working weekday) and PM peak (between 4pm and 6pm on a normal working weekday) is provided in Table 8-7.

Table 8-7 Existing (2016) peak hour traffic volumes – Gore Hill Freeway and Artarmon

Road	Direction	AM peak		PM peak	
		Volume (vehicles)	Heavy vehicle percentage	Volume (vehicles)	Heavy vehicle percentage
Gore Hill Freeway and Artarmon					
Reserve Road north of Dickson Avenue	Northbound	520	8%	1140	1%
	Southbound	1210	3%	610	2%
Reserve Road north of Frederick Street	Northbound	320	10%	670	3%
	Southbound	690	3%	490	1%
Frederick Street east of Reserve Road	Eastbound	440	5%	560	1%
	Westbound	360	8%	420	5%
Herbert Street north of Frederick Street	Northbound	250	3%	440	1%
	Southbound	530	3%	500	2%
Cleg Street east of Herbert Street	Eastbound	110	1%	190	1%
	Westbound	120	2%	180	2%

Road	Direction	AM peak		PM peak	
		Volume (vehicles)	Heavy vehicle percentage	Volume (vehicles)	Heavy vehicle percentage
Dickson Avenue east of Reserve Road	Eastbound	250	3%	150	0%
	Westbound	130	5%	30	2%
Reserve Road south of Barton Road	Northbound	350	3%	640	1%
	Southbound	470	2%	410	1%

Public transport network

The Gore Hill Freeway and Artarmon area is highly accessible by public transport. Heavy rail services are provided at Artarmon and St Leonards railway stations, which are located on the T1 North Shore and T9 Northern Lines. A new station as part of Sydney Metro City & Southwest is under construction in Crows Nest and is expected to be operational in 2024 (refer to Figure 8-4).

The Gore Hill Freeway and Artarmon area is also a major thoroughfare for buses, including services operating along the Warringah Freeway, Gore Hill Freeway/Lane Cove Tunnel and the Pacific Highway.

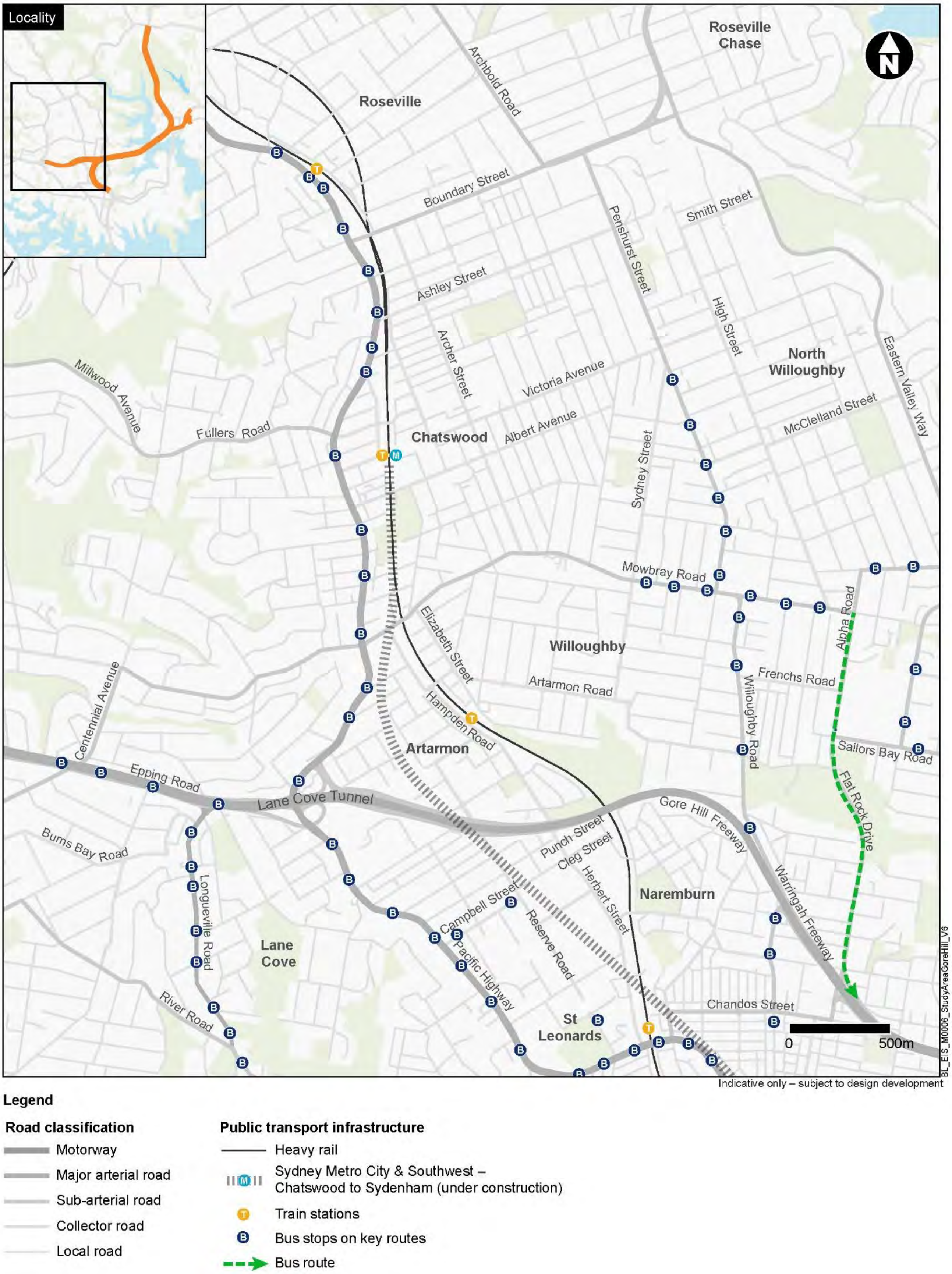


Figure 8-5 Transport network within the Gore Hill Freeway and Artarmon area

Active transport network

The pedestrian network in the Gore Hill Freeway and Artarmon area is well developed, with footpaths alongside most roads and controlled crossings at most signalised intersections. Pedestrians are prohibited from walking along the Gore Hill Freeway and through the Lane Cove Tunnel. However, a shared user path is provided adjacent to the southern side of the Gore Hill Freeway. High pedestrian activity occurs along Hampden Road within the vicinity of Artarmon railway station, around the commercial area of Artarmon, and around the health, educational and commercial land uses in St Leonards.

The cycle network in the Gore Hill Freeway and Artarmon area consists of a mix of off-road shared user paths and on-road cycle routes on local and collector roads.

Based on pedestrian and cyclist surveys carried out for the project, the shared user path adjacent to the southern side of the Gore Hill Freeway near Hampden Road in Artarmon was identified as being used by a high number of cyclists during the week, with lower volumes recorded on weekends. This can be attributed to the path forming part of a regional cycle route connecting Naremburn, Lane Cove and Macquarie Park, with the majority of cyclists likely to be commuting to and from work. Pedestrian volumes were low both during the week and at weekends.

Existing road performance

Road network performance

The Gore Hill Freeway connects the M2 Motorway corridor with the M1 Motorway corridor through Artarmon and Willoughby. Traffic volumes are highest heading southbound in the AM peak and northbound in the PM peak, as a result of trips heading into and out of the Sydney CBD as well as local traffic from Lane Cove and Ryde.

Most traffic on Reserve Road travels to and from the Gore Hill Freeway, limiting capacity for the off ramps that often operate at or close to capacity during the AM peak.

The intersection of Longueville Road and Epping Road is the primary surface road constraint in the corridor due to the high volumes of traffic travelling to and from Lane Cove and Riverview.

Bus priority is provided on Epping Road west of Longueville Road in the form of signal priority for westbound traffic at Longueville Road and continuous bus lanes on Epping Road. Signal priority for buses is also provided for eastbound buses on Longueville Road at Pacific Highway, while eastbound buses on the Gore Hill Freeway use the 24-hour T2 transit lane that extends to Willoughby Road.

Intersection performance

Modelled intersection performance under 2016 travel demands is provided in Table 8-8. The assessment indicates that the intersection of Epping Road, Longueville Road and Parklands Avenue is currently performing at an unsatisfactory level of service (LoS E) in the PM peak. This intersection has limited capacity due to the high volume of westbound traffic that conflicts with right turn traffic from Longueville Road south. Delays on the eastern approach of this intersection are also exacerbated by buses stopping at the Lane Cove interchange, which block traffic turning left into Longueville Road.

Table 8-8 Modelled intersection performance in the Gore Hill Freeway and Artarmon area (AM and PM peaks in 2016)

Intersection	AM peak (8am–9am) – LoS (average delay in seconds)	PM peak (5pm –6pm) – LoS (average delay in seconds)
Epping Road/Longueville Road/Parklands Avenue	D (48)	E (63)
Longueville Road/Pacific Highway	C (42)	C (36)
Pacific Highway/Howarth Road/Norton Lane	A (7)	A (7)
Pacific Highway/Gore Hill Freeway interchange	B (23)	B (23)
Reserve Road/Gore Hill Freeway interchange	D (47)	C (29)
Reserve Road/Dickson Road	A (14)	B (19)
Reserve Road/Barton Road	A (11)	A (6)

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

8.3.4 Northbridge to Seaforth (Middle Harbour crossing)

The project includes the crossing of Middle Harbour, extending from Northbridge in the south to Seaforth Bluff in the north. Construction of the project would also involve navigation through the outer part of Sydney Harbour (referred to as the Outer Harbour). These areas are described as follows:

- Outer Harbour is a wide waterway between Sydney Heads, the Opera House at Bennelong Point and Admiralty House at Kirribilli Point
- Middle Harbour borders the western side of the Outer Harbour, extending west of Middle Head and Grotto Head.

The Outer Harbour is relatively deep and wide, with water depths generally exceeding 20 metres below chart datum (the zero-reference point from which tidal heights and chart soundings are calculated) between South Head and North Head, decreasing to eight metres chart datum between Grotto Point and Middle Head.

The water depths in Middle Harbour are highly variable, ranging from three metres chart datum at the sand bar at the entrance to Middle Harbour, up to 26 metres chart datum on the eastern side of the Spit Bridge. Upstream of the Spit Bridge, the water depths are more than 20 metres chart datum with depths decreasing towards the heads of each of the bays off the main Middle Harbour channel. The depth of the channel at the proposed crossing location is particularly deep, up to 32 metres chart datum at its deepest point.

The entrance to Middle Harbour is about 750 metres wide, decreasing to a waterway width of about 165 metres at the Spit Bridge. Upstream of the Spit Bridge, the width of the waterway is generally about 400 metres, decreasing towards the heads of each of the bays of the main Middle Harbour channel. At the location of the proposed harbour crossing, the navigation width between the headland at Northbridge and the existing moorings and jetties near Seaforth Bluff is about 350 metres.

Spit Bridge (refer to Figure 8-6), spans 227 metres across Middle Harbour, connecting Mosman and Seaforth. When closed, the bridge presents a barrier to boats with heights greater than five or six metres above the water level (depending on tides). Clearance height under the bridge when closed is as follows:

- 4.7 metres at highest astronomical tide under the opening span
- 5.7 metres at highest astronomical tide under the first fixed span at the northern end.

Spit Bridge has scheduled daily openings to allow boats that are above the clearance height to pass through. When the bridge is open, the navigational channel between the piers of the lifting span is 24.3 metres wide. Current scheduled bridge opening times are listed in Table 8-9.

Table 8-9 Current Spit Bridge scheduled opening times

Weekday	Weekends and public holidays
10.15 am 11.15 am 1.15 pm 2:15 pm 8.15 pm 9.15 pm (during daylight saving only)	8.30 am 10.00 am 11.30 am 2.30 pm 4.30 pm 6.30 pm 8.30 pm 9.30 pm

Source: Transport for NSW (2019)

Users of Middle Harbour can be divided into three main groups: recreational users, community groups and clubs; commercial operators; and government organisations. Middle Harbour and the Outer Harbour are also used for recreational purposes, as well as some private uses. These are discussed in detail below and shown in Figure 8-6.

Recreational users, community groups and clubs

Middle Harbour supports a wide range of water based recreational activities. Key community groups and clubs using Middle Harbour include:

- Paddle craft users and clubs
- Recreational fishers
- Sailing and yacht clubs
- Scout and guide clubs
- Marine Rescue NSW.

Mosman Rowing Club, Northbridge Sailing Club, and two sea scout groups regularly use the waterway upstream of Spit Bridge, regularly traversing the location of the proposed Middle Harbour crossing. Marine Rescue NSW has its base for Middle Harbour located at The Spit.

Several boat storage and boat launching facilities are located in Middle Harbour that provide storage for recreational seagoing vessels. These include:

- Marina facilities
- Boat ramps
- Moorings.

Commercial marina facilities generally offer a wide range of premium services for the boating community, while boat ramp facilities attract smaller craft, typically from a larger geographical area.

The boat ramps in Middle Harbour are generally in good condition attracting a range of users that would navigate through all parts of Middle Harbour and the Outer Harbour. These vessels are typically not registered with a community group or club. The sand ramp used for informal launching in Clontarf Reserve is infrequently used, with users limited to surfboat rowers from nearby surf lifesaving clubs and other small craft.

In addition to marinas and boat ramps, numerous mooring fields are located throughout Middle Harbour. These include commercially and privately leased moorings with defined areas for vessels registered with a club or marina. Key facilities are outlined in Table 8-10. Recreational vessels which use these facilities would use the waterway upstream and downstream of Spit Bridge.

Table 8-10 Marinas, boat ramps and mooring fields within Middle Harbour

Facility	Location
Marinas	• Middle Harbour Yacht Club in Mosman • Smiths Boatshed Marina in Mosman • Fergusons Boat Shed in Mosman • D'Albora Marina in Mosman • Cammeray Marina in Cammeray • Northbridge Marina in Northbridge • Castlecrag Marina in Castlecrag • Roseville Bridge Marina in Roseville • Clontarf Marina in Clontarf.
Boat ramps	• Tunks Park boat ramp in Cammeray • Roseville Bridge boat ramp in Killarney Heights • An informal sand ramp at Clontarf Reserve in Clontarf.
Mooring fields	• Fisher Bay • Sandy Bay • The Spit • Pearl Bay • Beauty Point • Quakers Hat Bay • Long Bay • Willoughby Bay • Salt Pan Creek • Northbridge • Sailors Bay • Castlecrag • Pickering Point • Powder Hulk Bay • Seaforth.

Most of the yachts in the marinas around Spit Bridge (particularly Middle Harbour Yacht Club) and in the nearby mooring fields are used for racing and are registered with Middle Harbour Yacht Club. They are used around once a week on average, with most of the activity occurring downstream of Spit Bridge.

Other moored vessels, including motor cruisers and cruising yachts, are used less frequently and typically do not belong to a community group or club. These vessels travel upstream and downstream of Spit Bridge.

Three houseboats with permanent land access are located near the head of Pearl Bay. Several private jetties, pontoons and mooring pens are located at private residences on the foreshore of Seaforth Bluff, Long Bay and Sailors Bay.

Commercial operations within Middle Harbour

Most businesses that conduct commercial operations in Sydney Harbour are located in the Inner Harbour (ie the area between Outer Harbour and Parramatta River), particularly around The Bays and Darling Harbour. Vessels associated with commercial operations transit the Outer Harbour, and do not typically enter Middle Harbour. Access to Middle Harbour for deep draft vessels is restricted by water depth over the sand bar at the entrance to Middle Harbour.

A limited number of commercial operators are located in or navigate through Middle Harbour as summarised below.

Water taxis and charter companies

Several water taxi companies operate within Sydney Harbour, with some operators providing private harbour tours and charter services. A limited number of yacht charter and boat hire companies are located in Middle Harbour, including:

- Champagne Sailing in Clontarf, with pick up locations including Balmoral, Clontarf and Middle Harbour Yacht Club
- Eco Boats Hire in Northbridge.

Vessels from charter companies further afield may also enter Middle Harbour.

Jungle Float mobile water park

Jungle Float is a floating mobile waterpark that is about 11 metres long and three metres wide and can accommodate groups of up to 40 people. It is anchored about 20 metres off Clontarf Beach when in use. The Jungle Float allows participants to swing, dive, jump and/or slide into the water. Participants are required to swim to the floating waterpark from Clontarf Beach.

Government operations within Middle Harbour

Royal Australian Navy

HMAS Penguin, an Australian Defence Force facility, is located at Balmoral in Middle Harbour. Its primary purpose is to provide trained personnel to the fleet. A naval water exclusion zone is established around the facility. The navy also operates facilities in the Inner Harbour and Outer Harbour, but vessels from these facilities rarely enter Middle Harbour.

Water Police, Transport for NSW, and Department of Planning, Industry and Environment (Regions, Industry, Agriculture & Resources)

The NSW Police Marine Area Command, Transport for NSW, and the Department of Planning, Industry and Environment (Regions, Industry, Agriculture & Resources) are located in the Inner Harbour and require access to the waterway to perform their duties. Transport for NSW is the owner of several seawall assets in Sydney Harbour and is responsible for managing seabed leases, which may be held by private leases or commercial organisations such as marinas.

Navigation restrictions

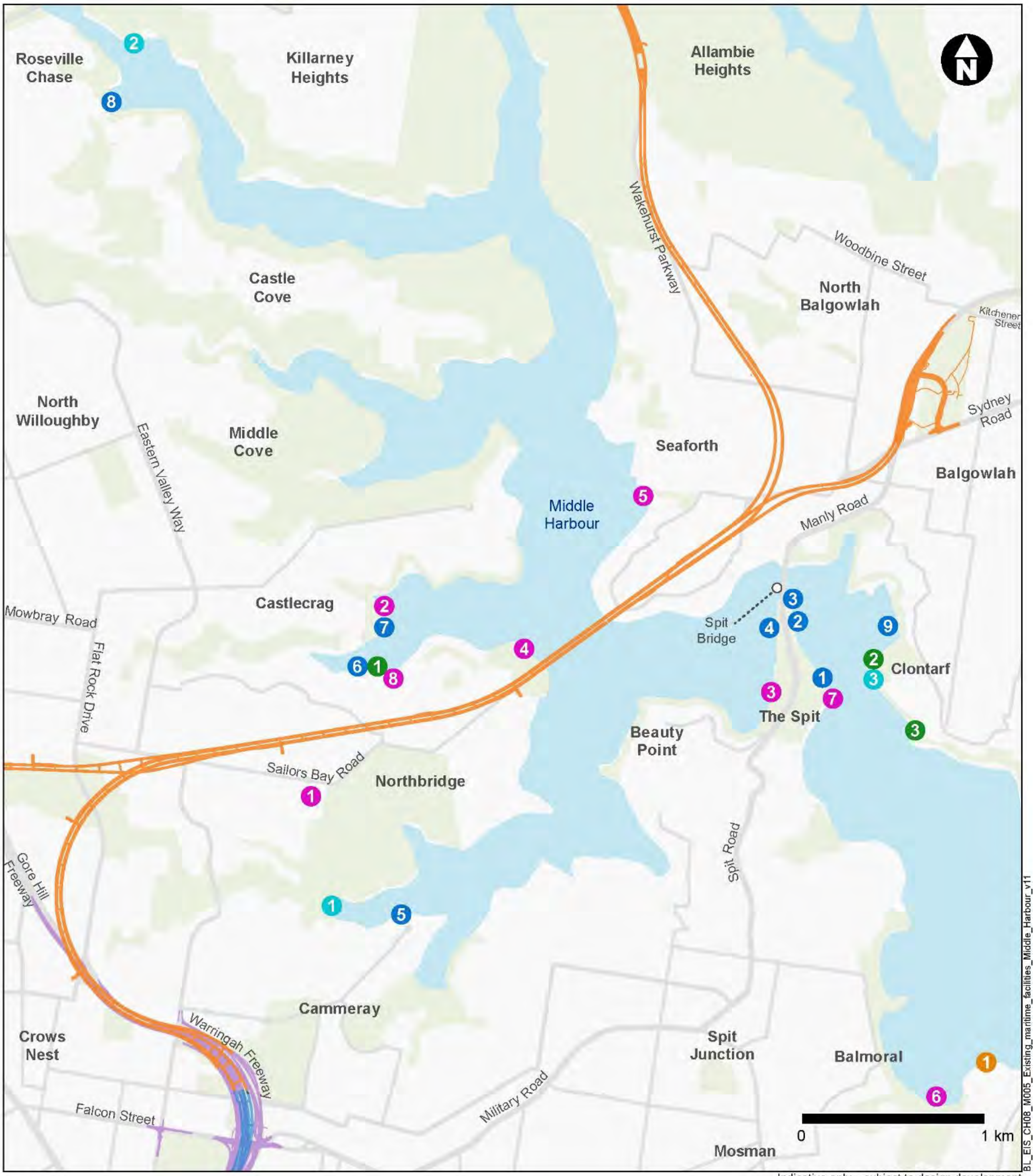
Relevant navigation restrictions within Middle Harbour include:

- An exclusion zone around the HMAS Penguin at Balmoral
- A four knots zone between Clontarf Point and Parriwi Point extending upstream to D'Albora Marina and the eastern end of Peach Tree Bay, including the area around Spit Bridge
- Vessels traveling at more than six knots are required to maintain 30 metres from all vessels, land or structures (including moorings)
- A speed limit of 12 knots is imposed on vessels exceeding 30 metres in length when navigating within Middle Harbour
- Spit Bridge when closed presents a barrier to boats with heights greater than five or six metres above the water level (depending on tides). Passage of boats that are above the clearance height is restricted to scheduled daily bridge openings (see Table 8-9).

Additional restrictions may be imposed by an aquatic event such as a race, competition or exhibition. An aquatic licence issued by Transport for NSW may be required for organised activities on navigable waters that restrict the availability of those waters for normal use by the public. Transport for NSW may elect to establish an exclusion zone around the activity.

The shallow depth at the entrance to Middle Harbour limits the type of vessels that can navigate through the harbour, restricting the passage of larger vessels. Vessels that transit through Middle Harbour, including at the location of the proposed crossing, would generally be up to 25 metres in length. However, most vessels would be less than 10 metres in length.

Access under Spit Bridge has limited width clearance. Vessels wider than 24 metres are unable to navigate between the bridge piers due to the fixed fender protection.



Indicative only – subject to design development

Legend

Operational features
- Beaches Link

Connecting projects
- Western Harbour Tunnel
- Warringah Freeway Upgrade

Boat launching facilities
1. Tunks Park, Cammeray
2. Roseville Bridge, Killarney Heights
3. Clontarf Reserve sand ramp, Clontarf

Community groups and clubs
1. Northbridge Sea Scouts
2. Sailors Bay Sea Scouts
3. Mosman Rowing Club
4. Northbridge Sailing Club
5. Seaforth Sailing Club
6. Balmoral Sailing Club
7. Middle Harbour Amateur Sailing Club
8. Northbridge Baths

Commercial operators
1. Eco Boat Hire Sydney
2. Jungle Float Mobile Water Park
3. Champagne Sailing Sydney

Government organisations
1. H.M.A.S Penguin

Private and commercial marinas
1. Middle Harbour Yacht Club, The Spit
2. Smiths Boatshed Marina, The Spit
3. Fergusons Boat Shed, The Spit
4. D'Albora Marina, The Spit
5. Cammeray Marina, Cammeray
6. Northbridge Marina, Northbridge
7. Castlecrag Marina, Castlecrag
8. Roseville Bridge Marina, Roseville
9. Clontarf Marina, Clontarf

Figure 8-6 Existing maritime facilities in Middle Harbour near the project

8.3.5 Balgowlah and surrounds

Description

Transport network

The existing transport network within the Balgowlah and surrounding areas is shown in Figure 8-7 and includes the suburbs of Balgowlah, Mosman, North Balgowlah and Seaforth.

Traffic volumes and patterns

A summary of existing peak hour traffic volumes for Balgowlah and surrounds in the AM peak (between 7am and 9am on a normal working weekday) and PM peak (between 4pm and 6pm on a normal working weekday) is provided in Table 8-11.

Table 8-11 Existing (2016) peak hour traffic volumes – Balgowlah and surrounds

Road	Direction	AM peak		PM peak	
		Volume (vehicles)	Heavy vehicle percentage	Volume (vehicles)	Heavy vehicle percentage
Balgowlah and surrounds					
Spit Road south of Parriwi Road	Northbound	1280	11%	2670	6%
	Southbound	2780	7%	1610	7%
Manly Road south of Sydney Road	Northbound	1540	8%	3050	5%
	Southbound	2760	11%	1650	6%
Sydney Road east of Manly Road	Eastbound	460	8%	1010	4%
	Westbound	940	7%	750	6%
Burnt Bridge Creek Deviation west of Condamine Street	Northbound	970	7%	1790	7%
	Southbound	1350	13%	1050	6%

Public transport network

The Balgowlah and surrounds area includes major bus corridors along Spit Road/Manly Road, Sydney Road and Burnt Bridge Creek Deviation.

Balgowlah and surrounds are also served in part by the Northern Beaches B-Line bus service, which provides a high capacity, limited stops service to Sydney CBD.

Legend

Road classification
- Motorway
- Major arterial road
- Sub-arterial road
- Collector road
- Local road

Public transport infrastructure
- Bus stops on key routes
- Ferry wharf
- B-Line

Figure 8-7 Transport network within Balgowlah and surrounds

Active transport network

The pedestrian network in the Balgowlah and surrounds area is well developed with footpaths along most roads and controlled crossings at most signalised intersections. Significant pedestrian activity occurs along Spit West Reserve, around the marinas at the southern end of Spit Bridge, and within the vicinity of the Balgowlah and Manly Vale local town centres on Sydney Road and Condamine Street.

The cycle network in the area consists of a mixture of off-road shared user paths and on-road cycle routes on local and collector roads. Based on pedestrian and cyclist surveys carried out for the project, the shared user path adjacent to the eastern side of Burnt Bridge Creek Deviation near Kitchener Street was identified as being used by a moderate number of pedestrians and cyclists both during weekdays and on weekends. These volumes are attributed to the shared user path providing links to The Spit cycle route, and to the Northern Beaches, accommodating commuter cyclists on weekdays and recreational users on weekends.

Existing road performance

Road network performance

Military Road, Spit Road, Manly Road, Burnt Bridge Creek Deviation, Condamine Street and Pittwater Road form the primary arterial road corridor between the Northern Beaches and Sydney CBD. Traffic volumes along these roads are highest heading southbound in the AM peak and northbound in the PM peak as a result of commuters travelling between the Northern Beaches and the Sydney CBD. Sydney Road also carries high traffic volumes providing access to Balgowlah and Manly.

The primary constraint for southbound traffic is the Spit Bridge, which frequently causes queues extending from the bridge to the intersection of Manly Road and Sydney Road. This also results in southbound queues on Burnt Bridge Creek Deviation and eastbound and westbound queues on Sydney Road.

Bus priority is provided at the intersection of Manly Road/Burnt Bridge Creek Deviation/Sydney Road, with bus lanes provided in both directions on Burnt Bridge Creek Deviation, southbound bus lanes provided on Manly Road, and westbound bus lanes provided on Sydney Road.

Intersection performance

Modelled intersection performance under 2016 travel demands is provided in Table 8-12. The assessment indicates that most intersections within the Balgowlah and surrounds area currently perform at a satisfactory level of service. The Frenchs Forest Road and Sydney Road intersection currently performs poorly during the PM peak, particularly on the western approach.

Table 8-12 Modelled intersection performance in the Balgowlah and surrounds area (AM and PM peaks in 2016)

Intersection	AM peak (8am–9am) – LoS (average delay in seconds)	PM peak (5pm–6pm) – LoS (average delay in seconds)
Sydney Road/Manly Road/Burnt Bridge Creek Deviation	D (52)	D (44)
Frenchs Forest Road/Sydney Road	B (19)	F (>100)
Sydney Road/Condamine Street	B (20)	B (24)
Condamine Street/Burnt Bridge Creek Deviation	B (28)	B (19)
Sydney Road/Maretimo Street	A (9)	A (9)

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

8.3.6 Frenchs Forest and surrounds

Description

Transport network

The existing transport network within the Frenchs Forest and surrounds area is shown in Figure 8-8 and includes the suburbs of Frenchs Forest, Killarney Heights and Seaforth.

Traffic volumes and patterns

In 2015, Transport for NSW commenced construction on the Northern Beaches Hospital road upgrade project which affected traffic conditions near the Northern Beaches Hospital. Construction works on the Northern Beaches Hospital road upgrade project were completed in August 2020. Permanent traffic counts on Warringah Road at Beacon Hill indicate that there was a substantial reduction in traffic volumes in 2016 by up to 17 per cent over the average weekday, indicating that construction activities in Frenchs Forest substantially reduced traffic volumes during the peak construction period. As a result, existing traffic volumes has been conservatively modelled based on 2012 pre-construction levels. Permanent traffic count data shows that by 2017, daily traffic volumes returned to 2012 levels, indicating that traffic conditions have generally returned to preconstruction levels and that there has been negligible growth in peak period traffic volumes through the area. Since completion of the Northern Beaches Hospital road upgrade project, updated data unaffected by COVID-19 is not readily available to assess if the grade separation works have influenced traffic. Traffic data for 2012 was therefore considered suitable to model existing traffic volumes.

A summary of existing peak hour traffic volumes for Frenchs Forest and surrounds in the AM peak (between 7am and 9am on a normal working weekday) and PM peak (between 4pm and 6pm on a normal working weekday) is provided in Table 8-13.

Table 8-13 Existing (2016) peak hour traffic volumes – Frenchs Forest and surrounds

Road	Direction	AM peak		PM peak	
		Volume (vehicles)	Heavy vehicle percentage	Volume (vehicles)	Heavy vehicle percentage
Frenchs Forest and surrounds					
Wakehurst Parkway north of Burnt Street	Northbound	620	4%	680	4%
	Southbound	440	8%	670	2%
Wakehurst Parkway north of Judith Street	Northbound	830	3%	830	3%
	Southbound	580	6%	860	2%
Wakehurst Parkway north of Kirkwood Street	Northbound	860	2%	800	3%
	Southbound	540	7%	820	1%
Warringah Road west of Wakehurst Parkway	Eastbound	2320	6%	3430	2%
	Westbound	3080	4%	2820	2%
Warringah Road east of Wakehurst Parkway	Eastbound	1690	7%	2140	2%
	Westbound	1460	5%	2160	2%

Public transport network

The Frenchs Forest area is well served by buses, with Warringah Road and Forest Way being major bus corridors for services to Sydney CBD, Chatswood, Terrey Hills and Belrose. A number of bus routes also operate along the Wakehurst Parkway. As part of the recent Growth Services Program 2018-2019, several new and expanded services are now in operation and support the Northern Beaches Hospital. Further, a rapid bus service, similar in nature to that of the existing B-Line, is proposed between Dee Why and Chatswood and is anticipated to be operation before the project commences construction.

Figure 8-8 Transport network within the Frenchs Forest area and surrounds

Active transport network

The pedestrian network in the Frenchs Forest area is limited with no footpaths alongside Wakehurst Parkway or on most local roads. However, footpaths are provided alongside other arterial roads and controlled crossings are provided at most signalised intersections. Significant pedestrian activity occurs around the Warringah Aquatic Centre, and in the vicinity of the Frenchs Forest local town centre on Warringah Road and Forest Way.

The cycle network in the Frenchs Forest area consists of a mixture of off-road shared user paths and on-road cycle routes on local and collector roads. The regional strategic cycle network provides connections between Frenchs Forest and surrounds and Balgowlah, Manly and Narrabeen. Off-road shared user paths are provided at the following locations:

- Karingal Crescent Reserve
- Shared pedestrian and cyclist bridge connecting Karginal Crescent Reserve and Forest Way
- Between Wakehurst Parkway north of Warringah Road and Frenchs Forest Road East, west of Inverness Avenue
- Shared pedestrian and cyclist bridge connecting Warringah Aquatic Centre and Bantry Bay Road
- Allambie Road between Aquatic Drive and Eaton Square
- Shared pedestrian and cyclist bridge across Warringah Road west of the intersection of Forest Way
- Shared pedestrian and cyclist bridge across Warringah Road on the western side of the intersection with Hilmer Street.
- Manly Dam Bike Tracks within Manly Dam Reserve, east of Wakehurst Parkway.

In addition, the Northern Beaches Hospital road upgrade project was completed in August 2020 and included upgrades for pedestrians and cyclists including shared user bridges at Hilmer Street and Forest Way, as well as the provision of shared user paths and footpaths on sections of Warringah Road, Wakehurst Parkway, Forest Way, Aquatic Drive and Allambie Road.

Existing road performance

Road network performance

Warringah Road and Forest Way carry high traffic volumes throughout the day, with Warringah Road providing a key route to and from North Sydney and the Sydney CBD via Eastern Valley Way. Wakehurst Parkway also forms an alternative north-south route to Pittwater Road, providing a sub-arterial connection between Narrabeen and Seaforth.

Warringah Road and Forest Way are also major bus corridors in the area. A southbound kerbside bus lane is provided on Wakehurst Parkway between Warringah Road and Frenchs Forest Road East and priority signalling for buses is provided westbound on Warringah Road east of Wakehurst Parkway and southbound on Forest Way north of Warringah Road.

The Northern Beaches Hospital road upgrade project, completed in August 2020, included the construction of three grade-separated underpasses on Warringah Road, allowing for traffic heading eastbound and westbound on Warringah Road to bypass the intersections of Wakehurst Parkway, Forest Way and Hilmer Street. The project also involved local road network upgrades and localised widening.

Intersection performance

Due to reductions in traffic volumes in 2016 associated with construction activities of the Northern Beaches Hospital road upgrade project, existing intersection performance has been conservatively modelled based on 2012 preconstruction levels.

The *Northern Beaches Hospital Stage 2 Network Enhancement Works environmental impact statement* (Roads and Maritime Services, 2015c) identifies that road network performance following the grade separation of Warringah Road would be slightly improved in the morning peak period when compared to 2012 road network performance. However, the assessment identified that road network performance would be slightly worse in the evening peak period when compared to 2012 road network performance due to additional traffic generated by the Northern Beaches Hospital. Overall, network performance at Frenchs Forest and surrounds would not be materially changed due to the Northern Beaches Hospital Stage 2 Network Enhancement Works. The use of 2012 for baseline conditions is therefore considered a reasonable proxy for current conditions with the Northern Beaches Hospital Stage 2 Network Enhancement Works operational.

Modelled intersection performance under 2012 travel conditions is provided in Table 8-14. The assessment indicates that several intersections within the Frenchs Forest and surrounds area currently perform at or above capacity.

Table 8-14 Modelled intersection performance in Frenchs Forest and surrounds (AM and PM peaks in 2012)

Intersection	AM peak (8am–9am) – LoS (average delay in seconds)	PM peak (5pm–6pm) – LoS (average delay in seconds)
Wakehurst Parkway/Frenchs Forest Road East	F (>100)	E (67)
Warringah Road/Allambie Road	E (65)	D (56)
Wakehurst Parkway/Warringah Road	F (>100)	D (48)
Warringah Road/Hilmer Street	E (58)	D (49)
Warringah Road/Forest Way	F (>100)	C (34)
Forest Way/Naree Road	A (>5)	A (7)
Warringah Road/Brown Street/Currie Road	F (70)	A (11)
Warringah Road/Starkey Street	C (37)	A (10)
Warringah Road/Darley Street	B (20)	B (22)
Warringah Road/Forestville Avenue	B (16)	B (28)

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

8.4 Assessment of potential impacts

During construction, the project would affect the surrounding road network as a result of the following:

- Construction vehicles using the surface road network, especially heavy vehicles transporting spoil
- Surface road works requiring temporary traffic, cyclist and/or pedestrian diversions, road occupation and temporary road closures
- Temporary changes to speed limits.

Construction impacts related to maritime traffic and transport are discussed in Section 8.4.3.

Mitigation and management measures detailed in Section 8.5 would be implemented where appropriate during construction to reduce potential traffic and transport impacts during construction.

Details of construction activities and the location and timing of construction works, including temporary construction support site layouts and provision of construction worker parking, are presented in Chapter 6 (Construction work).

8.4.1 Warringah Freeway and surrounds

Road network impacts

The anticipated routes to and from the Cammeray Golf Course (BL1) and Flat Rock Drive (BL2) construction support sites within the Warringah Freeway and surrounds area are summarised in Chapter 6 (Construction work), along with the respective daily maximum construction vehicle volumes.

Intersection and midblock performance with construction traffic

The performance of intersections within the Warringah Freeway and surrounds area with the introduction of construction traffic would generally remain the same as conditions without the project. However, the following intersections would experience a change in level of service:

- Warringah Freeway/Brook Street interchange would worsen from LoS B to LoS C during the AM peak
- Brook Street/Merrenburn Avenue would worsen from LoS C to LoS D during the PM peak.

These impacts would be minor and both intersections would continue to operate satisfactorily during construction.

A new signalised intersection would also be provided for access to the Flat Rock Drive construction support site (BL2) and would operate at LoS A during construction.

The intersection performance results for the road network operating under the worst case construction traffic scenario (2024) during the AM and PM peak periods are summarised in Table 8-15.

Table 8-15 Modelled intersection performance in the Warringah Freeway and surrounds area (AM peak (8am-9am) and PM peak (5pm-6pm) during construction in 2024)

Intersection/ peak period	Base case 2024 (without construction traffic)				Construction case 2024 (with construction traffic)			
	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C
Warringah Freeway/Falcon Street interchange								
AM peak	13,670	N/A*	F*	>1	14,140	N/A*	F*	>1
PM peak	14,000	N/A*	F*	>1	14,650	N/A*	F*	>1
Warringah Freeway/Ernest Street interchange								
AM peak	6410	N/A*	C*	0.60	6520	N/A*	C*	0.61
PM peak	5910	N/A*	D*	0.58	6060	N/A*	D*	0.60
Ernest Street/Merlin Street/BL1 construction support site access								
AM peak	2910	7	A	0.49	2980	8	A	0.49
PM peak	3220	9	A	0.78	3320	10	A	0.81

Intersection/ peak period	Base case 2024 (without construction traffic)				Construction case 2024 (with construction traffic)			
	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C
Ernest Street/Miller Street								
AM peak	3290	20	B	0.65	3330	20	B	0.65
PM peak	3700	32	C	0.79	3700	32	C	0.79
Warringah Freeway/Miller Street interchange								
AM peak	5160	N/A*	C*	0.79	5200	N/A*	C*	0.81
PM peak	5270	N/A*	D*	0.89	5270	N/A*	D*	0.89
Warringah Freeway/Brook Street interchange								
AM peak	5240	N/A*	B*	0.82	5430	N/A*	C*	0.85
PM peak	6530	N/A*	C*	0.89	6730	N/A*	C*	0.89
Brook Street/Merrenburn Avenue								
AM peak	3340	92	F	>1	3460	>100	F	>1
PM peak	3240	40	C	>1	3380	47	D	>1
Flat Rock Drive/BL2 construction support site access								
AM peak	-				2590	5	A	0.56
PM peak	-				2770	5	A	0.67

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F
*Interchanges were modelled as a network, where level of service is based on speed efficiency (SIDRA level of service criteria for networks) and not average vehicle delay.

The midblock performance (level of service) during construction would be unchanged when compared to the performance under conditions without the project at all locations except for:

- Miller Street north of Ernest Street in the southbound direction, where midblock performance would reduce from LoS B to LoS C during the AM peak
- Ernest Street west of Merlin Street in the eastbound direction, where midblock performance would reduce from LoS B to LoS C during AM peak
- Falcon Street west of Merlin Street in the eastbound direction, where midblock performance would reduce from LoS D to LoS E during the PM peak
- Falcon Street west of Merlin Street in the westbound direction, where midblock performance would reduce from LoS B to LoS C during the PM peak
- Brook Street south of Merrenburn Avenue in the southbound direction, where midblock performance would reduce from LoS C to LoS D during the PM peak.

Almost all midblock locations listed above would continue to operate with spare capacity and at a satisfactory level of service during construction, except for Falcon Street west of Merlin Street in the eastbound direction during the PM peak. However, this section of road is already operating close to the LoS D/E threshold; the additional vehicles are not expected to cause any major additional capacity issues for this road during construction.

The midblock performance results for the road network operating under the worst case construction traffic scenario (2024) during the AM and PM peak are summarised in Table 8-16.

Table 8-16 Modelled midblock performance in the Warringah Freeway and surrounds area (AM peak (8am-9am) and PM peak (5pm-6pm) during construction in 2024)

Location/ direction	Capacity (PCU)	AM Peak						PM Peak					
		Base case 2024 (without construction traffic)			Construction 2024 (with construction traffic)			Base case 2024 (without construction traffic)			Construction 2024 (with construction traffic)		
		Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS
Miller Street north of Ernest Street													
Northbound[1]	900 (AM) 1900 (PM)	660	0.74	D	660	0.74	D	880	0.47	C	880	0.47	C
Southbound[2]	2900 (AM) 1900 (PM)	1180	0.41	B	1220	0.42	C	1380	0.73	D	1380	0.73	D
Ernest Street east of Merlin Street													
Eastbound	1900	1250	0.66	D	1300	0.68	D	1580	0.83	E	1580	0.83	E
Westbound	1900	1030	0.54	C	1030	0.54	C	890	0.47	C	890	0.47	C
Ernest Street west of Merlin Street													
Eastbound	1900	780	0.41	B	820	0.43	C	2120	>1	F	2190	>1	F
Westbound	2900	2120	0.73	D	2170	0.75	D	1060	0.36	B	1120	0.39	B
Falcon Street west of Merlin Street													
Eastbound	3900	2590	0.67	D	2740	0.70	D	3140	0.80	D	3330	0.85	E
Westbound	5900	3520	0.60	D	3670	0.62	D	2370	0.40	B	2560	0.43	C
Brook Street south of Merrenburn Avenue													
Northbound	1900	900	0.48	C	990	0.52	C	1940	>1	F	2030	>1	F
Southbound	1900	2150	>1	F	2240	>1	F	1120	0.59	C	1210	0.64	D

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F
1: Miller Street north of Ernest Street in the northbound direction has a clearway in operation during the evening peak period only.
2: Miller Street north of Ernest Street in the southbound direction has a clearway in operation during the morning peak period only.

Impacts on local roads and parking

As part of the Western Harbour Tunnel and Warringah Freeway Upgrade project, the Ernest Street/Merlin Street intersection would be modified with the addition of a north approach allowing site access to the Cammeray Golf Course construction support site (BL1). This would be a secondary access point, with primary access for heavy vehicles to be provided directly to and from the Warringah Freeway. Up to 10 parking spaces on Ernest Street would be removed as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project to provide suitable access to the Cammeray Golf Course construction support site (BL1), with access maintained while the construction support site is operational. Clearways operate on Ernest Street during peak periods; therefore, any closure of the kerbside lane associated with the Cammeray Golf Course construction support site (BL1) would only result in loss of parking outside peak periods. The availability of parking on nearby local roads such as Ernest Street (east of Merlin Street), Oaks Avenue and Park Avenue would also reduce the impact of losing these parking spaces outside of peak periods. As such, the overall impact would be considered negligible.

Car parking areas for construction workers would be provided at the Cammeray Golf Course (BL1) and Flat Rock Drive (BL2) construction support sites. Worker parking would be maximised within the constraints of the respective temporary construction support site. The number of car parking spaces would be determined during construction planning.

Where on-site parking is not provided or where provision of on-site parking cannot accommodate the full construction workforce, the workforce would be actively encouraged to avoid parking on the surrounding road network. To minimise the potential parking impacts on the surrounding road network, parking will be actively managed using the following mitigation measures:

- The construction workforce would be encouraged to use public transport where feasible, with key bus corridors including Pacific Highway, Warringah Freeway, Miller Street, Falcon Street and Military Road. In addition, the T1 North Shore and T9 Northern Lines are accessible from North Sydney, St Leonards and Waverton railway stations
- Where public transport availability to temporary construction support sites is limited, shuttle bus transfers may also be provided from public transport centres where required.

Impacts on public transport

In Cammeray, there are no bus routes that travel on Ernest Street in the vicinity of the Cammeray Golf Course construction support site (BL1) and therefore there would be negligible impacts to the bus network due to construction vehicles travelling to and from this site. The use of traffic signals for the Flat Rock Drive construction support site (BL2) access would impact buses that use Flat Rock Drive and Brook Street. This would increase bus travel times slightly as buses could be required to stop at the new traffic lights while construction vehicles access the site. Overall impacts would be negligible given that the intersection would generate an additional five seconds of delay on average.

No direct impacts on heavy rail services or ferry services are anticipated during construction.

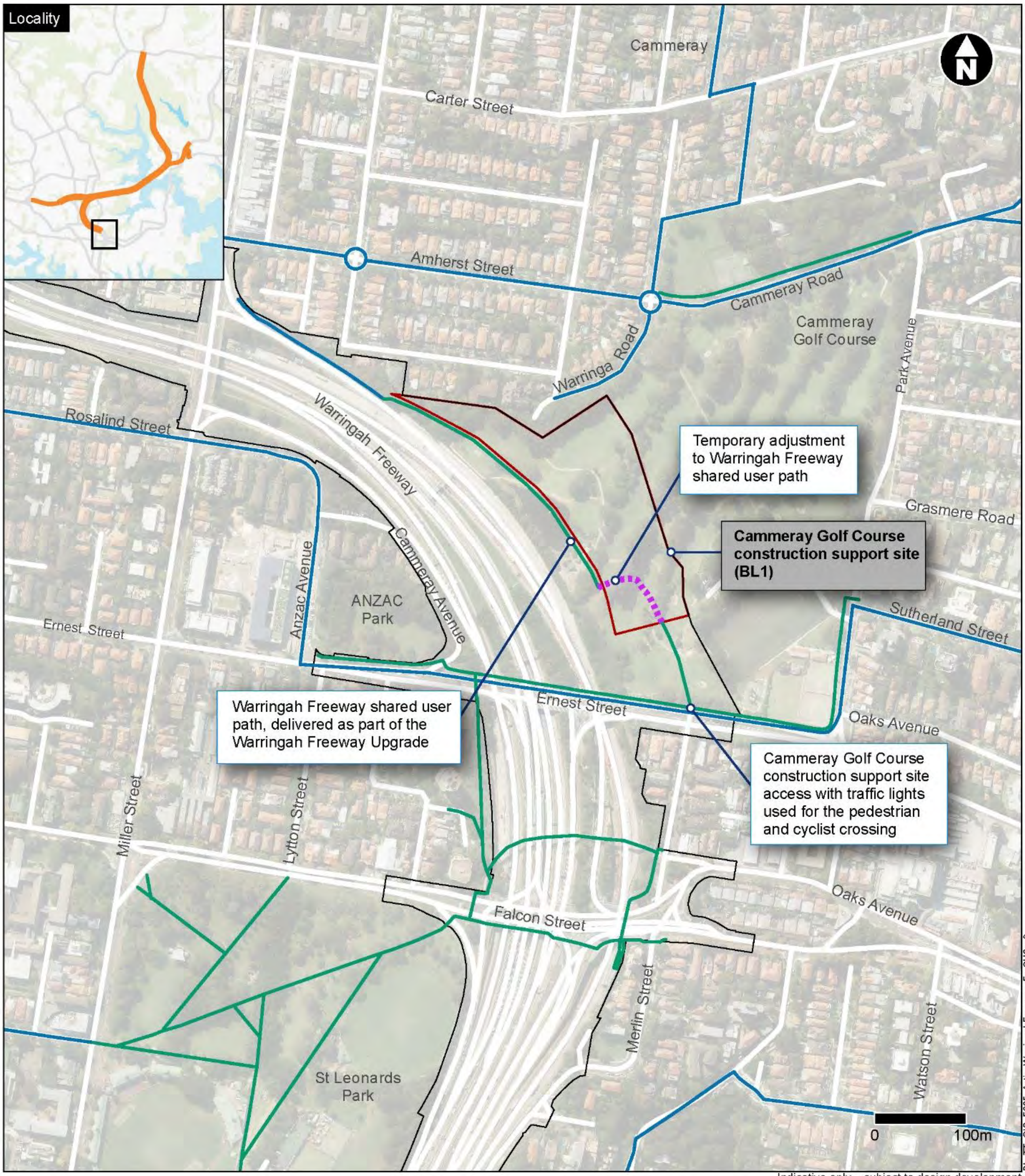
Impacts on active transport

Potential impacts on the active transport network within the Warringah Freeway and surrounds area during construction are summarised in Figure 8-9. Potential impacts on active transport around Naremburn are summarised in Figure 8-10.

Conflicts between pedestrians and/or cyclists using the footpaths or shared user paths near the Cammeray Golf Course construction support site (BL1) and Flat Rock Drive construction support site (BL2) would be managed through traffic lights to control of movements at the site entry/exit.

The access arrangements at Cammeray Golf Course construction support site (BL1) would be established as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project. The shared user path along Warringah Freeway near Cammeray Golf Course would be realigned to travel along the rear of the Cammeray Golf Course construction support site (BL1) until the Ernest Street/Merlin Street intersection as part of the Warringah Freeway Upgrade. Minor impacts to pedestrians and cyclists are anticipated given that existing connectivity would be maintained and a short additional travel distance of up to 100 metres. In addition, heavy vehicles at the Cammeray Golf Course construction support site (BL1) would be directed to access the site directly to and from the Warringah Freeway.

The temporary adjustment of the Flat Rock Reserve shared user path (parallel to Flat Rock Drive, on the western side of the construction support site) would be required to accommodate the Flat Rock Drive construction support site (BL2). This path would be temporarily realigned along the western perimeter of the construction support site, resulting in an additional travel distance of up to 100 metres (refer to Figure 8-10). The existing walking tracks along the eastern perimeter of the site would be largely maintained with two minor temporary diversions required. Given that existing connectivity would be maintained and the small potential increase in travel distance, impacts on pedestrians and cyclists using the shared user path are anticipated to be minor.



Legend

Construction features
- Construction support site boundary
- Construction footprint

Existing active transport infrastructure
- Existing off-road shared user path
- Existing on-road cycle path

Adjusted active transport infrastructure
- Warringah Freeway shared user path detour

Figure 8-9 Active transport impacts within the Warringah Freeway and surrounds area during construction

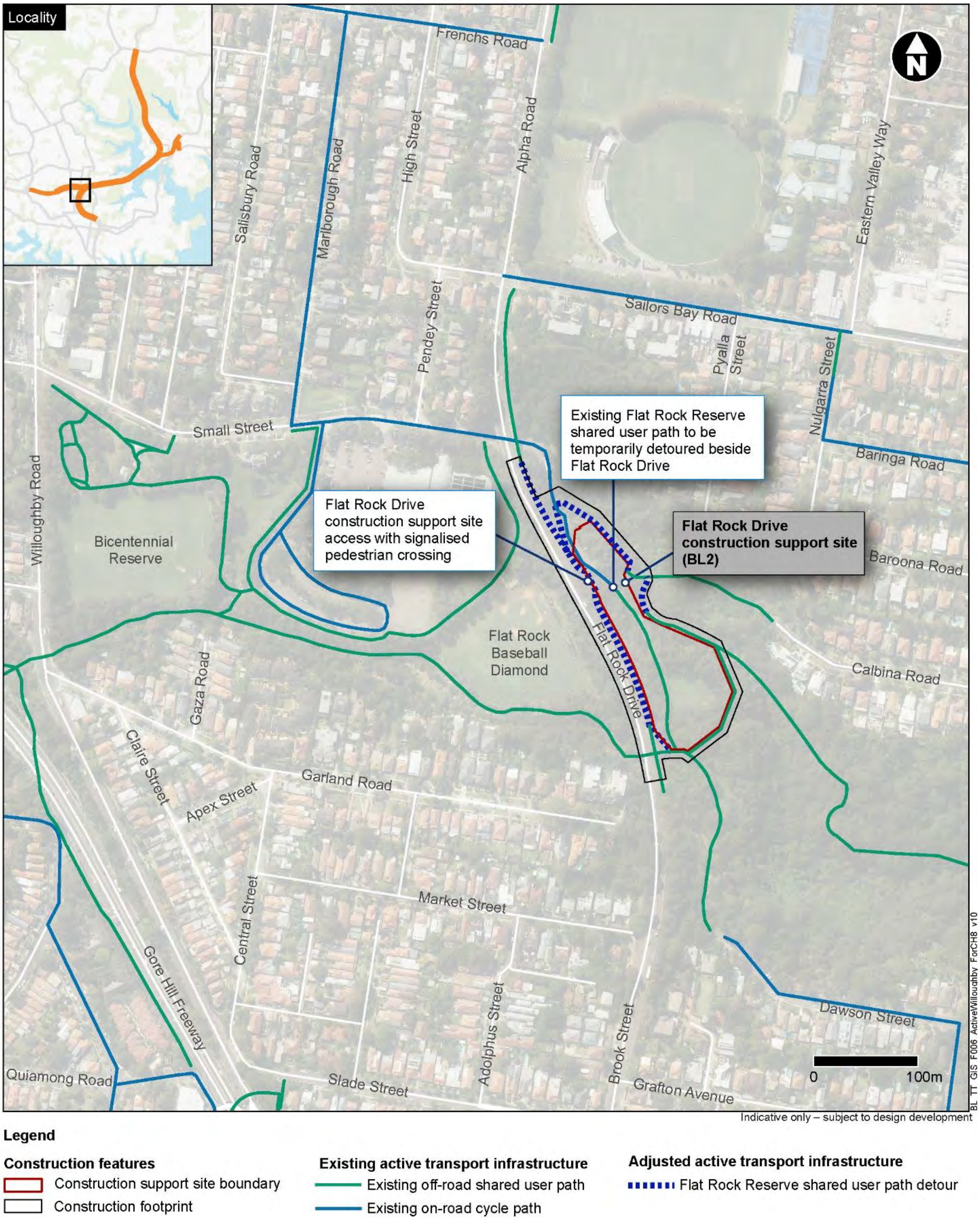


Figure 8-10 Active transport impacts around Naremburn during construction

8.4.2 Gore Hill Freeway and Artarmon

Road network impacts

The anticipated routes to and from the Punch Street (BL3), Dickson Avenue (BL4), Barton Road (BL5), and Gore Hill Freeway median (BL6) construction support sites are summarised in Chapter 6 (Construction work), along with the respective daily maximum construction vehicle volumes.

Intersection and midblock performance with construction traffic

The performance of intersections within the Gore Hill Freeway and Artarmon area with the introduction of construction traffic would generally remain the same as conditions without the project. However, the following intersections would experience a change in level of service:

- Gore Hill Freeway/Reserve Road interchange would worsen from LoS E to LoS F during the AM peak. The intersection already performs poorly during the AM peak
- Reserve Road/Dickson Avenue would worsen from LoS B to LoS C during the PM peak
- Herbert Street/Frederick Street would worsen from LoS B to LoS C during the PM peak.

The impacts at the Reserve Road/Dickson Avenue and Herbert Street/Frederick Street intersections would be minor and both intersections would continue to operate satisfactorily during construction.

The intersection performance results for the road network operating under the worst case construction traffic scenario (2024) during the AM and PM peak periods are summarised in Table 8-17.

Table 8-17 Modelled intersection performance in the Gore Hill Freeway and Artarmon area (AM peak (8am-9am) and PM peak (5pm-6pm) during construction in 2024)

Intersection/ peak period	Base case 2024 (without construction traffic)				Construction case 2024 (with construction traffic)			
	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C
Gore Hill Freeway/Reserve Road interchange								
AM peak	3890	N/A*	E*	>1	4200	N/A*	F*	>1
PM peak	3990	N/A*	F*	>1	4200	N/A*	F*	>1
Reserve Road/Dickson Avenue								
AM peak	1980	17	B	0.57	2160	20	B	0.68
PM peak	2000	27	B	0.74	2130	29	C	0.82
Reserve Road/Frederick Street								
AM peak	1140	9	A	0.43	1230	9	A	0.48
PM peak	1300	10	A	0.42	1400	10	A	0.46
Herbert Street/Frederick Street								
AM peak	1390	22	B	0.76	1490	24	B	0.81
PM peak	1750	28	B	0.79	1850	31	C	0.87

Intersection/ peak period	Base case 2024 (without construction traffic)				Construction case 2024 (with construction traffic)			
	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C
Herbert Street/Cleg Street								
AM peak	1110	12	A	0.43	1210	12	A	0.45
PM peak	1480	17	B	0.48	1580	18	B	0.51

*Interchanges were modelled as a network, where level of service is based on speed efficiency (SIDRA level of service criteria for networks) and not average vehicle delay
Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

The midblock performance (level of service) during construction would be unchanged from performance under conditions without the project at all locations, except for the following:

- Reserve Road north of Frederick Street in the southbound direction would worsen from LoS D to LoS E in the AM peak, and from LoS C to LoS D in the PM peak
- Herbert Street north of Frederick Street in the northbound and southbound direction would worsen from LoS C to LoS D in the PM peak
- Cleg Street east of Herbert Street in the eastbound direction would worsen from LoS A to LoS B during the PM peak.

The midblock performance results for the road network operating under the worst case construction traffic scenario (2024) during the AM and PM peak periods are summarised in Table 8-18.

Table 8-18 Modelled midblock performance in the Gore Hill Freeway and Artarmon area (AM peak (8am-9am) and PM peak (5pm-6pm) during construction in 2024)

Location/ direction	Capacity (PCU)	AM Peak						PM Peak					
		Base case 2024 (without construction traffic)			Construction 2024 (with construction traffic)			Base case 2024 (without construction traffic)			Construction 2024 (with construction traffic)		
		Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS
Reserve Road north of Dickson Avenue													
Northbound	1900	610	0.32	B	680	0.36	B	1180	0.62	D	1230	0.65	D
Southbound	1900	1290	0.68	D	1430	0.75	D	680	0.36	B	780	0.41	B
Reserve Road north of Frederick Street													
Northbound	900	370	0.42	C	420	0.46	C	680	0.76	D	730	0.81	D
Southbound	900	670	0.74	D	750	0.83	E	500	0.55	C	580	0.64	D
Frederick Street east of Reserve Road													
Eastbound	900	430	0.47	C	510	0.57	C	570	0.63	D	650	0.72	D
Westbound	900	410	0.46	C	460	0.51	C	430	0.48	C	470	0.53	C
Herbert Street north of Frederick Street													
Northbound	900	260	0.29	B	350	0.38	B	470	0.52	C	550	0.61	D
Southbound	900	550	0.62	D	600	0.66	D	510	0.57	C	550	0.62	D
Cleg Street east of Herbert Street													
Eastbound	900	110	0.13	A	180	0.20	A	200	0.22	A	270	0.30	B
Westbound	900	130	0.15	A	130	0.15	A	180	0.20	A	180	0.20	A

Location/ direction	Capacity (PCU)	AM Peak						PM Peak					
		Base case 2024 (without construction traffic)			Construction 2024 (with construction traffic)			Base case 2024 (without construction traffic)			Construction 2024 (with construction traffic)		
		Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS
Dickson Avenue east of Reserve Road													
Eastbound	900	260	0.29	B	320	0.35	B	180	0.20	A	200	0.22	A
Westbound	900	150	0.16	A	200	0.22	A	240	0.27	B	250	0.28	B
Reserve Road south of Barton Road													
Northbound	900	390	0.43	C	400	0.45	C	660	0.73	D	680	0.75	D
Southbound	900	510	0.56	C	520	0.58	C	420	0.47	C	430	0.48	C

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

Impacts on local roads and parking

The installation of traffic lights at the intersection of Pacific Highway with Dickson Avenue would result in the following impacts on traffic:

- Temporary lane closures on Pacific Highway during removal of existing median and line-marking, minor pavement works and relocation of the existing bus stop on Pacific Highway west of Dickson Avenue
- Temporary closure of Dickson Avenue during linemarking, minor kerb adjustment and minor pavement works
- Removal of about six motorbike parking spaces and three time-limited (four-hour) car parking spaces.

The existing mail zone on Dickson Avenue would be permanently relocated in proximity to the existing zone. Relocation of the mail zone would be carried out in consultation with Australia Post.

Temporary lane and road closures would be carried out outside peak periods and the impacts of these closures would be low.

Several roads would form part of construction vehicle routes within the Gore Hill Freeway and Artarmon area, including:

- Reserve Road
- Dickson Avenue
- Frederick Street
- Herbert Street
- Punch Street
- Hampden Road
- Barton Road
- Butchers Lane.

Most heavy vehicles accessing the construction area would be travelling to and from the Punch Street construction support site (BL3), with all other sites operating as smaller support sites and generating a substantially lower number of heavy vehicle movements. Relatively low impacts are anticipated on Hampden Road, Barton Road, Butchers Lane and Reserve Road north of Gore Hill Freeway given the low number of construction vehicles on these roads (maximum of 120 light vehicle and 60 heavy vehicle movements per day).

At peak production, the Punch Street construction support site (BL3) would generate a maximum of 580 light vehicle and 370 heavy vehicle movements per day while the Dickson Avenue construction support site (BL4) would generate a maximum of 500 light vehicle and 90 heavy vehicle movements per day at peak production. This would occur for a relatively short duration during peak construction period, with typical truck movements generally becoming less frequent throughout the course of construction. These vehicles would travel on Reserve Road south of Gore Hill Freeway, Dickson Avenue, Frederick Street, Herbert Street, Punch Street or Cleg Street. Across the broader network, construction traffic would access the construction site via the motorway network, where practical, to minimise impacts on local roads. Although these construction traffic volumes are relatively high in the context of existing traffic volumes, impacts on the local road network are anticipated to be low as these roads would operate with spare capacity during construction and form a direct route for construction vehicles to access the arterial road network.

Lambs Road between Punch Street and Cleg Street would be closed to allow for the Punch Street construction support site (BL3). Existing access to this section of Lambs Road is via Cleg Street and Punch Street, and therefore access impacts due to this closure would be minor. Periodic short-term closures of Reserve Road, Hampden Road, Dickson Avenue and Punch Street would also be required during construction. Given the extensive local road network in Artarmon, vehicles would have multiple alternative routes available during these interim closures. Potential detour roads include Herbert Street, Carlotta Street, Campbell Street, Frederick Street and Cleg Street.

Construction works in Artarmon would require the temporary and permanent removal of on-street parking spaces including the following:

- The closure of Lambs Road in conjunction with the requirement to detour pedestrians and cyclists due to adjustments to the Gore Hill Freeway shared user path resulting in the permanent loss of up to 25 parking spaces on Lambs Road and Punch Street
- Construction works at Artarmon Park requiring about six on-street parking spaces on Hampden Road to be removed temporarily for the duration of construction
- Short-term temporary removal of an additional 20 on-street parking spaces on Hampden Road during northern abutment works
- The potential temporary removal of up to 10 parking spaces on other local roads such as Cleg Street, Dickson Avenue and Barton Road to provide suitable access to the temporary construction support sites in the Artarmon area.

The cumulative loss of parking spaces associated with the establishment of temporary construction support sites may have some impact on on-street parking in surrounding streets in Artarmon that currently have high parking demand. The availability of on-street parking in the vicinity of the temporary construction support sites has the potential to be reduced for the duration of construction.

Some car parking would be provided at Punch Street (BL3), Dickson Street (BL4), and Barton Road (BL5) and Gore Hill Freeway median (BL6) construction support sites. Worker parking would be maximised within the constraints of the respective temporary construction support site. The number of car parking spaces would be determined during construction planning.

Where on-site parking is not provided or where provision of on-site parking cannot accommodate the full construction workforce, the workforce would be actively encouraged to avoid parking on the surrounding road network. To minimise the potential parking impacts on the surrounding road network, parking will be actively managed using the following mitigation measures:

- Construction workforce would be encouraged to use public transport where feasible, with key bus corridors including Pacific Highway, Gore Hill Freeway and Epping Road. In addition, the T1 North Shore and T9 Northern Lines are accessible from Artarmon and St Leonards railway stations
- Where public transport availability to temporary construction support sites is limited, shuttle bus transfers may also be provided from public transport centres where required.

It is noted that the acquisition of property for the Punch Street (BL3) and Dickson Avenue (BL4) construction support sites would result in a minor reduction in parking demand that would otherwise be generated by businesses currently located at these sites.

Impacts on public transport

Impacts on public transport within the Gore Hill Freeway and Artarmon area are shown in Figure 8-11.

Construction works in the Gore Hill Freeway and Artarmon area would require interim lane and ramp closures along the Gore Hill Freeway, which may impact bus travel times and reliability. Where practical, works would be scheduled outside peak periods to minimise disruption to bus services. The T2 transit lanes currently in operation in both directions along the Gore Hill Freeway would be converted to general traffic lanes to allow for construction of the Gore Hill Freeway Connection and to improve lane utilisation, however their removal is not expected to materially impact bus travel times.

The southbound bus stop located on Pacific Highway near Dickson Avenue would be permanently relocated during the construction works required to upgrade the Pacific Highway/Dickson Avenue intersection. Bus stop relocation would be determined in consultation with relevant stakeholders, including other divisions of Transport for NSW, and advanced notification would be provided to affected bus customers. Bus stops would be relocated within walking distance from their existing position to minimise disruption, where reasonable and feasible.

No direct impacts on heavy rail services are anticipated during construction.

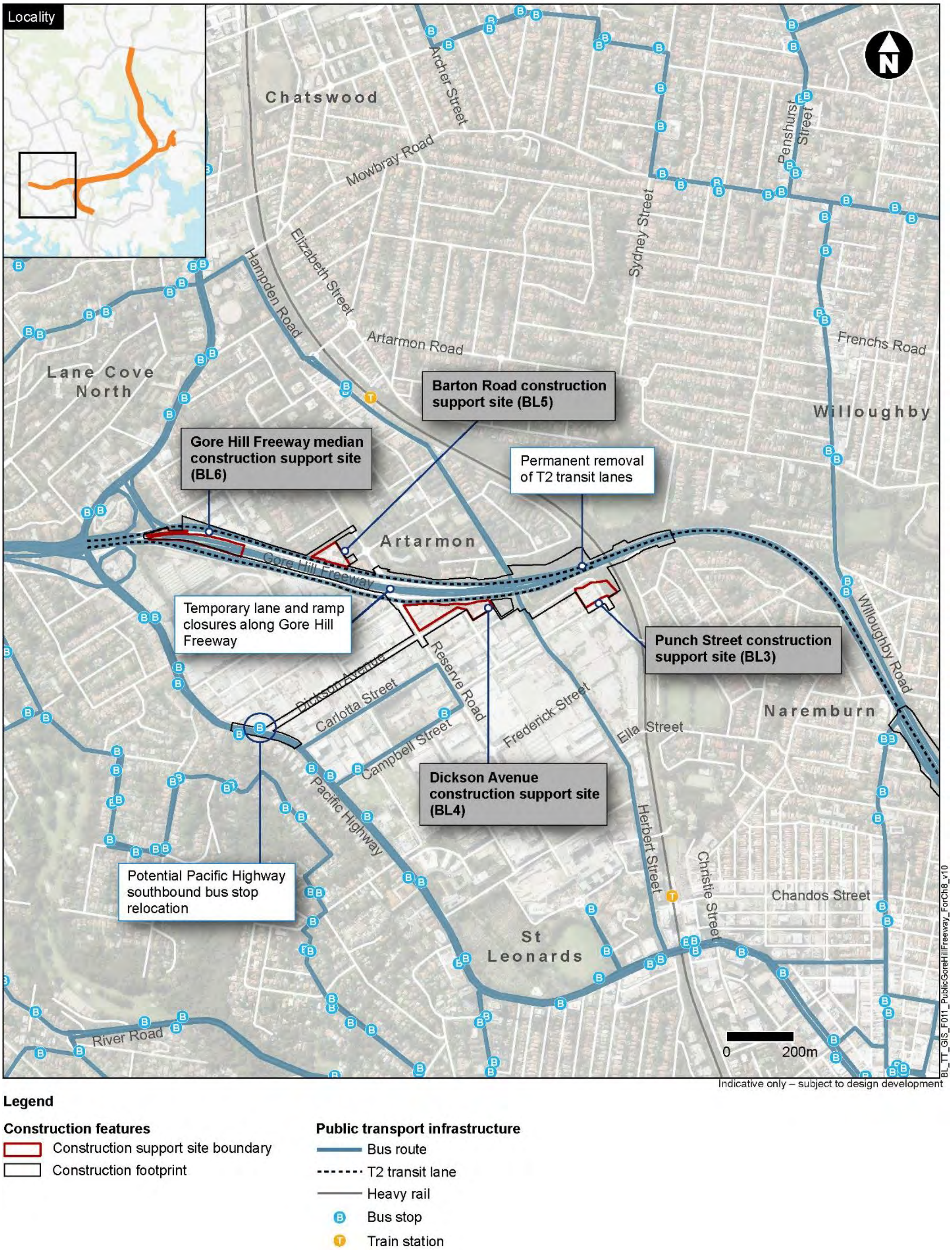


Figure 8-11 Public transport impacts within the Gore Hill Freeway and Artarmon area during construction

Impacts on active transport

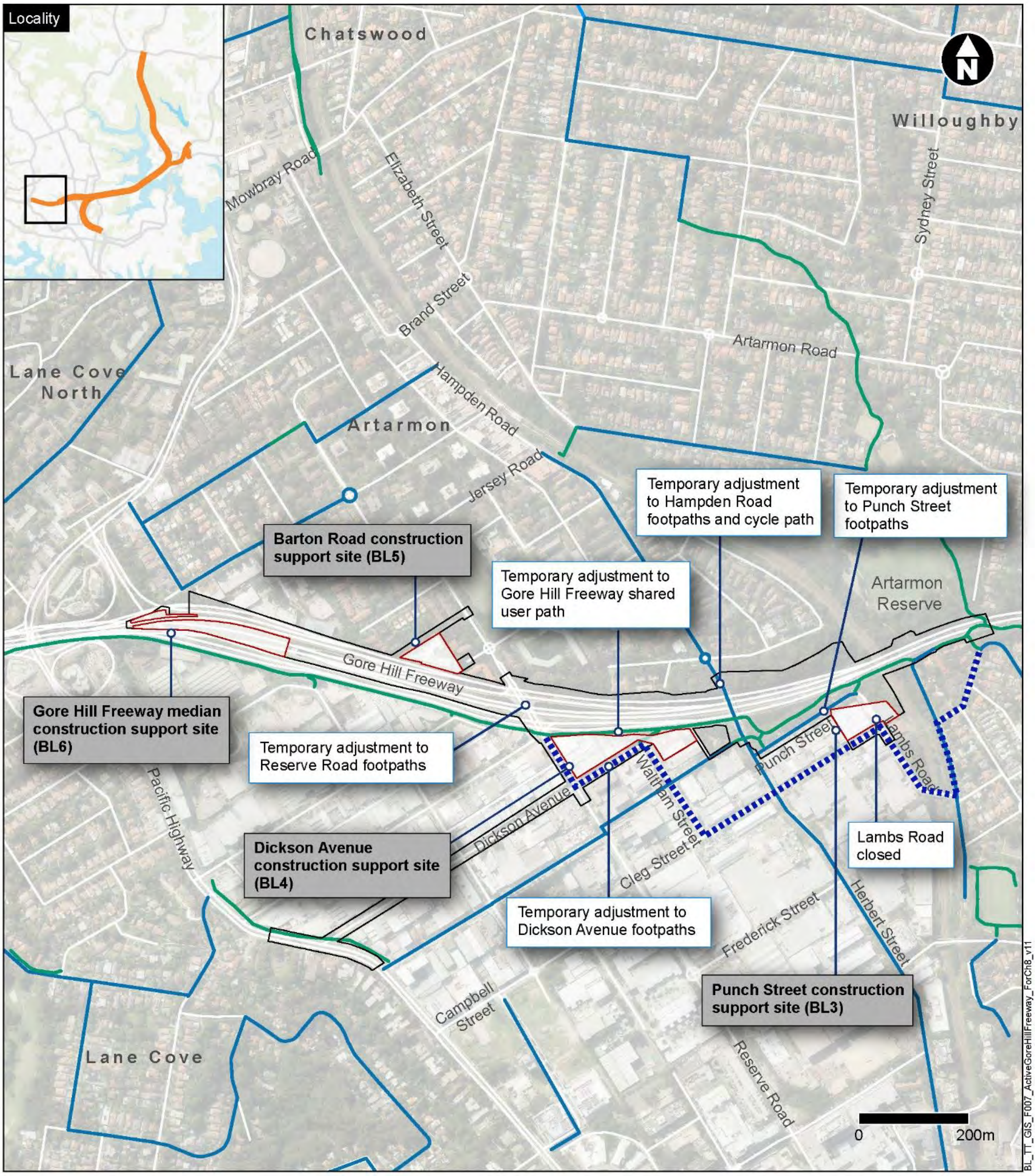
Impacts on the active transport network within the Gore Hill Freeway and Artarmon area are shown in Figure 8-12.

Modifications to the active transport network around Artarmon would be required during construction of the Gore Hill Freeway Connection, resulting in the following potential impacts:

- Reinstatement of the eastern footpath on Hampden Road, including diversion of pedestrians to the western footpath
- Temporary adjustment of the southern footpath on Punch Street adjacent to the Punch Street construction support site (BL3) boundary. Users would be diverted to Clegg Street resulting in an increase in travel distance of about 70 metres, which is considered a minor impact
- Temporary adjustment of the shared user path along Gore Hill Freeway between Reserve Road and Station Street impacting up to 150 pedestrians and cyclists who currently use the shared user path during the weekday peak periods. Alternative routes would divert these users via Station Street, Francis Road, Lambs Road, Cleg Street and Reserve Road, resulting in an additional travel distance of about 550 metres. This would have a moderate impact on pedestrians and a minor impact on cyclists, and would be managed by providing advanced notification to the community and appropriate linemarking and signage to clearly show the proposed detour route to pedestrians and cyclists.

Northern abutment works on Hampden Road would impact cyclists who currently travel on the road shoulder on either side of Hampden Road. During construction, one lane in each direction would be provided and cyclists would be required to travel on-road in traffic. Impacts would be minor given that these works are short in duration and parking would be removed on both sides of the road.

Periodic diversions of pedestrians to footpaths opposite construction activities or use of traffic control may also be required to ensure the safety of pedestrians, particularly on Punch Street, Dickson Avenue and Reserve Road. Residents may also be escorted through the work sites when accessing properties to ensure safe passage. Targeted engagement with affected residents would be carried out before and throughout the construction works in accordance with the relevant community and stakeholder engagement protocols for the project.



Legend

Construction features	Existing active transport infrastructure	Adjusted active transport infrastructure
Construction support site boundary	Existing off-road shared user path	Gore Hill Freeway shared user path detour
Construction footprint	Existing on-road cycle path	

Figure 8-12 Active transport impacts within the Gore Hill Freeway and Artarmon area during construction

8.4.3 Northbridge to Seaforth (Middle Harbour crossing)

Overview of maritime movements and activities

This section describes potential impacts from maritime movements and associated activities during construction of the immersed tube tunnel and establishment and operation of the Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and Spit West Reserve construction support site (BL9), along with the temporary mooring facility east of Clive Park in Middle Harbour to be used as a storage facility for immersed tube tunnel segments. This would result in an increase in marine traffic in Middle Harbour. Maritime construction vessel routes and volumes are summarised in Chapter 6 (Construction works).

The construction vessels would primarily include:

- Construction barges (including barges with cranes) for delivering construction materials, removing dredged and excavated material, or for other construction activities
- Dredging vessels
- Tugboats for manoeuvring barges
- Transport vessels for workers.

Movement of spoil barges would be controlled by the Port Authority of NSW's Vessel Traffic Service, which provides continuous monitoring of marine vessels within Middle Harbour.

The construction activities within Middle Harbour would require the establishment of localised maritime speed restrictions around construction equipment and facilities. Changes to maritime speeds would result in increased transit time for recreational, commercial and government vessels passing through the construction works area in Middle Harbour. The increased transit time would be relatively minor.

Potential road related impacts from the use of Spit West Reserve construction support site (BL9) are discussed in Section 8.4.4.

Maritime navigation impacts

Construction activities that would impact navigation in Middle Harbour are shown in Figure 8-13 and include the following:

- Construction of Middle Harbour north and south cofferdam temporary structures (BL7 and BL8) including excavation within the cofferdams. This would also include construction of the interface structures within the cofferdams and the establishment of appropriately controlled marine traffic exclusion zones required to ensure the safety of both the waterway users and the project's construction workforce
- Establishment and operation of the Spit West Reserve construction support site (BL9)
- Transport of partially constructed steel shell immersed tube tunnel units to Spit West Reserve construction support site (BL9)
- Dredging activities between Northbridge and Seaforth Bluff in preparation for the installation of immersed tube tunnels
- Piling for immersed tube tunnel unit supports between Northbridge and Seaforth Bluff, restricting navigation widths to about 100 metres
- Installation of the immersed tube tunnel elements, which would be carried out during up to six closures (likely two full closures and four partial closures) of Middle Harbour between Northbridge and Seaforth for a period of up to 48 hours during weekdays
- Barge movements to and from the project temporary construction support sites

- A temporary mooring facility east of Clive Park in Middle Harbour to be used as a storage facility for completed immersed tube tunnel units
- Boat movements transporting the construction workforce.

Prolonged periods of high maritime construction activity would occur over about three months of the construction program while the following activities are carried out:

- Concreting of interface structures
- Dredging of sediment and rock
- Transport of partially completed and completed immersed tube tunnel units.

Exclusion zones would be set up around the cofferdams, reducing navigation width to about 220 metres between the cofferdams. These zones would be marked by lit yellow buoys as specified by the Harbour Master to clearly identify the exclusion zones and facilitate the safe passage of vessels travelling within the vicinity of the cofferdams. Dredging activities and the installation of immersed tube tunnel support piles would also restrict navigational movements. The use of primary silt curtains during dredging activities would reduce navigation widths to about 100 metres. Impacts due to the reduced navigation widths would be manageable, with specific mitigations detailed in Section 8.5.

Navigation impacts in the Outer Harbour would not be considered substantial due to the lower frequency of construction vessel movements and the increased space the Outer Harbour provides for manoeuvrability.

Simulation model

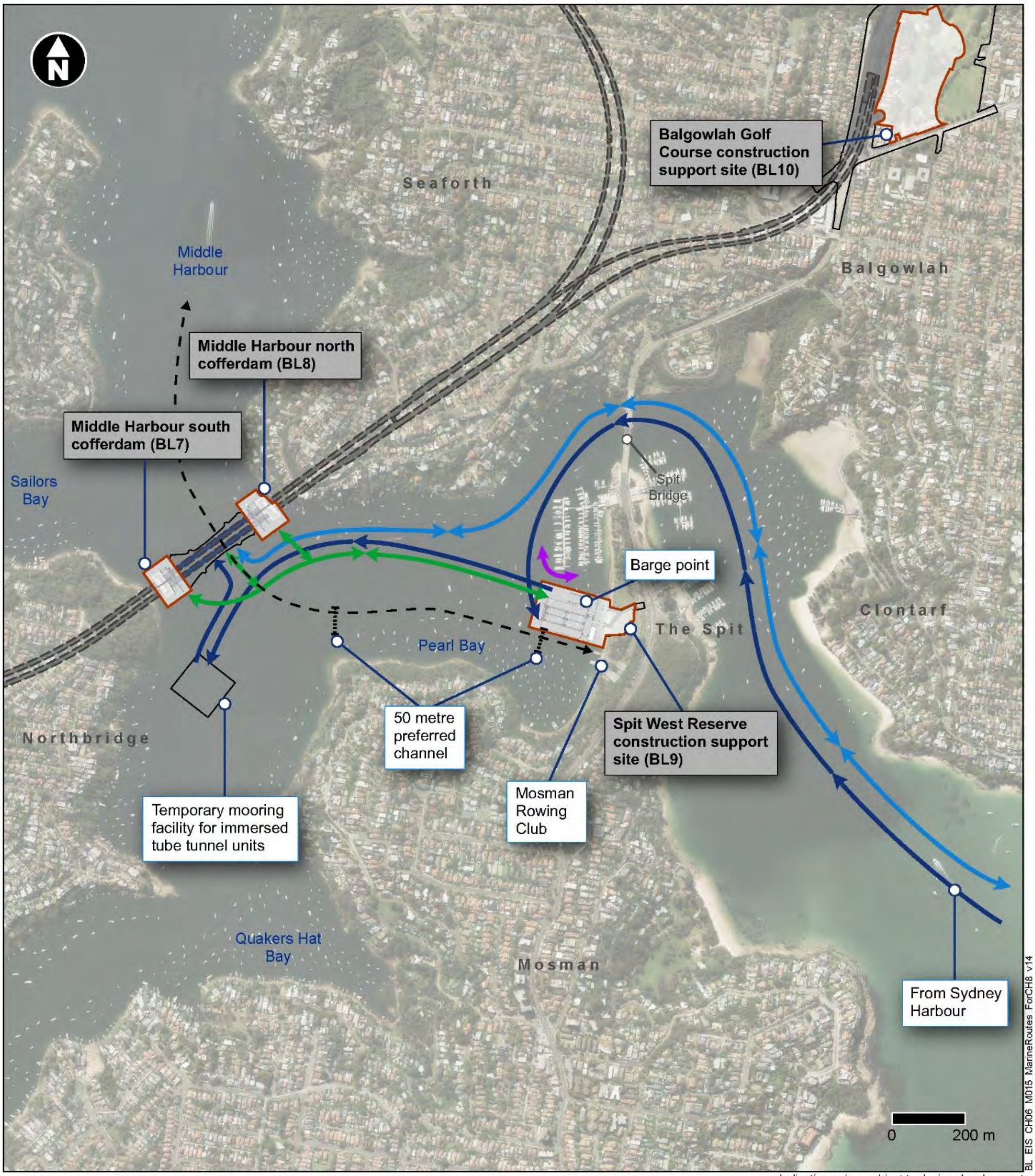
A model was prepared to simulate the transport of the partially constructed steel shell immersed tube tunnel units and identify any restrictions and towage requirements for the safe movement of vessels to and from the Outer Harbour, using the navigation channel through and between the Spit Bridge piers to berths at Spit West Reserve construction support site (BL9). The model found that the transportation of the partially constructed immersed tube tunnel units to the Spit West Reserve construction support site (BL9), and transportation of the completed immersed tube tunnel elements subsequently to the temporary mooring location before immersion, would be feasible and could be carried out safely based on the proposed methodology (refer to Chapter 6 (Construction works)).

Impacts on recreational users, community groups and clubs

Generally, recreational users, community groups and clubs downstream of the Spit Bridge would not be substantially impacted by construction activities in Middle Harbour due to the limited construction activities and associated vessel interactions in this part of the harbour.

Upstream of the Spit Bridge, Mosman Rowing Club would be located adjacent to the Spit West Reserve construction support site (BL9) and in the vicinity of construction vessel movements between the temporary construction support site, cofferdams, dredging and support piling works and the temporary mooring location. This has the potential to impact rowing club operations if not appropriately managed during construction. Measures to reduce and manage impacts on the operation of the Mosman Rowing Club would include avoiding impacts on the land based (ie via Spit West Reserve) or water based approaches to the club and maintaining the current 50 metre width of the navigation channel between the moorings on approach to the club where possible. Figure 8-13 shows the proposed rowing route and adjacent construction facilities and movements within Middle Harbour. This and other suitable management measures as required would be developed in consultation with the Mosman Rowing Club during construction planning.

Construction work, in particular dredging activities and the use of associated silt curtains, has the potential to impact the operation of the Northbridge Sailing Club. This club hosts races for dinghies and other sail craft that typically occupy the waterway in the immediate vicinity of the proposed Middle Harbour crossing. Opportunities to minimise and manage potential impacts, including the relocation of their racecourses to upstream of the Middle Harbour crossing, would be investigated prior to construction in consultation with the club.



Indicative only – subject to design development

Legend

Construction features

- Driven tunnel
- Immersed tube tunnel
- Construction footprint
- Construction support site

Maritime traffic routes

- Immersed tube tunnel transportation route
- Route for offshore disposal
- Marina access
- Marine construction traffic routes for dredging, cofferdams and permanent transition structures
- Proposed Mosman Rowing Club route

Figure 8-13 Maritime navigation impacts during construction

Impacts on commercial operations within Middle Harbour

Except for Eco Boat Hire at Northbridge, there is minimal commercial boating traffic that would be impacted by the construction activities. Furthermore, Eco Boat Hire charter small vessels that would always be permitted to traverse the crossing location during construction due to their size. The exception would be during the two full closures of the Middle Harbour crossing for immersion of the two central tunnel units which would be limited to about 48 hours per closure. There are no larger commercial operators known to navigate within the vicinity of, or through, the crossing location. Impacts on commercial operations within Middle Harbour are considered negligible.

Construction equipment and vessel movements would give way to larger vessels in the Outer Harbour or offshore areas (eg vessel movements associated with offshore disposal of dredged material) and would follow the Harbour Master's directions. Impacts on commercial operators in the Outer Harbour are also considered negligible due to the lower frequency of interaction with construction vessel movements and the increased space the Outer Harbour provides for manoeuvrability.

Impacts on government operations within Middle Harbour

Royal Australian Navy

The construction activities associated with the harbour crossing would not impact on navigation to and from HMAS Penguin at Balmoral. This is due to the HMAS Penguin being located away from the main construction activities, the width of the harbour at this location reducing the proximity to construction vessel movements, and the low number of naval vessels accessing the facility, reducing the potential interaction with construction vessel movements.

Water Police, Transport for NSW, and Department of Planning, Industry and Environment (Regions, Industry, Agriculture & Resources)

Impacts on government users would be limited to a minor increase in travel times resulting from imposed speed restrictions during construction. Speed restrictions would not apply to Water Police in an emergency.

Impacts on swing moorings and marina berths

About 45 swing moorings located in Pearl Bay would be temporarily relocated for about 48 months during construction due to the location of a casting facility off Spit West Reserve. About 10 swing moorings in Seaforth would also require temporary relocation due to the Middle Harbour north cofferdam (BL8). These moorings would be relocated for about 48 months, and likely just to the west of their existing locations in Middle Harbour, in consultation with the lease holders and therefore impacts on boat users due to the displaced moorings is considered to be minor.

Deliveries of immersed tube tunnel units between the temporary construction support sites may require a small number of additional swing moorings west of Bradys Point to be temporarily relocated. If required, arrangements would be determined in consultation with the lease holder(s). Impacts on any additional relocated moorings would be limited to a relatively small change to their location.

The location of the Middle Harbour north cofferdam (BL8) at Seaforth would also prohibit access to three private marina berths. Temporary alternative marina berths would be provided for about 48 months at marinas nearby.

8.4.4 Balgowlah and surrounds

Road network impacts

The anticipated routes to and from the Spit West Reserve (BL9), Balgowlah Golf Course (BL10), and Kitchener Street (BL11) construction support sites are summarised in Chapter 6 (Construction work), along with the respective daily maximum construction vehicle volumes.

Intersection and midblock performance with construction traffic

The performance of intersections (level of service) within the Balgowlah and surrounds area with the introduction of construction traffic would generally remain the same as conditions without the project. The intersection Manly Road/Sydney Road/Burnt Bridge Creek Deviation would worsen from LoS C to LoS D during the PM peak. In addition, the intersection of Spit Road/Parriwi Road/Spit West Reserve car park/BL9 construction support site access would worsen from a LoS B to LoS C also during the PM peak.

Direct access from the Balgowlah Golf Course construction support site (BL10) to Burnt Bridge Creek Deviation would be provided, which would reduce the potential traffic impacts possible at the Manly Road/Sydney Road/Burnt Bridge Creek Deviation intersection were access to the temporary construction support site provided from Sydney Road.

The Sydney Road/Maretimo Street intersection would improve from LoS E to LoS A during the AM peak and from LoS F to LoS A during the PM peak. This improvement would occur as a result of the proposed traffic signals at the intersection during construction and the addition of a northern approach that would provide access to the Balgowlah Golf Course construction support site (BL10). However, traffic signals at this intersection would increase delays for vehicles travelling east–west on Sydney Road that do not experience any delay under the existing configuration. The additional delays under traffic signal operation are considered to be minor.

The intersection performance results for the road network operating under the worst case construction traffic scenario (2024) during the AM and PM peak periods are summarised in Table 8-19.

Table 8-19 Modelled intersection performance in Balgowlah and surrounds (AM peak (8am-9am) and PM peak (5pm-6pm) during construction in 2024)

Intersection/ peak period	Base case 2024 (without construction traffic)				Construction case 2024 (with construction traffic)			
	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C
Spit Road/ Parriwi Road/ Spit West Reserve car park/ BL9 construction support site access								
AM peak	4850	8	A	0.73	5070	8	A	0.76
PM peak	5370	21	B	0.89	5700	31	C	0.94
Manly Road/ Sydney Road/ Burnt Bridge Creek Deviation								
AM peak	4740	49	D	0.91	4860	54	D	0.95
PM peak	5680	34	C	0.92	5840	45	D	0.99
Sydney Road/ Maretimo Street/ BL10 construction support site access								
AM peak	1460	70	E	0.24	1560	10	A	0.35
PM peak	1830	>100	F	0.27	1970	12	A	0.50

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

The midblock performance during construction would be comparable to performance under conditions without the project at all locations, with the exception of Sydney Road east of Manly Road in the eastbound direction which would reduce from LoS C to LoS D during the PM peak. However, it is expected that Sydney Road in this location and direction would still operate with spare capacity and at a satisfactory level of service during construction.

The midblock performance results for the road network operating under the worst case construction traffic scenario (2024) are summarised in Table 8-20 during the AM and PM peak periods.

Table 8-20 Modelled midblock performance in Balgowlah and surrounds (AM peak (8am-9am) and PM peak (5pm-6pm) during construction in 2024)

Location/ direction	Capacity (PCU)	AM Peak						PM Peak					
		Base case 2024 (without construction traffic)			Construction 2024 (with construction traffic)			Base case 2024 (without construction traffic)			Construction 2024 (with construction traffic)		
		Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS
Spit Road south of Parriwi Road													
Northbound	2900	3110	>1	F	3250	>1	F	1820	0.63	D	2010	0.69	D
Southbound	2900	1520	0.52	C	1670	0.58	C	2960	>1	F	3160	>1	F
Manly Road south of Sydney Road													
Northbound	2900	1720	0.59	D	1830	0.63	D	3400	>1	F	3550	>1	F
Southbound	2900	3270	>1	F	3390	>1	F	1840	0.63	D	1990	0.69	D
Sydney Road east of Manly Road													
Eastbound	1900	520	0.28	B	590	0.31	B	1080	0.57	C	1160	0.61	D
Westbound	2900	1060	0.37	B	1130	0.39	B	830	0.28	B	910	0.31	B
Burnt Bridge Creek Deviation west of Condamine Street													
Northbound	2900	1070	0.37	B	1070	0.37	B	2040	0.70	D	2040	0.70	D
Southbound	2900	1620	0.56	C	1620	0.56	C	1150	0.40	B	1160	0.40	B

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

Impacts on local roads and parking

All roads in the Balgowlah area that form part of construction vehicle routes are state or regional roads.

The Sydney Road/Maretimo Street intersection would be modified during construction, with an additional approach to allow access to the Balgowlah Golf Course construction support site (BL10) from Sydney Road. Providing traffic signals at the intersection would be beneficial to vehicles performing a right turn into or out of Maretimo Street including to and from the Northern Beaches Secondary College Balgowlah Boys Campus, which currently have to give way to multiple conflicting movements under the priority controlled intersection arrangement. In addition, construction vehicles exiting the temporary construction support site would be required to give way to vehicles turning left from Maretimo Street and would not conflict with vehicles turning right. Traffic movements north-south (and vice versa) through the intersection between Maretimo Street and the Balgowlah Golf Course construction support site (BL10) (and future access road) would not be permitted.

Access to the Kitchener Street construction support site (BL11) to and from the Burnt Bridge Creek Deviation is considered unlikely to result in significant impacts to traffic.

Car parking areas for construction workers would be provided at the Balgowlah Golf Course construction support site (BL10). Therefore, no loss of parking on adjacent local streets is anticipated during construction. Public parking spaces would be removed from the existing Balgowlah Golf Course car park during construction. These spaces are used for both the golf course and for the nearby Balgowlah Oval, but as the golf course would no longer be in operation during construction and alternative parking is available on Pickworth Avenue, impacts would be negligible.

The Spit West Reserve construction support site (BL9) and Kitchener Street construction support site (BL11) would have limited parking for supervision staff. The construction workforce at the Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8), Spit West Reserve construction support site (BL9) and Kitchener Street construction support site (BL11) would park at the Balgowlah Golf Course construction support site (BL10) and be transported to the site by shuttle bus (where required). The Spit West Reserve construction support site (BL9) would be accessed from the existing Spit West Reserve entry from Spit Road.

The construction workforce would also be encouraged to use public transport where possible, with key bus corridors (including the Northern Beaches B-Line) including Military Road, Spit Road, Manly Road, Sydney Road, Burnt Bridge Creek Deviation and Condamine Street.

Impacts on public transport

Impacts on public transport within the Balgowlah and surrounds area are shown in Figure 8-14.

Minor adjustments to bus stops on Sydney Road may be required during construction. As a major bus corridor, bus stops on Sydney Road serve buses that provide connections to Sydney CBD, North Shore, Manly, Brookvale/Dee Why area and Mona Vale. Additional minor adjustments to bus stops may be required on Maretimo Street and would be confirmed during further design development and construction planning. These adjustments may require bus customers to walk small additional distances, slightly increasing their travel times. Disruption to bus customers would be minimised by relocating the bus stops to the closest practical alternative location. Due to the minimal relocation distances, residual impacts would be minor. Any changes to bus stop locations would be communicated to the local community and developed in consultation with relevant stakeholders including other divisions of Transport for NSW.

Construction works would also impact Burnt Bridge Creek Deviation between Sydney Road and Kitchener Street bridge, which is a major bus corridor with bus lanes operating in both directions. The current bus lanes on Burnt Bridge Creek Deviation would operate on temporary alignments near the general traffic lanes. Given that the temporary alignments would be of a similar distance to the current configuration of Burnt Bridge Creek Deviation, impacts on bus travel times would be negligible.

Community and stakeholder consultation would be carried out before the start of works to consult with and inform all road users, including bus operators, of the upcoming network changes and proposed detours.

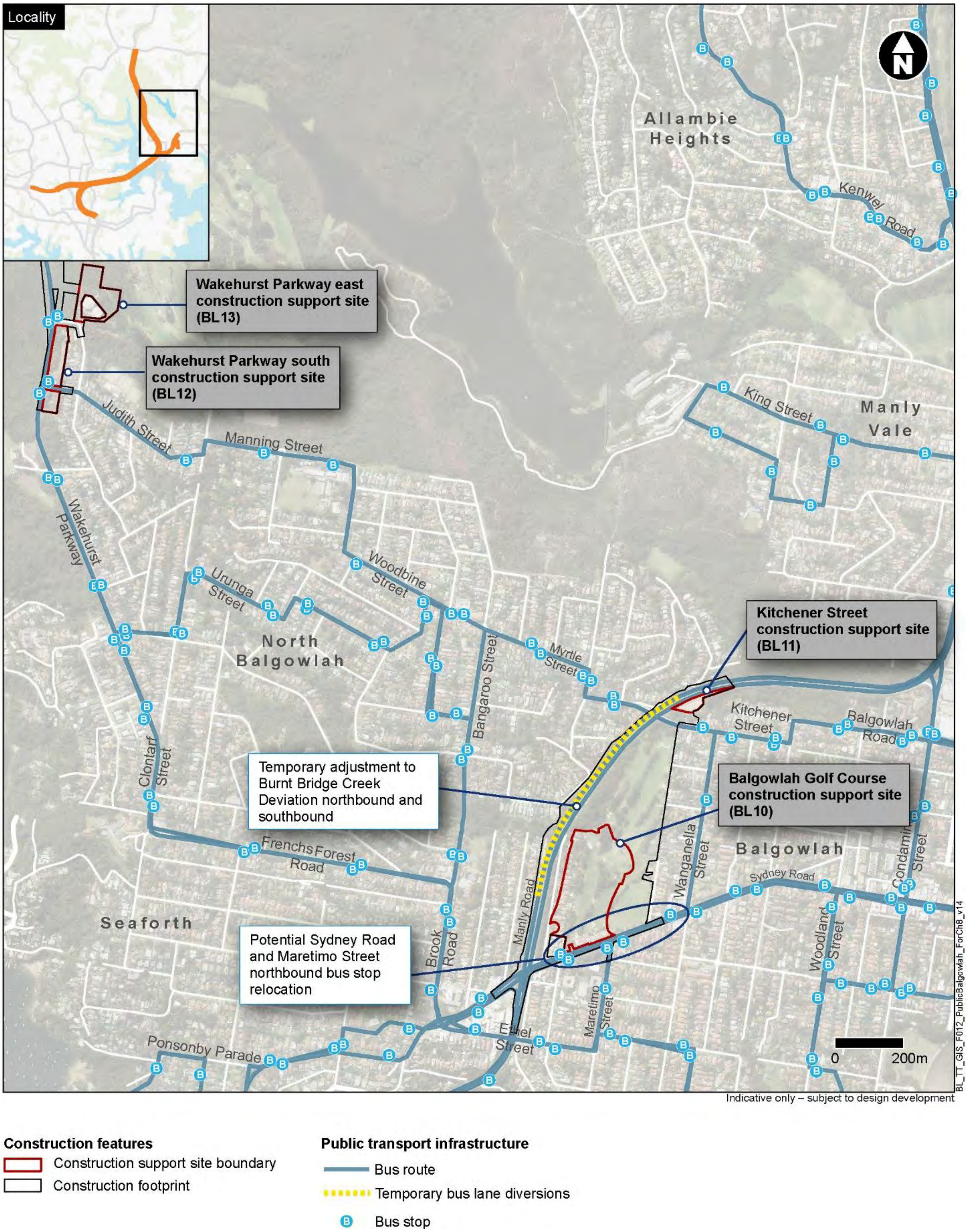


Figure 8-14 Public transport impacts within Balgowlah and surrounds during construction

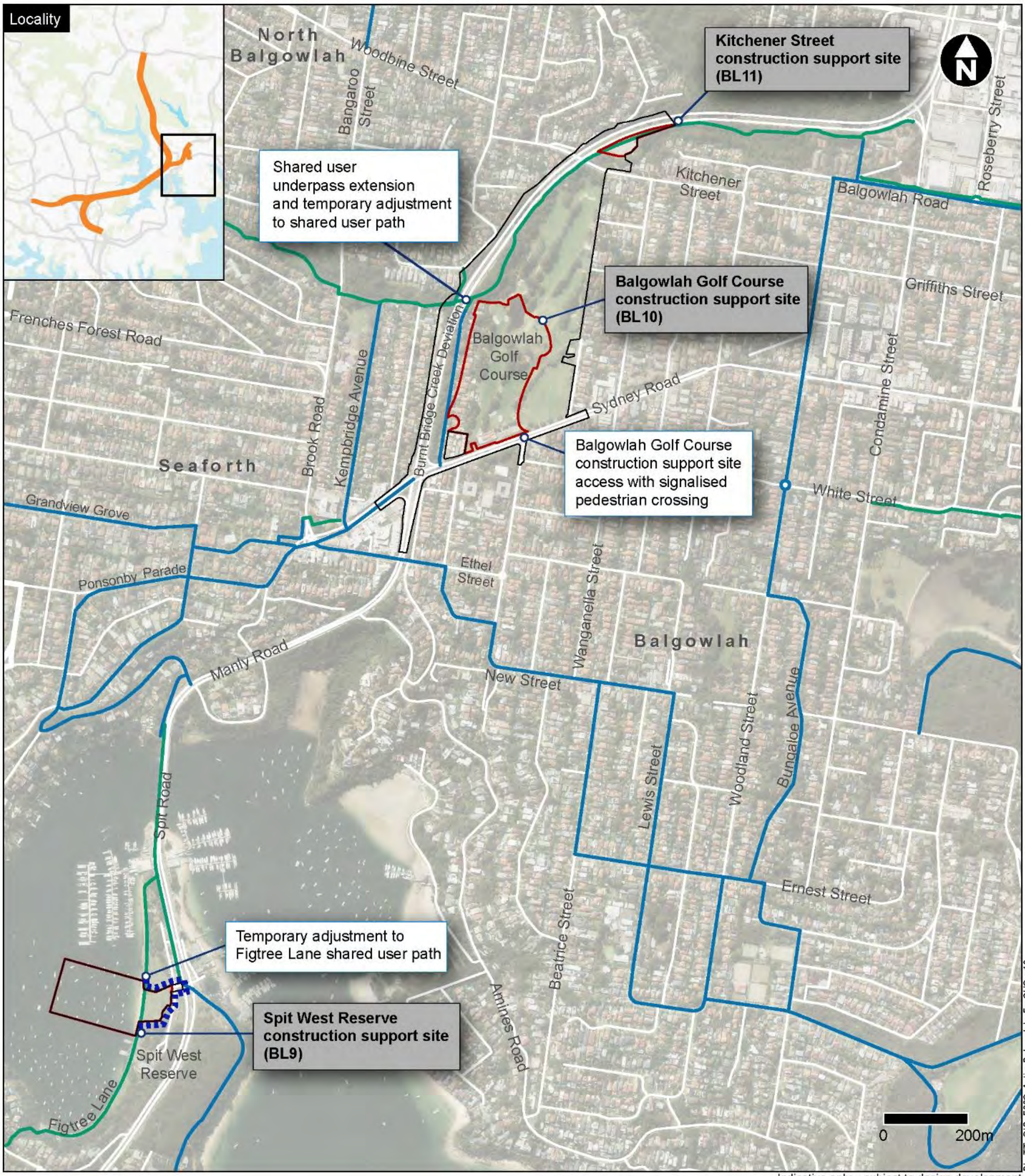
Impacts on active transport

Impacts on active transport network within the Balgowlah and surrounds area are shown in Figure 8-15.

Changes to the active transport network around Balgowlah during surface works would include:

- Temporary adjustment to paths at Spit West Reserve around the Spit West Reserve construction support site (BL9), specifically Fig Tree Lane, resulting in an increase in travel distance of up to 100 metres, which would be considered a minor impact due to the short detour distance
- A 50 metres temporary shared user path would be constructed within the Balgowlah Golf Course when the shared user path along the existing Burnt Bridge Creek Deviation is adjusted for the box culvert extension and the existing shared user underpass of Burnt Bridge Creek Deviation is extended. The extension of the existing shared user underpass beneath the Burnt Bridge Creek Deviation at Burnt Bridge Creek would be staged to maintain access at all times. Subject to final planning for staging of these works, additional short term detours may be required due to construction access restrictions
- A signalised pedestrian crossing would be provided at the entrance to the Balgowlah Golf Course construction support site (BL10) off Sydney Road via the traffic signals provided for the Sydney Road/Maretimo Street/Access Road intersection. This would ensure safe passage from users of the Sydney Road pedestrian bridge, including students from Northern Beaches Secondary College – Balgowlah Boys Campus, to the Balgowlah Oval.

Impacts on pedestrians and cyclists are expected to be minor given that existing connectivity would be maintained and additional travel distances via the temporary shared user path would be minimal. Appropriate linemarking and signage would be used to identify diversions and, where required, traffic controllers would ensure safe passage for users.



Legend

Construction features
- Construction support site boundary
- Construction footprint

Active transport infrastructure
- Existing off-road shared user path
- Existing on-road cycle path

Adjusted active transport infrastructure
- Temporary Figtree Lane shared user path detour

Figure 8-15 Active transport impacts within Balgowlah and surrounds during construction

8.4.5 Frenchs Forest and surrounds

Road network impacts

The anticipated routes to and from the Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites within the Frenchs Forest area and surrounds are summarised in Chapter 6 (Construction work), along with the respective daily maximum construction vehicle volumes.

Intersection and midblock performance with construction traffic

The performance of intersections within the Frenchs Forest and surrounds area with the introduction of construction traffic would generally remain the same as under conditions without the project.

The closure of Kirkwood Street to general traffic at its intersection with Wakehurst Parkway is predicted to result in a redistribution of traffic to Judith Street or Burnt Street. Given the relative difficulty in performing a right turn manoeuvre out of Judith Street across Wakehurst Parkway, the assessment has assumed that existing local traffic that currently turns right out of Judith Street and Kirkwood Street would use the traffic signals at Burnt Street instead. The impacts to the performance of the Wakehurst Parkway/Judith Street intersection are considered negligible and would worsen from LoS B to LoS C during the AM peak, however would improve from LoS D to LoS C in the PM peak.

The performance of the Wakehurst Parkway/Burnt Street intersection during construction would continue to operate at an acceptable level of service notwithstanding the small volume of additional detoured vehicles generated by the changes described above.

A new intersection with traffic signals would be constructed to provide access to the Wakehurst Parkway east construction support site (BL13). During construction, this intersection would operate at LoS C during the AM peak and LoS A during the PM peak.

With construction traffic included on the road network, the Wakehurst Parkway/Warringah Road intersection would continue to operate at LoS D during the AM peak and LoS E during the PM peak, taking into account the opening of the underpass arrangements along Warringah Road as part of the Northern Beaches Hospital road upgrade project. During the PM peak the intersection is forecast to continue to operate close to capacity. The remainder of intersections in the Frenchs Forest and surrounds area would not experience a change in level of service as a result of the construction of the project.

The intersection performance results for the road network operating under the worst case construction traffic scenario (2024) are summarised in Table 8-21 during the AM and PM peak periods.

Table 8-21 Modelled intersection performance in Frenchs Forest and surrounds (AM peak (8am-9am) and PM peak (5pm-6pm) during construction in 2024)

Intersection/peak period	Base case 2024 (without construction traffic)				Construction case 2024 (with construction traffic)			
	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C	Demand flow (vehicles per hour)	Average delay (seconds)	LoS	V/C
Wakehurst Parkway/Burnt Street/Seaforth Oval car park								
AM peak	1160	7	A	0.42	1470	21	B	0.67
PM peak	1430	6	A	0.47	1610	17	B	0.60
Wakehurst Parkway/Judith Street/BL12 construction support site access								
AM peak	1520	27	B	0.76	1640	30	C	0.51
PM peak	1800	49	D	0.82	1870	33	C	0.53
Wakehurst Parkway/Kirkwood Street/BL12 construction support site access								
AM peak	1470	52	D	0.65	1510	45	D	0.46
PM peak	1670	71	F	0.54	1710	59	E	0.44
Wakehurst Parkway/ BL13 construction support site access								
AM peak	-	-	-	-	1580	30	C	0.91
PM peak	-	-	-	-	1810	11	A	0.70
Wakehurst Parkway/Warringah Road								
AM peak	4080	43	D	0.79	4220	44	D	0.86
PM peak	4770	57	E	0.95	4940	69	E	1.00

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

The midblock performance during construction would be comparable to conditions without the project at all locations, except for:

- Wakehurst Parkway north of Judith Street in the northbound direction would change from LoS E to LoS F during AM peak and PM peak
- Wakehurst Parkway north of Kirkwood Street in the northbound direction would change from LoS E to LoS F during AM peak and PM peak
- Wakehurst Parkway north of Kirkwood Street in the southbound direction would change from LoS E to LoS F during PM peak.

Wakehurst Parkway north of Judith Street and north of Kirkwood Street is already operating close to LoS E/F. A small increase in traffic volume and volume to capacity ratio due to construction vehicles and general traffic diverted due to the temporary long-term closure of Kirkwood Street would not have any major additional impact on traffic performance.

The midblock performance results for the road network operating under the worst case construction traffic scenario during the AM and PM peak hours are summarised in Table 8-22.

Table 8-22 Modelled midblock performance in Frenchs Forest and surrounds (AM peak (8am-9am) and PM peak (5pm-6pm) during construction in 2024)

Location/ direction	Capacity (PCU)	AM Peak						PM Peak					
		Base case 2024 (without construction traffic)			Construction 2024 (with construction traffic)			Base case 2024 (without construction traffic)			Construction 2024 (with construction traffic)		
		Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS	Volume (PCU)	V/C	LoS
Wakehurst Parkway north of Judith Street													
Northbound	900	880	0.97	E	970	>1	F	860	0.96	E	910	>1	F
Southbound	900	670	0.74	D	690	0.77	D	910	>1	F	930	>1	F
Wakehurst Parkway north of Kirkwood Street													
Northbound	900	900	1.00	E	960	>1	F	830	0.92	E	920	>1	F
Southbound	900	630	0.70	D	700	0.77	D	860	0.96	E	950	>1	F
Warringah Road west of Wakehurst Parkway[2]													
Eastbound	3900	1670	0.43	C	1,750	0.45	C	1940	0.50	C	2030	0.52	C
Westbound	2900	620	0.21	A	710	0.24	A	1410	0.49	C	1510	0.52	C
Warringah Road east of Wakehurst Parkway[2]													
Eastbound	2900	710	0.24	A	720	0.25	A	580	0.20	A	590	0.20	A
Westbound	2900	620	0.21	A	620	0.21	A	1030	0.36	B	1030	0.36	B

Note 1: Cells shaded in dark grey denote an unsatisfactory LoS E or F
Note 2: Assumed capacity on Warringah Road refers to capacity on the surface lanes adjacent to the Wakehurst Parkway intersection. Eastbound capacity on Warringah Road west of Wakehurst Parkway is greater than the eastbound capacity east of Wakehurst Parkway due to the presence of the additional short right-turn lanes.

Impacts on local roads and parking

The closure of the northern section of Kirkwood Street would be required during construction to accommodate the Wakehurst Parkway south construction support site (BL12) and associated construction activities. The impact on diverted vehicles would be minor given that several nearby alternative local roads are available, including Judith Street and Burnt Street. Access to the properties owned by Sydney Water and Telstra would also be slightly impacted, with vehicles required to access the properties via Judith Street and Kirkwood Street south.

Spoil trucks exiting the Wakehurst Parkway east construction support site (BL13) would be required to travel north on Wakehurst Parkway, minimising the impact of spoil truck movements on surrounding local roads. Spoil trucks would not be permitted to travel south through Frenchs Forest Road and Sydney Road.

Allambie Road (north of Warringah Road) and Frenchs Forest Road east are local roads that would act as part of the egress route from the Wakehurst Parkway north construction support site (BL14). Minor impacts are anticipated on these roads given the low number of construction vehicle movements of about 90 light vehicle and 50 heavy vehicle movements (egress only) per day.

Blasting may be required along Wakehurst Parkway and would require the short-term closure (up to 10 minutes) of sections of Wakehurst Parkway to general traffic. Any road closures would be carried out under traffic control and outside peak periods to ensure safety and minimise disruption to the road network.

Car parking areas for construction workers would be provided at the Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites. Worker parking would be maximised within the constraints of the respective temporary construction support site. Parking for site vehicles associated with the realignment and upgrade of the Wakehurst Parkway would be managed as the works sites move and would be contained within the relevant work sites. The number of car parking spaces would be determined during construction planning.

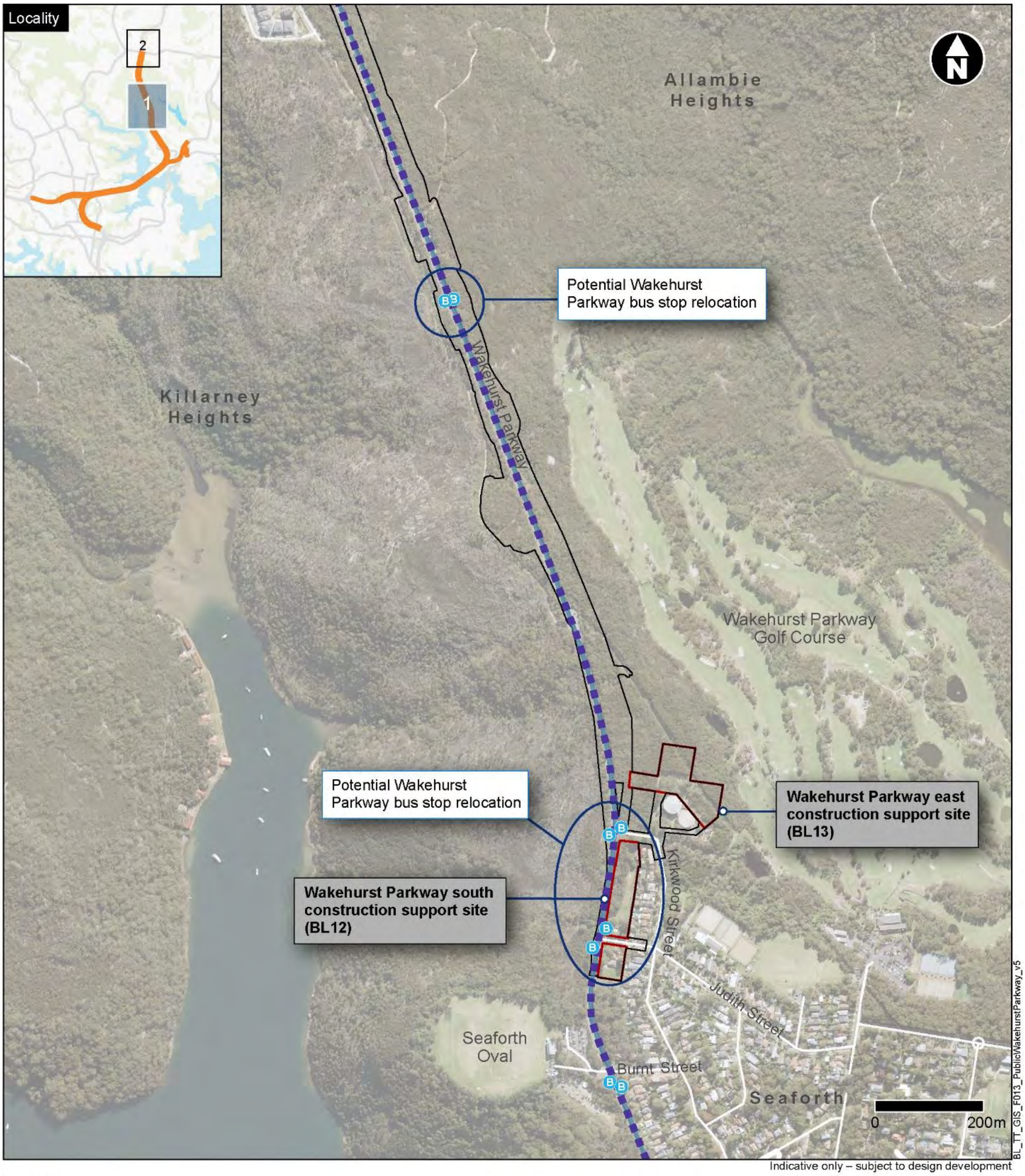
Notwithstanding, the construction workforce would be encouraged to use public transport where feasible, with key bus corridors including Warringah Road and Forest Way. Where public transport availability to temporary construction support sites is limited, shuttle bus transfers may also be provided from public transport centres where required.

Impacts on public transport

Impacts on public transport within the Frenchs Forest and surrounds area are shown in Figure 8-16 and Figure 8-17.

Bus stops within the construction footprint along Wakehurst Parkway in Seaforth, Killarney Heights and Frenchs Forest would be temporarily relocated during construction. This includes bus stops for bus services operating along Wakehurst Parkway (routes 141, 169, 173 and 169X) which provide connections to Austlink Corporate Centre, Narraweena, Manly and Sydney CBD. Adjustments to bus stops may require bus customers to walk small additional distances which would slightly increase their travel times. Bus stops would be relocated as close as practical to their existing positions to minimise disruption. As such, these impacts are expected to be minor.

Other bus stops on adjacent roads may also require temporary relocation during construction. This would be determined during construction staging and planning in consultation with relevant stakeholders, including other divisions of Transport for NSW, and advanced notification would be provided to affected bus customers. Bus stops would be relocated within walking distance of their existing position to minimise disruption where reasonable and feasible.



Legend

Construction features

Construction support site boundary

Construction footprint

Public transport infrastructure

Bus route 141, 169, 173 and 169X

Bus route

Bus stop

Figure 8-16 Public transport impacts within Frenchs Forest and surrounds (southern area) during construction (map 1)

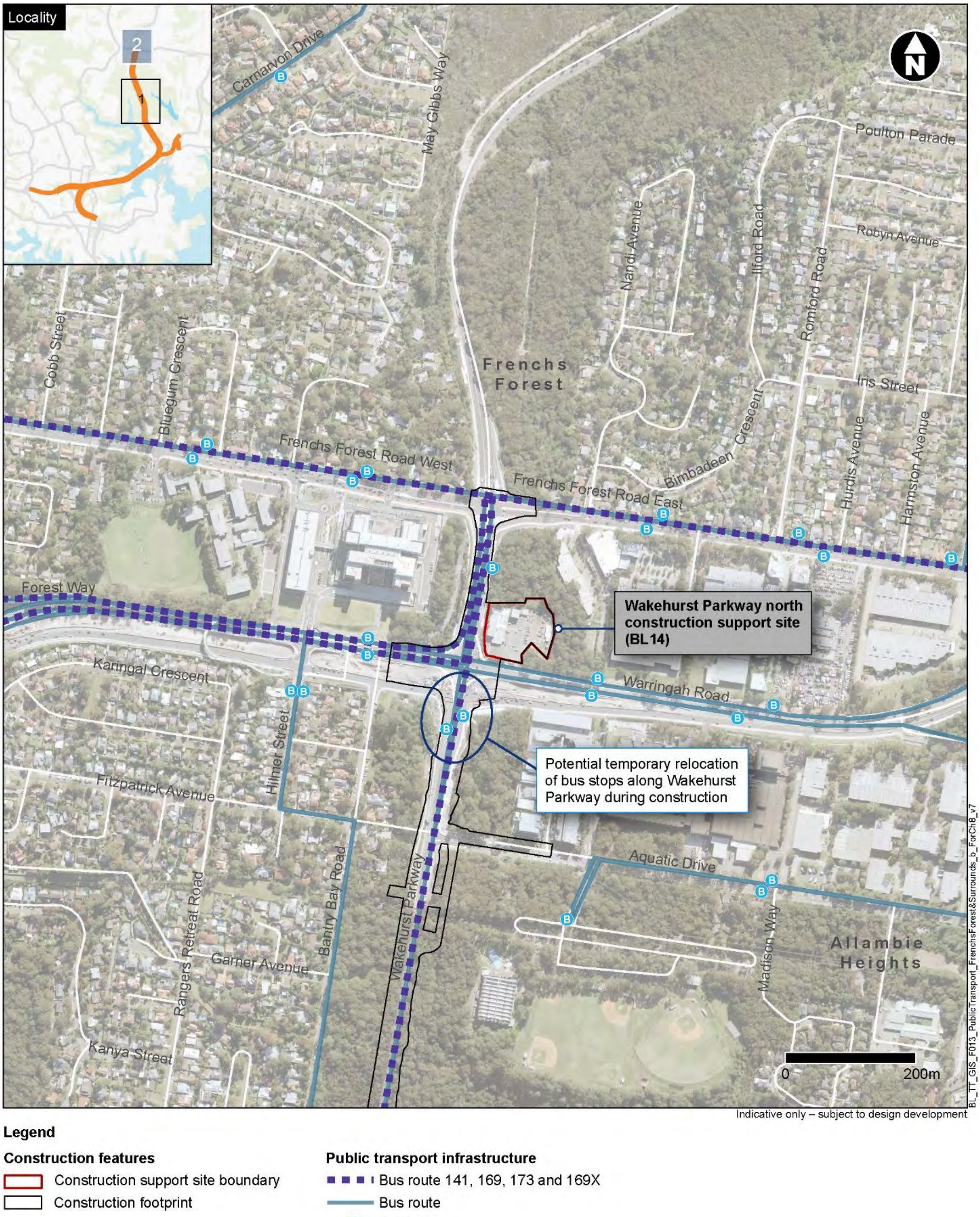


Figure 8-17 Public transport impacts within Frenchs Forest and surrounds (northern area) during construction (map 2)

Impacts on active transport

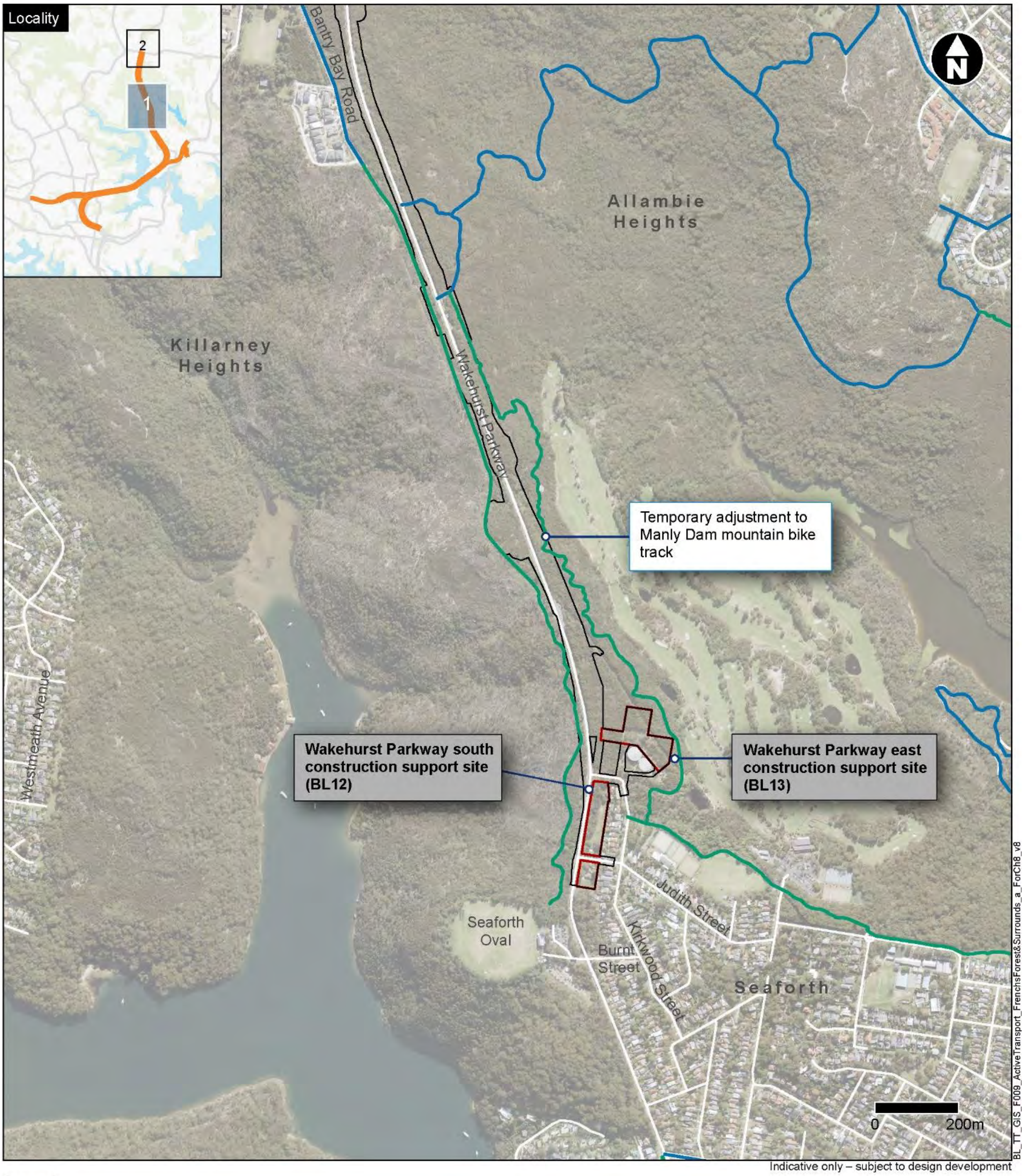
Impacts on active transport network within the Frenchs Forest and surrounds area are shown in Figure 8-18 and Figure 8-19.

New traffic lights would be installed to provide access to the Wakehurst Parkway east construction support site (BL13). Conflicts between pedestrians and cyclists using the footpath near this site and construction vehicles would be managed through the control of movements at the site entry/exit.

Temporary adjustment of some of the mountain bike tracks on either side of Wakehurst Parkway may be required. Minor detour routes would be implemented, and advanced notification of track closures provided at key locations. Construction of the three permanent shared user path underpasses along Wakehurst Parkway would be prioritised where feasible.

The existing shared user path adjacent to the Wakehurst Parkway north construction support site (BL14) would also be temporarily impacted during the use of the site. Affected areas would include the off-road shared user paths along Wakehurst Parkway, north of Warringah Road which may require minor detours. Pedestrian and cyclist access would be maintained during construction and the increase in travel distance would be negligible.

Additionally, the shared user path bridge over Wakehurst Parkway connecting the Warringah Aquatic Centre and Bantry Bay Road would be demolished and a new and lengthened replacement overpass constructed as part of the project. Construction would be staged to ensure pedestrian and cyclist access over Wakehurst Parkway would be maintained at all times.



Indicative only – subject to design development

Legend

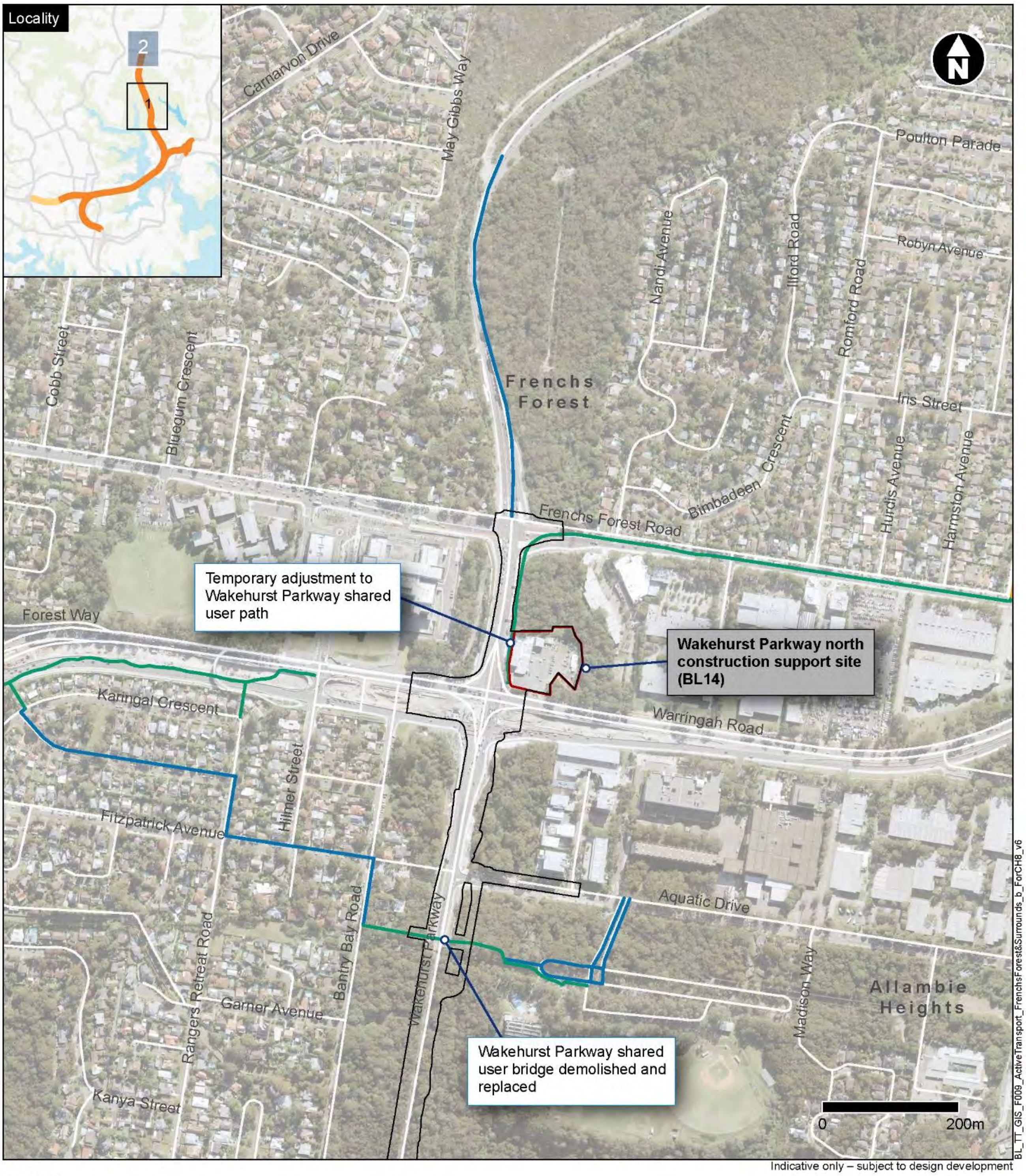
Construction features

- Construction support site boundary
- Construction footprint

Active transport infrastructure

- Existing off-road shared user path
- Existing on-road cycle path

Figure 8-18 Active transport impacts within Frenchs Forest and surrounds (southern area) during construction (map 1)



Legend

Construction features

- Construction support site boundary
- Construction footprint

Active transport infrastructure

- Existing off-road shared user path
- Existing on-road cycle path

Figure 8-19 Active transport impacts within Frenchs Forest and surrounds (northern area) during construction (map 2)

8.4.6 Cumulative impacts of the project and the Western Harbour Tunnel and Warringah Freeway Upgrade project (Warringah Freeway and surrounds)

Peak cumulative construction traffic is expected in 2024, if construction of the project and the Western Harbour Tunnel and Warringah Freeway Upgrade project (subject to separate assessment and approval) are carried out concurrently.

Road network performance

Analysis of network performance in the AM and PM peak periods with the project and the Western Harbour Tunnel and Warringah Freeway Upgrade project indicates that, when compared to forecast 2024 peak period without the project conditions, cumulative construction activities in the Warringah Freeway and surrounds area have the potential to:

- Increase traffic demand by about one per cent
- Create less than one additional stop per trip
- Reduce average trip speeds by about four per cent.

Cumulative construction activities are therefore only expected to have minor and manageable impacts on overall network performance in the area.

General travel times

Modelled travel times during AM and PM peaks for key routes relevant to the project are presented in Table 8-23.

Under the cumulative construction 2024 scenario, travel times would increase by less than one minute for most routes. Predicted travel time increases between one and three minutes are expected for the following routes:

- Warringah Freeway: Gore Hill Freeway to Sydney Harbour Bridge (AM peak)
- Warringah Freeway: Gore Hill Freeway to Sydney Harbour Tunnel (AM peak)
- Warringah Freeway: Falcon Street to Sydney Harbour Bridge (PM peak)
- Miller Street: Amherst Street to Berry Street (AM peak)
- Miller Street: Berry Street to Amherst Street (PM peak).

Table 8-23 Modelled AM and PM peaks traffic travel times for key routes relevant to the project

Route/ Peak period	Direction	Base case 2024 (without construction traffic) (minutes : seconds)	Cumulative construction 2024 (with construction traffic) (minutes : seconds)
Sydney Harbour Bridge to Warringah Freeway/Falcon Street interchange			
AM peak	Northbound	04:42	04:39
	Southbound	04:02	04:01
PM peak	Northbound	03:43	03:45
	Southbound	04:16	05:32
Sydney Harbour Tunnel to Warringah Freeway/Falcon Street interchange			
AM peak	Northbound	03:51	03:57
	Southbound	04:06	04:03

Route/ Peak period	Direction	Base case 2024 (without construction traffic) (minutes : seconds)	Cumulative construction 2024 (with construction traffic) (minutes : seconds)
PM peak	Northbound	03:36	03:42
	Southbound	14:27	15:05
Sydney Harbour Bridge to Gore Hill Freeway/Pacific Highway interchange			
AM peak	Northbound	06:13	06:13
	Southbound	08:48	10:53
PM peak	Northbound	05:31	05:59
	Southbound	16:15	16:13
Sydney Harbour Tunnel to Gore Hill Freeway/Pacific Highway interchange			
AM peak	Northbound	05:22	05:28
	Southbound	08:50	11:21
PM peak	Northbound	05:19	06:01
	Southbound	19:51	20:20
Berry Street to Amherst Street via Miller Street			
AM peak	Northbound	04:10	04:05
	Southbound	07:48	09:22
PM peak	Northbound	04:34	05:36
	Southbound	13:45	10:39

As shown in Table 8-23, for Miller Street southbound the base case was observed to experience longer travel times in comparison to the 2024 cumulative construction scenario. Falcon Street/Military Road westbound between Ben Boyd Road and Miller Street is predicted experience a slight increase in congestion in the 2024 cumulative construction scenario when compared to the 2024 base case resulting in less throughput and delays at the Falcon Street left turn onto Miller Street. As the performance of the Miller Street corridor is sensitive to the traffic arrival rates from side streets, this reduction in throughput results in the observed improvement to the Miller Street southbound travel time in the 2024 cumulative construction scenario.

Intersection performance

The intersection performance results for the road network under the 'Base case 2024' (without construction vehicles) and 'Cumulative construction 2024' (with construction vehicles and proposed intersection modifications during construction) scenarios are detailed in Appendix F (Technical working paper: Traffic and transport) for the AM and PM peak periods.

In summary, the addition of construction traffic for both projects would impact the level of service at the following intersections:

- Willoughby Road/Gore Hill Freeway interchange would be reduced from LoS E to LoS F during the AM peak, and from LoS C to LoS D during the PM peak
- Brook Street/Warringah Freeway off ramp would be reduced from LoS E to LoS F during the AM peak
- Amherst Street/West Street would be reduced from LoS A to LoS B during the PM peak
- Amherst Street/Miller Street would be reduced from LoS B to LoS C during the PM peak

- Miller Street/Warringah Freeway off ramp would be reduced from LoS A to LoS C during the AM peak
- Miller Street/Falcon Street would be reduced from LoS D to LoS E during the AM peak
- Military Road/Ben Boyd Road would be reduced from LoS C to LoS D during the PM peak
- Mount Street/Arthur Street would be reduced from LoS E to LoS F during the PM peak
- Pacific Highway/Berry Street would be reduced from LoS B to LoS C during the PM peak
- Pacific Highway/Bay Road would be reduced from LoS E to LoS F during the AM peak
- High Street/Alfred Street North would be reduced from LoS A to LoS B during the AM peak
- Ernest Street/Ben Boyd Road would be reduced from LoS C to LoS D during the AM peak, and from LoS A to LoS B during the PM peak.

During the AM peak, intersections which would experience a material increase in average vehicle delay (around 30 to 40 seconds) during construction include Willoughby Road/Gore Hill Freeway interchange, intersection of Brook Street and Merrenburn Avenue and Brook Street/Warringah Freeway ramp.

During the PM peak, some intersections within the North Sydney area would experience a minor increase in average vehicle delay.

Road network changes and access arrangements

The Cammeray Golf Course construction support site (BL1) would be used for the Beaches Link and Gore Hill Freeway Connection project and the Western Harbour Tunnel and Warringah Freeway Upgrade project (subject to separate assessment and approval). This would result in cumulative traffic volumes generated to and from this site. The potential for cumulative travel impacts associated within these projects, including haulage roads and intersections traversed by construction vehicles during concurrent works, has been assessed in this section. If both projects are under construction concurrently, works at the Cammeray Golf Course construction support site (BL1) would be planned and programmed to manage any overlap between the two projects and minimise impacts on the surrounding road network and road users.

Impacts on public transport

In relation to bus times, cumulative construction activities in the Warringah Freeway and surrounds have the potential to impact corridor travel times by less than one minute for most routes. However, when compared to forecast 2024 peak period base conditions, there would be an increase in travel times between one and three minutes for the following routes:

- Southbound via Miller Street to the Sydney Harbour Bridge (AM peak)
- Northbound via the Warringah Freeway and Military Road to Ben Boyd Road (PM peak).

The most substantial potential impact is on southbound travel times via the Warringah Freeway. For Warringah Freeway routes, increased traffic demand, including potential additional traffic movements across the southbound bus lane south of Falcon Street, could increase congestion, which could impact bus travel times. This issue would be mitigated by considered and tailored construction traffic planning based on actual traffic conditions and confirmed cumulative activities at the time of construction.

Impacts on active transport and maritime activities

Impacts on active transport and maritime activities would be similar to those discussed in each of the sections above given the minimal overlap in construction activities associated with this project and the Western Harbour Tunnel and Warringah Freeway Upgrade project.

8.4.7 Cumulative impacts of the project and other projects

Peak construction activity for the project would not overlap with peak construction activities for other committed major infrastructure projects such as Sydney Metro City & Southwest and the M4-M5 Link.

There is potential for some overlap with the construction of the Sydney Metro West or other major projects within the Sydney metropolitan area, including the Channel 9 site staged residential development. Spoil trucks and other construction vehicles associated with these projects have the potential to generate cumulative impacts on the broader road network. Overall, given that spoil trucks for the project and any overlapping major projects would predominantly use only major arterial roads, potential cumulative impacts would be minor.

8.4.8 Special events impacts

Construction works would have minimal impacts on special events as the temporary construction support sites and traffic routes would not be located near venues or locations that regularly schedule events that require traffic or public transport event plans.

Water based races within Middle Harbour held by the recreational clubs along the foreshore may be impacted by marine construction traffic, as identified in Section 8.4.3.

8.5 Environmental management measures

Environmental management measures relating to construction traffic and transport impacts are outlined in Table 8-24. Environmental management measures relating to cumulative impacts, including coordination of haulage routes and road occupancy, are detailed in Chapter 27 (cumulative impacts).

Table 8-24 Environmental management measures - construction traffic and transport

Ref	Phase	Impact	Environmental management measure	Location
CTT1	Pre-construction	Construction traffic	A road condition report will be prepared, in consultation with relevant councils and road owners, identifying existing conditions of local roads that will be used by heavy vehicles associated with the project and mechanisms to repair damage to the road network (beyond normal wear and tear) caused by these movements.	BL/GHF
CTT2	Pre-construction	Maritime construction	Transport for NSW will consult with the owners and/or leaseholders and/or licence holders of jetties and moorings that require temporary relocation to determine alternative arrangements. Moorings impacted during construction will be temporarily relocated elsewhere in Middle Harbour in consultation with the lease holder(s) and coordination with the Port Authority of NSW. All efforts will be made to relocate facilities as close to their original locations as possible. Impacted mooring licence holders may be entitled to a fee waiver or fee reimbursement where appropriate.	BL

Ref	Phase	Impact	Environmental management measure	Location
CTT3	Construction	Maritime construction traffic	Construction vessels will be required to operate in a manner that minimises wash to areas of shoreline.	BL
CTT4	Construction	Maritime construction traffic	Construction marine traffic activities will be scheduled to avoid times and locations of high recreational marine traffic where feasible and reasonable.	BL
CTT5	Construction	Maritime construction traffic	Harbour closures scheduling will be carried out in consultation with Port Authority of NSW, other divisions of Transport for NSW and other relevant stakeholders.	BL
CTT6	Construction	Construction traffic	Ongoing consultation, as relevant to the location, will be carried out with Greater Sydney Operations, the Port Authority of NSW, local councils, emergency services and bus operators to minimise traffic and transport impacts.	BL/GHF
CTT7	Construction	Construction traffic	The community will be notified in advance of proposed transport network changes, and maritime restrictions through appropriate media and other appropriate forms of community liaison.	BL/GHF
CTT8	Construction	Construction traffic	Construction road traffic will be managed to minimise impacts of movements during peak periods where feasible and reasonable.	BL/GHF
CTT9	Construction	Construction traffic	Vehicle movements to and from construction sites will be managed to ensure pedestrian, cyclist and road user safety. Depending on the location, this may require manual supervision, physical barriers, temporary traffic signals and modifications to existing signals or, on occasion, police presence.	BL/GHF
CTT10	Construction	Construction traffic	Directional signage, barriers and/or linemarking will be used as required to direct and guide motorists, cyclists and pedestrians past construction sites and on the surrounding network. This will be supplemented by Variable Message Signs to advise all road users of potential delays, traffic diversions, speed restrictions or alternative routes.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
CTT11	Construction	Construction traffic	Where provision of construction on-site parking cannot accommodate the full construction workforce, construction worker parking will be actively managed to minimise impacts on parking on local roads. Depending on the location, this will include encouraging the use of public transport and may include provision of shuttle buses for workforce transport where appropriate.	BL/GHF
CTT12	Construction	Construction traffic	Any adjustments to existing bus stops will be determined in consultation with relevant stakeholders including other divisions of Transport for NSW and advanced notification would be provided to affected bus customers. Relocations will be as close to their existing position where feasible and reasonable.	BL/GHF
CTT13	Construction	Construction traffic	Truck marshalling areas will be identified and used where feasible and reasonable, to minimise potential queueing and traffic and access disruptions in the vicinity of construction support sites.	BL/GHF
CTT14	Construction	Construction traffic	Activities requiring temporary partial road closures will be carried out outside of peak periods and/or during night time to minimise the impact of these activities on the road network where feasible and reasonable.	BL/GHF
CTT15	Construction	Construction traffic	Direct impacts to existing pedestrian and cycling facilities will be minimised where reasonable and feasible. Any detours and adjustments will be designed with consideration of user safety and convenience.	BL/GHF
CTT16	Construction	Maritime construction impacts	Consultation will be carried out with surrounding water based users of Middle Harbour including Mosman Rowing Club and Northbridge Sailing Club to minimise construction impacts.	BL

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 9

Operational traffic and transport

9 Operational traffic and transport

This chapter outlines the potential traffic and transport impacts arising from the operation of the Beaches Link and Gore Hill Freeway Connection and identifies measures which address these impacts. Potential construction traffic and transport impacts are discussed in Chapter 8 (Construction traffic and transport).

A detailed traffic and transport assessment has been carried out for the project and is included in Appendix F (Technical working paper: Traffic and transport).

The Secretary's environmental assessment requirements as they relate to operational traffic and transport, and where in the environmental impact statement these have been addressed, are detailed in Table 9-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to operational traffic and transport are included in Section 9.5.

Table 9-1 Secretary's environmental assessment requirements – operational traffic and transport

Secretary's environmental assessment requirements	Where addressed
2. The Proponent must assess and model the operational transport impacts of the project including, but not necessarily limited to: a. forecast travel demand and traffic volumes (expressed in terms of total numbers and heavy and light vehicle numbers) for the project and the surrounding road, cycle and public transport network, including potential shifts of traffic movements on alternate routes outside the proposal area (such as toll avoidance) and impact of permanent street closures directly attributable to the SSI;	Operational traffic and transport impacts for the project and surrounding network are discussed in **Section 9.4**. Further details on forecast traffic volumes and tolling scenarios and implications is provided in **Appendix F** (Technical working paper: Traffic and transport).
b. accessibility impacts in commercial centres within the vicinity of the project;	Accessibility impacts are discussed in **Chapter 21** (Socio-economics). Forecast 30-minute catchments by road for strategic centres in the vicinity of the project are provided in **Appendix F** (Technical working paper: Traffic and transport).
c. travel time analysis;	An assessment on impacts to travel time is provided in **Section 9.4**.
d. performance of key interchanges and intersections by undertaking a level of service analysis at key locations;	Interchange and intersection performance during operation is discussed in **Section 9.4**.

Secretary's environmental assessment requirements	Where addressed
e. wider transport interactions (local and regional roads, cycling, public and freight transport);	**Chapter 3** (Strategic context and project need) describes the relationship and/or integration of the project with existing and proposed public and freight transport services. **Section 9.1** outlines how the project considers specific transport strategies. **Section 9.4** provides an assessment of future traffic and transport interactions.
f. induced traffic and operational implications for existing and proposed public transport (particularly with respect to strategic bus corridors and bus routes and permanent closure/relocation of bus stops) and consideration of opportunities to improve public transport;	Implications and impacts on public transport are described in **Section 9.4**.
g. impacts on cyclists and pedestrian access and safety;	Impacts on pedestrians and cyclists, including access and safety, are described in **Section 9.4**.
h. property and business access and on street parking; and	Road network changes, operational impacts to parking, and access arrangements are described in **Section 9.4**. Impacts to properties and businesses are detailed in **Chapter 21** (Socio-economics).
i. an explanation for the scope of the modelled area, including justification of the nominated boundaries.	The assessment methodology is summarised in **Section 9.2** and outlined in detail in **Appendix F** (Technical working paper: Traffic and transport).

9.1 Strategic transport planning context

Details regarding the project's compatibility with key Australian Government and State strategic planning and transport policies are provided in Chapter 3 (Strategic context and project need).

A summary of more specific transport strategies relevant to the project are provided below.

9.1.1 North Sydney Integrated Transport Program

The *North Sydney Integrated Transport Program* (NSITP or the North Sydney Program) is a multi-agency collaboration between Transport for NSW, North Sydney Council, Greater Sydney Commission and Government Architect of NSW, to guide future integrated transport planning and investment in the North Sydney CBD and interconnected areas over the next 20 years and beyond. Led by Transport for NSW since 2018, it aims to deliver a shared place-based vision for the North Sydney CBD.

The North Sydney Program is being developed to support and facilitate the outcomes envisaged by the *Greater Sydney Region Plan* (Greater Sydney Commission, 2018a) and *Future Transport Strategy 2056* (NSW Government, 2018). The timing for deliverables in the North Sydney Program would be cognisant of the Western Harbour Tunnel and Beaches Link program of works delivery timeframes.

The North Sydney Program considers strategic public transport connections to the North Sydney CBD, land use and public domain objectives, improved pedestrian amenity and safety, road network changes, improved access for cyclists to and through the CBD, convenient interchanges between bus and rail services, management of kerbside access to support business activity across the day, and place outcomes within the CBD. As such, a key focus of the North Sydney Program is to ensure major projects, such as the Western Harbour Tunnel and Beaches Link program of works, integrate with the North Sydney CBD in a manner that supports the globally connected ‘Harbour CBD’ and enables delivery of befitting place-based outcomes.

The development of the North Sydney Program is ongoing, with validation of the vision for North Sydney currently underway with several scenarios being considered to support the place-based outcomes. As part of the collaboration, the multi-agency group will ensure the future integrated transport network and place-based vision for North Sydney is supported through projects such as the Beaches Link and Gore Hill Freeway Connection project. Further refinements to movement and place outcomes within the North Sydney CBD may occur as part of the North Sydney Program.

To minimise the impact of the Western Harbour Tunnel and Beaches Link program of works on the North Sydney CBD, planning and design to date has been developed to:

- Continue to provide motorway access only via existing major road corridors
- Focus on the utilisation of existing road space to maintain network efficiency and balance the needs of all road users while minimising road widenings
- Ensure operational impacts are minimised (and critical performance issues avoided), by spreading the demand generated by new infrastructure across multiple locations
- Provide network efficiencies and safer outcomes by simplifying network operations, prioritising strategic movements, and minimising conflicts
- Adopt ‘movement and place’ principles to help reprioritise access and support efficient connections for traffic, pedestrians, and other transport customers.

The proposed network integration works would result in a resilient network that can accommodate key road transport customers, while at the same time promoting walking, cycling and public transport access to and within the North Sydney CBD. In the event that road transport demand is lower or demands otherwise differ as land use and transport developments mature, this approach would also provide flexibility to adjust the future transport network in response to customer needs.

Transport for NSW will continue to work with North Sydney Council and key stakeholders through agreed governance structures to investigate options to improve movement and place outcomes though the North Sydney Program, further leveraging the strategic benefits of the Western Harbour Tunnel and Beaches Link program of works.

9.1.2 Northern Beaches Hospital Precinct Structure Plan

The *Northern Beaches Hospital Precinct Structure Plan* (Northern Beaches Council, 2017b) defines the desired future land uses and consequent multi-modal transport operation and infrastructure requirements to, from and through Frenchs Forest. The plan also acknowledges that a suite of regional transport network upgrades including both public transport and road upgrades would be required to maintain effective transport connections to, from and through Frenchs Forest in the medium to long term.

The project would support the implementation of the plan through supporting medium to long term growth in the area (including a proposed 5360 new dwellings in the next 20 years) by providing a new, safe high-speed road link between the precinct and broader metropolitan Sydney and removing North Sydney and Sydney CBD bound traffic from Warringah Road, thereby improving connectivity and accessibility surrounding the Northern Beaches Hospital. Further details are provided in Section 9.4.6.

9.1.3 Sydney's Bus Future

Sydney's Bus Future (Transport for NSW, 2013a) presents a three-stage approach to improve service outcomes, focusing on improving customer experience, integrating bus services across Sydney and serving future growth. Bus initiatives include the bus rapid transit services for the Northern Beaches (eg Northern Beaches B-Line) to improve capacity and efficiency for bus users.

By reducing network congestion, improving network resilience and increasing reliability in peak periods, the project would make buses a more attractive transport option, supporting and encouraging a mode shift to public transport. The project would also allow new public transport routes to be developed in response to diverse travel demands and future social and economic development, as express buses would be permitted to use the tunnel. The project provides the opportunity to supplement existing services with the opportunity for express buses to use the Beaches Link tunnel to North Sydney, St Leonards and Sydney CBD, as well as to the north-west to employment areas like Macquarie Park via Gore Hill Freeway and Lane Cove Tunnel. There would also be the opportunity for express bus services using the project to interchange with Sydney Trains and the new Sydney Metro at North Sydney and Crows Nest.

The Northern Beaches B-Line began operation in 2017 which provides frequent and more reliable services between the Northern Beaches and Sydney CBD. The project would support the continued operation of the B-Line program along with other existing and proposed bus services by improving travel times and reliability on key routes connecting the Northern Beaches to key centres including Spit Road/Military Road and Warringah Road/Eastern Valley Way.

The reduced vehicle congestion on Warringah Road between Frenchs Forest and Roseville would support the possible implementation of a proposed rapid bus service, similar in nature to the existing B-Line, between Dee Why and Chatswood.

9.1.4 Sydney's Cycling Future

Sydney's Cycling Future (Transport for NSW, 2013b) identifies priority cycleways to improve connection to major centres for trips of up to five kilometres. The strategy also includes walking and cycling projects linking to public transport interchanges and stops. Sydney's Cycling future is identified in the *Future Transport Strategy 2056* (NSW Government, 2018), outlining initiatives such as secure bike storage to increase active transport.

The project would provide a new shared user path along Wakehurst Parkway between Seaforth/North Balgowlah and the developing Northern Beaches Hospital Precinct, improving connectivity to the new strategic centre.

The project would also result in reduced congestion on surface roads, which would contribute to improved conditions for cyclists.

9.1.5 Sydney's Walking Future

Sydney's Walking Future (Transport for NSW, 2013c) is the NSW Government's long-term plan to promote walking as a transport mode throughout Sydney and an integral component in the planning of urban growth precincts and new transport infrastructure. The project would support the objectives of *Sydney's Walking Future* by providing improved pedestrian infrastructure along the Wakehurst Parkway along with new and realigned shared user paths within the proposed new and improved open space and recreation facilities at Balgowlah. Amenity improvements resulting from reduced vehicle congestion would also improve the attractiveness of walking as a transport mode.

9.1.6 Transport for NSW Walking and Cycling Program

The *Walking and Cycling Program 2020-2021* (Transport for NSW, 2019a) supports the walking and cycling outcomes set out in the *Future Transport Strategy 2056* (NSW Government, 2018). The key objectives of the 2020/21 Walking and Cycling Program are to:

- Ensure walking and cycling are the most convenient option for short trips to key destinations and within centres
- Reduce congestion on our roads and public transport networks by delivering projects that encourage walking and cycling mode shift
- Enable efficient, safe and reliable journey times by prioritising infrastructure that supports pedestrian or cycling movement on certain corridors, consistent with the Movement and Place Framework
- Deliver projects that make walking and cycling safe, comfortable and convenient transport modes that are accessible to a wide range of users
- Enable positive health, wellbeing, social and environmental outcomes.

Under the Walking and Cycling Program, key stakeholders can apply for funding for active transport projects. The proposed scope of the project would complement other active transport planning being carried out as part of this program.

9.2 Assessment methodology

9.2.1 Overview

The assessment methodology of operational traffic and transport impacts considered four core components:

- Road traffic
- Public transport
- Pedestrian and cyclists (active transport)
- Maritime traffic.

The method and outputs of assessment for each of these components are summarised in Table 9-2.

Table 9-2 Overview of approach to the operational traffic and transport assessment

Project impacts	Method of assessment	Assessment output
Road traffic	Analysis of road network performance based on strategic traffic forecasting and operational traffic modelling.	Quantitative assessment of road network performance with and without the project.
Local roads and parking	Analysis of changes to local road access arrangements, loss of parking spaces and availability of comparable alternative parking in nearby locations. The analysis considers permanent impacts. Temporary impacts (ie during construction) are considered in Chapter 8 (Construction traffic and transport).	Qualitative assessment of local road changes. Estimate of number of lost parking spaces. Qualitative assessment of the impact of parking overflow to parking in nearby locations.

Project impacts	Method of assessment	Assessment output
Public transport	Analysis of service accessibility (rail and road public transport modes) and service timeliness and efficiency (road public transport mode) based on operational traffic modelling.	Qualitative assessment of service accessibility and semi-quantitative assessment of service timeliness and efficiency (increase or decrease in number of stops or change in stop coverage).
Pedestrians and cyclists (active transport)	Analysis of pedestrian and cycle demands and changes to shared user paths and other pedestrian and cycle facilities.	Semi-quantitative assessment of impacts on pedestrian and cycling networks and accessibility.
Maritime traffic	Analysis of changes in water depths in Middle Harbour with the immersed tube tunnels in place and the potential impact on maritime traffic.	Qualitative assessment of impacts on future waterway navigation and commercial and recreational usage.

9.2.2 Road traffic assessment methodology

The potential impacts of the project on road network performance were assessed through strategic traffic forecasting and operational traffic modelling. The assessment included both regional and local scale modelling which enabled existing and future traffic and transport conditions, and road network performance to be characterised, both with and without the project. An overview of the modelling methodology used in the assessment of the project is provided in Figure 9-1, with further details provided in Appendix F (Technical working: Traffic and transport).

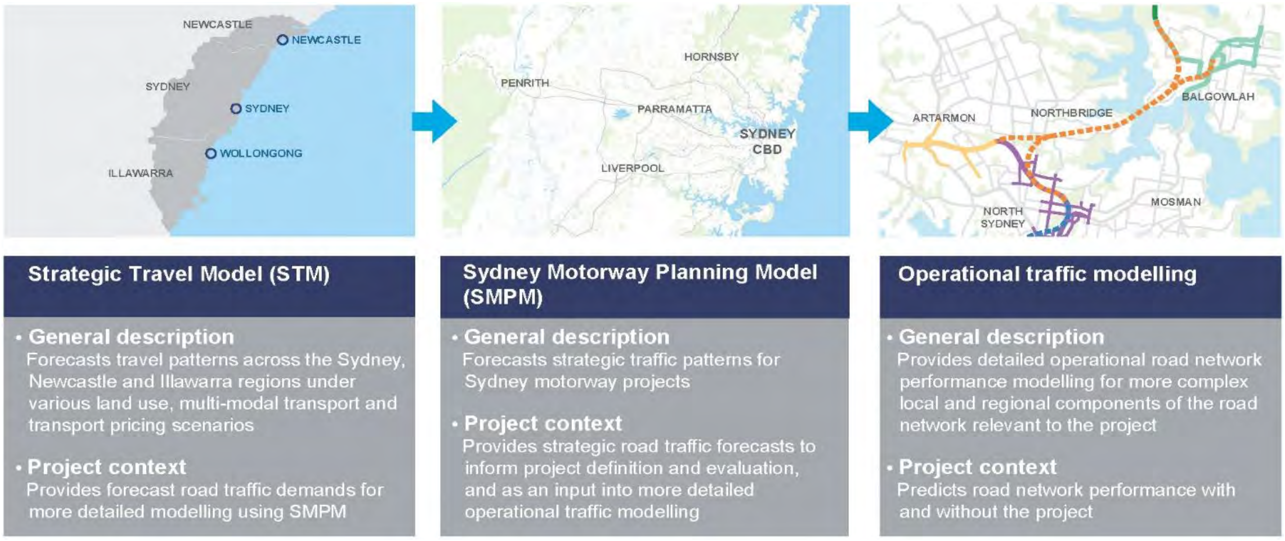


Figure 9-1 Overview of transport modelling approach

Operational traffic modelling scenarios

Future year networks and traffic demand were developed for 2027 (planned year of opening) and 2037 (year of planned opening plus 10 years) to assess the future performance of the project. Future performance was assessed for the AM peak (7am to 9am on a normal working weekday) and PM peak (4pm to 6pm on a normal working weekday) for the following model scenarios:

- Without the project ('Do minimum')
- With the project ('Do something')
- With the project and other planned or proposed projects ('Do something cumulative').

The ‘Do something’ scenario included the Warringah Freeway Upgrade component of the proposed Western Harbour Tunnel and Warringah Freeway Upgrade project, on the basis that the project requires this to function. The modelled operational scenarios are summarised in Table 9-3.

Table 9-3 Operational road traffic modelling scenarios

Scenario	Description	2016	2027	2037
‘Base year’	Developed for calibration purposes and quantification of existing network performance	✓		
‘Do minimum’[1]	Includes approved, under construction and/or recently opened 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 Motorway (Stage 1) projects. Also reflects operational effects of approved, under construction and/or recently completed major projects (eg Sydney Metro City & Southwest and Northern Beaches Hospital road upgrade project).		✓	✓
‘Do something’[1]	Includes NorthConnex, WestConnex, Beaches Link and Gore Hill Freeway Connection and Warringah Freeway Upgrade projects but without Western Harbour Tunnel, Sydney Gateway and M6 Motorway (Stage 1) projects. Also includes Sydney Metro City & Southwest and Northern Beaches Hospital road upgrade project.		✓	✓
‘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 [2, 3] projects. Also includes Sydney Metro City & Southwest and Northern Beaches Hospital road upgrade project.		✓	✓

Note 1: The M6 Motorway (Stage 1) and Sydney Gateway projects were not included in the ‘Do minimum’ or ‘Do something’ scenarios as they were not approved projects at the time the modelling and analysis assumptions were confirmed. Since the confirmation of these assumptions for this assessment, the M6 Motorway (Stage 1) and Sydney Gateway projects have been approved. Sensitivity testing has shown that these projects would not have a material impact on the Beaches Link and Gore Hill Freeway Connection project ‘Do minimum’ or ‘Do something’ traffic assessments; they are included in the ‘Do something cumulative’ traffic assessment.
Note 2: M6 Motorway (Stage 1) is considered as part of the 2027 ‘Do something – cumulative’ scenario
Note 3: M6 Motorway (full project) is considered as part of the 2037 ‘Do something – cumulative’ scenario

The 2016 baseline year represents transport network conditions at the time of the traffic and transport assessment. Ongoing and continuous traffic surveys carried out by Transport for NSW indicate that the 2016 baseline year is appropriate for modelling purposes as there is little material difference between 2016 and existing (2020) traffic conditions in the project area.

As outlined in Figure 9-1, the Sydney Motorway Planning Model (SMPM) forecasts strategic traffic patterns for Sydney motorway projects and was used in this assessment. The SMPM is a network-wide model that includes recently completed and future infrastructure projects, and population and employment growth forecasts provided by the Transport for NSW Transport Performance and Analytics division, consistent with demographics released by NSW Department of Planning, Industry and Environment. The project traffic and transport assessment therefore took into consideration planned population and employment demand and growth throughout Sydney over the next 20 years. The SMPM also took into account change in traffic associated with project-related induced demand (new trips), which equates to about 0.3 per cent of additional daily trips in the Sydney metropolitan area in 2037.

A tunnel model for the project was used to assess the future year performance of the proposed road layout within the tunnelled carriageways, including merge and diverge locations and the impact of grades. Four surface interface model areas (Warringah Freeway and surrounds, Gore Hill Freeway and Artarmon, Balgowlah and surrounds, and Frenchs Forest and surrounds) were used to assess 2027 and 2037 road network performance, both with and without the project.

Figure 9-2 shows the operational road traffic model areas for the Western Harbour Tunnel and Beaches Link program of works. All operational road traffic model areas except for the Western Harbour Tunnel, and Rozelle and surrounds (relevant for the Western Harbour Tunnel and Warringah Freeway Upgrade project) were subject to assessment for this project. Cumulative assessment of potential impacts related to operational traffic and transport includes the consideration of potential impacts resulting from the Western Harbour Tunnel and Warringah Freeway Upgrade project.

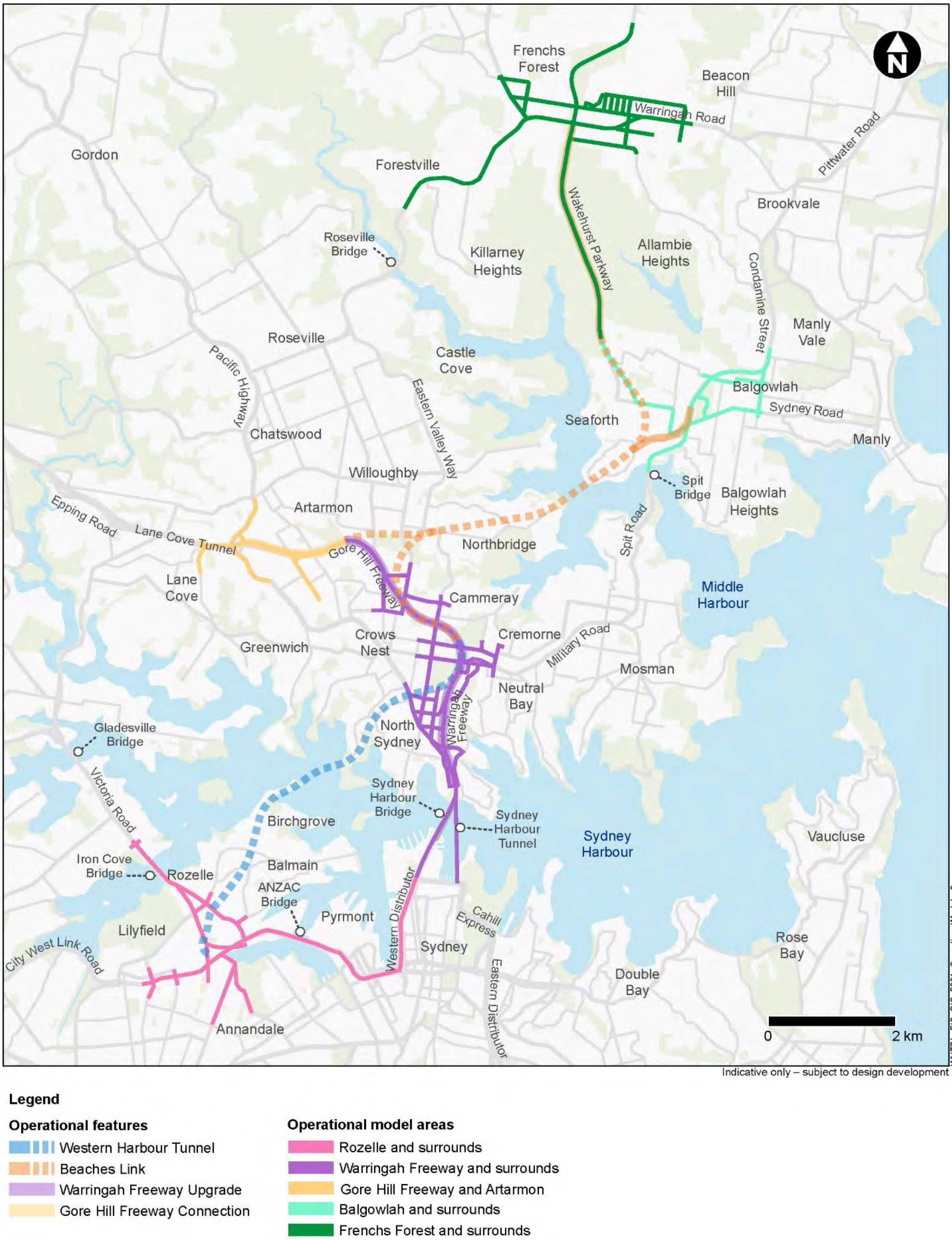


Figure 9-2 Operational road traffic model areas

9.2.3 Assessment criteria

The criteria used to assess road network performance were as follows:

- At a network level – traffic demand, average speed, number of stops (the number of times vehicles within the road network are required to stop during peak periods) and general travel times
- At an intersection level – level of service (LoS) and average delay (expressed in seconds per vehicle).

The assessment criteria for network performance and intersection and midblock level of service is described in detail in Chapter 8 (Construction traffic and transport) and Appendix F (Technical working paper: Traffic and transport).

9.3 Existing environment

The existing traffic and transport environment for the project is described in Chapter 8 (Construction traffic and transport). The existing environment is described within the context of the broader strategic transport network, along with more detailed analysis across of the following local areas:

- Warringah Freeway and surrounds
- Gore Hill Freeway and Artarmon
- Northbridge to Seaforth (Middle Harbour crossing)
- Balgowlah and surrounds
- Frenchs Forest and surrounds.

9.4 Assessment of potential impacts

The operational traffic and transport impacts of the project are outlined below in the context of the broader road network, along with detailed analysis of local area impacts. Impacts are assessed for future year scenarios with the project ('Do something') compared to the scenario without the project ('Do minimum'), as well as the cumulative future year scenario with the addition of the Western Harbour Tunnel and other planned, proposed and recently opened transport projects ('Do something cumulative') as described in Section 9.2.2.

9.4.1 Broader road network

Road network performance

'Do something' scenario

The project is forecast to reduce traffic demands on the existing arterial roads into and out of the Northern Beaches peninsula, with the largest reductions in traffic demand being on the Spit Road and Military Road corridor. In general, users of existing connections to the Northern Beaches peninsula, including Eastern Valley Way and the Spit Road and Military Road corridor, would benefit from reduced congestion and improved road safety, as a result of the project lowering daily traffic demand on existing routes by introducing a new, higher standard of road as an alternative (the project). This is reflected in the forecast travel times for key trips across the network in the AM peak and PM peak, as shown in Figure 9-3 and Figure 9-4.

Overall modelled traffic demand across Middle Harbour with the project in 2037 indicate that:

- Peak period traffic demand on Spit Road and Warringah Road would decrease substantially as a result of the project, by up to 33 per cent and 23 per cent, respectively

- Peak period traffic demand on Mona Vale Road would decrease by up to eight per cent as a result of the project
- Daily traffic demand on Eastern Valley Way would decrease by up to 30 per cent as a result of the project
- Daily traffic demand on Brook Street (north of Merrenburn Avenue) would decrease by up to four per cent (increasing to up to 14 per cent in the 'Do something cumulative' scenario).

It is noted that through changing trip patterns and reduced demand on some routes, the project would provide the opportunity for Transport for NSW network management teams and other stakeholders to investigate further opportunities for local road improvements and adjustments.

The project supports the strategic vision presented in the *Future Transport Strategy 2056* (NSW Government, 2018) for the road network for Greater Sydney by supporting key movements by road for public transport, private vehicles and freight. The reduction in private vehicle travel times would also be reflected in reduced travel times for buses and would increase the size of equivalent public transport catchments, which could be further extended by express buses potentially operating through the Beaches Link tunnel.

Analysis of the 30-minute catchments for the 'Do something' scenarios show that overall the project would substantially increase accessibility from the Northern Beaches to nearby strategic centres, including Chatswood, St Leonards, Macquarie Park and North Sydney. However, the project on its own would not substantially increase the extent of the 30-minute catchments around strategic centres south of Sydney Harbour (but would do so as part of a complementary multi-modal transport strategy including rail, bus, and road projects being delivered by the NSW Government). The Gore Hill Freeway Connection component of the project would facilitate additional traffic travelling through the corridor. This change would represent increased connectivity and capacity in the network, although travel times and speeds (ie the rate of travel) are not expected to improve in this area.

The project would substantially change the volume of traffic travelling on arterial roads in the Greater Sydney Region. Due to the increased accessibility provided by the project, the project would result in an overall increase in traffic demand into and out of the Northern Beaches peninsula. However, trips through the Beaches Link tunnel would be made on a higher standard of road compared to other urban arterial roads. This would have an impact on the number of crashes on the arterial road network, with crashes across the network estimated to reduce by up to 562 incidents per year as a result of the project. A summary of forecast growth at key locations for the 2027 and 2037 is provided in Table 9-4.

'Do something cumulative' scenario

The project when combined with the Western Harbour Tunnel and Warringah Freeway Upgrade project would not result in substantially more traffic travelling into and out of the Northern Beaches peninsula. Under the 'Do something cumulative' scenario demand on Warringah Road, Spit Road/Military Road corridor, Brook Street, and Eastern Valley Way would be further reduced, with more of this traffic travelling via the Beaches Link tunnel. The forecast travel times shown in Figure 9-3 and Figure 9-4 indicate travel times along key routes near the project would be reduced under the 'Do something cumulative' scenario when compared to the 'Do something' scenario, as vehicles travelling south would have the additional option of using the Western Harbour Tunnel.

Overall, the 'Do something cumulative' scenario would increase the accessibility between Manly and the Sydney CBD (and beyond) due to the improved capacity and connectivity across Sydney Harbour provided by the Western Harbour Tunnel, but have limited impact on other centres (compared to the 'Do something' scenario). The 'Do something cumulative' scenario would substantially reduce travel times for private vehicles between the Northern Beaches and destinations south of Sydney Harbour, linking people with jobs, education and services. There would be a similar benefit to bus travel times and a resulting increase in the size of equivalent public transport catchments.

Table 9-4 Modelled daily traffic demands at key locations

Road	Location	Direction	'Do minimum 2027'	'Do something 2027'	'Do something cumulative 2027'	'Do minimum 2037'	'Do something 2037'	'Do something cumulative 2037'
Spit Road	Spit Bridge	Combined	74,500	48,500	46,500	80,000	52,000	49,500
Warringah Road	Roseville Bridge	Combined	83,000	62,000	61,500	87,000	66,000	65,500
Mona Vale Road	St Ives Showground	Combined	59,500	54,500	53,000	62,500	56,500	55,500
Beaches Link tunnel	Killarney Heights	Combined	N/A	58,000	64,000	N/A	64,500	71,500
Eastern Valley Way	Castle Cove	Combined	33,000	21,000	20,000	35,500	25,000	25,500
Brook Street	Naremburn (north of Merreburn Avenue)	Combined	35,500	33,500	29,000	37,500	36,000	32,500

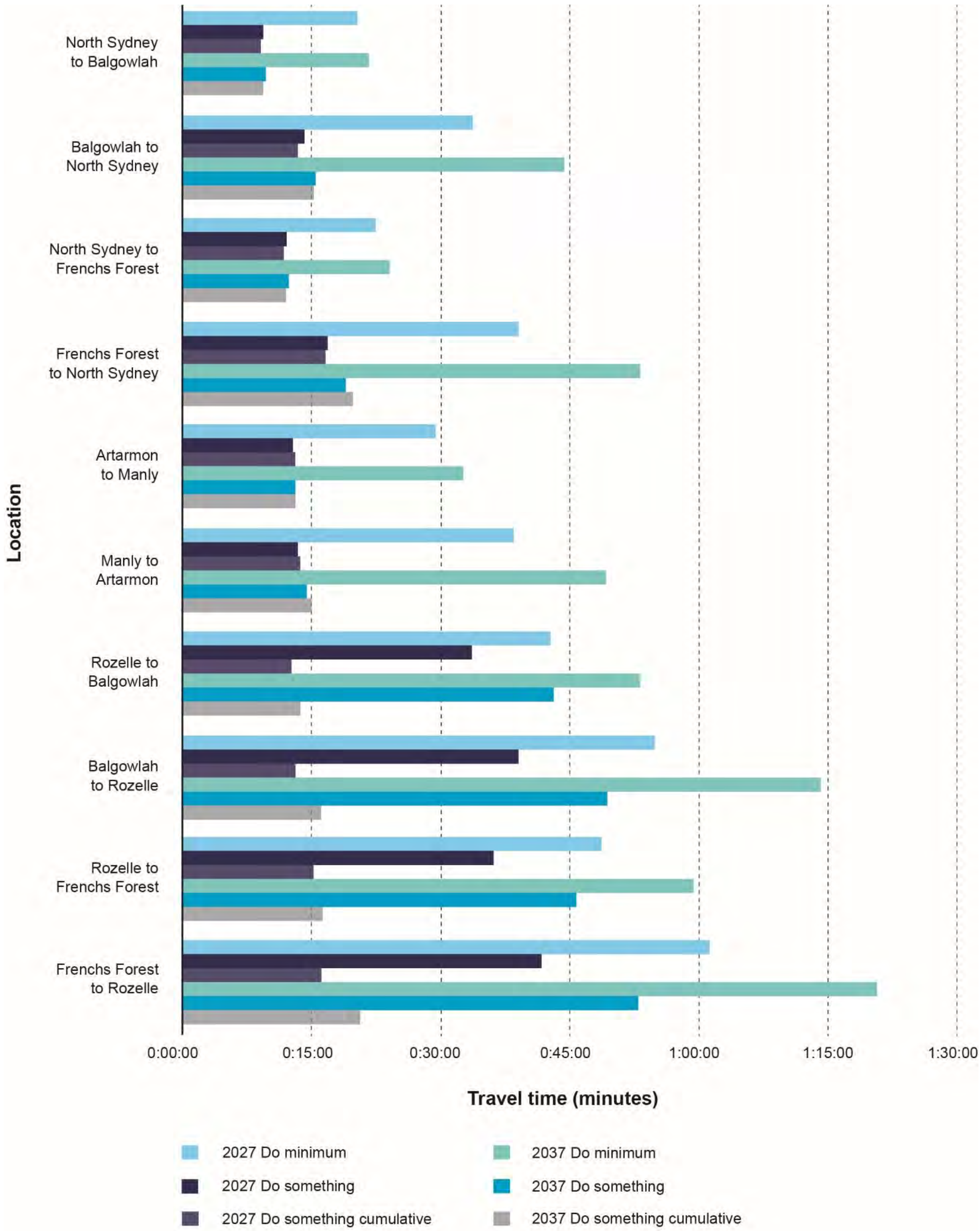


Figure 9-3 Forecast AM peak period (8am-9am) travel times along key road network corridors

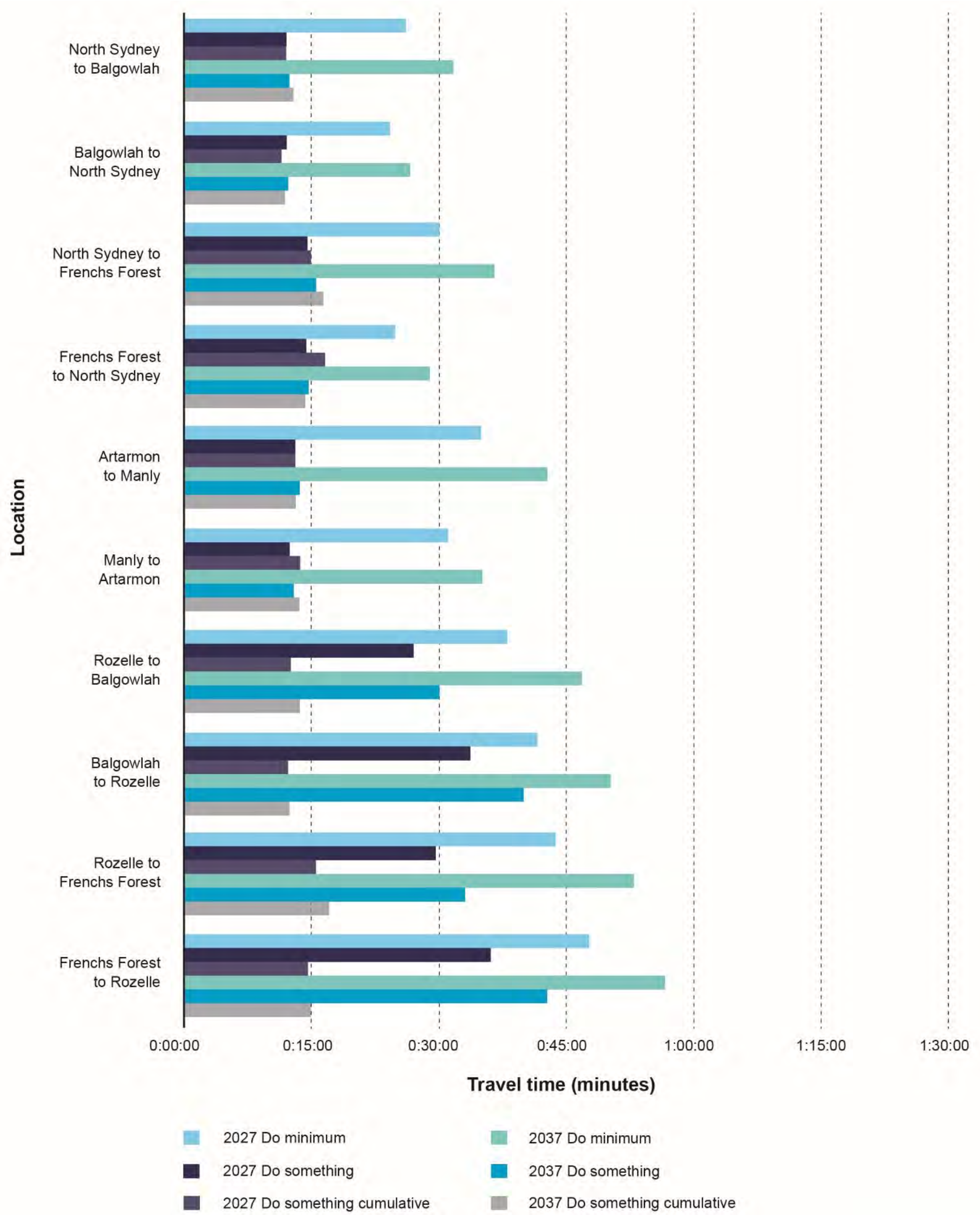


Figure 9-4 Forecast PM peak period (5pm-6pm) travel times along key road network corridors

Heavy vehicles and freight

As outlined in Chapter 8 (Construction traffic and transport), the largest portion of truck movements into and out of the Northern Beaches peninsula in 2016 occurred via Mona Vale Road, likely due to lower congestion and its proximity to the M1 Pacific Motorway and industrial areas in Mona Vale, Warriewood, Belrose and Terrey Hills. Conversely, Spit Road and Military Road carried lower volumes of heavy vehicles due to access restrictions for large articulated trucks and persistent congestion on this route.

The project would result in most heavy vehicle trips on the existing arterial road network to and from the Northern Beaches peninsula transferring to the project, with the largest proportional reductions in traffic volumes being on Spit Road/Military Road corridor. Analysis of the modelled forecast heavy vehicle demands crossing Middle Harbour under the 'Do something' scenario shows:

- Peak period heavy vehicle demand on Spit Road/Military Road corridor and Warringah Road would decrease substantially as a result of the project, by up to 74 per cent and 62 per cent, respectively
- Peak period heavy vehicle demand on Mona Vale Road would decrease by up to 35 per cent as a result of the project
- Peak period of heavy vehicle demand into and out of the Northern Beaches would not change substantially as a result of the project.

While the project would not generally change the heavy vehicle demand travelling into and out of the Northern Beaches peninsula, it would substantially reduce the travel times of these freight trips and increase their productivity. The movement of heavy vehicle trips from surface arterial roads to the motorway tunnels would increase the amenity of the existing arterial road network to and from the Northern Beaches peninsula. This movement would also reduce interactions between general traffic, heavy vehicles, public transport vehicles, pedestrians and cyclists. This reduced interaction would improve road safety and reduce the severity of crashes on the arterial road network.

9.4.2 Warringah Freeway and surrounds

Road network performance

'Do something' scenario

Key outcomes of the modelled future road network performance in the Warringah Freeway and surrounds area under the 'Do something' scenario include:

- Peak period travel demand is forecast to increase by up to two per cent by 2037
- Average travel speeds through the Warringah Freeway and surrounds area would decrease by up to six per cent in the AM peak, but increase by up to 23 per cent in the PM peak
- The number of stops during peak periods is forecast to increase in the AM peak by up to 29 per cent, indicating that the additional demand facilitated by the project could increase localised delays. This is due to the transfer of traffic from existing surface roads to the project, which would increase the rate of demand on the Sydney Harbour Bridge and Sydney Harbour Tunnel. In the absence of the capacity and connectivity upgrades provided by the Western Harbour Tunnel under the 'Do something cumulative' scenario, this increase in demand would increase delays on the existing harbour crossings, with upstream effects on adjacent network connections
- In the PM peak the project would provide additional capacity for outbound traffic crossing Sydney Harbour and leaving the Lower North Shore, relieving existing corridors including Military Road and Eastern Valley Way. As a result, there would be substantial improvements in terms of average network speed and number of stops.

'Do something cumulative' scenario

The introduction of the Western Harbour Tunnel would generally result in improved network performance in the Warringah Freeway and surrounds area when compared with the 'Do something' scenario. Key outcomes of the modelled road network performance in the Warringah Freeway and surrounds area, under the 'Do something cumulative' scenario (compared with the 'Do something' scenario) includes:

- Peak period travel demand through the Warringah Freeway and surrounds area would increase by up to 15 per cent by 2037 as a result of the introduction of the Western Harbour Tunnel
- The project would result in a greater portion of forecast demand being able to travel during the AM peak
- Average travel speeds through the Warringah Freeway and surrounds area would improve by up to 30 per cent as a result of the introduction of the Western Harbour Tunnel
- The number of stops during peak periods would substantially decrease as a result of the introduction of the Western Harbour Tunnel, particularly in the AM peak.

Overall, the Western Harbour Tunnel and Beaches Link program of works would improve network capacity and connectivity across Sydney Harbour. It would reduce demand and delays on Sydney Harbour Bridge and Sydney Harbour Tunnel and improve network performance throughout the Warringah Freeway and surrounds area during peak periods.

Traffic travel times

'Do something' scenario

Modelled travel times during AM and PM peaks for key routes through the Warringah Freeway and surrounds area are presented in Table 9-5.

The modelled travel times under the 'Do something' scenario show:

- AM peak travel times from the Warringah Freeway to the Cahill Expressway would increase as a result of the project due to increased inbound demand on the Sydney Harbour Bridge and Sydney Harbour Tunnel. In the absence of the capacity and connectivity upgrades provided by the Western Harbour Tunnel, this increase in demand would increase delays on the existing harbour crossings and upstream motorway corridor
- PM peak travel times for the majority of routes along the Warringah Freeway would remain similar or improve as a result of the project, due to the additional outbound capacity and simplification of weaving and merging arrangements provided as part of the Warringah Freeway Upgrade.

'Do something cumulative' scenario

The introduction of the Western Harbour Tunnel would generally result in improved travel times when compared to the 'Do something' scenario. Analysis of modelled travel times for routes through the Warringah Freeway and surrounds area under the 'Do something cumulative' scenario (refer to Table 9-5) predicts:

- Travel times along Warringah Freeway would generally improve due to the transfer of trips to Western Harbour Tunnel, with some of this traffic travelling directly between Beaches Link and Western Harbour Tunnel. This would relieve capacity constraints on the Warringah Freeway, Sydney Harbour Bridge, and Sydney Harbour Tunnel both northbound and southbound
- Localised increases in travel times for local trips within North Sydney such as the Miller Street corridor, as a result of changes to traffic patterns and access arrangements to, from and within North Sydney.

Table 9-5 Modelled AM peak (8am–9am) and PM peak (5pm–6pm) traffic travel times for key routes through the Warringah Freeway and surrounds area

Route/ Peak period	Direction	'Do minimum 2027'	'Do something 2027'	'Do something cumulative 2027'	'Do minimum 2037'	'Do something 2037'	'Do something cumulative 2037'
Sydney Harbour Bridge to Warringah Freeway/Falcon Street interchange							
AM peak	Northbound	04:40	05:47	03:33	04:51	04:56	04:12
	Southbound	04:03	04:06	04:07	04:02	04:13	04:06
PM peak	Northbound	04:02	03:26	03:25	07:51	04:51	03:28
	Southbound	06:09	04:44	04:37	05:02	04:41	04:33
Sydney Harbour Tunnel to Warringah Freeway/Falcon Street interchange							
AM peak	Northbound	03:55	11:50	03:31	04:08	12:07	04:27
	Southbound	04:03	04:17	04:27	04:02	04:18	04:26
PM peak	Northbound	03:57	03:22	03:24	07:36	03:25	03:31
	Southbound	14:54	05:52	05:28	14:59	07:41	05:35
Sydney Harbour Bridge to Gore Hill Freeway/Pacific Highway interchange							
AM peak	Northbound	06:13	07:41	05:26	06:16	06:45	05:29
	Southbound	13:35	13:29	08:02	15:22	13:46	07:54
PM peak	Northbound	05:35	05:26	05:21	06:45	06:53	05:24
	Southbound	13:56	06:18	06:10	17:31	07:28	06:10
Sydney Harbour Tunnel to Gore Hill Freeway/Pacific Highway interchange							
AM peak	Northbound	05:26	16:21	05:18	05:30	17:03	05:23
	Southbound	11:39	11:20	07:59	12:37	11:30	08:08
PM peak	Northbound	05:28	05:17	05:12	06:46	05:22	05:14
	Southbound	25:21	07:23	07:00	30:09	13:50	07:07
Berry Street to Amherst Street via Miller Street							
AM peak	Northbound	03:42	03:56	04:06	03:53	04:07	04:03
	Southbound	04:25	04:04	06:01	05:43	04:05	07:01
PM peak	Northbound	03:52	04:39	04:46	03:50	01:22	05:14
	Southbound	05:01	05:30	04:35	08:39	05:01	05:37

Intersection performance

'Do something' scenario

Modelled intersection performance for key intersections in the Warringah Freeway and surrounds area under the 'Do something' scenario is presented in Table 9-6 and indicates:

- Average delays around some local intersections along Berry Street and Pacific Highway could increase by around 30 to 40 seconds from additional traffic using these intersections as a result of the project
- Intersection performance along Brook Street near the Warringah Freeway would improve substantially during the AM peak as a result of the project. This is due to the changes in access to Brook Street from the Warringah Freeway, which under the Warringah Freeway Upgrade would be limited to trips from the Sydney Harbour Bridge and Berry Street. In the PM peak, localised congestion on the Warringah Freeway may continue to impact the efficiency of this interchange
- Intersections along the Pacific Highway would experience increased delays at some locations in the AM peak as a result of the project. This is due to the changes to traffic patterns and access arrangements to, from and within North Sydney as a result of the Warringah Freeway Upgrade
- The intersection of Ben Boyd Road and Military Road has the potential to experience longer delays as a result of the Warringah Freeway Upgrade project, due to the reconfiguration of Warringah Freeway, which would change the accessibility of the Ernest Street ramps to and from the Warringah Freeway. Traffic that currently uses the Ourimbah Road corridor as an alternative to Military Road would no longer be able to access all the same destinations that are currently accessible from Ernest Street.

Although the project would generally improve network performance for roads within and around North Sydney, it would not resolve existing localised performance issues at several intersections. The proposed road integration works and resulting improved traffic performance in the North Sydney area have been developed in the context of the growing North Sydney CBD environment.

While there would be some localised delays at some intersections at peak times, this would be offset by the substantial travel time benefits provided by the project at the broader network level.

The project seeks to maintain an appropriate level of traffic movement within the Warringah Freeway and surrounds area while also preserving capacity and connectivity for other customers whose needs conflict with traffic, particularly pedestrians.

Options to further improve traffic performance at intersections throughout the area have been investigated. However, these alternative options would result in further impacts on other customers. The proposed works are therefore considered to provide an equitable and balanced outcome from the perspective of maintaining a balanced and integrated transport network through North Sydney.

Further refinements to movement and place outcomes within the North Sydney CBD may occur as part of works associated with the North Sydney Program, an ongoing multi-agency collaboration between Transport for NSW, North Sydney Council, Greater Sydney Commission and the Government Architect of NSW to guide future integrated transport planning and investment in the North Sydney CBD and interconnected areas (see Section 9.1.1 for more information).

‘Do something cumulative’ scenario

The introduction of the Western Harbour Tunnel would generally result in improved intersection performance when compared to the ‘Do something’ scenario. Modelled intersection performance under the ‘Do something cumulative’ scenario is presented in Table 9-6. Overall:

- Most intersections would perform similarly to the ‘Do something’ scenario
- Some intersections on the Pacific Highway, Walker Street, Miller Street and Berry Street could experience increased localised delays with the introduction of the Western Harbour Tunnel due to increased demand and changes to local traffic patterns
- Intersections along the Falcon Street and Military Road corridor would generally perform marginally better with the introduction of the Western Harbour Tunnel, as trips from the Pittwater Road corridor bypassing the Sydney CBD would avoid Spit Road/Military Road and use the direct connection from the project to Western Harbour Tunnel.

Although some traffic would be impacted by an increase in localised intersection delays, road users would generally benefit from substantial overall travel time savings on the broader network (eg via the Beaches Link and Gore Hill Freeway Connection project, Western Harbour Tunnel, ANZAC Bridge, and Sydney Harbour Bridge). Traffic impacted at individual intersections in the North Sydney area is therefore still anticipated to receive a substantial net benefit due to the broader connectivity and efficiency improvements.

As discussed above, further refinements to movement and place outcomes within the North Sydney CBD may occur as part of works associated with the North Sydney Program.

Table 9-6 Modelled intersection performance on the Warringah Freeway and surrounds area (AM peak (8am–9am) and PM peak (5pm–6pm) during operation in 2027 and 2037)

Intersection/ peak period	‘Do minimum 2027’ – LoS (average delay in seconds)	‘Do something 2027’ – LoS (average delay in seconds)	‘Do something cumulative 2027’ – LoS (average delay in seconds)	‘Do minimum 2037’ – LoS (average delay in seconds)	‘Do something 2037’ – LoS (average delay in seconds)	‘Do something cumulative 2037’ – LoS (average delay in seconds)
Willoughby Road/Gore Hill Freeway interchange						
AM peak	F (>100)	B (27)	A (9)	F (>100)	B (21)	A (10)
PM peak	C (38)	A (10)	A (11)	F (76)	A (10)	A (11)
Brook Street/Warringah Freeway on ramp						
AM peak	F (>100)	A (13)	A (8)	F (>100)	E (70)	E (64)
PM peak	B (14)	A (9)	A (<5)	B (17)	F (92)	B (25)
Brook Street/Warringah Freeway off ramp						
AM peak	E (61)	B (21)	A (9)	E (67)	A (9)	B (16)
PM peak	B (22)	B (17)	B (17)	B (20)	F (87)	C (29)
Brook Street/Merrenburn Avenue						
AM peak	F (>100)	C (31)	B (26)	F (>100)	E (70)	D (50)
PM peak	A (11)	D (53)	B (17)	A (13)	E (59)	C (39)

Intersection/ peak period	'Do minimum 2027' – LoS (average delay in seconds)	'Do something 2027' – LoS (average delay in seconds)	'Do something cumulative 2027' – LoS (average delay in seconds)	'Do minimum 2037' – LoS (average delay in seconds)	'Do something 2037' – LoS (average delay in seconds)	'Do something cumulative 2037' – LoS (average delay in seconds)
Amherst Street/West Street						
AM peak	A (5)	A (7)	D (50)	A (5)	F (>100)	F (>100)
PM peak	A (9)	F (89)	D (43)	A (14)	F (>100)	F (73)
Amherst Street/Miller Street						
AM peak	B (21)	C (38)	C (42)	B (20)	E (58)	D (44)
PM peak	C (29)	D (47)	D (43)	C (31)	D (52)	D (48)
Miller Street/Warringah Freeway on ramp						
AM peak	A (7)	A (<5)	A (<5)	A (6)	A (<5)	A (5)
PM peak	A (6)	A (6)	A (6)	A (6)	A (6)	A (7)
Miller Street/Warringah Freeway off ramp						
AM peak	A (12)	A (5)	A (8)	A (13)	A (5)	A (8)
PM peak	B (15)	A (9)	A (7)	B (15)	A (9)	A (8)
Miller Street/Ernest Street						
AM peak	B (25)	D (44)	C (42)	C (32)	C (40)	C (41)
PM peak	C (41)	C (36)	C (34)	D (43)	C (35)	C (39)
Miller Street/Falcon Street						
AM peak	C (35)	B (27)	C (30)	C (38)	B (25)	D (44)
PM peak	D (44)	F (82)	C (38)	D 49)	F (95)	D (48)
Ernest Street/Warringah Freeway on ramp						
AM peak	A (5)	B (19)	C (28)	A (5)	D (48)	C (34)
PM peak	B (15)	A (12)	A (13)	B (15)	A (12)	A (13)
Ernest Street/Warringah Freeway off ramp (off ramp in PM, on ramp AM)						
AM peak	A (5)	B (19)	B (28)	A (5)	D (48)	C (34)
PM peak	B (17)	A (13)	A (14)	B (17)	A (14)	B (15)
Falcon Street/Warringah Freeway ramps						
AM peak	C (29)	C (36)	C (42)	B (15)	D (45)	D (51)
PM peak	F (72)	E (70)	D (52)	F (>100)	E (68)	E (60)
Watson Street/Military Road						
AM peak	B (18)	C (38)	C (28)	B (26)	C (37)	C (30)
PM peak	D (46)	D (50)	C (37)	E (59)	D (46)	C (38)

Intersection/ peak period	'Do minimum 2027' – LoS (average delay in seconds)	'Do something 2027' – LoS (average delay in seconds)	'Do something cumulative 2027' – LoS (average delay in seconds)	'Do minimum 2037' – LoS (average delay in seconds)	'Do something 2037' – LoS (average delay in seconds)	'Do something cumulative 2037' – LoS (average delay in seconds)
Military Road/Ben Boyd Road						
AM peak	B (15)	D (47)	D (47)	B (23)	D (44)	D (43)
PM peak	D (54)	E (65)	D (55)	E (70)	F (>100)	F (83)
Falcon Street/Merlin Street						
AM peak	B (24)	D (46)	C (39)	C (32)	D (47)	D (54)
PM peak	F (>100)	F (94)	F (83)	F (>100)	F (93)	F (88)
Berry Street/Walker Street						
AM peak	C (29)	F (76)	C (41)	C (39)	D (46)	D (50)
PM peak	D (44)	F (82)	E (69)	F (73)	F (81)	F (74)
Berry Street/Miller Street						
AM peak	D (55)	D (49)	E (58)	E (69)	C (39)	E (57)
PM peak	D (46)	C (35)	D (54)	F (70)	F (76)	E (63)
Mount Street/Arthur Street						
AM peak	D (46)	D (46)	B (18)	E (59)	C (33)	C (33)
PM peak	D (49)	B (17)	B (21)	F (92)	B (18)	F (>100)
Mount Street/Walker Street						
AM peak	C (36)	D (47)	C (35)	D (48)	C (41)	D (43)
PM peak	C (32)	D (47)	F (78)	F (75)	E (59)	F (96)
Pacific Highway/High Street/Arthur Street						
AM peak	B (19)	E (57)	B (18)	C (38)	D (45)	B (19)
PM peak	D (46)	A (14)	B (16)	E (61)	B (23)	B (21)
Pacific Highway/Walker Street/Blue Street						
AM peak	C (36)	D (55)	C (33)	E (65)	D (49)	C (32)
PM peak	D (40)	E (65)	D (54)	F (80)	F (79)	E (60)
Pacific Highway/Miller Street/Mount Street						
AM peak	C (38)	F (79)	E (62)	C (41)	F (72)	E (62)
PM peak	C (41)	E (57)	D (50)	E (58)	F (78)	E (66)
Pacific Highway/Berry Street						
AM peak	E (56)	B (17)	E (60)	D (52)	B (16)	E (60)
PM peak	B (23)	B (15)	F (85)	E (56)	C (34)	F (87)

Intersection/ peak period	'Do minimum 2027' – LoS (average delay in seconds)	'Do something 2027' – LoS (average delay in seconds)	'Do something cumulative 2027' – LoS (average delay in seconds)	'Do minimum 2037' – LoS (average delay in seconds)	'Do something 2037' – LoS (average delay in seconds)	'Do something cumulative 2037' – LoS (average delay in seconds)
Pacific Highway/Bay Road						
AM peak	D (55)	B (23)	D (42)	F (77)	B (23)	F (88)
PM peak	B (15)	B (22)	B (27)	C (41)	C (40)	C (33)
Miller Street/McLaren Street						
AM peak	B (23)	C (40)	E (56)	F (72)	C (42)	E (62)
PM peak	B (21)	C (39)	C (37)	D (55)	F (76)	D (50)
Miller Street/Ridge Street						
AM peak	C (38)	C (33)	E (63)	D (53)	D (45)	E (70)
PM peak	C (40)	B (15)	B (21)	F (91)	E (57)	C (39)
Miller Street/Carlow Street						
AM peak	A (13)	A (8)	B (15)	A (13)	A (8)	C (28)
PM peak	A (8)	A (6)	A (7)	B (19)	D (55)	A (7)
High Street/Clark Road						
AM peak	B (18)	C (32)	C (36)	D (55)	C (37)	C (38)
PM peak		D (50)	D (56)	F (97)	D (52)	E (65)
High Street/Alfred Street North						
AM peak	A (13)	D (49)	B (19)	E (62)	C (32)	B (18)
PM peak	F (>100)	C (41)	C (42)	F (>100)	C (42)	D (46)
Mount Street/Alfred Street North						
AM peak	A (<5)	B (16)	B (14)	A (<5)	B (16)	A (14)
PM peak	A (12)	A (14)	A (12)	A (10)	A (14)	A (13)
Ernest Street/Ben Boyd Road						
AM peak	A (12)	A (11)	B (18)	A (12)	B (14)	B (26)
PM peak	D (44)	A (10)	A (10)	F (94)	C (38)	D (46)
Pedestrian crossing at Military Road						
AM peak	A (6)	A (<5)	A (5)	A (5)	A (<5)	A (6)
PM peak	B (27)	A (5)	A (<5)	C (34)	A (5)	A (5)

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

Road network changes and access arrangements

'Do something' scenario

The project would connect directly via on and off ramps to the Warringah Freeway at Cammeray, north of Ernest Street Bridge. The project would also connect to the Western Harbour Tunnel via a direct underground connection in the Warringah Freeway and surrounds area.

The remaining road network changes in the Warringah Freeway and surrounds area, including connection to North Sydney, Bradfield Highway and Cahill Expressway would be associated with the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project (subject to separate assessment and approval), which is required for the project to be operational.

The Warringah Freeway Upgrade is proposed to substantially improve the safety and efficiency of the motorway and arterial road interfaces. The upgrade would involve extensive upgrades to surface roads and existing connections that would:

- Connect and integrate with the Western Harbour Tunnel and Beaches Link
- Improve wayfinding and separate traffic on the freeway based on trip function (through traffic, traffic for arterial distribution and traffic for local destinations).

The upgrades would include the removal of the existing tidal flow arrangements on the Warringah Freeway, while the existing tidal flow arrangements on the Sydney Harbour Bridge would not be affected by the project. The upgraded Warringah Freeway would simplify traffic flow and improve wayfinding by providing the following traffic lanes:

- A northbound outer carriageway comprising:
  - An outer western carriageway, carrying northbound traffic from the Sydney Harbour Bridge to the Beaches Link northbound on ramp and facilitating local distribution to local destinations such as North Sydney and Crows Nest
  - Inner western carriageways, carrying northbound traffic from the Sydney Harbour Bridge and Sydney Harbour Tunnel
- A central carriageway carrying northbound and southbound motorway traffic between the Western Harbour Tunnel, Gore Hill Freeway and Willoughby Road
- A southbound outer carriageway comprising:
  - Inner eastern carriageways carrying southbound traffic to the Sydney Harbour Tunnel and for facilitating distribution to local destinations such as Neutral Bay
  - An outer eastern carriageway, carrying southbound traffic for the Sydney Harbour Bridge (both the Bradfield Highway and Cahill Expressway) and for distribution to local destinations such as North Sydney and Kirribilli
  - A dedicated bus lane between Miller Street, Cammeray and the Sydney Harbour Bridge, Milsons Point which would carry southbound buses and other permitted bus lane vehicles.

Following the upgrades, connections between the upgraded Warringah Freeway and the arterial road network would be provided at all existing interchange locations. However, changes to existing Warringah Freeway accesses would be carried out as part of the Warringah Freeway Upgrade project at Falcon Street, Miller Street, Brook Street, Berry Street and Alfred Street North.

Figure 9-5 provides an overview of these connections and their associated access arrangements.

Further details of access arrangements following the completed upgrading of the Warringah Freeway as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project is provided in Section 7.4.4 of Appendix F (Technical working paper: Traffic and transport).

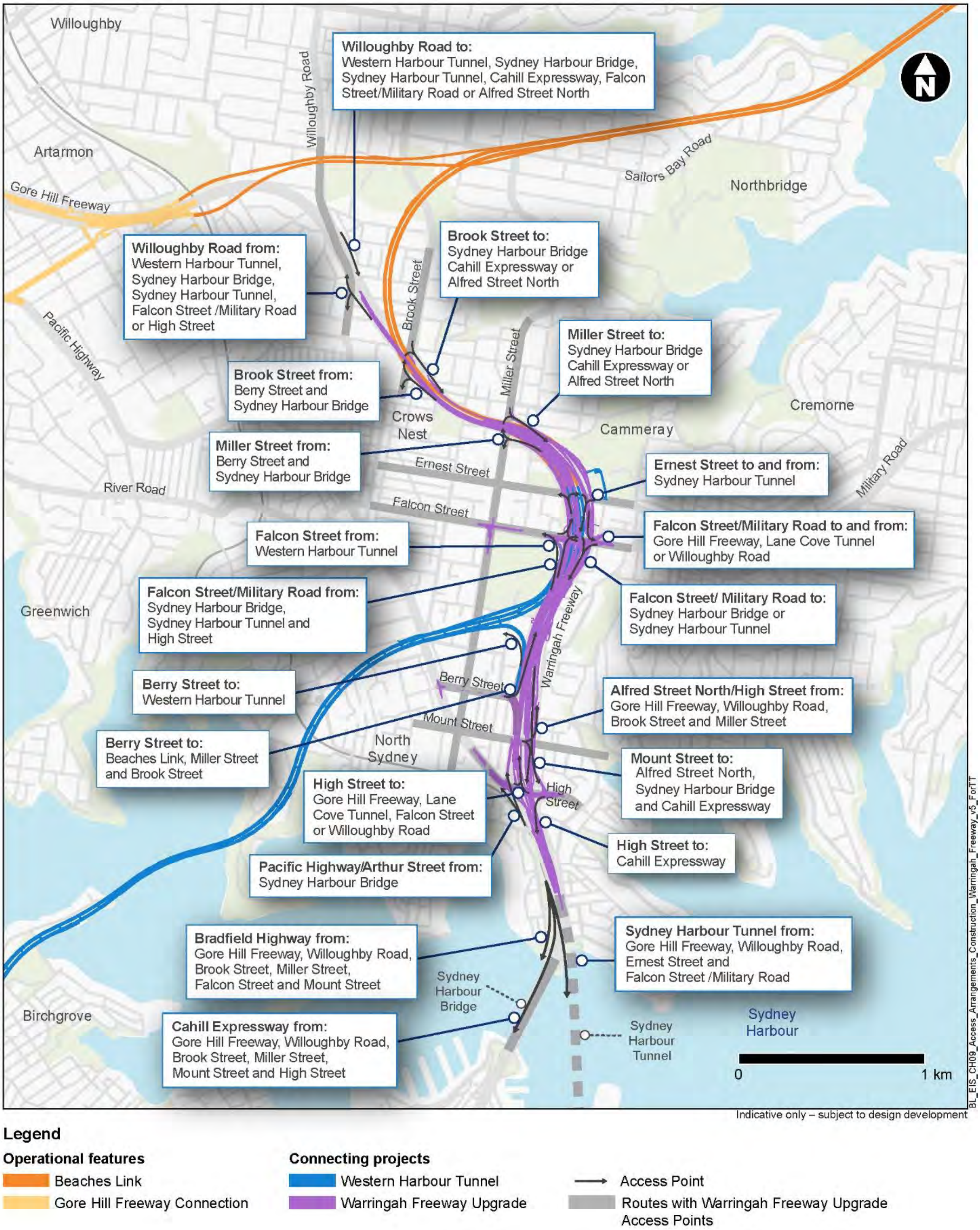


Figure 9-5 Access arrangements upon completion of construction works at the Warringah Freeway

'Do something cumulative' scenario

In the 'Do something cumulative' scenario, the Western Harbour Tunnel would connect to North Sydney via an on ramp from Berry Street for vehicles travelling southbound and via an off ramp to Falcon Street for vehicles travelling north.

Additional access restrictions and local road changes under the 'Do something cumulative' scenario would be as follows:

- The existing Falcon Street westbound off ramp from the Warringah Freeway would be converted to the northbound off ramp from Western Harbour Tunnel, thereby removing connectivity between the Warringah Freeway and Sydney Harbour Tunnel northbound and Falcon Street westbound. Adjacent interchanges north and south of Falcon Street would provide similar connectivity
- Berry Street east of Walker Street would be reconfigured with the provision of two traffic lanes connecting to the Western Harbour Tunnel, one traffic lane providing connection to the Warringah Freeway northbound and Arthur Street southbound, and one traffic lane connecting to Arthur Street southbound only.

In general, these access restrictions would result in minor increases in travel distance and time for the affected trips. However, these changes would result in improved traffic performance and reduced congestion through the North Sydney road network and would contribute to a road network arrangement that balances the needs of all customers including public transport passengers, pedestrians and cyclists.

Impacts on public transport

'Do something' scenario

In the 'Do something' scenario, modelled future bus travel times for key routes through the Warringah Freeway and surrounds area indicate the following:

- Travel times on bus routes through North Sydney may incur localised impacts due to changed traffic patterns at the perimeter of North Sydney CBD
- Travel times for southbound buses through North Sydney via Pacific Highway and Berry Street would improve due to the changes to the arrangements at the intersection of Berry Street and Miller Street, which would simplify signal phasing and remove the existing conflict between right turning buses and pedestrians
- Travel times for buses from Gore Hill Freeway to the Sydney Harbour Bridge would improve substantially, particularly southbound in the AM and PM peaks. This is due to the reconfiguration of the southbound bus lane between Miller Street and the Cahill Expressway, which would be separated from the general traffic lanes, thereby removing two existing weave movements between buses and cars. Buses would no longer be required to merge from left to right to access the bus lane from the north and cars would no longer be able to cross the bus lane between Falcon Street and the Cahill Expressway
- Travel times for buses to and from Falcon Street would generally improve as a result of the upgrade of this interchange and reconfiguration of the southbound bus lane, which removes the existing conflict with general traffic, and as a result of the reduction in traffic demand to the Willoughby Road and Falcon Street ramps, which would otherwise cause increasing congestion, blocking access to the northbound bus off ramp to Falcon Street.

As part of the Warringah Freeway Upgrade, a new dedicated southbound bus lane on the Warringah Freeway would extend from Miller Street to the Sydney Harbour Bridge, with new bus lane connections at Falcon Street and Mount Street. This would remove direct interaction between buses and general traffic on the approach to the Sydney Harbour Bridge, thereby improving southbound bus operations on the Warringah Freeway.

Bus lanes at the Falcon Street interchange would be maintained with the diverging diamond configuration, which would support the Northern Beaches B-Line and other bus services.

The northbound bus only lane that operates during the weekday AM peak on Arthur Street would also be removed as part of the upgrade, however bus services would have the ability to access the Sydney Harbour Bridge via the general traffic lanes provided.

The Warringah Freeway Upgrade would also relocate existing bus layover facilities on the Warringah Freeway north of Ernest Street to within a widened section of the motorway near Cammeray Golf Course and on the Cahill Expressway south of High Street. Similar layover space would be provided as per the existing arrangement.

Overall, the impacts of the project on buses would be generally positive, with travel time savings for the high-demand bus routes from Gore Hill Freeway and Military Road corridors, although in some instances there is the potential for some marginal localised increases in bus travel times through the North Sydney CBD area.

'Do something cumulative' scenario

Under the 'Do something cumulative' scenario, the modelled future bus travel times in the Warringah Freeway and surrounds area indicates the following:

- Bus travel times through North Sydney could experience some localised delays that may occur during the busiest peak periods as a result of the introduction of the Western Harbour Tunnel
- Bus travel times along the Warringah Freeway would generally improve compared to the 'Do something' scenario, due to the reduction of demand on Warringah Freeway caused by trips transferring to the project and Western Harbour Tunnel
- Bus travel times for trips travelling between Warringah Freeway and Military Road would remain largely unchanged compared to the 'Do something' scenario. The introduction of the Western Harbour Tunnel would not substantially change traffic conditions for these routes, which would retain the same level of priority.

Impacts on active transport

'Do something' scenario

The changes to the active transport network within the Warringah Freeway and surrounds area would be due to the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project. This would include:

- A new shared user path would be provided on the southern side of the High Street bridge and signalised pedestrian crossings at the Alfred Street North/High Street intersection
- A new shared user bridge to the north of Ernest Street at Cammeray, connecting Cammeray Golf Course with ANZAC Park, would provide the same pedestrian and cycle connectivity as the existing shared user path and cycleway on the Ernest Street bridge
- Replacement of the Ridge Street bridge with a wider structure with dedicated cycle lanes and a pedestrian path and replacement of the Falcon Street shared user bridge with a new structure
- Consolidating pedestrian crossings into a central median shared user path at the Falcon Street interchange
- Improved pedestrian crossings at the Falcon Street interchange ramp connections and increased pedestrian safety with fencing along the footpath
- A new dedicated cycleway on the eastern side of Warringah Freeway between Miller Street and Falcon Street
- The pedestrian and cycle underpass on the eastern side of the Falcon Street Bridge would be permanently removed. The alternative route via Military Road would result in users having to travel an additional 380 metres, increasing their travel time. However, existing pedestrian and

cyclist volumes at this underpass are low and the overall impacts of the closure are expected to be minor.

'Do something cumulative' scenario

There would be no additional impacts on the active transport network under the 'Do something cumulative' scenario when compared to the 'Do something' scenario.

9.4.3 Gore Hill Freeway and Artarmon

Road network performance

'Do something' scenario

Key outcomes of the modelled road network performance in the Gore Hill Freeway and Artarmon area under the 'Do something' scenario include:

- Peak period traffic demand through the Gore Hill Freeway and Artarmon area would increase by up to 13 per cent by 2037
- Average travel speeds would improve by up to 19 per cent in the AM peak by 2037 due to the conversion of the existing eastbound T2 transit lane to a general traffic lane, but would not change substantially in the PM peak
- The number of stops would remain generally similar to the 'Do minimum' scenario, except during the 2037 AM peak, when they would reduce substantially. This is due to the conversion of the existing eastbound T2 transit lane to a general traffic lane, providing additional capacity in the AM peak to meet forecast demand.

Under the 'Do something' scenario, the Gore Hill Freeway Connection component of the project in Artarmon would facilitate additional traffic travelling through the corridor at a generally similar or reduced level of delay. This change would represent increased connectivity and capacity in the network, with the rate of travel expected to remain similar or increase slightly when compared to 'Do minimum' scenario.

The project would also substantially increase accessibility for the Northern Beaches to nearby strategic centres such as Chatswood, St Leonards and Macquarie Park, through improved connectivity via Reserve Road and the Gore Hill Freeway. In addition, the project would provide the opportunity for express bus services in the Beaches Link tunnel between the Northern Beaches and strategic centres, via the Gore Hill Freeway, such as Macquarie Park.

'Do something cumulative' scenario

Key outcomes of the assessment of the Gore Hill Freeway and Artarmon area under the 'Do something cumulative' scenario (when compared with the 'Do Something' scenario) include:

- Peak period traffic demand through the area would increase by up to 2.5 per cent by 2037
- Average travel speeds through the area would not substantially change in the AM peak when compared to the 'Do something' scenario, but would decrease by up to seven per cent in the PM peak due to increased traffic demand on the Gore Hill Freeway generated by the Western Harbour Tunnel
- The number of stops would not materially change in the AM peak but increase in the PM peak when compared to a 'Do minimum' scenario. This is also due to the increased traffic volumes heading west from Gore Hill Freeway, which would require increased priority at the intersection of Epping Road and Longueville Road so that queues from this intersection do not interfere with the operation of the Gore Hill Freeway. This change to intersection operation would increase queues on Longueville Road and Parklands Avenue.

Network performance measures for the Gore Hill Freeway and Artarmon study area indicate that the network integration works associated with the project would facilitate additional traffic travelling through the corridor while maintaining a similar level of overall network performance. The introduction of Western Harbour Tunnel would increase demand in the area, marginally reducing network speeds during PM peaks. The additional regional connectivity from the Artarmon area added by the Western Harbour Tunnel and Beaches Link program of works would create only localised residual impacts to traffic through the Artarmon area.

Traffic travel times

'Do something' scenario

Modelled travel times during AM and PM peaks for key routes through the Gore Hill Freeway are presented in Table 9-7.

Travel times along the Gore Hill Freeway through Artarmon are not predicted to change substantially under the 'Do something' scenario, with the exception of westbound trips from Gore Hill Freeway to the Lane Cove Tunnel, which would marginally improve in the AM peak due to the reduction in traffic volumes from the Reserve Road interchange to the Lane Cove Tunnel.

'Do something cumulative' scenario

Table 9-7 indicates travel times along the Gore Hill Freeway through Artarmon would not change substantially as a consequence of the 'Do something cumulative' scenario (when compared with the 'Do something' scenario), with the exception of the westbound travel to Longueville Road in the PM peak, which would experience a relatively minor increase. Additional traffic demand as a result of the introduction of the Western Harbour Tunnel would mean that delays at the intersection of Epping Road and Longueville Road would need to be managed to avoid propagation to Gore Hill Freeway.

Table 9-7 Modelled AM peak (8am–9am) and PM peak (5pm–6pm) traffic travel times for key routes through the Gore Hill Freeway and Artarmon area

Route/ Peak period	Direction	'Do minimum 2027'	'Do something 2027'	'Do something cumulative 2027'	'Do minimum 2037'	'Do something 2037'	'Do something cumulative 2037'
Longueville Road to Gore Hill Freeway							
AM peak	Eastbound	01:28	01:28	01:29	01:24	01:28	01:29
	Westbound	01:24	01:22	01:23	01:28	01:22	01:23
PM peak	Eastbound	01:26	01:26	01:26	01:25	01:26	01:27
	Westbound	01:23	01:23	01:23	01:23	01:23	02:02
Lane Cove Tunnel to Gore Hill Freeway							
AM peak	Eastbound	01:18	01:16	01:16	01:24	01:17	01:17
	Westbound	01:17	01:17	01:18	02:16	01:18	01:18
PM peak	Eastbound	01:22	01:16	01:16	01:23	01:16	01:18
	Westbound	01:12	01:17	01:17	01:12	01:17	01:17

Intersection performance

'Do something' scenario

Modelled intersection performance for key intersections in the Gore Hill Freeway and Artarmon area under the 'Do something' scenario is presented in Table 9-8, and indicate the following:

- The intersection of Epping Road, Longueville Road and Parklands Avenue would continue to operate with substantial delays during AM peak and PM peak due to continued high levels of traffic demand. As a result, queues extending on Parklands Avenue and Longueville Road may increase as priority is given to the east–west movements through this intersection
- The intersection of Longueville Road and Pacific Highway would operate satisfactorily as a result of the project, indicating that additional traffic volumes at the intersection of Epping Road and Longueville Road would not impact on performance at this adjacent intersection
- The Gore Hill Freeway/Reserve Road interchange would continue to operate at a similar or improved level of service with the project in operation due to the proposed capacity and traffic signal operation upgrades.

Overall, the project would result in increased demand through the Gore Hill Freeway and Artarmon area and would facilitate this additional travel without substantially increasing delays at critical intersections on the arterial road network.

'Do something cumulative' scenario

Modelled intersection performance for key intersections in the Gore Hill Freeway and Artarmon area under the 'Do something cumulative' scenario is presented in Table 9-8, and indicate the following:

- The Epping Road/Longueville Road/Parklands Avenue intersection would continue to operate at a poor level of service as a result of continued high traffic demand through this intersection
- Increased delays from the Epping Road/Longueville Road intersection are likely to result in increased localised delays at the Longueville Road/Pacific Highway intersection during the PM peak
- The Gore Hill Freeway/Reserve Road interchange would continue to operate at capacity during the PM peak, with the potential for increased queuing due to the increased traffic demand in the corridor. This has the potential to increase delays at adjacent intersections along Reserve Road, with the intersection at Dickson Road and Reserve Road operating at LoS F.

Increased traffic demand would result in some increased delays at intersections in the Gore Hill Freeway and Artarmon area. These intersections could be optimised to ensure the Gore Hill Freeway would continue to operate satisfactorily, however a consequence of this optimisation would be longer delays on side streets and surface roads during peak periods.

Although traffic may be impacted by an increase in localised intersection delays under the 'Do something cumulative' scenario, strategic modelling indicates that road users would benefit from substantial travel time savings on the broader network (eg via Western Harbour Tunnel and improved efficiency of the Warringah Freeway and beyond). Consequently, road users who travel on and around the Gore Hill Freeway would still benefit from the construction of the Western Harbour Tunnel due to the increased connectivity to the area and on the surrounding broader road network.

Table 9-8 Modelled intersection performance on the Gore Hill Freeway and Artarmon area (AM peak (8am–9am) and PM peak (5pm–6pm) during operation in 2027 and 2037)

Intersection/ peak period	'Do minimum 2027'– LoS (average delay in seconds)	'Do something 2027' – LoS (average delay in seconds)	'Do something cumulative 2027' – LoS (average delay in seconds)	'Do minimum 2037' – LoS (average delay in seconds)	'Do something 2037' – LoS (average delay in seconds)	'Do something cumulative 2037' – LoS (average delay in seconds)
Epping Road/Longueville Road/Parkland Avenue						
AM peak	D (52)	F (73)	F (75)	F (83)	F (74)	F (77)
PM peak	F (80)	E (66)	F (81)	F (87)	F (71)	F (>100)
Longueville Road/Pacific Highway						
AM peak	C (40)	D (49)	C (39)	D (54)	C (33)	C (38)
PM peak	C (42)	C (38)	D (45)	D (49)	C (42)	F (86)
Pacific Highway/Howarth Road/Norton Lane						
AM peak	B (20)	A (8)	A (10)	B (28)	A (9)	A (11)
PM peak	A (42)	A (38)	A (45)	A (49)	A (42)	A (86)
Pacific Highway/Gore Hill Freeway interchange						
AM peak	B (29)	C (32)	B (25)	C (41)	B (24)	B (25)
PM peak	C (29)	B (17)	B (29)	B (23)	B (17)	B (29)
Reserve Road/Gore Hill Freeway interchange						
AM peak	E (61)	D (46)	D (52)	D (47)	D (55)	E (60)
PM peak	D (29)	D (17)	D (29)	E (23)	D (17)	D (29)
Reserve Road/Dickson Road						
AM peak	A (14)	B (21)	B (24)	B (19)	B (29)	B (27)
PM peak	F (73)	D (50)	F (87)	F (85)	E (66)	F (95)
Reserve Road/Barton Road						
AM peak	E (69)	F (87)	F (77)	F (>100)	F (84)	F (85)
PM peak	F (>100)	E (69)	F (>100)	F (>100)	F (>100)	F (>100)

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

Road network changes and access arrangements

'Do something' scenario

At its western end, the project would connect to the Gore Hill Freeway at Artarmon, west of the T1 North Shore and Western line and T9 Northern line. The connection would include:

- Eastbound on ramps to Beaches Link from the Lane Cove Tunnel, Epping Road, and Reserve Road, providing three access points from Artarmon and beyond
- Westbound off ramps from Beaches Link onto Reserve Road and the Lane Cove Tunnel, providing access points to Artarmon and beyond.

The Gore Hill Freeway Connection component of the project would also involve local road changes to integrate the project with the existing road network as follows:

- Dickson Avenue east of Reserve Road would be converted to a cul-de-sac, and property access from Reserve Road would be removed to accommodate the westbound off ramp onto Reserve Road. Access to properties would be provided via Hesky Lane and the surrounding road network, such as Taylor Lane, Cleg Street, Herbert Street and Waltham Street. Access to Dickson Avenue west of Reserve Road would be maintained
- The Reserve Road/Dickson Avenue intersection would be modified to accommodate the westbound off ramp onto Reserve Road
- Lambs Road would be disconnected from the road network between Punch Street and Cleg Street to facilitate the installation of tunnel support facilities. Lambs Road would connect directly onto Cleg Street at its northern end while a cul-de-sac would be installed on Punch Street at its eastern end. Vehicles would be redirected from Lambs Road to Punch Street and Herbert Street. This would not substantially increase the travel time, with the additional distance is limited to around 480 metres
- Traffic signals would be provided for the Pacific Highway/Dickson Avenue intersection to increase safety and connectivity.

Additional capacity would be provided at the Reserve Road bridge where the existing footpaths would be converted to traffic lanes, a new footpath would be constructed on the eastern side of the bridge and the T2 transit lanes on the Gore Hill Freeway in both directions would be removed.

Twenty five on-street parking spaces removed on Lambs Road and Punch Street during construction would not be reinstated. About 10 on-street parking spaces for cars and six on-street parking spaces for motorcycles would also be removed at the Pacific Highway/Dickson Avenue intersection during construction and would not be reinstated. Given the availability of parking on surrounding streets this impact is anticipated to be absorbed by the surrounding network.

Beaches Link operational facilities including the motorway control centre at the Gore Hill Freeway would provide sufficient off-street parking for staff and would therefore avoid any additional on-street parking demand as a result of the project. Therefore, there would be no additional impacts on parking once the project is operational.

These network changes and access arrangements are shown in Figure 9-6.

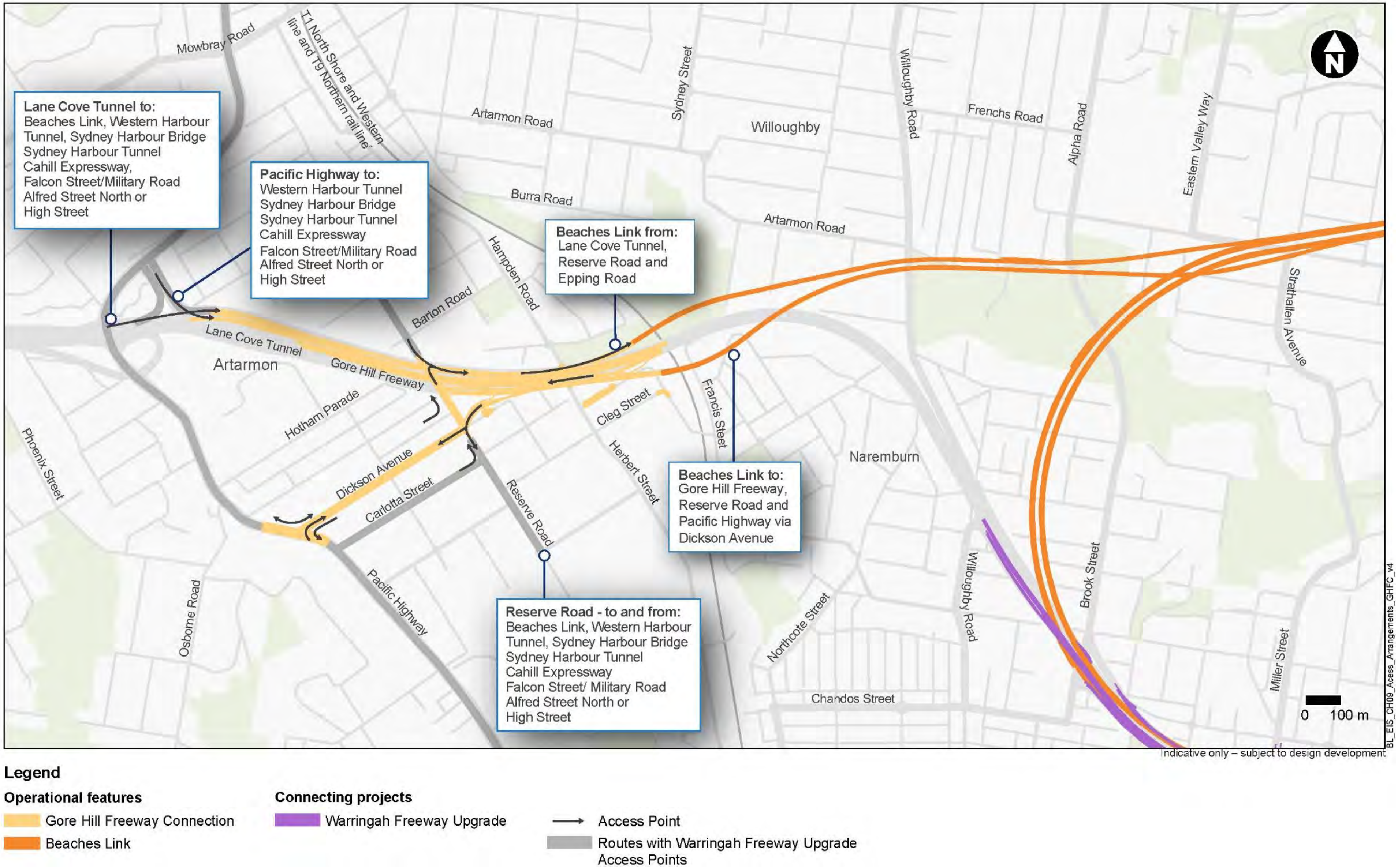


Figure 9-6 Access arrangements upon completion of construction works at Gore Hill Freeway

'Do something cumulative' scenario

There would be no additional road network changes within the Gore Hill Freeway and Artarmon area under the 'Do something cumulative' scenario compared to the 'Do something' scenario.

Impacts on public transport

'Do something' scenario

The existing T2 transit lanes in the area would be converted to general traffic lanes as part of the project. Forecast bus travel times for key routes through the Gore Hill Freeway and Artarmon area indicate that the conversion of the T2 transit lanes would not have a material impact on travel times during the AM and PM peaks towards the Sydney CBD (Lane Cove Tunnel to Gore Hill Freeway).

The project also offers the opportunity for express bus services in the Beaches Link tunnel between the Northern Beaches and strategic centres (such as Macquarie Park) via the Gore Hill Freeway.

The southbound bus stop on Pacific Highway would be permanently relocated once traffic signals are provided for the Pacific Highway/Dickson Avenue intersection. The bus stop would be relocated within 50 metres of its existing location and only minor impacts are therefore anticipated given the minor increase in travel distance.

'Do something cumulative' scenario

Forecast bus travel times for key routes through the Gore Hill Freeway and Artarmon area indicate that bus travel times would not change substantially under the 'Do something cumulative' scenario, and increased traffic flows through the area would not materially impact bus travel times for key routes.

Impacts on active transport

'Do something' scenario

The following pedestrian and cyclist infrastructure would be provided as part of the project:

- The existing shared user path on the southern side of the Gore Hill Freeway would be replaced in areas directly impacted by the project between the T1 North Shore and Western line and T9 Northern line. Pedestrian fencing would be installed along the northern side of the shared user path to improve safety of the active transport network
- The existing pedestrian footpath along the eastern side of the Reserve Road bridge would be replaced, maintaining existing connectivity.

'Do something cumulative' scenario

There would be no additional changes to the active transport network within the Gore Hill Freeway and Artarmon area under the 'Do something cumulative' scenario when compared to the 'Do something' scenario.

9.4.4 Northbridge to Seaforth (Middle Harbour crossing – maritime traffic)

There would be no operational impacts on maritime movements and activities as a result of the project.

The project would result in a reduction in water depth of around 10 metres at some locations within the proposed harbour crossing. This is not expected to have an impact on navigation, given the current depth is typically greater than 20 metres chart datum at the crossing location, and vessels in this part of the harbour are already constrained by shallow water depths downstream, with the maximum water depth at the entrance to Middle Harbour being around 3.5 metres at low tide to 5.1 metres at high tide below chart datum.

Moorings impacted during construction would be reinstated as close as practical to their current locations.

9.4.5 Balgowlah and surrounds

Road network performance

'Do something' scenario

Key outcomes of the modelled road network performance in the Balgowlah and surrounds area under the 'Do something scenario' include:

- Peak period traffic demand would increase by up to 15 per cent by 2037
- Average travel speeds would improve by up to 77 per cent in the AM peak and 49 per cent in the PM peak by 2037 due to the shift in traffic demand to the project road network. The transfer of this demand from surface arterial roads to the project would reduce congestion and improve travel speeds for local trips
- The number of stops would reduce substantially by up to 56 per cent in the AM peak and 22 per cent in the PM peak. This is due to the reduction in traffic on the surface roads, particularly through the intersection of Manly Road and Sydney Road, which is the primary source of delays in the area.

The assessment indicates that the operation of the project would facilitate additional traffic travelling through the corridor within the Balgowlah and surrounds area at greatly reduced levels of delay, and would benefit both regional and local trips. This would result in improved travel times on key routes through the area as a result of the project.

'Do something cumulative' scenario

Key outcomes of the modelled road network performance in the Balgowlah and surrounds area under the 'Do something cumulative' scenario (when compared with the 'Do something' scenario) include:

- Peak period traffic demand would not substantially change
- Average travel speeds would not substantially change.

Network performance measures for the Balgowlah and surrounds area indicate that the project would facilitate additional traffic through the area. Extending connectivity further with the inclusion of the Western Harbour Tunnel would result in similar travel times and speeds to the 'Do something' scenario.

Traffic travel times

'Do something' scenario

Modelled travel times during AM and PM peaks for key routes through the Balgowlah and surrounds area are presented in Table 9-9. Analysis of the modelled general traffic travel times indicates that performance on most key routes throughout the modelled area is expected to improve as a result of the project.

'Do something cumulative' scenario

Table 9-9 indicates there would be minimal change in general traffic travel times as a result of the introduction of Western Harbour Tunnel when compared to the 'Do something' scenario.

Table 9-9 Modelled AM peak (8am–9am) and PM peak (5pm–6pm) traffic travel times for key routes through Balgowlah and surrounds area

Route/ Peak period	Direction	'Do minimum 2027'	'Do something 2027'	'Do something cumulative 2027'	'Do minimum 2037'	'Do something 2037'	'Do something cumulative 2037'
Spit Bridge to Burnt Bridge Creek Deviation/Condamine Street							
AM peak	Northbound	03:09	03:27	03:25	04:08	03:29	03:28
	Southbound	06:15	03:44	03:48	11:46	03:38	03:40
PM peak	Northbound	05:24	03:54	04:00	05:48	04:00	03:47
	Southbound	07:49	05:41	04:57	11:12	05:13	05:10
Spit Bridge to Wakehurst Parkway/Judith Street (via Frenchs Forest Road)							
AM peak	Northbound	05:55	06:23	06:33	06:47	06:03	05:58
	Southbound	07:37	06:31	06:36	09:22	06:30	06:30
PM peak	Northbound	09:57	08:28	07:17	10:19	08:13	07:39
	Southbound	14:19	14:05	14:16	16:07	14:20	14:23

Intersection performance

'Do something' scenario

Modelled intersection performance for key intersections in the Balgowlah and surrounds area under the 'Do something' scenario is presented in Table 9-10, and indicates:

- Demand at the roundabout-controlled Frenchs Forest Road/Sydney Road intersection would continue to exceed capacity, resulting in relatively poor performance during PM peak periods
- The intersection of Sydney Road, Manly Road and Burnt Bridge Creek Deviation would improve in the AM peak but continue to operate at a poor level of service during the PM peak, when average delays would be comparable to those under the 'Do minimum' scenario. The proximity of this intersection to the Frenchs Forest Road/Sydney Road intersection would result in queues from each intersection impacting the capacity and performance of the other
- All other intersections would operate at similar level of service to those under the 'Do minimum' scenario.

Analysis of the modelled general traffic travel times indicates that travel times on most key routes throughout the modelled area are expected to improve as a result of the project. While some intersections would continue to experience a poor level of service, when combined with the above travel time benefits, the project would result in an overall improvement to network performance.

'Do something cumulative' scenario

Modelled intersection performance in the Balgowlah and surrounds area under the 'Do something cumulative' scenario is presented in Table 9-10 and indicates:

- Most intersections in the area would generally continue to operate at a similar level of delay when compared to the 'Do something' scenario
- Reduced traffic volumes from Spit Road associated with the introduction of the Western Harbour Tunnel would reduce the extent of queueing at the roundabout of Sydney Road and Frenchs Forest Road. This would reduce the impact on adjacent intersections,

including Sydney Road/Manly Road/Burnt Bridge Creek Deviation and Sydney Road/Maretimo Street during the PM peak.

Table 9-10 Modelled intersection performance on the Balgowlah and surrounds area(AM peak (8am–9am) and PM peak (5pm–6pm) during operation in 2027 and 2037)

Intersection/ peak period	'Do minimum 2027' – LoS (average delay in seconds)	'Do something 2027' – LoS (average delay in seconds)	'Do something cumulative' 2027 – LoS (average delay in seconds)	'Do minimum 2037' – LoS (average delay in seconds)	'Do something 2037' – LoS (average delay in seconds)	'Do something cumulative 2037' – LoS (average delay in seconds)
Sydney Road/Manly Road/Burnt Bridge Creek Deviation						
AM peak	D (48)	B (26)	B (28)	E (68)	B (27)	B (26)
PM peak	F (93)	F (86)	E (62)	F (>100)	F (93)	F (73)
Frenchs Forest Road/Sydney Road						
AM peak	B (21)	B (29)	B (25)	C (32)	B (28)	C (40)
PM peak	F (>100)	F (>100)	F (>100)	F (>100)	F (>100)	F (>100)
Sydney Road/Condamine Street						
AM peak	C (33)	B (24)	B (23)	B (26)	C (29)	B (26)
PM peak	C (33)	C (39)	C (42)	C (40)	D (48)	D (45)
Condamine Street/Burnt Bridge Creek Deviation						
AM peak	B (19)	B (31)	C (32)	C (32)	C (38)	C (36)
PM peak	B (17)	C (35)	C (40)	B (16)	C (38)	C (41)
Access Road/Sydney Road/Maretimo Street						
AM peak	A (10)	B (23)	C (29)	A (9)	B (28)	B (27)
PM peak	A (9)	B (20)	B (20)	C (30)	B (27)	C (30)
Access Road/Burnt Bridge Creek Deviation						
AM peak	N/A	A (11)	A (10)	N/A	A (14)	A (14)
PM peak	N/A	A (11)	A (11)	N/A	A (12)	A (11)

Note: Cells shaded in dark grey denote an unsatisfactory LoS E or F

Road network changes and access arrangements

'Do something' scenario

In the 'Do something' scenario, the project would connect to Burnt Bridge Creek Deviation at Balgowlah, just north of its intersection with Sydney Road. This would include a two-lane southbound on ramp and a three-lane northbound off ramp. Local road changes would be required to integrate the project with the existing road network as follows:

- Provision of a new access road in Balgowlah, providing local access and connectivity to the new open space and recreation facilities and connecting the tunnel portals/Burnt Bridge Creek Deviation and Sydney Road. The new access road would accommodate travel in either direction

- A new intersection with traffic signals connecting the new access road with Burnt Bridge Creek Deviation and the tunnel portals adjacent to the northern end of Dudley Street. This would include right turn lanes into the new access road from the Beaches Link off ramp and left turn lanes out of the new access road to the Beaches Link on ramp and Burnt Bridge Creek Deviation southbound. Non-tunnel northbound traffic on Burnt Bridge Creek Deviation would bypass these traffic signals
- A new signalised intersection would be provided at the southern end of the new access road to accommodate its connection with Sydney Road. Traffic movements north-south (and vice versa) through the intersection between Maretimo Street and the access road would not be permitted. The new intersection would include a pedestrian crossing across the new access road on the northern side of Sydney Road. Pedestrian connectivity between the new open space and recreation facilities, the Northern Beaches Secondary College – Balgowlah Boys Campus and Maretimo Street would be provided via the existing pedestrian bridge to the west of the new access road and would continue to provide north-south connectivity for pedestrians in the area. Pedestrian connectivity across Sydney Road to and from Maretimo Street would not be provided at the intersection
- Relocating the existing cul-de-sac at Dudley Street further south to accommodate construction of the new tunnel portals and the associated realignment of Burnt Bridge Creek Deviation.

Potential access impacts associated with the relocation of the cul-de-sac on Dudley Street are expected to be minor given remaining properties would still be accessible from Dudley Street.

Surface connections at Balgowlah would attract traffic demand from both east and west of Burnt Bridge Creek Deviation. The additional traffic from North Balgowlah could cross at Kitchener Street to access the new access road from Sydney Road east. This could increase traffic volumes on local roads between Kitchener Street and Sydney Road. Local area traffic management would assist in minimising increased traffic on local roads. Local area traffic management on Wanganella Street, Rickard Street and West Street could result in traffic using Woodland Street and Condamine Street instead, which would be more appropriate to the function of these roads. Local traffic management measures proposed would be discussed further and agreed with Northern Beaches Council during detailed design.

'Do something cumulative' scenario

There would be no additional road network changes within Balgowlah and surrounds under the 'Do something cumulative' scenario (when compared to the 'Do something' scenario).

Impacts on public transport

'Do something' scenario

In the 'Do something' scenario, bus travel times would be maintained or improved as a result of the project, as existing bus priority in the area would be maintained and traffic congestion reduced in the Balgowlah and surrounds area.

'Do something cumulative' scenario

In the 'Do something cumulative' scenario bus travel times may increase marginally along Frenchs Forest Road during the PM peak as a result of the increased traffic travelling through the Sydney Road/Frenchs Forest Road roundabout, when compared to the 'Do something' scenario.

All other bus routes would be generally unaffected by the changes in traffic as a result of the 'Do something cumulative' scenario when compared to the 'Do something' scenario.

Impacts on active transport

'Do something' scenario

Pedestrian and cyclist facilities provided as part of the 'Do something' scenario would generally improve the extent of the overall active transport network in Balgowlah and surrounds. The following is proposed as part of the project:

- New shared user paths would be provided along the eastern side of the new access road
- A portion of the existing shared user path along Burnt Bridge Creek within the existing golf course would require minor adjustment due to a localised adjustment of the creek alignment
- The existing box culvert crossing of Burnt Bridge Creek Deviation and adjacent pedestrian underpass beneath Burnt Bridge Creek Deviation would both be extended under the realigned road, maintaining existing connectivity across the widened Burnt Bridge Creek Deviation. This would connect to the existing shared user path at Dudley Street. Pedestrian fencing would be provided along the outside of the shared user path and the realigned section of Burnt Bridge Creek Deviation
- New signal controlled pedestrian crossings across the new access road at its interfaces with Sydney Road and Burnt Bridge Creek deviation would maintain connectivity to the existing Balgowlah Oval from Northern Beaches Secondary College – Balgowlah Boys Campus
- An at grade signalised crossing of the access road would provide access to the intersections of the Burnt Bridge Creek Deviation and the new public car park within the open space and recreation facilities area at Balgowlah.

The final layout of the new and improved open space and recreation facilities at Balgowlah including shared user paths are subject to a dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council to give the community an opportunity to provide input (refer to Chapter 6 (Construction work) for further details). This consultation would be separate to the consultation for the environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting. As part of this consultation process, a community reference group will be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space.

'Do something cumulative' scenario

There would be no additional changes to the active transport network under the 'Do something cumulative' scenario when compared to the 'Do something' scenario.

9.4.6 Frenchs Forest and surrounds

Road network performance

Northern Beaches Hospital road upgrade project

The assessment of the Frenchs Forest and surrounds area without the project includes the road network performance benefits from the recently completed Northern Beaches Hospital road upgrade project. 'Do minimum 2027' results indicate that:

- Peak period traffic demand through the area is forecast to increase by 10 per cent
- Overall network speeds would be improved by up to 40 per cent
- Travel speeds along Warringah Road and other key corridors would be improved by more than 50 per cent in some cases.

The results of the ‘Do minimum 2037’ scenario illustrate similar benefits, but also indicate that continued long-term background demand growth in the area would reduce road network performance over time. Between 2027 and 2037:

- Demand is forecast to increase by an additional five per cent
- Network speeds would consequently reduce by around five to 10 per cent.

Overall, the ‘Do minimum’ results indicate that despite continuous growth in background demand over the next 20 years, network performance in the area would still be substantially improved when compared to existing conditions, due to the Northern Beaches Hospital road upgrade project.

‘Do something’ scenario

Key outcomes of the modelled road network performance in the Frenchs Forest and surrounds area under the ‘Do something’ scenario includes the following:

- Peak period traffic demand through the Frenchs Forest and surrounds area would increase by up to 10 per cent by 2037
- Average travel speeds through the Frenchs Forest and surrounds area may decrease by up to 13 per cent. This is primarily a consequence of the change in traffic patterns and demand as a result of the project. A substantial proportion of traffic that currently travels east–west along Warringah Road would travel from east to south and from south to east along Wakehurst Parkway and Warringah Road and through the intersection of Warringah Road and Wakehurst Parkway instead of passing through the underpass. Similarly, southbound traffic on Forest Way that would turn right onto Warringah Road would instead turn left, then right from Warringah Road to Wakehurst Parkway, increasing localised delays at the intersection of Warringah Road and Wakehurst Parkway
- The number of stops would increase by up to 26 per cent as a result of the project due to the change in the pattern of demand with more trips travelling through surface road intersections rather than through the underpass.

The new underpasses at Forest Way and Wakehurst Parkway would not be impacted for the main east/west traffic route on Warringah Road. However, the changes to traffic patterns associated with the project would generally result in increased localised delays on the Warringah Road surface lanes between Forest Way and Wakehurst Parkway and reduced travel speeds through the area. This would be due to the change in the pattern of traffic demand from mostly east and west to mostly east and south, reflecting a change in the main southbound route from Warringah Road to Wakehurst Parkway and the new motorway tunnels introduced by the project. This would transfer traffic demand from a largely grade-separated movement through several additional intersections, resulting in localised delays.

Although some localised delays may be experienced during peak periods, broader modelling indicates that most road users would benefit from substantial travel time savings on the broader network due to the strategic benefits provided by Beaches Link.

‘Do something cumulative’ scenario

Key outcomes of the modelled road network performance in the Frenchs Forest and surrounds area, under the ‘Do something cumulative’ scenario (compared with the ‘Do something’ scenario) includes the following:

- AM and PM peak period traffic demand would increase marginally by up to two per cent
- Average travel speeds through the area could decrease by as much as 12 per cent, largely due to additional demand and redistribution of traffic from Warringah Road (Roseville Bridge) to the project. This would increase the volume of traffic through the intersection of Warringah Road and Wakehurst Parkway, and reduce the volume travelling through the underpass along Warringah Road

- The number of stops would increase under the 'Do something cumulative' scenario by up to 15 per cent. This would be a consequence of the small distribution of traffic from the Warringah Road grade separation to the Warringah Road and Wakehurst Parkway intersection.

There would not be a substantial increase in overall travel demand, but the additional redistribution of demand from Warringah Road to the project would result in some additional localised delay through the network. This is a result of these trips being transferred from the Warringah Road grade separation to the Warringah Road and Wakehurst Parkway surface intersection, which would be operating at capacity.

The strategic benefits of the project are expected to substantially offset localised impacts. The potential localised increases in travel times on the key corridors of Warringah Road and Wakehurst Parkway within the area are expected to be less than five minutes. Conversely, average travel time savings between key centres, eg Dee Why to and from Macquarie Park, are expected to be around 20 minutes. In this example, a 15-minute net saving would be created by the project providing new high capacity connectivity and reducing congestion on existing regional routes.

Notwithstanding this, Transport for NSW is continuing to investigate options to mitigate potential localised network performance issues in the area, and further leverage the overall benefits and opportunities of the project. This work is cognisant of and reliant on the outcomes of the ongoing implementation of the *Northern Beaches Hospital Precinct Structure Plan* (Northern Beaches Council, 2017b), which highlights that future precinct development beyond Stage 1 of the development is dependent on further delivery of improved transport infrastructure and a continued modal shift from private to public transport (refer to Section 9.1.2).

Traffic travel times

'Do something' scenario

Modelled travel times during the AM and PM peaks for key routes through the Frenchs Forest and surrounds area are presented in Table 9-11.

The modelled travel times under the 'Do something' scenario show the following:

- Overall travel times for general traffic on Warringah Road and Forest Way would remain generally unaffected by the project, indicating that potentially increased delays at the intersections along Wakehurst Parkway would not impact east–west trips
- In the AM peak, southbound travel times along Wakehurst Parkway would increase as a result of the project due to the change in traffic pattern that would increase the volumes of traffic turning right from Warringah Road to Wakehurst Parkway, conflicting with the increase in southbound traffic on Wakehurst Parkway
- In the PM peak, travel times for general traffic along Wakehurst Parkway would remain comparable or would improve as a result of the project because the primary southbound movements in the PM peak do not conflict as they do in the AM peak and would have additional capacity provided on Wakehurst Parkway south of Warringah Road.

Overall, traffic modelling predicts that potentially increased localised delays at intersections would be offset by the broader improvement in connectivity and reduction in congestion created by the project.

'Do something cumulative' scenario

Table 9-11 indicates travel times would generally be maintained following the introduction of the Western Harbour Tunnel. There would, however, be some changes, including:

- Increased travel times on Wakehurst Parkway southbound through the area
- Increased demand at the intersections with Frenchs Forest Road and Warringah Road that would create localised delays during the busiest peak periods in 2037.

Table 9-11 Modelled AM peak (8am–9am) and PM peak (5pm–6pm) traffic travel times for key routes through the Frenchs Forest and surrounds area

Route/ Peak period	Direction	'Do minimum 2027'	'Do something 2027'	'Do something cumulative 2027'	'Do minimum 2037'	'Do something 2037'	'Do something cumulative 2037'
Wakehurst Parkway/Judith Street to Wakehurst Parkway/Dreadnought Road							
AM peak	Northbound	04:27	04:17	04:11	06:59	04:27	04:00
	Southbound	04:29	09:13	10:07	05:05	07:36	10:14
PM peak	Northbound	04:37	05:35	06:15	07:02	05:30	05:39
	Southbound	04:10	03:20	03:40	04:04	03:24	09:12
Warringah Road/Forestville Avenue to Ellis Road/Warringah Road							
AM peak	Eastbound	05:25	05:26	05:21	05:24	05:22	06:39
	Westbound	05:55	05:24	05:30	06:11	05:53	06:13
PM peak	Eastbound	06:05	06:09	05:58	06:22	06:42	06:21
	Westbound	05:15	05:24	05:19	05:36	05:15	05:24

Intersection performance

'Do something' scenario

Modelled future performance for key intersections in the Frenchs Forest and surrounds area under the 'Do something' scenario is presented in Table 9-12. Changes to traffic patterns and demand would result in the following intersections operating at a relatively poor level of service during peak hours, when compared to the scenario without the project:

- Wakehurst Parkway and Frenchs Forest Road East (particularly during the AM peak)
- Wakehurst Parkway and Warringah Road
- Warringah Road and Hilmer Street (due to queues from Wakehurst Parkway) (during 2037 PM peak only).

These intersections would experience increased localised delays as a result of the changes in traffic patterns that would arise from the project. However, the project would reduce congestion and delays at intersections along the broader Warringah Road corridor due to the substantial reductions in traffic volumes along Warringah Road to the west of Forest Way.

'Do something cumulative' scenario

Modelled future performance for key intersections in the Frenchs Forest and surrounds area under the 'Do something cumulative' scenario is presented in Table 9-12 and indicate the following when compared with the 'Do something' scenario:

- The intersections of Wakehurst Parkway and Warringah Road, and Wakehurst Parkway and Frenchs Forest Road East would operate with higher average delays due to the redistribution of traffic from Warringah Road to the project
- Delays at the Forest Way/Naree Road intersection would increase as a result of the increase in demand through the area.

The 'Do something cumulative' scenario would result in increased localised delays at intersections when compared with the 'Do something' scenario, primarily as a result of the redistribution of traffic from Warringah Road to the project, but also due to an increase in forecast demand through the area created by the Western Harbour Tunnel.

Although there would be an increase in localised intersection delays, road users would generally benefit from substantial overall travel time savings on the broader network (eg via the project, Warringah Road, Wakehurst Parkway and beyond, particularly through the connectivity to Western Harbour Tunnel). Consequently, traffic impacted at individual intersections in the area is still anticipated to receive a substantial net benefit due to the broader connectivity and efficiency improvements.

Table 9-12 Modelled intersection performance on the Frenchs Forest and surrounds area (AM peak (8am–9am) and PM peak (5pm–6pm) during operation in 2027 and 2037)

Intersection/ peak period	'Do minimum 2027' – LoS (average delay in seconds)	'Do something 2027' – LoS (average delay in seconds)	'Do something cumulative' 2027 – LoS (average delay in seconds)	'Do minimum 2037' – LoS (average delay in seconds)	'Do something 2037' – LoS (average delay in seconds)	'Do something cumulative 2037' – LoS (average delay in seconds)
Wakehurst Parkway/Frenchs Forest Road East						
AM peak	D (44)	F (>100)	F (>100)	E (66)	F (86)	F (>100)
PM peak	D (46)	D (45)	D (45)	D (46)	C (43)	F (98)
Warringah Road/Allambie Road						
AM peak	D (44)	D (50)	D (54)	D (46)	D (51)	D (50)
PM peak	D (46)	D (52)	D (50)	D (49)	D (52)	D (48)
Wakehurst Parkway/Warringah Road						
AM peak	E (58)	F (93)	F (94)	F (78)	F (73)	F (81)
PM peak	C (33)	F (75)	F (86)	C (41)	E (59)	E (60)
Warringah Road/Hilmer Street						
AM peak	A (14)	B (18)	C (35)	C (38)	D (50)	D (57)
PM peak	A (12)	B (17)	B (21)	A (13)	F (88)	F (73)
Warringah Road/Forest Way						
AM peak	B (18)	A (15)	B (18)	B (21)	B (16)	B (26)
PM peak	B (24)	B (24)	C (33)	B (26)	C (31)	B (24)
Forest Way/Naree Road						
AM peak	B (24)	D (56)	D (57)	C (36)	D (54)	E (69)
PM peak	B (19)	B (28)	B (24)	B (27)	B (28)	D (53)
Warringah Road/Brown Street/Currie Road						
AM peak	B (20)	B (16)	B (17)	B (23)	B (18)	B (17)
PM peak	A (10)	A (9)	A (9)	A (11)	A (9)	A (10)
Warringah Road/Starkey Street						
AM peak	B (23)	B (20)	B (21)	B (26)	B (21)	B (25)
PM peak	B (20)	B (20)	B (18)	B (19)	B (20)	B (19)

Intersection/ peak period	'Do minimum 2027' – LoS (average delay in seconds)	'Do something 2027' – LoS (average delay in seconds)	'Do something cumulative' 2027 – LoS (average delay in seconds)	'Do minimum 2037' – LoS (average delay in seconds)	'Do something 2037' – LoS (average delay in seconds)	'Do something cumulative 2037' – LoS (average delay in seconds)
Warringah Road/Darley Street						
AM peak	B (28)	B (27)	B (29)	C (30)	B (26)	B (26)
PM peak	B (19)	B (17)	B (15)	B (19)	B (19)	B (15)
Warringah Road/Forestville Avenue						
AM peak	A (10)	A (14)	A (14)	A (14)	A (14)	A (14)
PM peak	C (35)	B (29)	B (21)	D (46)	C (35)	C (34)

Note: Cells shaded in dark grey denote an unsatisfactory LoS E and F

Road network changes and access arrangements

'Do something' scenario

In the 'Do something' scenario, the project would connect to Wakehurst Parkway at Killarney Heights, north of Kirkwood Street. This connection would include a two-lane southbound on ramp and a two-lane northbound off ramp. This would involve minor local road changes to the intersections of Wakehurst Parkway with Kirkwood Street, Fitzpatrick/Aquatic Drive, Warringah Road and Frenchs Forest Road East and Frenchs Forest Road West to integrate the project with the existing surface road network as follows:

- Provision of additional capacity on Wakehurst Parkway, which would be upgraded to two lanes in each direction between the tunnel portal and Warringah Road
- Removal of the right turn movement from Wakehurst Parkway northbound onto Frenchs Forest Road eastbound, resulting in an additional travel distance of up to 1.3 kilometres via Warringah Road and Allambie Road for affected trips
- Alterations to line marking, adjustments to medians and asphalt resurfacing along local roads.

Given the minimal changes required to local roads, these impacts would be considered minor.

'Do something cumulative' scenario

There would be no additional road network changes within the Frenchs Forest and surrounds area under the 'Do something cumulative' scenario, when compared to the 'Do something' scenario.

Impacts on public transport

'Do something' scenario

In the 'Do something' scenario, bus travel times for key routes through the Frenchs Forest and surrounds area would not be materially impacted by the project. Regional and local buses that are serviced by the Warringah Road and Eastern Valley Way corridors would benefit from improved travel times and reliability as a result of reduced traffic demand and congestion on these roads as a result of the project.

Four new dedicated bus bays and two associated shared user path underpasses would be provided along Wakehurst Parkway, improving bus safety and reducing conflict between stopped buses and general traffic.

'Do something cumulative' scenario

In the 'Do something cumulative' scenario, bus travel times would generally be maintained during the PM peak, compared to the 'Do something' scenario. In the AM peak, when compared with the 'Do something' scenario, there would be some localised impacts on travel times due to the increased demand created by the Western Harbour Tunnel, with increased intersection delays along Warringah Road and Wakehurst Parkway.

The 'Do something cumulative' scenario would reduce traffic demand heading to the Sydney CBD and employment centres like Macquarie Park via the alternative Warringah Road and Eastern Valley Way corridors to the west and south of Frenchs Forest. Both corridors carry regional and local buses, and these services would benefit from improved travel times and reliability as result of reduced congestion.

Impacts on active transport

'Do something' scenario

Under the 'Do something' scenario, the following changes to the active transport network within the Frenchs Forest and surrounds area would be carried out as part of the project:

- A new shared user path on the eastern side of Wakehurst Parkway from the northern end of Kirkwood Street to Warringah Road
- A new shared user underpass beneath Wakehurst Parkway near Yarraman Avenue
- A new shared user bridge over the drainage culvert and fauna underpass (constructed as part of the Northern Beaches Hospital road upgrade project) on the eastern side of Wakehurst Parkway about 150 metres south of Warringah Road
- Three new shared user underpasses beneath Wakehurst Parkway, connecting Garigal National Park and Manly Dam Reserve
- Replacement of the existing pedestrian bridge with a new longer pedestrian bridge over Wakehurst Parkway, about 350 metres south of Warringah Road.

The modified and new pedestrian and cycle crossings proposed would improve the safety and connectivity of the active transport network to, from, and within the Frenchs Forest and surrounds area.

'Do something cumulative' scenario

There would be no additional changes to the active transport network under the 'Do something cumulative' scenario when compared to the 'Do something' scenario.

9.5 Environmental management measures

Environmental management measures relating to operational traffic and transport impacts are outlined in Table 9-13.

Table 9-13 Environmental management measures – operational traffic and transport

Ref	Phase	Impact	Environmental management measures	Location*
OT1	Operation	Operational traffic	A review of operational network performance will be carried out 12 months and five years from the opening of the project to confirm the operational impacts of the project on surrounding arterial roads and major intersections. The assessment will be based on updated traffic data at the time and the methodology used will be comparable with that used in Appendix F (Technical working paper: Traffic and transport) of the environmental impact statement. Where required, additional feasible and reasonable mitigation measures will be identified in consultation with Department of Planning, Industry and Environment and the relevant council to manage any additional traffic performance impacts identified during the review of operational network performance.	BL/GHF
OT2	Operation	Impacts on local roads	Where required, Transport for NSW will investigate local area traffic management measures to minimise the impact of the project on the surrounding local road network. Such measures will be determined in consultation with relevant councils and implemented where feasible and reasonable.	BL/GHF

*BL = Beaches Link, GHF = Gore Hill Freeway Connection

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 10

Construction noise and vibration

10 Construction noise and vibration

This chapter considers the potential noise and vibration impacts from the construction of the project and identifies management measures to minimise these impacts. Potential noise and vibration impacts associated with the operation of the project are included in Chapter 11 (Operational noise and vibration).

A detailed noise and vibration assessment has been carried out for the project and is included in Appendix G (Technical working paper: Noise and vibration). The impacts associated with underwater noise are considered in Chapter 13 (Human health) and Chapter 19 (Biodiversity).

The Secretary's environmental assessment requirements as they relate to construction noise and vibration and where in the environmental impact statement these have been addressed, are detailed in Table 10-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to construction noise and vibration are included in Section 10.7.

Table 10-1 Secretary's environmental assessment requirements – construction noise and vibration

Secretary's requirement	Where addressed in EIS
Noise and Vibration – Amenity	
1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must take into consideration and address the redistribution of traffic (including on local feeder roads) and operational plant and equipment, and must include consideration of impacts to sensitive receivers and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	Relevant NSW noise and vibration guidelines used in the assessment are discussed in **Section 10.4.** Impacts from redistribution of traffic (including on local feeder roads) and operational plant and equipment are documented in **Chapter 11** (Operational noise and vibration).
2. An assessment of construction noise and vibration impacts which must address: a. the nature of construction activities (including transport, tonal or impulsive noise–generating works and the removal of operational noise barriers, as relevant);	The nature of construction activities and potential noise and vibration impacts are outlined in **Section 10.6,** while additional detail is provided in **Appendix G** (Technical working paper: Noise and vibration).
b. the intensity and duration of noise and vibration impacts (both air and ground borne). This must include consideration of extended construction impacts associated with ancillary facilities (and the like) and construction fatigue;	The intensity and duration of potential noise and vibration impacts are described in **Section 10.6**, however further detail is provided within **Appendix G** (Technical Working Paper: Noise and vibration).

Secretary's requirement	Where addressed in EIS
	Environmental management measures related to construction fatigue are in **Section 10.7**. Construction fatigue is also discussed in **Chapter 27** (Cumulative impacts).
c. the identification of receivers, existing and likely, during the construction period;	**Section 10.5** outlines the identification of receivers, both existing and likely, while **Section 10.6** outlines potential impacts on such receivers.
d. the nature, sensitivity and impact to receivers;	**Section 10.5** and **Section 10.6** present information on the nature, sensitivity and impact on receivers, however further detail is provided within **Appendix G** (Technical Working Paper: Noise and vibration).
e. the need to balance timely conclusion of noise and vibration–generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic management);	Information regarding the need to balance timely conclusion of noise and vibration-generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic management) is outlined **Section 10.6** as well as within **Appendix G** (Technical Working Paper: Noise and vibration).
f. the potential for works outside standard construction hours, including predicted levels, exceedances, number of potentially affected receivers, and justification for the activity in terms of the Interim Construction Noise Guideline (DECCW, 2009);	**Section 10.6** as well as **Appendix G** (Technical Working Paper: Noise and vibration) present details on the potential (and parameters) for works outside of standard construction hours.
g. a cumulative noise and vibration assessment inclusive of impacts from the project (including concurrent project construction activities);	**Section 10.6** as well as Appendix G (Technical working paper: Noise and vibration) present details on the cumulative noise and vibration assessment inclusive of impacts from the project (including concurrent project construction activities).
h. a cumulative noise and vibration assessment of the impacts from the project and the construction of other relevant development in the vicinity of the proposal;	**Section 10.6** as well as **Appendix G** (Technical working paper: Noise and vibration) presents detail on the cumulative noise and vibration assessment of impacts from the project and the construction of other relevant development in the vicinity of the proposal. **Chapter 27** (Cumulative impacts) assesses the cumulative construction noise and other relevant developments in the vicinity of the proposal.
i. details and analysis of the effectiveness of mitigation measures to adequately manage identified impacts, including	**Section 10.6** and **Appendix G** (Technical working paper: Noise and vibration) present details and analysis of the effectiveness of

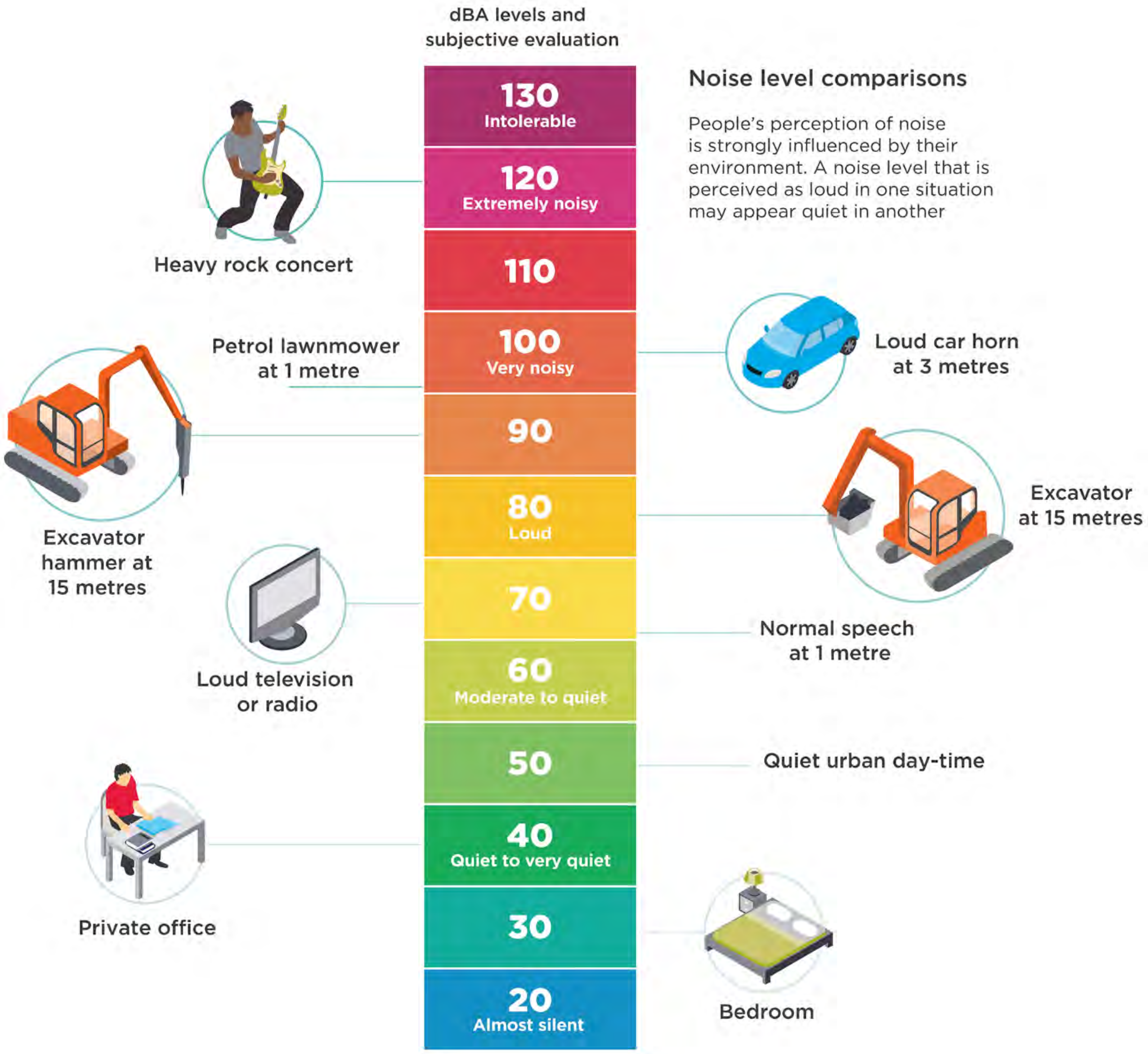
Secretary's requirement	Where addressed in EIS
cumulative impacts as identified in (g) and (h) and a clear identification of residual noise and vibration following application of mitigation measures; and	mitigation measures (as outlined in **Section 10.9**).
j. a description of how community preferences have been taken into account in the design of mitigation measures and consider tailored mitigation, management and communication strategies for vulnerable community members.	**Appendix E** (Technical working paper: Community consultation framework) presents details of how community preferences would be taken into account in the design of mitigation measures and commitments to tailored mitigation, management and communication strategies for vulnerable community members.
3. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	**Section 10.4** and **Section 10.6** outline how blast impacts are capable of complying with respect to relevant guidelines. Further detail is provided within **Appendix G** (Technical Working Paper: Noise and vibration).
Noise and Vibration – Structural	
1. The Proponent must assess construction and operation noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage).	**Section 10.6** as well as **Appendix G** (Technical working paper: Noise and vibration) presents details on the assessment of construction and operation noise and vibration impacts in respect to relevant NSW noise and vibration guidelines as well as the consideration of impacts on the structural integrity of buildings and heritage significance items. **Chapter 11** (Operational noise and vibration) presents information with respect to the operational phase. **Chapter 14** (Non-Aboriginal heritage) presents an assessment of impacts to items of significance as a result of vibration. **Chapter 15** (Aboriginal cultural heritage) provides an assessment of impacts to items of significance as a result of vibration.
2. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	**Section 10.3** and **Section 10.6** outlines how blast impacts are capable of complying with respect to relevant guidelines. Further detail is provided within **Appendix G** (Technical Working Paper: Noise and vibration).

10.1 Acoustic terminology

Common acoustic terms used throughout this chapter and Chapter 11 (Operational noise and vibration) are explained in Table 10-2.

Table 10-2 Acoustic terminology

Term	Definition
Ambient noise	The all-encompassing noise associated within a given environment at a given time, usually composed of sound from all sources near and far.
dB(A)	dB(A) stands for A-weighted decibel, a unit used to measure noise. A summary of noise levels in the context of comparable activities is shown in Figure 10-1 to assist in the interpretation of the noise levels presented in this chapter. In terms of sound perception, a change of 1 dB(A) or 2 dB(A) in the sound pressure level is difficult for most people to detect. A 3 dB(A) to 5 dB(A) change corresponds to a small but noticeable change in loudness. An increase in sound level of 10 dB(A) is perceived as a doubling of loudness. However, individuals may perceive the same sound differently since many factors can influence an individual's response, including: • The specific characteristics of the noise (eg frequency, intensity, duration of the noise event) • Time of day noise events occur • Individual sensitivities and lifestyle • Reaction to an unfamiliar sound • Understanding of whether the noise is avoidable and the notions of fairness.
L_{A90}	L_{A90} is the level of noise exceeded for 90 per cent of the time. The bottom 10 per cent of the sample is the L_{A90} noise level expressed in units of dB(A).
$L_{Aeq(period)}$	$L_{Aeq(period)}$ is the A-weighted equivalent noise level. It is the summation of noise events and integrated over a period of time.
L_{Amax}	L_{Amax} is the maximum A-weighted sound pressure level measured over a given period.
Noise catchment area (NCA)	Noise catchment area is an area where noise and vibration sensitive receivers have similar acoustic environment. Refer to Section 10.3.1 for more information on NCAs.
Rating background level (RBL)	Rating background level is the background noise level in the absence of proposed construction activities. This parameter represents the average minimum noise level during the daytime, evening and night time periods and is used to set the $L_{Aeq(15\ minute)}$ noise management levels for residential receivers.



Note:

- A change of 1 dBA or 2 dBA in the level of a sound is difficult for most people to detect.
- A 3-5 dBA change corresponds to a small but noticeable change in loudness.
- A 10 dBA change corresponds to an approximate doubling or halving in loudness.

Figure 10-1 Noise level comparison

10.2 Legislative and policy framework

Construction noise and vibration from State significant infrastructure projects is regulated by the Department of Planning, Industry and Environment through project approval requirements under the *Environmental Planning and Assessment Act 1979* and by the NSW Environment Protection Authority through environment protection licences issued under the *Protection of the Environment Operations Act 1997*. In addition, the Protection of the Environment Operations (Noise Control) Regulation 2017 includes controls on noise from motor vehicles and marine vessels, while the *Heavy Vehicle (Vehicle Standards) National Regulation (NSW)* includes controls on noise from heavy vehicles.

The *Interim Construction Noise Guideline* (DECC, 2009a) provides guidance on assessing and managing construction noise, and to assist setting conditions in approvals and licences. The guideline covers noise and ground-borne noise impacts (including construction traffic within the construction footprint) and identifies noise management levels that guide the need to apply reasonable and feasible mitigation and management measures to minimise noise impacts. For construction vibration, *Assessing Vibration: a technical guideline* (DECC, 2006) provides guidance on managing the risk of vibration impacts on human comfort.

The *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) integrates and adapts, for Transport for NSW projects, the direction and guidance provided by several other policies, guidelines and standards, including the *Interim Construction Noise Guideline* (DECC, 2009a), *Assessing Vibration: a technical guideline* (DECC, 2006), and Australian criteria for blasting (AS 2187.2 2006 (Standards Australia, 2006)). The *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) is the key document providing guidance for the assessment and mitigation of construction noise and vibration on this project. It is supported by the *NSW Road Noise Policy* (DECCW, 2011), which addresses construction road traffic noise impacts (on public roads) and sleep disturbance, and the *Noise Criteria Guideline* (Roads and Maritime Services, 2015f), which provides an assessment process for construction traffic noise impacts.

10.3 Assessment methodology

10.3.1 Noise sensitive receivers and noise catchment areas

The location and type of noise sensitive receivers near temporary construction support sites, construction sites and haulage routes were identified using a combination of aerial photography and visual inspections. These noise sensitive receivers were then grouped into noise catchment areas (NCAs) along the project alignment, being areas of similar acoustic environments. The noise catchment areas are shown in Figure 10-2 to Figure 10-5.

10.3.2 Background noise monitoring

Noise monitoring was carried out at 47 locations between June 2017 and April 2019 to establish existing background and existing traffic noise levels within the noise catchment areas. The noise monitoring locations are shown in Figure 10-2 to Figure 10-5. Noise monitoring carried out from 2017 is considered representative of the 2020 noise environment and is applicable for the purposes of the construction and operational noise assessment.

Further details of the noise monitoring are provided in Section 2 and Annexure C of Appendix G (Technical working paper: Noise and vibration).

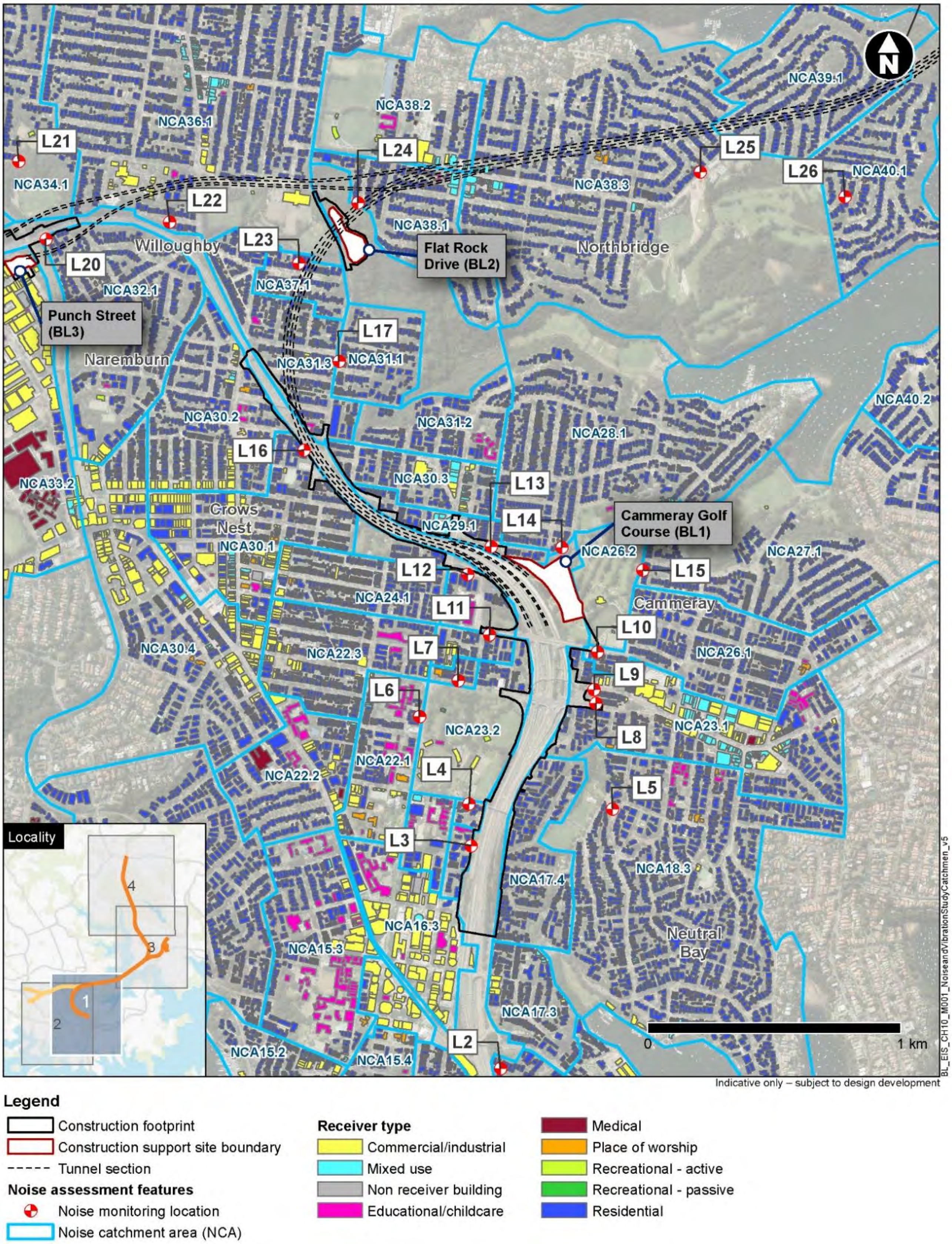


Figure 10-2 Noise catchment areas and monitoring locations (map 1)

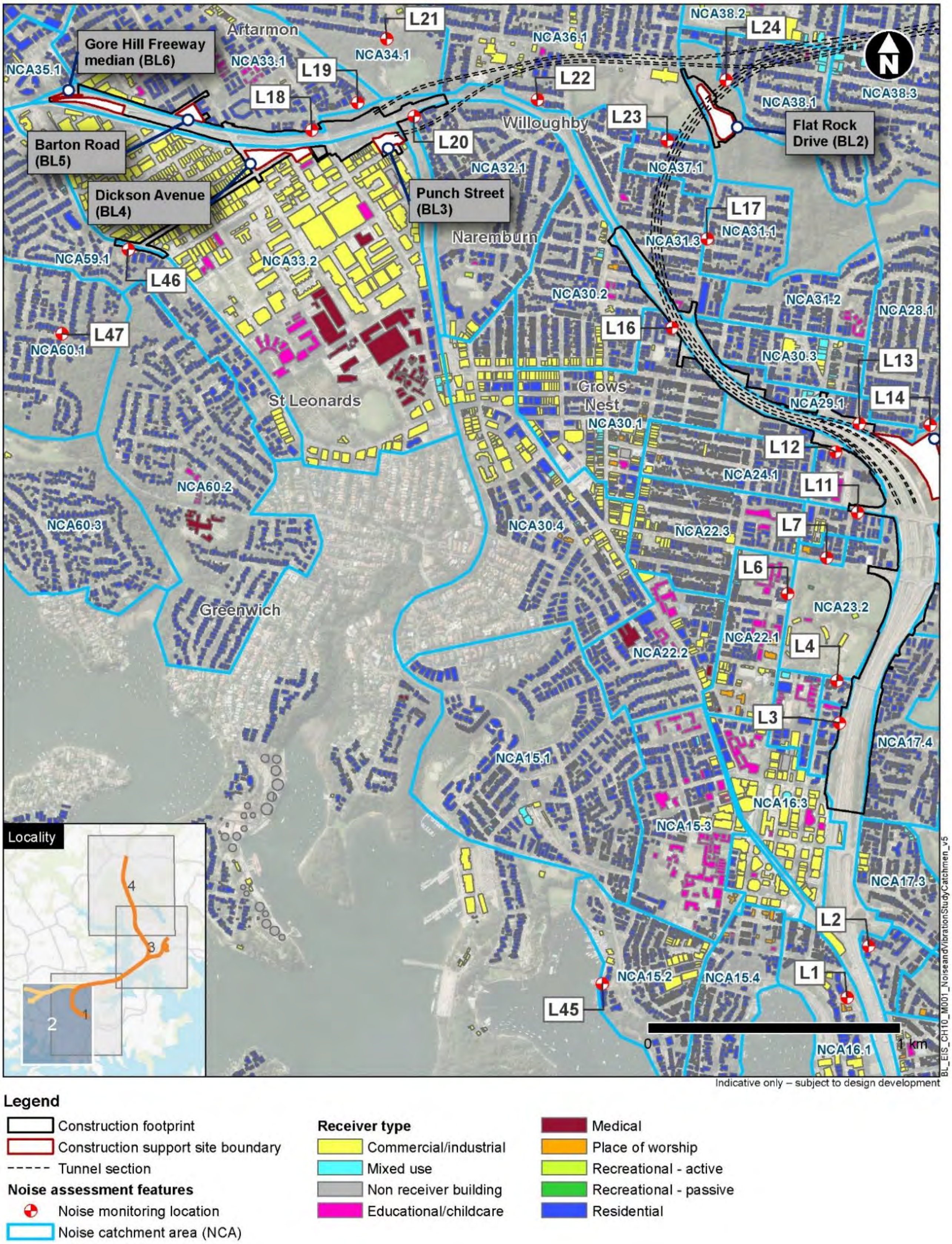
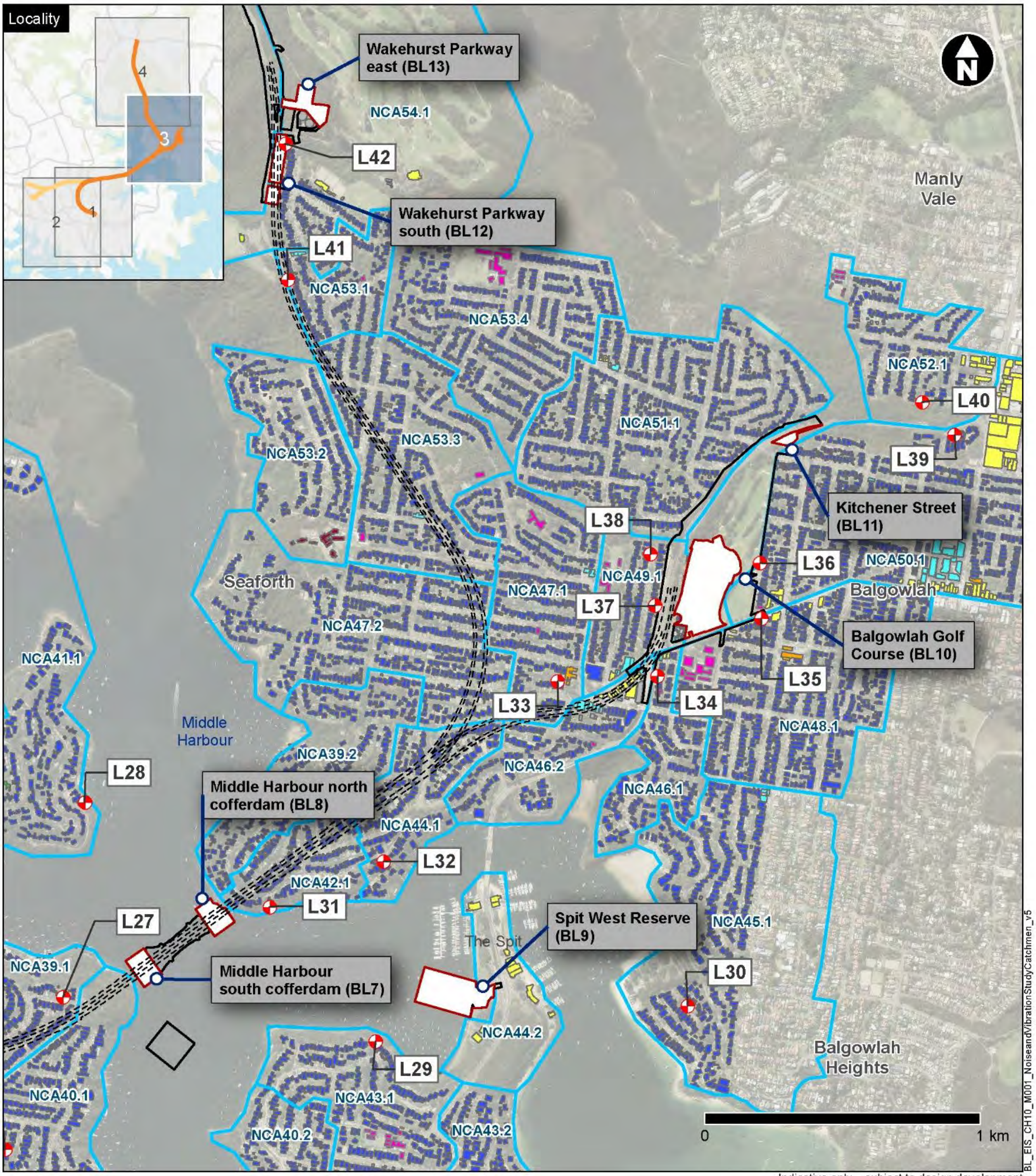


Figure 10-3 Noise catchment areas and monitoring locations (map 2)



Legend

- Construction footprint
- Construction support site boundary
- Tunnel section

Noise assessment features

- Noise monitoring location
- Noise catchment area (NCA)

Receiver type

- Commercial/industrial
- Mixed use
- Non receiver building
- Educational/childcare
- Medical
- Place of worship
- Recreational - active
- Recreational - passive
- Residential

Figure 10-4 Noise catchment areas and monitoring locations (map 3)

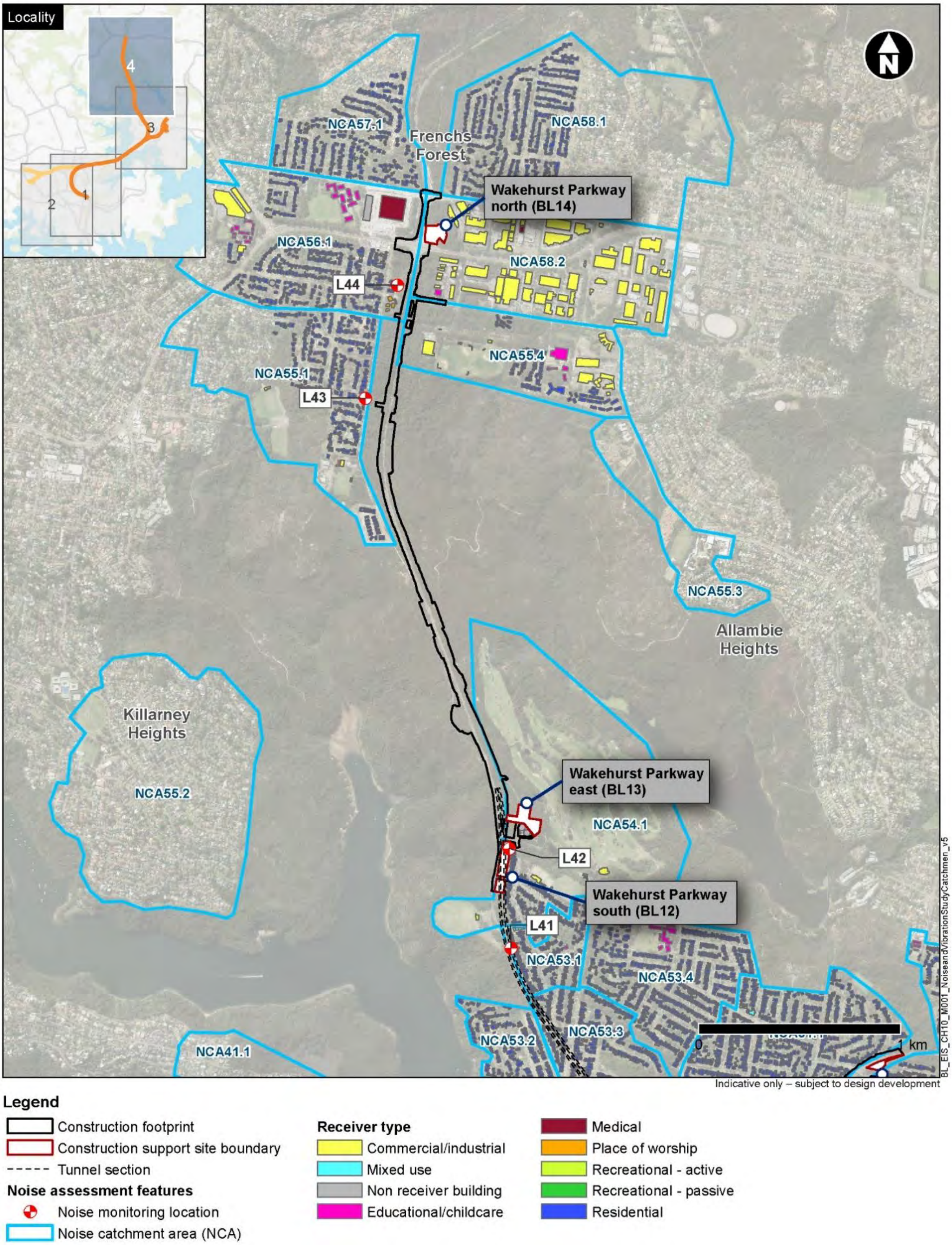


Figure 10-5 Noise catchment areas and monitoring locations (map 4)

10.3.3 Construction noise and vibration assessment

The construction noise and vibration assessment for the project considered the potential impacts associated with airborne noise, ground-borne noise and vibration, and included the following key steps:

- Identification of potentially affected noise and vibration sensitive receivers for each construction area and temporary construction support site
- Determination of noise and vibration objectives for residential and non-residential receivers
- Identification of indicative construction stages/scenarios including locations, working hours and the plant and equipment to be used
- Identification of other nearby construction projects that might also contribute noise levels in areas affected by the project if construction activities occur at the same time (cumulative noise impacts)
- Prediction of construction airborne noise, ground-borne noise, construction traffic noise and vibration impacts for the identified construction stages/scenarios
- Identification of environmental management measures to be implemented to avoid, minimise and mitigate noise and vibration impacts during construction.

For the prediction of airborne noise impacts from temporary construction support sites, consideration was given to realistic worst case construction activities as required by the *Interim Construction Noise Guideline* (DECC, 2009a). The realistic worst case scenario is conservative because it assumes all equipment expected to be used at a given site would be operating simultaneously, at a worst case intensity, and with a worst case orientation during a 15 minute period and at the closest possible location to an affected sensitive receiver. While the realistic worst case scenario might occur, noise levels at any one location would typically vary throughout construction as different plant and equipment is used and the activities move around the works area. Therefore, actual construction noise levels most of the time are likely to be lower than modelled within Appendix G (Technical working paper: Noise and vibration) and presented in this chapter.

For the prediction of airborne noise impacts from surface road works outside temporary construction support sites (eg surface road works in the Warringah Freeway, Gore Hill Freeway Connection surface road works, Balgowlah surface road works and surface road works associated with the connection and realignment and upgrade of the Wakehurst Parkway), consideration was given to both realistic typical and worst case construction noise impact scenarios. The realistic worst case scenarios are used to predict worst case noise impacts in terms of magnitude and distribution that might be expected from a given activity. As stated above, however, this might only occur part of the time and potentially for short durations. The typical impact scenarios were developed to represent the impacts from noise intensive construction activities when the loudest plant and equipment items (eg rock hammers or road saws) are not being used. These scenarios are likely to be more reflective of typical noise impacts that would more commonly occur during a particular construction activity. Figure 10-6 provides an example of how both typical and worst case noise scenarios could occur in a given period of time. The example provided is for utility modification works occurring at night.

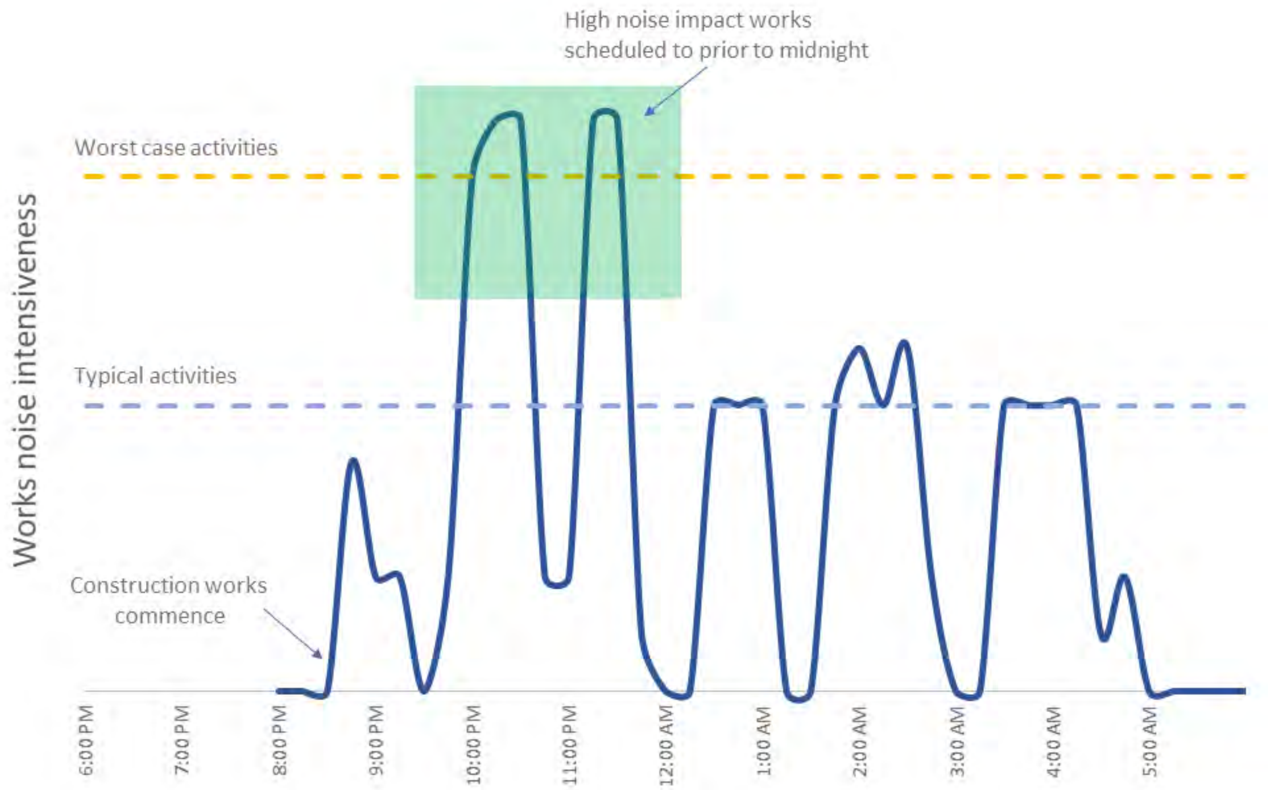


Figure 10-6 Example of noise intensiveness for typical and worst case construction noise impact scenarios

10.4 Assessment objectives and criteria

The construction noise and vibration assessment objectives and criteria applied to the project are summarised in the following sections and consider recommendations provided in the guidelines, policies and standards discussed in Section 10.2.

10.4.1 Airborne noise

Residential receivers

The noise management levels for residential receivers set in accordance with the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) are provided in Table 10-3. Construction noise impacts on residential receivers are assessed using these noise management levels, set with reference to time of day and background noise (Rating Background Level (RBL)). The RBL for each location was determined based on the quietest period of the day, evening or night assessment period in accordance with the *Noise Policy for Industry* (NSW EPA, 2017a). Where noise levels are above the noise management level, reasonable and feasible noise mitigation needs to be considered. Reasonable and feasible noise mitigation includes site specific measures for noise management, mitigation and treatment measures such as construction noise barriers, acoustic sheds, acoustic enclosures, and restricted construction hours and activities.

There is also a highly noise affected level for construction, above which further mitigation needs to be considered, such as additional consultation and notification, additional respite periods, and alternative accommodation.

Table 10-3 Noise management levels at residential receivers

Time of day	Applicable noise management level ($L_{Aeq\ (15\ minute)}$)[1]
Recommended standard construction hours: Monday to Friday 7am to 6pm Saturday 8am to 1pm No work on Sundays or public holidays	Noise affected RBL + 10 dB(A)[2]
	Highly noise affected 75 dB(A)
Outside recommended standard construction hours	Noise affected RBL + 5 dB (A)

Note 1: $L_{Aeq(15\ minute)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a period of 15 minutes
Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities.

As discussed in Chapter 6 (Construction works), recent planning approval conditions for State significant infrastructure projects have included an extension to standard construction hours on Saturdays, allowing certain activities to be carried out until 6pm. This approval condition has been provided on other major infrastructure projects such as Sydney Gateway, M6 Motorway (Stage 1) and WestConnex M4-M5 Link. Should the project construction contractor elect to use this additional allowance on Saturdays, site specific construction noise and vibration impact statements prepared for the project (refer to Section 10.7) would assess any associated noise impacts, and appropriate noise mitigation measures would be adopted accordingly.

Non-residential receivers

The noise management levels for non-residential receivers set in accordance with the *Interim Construction Noise Guideline* (DECC, 2009a) are provided in Table 10-4. These levels apply only during hours when the non-residential premises are being used.

The difference between an internal noise level and the external noise level is assumed to be 10 dB(A), which provides a conservative assumption that windows are open for ventilation. Buildings where windows are fixed or cannot otherwise be opened may achieve a greater noise level performance.

Table 10-4 Noise management levels at other noise sensitive land uses

Land use	Where objective applies	Noise management level $L_{Aeq\ (15\ minute)}$[1]
Classrooms at schools, and other educational institutions	Internal noise level	45 dB(A)[2]
Hospital wards and operating theatres	Internal noise level	45 dB(A)
Places of worship	Internal noise level	45 dB(A)
Childcare centre	External noise level	50 dB(A)
Active recreation areas (eg sports fields/activities which generate their own noise and are generally less sensitive to external noise)	External noise level	65 dB(A)
Passive recreation areas (eg area used for low intensity and low noise producing activities which could be impacted by external noise such as reading or meditation)	External noise level	60 dB(A)

Land use	Where objective applies	Noise management level $L_{Aeq\ (15\ minute)}$[1]
Community centres	Depends on the intended use of the centre	Refer to the 'maximum' internal levels in AS2107 for specific uses
Commercial premises (including offices and retail outlets)	External noise level	70 dB(A)
Industrial premises	External noise level	75 dB(A)
Special noise and/or vibration sensitive (eg laboratories, recording studios)	Depends on the intended use	Refer to the 'maximum' internal levels in AS2107 for specific uses.

Note 1: $L_{Aeq(15\ minute)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a period of 15 minutes
Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities.

Sleep disturbance criterion

A night time sleep disturbance 'screening criterion' noise goal of RBL + 15 dB(A) is used to identify the receivers where there is potential for sleep disturbance.

Where the sleep disturbance screening criterion is exceeded, further assessment is conducted to determine whether the 'awakening reaction' level of L_{Amax} 65 dB(A) would be exceeded and the likely number of these events. The awakening reaction level is the level above which sleep disturbance is considered likely.

Definition of 'feasible and reasonable'

As defined by the *Noise Policy for Industry* (NSW EPA, 2017a) a feasible mitigation measure is one that can be engineered and is practical to build and/or implement given project constraints such as safety, maintenance and reliability requirements and may also include options such as amending operational practices. Selecting reasonable measures from those that are feasible involves judging whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects, including the cost of the mitigation measure. Noise impacts, noise mitigation benefits, cost effectiveness of noise mitigation and community views are considered when making this judgement.

10.4.2 Construction traffic noise

For locations within the construction footprint, where noise levels would increase by more than 2 dB(A) due to maximum construction traffic volumes or a temporary detour due to a road closure, further assessment was completed as per the *Noise Criteria Guideline* (Roads and Maritime, 2015f).

10.4.3 Ground-borne noise

Ground-borne noise is generated by vibration transmitted through the ground into a structure and is more likely to be noticeable during the evening and night periods, when masking by airborne noise is less likely. Ground-borne noise objectives set in accordance with the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) are provided in Table 10-5.

Table 10-5 Ground-borne noise objectives

Receiver type	Ground-borne noise objectives ($L_{Aeq(15\ minute)}$)[1]
Residential (day – 7am to 6pm)	Not applicable
Residential (evening – 6pm to 10pm)	40 dB(A)[2] internal
Residential (night – 10pm to 7am)	35 dB(A) internal
Hospital wards and operating theatres	45 dB(A)
Childcare centres	40 dB(A)
Classrooms at schools and other educational institutions	45 dB(A)
Places of worship	45 dB(A)
Community centre	45 dB(A)
Commercial premises (including offices)	50 dB(A)
Commercial premises (including retail outlets)	55 dB(A)
Other noise-sensitive receivers	Refer to the 'maximum' internal levels in AS/NZS 2107 for specific uses

Note 1: $L_{Aeq(15\ minute)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a period of 15 minutes

Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities.

10.4.4 Vibration

For assessment purposes, a conservative vibration damage screening level for structurally sound structures of 7.5 mm/s (peak particle velocity) has been adopted to identify where further investigation is required. For structures where the screening level is predicted to be exceeded, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure would be done during further construction planning to determine the applicable safe vibration level and approach to construction near the structure.

A conservative vibration damage screening level of 2.5 mm/s has also been adopted for heritage items. Where vibration at any heritage structure is predicted to exceed the screening level, the structure would be investigated during further construction planning to determine the susceptibility of the structure to vibration-induced damage. A site-specific construction approach would be developed to minimise the potential for damage and implemented during vibration intensive activities in the vicinity as required.

The recommended minimum working distances for construction plant in Table 10-6 consider both human comfort and impacts to structures and are referenced from the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a), British Standard *BS 7385 Part 2–1993 Evaluation and measurement for vibration in buildings Part 2* (British Standards Institution, 1993), German Standard *DIN 4150: Part 3–1999 Structural vibration – Effects of vibration on structures* (German Institute for Standardisation, 1999) and the United States Department of Transportation *Federal Transit Administration Noise and Vibration manual* (FTA, 2018).

Where specified construction plant and equipment is used at greater distances from receiver locations than the specified safe working distance, there is negligible risk of structural damage or impacts to human comfort outside of the construction site. Where vibration intensive activities are required within the recommended minimum working distances, more detailed consideration of potential vibration impacts and the construction approach would occur during further design development and construction planning.

Table 10-6 Recommended minimum working distances for vibration intensive plant and equipment

Plant and equipment	Rating description	Minimum working distance in metres		
		Potential for cosmetic damage impacts		Potential for human response impacts[3] (outside construction site)
		Structurally sound[1] (eg residential and light commercial)	Structurally unsound[2] (eg unsound heritage structures)	
Vibratory roller	< 50kN (typically 1-2t)	5	11	15-20
	< 100kN (typically 2-4t)	6	13	20
	< 200kN (typically 4-6t)	12	15	40
	< 300kN (typically 7-13t)	15	31	100
	> 300kN (typically 13-18t)	20	40	100
	> 300kN (typically >18t)	25	50	100
Compactor	32t (non-vibratory)	15	30	40
Bulldozer	70t bulldozer with ripper	2	10	20
Excavators	< 30t (travelling/digging)	10	15	15
Small hydraulic hammer	300kg on 5-12t excavator	2	5	7
Medium hydraulic hammer	900kg on 12-18t excavator	7	15	23
Large hydraulic hammer	1600kg on 18-34t excavator	22	30	73
Vibratory pile driver	Sheet piles	2-20	5-30	20-50
Impact piling hammer	Typical driven pile[4]	20	30	110
	338kJ per stroke (23t hammer with 1.5m stroke)	70	140	330
Pile boring	≤800mm	2	5	N/A
Jackhammer	Hand held	1	3	5
Roadheader	Tunnelling	5	5	10
Rock drilling	Tunnelling	5	5	10
Hydraulic hammer	Tunnelling (35t excavator benching with large rock–hammer)	10	20	50
Truck traffic	On uneven construction haul roads	5	10	20

Plant and equipment	Rating description	Minimum working distance in metres		
		Potential for cosmetic damage impacts		Potential for human response impacts[3] (outside construction site)
		Structurally sound[1] (eg residential and light commercial)	Structurally unsound[2] (eg unsound heritage structures)	
Blasting operations	Over irregular surfaces	To be determined during test blasts to establish appropriate propagation characteristics for the site and increase the accuracy of blasting predictions		

Note 1: Criteria referenced from British Standard BS 7385 Part 2–1993 Evaluation and measurement for vibration in buildings Part 2 (British Standards Institution, 1993)
Note 2: Criteria referenced from German Standard DIN 4150 Structural Damage – Safe Limits for Short–term Building Vibration (including heritage items) (German Institute for Standardisation, 1999)
Note 3: Criteria referenced from Assessing Vibration: a technical guideline (DECC, 2006)
Note 4: Referenced to a 'typical' pile driver (impact) taken from US Department of Transportation Federal Transit Administration Noise and Vibration manual (FTA, 2018).

10.4.5 Blasting noise and vibration management levels

Underground blasting may be used for discrete elements of subsurface excavation. Controlled blasting has also been identified as an alternative to rock hammering in deep cut areas along the Wakehurst Parkway.

Criteria from AS 2187.2-2006 *Explosives - Storage and use - Part 2 Use of explosives* (Standards Australia, 2006) have been adopted for the project, including recommended limits for structural damage and human comfort, blasting operation hours, and underwater pressure. This is considered to be the appropriate blasting criteria for linear civil construction projects and has been included as a condition of approval on all stages of the WestConnex program of works. The limits for structural damage and human comfort presented in AS 2187.2-2006 are similar to those presented in the *Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration* (ANZEC, 1990) for long term projects, but AS 2187.2-2006 provides further guidance for consideration of the duration of blasting within a project where only a small amount of blasting is required or blasting may occur for less than one year.

10.5 Existing noise environment

The existing acoustic environment of the construction footprint and surrounds varies. The areas surrounding the construction footprint are mostly residential, except for clusters of commercial and industrial receivers around Artarmon and Frenchs Forest.

The acoustic environment in these residential areas is mostly influenced by noise from major roads. Traffic volumes on these major roads, and resulting noise levels, are generally highest in the morning between 7am and 9am, and lowest between 2am and 3am. Traffic noise on major roads during periods of high traffic volumes is generally continuous, rather than intermittent.

Noise generated by commercial and industrial areas influences the acoustic environment and contributes to higher ambient noise levels in some locations, masking road traffic noise.

The results of the noise monitoring for background and ambient traffic noise levels for the project are provided in Table 10-7. The location of noise monitoring surveys and noise catchment areas are shown on Figure 10-2 to Figure 10-5. The background noise levels are typical of urbanised environments with daytime background noise levels ranging from 36 dB(A)(L_{A90}) to 73 dB(A)(L_{A90}), and in most cases several decibels quieter during the evening period. Night time background noise levels are variable, from around 27 dB(A)(L_{A90}) to 55 dB(A)(L_{A90}) depending on the proximity of receiver locations to 24 hour noise sources such as major transport corridors and industrial developments.

A comparison of noise levels to various activities is show in Figure 10-1 to assist in the interpretation of the noise levels presented in this chapter.

Table 10-7 Background and ambient traffic noise monitoring

Suburb	NCA	Noise monitoring location	Rating background level (dB(A))[1](L_{A90})[2] - Day (7am to 6pm)	Rating background level (dB(A))[1](L_{A90})[2] - Evening (6pm to 10pm)	Rating background level (dB(A))[1](L_{A90})[2] - Night (10pm to 7am)	Existing road noise level (dB(A)) - Day (7am to 10pm) ($L_{Aeq(15\ hour)}$)[3]	Existing road noise level (dB(A)) - Night (10pm to 7am) ($L_{Aeq(9\ hour)}$)[4]
Milsons Point	16.1	Location L1	60	60	50	–	–
McMahons Point	15.2	Location L45	42	41	38	–	–
Kirribilli	17.2	Location L2	55	54	45	62	58
North Sydney	19.1	Location L3	73	71	55	79	74
	20.1	Location L4	52	52	45	60	54
	22.1	Location L6	52	47	36	67	61
Neutral Bay	18.3	Location L5	54	52	43	–	–
	23.1	Location L8	61	54	44	71	68
	23.1	Location L9	58	54	44	74	70
Cremorne	27.1	Location L15	49	48	39	–	–
Cammeray	26.1	Location L10	58	54	41	71	65
	21.1	Location L11	56	52	37	70	64
	25.1	Location L12	58	55	43	64	59
	29.1	Location L13	64	63	47	70	66
	28.1	Location L14	47	45	37	–	–
Crows Nest	21.1	Location L7	53	49	41	70	66
	30.1	Location L16	58	56	38	65	60

Suburb	NCA	Noise monitoring location	Rating background level (dB(A))[1](L_{A90})[2] - Day (7am to 6pm)	Rating background level (dB(A))[1](L_{A90})[2] - Evening (6pm to 10pm)	Rating background level (dB(A))[1](L_{A90})[2] - Night (10pm to 7am)	Existing road noise level (dB(A)) - Day (7am to 10pm) ($L_{Aeq(15\ hour)}$)[3]	Existing road noise level (dB(A)) - Night (10pm to 7am) ($L_{Aeq(9\ hour)}$)[4]
Naremburn	31.1	Location L17	56	49	37	73	67
	32.1	Location L20	59	55	40	65	61
	37.1	Location L23	45	44	34	–	–
Artarmon	33.1	Location L18	67	63	46	74	69
	33.1	Location L19	55	53	40	61	57
	34.1	Location L21	44	44	37	–	–
Greenwich	59.1	Location L46	60	55	40	72	66
Lane Cove	60.1	Location L47	39	37	31	–	–
Willoughby	36.1	Location L22	50	48	38	–	–
Northbridge	38.1	Location L24	52	48	37	–	–
	38.3	Location L25	43	40	36	–	–
	40.1	Location L26	37	37	33	–	–
	39.1	Location L27	37	34	28	–	–
Castlecrag	41.1	Location L28	36	32	27	–	–
Mosman	43.1	Location L29	45	43	36	–	–
Clontarf	45.1	Location L30	40	38	33	–	–

Suburb	NCA	Noise monitoring location	Rating background level (dB(A))[1](L_{A90})[2] - Day (7am to 6pm)	Rating background level (dB(A))[1](L_{A90})[2] - Evening (6pm to 10pm)	Rating background level (dB(A))[1](L_{A90})[2] - Night (10pm to 7am)	Existing road noise level (dB(A)) - Day (7am to 10pm) ($L_{Aeq(15\ hour)}$)[3]	Existing road noise level (dB(A)) - Night (10pm to 7am) ($L_{Aeq(9\ hour)}$)[4]
Seaforth	42.1	Location L31	42	38	36	–	–
	44.1	Location L32	50	49	40	–	–
	47.1	Location L33	43	39	30	–	–
	49.1	Location L37	45	42	31	56	51
	49.1	Location L38	43	40	33	54	49
	53.1	Location L41	48	39	28	68	61
	54.1	Location L42	45	39	29	55	50
Balgowlah	46.1	Location L34	58	54	37	67	64
	48.1	Location L35	55	50	32	73	71
	50.1	Location L36	47	45	35	55	52
	50.1	Location L39	47	45	30	55	51
Manly Vale	52.1	Location L40	49	45	36	61	56
Frenchs Forest	55.1	Location L43[5]	46	40	30	58	50
	56.1	Location L44[5]	53	48	34	–	–

Note 1: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 2: L_{A90} is the level of noise exceeded for 90 per cent of the time. The bottom 10 per cent of the sample is the L_{A90} noise level expressed in units of dB(A)
Note 3: $L_{Aeq(15\ hour)}$ is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a 15 hour period (7am to 10pm).
Note 4: $L_{Aeq(9\ hour)}$ is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a 9 hour period (10pm to 7am)
Note 5: Adopted from the Northern Beaches Hospital, Connectivity and Network Enhancements, Stage 2 project EIS (Roads and Maritime Services, 2015a). See Appendix G (Technical working paper: Noise and vibration) for further detail.

10.6 Assessment of potential impacts

10.6.1 Overview

This section provides an assessment of the potential noise and vibration impacts associated with the construction work areas and temporary construction support sites for the project.

For each area or site the key outcomes of the assessment for construction airborne noise, ground-borne noise (where relevant), road traffic noise and construction vibration are presented.

10.6.2 Mainline and ramp tunnelling ground-borne noise, vibration and blasting impacts

Ground-borne noise impacts

Ground-borne L_{Aeq} noise levels have been calculated for receiver buildings located above the mainline tunnels, and above tunnel on and off ramps to the mainline tunnels.

The number of buildings potentially exposed to ground-borne noise above the noise management levels during roadheader tunnelling and other subsurface activities are provided in Table 10-8. The number of buildings reported are based on the peak noise levels that a receiver building would be exposed to when the roadheader is at its closest point to the property.

The results show the following:

- Up to 107 residential receivers could experience ground-borne noise levels between 35 and 40 dB(A) from roadheader tunnelling, which would exceed the night time ground-borne noise management levels, but not the evening ground-borne noise management levels. The majority of these residential receivers are within Seaforth. However, exceedances of this magnitude are very small and unlikely to result in significant amenity impacts to affected sensitive receivers
- Other sensitive receiver buildings and commercial and industrial buildings are not predicted to experience ground-borne noise levels above their relevant ground-borne noise management level.

Ground-borne noise from excavation with roadheaders along the majority of the tunnel alignment would be audible only while the roadheader is directly beneath a particular sensitive receiver. Depending on the location of the receiver and the distance to the tunnel excavation location, ground-borne noise could be audible for a number of weeks as the tunnelling approaches and then moves away. Variation in ground-borne noise with the progression of works is illustrated in Figure 10-7. It is noted, however, that affected sensitive receivers might experience ground-borne noise on multiple occasions associated with excavation of each tunnel tube, and other subsurface excavations such as ventilation shafts, cross passages and niches for tunnel operational infrastructure.

Rock hammers are proposed to be used for clearing the bench of the tunnel and would follow behind the roadheader. Rock hammers might also be required for other subsurface excavations, such as niches and trenches for tunnel operational infrastructure. Table 10-8 shows there are more receivers that could be impacted during rock hammering than roadheader tunnelling. However, rock hammering work has more scope to be programmed outside evening and night time periods where feasible and reasonable to avoid ground-borne noise impacts during those more sensitive periods. Where rock hammers are required to carry out subsurface excavations that leaves exposed rock that needs ground support, there is potential that some rock hammering might be required outside standard construction hours. Such occurrences are not anticipated to the required frequently.

Where rock hammers are required to be used for subsurface excavations outside standard construction hours, a large number of residential receivers could experience ground-borne noise levels that exceed either the night time ground-borne noise management level of 35 dB(A) or the evening ground-borne noise management level of 40 dB(A) as provided in Table 10-8.

The predictions for the use of rock hammers in the tunnel show the following:

- Up to 531 residential receivers could be exposed to ground-borne noise levels above 45 dB(A). The potentially affected residential receivers are mainly within Seaforth and in particular NCA 53.3 (north of Frenchs Forest Road)
- Eight other sensitive receiver buildings could be ground-borne noise affected (ie above ground-borne noise management level)
- 16 commercial buildings could be ground-borne noise affected during rock hammer tunnelling activities.

Table 10-8 Sensitive receiver buildings potentially affected by ground-borne noise from roadheader rock hammer tunnelling

Suburb	NCA	Roadheader tunnelling					Rock hammer tunnelling				
		Residential receivers			Other sensitive receivers	Commercial /industrial receivers	Residential receivers			Other sensitive receivers	Commercial /industrial receivers
		> 35 to ≤ 40 dB(A)[1]	> 40 to ≤ 45 dB(A)	>45 dB(A)			> 35 to ≤ 40 dB(A)	> 40 to ≤ 45 dB(A)	>45 dB(A)		
North Sydney	23.2	–	–	–	–	–	–	1	–	–	–
Neutral Bay	23.1	–	–	–	–	–	–	–	–	–	–
Crows Nest	24.1	–	–	–	–	–	2	–	–	–	–
	30.1	–	–	–	–	–	28	28	18	1	–
Cammeray	25.1	5	–	–	–	–	11	13	29	–	–
	28.1	–	–	–	–	–	3	5	1	–	–
	29.1	3	–	–	–	–	13	18	32	–	–
	30.3	–	–	–	–	–	15	11	1	1	–
	31.2	–	–	–	–	–	–	–	–	–	–
Cremorne	26.1	–	–	–	–	–	–	–	–	–	–
Naremburn	30.2	–	–	–	–	–	2	–	–	–	–
	31.1	–	–	–	–	–	–	–	–	–	–
	31.3	–	–	–	–	–	111	13	2	1	–
	32.1	15	–	–	–	–	11	8	28	–	–
	37.1	–	–	–	–	–	32	19	–	–	–

Suburb	NCA	Roadheader tunnelling					Rock hammer tunnelling				
		Residential receivers			Other sensitive receivers	Commercial /industrial receivers	Residential receivers			Other sensitive receivers	Commercial /industrial receivers
		> 35 to ≤ 40 dB(A)[1]	> 40 to ≤ 45 dB(A)	>45 dB(A)			> 35 to ≤ 40 dB(A)	> 40 to ≤ 45 dB(A)	>45 dB(A)		
Artarmon	33.1	–	–	–	–	–	2	1	–	–	–
	33.2	–	–	–	–	–	–	–	–	–	–
	34.1	–	–	–	–	–	-	–	–	–	–
Willoughby	36.1	1	–	–	–	–	40	29	47	2	1
Northbridge	38.1	–	–	–	–	–	0	4	–	–	–
	38.2	–	–	–	–	–	–	–	–	–	–
	38.3	–	–	–	–	–	25	–	–	–	–
	39.1	–	–	–	–	–	60	6	–	–	–
	40.1	–	–	–	–	–	15	11	–	–	–
Seaforth	39.2	–	–	–	–	–	17	4	1	–	–
	42.1	–	–	–	–	–	24	59	7	–	–
	44.1	–	–	–	–	–	14	54	40	–	–
	46.2	–	–	–	–	–	19	9	32	–	13
	47.1	–	–	–	–	–	21	3	21	2	–
	47.2	–	–	–	–	–	61	37	6	–	–
	49.1	3	-	–	–	–	16	15	27	-	–
	53.1	26	–	–	–	–	2	9	44	–	–
	53.2	–	–	–	–	–	8	5	5	–	–

Suburb	NCA	Roadheader tunnelling					Rock hammer tunnelling				
		Residential receivers			Other sensitive receivers	Commercial /industrial receivers	Residential receivers			Other sensitive receivers	Commercial /industrial receivers
		> 35 to ≤ 40 dB(A)[1]	> 40 to ≤ 45 dB(A)	>45 dB(A)			> 35 to ≤ 40 dB(A)	> 40 to ≤ 45 dB(A)	>45 dB(A)		
	53.3	42	–	–	–	–	36	44	151	1	–
	54.1	12	–	–	–	–	6	6	33	–	–
Clontarf	46.1	–	–	–	–	-	4	7	6	-	2
Balgowlah	48.1	–	–	–	–	–	–	–	–	–	–
	50.1	–	–	–	–	–	–	–	–	–	–
North Balgowlah	51.1	–	–	–	–	–	–	–	–	–	–
		107	**0**	**0**	**0**	**0**	**638**	**419**	**531**	**8**	**16**

Note 1: dB(A) stands for A-weighted decibel, a unit used to measure noise.

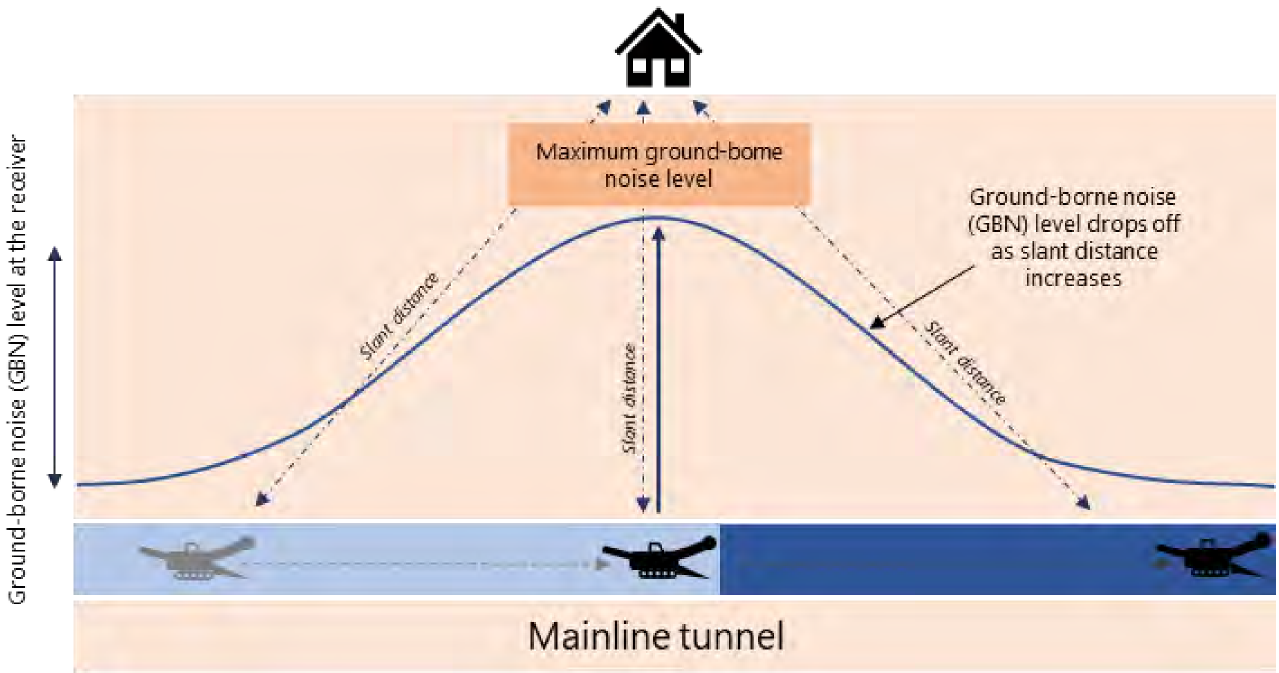


Figure 10-7 Indicative ground-borne noise impacts as tunnelling progresses

Vibration impacts

The number of receiver buildings exceeding the construction vibration screening levels from mainline and ramp tunnelling works is provided in Table 10-9. Vibration impacts from the operation of roadheaders are predicted to be below the vibration limits for human comfort at all receivers. One heritage listed receiver in NCA 33.1 (Artarmon Park potential archaeological deposit (PAD) (45-6-3362)) is located within the minimum working distance for vibration limits for cosmetic damage (unsound structure).

Up to 440 receiver buildings are predicted to be exposed to construction vibration levels above the human comfort criteria (refer to Section 10.4.4) from the operation of rock hammers during tunnelling. For these receivers, standard and additional mitigation measures from the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a) would be implemented, which might include respite. It is noted that vibration is perceived by humans well below levels that could cause property damage.

Vibration levels during rock hammering at two heritage items located in NCA 26.2 (Cammeray Park (including golf course) and NCA 33.1 (Artarmon Park PAD (45-6-3362)) would potentially exceed the vibration screening criterion for cosmetic damage (unsound structure). Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) and Chapter 15 (Aboriginal heritage) for details on the heritage items potentially impacted. Identified heritage items would be further investigated to determine the susceptibility of the items to damage from vibration and to identify appropriate mitigation and management measures as required.

Table 10-9 Number of receiver buildings exceeding construction vibration screening criteria from mainline tunnel construction

Suburb	Noise catchment area	Number of receiver buildings affected by mainline tunnelling	
		Roadheaders	Rock hammers
Risk of structural or cosmetic damage			
	All	–	–
Heritage items requiring further investigation			
Cammeray	26.2	–	1
Artarmon	33.1	1	1
Total heritage items requiring further assessment		**1**	**2**
Buildings with screening level above risk of human comfort			
Cammeray	25.1	–	22
	29.1	–	16
Crows Nest	30.1	–	8
Naremburn	32.1	–	27
Artarmon	33.2	–	1
Willoughby	36.1	–	41
Seaforth	42.1	–	6
	44.1	–	31
	46.2		35
	47.1	–	22
	47.2	-	4
	49.1	–	25
	53.1	–	36
	53.2	–	3
	53.3	–	124
	54.1	–	32
Clontarf	46.1	-	7
Total buildings with screening level above risk of human comfort		**0**	**440**

Impacts from blasting

Blasting may be occasionally required during mainline tunnelling or excavation works.

There are two main impacts from blasting:

- Overpressure travelling as an airwave causing a vibration response in structures such as buildings
- Ground vibration transmitted through the ground that surrounds the blast.

Overpressure and ground vibration have the potential to cause discomfort or annoyance to sensitive receivers near the blast area. At high levels, overpressure and ground vibration have the potential to cause structural damage to building structures.

Blasting might, however, avoid the need to carry out vibration intensive activities, such as excavation with rock hammers, for long durations, thereby avoiding the associated amenity issues due to noise and vibrations. Blasting can, therefore, provide a lower impact alternative to traditional excavation methods. Blasting has been carried out safely and in compliance with the relevant criteria on other recent tunnelling projects in Sydney.

Where blasting is proposed during construction planning, potential overpressure and ground vibration impacts from blasting would be managed through site and blast specific assessments. Overpressure and vibration would be predicted during blast design, which would include test blasts to establish and develop site rules and confirm appropriate blast charges and configurations to ensure the objectives and criteria identified in AS 2187.2-2006 *Explosives – Storage and use – Part 2 Use of explosives* (Standards Australia, 2006) are achieved. All blasting and associated activities would be carried out in a manner that would not generate unacceptable noise and vibration impacts or pose a significant risk to nearby structures and sensitive receivers in accordance with the environmental management measures outlined in Section 10.7.

Controlled blasting proposed for Wakehurst Parkway surface road works is discussed in Section 10.6.15.

10.6.3 Warringah Freeway surface road works

Construction works summary

The following works would be required to connect Beaches Link to the Warringah Freeway:

- Construction of Beaches Link cut and cover portal structures and completion of associated ramps and works to tie-in to surface roads
- Upgrade drainage infrastructure at the connection to the Warringah Freeway.

During the works the Cammeray Golf Course construction support site (BL1) would be the main support site. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-10 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels during a typical and realistic worst case construction noise intensive work scenario.

As noted previously, for the prediction of airborne noise impacts from construction sites, consideration was given to realistic worst case construction activities as required by the *Interim Construction Noise Guideline* (DECC, 2009a). While the noise levels for the realistic worst case might occur at a sensitive receivers during the works, noise levels associated with the typical scenario would occur more frequently.

No receivers are predicted to be highly noise affected (ie predicted noise levels greater than 75 dB(A)) during typical works, however up to six residential receiver buildings in NCAs 23.2 and 25.1 (within Cammeray, on the western side of the Warringah Freeway) are predicted to be highly noise affected during worst case works when rock hammers are operating for the portal (northbound) construction works.

During standard working hours:

- No receivers are predicted to exceed the noise management level during typical works
- Up to 18 residential receiver buildings are predicted to experience noise levels of up to 20 dB(A) above the noise management level during worst case works.

During cut and cover portal structures works at night:

- Up to 148 residential receiver buildings are predicted to experience noise levels greater than the noise management level during paving and asphalting road works activities
- Up to 1917 receiver buildings would experience noise levels greater than the noise management level during worst case works.

The most likely source of potential sleep disturbance would be from airbrakes or metal rattling during night construction works. The predicted maximum noise levels show exceedances of the sleep disturbance screening levels as follows:

- During typical works, operations such as airbrakes may exceed the sleep disturbance screening level at up to 65 receiver buildings. Noise levels may exceed the awakening reaction levels at up to eight receiver buildings, with the highest number of exceedances occurring in NCAs 23.2, 24.1 and 25.1 (within Cammeray and Crows Nest, on the western side of the Warringah Freeway)
- During the worst case construction activities, up to 692 receiver buildings may exceed the sleep disturbance screening level. Noise levels may exceed the awakening reaction level at up to 46 receiver buildings.

Construction noise levels at non-residential receivers are not predicted to exceed the noise management levels during typical construction works.

For worst case activities, noise management level exceedances may occur at the following non-residential receivers:

- One childcare receiver with buildings located in NCA 28.1 (KU Cammeray Preschool)
- One educational receiver with buildings located in NCA 25.1 (ANZAC Park Public School)
- One recreational receiver in NCA 25.1 (ANZAC Park).

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-10 Number of residential receiver buildings over the noise management levels during Warringah Freeway surface road works (typical and realistic worst case scenarios)

Stage activity	Scenario	Highly noise affected >75 dB(A)[3] L_{Aeq}[1]		Day (standard construction hours) L_{Aeq}			Day (out of hours) L_{Aeq}				Evening L_{Aeq}				Night L_{Aeq}				Sleep disturbance L_{Amax}[2]	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Portal structures/ramps (northbound)	Typical	0	0	0	0	0	6	0	0	0	2	4	0	0	113	29	6	0	65	8
	Worst case	6	6	16	2	0	180	16	2	0	266	39	6	0	1146	710	54	7	692	46
Portal structures/ramps (southbound)	Typical	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	10	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

Depending on the detailed construction methodologies and programs, works on Warringah Freeway associated with both the Beaches Link and Gore Hill Freeway Connection project and Western Harbour Tunnel and Warringah Freeway Upgrade might be required at the same time in close proximity. Elevated noise levels from both projects might affect the same sensitive receivers. If this occurs, those receivers might experience amenity impacts over extended durations (construction fatigue). Also, works outside standard construction hours might be scheduled for both projects so that affected receivers do not get appropriate respite. In order to avoid these cumulative impacts, the project would consider and manage construction activities with consideration of amenity of the affected receivers, and would coordinate works outside standard construction hours with the Western Harbour Tunnel and Warringah Freeway Upgrade works where feasible and reasonable to provide affected revivers with appropriate respite Cumulative airborne construction noise impacts would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate the construction of the project, and construction vehicle movements associated with the Warringah Freeway surface road works are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Construction ground-borne noise

Ground-borne noise levels have the potential to be generated by vibration intensive works at the surface road works. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Vibration intensive activities such as rock hammering could be required as part of the Warringah Freeway surface road works. Table 10-11 shows the number of properties that fall within the minimum working distances for the Warringah Freeway surface road works, two of which are identified heritage items (Cammeray Park (including Golf Course) and Northern Suburbs Ocean Outfall Sewer). The locations of the properties and heritage items are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) for details on the heritage items potentially impacted.

Table 10-11 Number of receiver buildings within minimum working distances for vibration intensive work – Warringah Freeway surface road works

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item[1]	Sound structure	
24.1	–	–	2
23.2	–	1	1
25.1	–	6	19
26.2	2	–	–
29.1	–	–	2

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.4 Cammeray Golf Course (BL1)

Construction works summary

The Cammeray Golf Course construction support site (BL1) is located within the north-west portion of the Cammeray Golf Course. This site will have been previously utilised by the Western Harbour Tunnel and Warringah Freeway Upgrade project. This site would then be used for the construction and fitout of the project's motorway facilities at the Warringah Freeway and would provide tunnel and construction support for the Beaches Link component of the project. Works associated with the establishment, use and demobilisation of the site would occur over three years. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-12 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

Two receivers are predicted to be highly noise affected (ie predicted noise levels greater than 75 dB(A)) during decline piling works. Additionally, during standard construction hours, up to 157 receiver buildings in NCA 29.1 (within Cammeray, on the eastern side of the Warringah Freeway) are predicted to experience noise levels above the noise management level during these works.

Receiver buildings within NCA 28.1 (within Cammeray, on the eastern side of the Warringah Freeway) are expected to be noise affected during standard construction hours throughout most of the construction works at this temporary construction support site. However, construction noise in only expected to be above the daytime noise management level by about 3 dB(A) for the majority of works.

Up to eight receiver buildings in NCA 24.1 (within Crows Nest, on the western side of the Warringah Freeway) and NCAs 26.1 and 28.1 (within Cammeray and Cremorne, on the eastern side of the Warringah Freeway) are predicted to experience noise levels above the noise management level during the night period. This would occur during construction of the cut and cover portals, trough structures, and tunnels, and also during tunnel fitout. Exceedances would be largely due to truck movements as they enter and move along the internal roads within the site to the acoustic shed.

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 69 receiver buildings. However, no receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

For non-residential receivers:

- Up to six receivers are predicted to experience noise levels above the noise management level during access decline piling works. A childcare receiver located in NCA 28.1 (KU Cammeray Preschool) is predicted to experience noise levels above the noise management level by 12 dB(A) during access decline piling and 6 dB(A) during site rehabilitation
- One educational sensitive receiver in NCA 25.1 (ANZAC Park Public School) is up to 2 dB(A) above the noise management level during access decline piling
- Three recreational receivers including the Cammeray Golf Course, Cammeray Playing Field and the Green Park Tennis Courts are predicted to be noise affected. Only the Cammeray Golf Course is predicted to be noise affected by more than 2 dB(A) above the noise management level during any stage of construction.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-12 Number of residential receiver buildings over the noise management levels during construction at Cammeray Golf Course construction support site (BL1) (realistic worst case scenario)

Stage activity	Highly noise affected >75 dB(A)[3] (L_{Aeq}[1])		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Site establishment	0	–	7	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Decline, shed and ventilation excavation and construction	2	–	156	8	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Civil works and tunnel construction	0	0	4	0	0	0	0	0	0	0	0	0	0	8	0	0	0	68	0
Civil works and tunnel fitout and permanent facilities construction	0	0	2	0	0	0	0	0	0	0	0	0	0	7	0	0	0	69	0
Civil works and permanent facilities fitout	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	69	0
Site rehabilitation	0	–	10	3	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

There is potential for cumulative increases of construction noise from concurrent use of Cammeray Golf Course construction support site (BL1) and works associated with the final stages of the Western Harbour Tunnel and Warringah Freeway Upgrade project. Sensitive receivers in the vicinity have the potential to experience elevated noise levels over extended durations due to the use of the adjacent areas for temporary construction support sites by both projects. There is also potential for increased disturbance associated with works outside standard construction hours that these temporary construction support sites would support.

Site specific mitigation measures would be developed for Cammeray Golf Course construction support site (BL1) with the aim of ensuring that relevant noise management levels are met, minimising the potential for construction fatigue. Works outside standard construction hours, and the associated use of Cammeray Golf Course construction support site (BL1) and the temporary construction support sites associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project, would be coordinated where feasible and reasonable to provide the affected receivers with appropriate respite.

Cumulative airborne construction noise impacts would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate the construction of the project, and construction vehicle movements associated with the Cammeray Golf Course construction support site (BL1) are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Night time heavy vehicle movements from this site would be limited to four trucks per night. Since the number of truck movements generated by the site is not significant compared to existing heavy vehicle numbers on the Warringah Freeway, the number of maximum noise events that could disturb sleep are not likely to substantially increase. Additionally, all heavy vehicle haulage access to this construction site during tunnel construction and some civil works, would be directly to and from the Warringah Freeway, which would assist in managing potential noise impacts to nearby residential receivers.

Construction ground-borne noise

For the construction of the tunnel access decline and ventilation tunnels between the temporary construction support site at Cammeray Golf Course (BL1) and the mainline tunnel alignment, ground-borne noise levels are predicted to be below the ground-borne noise management level.

Ground-borne noise may also be generated by vibration intensive works within the temporary construction support site. However, throughout the construction works associated with the temporary construction support site it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby residential receivers.

Construction vibration

The major activities at Cammeray Golf Course construction support site (BL1) that would include vibration intensive works would include piling associated with access decline excavations and acoustic shed installation, and ventilation tunnel construction, where rock hammers and piling rigs may be needed. Table 10-13 shows one heritage item in NCA 26.2 (Cammeray Park (including Golf Course)) is predicted to be within the minimum working distances for major vibration generating activities. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) for further details on the heritage item potentially impacted.

Two receiver buildings within NCA 26.2 (Cammeray) may also be exposed to vibration levels above the human response screening level. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The risk of annoyance is considered low with duration of rock hammering limited to works associated with the surface level decline construction and acoustic shed construction.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-13 Number of receiver buildings within minimum working distances for vibration intensive work – Cammeray Golf Course construction support site (BL1)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item[1]	Sound structure	
26.2	1	–	2

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.5 Gore Hill Freeway Connection surface road works

Construction works summary

The following works would be required as part of the Gore Hill Freeway Connection surface road works:

- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore and Western rail line and T9 Northern rail corridor and the Pacific Highway
- Modifications to the Reserve Road and Hampden Road bridges
- Construction of Beaches Link ramps and cut and cover tunnel access structures
- 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 ancillary facilities, including surface drainage and utility modification works, signage and lighting, CCTV and other traffic management systems, environmental controls and landscape treatments.

The Gore Hill Freeway Connection surface road works also includes the use of the following temporary construction support sites:

- Dickson Avenue site (BL4)
- Barton Road site (BL5)
- Gore Hill Freeway median site (BL5).

The works would take about four years. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-14 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels during typical and realistic worst case construction noise intensive work scenarios.

One residential receiver building in NCA 59.1 (Greenwich) is predicted to experience noise levels greater than 75 dB(A) during typical works at the intersection of Pacific Highway and Dickson Avenue during bus stop relocation, pavement and road modification works. This would occur when works are carried out near the receiver when road saws are in use. Up to eight residential receiver buildings are predicted to experience noise levels greater than 75 dB(A) during worst case works during standard construction hours, which include the use of rock hammers during utility modification works.

For the Gore Hill Freeway Connection surface road works during standard construction hours:

- For typical surface road works, up to eight residential receiver buildings within any one major works area are predicted to exceed the daytime noise management level, however the exceedances would be below 10 dB(A). Notwithstanding, receivers closest to the Gore Hill Freeway would experience existing traffic noise levels above the noise management level. For typical works at temporary construction support sites, no receivers are predicted to exceed the noise management level
- For worst case surface road works, up to 131 residential receiver buildings are predicted to exceed the noise management level. However, the majority of exceedances would be below 10 dB(A) and would occur only during the use of rock hammers or during concrete saw cutting for utility modification works. For worst case works at temporary construction support sites, no receivers are predicted to exceed the noise management level.

Outside standard construction hours:

- For typical surface road works at night time, up to 112 residential receiver buildings are predicted to exceed the noise management level from any one major works area during typical works. For typical works at temporary construction support sites at night time, up to 42 receivers are predicted to exceed the noise management level
- For worst case surface road works, up to 1453 noise affected residential receiver buildings are predicted to exceed the noise management level from any one major works area. The key noise generating activities would be utility modification works, and the use of excavators with rock hammers or concrete saws and pavement/road modifications. When these noise intensive activities are not occurring, the number of potentially noise affected receiver buildings are reduced to only 10 to 20 per cent of the worst case total
- For worst case works at temporary construction support sites at night time, up to 33 residential receiver buildings are predicted to exceed the noise management level for the Dickson Avenue construction support site (BL4), up to 27 residential receiver buildings are predicted to exceed the noise management level for the Barton Road construction support site (BL5) and up to 45 receivers are predicted to exceed the noise management level for the Gore Hill Freeway median temporary construction support site (BL6). The majority of these exceedances would be below 5 dB(A).

The most likely source of potential sleep disturbance from night construction works would be from the use of pneumatic hammers (including rock hammers) or saws during utility modification or road pavement work, or from air brakes from truck movements on site. The predicted maximum noise levels show exceedances of the sleep disturbance screening level across all areas with night construction works for both typical and worst case construction activities as follows:

- Up to 63 receiver buildings are predicted to be above the sleep disturbance screening level during typical construction works
- Up to 19 residential receiver buildings have potential to exceed the awakening reaction level during typical construction works

- Up to 454 receiver buildings are predicted to be above the sleep disturbance screening level during worst case construction activities, with only up to 46 residential receiver buildings have potential to exceed the awakening reaction level during worst case construction work.

For the prediction of airborne noise impacts from construction sites, consideration was given to realistic worst case construction activities as required by the *Interim Construction Noise Guideline* (DECC, 2009a). While the noise levels for the realistic worst case might occur at a sensitive receivers during the works, noise levels associated with the typical scenario occur more frequently.

Noise management level exceedances may occur at the following non-residential receivers:

- Six childcare receivers in NCAs 33.1 and 33.2 (within Artarmon both south and north of the Gore Hill Freeway), three of which are predicted to exceed the noise management level by more than 20 dB(A) during worst case works
- Up to a 5 dB(A) increase at two educational receivers (Artarmon Public School and Thrive Learning Centre, Artarmon) in NCA 33.1 and 33.2 for typical and worst case construction works
- One place of worship in NCA 33.1 (St Basil’s Anglican Church, Artarmon) for worst case construction works only
- One recreational receiver in NCA 59.1 (Coronation Viewpoint, Greenwich) for typical and worst case construction works and up to 17 dB(A) at recreational parks nearby works at Dickson Avenue and the Pacific Highway
- Up to 27 commercial and industrial receivers in NCAs 33.1 and 33.2 ((within Artarmon both south and north of the Gore Hill Freeway) for typical and worst case construction works.

Three childcare centres (Butterflies Early Learning Childcare Centre, Willoughby/Lane Cove Family Day Care and Innovative Early Learning Artarmon) and one commercial receiver are predicted to exceed the noise management level as a result of activities within the temporary construction support sites. However, due to existing ambient noise levels, it is likely that internal spaces are sufficiently acoustically treated to protect internal spaces from construction noise.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-14 Number of residential receiver buildings over the noise management levels during Gore Hill Freeway Connection surface road works (typical and realistic worst case scenarios)

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Gore Hill Freeway median (BL6)	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	63	7
	Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	37	8	0	0	117	12
Barton Road (BL5)	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	9	5	0	0	30	9
	Worst case	0	0	1	0	0	1	0	0	0	3	0	0	0	13	13	1	0	40	14
Dickson Avenue (BL4)	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	9	7	0	0	28	9
	Worst case	0	0	0	0	0	0	0	0	0	0	0	0	0	17	16	0	0	43	16
Gore Hill Freeway eastbound lanes west of Reserve Road	Typical	0	0	3	0	0	2	3	0	0	4	3	0	0	48	18	5	0	30	10
	Worst case	3	3	7	3	0	10	7	3	0	25	8	3	0	192	147	18	5	158	36
Gore Hill Freeway eastbound lanes between Reserve Road and Hampden Road	Typical	0	0	8	0	0	5	8	0	0	6	9	1	0	23	19	9	4	27	19
	Worst case	8	8	12	8	0	13	12	8	0	24	10	9	1	343	100	19	13	126	37

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Gore Hill Freeway eastbound lanes west of Hampden Road	Typical	0	0	1	0	0	0	1	0	0	4	1	0	0	43	33	1	0	40	5
	Worst case	1	1	15	1	0	74	15	1	0	88	20	1	0	883	280	33	1	397	37
Gore Hill Freeway westbound lanes and off ramp west of Hampden Road	Typical	0	0	2	0	0	6	2	0	0	3	6	0	0	18	24	8	0	28	9
	Worst case	2	2	13	2	0	19	13	2	0	17	16	6	0	460	118	24	8	141	32
Gore Hill Freeway westbound lanes and off ramp east of Hampden Road	Typical	0	0	1	0	0	0	1	0	0	1	1	0	0	66	45	1	0	63	2
	Worst case	1	1	19	1	0	124	19	1	0	128	34	1	0	1059	348	45	1	454	46
Modifications to Reserve Road bridge and ramps	Typical	0	0	7	0	0	6	7	0	0	7	9	1	0	36	15	10	3	21	17
	Worst case	7	7	13	7	0	8	13	7	0	17	11	9	1	619	81	15	13	105	33
Beaches Link eastbound portal cut and cover and on ramp	Typical	0	–	1	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	20	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Beaches Link westbound southern portal cut and cover and off ramp west of Hampden Road	Typical	0	0	0	0	0	6	0	0	0	6	1	0	0	27	26	6	0	31	7
	Worst case	0	0	14	0	0	23	14	0	0	19	23	1	0	892	158	26	6	243	35
Beaches Link westbound southern portal cut and cover and off ramp east of Hampden Road	Typical	0	0	0	0	0	0	0	0	0	1	0	0	0	50	24	0	0	34	1
	Worst case	0	0	12	0	0	85	12	0	0	98	15	0	0	817	240	24	0	336	29
Motorway Control Centre construction and tunnel support	Typical	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	10	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Beaches Link westbound northern portal cut and cover and off ramp to Reserve Road	Typical	0	0	0	0	0	0	0	0	0	1	0	0	0	66	23	0	0	37	1
	Worst case	0	0	31	0	0	106	14	0	0	115	18	0	0	978	293	23	0	384	28
Pacific Highway east bus stop relocation, pavement and road modification works	Typical	0	1	1	0	0	5	1	0	0	8	1	1	0	60	15	2	1	8	4
	Worst case	1	2	2	1	0	117	20	1	0	224	47	1	1	677	364	15	3	86	9

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Pacific Highway west pavement and road modification works	Typical	0	–	2	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	3	–	98	2	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities.
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

There is potential for cumulative increases of construction noise from the Gore Hill Freeway Connection surface road works and the construction of the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project, which includes the use of a temporary construction support site at Waltham Street at Artarmon. Sensitive receivers in NCAs 32.1, 33.1 and 36.1 (residential areas of Naremburn, Artarmon and Willoughby in proximity to the surface works areas) have the potential to experience elevated noise levels over extended durations due to the use of the adjacent areas for temporary construction support sites by both projects. There is also potential for increased disturbance associated with works outside standard construction hours associated with the Gore Hill Freeway Connection surface road works and the Warringah Freeway Upgrade.

Site specific mitigation measures would be developed for the Gore Hill Freeway Connection surface road works with the aim of ensuring that relevant noise management levels are met, minimising the potential for construction fatigue. Works outside standard construction hours would be coordinated with the Warringah Freeway Upgrade where feasible and reasonable to provide the affected receivers with appropriate respite.

There is also potential for construction fatigue from the Gore Hill Freeway Connection surface road works and the Sydney Metro City & Southwest (Chatswood to Sydenham) project. This is due to works associated with the Artarmon substation site as part of the Sydney Metro City & Southwest (Chatswood to Sydenham) project and proximity to the project. Notwithstanding, given there would be a twelve month break between the commencement of construction at the Gore Hill Freeway Connection surface road works and the completion of works for the Artarmon substation site, the risk of construction is considered minor and would be managed Cumulative airborne construction noise impacts would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate the construction of the project, and construction vehicle movements associated with the Gore Hill Freeway Connection surface road works and temporary construction support sites are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible. However, temporary construction support sites that have heavy vehicle movements during the night period have the potential to exceed the sleep disturbance screening levels and awakening reaction levels from air brake releases or metal bangs associated with the loads being carried.

Construction ground-borne noise

Ground-borne noise levels have the potential to be generated by vibration intensive works at the surface road works and associated temporary construction support sites. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Table 10-15 shows 16 and 84 receiver buildings fall within the minimum working distances for cosmetic damage (sound structures) and human response, respectively. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). One heritage item within the minimum working distances is a potential archaeological deposit (Artarmon Park PAD (45-6-3362)). It is within the minimum working distance for cosmetic damage (unsound structures), assuming that vibration intensive plant such as a large rock hammer would be used. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 15 (Aboriginal heritage) for details on this potential impacted heritage item.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-15 Number of receiver buildings within minimum working distances for vibration intensive work – Gore Hill Freeway Connection surface road works

Location	NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
		Cosmetic damage		Human response
		Heritage item	Sound Structure	
Gore Hill Freeway eastbound lanes including Epping Road and Pacific Highway on ramps	33.1	–	15	38
	33.2	–	–	32
	35.1	–	1	14
Gore Hill Freeway westbound lanes including the Epping Road and Pacific Highway off ramp	33.1	–	–	8
	33.2	–	1	38
Modifications to Reserve Road bridge and ramps	33.1	–	4	19
	33.2	–	4	25
Beaches Link eastbound portal cut and cover tunnel and on ramp	33.1	1[1]	–	4
Beaches Link westbound southern portal cut and cover tunnel and off ramp to Reserve Road	33.1	1[1]	–	3
	33.2	–	9	43
Beaches Link westbound northern portal cut and cover and off ramp to Reserve Road	33.2	–	2	17
Intersection of Pacific Highway and Dickson Avenue modification works and bus stop relocation	33.2	–	6	18
	59.1	–	3	11

Note 1: Artarmon Park PAD (45-6-3362).

10.6.6 Flat Rock Drive (BL2)

Construction works summary

The Flat Rock Drive construction support site (BL2) is proposed in Flat Rock Reserve, Northbridge, on the eastern side of Flat Rock Drive, opposite to the Bicentennial Reserve Baseball Diamond. The site would support tunnelling. Works associated with the establishment, use and demobilisation of the site would occur over about five years. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-16 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

During standard construction hours three residential receiver buildings in NCAs 36.1, 37.1 and 38.1 (within Willoughby, Naremburn and Northbridge respectively) are predicted to experience noise levels greater than 75 dB(A) during early works and site establishment. An additional residential receiver building would be highly noise affected (greater than 75 dB(A)) during road widening works.

During standard construction hours, up to 174 residential receiver buildings in NCAs 36.1, 37.1 and 38.1 (within Willoughby, Naremburn and Northbridge respectively) are predicted to experience noise levels greater than the relevant noise management level. These exceedances are predicted during utility modification, vegetation clearing, access decline excavation and road modification works.

During night time works, noise levels are predicted to be below the noise management levels except during short-term works associated with the road widening and modification of Flat Rock Drive. Up to 698 residential receiver buildings across several NCAs are predicted to exceed noise management levels during these works. The majority of the exceedances (88 per cent) would be less than 15 dB(A).

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 555 receiver buildings across several NCAs from the short-term road works. Twenty-six of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level. Predicted noise levels are intended to be conservative and represent realistic worst case impacts during the project. Night time works would be minimised to reduce potential impacts where possible. Additionally, the number of heavy vehicle movements during night time periods generated by the site is not substantial compared to existing traffic numbers on Flat Rock Drive.

For non-residential receivers:

- A commercial receiver in NCA 36.1 (within Willoughby, west of Flat Rock Drive) is predicted to experience noise levels above the noise management level during site establishment works and road widening works
- Two childcare receivers in within NCA 36.1 (Tree of Life Early Learning School – Willoughby and Koala Cottage) and one within NCA 30.2 (Catholic Care Naremburn Family Centre) are predicted to experience noise levels above the noise management level during early works
- Five recreational receivers in NCAs 31.1 (Dawson Playground), 36.1 (Bicentennial reserve including Willoughby basketball and netball courts and the Flat Rock Baseball Diamond) and 38.2 (Shore playing fields) are predicted to experience noise levels above the noise management levels during the majority of the construction activities.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-16 Number of residential receiver buildings over the noise management levels during construction at Flat Rock Drive construction support site (BL2) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Early works	1	–	143	31	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	2	–	108	25	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Road widening	1	1	118	27	1	98	33	3	1	103	69	4	1	305	309	79	5	555	26
Piling for access decline and shed	0	–	23	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Access decline construction	0	–	57	8	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Acoustic shed construction	0	–	15	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tunnelling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143	0
Tunnel fitout	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143	0
Site rehabilitation	0	–	28	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

There is potential for cumulative increases of construction noise from concurrent use of Flat Rock Drive construction support site (BL2) and works associated with the final stages of the Western Harbour Tunnel and Warringah Freeway Upgrade project. Sensitive receivers in the vicinity have the potential to experience elevated noise levels over extended durations due to the use of Flat Rock Drive construction support site (BL2) and temporary construction support sites and surface works associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project. There is also potential for increased disturbance associated with works outside standard construction hours carried by both projects.

Site specific mitigation measures would be developed for Flat Rock Drive construction support site (BL2) with the aim of ensuring that relevant noise management levels are met, minimising the potential for construction fatigue. Works outside standard construction hours, and the associated use of Flat Rock Drive construction support site (BL2) and the temporary construction support sites surface works associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project, would be coordinated where feasible and reasonable to provide the affected receivers with appropriate respite.

Cumulative airborne construction noise impacts would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate the construction of the project, and construction vehicle movements associated with the Flat Rock Drive construction support site (BL2) are predicted to increase road traffic noise levels by less than 2 dB(A). Changes of this magnitude are not typically noticeable and are considered to be a minor impact.

Night time heavy vehicle movements to and from this site would be limited to one vehicle per hour (no more than five trucks in total). Since the number of night truck movements generated by the site is insignificant compared to existing heavy vehicle numbers on Flat Rock Drive, the number of maximum noise events that could disturb sleep are not likely to substantially increase.

Construction ground-borne noise

Ground-borne noise could result from the excavation of the tunnel access decline between the Flat Rock Drive construction support site (BL2) and the tunnel alignment. However, due to the terrain and the depth of the tunnel access decline and the resulting slant distances to nearby occupied receiver buildings, no receiver buildings (occupied buildings) are predicted to experience ground-borne noise above the relevant noise management levels from access decline tunnel construction.

Construction vibration

For the Flat Rock Drive construction support site (BL2), the major work stages that may include vibration intensive works are site establishment, road widening, construction of the access decline and acoustic shed, and tunnelling. The results included in Table 10-17 indicate:

- Two buildings within NCAs 36.1 (Willoughby) and 37.1 (Naremburn) west of Flat Rock Drive have been identified within the minimum working distance for cosmetic damage (sound structures)
- One heritage item in NCA 37.1 (Flat Rock Creek PAD (45-6-3361)) is predicted to be within the minimum working distances for cosmetic damage (unsound structures)
- Up to eleven properties may be exposed to vibration levels above the human response screening level (ie residents may feel vibration) from rock hammering during early works and site establishment works.

The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be construction of the tunnel access decline and the use of rock hammers for utility modification during early and site establishment works. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 15 (Aboriginal heritage) for further details on the potentially impacted heritage item.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-17 Number of receiver buildings within minimum working distances for vibration intensive work – Flat Rock Drive construction support site (BL2)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item[1]	Sound structure	
36.1	–	1	3
37.1	1	1	4
38.1	–	–	4

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.7 Punch Street (BL3)

Construction works summary

The Punch Street construction support site (BL3) is proposed within the Artarmon industrial area, adjacent to the rail corridor on the southern side of the Gore Hill Freeway. The site would be a tunnel support and project management site and would be used for the construction of the Gore Hill Freeway Connection and the ramp tunnels for Beaches Link. Works associated with the establishment, use and demobilisation of the site would occur over about three years and nine months. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-18 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

No receiver buildings are predicted to experience noise levels greater than 75 dB(A).

During standard construction hours, up to 97 residential receiver buildings in NCAs 33.1, 34.1 and 36.1 (within Artarmon and Willoughby, north of Gore Hill Freeway) are predicted to experience noise levels above the noise management level. These exceedances are predicted during early works, site establishment works and construction of the acoustic shed.

During out of hours works, noise levels are predicted to be below the noise management levels.

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 107 receiver buildings from tunnelling support works. Three of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

For non-residential receivers:

- Up to 12 commercial buildings in NCA 33.2 (within the Artarmon industrial area) are predicted to experience noise levels above the noise management level during early works, site establishment and the construction of the acoustic shed

- Two childcare receivers in NCA 33.2 (Creative Acorn Early Learning Centre and Butterflies Early Learning Childcare Centre) and one in NCA 36.1 (Tree of Life Early Learning School – Willoughby) are predicted to experience noise levels above the noise management level during site establishment and the construction of the acoustic shed
- One educational receiver in NCA 33.1 (Artarmon Public School) is predicted to experience noise levels above the noise management level during site establishment and the construction of the acoustic shed.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-18 Number of residential receiver buildings over the noise management levels during construction at Punch Street construction support site (BL3) (realistic worst case noise)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside of standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Early works	0	–	2	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	0	–	97	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Surface level access decline excavation and acoustic shed construction	0	–	38	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tunnelling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107	3
Tunnel fitout	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107	3
Build operational motorway facilities	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Site rehabilitation	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

There is potential for cumulative increases of construction noise from the Punch Street construction support site (BL3) and the construction of the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project. There is also potential for increased disturbance associated with works outside standard construction hours associated with the Punch Street construction support site (BL3) and the Warringah Freeway Upgrade. Cumulative construction noise increases are likely to occur rarely at shared receivers between both projects, if noise generating activities associated with both projects need to occur simultaneously.

Site specific mitigation measures would be developed for the Punch Street construction support site (BL3) with the aim of ensuring that relevant noise management levels are met, minimising the potential for construction fatigue. Works outside standard construction hours would be coordinated with the Warringah Freeway Upgrade where feasible and reasonable to provide the affected receivers with appropriate respite.

Cumulative airborne construction noise impacts would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Construction traffic noise

Construction vehicle movements associated with the Punch Street construction support site (BL3) are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Over the entire night time period there would be six vehicles (12 movements) typically accessing the temporary construction support site. Since the number of truck movements generated by the site is not significant compared to existing heavy vehicle numbers on Gore Hill Freeway, the number of maximum noise events that could disturb sleep are not likely to substantially increase. Additionally, direct access would be provided from the site to the Gore Hill Freeway as the Gore Hill Freeway Connection works progresses, minimising use of local roads.

Construction ground-borne noise

For the construction of the tunnel access decline between the Punch Street construction support site (BL3) and the tunnel alignment, ground-borne noise levels are predicted to be between 35 and 40 dB(A) at seven receivers located in NCA 32.1 (within Naremburn, east of the T1 North Shore and Western rail line and T9 Northern rail corridor). These exceedances have the potential to exceed the night time ground-borne noise management level.

Construction vibration

Table 10-19 shows six and 25 receiver buildings fall within the minimum working distances for cosmetic damage (sound structures) and human response respectively. The majority of the receiver buildings are located within the Artarmon industrial area with further detail presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be the use of a large rock hammer during site establishment stages.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-19 Number of receiver buildings within minimum working distances for vibration intensive work – Punch Street construction support site (BL3)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage structure	Sound structure	
Early works, establish site, build decline and shed			
32.1	–	–	3
33.2	–	6	22

10.6.8 Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8)

Construction works summary

The Middle Harbour south (BL7) and Middle Harbour north (BL8) construction support sites would be located at each end of the Middle Harbour crossing and within the harbour at Northbridge to the south and Seaforth to the north. The cofferdams would facilitate construction of the interface structures between the driven mainline tunnels and the immersed tube tunnel units. Works associated with the establishment, use and demobilisation of these temporary construction support sites would occur over about four years. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-20 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels from the Middle Harbour south cofferdam (BL7) and the Middle Harbour north cofferdam (BL8) construction support sites as well as construction activities associated with the installation of the immersed tube tunnel.

Up to 10 residential receiver buildings in NCAs 39.2 and 42.1 (within Seaforth) are predicted to be highly noise affected experiencing noise levels greater than 75 dB(A) during impact piling (also known as hammer piling) for the installation of the Middle Harbour north cofferdam. To ensure appropriate respite is provided to sensitive receivers in the vicinity, impact piling in any given week would be carried out over no more than either a two hour period each work day or over a 6 hour period on a single work day. Impact piling is expected to be completed over a 12 month period.

During standard construction hours, up to 1075 residential receiver buildings across NCAs either side of the crossing of Middle Harbour are predicted to experience noise levels greater than the noise management level. However, the majority of receivers (82 per cent) would experience exceedances of less than 10 dB(A). The majority of noise affected receivers would result from the installation of the Middle Harbour north and south cofferdams, cofferdam excavation works and immersed tube tunnel foundation works.

Immersion of tube tunnel units would require activities outside standard construction hours as a typical immersion process for one immersed tube tunnel unit would take 24 to 48 hours. Once started, it is not possible to halt the installation process at the end of a daytime work shift. During this time, up to 295 residential receiver buildings in NCAs 39.1, 39.2, 40.1, 40.2, 41.1 and 42.1 (within Northbridge, Castlecrag and Seaforth) are predicted to experience noise levels that exceed noise management levels. However, the majority of the exceedances (66 per cent) would be less than 5 dB(A). It is expected that the six tunnel tube units would be immersed at intervals over a six to nine month period, providing affected sensitive receivers with respite in between individual tube immersions.

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 224 receiver buildings across several NCAs either side of the crossing of Middle Harbour from the immersion of tube tunnel units. Thirteen of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

One commercial receiver (Northbridge Sailing Club) within NCA 39.1 is predicted to be noise affected during construction of the Middle Harbour south cofferdam and piling for the foundations for immersed tube tunnel. Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-20 Number of residential receiver buildings over the noise management levels during construction at Middle Harbour (realistic worst case noise intensity scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1-10 dB(A)	11-20 dB(A)	>20bB(A)	1-5 dB(A)	6-15 dB(A)	16-25 dB(A)	>25 dB(A)	1-5 dB(A)	6-15 dB(A)	16-25 dB(A)	>25 dB(A)	1-5 dB(A)	6-15 dB(A)	16-25 dB(A)	>25 dB(A)	Screening	Awakening
Build Middle Harbour north cofferdam	10	–	794	175	17	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Build Middle Harbour south cofferdam	0	–	882	185	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dewater cofferdams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Excavate cofferdams	1	0	200	15	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pile moorings	0	–	110	14	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cast Interface structures	0	–	54	3	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Remove cofferdams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prepare foundations	0	–	50	6	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pile foundations	0	–	555	206	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Immerse tunnel units	0	0	23	0	0	65	23	0	0	94	56	1	0	195	93	7	0	224	13

Note 1: L_{Aeq} is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Middle Harbour south (BL7) and Middle Harbour north (BL8) construction support sites would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

Impact piling associated with cofferdam construction and immersed tunnel tube support piles has the potential to generate significant noise levels and impacts. Impact piling in any given week would, however, be carried out over no more than either a two hour period each work day or a six hour period on a single work day. Also, once these noise intensive activities are completed, the remaining activities in this locality would be less noise intensive and would have a lower potential to cause amenity impacts. Hence the potential for construction fatigue due to extended duration noise impacts is considered to be low.

All works outside standard construction hours associated with the project occurring around Middle Harbour, including the use of the Spit West Reserve construction support site (BL9), would be managed to ensure that affected receivers are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with these temporary construction support sites.

Construction traffic noise

The crossing of Middle Harbour would be accessed by barges, usually from the Spit West Reserve construction support site (BL9) and there would therefore be no direct construction road traffic impacts associated with the Middle Harbour south (BL7) and Middle Harbour north (BL8) construction support sites. It is expected that noise from barge movements would not cause substantial amenity or sleep disturbance impacts.

Construction ground-borne noise

While there is some potential for ground-borne noise from vibration intensive activities, associated airborne noise is expected to dominate noise emitted from the Middle Harbour south (BL7) and Middle Harbour north (BL8) construction support sites. Airborne noise levels would typically be greater than ground-borne noise levels at the nearby residential receivers. No vibration intensive activities are proposed at either temporary construction support site outside standard construction hours. Therefore, no amenity impacts outside standard construction hours due to ground-borne noise are anticipated.

Construction vibration

Table 10-21 shows six heritage items in NCAs 40.1 and 39.1 (Clive Park and Tidal Pool, Clive Park one (Northbridge), Clive Park two (Northbridge, Cicada Pupa Cave), Clive Park four (Northbridge),Clive Park 8 (Shelter Midden WILL 170) and Clive Park (Midden WILL 169)) and one heritage item within NCA 42.1 (Harbour foreshore) are predicted to be within the minimum working distances for major vibration generating activities. Up to 148 buildings within Northbridge and Seaforth may be exposed to vibration levels above the human response screening level. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site are likely to be impact piling and vibratory piling for the installation of the Middle Harbour south (BL7) and Middle Harbour north (BL8) cofferdams, cofferdam excavation works and immersed tube tunnel foundation works. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) and Chapter 15 (Aboriginal heritage) for details on the heritage items potentially impacted.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

A number of underwater maritime heritage items are located in proximity to the Middle Harbour crossing and may experience potential direct or indirect impacts from construction works. These items are not specifically addressed in Appendix G (Technical working paper: Noise and vibration), as both the submerged nature of these heritage items and that they are generally not building structures that require structural integrity for any specific purpose means that the standards and limits for managing structural damage are not directly applicable. For further information on impacts from construction works on these items including the potential for vibration impacts, refer to Appendix K (Technical working paper: Maritime heritage).

Table 10-21 Number of receiver buildings within minimum working distances for vibration intensive work – Middle Harbour construction support sites

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item[1]	Sound structure	
39.1	1	–	19
39.2	–	2	51
40.1	5	–	17
42.1	1	6	61

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.9 Spit West Reserve (BL9)

Construction works summary

The Spit West Reserve construction support site (BL9) is located in the water west of Spit West Reserve, with a small adjoining land-based site. The proposed construction works at the site would include a temporary floating immersed tube tunnel casting facility that would be connected to Spit West Reserve by two temporary fixed jetties. The casting facility would provide space for two immersed tube tunnel units to be cast concurrently. Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about four years and six months. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-22 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

No receivers are predicted to be highly noise affected (ie predicted noise levels greater than 75 dB(A)).

During standard construction hours, up to 131 residential receiver buildings in NCAs 39.2, 40.2, 42.1, 43.1 and 43.2 (within Mosman and Seaforth) are predicted to experience noise levels above the noise management levels, mostly during early works and the construction of the temporary wharf and office building. During other stages, noise impacts would be less, with up to 52 receiver buildings noise affected.

Due to construction limitations of concrete pours associated with the casting of the tunnel units, these activities may be required to extend outside standard construction hours. If concrete pours extend into the evening period up to 171 residential receiver buildings are predicted to be noise affected by 1 to 5 dB(A) with an additional 48 residential receiver buildings noise affected by 6 to 15 dB(A).

Immersion of tube tunnel units would be supported from the Spit West Reserve construction support site (BL9) and would be required during out of hours of work as a typical immersion process for one immersed tube tunnel unit would take 24 to 48 hours. During this time, up to 79 residential receiver buildings across various NCAs surrounding the temporary construction support site are predicted to exceed noise management levels, however the majority of the exceedances (80 per cent) would be less than 5 dB(A).

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 132 receiver buildings across several NCAs from the immersion of tube tunnel units. None of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

For non-residential receivers:

- Five commercial receivers located in NCA 44.2 (within The Spit area of Mosman) are predicted to experience noise levels above the noise management level during early works by less than 10 dB(A)
- Up to two recreational receivers located in NCA 44.2 (Spit West Reserve and Pearl Bay Reserve) are predicted to experience noise levels above the noise management level at various construction work stages by less than 20 dB(A).

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-22 Number of residential receiver buildings over the noise management levels during construction at Spit West Reserve construction support site (BL9) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Early works	0	–	131	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Construct office and wharf	0	–	52	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Support dredging, pile installation and cofferdam/ interface structure works	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cast and fitout tunnel units	0	0	11	0	0	92	11	0	0	171	48	0	0	0	0	0	0	0	0
Support tunnel unit immersion	0	0	0	0	0	0	0	0	0	10	0	0	0	66	13	0	0	132	0
Site rehabilitation	0	–	45	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Spit West Reserve construction support site (BL9) would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

The predicted noise levels generated by the temporary construction support site are unlikely to result in significant amenity impacts for sensitive receivers in the vicinity. The use of the site is therefore unlikely to result in construction fatigue due to extended duration noise impacts is considered to be low.

All works outside standard construction hours associated with the project occurring around Middle Harbour, including the use of the Spit West Reserve construction support site (BL9), would be coordinated managed to ensure that affected receivers are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with this temporary construction support site.

Construction traffic noise

While the Spit West Reserve construction support site (BL9) would be accessed outside standard construction hours to support tunnel tube construction and immersion, the volume of construction vehicle movements are likely to be low compared to existing volumes on Spit Road. Therefore, construction vehicle movements are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Heavy vehicle movements are expected during the evening period however no night time heavy vehicle movements would occur at this site. Road traffic related sleep disturbance impacts are not expected to occur.

Construction ground-borne noise

Ground-borne noise may be generated by vibration intensive works within the Spit West Reserve construction support site (BL9). Given the closest building to the site is around 60 metres away, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers. No vibration intensive activities are proposed at this temporary construction support site outside standard construction hours. Therefore, no amenity impacts outside standard construction hours due to ground-borne noise are anticipated.

Construction vibration

The most vibration intensive activities at this site are likely to be screw pile driving during wharf building works and the use of rock hammers during establishment works. There are no receiver buildings within the minimum working distances for major vibration generating activities. However, occupants of up to two commercial properties in NCA 44.2 (within The Spit area of Mosman) may be exposed to vibration levels above the human response screening level during early works and the construction of the office and wharf should rock hammers and screw pile driving be used.

A number of underwater maritime heritage items are located in proximity to the Spit West Reserve construction support site (BL9) and may experience potential direct or indirect impacts from construction works. These items are not specifically addressed in Appendix G (Technical working paper: Noise and vibration), as both the submerged nature of these heritage items and that they are generally not building structures that require structural integrity for any specific purpose means that the standards and limits for managing structural damage are not directly applicable. For further information on impacts from construction works on these items including the potential for vibration impacts, refer to Appendix K (Technical working paper: Maritime heritage).

10.6.10 Balgowlah Golf Course (BL10)

Construction works summary

The Balgowlah Golf Course construction support site (BL10) would be located partially within Balgowlah Golf Course and on privately owned lots on Dudley Street. This would be a tunnel support site and project management site. It would also be used for the construction of Beaches Link tunnel connection to Burnt Bridge Creek Deviation and surface works, construction of operational facilities and the development of new and improved open space and recreation facilities and support of the construction of the immersed tube tunnels at the Spit West Reserve construction support site (BL9). Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about five years. Staged construction of the open space and recreation facilities would be delivered progressively and continue for another year after the main construction works have been completed. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-23 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

During standard construction hours, up to 1004 residential receiver buildings in NCAs 47.1, 48.1, 49.1, 50.1 and 51.1 (within Seaforth, Balgowlah and North Balgowlah) are predicted to experience noise levels greater than the noise management level. This would be mostly during site establishment works. The majority of receivers would experience exceedances of less than 10 dB(A). Other activities for which construction noise could affect a number of nearby residential receivers are bulk earthworks, access decline construction and construction of the new recreation facilities.

During standard construction hours two residential receiver buildings within NCA 49.1 (within Seaforth, west of Burnt Bridge Creek Deviation) also have the potential to experience noise levels greater than 75 dB(A) during site establishment works while excavators with rock hammers, chainsaws and mulchers are in use.

During night road works for road and intersection modifications, up to 548 residential receiver buildings are predicted to experience noise levels above the relevant noise management levels. The majority of receivers (96 per cent) are predicted to experience exceedances of less than 15 dB(A).

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 267 receiver buildings across several NCAs surrounding the Balgowlah Golf Course construction support site (BL10) during night road works. Eleven of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

During night time tunnelling and tunnel fitout works, occasional night time concrete truck movements could result in the high instantaneous noise impacts during arrival or departure. Up to 136 receiver buildings are predicted to potentially be exposed to maximum noise levels above the sleep disturbance screening level. No receivers are predicted to exceed the awakening reaction level.

A number of non-residential receivers could be noise affected during establishment and use of this temporary construction support site. Up to 32 non-residential receivers could experience noise level that exceed the relevant noise management levels during site establishment. The identified receivers include:

- Up to two childcare receivers located in NCAs 47.1 (Peacock Street Long Day Care and Seaforth Infants School) are predicted to be would be noise affected by up to 10 dB(A) above the noise management level and one receiver located in in NCA 50.1 (Balgowlah Kinder Haven) is predicted to experience noise levels above the noise management level during various project stages by up to 21 dB(A)

- Up to three educational receivers located in NCAs 48.1 (Northern Beaches Secondary College – Balgowlah Boys Campus), 49.1 (Seaforth Public School) and 50.1 (Punchinello Kindergarten) are predicted to experience noise levels above the noise management level during various project stages by up to 16 dB(A). Multiple buildings at Northern Beaches Secondary College Balgowlah Boys (NCA 48.1) and Seaforth Public School (NCA 49.1) may potentially be impacted.
- One recreational receiver (Balgowlah Oval) is predicted to experience noise levels above the noise management level by up to 14 dB(A)
- Up to three place of worship receivers located in NCAs 47.1 (Seaforth Anglican Church and Seaforth Baptist Church) and 48.1 (The Catholic Community of North Harbour) are predicted to experience noise levels above the noise management level during site rehabilitation by up to 7 dB(A).

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-23 Number of residential receiver buildings over the noise management levels during construction at Balgowlah Golf Course construction support site (BL10) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Early works	0	–	299	21	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	2	–	863	137	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Road/intersection modification	0	0	3	0	0	16	3	0	0	26	10	0	0	388	136	21	3	256	11
Bulk earthworks	0	–	188	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Build access decline	0	–	332	12	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish construction facilities	0	–	10	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Piling for acoustic shed	0	–	35	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Build acoustic shed	0	–	6	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Balgowlah road surface support works	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136	0
Tunnelling	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136	0
Tunnel fitout	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	0

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Concrete batching	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	0
Golf course north works	0	0	208	9	0	0	0	0	0	0	0	0	0	0	0	0	0	136	0
Build operational facilities	0	–	14	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Remove acoustic shed	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Decommission site	0	–	5	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Construct new oval	0	–	70	2	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Construct new field	0	–	34	9	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Balgowlah Golf Course construction support site (BL10) would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

While the temporary construction support site would be in use for an extended duration, the majority of the activities that would onsite would not be noise intensive. Site specific mitigation measures would be developed for Balgowlah Golf Course construction support site (BL10) with the aim of ensuring that relevant noise management levels are met during site use, minimising the potential for construction fatigue.

The use of the temporary construction support site outside standard construction hours would typically be to support the Balgowlah surface road works described in Section 10.6.11. The use of Balgowlah Golf Course construction support site (BL10) and the Balgowlah surface road works would be coordinated to ensure that affected receivers in the vicinity are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with this temporary construction support site.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate the construction of the project, and construction vehicle movements associated with the Balgowlah Golf Course construction support site (BL10) are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Since the number of night period truck movements generated by the site is small compared to existing heavy vehicle numbers on Sydney Road and Burnt Bridge Creek Deviation, the number of maximum noise events that could disturb sleep are not likely to substantially increase.

Construction ground-borne noise

For the construction of the tunnel access decline between the Balgowlah Golf Course construction support site (BL10) and the ramp tunnel alignment, ground-borne noise levels are predicted to be between 35 and 40 dB(A) at four receivers located in NCA 49.1 (within Balgowlah, east of Burnt Bridge Creek Deviation), with one receiver potentially experiencing ground-borne noise levels above 40 dB(A). During the construction of the ventilation tunnel and shaft, one residential receiver building within NCA 49.1 (in Seaforth, west of Burnt Bridge Creek Deviation) is predicted to be impacted by ground-borne noise levels above 35 dB(A). Both the tunnel access decline and the ventilation tunnel are not located directly below any residential receivers, limiting the potential ground-borne noise impacts.

Construction vibration

Table 10-24 shows 37 and 198 receiver buildings fall within the minimum working distances for cosmetic damage (sound structures) and human response respectively. The majority of these receiver buildings are within NCA 50.1 (in Balgowlah, east of Balgowlah Golf Course) with further detail on other properties provided in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be construction of the tunnel access decline and the use of rock hammers for site establishment and excavation works. The risk of annoyance at this site is considered low as piling, earth compaction works and rock hammering would occur for a limited duration only.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-24 Number of receiver buildings within minimum working distances for vibration intensive work – Balgowlah Golf Course construction support site (BL10)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item	Sound structure	
46.1	–	–	4
48.1	–	1	30
49.1	–	10	37
50.1	–	26	101
51.1	–	–	26

10.6.11 Balgowlah surface road works

Construction works summary

The Balgowlah surface road works are located on and adjacent to the Burnt Bridge Creek Deviation, on the border between Seaforth and Balgowlah. The works would connect the Beaches Link tunnel to Burnt Bridge Creek Deviation, and include works required to properly integrate this new connection into the existing network. Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about three years and three months.

The Balgowlah surface road works also includes the use of Kitchener Street construction support site (BL11).

Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-25 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels during typical and realistic worst case construction noise intensive work scenarios.

During standard construction hours, no residential receiver buildings are predicted to experience noise levels greater than 75 dB(A) during typical works. However, up to 25 residential receiver buildings are predicted to experience noise levels greater than 75 dB(A) during worst case works, such as during the use of rock hammers during excavations of rock or utility modification works.

During standard construction hours:

- The highest predicted noise levels occur for receivers directly adjacent to the works or in close proximity in NCAs 46.1, 48.1, 49.1, 50.1 and 51.1 in Seaforth, Clontarf, Balgowlah and North Balgowlah,
- For typical surface road works, up to 127 residential receiver buildings are predicted to exceed the noise management level. For typical works at the Kitchener Street construction support site (BL11), up to 100 receivers are predicted to exceed the noise management level
- For worst case construction, up to 912 residential receiver buildings are predicted to exceed the noise management level. The highest predicted noise levels occur are associated with excavation or utility modification works when equipment such as road saws or rock hammers are in use. For worst case works at the Kitchener Street construction support site, up to 117 receivers are predicted to exceed the noise management level during oversized deliveries to the site, with most exceedances less than 10 dB(A).

Outside standard construction hours, the key noise generating activities associated with the Balgowlah surface road works would be installation of traffic management controls to facilitate traffic switches, resurfacing works along Burnt Bridge Creek Deviation, support and deliveries for the cut and cover portal construction works, and intersection and road works in the areas where the new access road would connect to the Burnt Bridge Creek Deviation and Sydney Road (activities that cannot take place during standard construction hours to avoid significant traffic disruption in the network):

- For typical surface works during the night time period, up to 2318 residential receiver buildings are predicted to exceed the noise management level. No noise management level exceedances are expected at the Kitchener Street construction support site since the site would operate typically during standard working hours only
- For worst case construction works, up to 4059 residential receiver buildings are predicted to exceed the noise management level at night time.
- During works outside standard construction hours up to nine receivers could be highly noise affected (ie greater than 75 dB(A)) when plant and equipment are close to a receiver building.

For the prediction of airborne noise impacts from construction sites, consideration was given to realistic worst case construction activities as required by the *Interim Construction Noise Guideline* (DECC, 2009a). While the noise levels for the realistic worst case might occur at a sensitive receiver during the works, noise levels associated with the typical scenario occur more frequently.

The most likely source of potential sleep disturbance from night construction works would be from the use of rock hammers or concrete saws during utility modification works. The predicted maximum noise levels show exceedances of the sleep disturbance screening level across all areas with night construction works for both typical and worst case construction activities as follows:

- During typical surface works up to 718 buildings are predicted to exceed the sleep disturbance screening level with up to 97 residential receiver buildings have potential to exceed the awakening reaction level during typical construction works
- During worst case surface works up to 1097 buildings are predicted to exceed the sleep disturbance screening level. However only up to 148 residential receiver buildings have potential to exceed the awakening reaction level during worst case construction work.

Noise management level exceedances may occur at the following non-residential receivers:

- Up to two childcare centres in NCA 47.1 (Peacock Street Long Day Care and Seaforth Infants School) and one childcare receiver in NCA 50.1 (Balgowlah Kinder Haven) are predicted to be noise affected
- Up to two commercial receivers on Sydney Road in NCA 46.1 and two commercial receivers on Sydney Road in NCA 48.1 are predicted to be noise affected
- Up to four schools located in NCAs 46.1 (Northside Preschool), 48.1 (Northern Beaches Secondary College – Balgowlah Boys Campus), 49.1 (Seaforth Public School) and 50.1 (Punchinello Kindergarten) are predicted to be above the noise management level during various stages of the works, two of which are predicted to more than 10 dB(A) above the noise management level
- Up to 5 dB(A) above the noise management level is predicted at two places of worship in NCA 47.1 (Seaforth Anglican Church and Seaforth Baptist Church), and one places of worship in NCA 48.1 (The Catholic Community of North Harbour)
- Up to 7 dB(A) above the noise management level at the Balgowlah Scout Hall when the works are at the closest location.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-25 Number of residential receiver buildings over the noise management levels during Balgowlah surface road works (typical and realistic worst case scenarios)

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Existing road corridor (southbound)	Typical	0	0	116	11	0	35	11	0	0	49	31	0	0	259	147	24	0	718	97
	Worst case	20	0	730	158	24	97	57	1	0	163	88	6	0	573	450	79	5	1097	148
Existing road corridor (northbound)	Typical	0	1	104	15	1	218	161	32	1	364	251	64	3	984	1059	212	63	654	99
	Worst case	25	9	624	148	24	604	376	89	14	762	642	139	24	1458	1807	657	137	994	153
Trough works	Typical	0	0	52	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	0	464	45	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cut and cover portal works	Typical	0	0	37	1	0	43	22	0	0	99	37	1	0	780	434	30	1	196	7
	Worst case	0	0	401	29	0	54	24	0	0	134	42	1	0	857	509	37	2	455	22
Access road	Typical	0	0	11	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	0	225	17	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Works area	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Access road intersection at Burnt Bridge Creek Deviation	Typical	0	0	5	0	0	22	5	0	0	50	14	1	0	622	191	8	0	90	3
	Worst case	0	0	99	5	0	449	99	5	0	682	282	15	1	1217	1590	220	8	939	27
Sydney Road roadworks	Typical	1	1	8	1	0	11	8	1	0	25	12	4	0	1523	1940	264	41	935	85
	Worst case	6	6	53	8	1	394	53	8	1	797	217	13	4	1523	1940	264	41	935	85
Kitchener Street construction support site (BL11)	Typical	0	0	94	6	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	0	109	8	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Balgowlah surface road works would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

While these road works would occur over an extended duration and would generate significant noise levels at times, the majority of the activities that would onsite would not result in significant amenity impacts for nearby receivers, limiting the potential for construction fatigue.

Balgowlah Golf Course construction support site (BL10) would generally support any outside standard construction hours work for the Balgowlah surface road works instead of the Kitchener Street construction support site (BL11). The use of Balgowlah Golf Course construction support site (BL10) and the Balgowlah surface road works would be coordinated to ensure that affected receivers in the vicinity are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with the Balgowlah surface road work.

Construction traffic noise

Changes in traffic movements due to alterations made to existing traffic arrangements to facilitate construction, and heavy vehicle movements associated with the Balgowlah surface road works between work areas via the Burnt Bridge Creek Deviation, Sydney Road or from the Balgowlah Golf Course construction support site (BL10), are unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Reduced speed limit during traffic switching arrangements along the Balgowlah surface road works is likely to reduce road traffic noise levels at residential receiver buildings in NCA 50.1 (within Balgowlah, east of the Balgowlah Golf Course).

Construction ground-borne noise

Ground-borne noise levels have the potential to be generated by vibration intensive works during surface road works. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Table 10-26 shows up to 44 receiver buildings would be within minimum working distances for cosmetic damage (sound structures). Up to 197 receiver buildings would be within minimum working distance for human response. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be the use of rock hammers for surface road works.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-26 Number of receiver buildings within minimum working distances for vibration intensive work – Balgowlah connection surface road works

Location	NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
		Cosmetic damage		Human response
		Heritage item	Sound structure	
Existing road corridor (southbound)	46.1	–	–	8
	49.1	–	1	40
	50.1	–	–	7
	51.1	–	1	50
Existing road corridor (northbound)	46.1	–	–	6
	49.1	–	19	51
	50.1	–	–	3
	51.1	–	17	75
Trough works	49.1	–	–	16
Cut and cover portal works	49.1	–	–	16
Access road	48.1	–	–	7
	49.1	–	–	2
	50.1	–	–	2
	51.1	–	–	3
Access road intersection at Burnt Bridge Creek Deviation	49.1	–	–	3
	51.1	–	–	4
Sydney Road roadworks	48.1	–	8	31
	49.1	–	–	3
	50.1	–	–	5

10.6.12 Wakehurst Parkway south (BL12)

Construction works summary

The Wakehurst Parkway south construction support site (BL12) is located on the eastern side of Wakehurst Parkway between just south of Judith Street and Kirkwood Street at Seaforth. Construction works at the site would support the upgrade of Wakehurst Parkway and also the construction of the cut and cover tunnel connection and motorway facilities at Wakehurst Parkway. Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about four years and nine months. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-27 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

Up to 18 residential receiver buildings are predicted to experience noise levels greater than 75 dB(A) during standard construction hours when rock hammers, chainsaws and mulchers are in use as part of the site establishment and early works.

During standard construction hours, up to 54 residential receiver buildings in NCAs 53.1 and 54.1 (within Seaforth) are predicted to experience noise levels above the noise management level during site establishment, early works, and site restoration works. The majority of receivers (56 per cent) would experience increases of less than 10 dB(A).

No works outside standard working hours are proposed at this temporary construction support site.

For non-residential receivers, up to two recreational receivers located at Seaforth Oval in NCA 54.1 (within Seaforth) are predicted to experience noise levels above the noise management level during site establishment and early works by up to 11 dB(A).

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-27 Number of residential receiver buildings over the noise management levels during construction at Wakehurst Parkway south construction support site (BL12) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Early works	9	–	15	19	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	18	–	30	6	18	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Support surface works	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Support cut and cover and motorway facilities	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Site rehabilitation	0	–	6	17	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Wakehurst Parkway south construction support site (BL12) would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

While the temporary construction support site would be in use for an extended duration, the majority of the activities that would onsite would not be noise intensive. Site specific mitigation measures would be developed for this temporary construction support site with the aim of ensuring that relevant noise management levels are met during site use, minimising the potential for construction fatigue.

The use of Wakehurst Parkway south construction support site (BL12) outside standard construction hours would typically be to support the Wakehurst Parkway surface road works. The use of the temporary construction support site and the Wakehurst Parkway surface road works would be coordinated to ensure that affected receivers in the vicinity are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with this temporary construction support site.

Construction traffic noise

Construction traffic associated with the Wakehurst Parkway south construction support site (BL12) is unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

No night time heavy vehicle movements would occur to or from this site. Road traffic related sleep disturbance impacts are not expected to occur.

Construction ground-borne noise

Ground-borne noise may be generated by vibration intensive works within the Wakehurst Parkway south construction support site (BL12). However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Table 10-28 shows two heritage structures in NCA 54.1 (Bantry Bay Water Pumping Station and the Bantry Bay Reservoir) are predicted to be within the minimum working distances for major vibration generating activities. Up to 27 receiver buildings within NCA 54.1 (Seaforth) may be exposed to vibration above the human response screening level during early works. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be rock hammers for utility modification works. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) for further details on the heritage items potentially impacted.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/ or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-28 Number of receiver buildings within minimum working distances for vibration intensive work – Wakehurst Parkway south construction support site (BL12)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage items[1]	Sound structure	
54.1	2	21	27

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.13 Wakehurst Parkway east (BL13)

Construction works summary

The Wakehurst Parkway east construction support site (BL13) is located on the eastern side of Wakehurst Parkway, on land surrounding Sydney Water's Bantry Bay Reservoir site, adjacent to the Wakehurst Parkway Golf Course. This would be a tunnel support site and project management site. The site would be used for the construction of Beaches Link tunnel connection to Wakehurst Parkway, to support the construction of the ramp tunnels for the Beaches Link component of the project. Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about four years and six months. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-29 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

No receiver buildings are predicted to experience noise levels greater than 75 dB(A).

During standard construction hours, up to two residential receiver buildings in NCAs 54.1 (located on Kirkwood Street, Seaforth) are predicted to experience noise levels above the noise management level during early works and site establishment.

During night time works, noise levels are predicted to exceed noise management levels during site establishment works at up to 63 residential receiver buildings in NCAs 53.1 and 54.1 (within Seaforth). A high proportion of receivers (about 67 per cent) would experience exceedances of less than 5 dB(A).

Maximum noise levels at night could exceed the sleep disturbance screening level at up to 35 receiver buildings due to site establishment and tunnelling support works. None of these receivers are predicted to be exposed to maximum noise levels above the awakening reaction level.

No non-residential receivers are predicted to experience noise levels above the noise management levels.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-29 Number of residential receiver buildings over the noise management levels during construction at Wakehurst Parkway east construction support site (BL13) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Early works	0	–	1	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	0	0	2	0	0	1	1	0	0	8	2	0	0	42	19	2	0	35	0
Establish facilities	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Piling for access decline and acoustic shed	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Build acoustic shed	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tunnelling	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	8	0
Tunnel fitout	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	8	0
Remove acoustic shed	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Site rehabilitation	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted “equivalent noise level”. It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities.
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Wakehurst Parkway east construction support site (BL13) would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

While the temporary construction support site would be in use for an extended duration, the majority of the activities that would occur onsite would not be noise intensive. Site specific mitigation measures would be developed for this temporary construction support site with the aim of ensuring that relevant noise management levels are met during site use, particularly outside standard construction hours, minimising the potential for construction fatigue.

No cumulative airborne construction noise impacts are anticipated associated with this temporary construction support site.

Construction traffic noise

Construction traffic associated with the Wakehurst Parkway east construction support site (BL13) is unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Over the entire night time period there would be eight heavy vehicle movements (four vehicles). Since the number of night truck movements generated by the site is not significant compared to existing heavy vehicle numbers on Wakehurst Parkway, the number of maximum noise events that could disturb sleep are not likely to substantially increase.

Construction ground-borne noise

Ground-borne noise would be generated from the construction of the tunnel access decline between the temporary construction support site and mainline tunnel and by vibration intensive works within the temporary construction support site. No sensitive receivers are predicted experience ground-borne noise levels above the noise management level.

Construction vibration

Table 10-30 shows two heritage structures in NCA 54.1 (Bantry Bay Water Pumping Station and the Bantry Bay Reservoir) are predicted to be within the minimum working distances for major vibration generating activities. The most vibration intensive activity at this site is likely to be construction of the tunnel access decline, construction of the acoustic shed and the use of rock hammers for utility modification during early works. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) for further details on the heritage items potentially impacted.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-30 Number of receiver buildings within minimum working distances for vibration intensive work – Wakehurst Parkway east construction support site (BL13)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item[1]	Sound structure	
54.1	2	–	-

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

10.6.14 Wakehurst Parkway north (BL14)

Construction works summary

The Wakehurst Parkway north construction support site (BL14) is located on the north east corner of Wakehurst Parkway and Warringah Road at Frenchs Forest. Construction works at the site would be related to the Wakehurst Parkway surface road works, minor intersection works at Wakehurst Parkway/Warringah Road and Wakehurst Parkway/Frenchs Forest Road and construction of the permanent tunnel support facilities. The site would also support the construction and operation of a temporary concrete batching plant. Works associated with the establishment, use and demobilisation of this temporary construction support site would occur over about five years. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-31 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels.

No receivers are expected to experience noise levels greater than 75 dB(A).

During standard construction hours, up to 31 residential receiver buildings in NCAs 56.1 and 57.1 (within Frenchs Forest, south and north of Warringah Road, west of Wakehurst Parkway) are predicted to experience noise levels above the noise management level during early works. All receivers are predicted to experience noise exceedances of less than 10 dB(A).

During night time support for the Wakehurst Parkway road surface works, no noise management level exceedances are predicted.

Maximum noise levels could exceed the sleep disturbance screening level at up to 161 receiver buildings from truck deliveries at night during surface activities. No receivers are expected to receive noise above the awakening reaction level.

Noise management level exceedances may occur at the following non–residential receivers:

- Three commercial receivers located in NCA 58.2 (within Frenchs Forest, east of Wakehurst Parkway)
- One childcare receiver located in NCA 58.2 (Kindalin Early Childhood Learning Centre)
- One educational receiver located in NCA 57.1 (The Forest High School)
- One recreational receiver in NCA 56.1 (Brick Pit Reserve)
- Four place of worship receivers in NCA 56.1
- One other sensitive receiver in NCA 56.1 (Northern Beaches Hospital).

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-31 Number of residential receiver buildings over the noise management levels during construction at Wakehurst Parkway north construction support site (BL14) (realistic worst case scenario)

Stage activity	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
	Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Early works	0	0	31	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Establish site	0	0	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Surface activities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	161	0
Build maintenance facility	0	0	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Site rehabilitation	0	0	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Wakehurst Parkway north construction support site (BL14) would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely. Also, the temporary construction support site would be in a location where the most affected receivers are not particularly noise sensitive.

The use of Wakehurst Parkway north construction support site (BL14) outside standard construction hours would typically be to support the Wakehurst Parkway surface road works. The use of the temporary construction support site and the Wakehurst Parkway surface road works would be coordinated to ensure that affected receivers in the vicinity are provided with appropriate respite.

No cumulative airborne construction noise impacts are anticipated associated with this temporary construction support site.

Construction traffic noise

Construction traffic associated with the Wakehurst Parkway east construction support site (BL13) is unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Night time heavy vehicle movements from this site would be limited to one vehicle per hour, which is not a substantial number when compared to existing heavy vehicle movements on Warringah Road and Wakehurst Parkway. Nearby receivers are not likely to notice the increase in the number of maximum noise events caused by the additional truck movements generated by the site.

Sleep disturbance impacts from construction traffic are not likely to occur.

Construction ground-borne noise

Ground-borne noise levels have the potential to be generated during early works, where rock hammering may be needed for utilities adjustments. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Table 10-32 shows two receiver buildings in NCA 58.2 (within Frenchs Forest, east of Wakehurst Parkway) are predicted to be within the minimum human response working distances for major vibration generating activities. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be use of rock hammers for utility modifications.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-32 Number of receiver buildings within minimum working distances for vibration intensive work – Wakehurst Parkway north construction support site (BL14)

NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
	Cosmetic damage		Human response
	Heritage item	Sound structure	
58.2	–	–	2

10.6.15 Wakehurst Parkway surface road works

Construction works summary

The Wakehurst Parkway connection and upgrade is located on the Wakehurst Parkway, between Killarney Heights and Frenchs Forest. Works would include on and off ramps along with tunnel portals, ventilation facility and widening and upgrading of the Wakehurst Parkway through to Warringah Road. Works associated with the establishment, use and demobilisation of this temporary construction support site would take about three years and nine months. Refer to Chapter 6 (Construction work) for further information.

Construction airborne noise

Table 10-33 provides a summary of the number of residential receiver buildings predicted to experience airborne noise levels above noise management levels during realistic worst case and typical construction noise intensive work scenario.

During standard construction hours one residential receiver building is predicted to experience noise levels greater than 75 dB(A) when works take place nearby for the Warringah Road and Wakehurst Parkway intersection. Up to five residential receiver buildings are predicted to experience noise levels greater than 75 dB(A) when works take place in the southern section of the Wakehurst Parkway surface road works at Seaforth.

During standard construction hours:

- For typical surface road works, there would be no exceedances greater than 20 dB(A).
- The highest noise impacts during typical surface road works would likely be during clearing and grubbing activities associated with the southern and central sections of Wakehurst Parkway. Daytime noise management levels for the southern section could be exceeded at up 15 residential receiver buildings, with six receivers by greater than 10 dB(A). For the central section, daytime noise management levels could be exceeded at up 20 residential receiver buildings. However, all exceedance levels would be less than 10 dB(A). Two receiver buildings would be exceeded in the northern area.
- For worst case surface road works, up to 21 residential receiver buildings could experience noise levels that exceed the relevant noise management levels during bulk earthworks for the cut and cover portal, with four receivers by greater than 10 dB(A).
- The highest worst case noise impacts during surface road works would likely be during paving and asphalting, when daytime noise management levels could be exceeded at up to 15 receiver buildings in the northern area, 77 in the central and 34 in the southern area along Wakehurst Parkway. Noise levels are predicted to be greater than 20 dB(A) above the daytime noise management level at up to five of those receiver buildings where noise levels could be considered highly intrusive. However, noise levels are not predicted to be more than 20 dB(A) above the daytime noise management level at any receiver buildings during typical construction work.

Outside standard construction hours:

- Around the Warringah Road and Wakehurst Parkway intersection, up to 431 receiver buildings could experience noise levels that exceed the noise management levels during typical works. Up to 886 receiver buildings are predicted to be noise affected during worst case works
- For oversized lifting works in the northern section of the Wakehurst Parkway surface road works area, up to 199 receiver buildings are predicted to exceed the noise management levels during typical works. Up to 249 receiver buildings are predicted to be noise affected during worst case works

- For the central and southern sections of the Wakehurst Parkway surface road works area, up to 77 and 33 receiver buildings respectively could experience noise levels that exceed the noise management levels during typical works. Up to 139 and 59 receiver buildings respectively are predicted to be noise affected during worst case works
- For the cut and cover portals and works associated with the ventilation outlet and motorway facilities, up to 91 receiver buildings could experience noise levels that exceed the noise management levels during typical works. Up to 168 receiver buildings are predicted to be noise affected during worst case works.

For the prediction of airborne noise impacts from construction sites, consideration was given to realistic worst case construction activities as required by the *Interim Construction Noise Guideline* (DECC, 2009a). While the noise levels for the realistic worst case might occur at a sensitive receiver during the works, noise levels associated with the typical scenario occur more frequently.

The most likely source of potential sleep disturbance from night construction works would be from the use of rock hammers or concrete saws during utility modification works. The predicted maximum noise levels show exceedances of the sleep disturbance screening level across all areas with night construction works for both typical and worst case construction activities as follows:

- During typical construction works up to 86 receiver buildings would exceed the sleep disturbance screening levels, with up to 11 residential receiver buildings have the potential to experience noise levels in excess of the awakening reaction level during typical construction works
- During periods of worst case works up to 115 receiver buildings above the sleep disturbance screening level, with up to 16 residential receiver buildings have the potential to experience noise levels in excess of the awakening reaction level during worst case construction work.

Noise management level exceedances may occur at the following non-residential receivers:

- Two commercial receivers located in NCA 58.2 for worst case construction works
- Up to one childcare receiver located in NCA 58.2 (Kindalin Early Childhood Learning Centre) for typical construction works, and up to two childcare receivers located in NCAs 55.1 (Little Bloomers Early Learning Centre) and 58.2 (Kindalin Early Childhood Learning Centre) for worst case construction works
- Two recreational receivers in NCAs 55.1 and 56.1 during the Warringah Road and Wakehurst Parkway intersection upgrade works and three recreational areas/facilities in NCAs 54.1, 55.1, and 55.4 during surface works along the Wakehurst Parkway
- One place of worship receiver in NCA 56.1 (Frenchs Forest Anglican Church)
- When works are closest to the Northern Beaches Hospital, construction noise levels are predicted to exceed the noise management level by up to 5 dB(A) during typical works, or 16 dB(A) during worst case construction works
- Two other sensitive receivers (community centres) in NCA 55.1.

Where noise management levels are exceeded there is a requirement to implement reasonable and feasible noise mitigation. Measures to avoid, minimise and mitigate the potential noise impacts from construction works during construction are provided in Section 10.7.

Table 10-33 Number of residential receiver buildings over the noise management levels during Wakehurst Parkway surface road works (typical and realistic worst case scenarios)

Work activity	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Warringah Road/ Wakehurst Parkway works area																				
Surface road works	Typical	0	0	3	1	0	9	3	1	0	32	15	1	0	288	188	24	1	76	7
	Worst case	1	0	44	4	1	29	12	1	0	80	43	4	1	455	374	51	6	115	16
Wakehurst Parkway road upgrade (north) works area																				
Clearing and grubbing	Typical	0	–	2	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	4	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Surface road works	Typical	0	0	0	0	0	3	1	0	0	14	4	0	0	138	48	13	0	36	4
	Worst case	0	0	14	1	0	2	2	0	0	18	4	0	0	171	63	14	1	57	7
Concrete barriers and traffic controls	Typical	0	0	0	0	0	0	0	0	0	0	0	0	0	14	7	0	0	36	4
	Worst case	0	0	0	0	0	1	0	0	0	3	1	0	0	35	22	4	0	57	7
	Typical	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Work activity	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Road furniture installation/ modification	Worst case	0	–	4	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Work activity	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Wakehurst Parkway road upgrade (centre) works area																				
Clearing and grubbing	Typical	0	–	20	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	51	1	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Surface road works	Typical	0	–	4	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	67	10	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Concrete barriers and traffic controls	Typical	0	0	0	0	0	0	0	0	0	10	0	0	0	30	47	0	0	86	2
	Worst case	0	0	0	0	0	10	0	0	0	37	15	0	0	51	73	15	0	103	15
Road furniture installation/ modification	Typical	0	–	1	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	37	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Work activity	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Wakehurst Parkway road upgrade (south) works area																				
Clearing and grubbing works	Typical	0	–	9	6	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	1	–	13	9	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Surface road works	Typical	0	–	8	5	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	5	–	21	8	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Concrete barriers and traffic controls	Typical	0	0	5	0	0	2	5	0	0	4	8	1	0	12	14	7	0	26	11
	Worst case	0	0	8	1	0	4	8	1	0	10	8	5	0	22	24	8	5	31	13
Road furniture installation/ modification	Typical	0	–	8	3	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	12	7	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Work activity	Scenario	Highly noise affected (L_{Aeq}[1]) >75 dB(A)[3]		Day (standard construction hours) (L_{Aeq})			Day (out of hours) (L_{Aeq})				Evening (L_{Aeq})				Night (L_{Aeq})				Sleep disturbance (L_{Amax}[2])	
		Standard hours	Outside standard hours	1–10 dB(A)	11–20 dB(A)	>20dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	1–5 dB(A)	6–15 dB(A)	16–25 dB(A)	>25dB(A)	Screening	Awakening
Tunnel portals – cut and cover works area																				
Piling – Bored	Typical	0	–	3	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	11	3	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bulk earthwork	Typical	0	0	11	3	0	2	4	0	0	11	8	2	0	55	21	6	0	18	3
	Worst case	0	0	17	4	0	13	6	0	0	14	17	4	0	86	63	15	4	21	4
Oversized lifting works	Typical	0	0	4	0	0	6	4	0	0	9	10	2	0	56	25	8	2	18	3
	Worst case	0	0	5	0	0	7	5	0	0	9	11	2	0	57	30	10	2	21	4
Deliveries	Typical	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Concrete pours	Typical	0	–	6	0	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Worst case	0	–	10	2	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note 1: L_{Aeq} is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a selected period of time
Note 2: L_{Amax} is the maximum A-weighted sound pressure level measured over a given period
Note 3: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities
Note 4: Cells shaded in dark grey denote a result above the noise management level.

Cumulative airborne construction noise

The Wakehurst Parkway surface road works would be sufficiently far removed from locations where activities associated with other major projects would be occurring that cumulative impacts are unlikely.

While these road works would occur over an extended duration and would generate significant noise levels at times, the majority of the activities that would onsite would not result in significant amenity impacts for nearby receivers due to the distances between the receiver and the work locations. The risk of construction fatigue due to elevated construction noise levels over an extended duration is therefore low.

Wakehurst Parkway south and north construction support sites (BL12 and BL14) would generally support any outside standard construction hours work for the Wakehurst Parkway surface road works. The use of Wakehurst Parkway south and north construction support site (BL12 and BL14) and the Wakehurst Parkway surface road works would be coordinated to ensure that affected receivers in the vicinity are provided with appropriate respite, minimising potential amenity impacts.

No cumulative airborne construction noise impacts are anticipated associated with the Wakehurst Parkway surface road work.

Construction traffic noise

Construction traffic associated with the Wakehurst Parkway connection is unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is barely perceptible.

Two heavy vehicles per hour are expected to be required during the standard hours works typically associated with the road works upgrade and the operation of the support sites such as the Wakehurst Parkway south (BL12) or Wakehurst Parkway north (BL14). There would be additional heavy vehicle movements associated with the concrete batch plant at Wakehurst Parkway north construction support site (BL14) which could be a maximum of three heavy vehicles per hour. No vehicle movements other than oversized deliveries are expected to be required outside standard construction hours.

Construction ground-borne noise

Ground-borne noise levels have the potential to be generated by vibration intensive works at the surface road works and associated temporary construction support sites. However, throughout these construction works it is likely that the airborne noise levels would be greater than ground-borne noise levels at the nearby noise sensitive receivers.

Construction vibration

Table 10-34 shows four heritage items located in NCAs 54.1 (Frenchs Bullocks Track, Frenchs Forest; Bantry Bay; Wakehurst Parkway (45-6-0662) and Rock engraving (Garigal National Park) (45-6-2940)) and 55.1 (Bantry Bay Aboriginal Engraving Site (45-6-0655)) are predicted to be within the minimum working distances for major vibration generating activities. Up to 27 sensitive receiver buildings are identified within the minimum working distance for human response from the Wakehurst Parkway surface road works. The locations of these properties are presented in Annexure L of Appendix G (Technical working paper: Noise and vibration). The most vibration intensive activity at this site is likely to be use of large rock hammers for the cut and cover portal works. Refer to Appendix G (Technical working paper: Noise and vibration) and Chapter 14 (Non-Aboriginal heritage) and Chapter 15 (Aboriginal heritage) for further details on the heritage items potentially impacted.

Where vibration intensive works occur within the minimum working distances the risk of structural damage and/or human discomfort would be mitigated in accordance with the environmental management measures outlined in Section 10.7.

Table 10-34 Number of receiver buildings within minimum working distances for vibration intensive work – Wakehurst Parkway surface road works

Location	NCA	Number of receiver buildings within minimum working distances for vibration intensive work		
		Cosmetic damage		Human response
		Heritage item[1]	Sound structure	
Warringah Road/Wakehurst Parkway	57.1	–	–	2
	58.1	–	–	1
Road length upgrade	54.1	3	–	9
	55.1	1	–	6
	56.1	–	–	9
Cut and cover portals and ventilation facility	54.1	1	–	–

Note 1: Conservation areas have not been considered as they do not form a structure that would be impacted by vibration

Controlled blasting

Controlled blasting has been identified as an alternative to rock hammering in deep cuts areas along the Wakehurst Parkway. While rock hammering may be still required for secondary breakage and/or trimming walls, controlled blasting has the potential to significantly reduce noise exposure period compared to traditional rock hammering excavation, which might have to occur over very long periods of time.

If controlled blasting is carried out, it would be planned to comply with overpressure noise and ground vibration management levels discussed in Section 10.4.5 and environmental management measures included in Chapter 19 (Biodiversity) regarding the Large-eared Pied Bat (*Chalinolobus dwyeri*). Refer to Appendix G (Technical working paper: Noise and vibration) and Appendix S (Technical working paper: Biodiversity development assessment report) for further detail.

10.6.16 Other construction activities

Local area works

Local area and utility connection works, such as service and utility identification works, electricity, sewer, communications and other utility adjustments, and local road integration works, may be needed as part of establishing temporary construction support sites. While some locations where local area work would be required are known and have been assessed as part of the relevant compound or surface road work area, other requirements are still being investigated or are unknown. They could, therefore, be required outside of areas specifically assessed in this document. These works are typically very short duration and are similar to works regularly carried out by utilities providers and road maintenance crews across Greater Sydney.

Around the temporary construction support sites, residences are typically set back by about ten metres from the nearest road. Table 10-35 shows predicted typical noise levels that would be expected at ten metres from local area works. The predictions account for distance attenuation and some localised shielding (such as temporary noise barriers) and are expected to be conservative (over-predict) as they do not account for other effects such as ground absorption and terrain effects.

Table 10-35 Assessment local area works noise at the nearest receiver building

Item	Utilities modification		Pavement modification		Paving or asphalting		Linemarking	
	Typical	Worst case	Typical	Worst case	Typical	Worst case	Typical	Worst case
Distance to the highly noise affected level (m)	13	43	13	42	12	42	12	17
$L_{Aeq(15\ minute)}$[1] noise level at 10 m (dB(A))[2]	77	88	77	87	76	87	77	80

Note 1: $L_{Aeq(15\ minute)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a period of 15 minutes

Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.5 for a comparison of dB(A) for various activities

The results presented in Table 10-35 show that receiver buildings have the potential to be highly noise affected during local areas works, depending on the activity, the plant and equipment in use and the proximity of the works to the affected receivers. In most noise catchment areas, with a standard construction hours noise management level of 55 dB(A) or more, noise from local area works at the closest receivers would typically exceed the noise management level by about 20 dB(A) and in the worst case up to 33 dB(A).

Outside standard construction hours, noise from local area works at the closest receivers would typically exceed the night time noise management level by about 35dB(A) and in the worst case up to about 50 dB(A). This is based on a noise management level in most noise catchment areas of 40 dB(A) or more.

Local area works would typically consist of short duration (up to one week at any location) and would be managed in accordance with guidance *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a).

Truck marshalling areas

Spoil haulage trucks would likely require marshalling areas to be used when delays are experienced at the tunnel sites. The locations of these staging areas would be selected during development of the detailed construction methodology.

Where required, truck marshalling locations would be selected away from residential receivers and the site layout would take advantage of on-site or adjacent non-receiver structures to maximise acoustic shielding to nearby noise sensitive receivers.

All drivers would be required to comply with a Heavy Vehicle Code of Conduct, which would include noise management methods such as limiting idling and compression braking, and traffic management practises to minimise noise emissions from vehicles entering and leaving the site.

10.7 Environmental management measures

Environmental management measures for potential noise and vibration impacts during construction are outlined in Table 10-36. Additional measures to address cumulative impacts are included in Chapter 27 (Cumulative impacts).

Table 10-36 Environmental management measures – construction noise and vibration

Ref	Phase	Impact	Environmental management measure	Location
CNV1	Pre-construction and construction	Construction noise and vibration impacts	A Construction Noise and Vibration Plan will be developed for the project. This plan will: a) Identify relevant criteria and management levels in relation to noise and vibration b) Identify noise and vibration sensitive receivers and features in the vicinity of the project c) Include standard and additional mitigation from the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016) and detail how and when these will be applied in the project d) Describe the approach that will be adopted for carrying out location and activity specific construction noise and vibration impact assessments to assist with designing and selecting of the appropriate mitigation and management measures e) Include protocols that will be adopted to manage works required outside standard construction hours f) Detail the methodology and approach for managing construction noise impacts g) Detail the process for managing construction vibration, including for heritage structures, considering all types of vibration generating works, including blasting h) Outline the approach for identifying and managing potential cumulative impacts, including ensuring appropriate respite for works outside standard construction hours i) Outline the procedures and approach for noise and vibration monitoring to be carried out to confirm construction noise and vibration levels in relation to noise and vibration management levels j) Detail how construction noise impacts from concurrent or consecutive nearby construction works associated with the project will be managed where feasible and reasonable.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			The Construction Noise and Vibration Management Plan will be implemented for the duration of construction of the project.	
CNV2	Pre-construction	Construction noise and vibration impacts	Detailed location and activity specific construction noise and vibration impact statements will be prepared and implemented to cover: • Construction support sites • Works outside standard construction hours • Works with the potential to result in highly noise affected residential receivers (ie exposed to noise levels that exceed 75 dB(A)) • Works with the potential to exceed relevant human response and cosmetic damage criteria for vibration • Subsurface tunnelling activities. The statements will consider the proposed site layouts and noise generating activities that will occur, identify potentially impacted sensitive receivers and assess predicted noise and vibration levels against the relevant criteria and management levels, and specify the feasible and reasonable mitigation and management measures that will be implemented in accordance with the requirements of the *Interim Construction Noise Guideline* (DECC, 2009) and the *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016).	BL/GHF
CNV3	Construction	Construction noise and vibration impacts during out of hours work	An out of hours works protocol will be developed for the construction of the project. The protocol will include: a) Details of works required outside standard construction hours justifications of why the works are required outside standard construction hours b) The noise and vibration impact assessment processes that will be followed to identify potentially affected receivers and clarify potential impacts c) Mitigation and management measures that are to be considered and implemented where appropriate to manage potential impacts	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			associated with works outside standard construction hours d) Details of the approval process (internal and external) for works proposed outside standard construction hours. The protocol will be prepared in consultation with Department of Planning, Industry and Environment and the NSW Environment Protection Authority. The project protocol will be implemented during the duration of the construction of the project.	
CNV4	Construction	Construction noise and vibration impacts during out of hours work	For works outside standard construction hours on and adjacent to major roadways, the elevated existing ambient and background noise levels during the following shoulder periods will be investigated and confirmed: • Shoulder period (night-day) – between 5.00am and 7.00am • Shoulder period (evening-night) – between 10.00pm and 12.00am. Where appropriate, these shoulder periods will be utilised where feasible and reasonable to minimise potential amenity impacts associated with project activities outside standard construction hours.	BL/GHF
CNV5	Construction	Construction noise and vibration impacts	Construction noise and vibration impacts will be monitored periodically throughout all stages of the construction support site to ensure that: a) Noise and vibration levels are consistent with the predictions detailed in the relevant construction noise and vibration impact statements b) Noise and vibration impacts are being appropriately managed c) Mitigation measures are effective.	BL/GHF
CNV6	Construction	Construction noise impacts	Where feasible and reasonable, unless compliance with the relevant traffic noise criteria can be achieved, or alternative arrangements have been agreed with affected receivers, construction vehicle movements will not occur on local roads beyond those required for direct access to construction sites.	BL/GHF
CNV7	Construction	Construction vibration impacts	Vibration generating activities will be managed through the establishment of	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			minimum working distances to achieve vibration screening levels. Where vibration levels are predicted to exceed the screening levels, a more detailed assessment of the impacted structure will be carried out to assess the susceptibility of the structure to damage from vibration due to the project. Appropriate mitigation and management measures, such as equipment substitution and alternative methods, will be identified and implemented to avoid damage. Attended vibration monitoring will be carried out during vibration intensive activities in the vicinity to ensure vibration levels remain below appropriate limits for that structure. For heritage items, the more detailed assessment will specifically consider the heritage values of the structure in consultation with a heritage specialist to ensure sensitive heritage fabric is adequately monitored and managed. Pre-construction building structure condition surveys will be carried out in accordance with environmental management measure SG7. Any building and/or structure damage from vibration caused by the project would be repaired at no cost to the owner.	
CNV8	Construction	Construction ground–borne noise impacts	Where ground-borne levels are predicted to exceed the relevant noise management levels, alternative construction techniques and equipment that are likely to generate less ground-borne noise will be investigated and used where feasible and reasonable.	BL/GHF
CNV9	Construction	Construction impacts from surface road works	Mitigation measures will be implemented for surface road works, local area and utility works, where construction activities are predicted to exceed noise management levels at receivers. Where feasible and reasonable, the approaches that will be used include: a) Carrying out works during the daytime period when near residential receivers b) Selection of plant and equipment to minimise noise and vibration impacts c) Management of plant and equipment to minimise the generation of noise and vibration impacts	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			d) Community consultation, engagement and notification e) Detailed programming and respite protocols f) Where out of hours works are required, programming the noisiest activities to occur during the less sensitive time periods g) Out of hours works protocols h) Limiting timing of noise intensive work i) Use of portable noise barriers around particularly noisy equipment such as concrete saws and rock hammers in cases where it will effectively reduce noise levels at nearby receivers j) Management of construction traffic to minimise movements during the night periods along local roads k) Establishing minimum vibration working distances for vibration intensive works l) Vibration and blasting trials and/or monitoring along with building condition surveys Construction support sites that support surface road works will be designed to ensure that primary noise sources are located as far as possible from the nearby noise sensitive receivers, with solid structures (shed, containers, barriers, etc) placed between the noise sensitive receiver where feasible and reasonable to maximise acoustic shielding and block the line of site between the source and the receiver.	
CNV10	Construction	Construction impacts from surface road works	Where feasible and reasonable, noise barriers proposed as part of the project to address road traffic noise will be implemented as early as possible to attenuate construction noise.	BL/GHF
CNV11	Construction	Increased road traffic noise levels due to noise barrier removal	Where it is necessary to relocate or remove existing noise barriers to facilitate construction of new road infrastructure, the new noise barriers will be installed before removing the existing barriers where feasible and reasonable. Where it is not possible to install the new barriers before removing the existing barriers, the duration between removing the existing and installing the new barriers will be minimised. Temporary noise barriers will	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			be installed to ensure that road traffic noise levels do not increase by more than 2 dB(A) at the affected residential receiver buildings, where feasible and reasonable.	
CNV12	Construction	Construction blasting impacts	Any blasting and associated activities will be carried out in a manner that does not generate unacceptable overpressure and vibration impacts or pose a significant risk of impact to structures and sensitive receivers (including threatened fauna and fauna habitat adjacent Wakehurst Parkway). Prior to any blasting all potentially affected sensitive receivers and features in the vicinity would be identified. Appropriate tests will be carried out at each proposed blasting location to develop site-specific laws that take into account relevant factors such as underlying geology and separation distance to sensitive receivers and features to determine appropriate charge sizes and blasting design to ensure compliance with relevant vibration and overpressure criteria. All blasting will be carried out in accordance with the specific-laws. Monitoring will occur to determine compliance with the relevant criteria, and the site-specific laws will be adjusted as required based on the monitoring results to ensure ongoing compliance. The potentially affected community will be kept informed about proposed blasting activities.	BL/GHF
CNV13	Construction	Cumulative construction noise impacts and construction fatigue	Construction noise from concurrent and consecutive major projects in the vicinity of work locations associated with the project will be managed to minimise cumulative construction noise impacts. Where feasible and reasonable the approaches that will be used include: a) Considering the potential for cumulative impacts due to other major projects in the locality during development of the detailed construction methodology. The construction methodology will be developed to minimise overall noise impacts and the need for respite for receivers potentially affected by cumulative impacts wherever feasible and reasonable	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			b) Consulting with other major projects in the vicinity with the aim of coordinating work between the different projects that will affect the same area to ensure that affected receivers get appropriate respite from high noise impact activities and works outside standard construction hours c) Implementing additional feasible and reasonable source mitigation for cumulative construction activities, where programming is not practical to avoid cumulative noise impacts d) Community consultation to seek feedback on and identify key noise and vibration issues relevant to the local community so that current and future works can be managed to limit cumulative impacts.	
CNV14	Construction	Impact piling	In any given week, impact piling will be carried out over no more than either: • a two hour period each work day or • a six hour period on a single work day.	BL

Note 1: BL = Beaches Link, GHF = Gore Hill Freeway Connection

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 11

Operational noise and vibration

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DECEMBER 2020

11 Operational noise and vibration

This chapter considers the potential noise and vibration impacts associated with the operation of the project and identifies management measures to address these impacts. Potential noise and vibration impacts associated with the construction of the project are included in Chapter 10 (Construction noise and vibration).

A detailed noise and vibration assessment has been carried out for the project and is included in Appendix G (Technical working paper: Noise and vibration).

Common acoustic terms used throughout this chapter are explained in Chapter 10 (Construction noise and vibration).

The Secretary's environmental assessment requirements as they relate to operational noise and vibration and where in the environmental impact statement these have been addressed, are detailed in Table 11-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to operational noise and vibration are included in Section 11.8.

Table 11-1 Secretary's environmental assessment requirements – operational noise and vibration

Secretary's requirement	Where addressed in EIS
Noise and Vibration – Amenity	
1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must take into consideration and address the redistribution of traffic (including on local feeder roads) and operational plant and equipment, and must include consideration of impacts to sensitive receivers and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	**Section 11.5** and **Section 11.6** documents the impacts from the redistribution of traffic (including on local feeder roads), operational plant and equipment and the new and improved open space and recreation facilities at Balgowlah. **Chapter 10** (Construction noise and vibration) outlines the relevant NSW noise and vibration guidelines informing the construction noise and vibration assessment.
Noise and Vibration – Structural	
1. The Proponent must assess construction and operation noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage).	**Section 11.2**, **Section 11.7** and **Appendix G** (Technical working paper: Noise and vibration) presents details on the assessment of operational noise and vibration impacts in respect to relevant NSW noise and vibration guidelines as well as the consideration of impacts on the structural integrity of buildings and heritage significance items. **Chapter 10** (Construction noise and vibration) details similar information in respect to construction impacts.

11.1 Legislative and policy framework

Operational road traffic noise relating to State significant infrastructure projects is primarily regulated by the Department of Planning, Industry and Environment through project approval requirements under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979*.

In addition, the Protection of the Environment Operations (Noise Control) Regulation 2017 includes controls on noise from motor vehicles, while the Heavy Vehicle (Vehicle Standards) National Regulation (NSW) includes controls on noise from heavy vehicles.

NSW Road Noise Policy (DECCW, 2011) is the NSW Environment Protection Authority guideline which defines criteria to be used in assessing the impact of road traffic noise and to protect amenity and wellbeing. The policy is intended for use during the environmental assessment of road proposals to develop feasible and reasonable noise mitigation measures.

NSW Road Noise Policy (DECCW, 2011) is supported by *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) and *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g), which present a practical approach in applying *NSW Road Noise Policy* (DECCW, 2011) and address specific situations relevant to Transport for NSW road projects.

Noise Policy for Industry (NSW EPA, 2017a) provides intrusiveness and amenity criteria for fixed facilities that operate continuously and is relevant to the assessment project components including substations, wastewater treatment plants and ventilation facilities.

Noise Guide for Local Government (NSW EPA, 2013b) provides guidance on whether noise from the new and improved open space and recreation facilities at Balgowlah would be considered intrusive in the absence specific noise criteria for open areas and recreation facilities.

11.2 Assessment methodology

The operational noise assessment for the project considered the potential impacts associated with changes in traffic noise and noise from the operation of fixed facilities. The assessment included the following key steps:

- Identification of potentially affected noise catchment areas (NCAs) and noise sensitive receivers, development of a study area for the assessment, and background noise monitoring to determine existing noise levels. These are documented in Chapter 10 (Construction noise and vibration)
- Confirmation of noise and vibration objectives with reference to *NSW Road Noise Policy* (DECCW, 2011) and *Noise Criteria Guideline* (Roads and Maritime Services, 2015f)
- Selection and definition of the road traffic noise scenarios to be modelled and compared. Operational road traffic noise scenarios are presented in Table 11-2, which include scenarios with the project (‘Do Something’ and ‘Do something cumulative’) and without the project (‘Do minimum’)
- Calculation of road traffic noise changes for each scenario and for both the year of opening of the project and ten years after opening
- Prediction of operational noise from fixed facilities using the sound power levels expected from typical plant and equipment, for comparison against *Noise Policy for Industry* (NSW EPA, 2017a) intrusiveness and amenity criteria
- Prediction of operational noise associated with the new and improved open space and recreation facilities at Balgowlah using indicative sound power levels of recreational activities, for comparison against *Noise Guide for Local Government* (NSW EPA, 2013b) intrusiveness criterion
- Identification of environmental management measures to avoid, minimise and mitigate noise and vibration impacts during operation.

Operational road traffic noise scenarios have been modelled at the anticipated year of opening of the project (2027) and ten years later (2037). These scenarios have been informed by road traffic volumes from the Sydney Motorway Projects Model. A summary of scenarios is provided in Table 11-2 with full details of projects described in Chapter 9 (Operational Traffic and Transport).

Table 11-2 Summary of operational road traffic noise modelling scenarios for year of opening of the project (2027) and ten years later (2037)

Modelled Scenario	Included projects					
	Beaches Link and Gore Hill Freeway Connection	Western Harbour Tunnel[1]	Warringah Freeway Upgrade[1]	WestConnex	Sydney Gateway	M6 Motorway[2]
'Do minimum'	×	×	×	✓	×	×
'Do something'	✓	×	✓	✓	×	×
'Do something cumulative'	✓	✓	✓	✓	✓	✓

Note 1: Part of the Western Harbour Tunnel and Warringah Freeway Upgrade project

Note 2: For assessment at the year of opening Stage 1 of the M6 Motorway was included in the 'Do something cumulative' scenario. For 2037, the full M6 Motorway was included.

11.3 Assessment objectives and criteria

The operational noise and vibration assessment objectives and criteria applied to the project are summarised in the following sections and consider recommendations provided in the guidelines, policies and standards discussed in Section 11.1.

11.3.1 Road traffic noise

Residential receivers

Potential road traffic noise impacts on residential receivers are assessed using assessment criteria based on the category of the road that would generate the noise. In some instances, a residence may be exposed to traffic noise from a combination of new and redeveloped roads or different categories of roads.

In addition to road traffic noise which exceeds the assessment criteria, large increases in the level of noise can change the acoustic environment of a location, particularly for quieter areas. To address large increases in noise levels, a relative increase criterion was used.

Where criteria for a particular road category or relative increase criteria are likely exceeded due to the project, the eligibility of reasonable and feasible mitigation measures is evaluated in accordance with *Noise Mitigation Guideline (*Roads and Maritime Services, 2015g).

A summary of the applicable road traffic noise criteria for residential receivers in accordance with *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) is presented in Table 11-3.

Table 11-3 Road traffic noise criteria for residential receivers (external)

Road category	Type of project/land use	Assessment criteria dB(A)[1]	
		Daytime (7am – 10pm)	Night–time (10pm – 7am)
Freeway/ arterial/ sub–arterial roads	Existing residences affected by noise from new freeway/arterial/sub-arterial road corridors.	55 $L_{Aeq(15\ hour)}$[2]	50 $L_{Aeq(9\ hour)}$
	Existing residences affected by noise from redevelopment of existing freeway/arterial/sub-arterial roads. Existing residences affected by additional traffic on existing freeways/arterial/sub-arterial roads generated by land use developments.	60 $L_{Aeq(15\ hour)}$	55 $L_{Aeq(9\ hour)}$
	Existing residences affected by both new roads and the redevelopment of existing freeway/arterial/sub-arterial roads in a transition zone[3].	55–60 $L_{Aeq(15\ hour)}$	50–55 $L_{Aeq(9\ hour)}$
	Existing residences affected by increases in traffic noise of 12 dB(A) or more from new freeway/arterial/sub-arterial roads.	42–55 $L_{Aeq(15\ hour)}$	42–50 $L_{Aeq(9\ hour)}$
	Existing residences affected by increases in traffic noise of 12 dB(A) or more from redevelopment of existing freeway/arterial/sub-arterial roads.	42–60 $L_{Aeq(15\ hour)}$	42–55 $L_{Aeq(9\ hour)}$
Local roads	Existing residences affected by noise from new local road corridors.	55 $L_{Aeq(1\ hour)}$	50 $L_{Aeq(1\ hour)}$
	Existing residences affected by noise from redevelopment of existing local roads.		
	Existing residences affected by additional traffic on existing local roads generated by land use developments.		

Note 1: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.4 in Chapter 10 (Construction noise and vibration) for a comparison of dB(A) for various activities

Note 2: $L_{Aeq(X\ hour)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a number of hours

Note 3: The applicable noise criteria for a particular receiver would be dependent on its location relative to where the new road joins the redeveloped road (transition zone). See Section 7.1 and Table 1 of the Noise Criteria Guideline (Roads and Maritime Services, 2015f) for further information.

Non-residential receivers

Consistent with *NSW Road Noise Policy* (DECCW, 2011), *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) also sets criteria for the assessment of road traffic noise on the internal or external areas of non-residential land uses, such as schools, hospitals, places of worship and recreation areas. The applicable criteria for non-residential receivers are shown in Table 11-4.

Outdoor open space can be characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion. Indoor spaces that are deemed 'noise sensitive' generally serve the purpose of education, health care, religious practice or sleeping.

For sensitive land uses such as schools, hospitals, places of worship and childcare centres, criteria have been set for internal areas so the associated activities will not be unduly disturbed by external noise. It is generally accepted that with open windows, the noise level within a building will be at least 10 dB(A) less than the external noise level. This attenuation can increase to more than 30 dB(A) depending on the building type, location of the room within the building, window type and whether the use of the space requires the window to be fully opened, slightly opened or closed. For assessment purposes, a noise reduction of 10 dB(A) is added to the criterion for an internal area to identify an external screening criterion. The non-residential receivers identified to exceed the external screening criterion in this assessment will require further investigation during further design development to confirm the extent of noise impact and eligibility for consideration of noise mitigation.

Table 11-4 Criteria for non–residential sensitive land uses

Existing sensitive land use	Assessment criteria, dB(A)[1]	
	Day (7am – 10pm)	Night (10pm – 7am)
School classrooms	40 $L_{Aeq(1\ hour)}$[2] (internal)	–
Hospital wards	35 $L_{Aeq(1\ hour)}$ (internal)	35 $L_{Aeq(1\ hour)}$ (internal)
Places of worship	40 $L_{Aeq(1\ hour)}$ (internal)	40 $L_{Aeq(1\ hour)}$ (internal)
Open space (active use)	60 $L_{Aeq(15\ hour)}$ (external) when in use	–
Open space (passive use)	55 $L_{Aeq(15\ hour)}$ (external) when in use	–
Childcare facilities	Sleeping rooms 35 $L_{Aeq(1\ hour)}$ (internal) Indoor play areas 40 $L_{Aeq(1\ hour)}$ (internal) Outdoor play areas 55 $L_{Aeq(1\ hour)}$ (external)	–
Aged care facilities	Residential land use noise assessment criteria apply	Residential land use noise assessment criteria apply

Note 1: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.4 in Chapter 10 (Construction noise and vibration) for a comparison of dB(A) for various activities

Note 2: $L_{Aeq(X\ hour)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a number of hours

Road traffic noise impacts along existing roads

Noise Criteria Guideline (Roads and Maritime Services, 2015f) provides guidance for assessing traffic noise from existing roads not subject to any redevelopment. This is where there is a predicted increase in traffic noise levels of more than 2 dB(A) on the surrounding road network due to the redistribution of traffic flow facilitated by the project. The criteria are provided in Table 11-5.

Table 11-5 Criteria for existing roads not subject to redevelopment

Existing road category	Target noise level dB(A)[1]	
	Day (7am – 10pm)	Night (10pm – 7am)
Freeway/ arterial/ sub-arterial road	$L_{Aeq(15\ hour)}$[2] 60 (external)	$L_{Aeq(9\ hour)}$ 55 (external)
Local road	$L_{Aeq(1\ hour)}$ 55 (external)	$L_{Aeq(1\ hour)}$ 50 (external)

Note 1: dB(A) stands for A-–weighted decibel, a unit used to measure noise. Refer to Section 10.4 in Chapter 10 (Construction noise and vibration) for a comparison of dB(A) for various activities

Note 2: $L_{Aeq(X\ hour)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a number of hours.

Maximum road traffic noise levels

Maximum noise levels are generally due to heavy vehicles passing by. The measured maximum noise level and the number of maximum noise level events are used as indicators of the potential for sleep disturbance.

11.3.2 Sleep disturbance

Guidance for considering sleep disturbance due to maximum noise levels is provided in Practice Note (iii) of *Environmental Noise Management Manual* (RTA, 2001). The relevant considerations are:

- Maximum noise levels
- The extent to which the maximum noise levels for individual vehicle pass-bys exceed the L_{Aeq} noise level for each hour of the night
- The number of maximum noise events.

At locations where road traffic is continuous rather than intermittent, the $L_{Aeq(9\ hour)}$ criteria for operational noise assessment accounts for sleep disturbance impacts. However, where the emergence of L_{Amax} over the ambient L_{Aeq} is equal to or greater than 15 dB(A), the $L_{Aeq(9\ hour)}$ criteria may not sufficiently account for sleep disturbance impacts.

The sleep disturbance assessment does not influence the extent of mitigation required but is used to rank and prioritise design options and noise mitigation strategies.

11.3.3 Operational road traffic mitigation

Modelling of operational road traffic noise based on the ‘Do minimum’ (without the project) and the ‘Do something cumulative’ (with the project and other projects) scenarios were used to identify road traffic noise levels at receivers in the vicinity of the project.

The following *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g) eligibility triggers were applied where a sensitive receiver may qualify for consideration of noise mitigation beyond the adoption of road design and traffic management measures:

- The predicted ‘build’ (with the project) noise level exceeds *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) controlling criteria and the predicted noise level increase due to the project
(ie the noise predictions for the ‘build’ (with the project) minus the ‘no build’ (without the project)) is greater than 2 dB(A), or
- The predicted ‘build’ (with the project) noise level is 5 dB(A) or more above the criteria (at or exceeds the cumulative limit) and the receiver is significantly influenced by traffic noise from the road project, regardless of the incremental impact of the project, or
- The noise level contribution from the project is acute even if noise levels are dominated by another road. The acute noise level for day time (7am to 10pm) is an $L_{Aeq(15\ hour)}$ of 65 dB(A) or higher, and for night time (10pm to 7am) is an $L_{Aeq(9\ hour)}$ of 60 dB(A) or higher. Buildings predicted to be subject to acute noise levels qualify for consideration of noise mitigation even if noise levels are dominated by another road.

When the eligibility triggers are exceeded, additional mitigation is considered. The mitigation options considered (in order of preference) include:

- Source controls (such as quieter noise pavements)
- Path controls (such as noise barriers)
- At-property controls (such as architectural treatments).

A noise barrier analysis was also completed to identify reasonable and feasible locations where barriers would potentially be provided. The analysis followed the process outlined in *Noise*

Mitigation Guideline (Roads and Maritime Services, 2015g) and guidance in *Noise Wall Design Guideline* (Roads and Maritime Services, 2016ba).

11.3.4 Operational noise from fixed facilities

Fixed facilities and ancillary infrastructure associated with the operation of the project would include motorway facilities and ventilation outlets, a motorway control centre, tunnel support facilities, and groundwater and tunnel drainage management and treatment systems, including a wastewater treatment plants. Certain equipment associated with the fixed facilities, such as in-tunnel jet fans, axial fans at ventilation outlets, substations and pumps, have the potential to emit noise that could impacts sensitive receivers the vicinity.

Noise levels from fixed facilities are assessed in accordance with *Noise Policy for Industry* (NSW EPA, 2017a), which includes both intrusiveness and amenity criteria. The intrusiveness criterion aims to minimise noise increases from a single new development by applying a criterion of 5 dB(A) above background levels. The amenity criteria aims to limit continuing increases in ambient noise by applying recommended levels for certain receiver types. The most stringent of the two applies.

11.3.5 Open space and recreation facilities noise

Noise impacts from the use of the new and improved open space and recreational facilities at Balgowlah was assessed in accordance with *Noise Guide for Local Government* (NSW EPA, 2013b). This guideline applies a criterion of 5 dB(A) above background levels to determine whether noise levels from open space and recreational facilities would be considered intrusive. It is noted that the open space and recreation facilities are anticipated to operate during the day and evening periods (up to 10pm). Therefore, potential noise impacts have been assessed for the quieter evening period.

11.4 Existing noise environment

The existing noise environment, including ambient noise levels, is described in Chapter 10 (Construction noise and vibration). These ambient noise levels would also be applicable to the operational noise assessment discussed below.

11.5 Assessment of operational impacts

11.5.1 Overview

This section provides an assessment of operational road traffic noise impacts for surface roads associated with the project as well impacts from project operational facilities. This section assesses potential operational noise levels and impacts without any mitigation in place. It also outlines indicative mitigation measures to address the predicted noise levels and impacts. This assessment is for environmental impact assessment and planning approval purposes and would be reviewed and adjusted during further design development to confirm the suite of mitigation measures that would be adopted for the project.

11.5.2 Road traffic noise before mitigation

The operational road traffic noise model scenarios listed in Table 11-2 were first considered before the inclusion of additional or augmented noise barriers, but do consider the following:

- Existing noise barriers
- Quieter pavements for some surface roads (eg open grade asphalt where functionality appropriate) providing up to 2 dB(A) noise reduction benefits (compared to dense graded asphalt).

This analysis is presented below.

‘Do something’ scenario

Table 11-6 shows predicted changes in noise levels for receivers under a ‘Do minimum’ (without the project) and ‘Do something’ (with the project) noise model scenarios for sensitive receiver buildings at the following locations:

- Warringah Freeway and surrounds
- Gore Hill Freeway and Artarmon – includes connections to and from the Gore Hill Freeway
- Balgowlah and surrounds – includes connections to and from Burnt Bridge Creek Deviation and surface road works at Balgowlah
- Seaforth to Frenchs Forest – includes connections to and from the Wakehurst Parkway and the realignment and upgrade of the Wakehurst Parkway.

Table 11-6 Predicted changes in noise levels before mitigation (2037 ‘Do minimum’ scenario compared to ‘Do something’ scenario)[1]

Location	Number of receiver buildings experiencing changes in noise levels from operational traffic					
	Noise level reduction		Increase 0 dB(A)[2] – 2 dB(A)		Increase > 2 dB(A)	
	Day	Night	Day	Night	Day	Night
Warringah Freeway and surrounds	5326	5582	1423	1169	15	13
Gore Hill Freeway and Artarmon	149	719	993	425	5	3
Balgowlah and surrounds	822	896	1493	1303	37	153
Seaforth to Frenchs Forest	17	33	901	783	317	419

Note 1: The ‘with the project’ scenario includes the Beaches Link and Gore Hill Freeway Connection, WestConnex, and the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project

Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.4 in Chapter 10 (Construction noise and vibration) for a comparison of dB(A) for various activities.

Overall:

- The project is predicted to reduce traffic noise for about 59 per cent of receiver buildings within noise catchment areas surrounding the project surface road works
- Thirty-seven per cent of receiver buildings are predicted to experience traffic noise level increases of less than 2 dB(A), which represents a minor impact that is likely to be barely perceptible
- Four per cent of receiver buildings are predicted to experience increases greater than 2 dB(A) due to the project.

The project is predicted to decrease the number of receiver buildings exceeding the relevant noise criteria when compared to the ‘Do minimum’ scenario during the day and night periods at noise catchment areas surrounding the Warringah Freeway and Gore Hill Freeway and Artarmon. This is due to traffic being moved from the existing surface roads into the proposed tunnels.

The project is predicted to result in road traffic noise levels that exceed the criteria and increase by 2 dB(A) or more compared to the ‘Do minimum’ scenario during the day and night periods in certain locations in the noise catchment areas surrounding Balgowlah, Seaforth, North Balgowlah, Killarney Heights, Allambie Heights and Frenchs Forest. This is due to predicted increases in traffic volumes and redistributed traffic on local roads associated with vehicles entering and exiting the tunnel portals at Killarney Heights and Balgowlah. In the absence of additional traffic calming measures, the following local roads are predicted to be impacted:

- Traffic volumes during the night period along Wanganella Street at Balgowlah are forecast to increase noise levels by more than 2 dB(A) and result in exceedances of the road traffic noise criteria
- Traffic volumes during the night period along Judith Street at Seaforth and Woodbine Street at North Balgowlah are forecast to increase noise levels by more than 2 dB(A), which could potentially result in exceedances of the road traffic noise criteria.

Traffic calming measures would be designed and implemented in consultation with Northern Beaches Council to ensure impacts due to potential increased traffic are minimised (refer to environmental management measure ONV3 in Table 11-12).

With the exception of Wakehurst Parkway at Frenchs Forest and local roads indicated above, the majority of properties that are eligible for consideration of noise mitigation beyond the adoption of road design and traffic management measures (refer to Section 11.3.3) are due to predicted exceedances of the cumulative limit and acute noise levels, rather than increases due to the project. This indicates that existing road traffic noise levels, rather than changes due to the project, are the main driver for additional noise mitigation.

'Do something cumulative' scenario

Table 11-7 shows predicted changes in noise levels for receivers under a 'Do minimum' (without the project) and 'Do something cumulative' (with the project and other projects) noise model scenarios for sensitive receiver buildings surrounding the Warringah Freeway, the Gore Hill Freeway and Artarmon, Balgowlah and surrounds and Seaforth to Frenchs Forest. The properties that would be eligible for consideration of noise mitigation beyond the adoption of road design and traffic management measures in this scenario, based on the criteria specified in Section 11.3.3, are indicated in Figure 11-1 to Figure 11-3. For further detail refer to Annexure N of Appendix G (Technical working paper: Noise and vibration). Noise barriers around the Warringah Freeway would be deliver as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

Table 11-7 Predicted changes in noise levels before mitigation (2037 'Do minimum' scenario compared to 'Do something')[1]

Location	Number of receiver buildings experiencing changes in noise levels from operational traffic					
	Noise level reduction		Increase 0 dB(A)[2] – 2 dB(A)		Increase > 2 dB(A)	
	Day	Night	Day	Night	Day	Night
Warringah Freeway and surrounds	5140	5923	1588	808	36	33
Gore Hill Freeway and Artarmon	79	1002	1056	142	12	3
Balgowlah and surrounds	813	901	1500	1301	39	150
Seaforth to Frenchs Forest	36	22	868	790	331	423

Note 1: 'The project and other projects' scenario includes the following projects: Beaches Link and Gore Hill Freeway Connection, Western Harbour Tunnel and Warringah Freeway Upgrade, WestConnex, Sydney Gateway, and the M6 Motorway

Note 2: dB(A) stands for A-weighted decibel, a unit used to measure noise. Refer to Section 10.4 in Chapter 10 (Construction noise and vibration) for a comparison of dB(A) for various activities.

Overall:

- The project, in combination with other projects, is predicted to reduce traffic noise for about 61 per cent of receiver buildings within noise catchment areas surrounding the project surface road works
- Thirty-five per cent of receiver buildings are predicted to experience traffic noise level increases of less than 2 dB(A) which represents a minor impact that is likely to be barely perceptible

- Four per cent of receiver buildings are predicted to experience increases greater than 2 dB(A).

Changes in traffic from the project and other major road projects are predicted to decrease the number of receiver buildings exceeding the *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) noise criteria when compared to the ‘Do minimum’ scenario during the day and night periods at noise catchment areas surrounding the Warringah Freeway and Gore Hill Freeway. This is due to traffic being moved from the existing surface roads into the proposed tunnels.

The project is predicted to result in road traffic noise levels that exceed the criteria and increase by 2 dB(A) or more (compared to the ‘Do minimum’ scenario) during the day and night periods in the same locations in Balgowlah and Seaforth to Frenchs Forest as for the ‘Do something’ scenario. Traffic calming measures would be designed and implemented in consultation with Northern Beaches Council to ensure impacts due to potential increased traffic are minimised (refer to environmental management measure ONV3 in Table 11-12).

As for the ‘Do something’ scenario, with the exception of Wakehurst Parkway at Frenchs Forest and certain local roads in Seaforth, North Balgowlah and Balgowlah indicated above, the majority of properties that are eligible for consideration of noise mitigation beyond the adoption of road design and traffic management measures (refer to Section 11.3.3) are due to predicted exceedances of the cumulative limit and acute noise levels, rather than increases due to the project. This indicates that existing road traffic noise levels, rather than changes due to the project, are the main driver for additional noise mitigation.

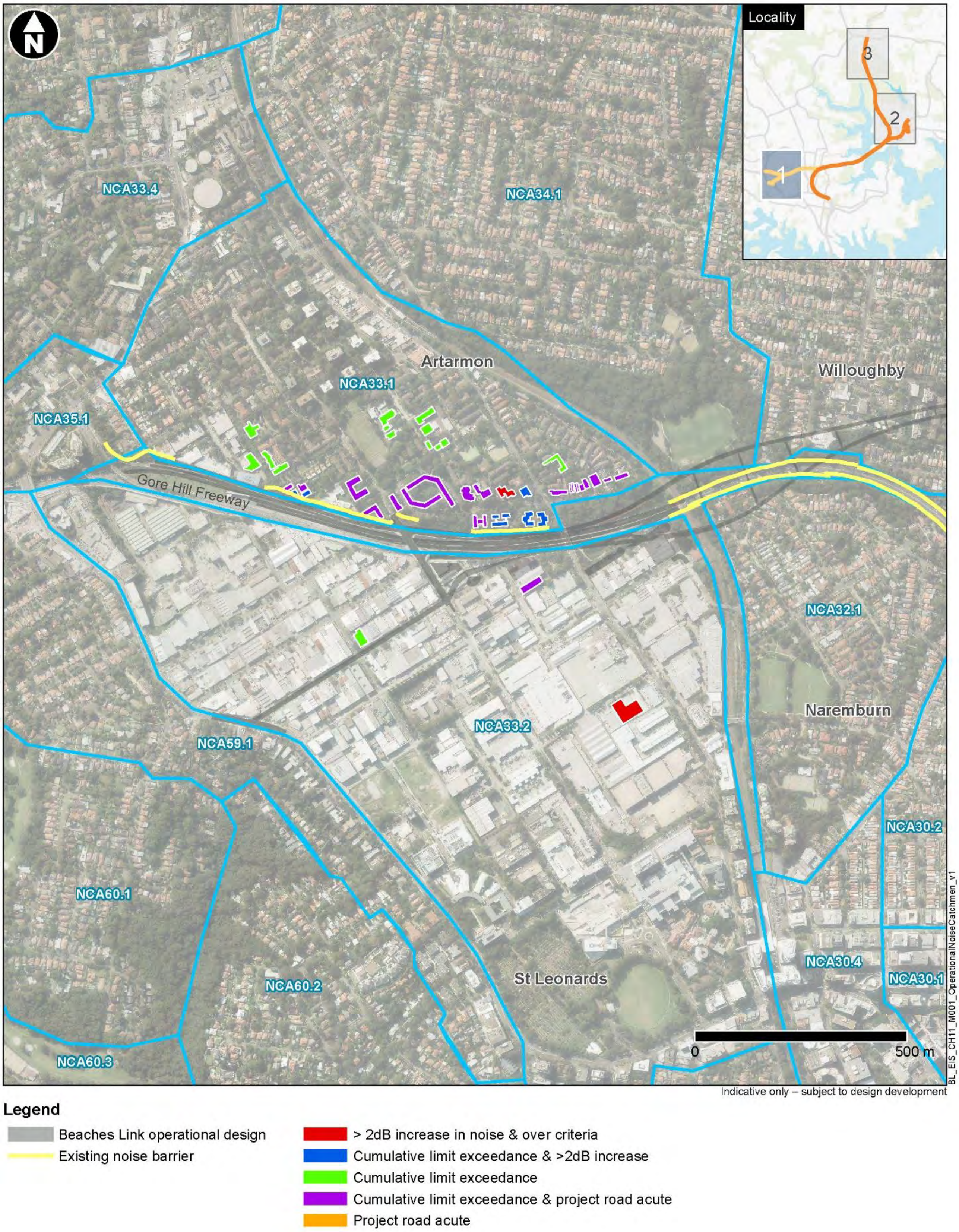

Figure 11-1 Receiver buildings eligible for consideration of additional noise mitigation (map 1)

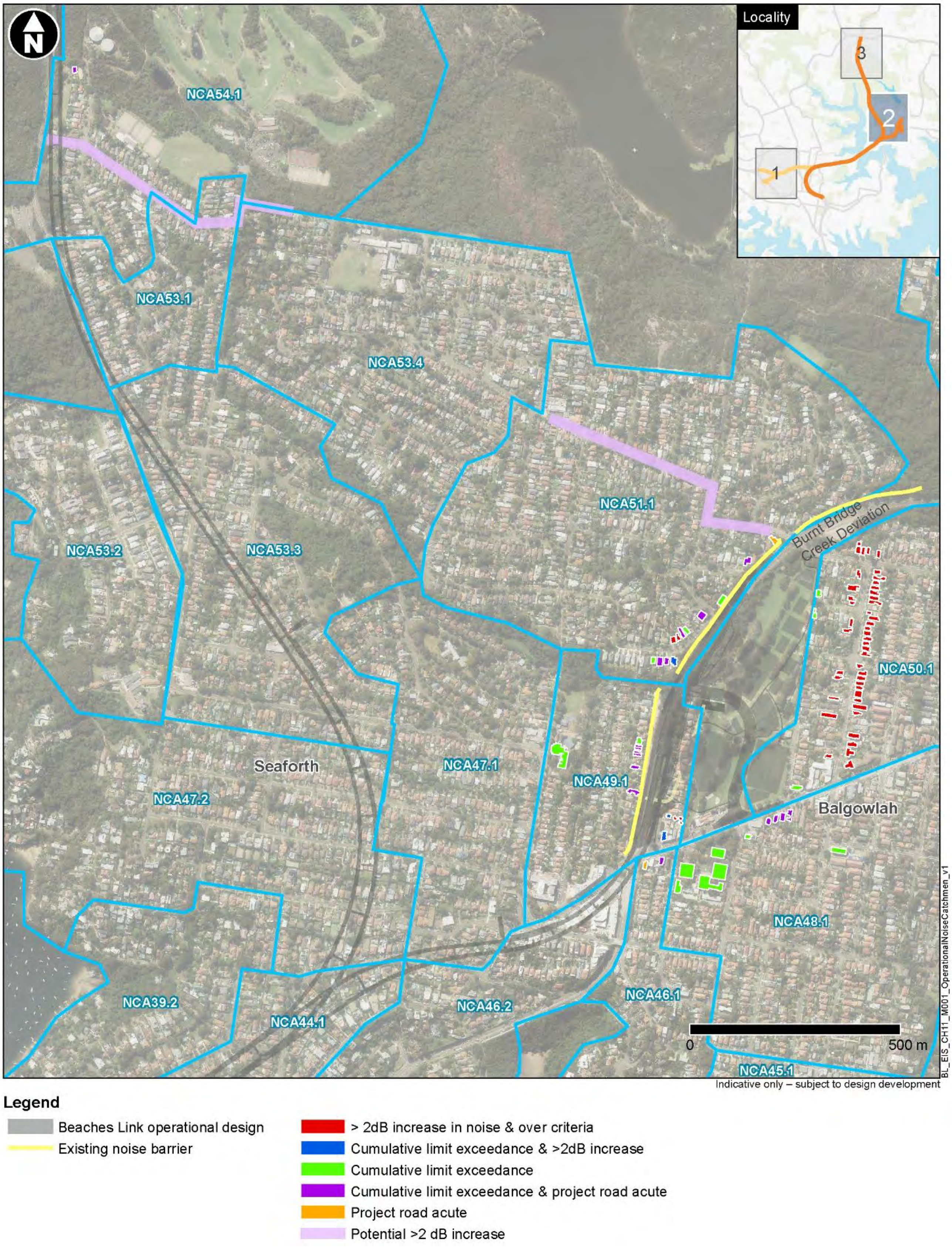

Figure 11-2 Receiver buildings eligible for consideration of additional noise mitigation (map 2)

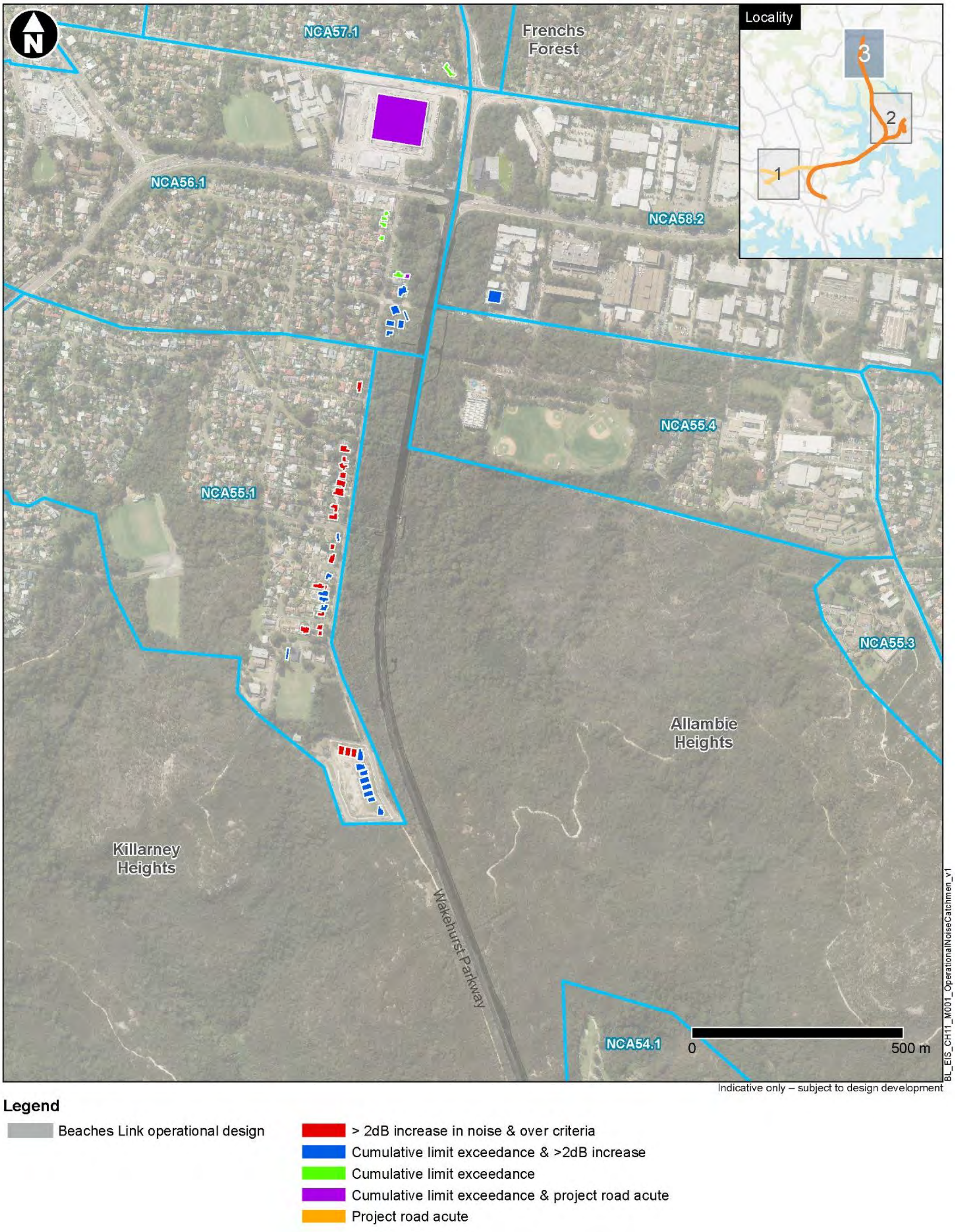

Figure 11-3 Receiver buildings eligible for consideration of additional noise mitigation (map 3)

11.5.3 Mitigation of road traffic noise

Quieter pavements

Noise Mitigation Guideline (Roads and Maritime Services, 2015g) sets out that quieter pavement is the preferred form of noise mitigation for road traffic noise as it reduces source noise levels and provides protection to both external and internal sensitive areas and also has the least visual impact. Quieter pavements may be considered where there are groups of four or more closely spaced receivers (ie facades are separated by less than 20 metres) that exceed the *Noise Criteria Guideline* (Roads and Maritime Services, 2015f). Quieter pavement, however, is not always appropriate for engineering reasons (durability) based on likely traffic conditions and does not always provide reasonable attenuation based on likely traffic speed. Quieter pavement is not, therefore, appropriate in all locations and situations.

For the purpose of operational noise assessment, quieter pavements, such as open grade asphalt or similar, has been assumed for sections of Gore Hill Freeway and Burnt Bridge Creek deviation affected by the project. A 2 dB(A) noise reduction (compared to dense graded asphalt) has been assumed for the quieter pavements. The resultant road traffic noise levels have been used to consider additional mitigation required.

The use of quieter pavements to reduce operational road traffic noise would continue to be investigated during further design development. Pavements would ultimately be selected by balancing performance, design life, durability, serviceability and noise emissions.

Noise barriers

Noise barriers are considered reasonable and feasible where four or more receivers are predicted to experience noise levels that exceed the noise criteria and are closely grouped (ie facades are separated by less than 20 metres), where the barriers do not make access to properties difficult, and where they are visually acceptable.

The process provided in *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g) was used to identify the design barrier height for each existing barrier and new barrier proposed in the areas affected by the project. The feasibility of each barrier at the identified design height was then evaluated by considering engineering constraints, constructability constraints, land and property impacts, potential over shadowing, visual amenity and other environmental considerations in accordance with the process provided in *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g). For a number of the proposed new and existing barriers, the identified design height is not feasible and reasonable based on these considerations. For the proposed new barriers, an alternative feasible and reasonable barrier height is proposed. The alternative barrier heights were assessed to confirm that they provide appropriate noise attenuation benefits. The existing barriers were also assessed. As they provide appropriate attenuation, the existing barriers would be retained at the existing heights. The alternative barrier heights and existing barriers were then assessed to identify which property would be eligible for consideration for at-property treatment.

The noise barrier analysis is presented in Table 7-7 and Annexure N in Appendix G (Technical working paper: Noise and vibration). A summary of indicative noise barriers proposed as part of the project is provided in Table 11-8. Chapter 5 (Project description) provides the locations of the proposed new and existing retained noise barriers relevant to the Beaches Link and Gore Hill Freeway Connection project. New noise barriers have not been proposed as a result of the connection to and from the Burnt Bridge Creek Deviation due to reasonable and feasible considerations (see Table 7-7 of Appendix G (Technical working paper: Noise and vibration) for further discussion).

The proposed new and upgraded noise barriers along Warringah Freeway described in Appendix G (Technical working paper: Noise and vibration) would be delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project and are not included here.

The details of new barriers, any changes to existing barriers and the eligibility and suitability of receiver buildings for at-property treatment would be confirmed during detailed design (refer to environmental management measure ONV1 in Table 11-12 below).

Table 11-8 Summary of indicative new noise barriers

Approximate location	Barrier considered	Approx. length (metres)	Barrier height (metres)
Gore Hill Freeway			
Northern side, between Hampden Road, Artarmon and the T1 North Shore and Western and T9 Northern rail lines	New	263	5
Wakehurst Parkway			
Western side, adjacent to Bayview Close, Frenchs Forest	New	339	5
Western side, south from Yarraman Avenue Walkway bus stop, Frenchs Forest	New	253	4

Receiver buildings potentially eligible for consideration of additional noise mitigation

Further assessment has been conducted to compare the 'Do minimum' and the 'Do something cumulative' scenarios, including proposed quieter pavements (eg open grade asphalt where functionality appropriate) and proposed new and existing retained noise barriers.

Table 11-9 identifies the number of receivers to be considered for at-property treatment after the potential benefits of quieter pavements and new and existing retained noise barriers have been included. At-property treatments may include but are not limited to mechanical ventilation, glazing, window and door seals, sealing of vents and sealing of underfloor areas.

Noise mitigation options (quieter pavements, noise barriers, at-property treatment or a combination) will be confirmed as part of the further design development taking into consideration community preferences (refer to environmental management measure ONV1 in Table 11-12).

Due to the widening of the Burnt Bridge Creek Deviation and the Wakehurst Parkway and the predicted increase in traffic volumes due to the project and other major road projects, the overall number of receiver buildings at which road traffic noise levels are predicted to exceed the noise criteria during the day and night periods is predicted to increase compared to the 'Do Minimum' scenario. Receivers along some local roads in Balgowlah, North Balgowlah and Seaforth are predicted to experience traffic noise levels increasing by more than 2 dB(A) due to operational road traffic volume increases (refer to Section 11.5.2). This has resulted in a large number of receivers being considered for at-property treatment. Transport for NSW will investigate the implementation of traffic calming on the affected local roads with the aim of limiting road traffic noise increases to no more than 2 dB(A) in consultation with Northern Beaches Council to reduce road traffic noise impact at these receivers (refer to environmental management measure ONV3 in Table 11-12).

Annexure R of Appendix G (Technical working paper: Noise and vibration) shows the locations of receiver buildings identified in Table 11-9. It is noted that Annexire R includes properties along Warringah Freeway and in adjacent areas. Mitigation for road traffic noise, including at-property treatment, for Warringah Freeway and surrounds would be carried out as part of the Western Harbour Tunnel and Warringah Freeway Upgrade, and are not considered further here.

The properties that are eligible for consideration for at-property treatments, with all other proposed mitigations in place, would be confirmed during further design development in accordance with the process in *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g).

Table 11-9 Number of receivers considered for at–property treatment[1]

NCA[2]	Location	Number of receiver floors[3]	Number of receiver buildings
Gore Hill Freeway and Artarmon			
33.1	Artarmon	79	42
33.2	Artarmon	13	3
	Total	**92**	**45**
Balgowlah and surrounds			
46.1	Balgowlah	4	2
48.1	Balgowlah	23	10
49.1	Seaforth	16	13
50.1	Balgowlah	63	47
51.1	North Balgowlah	72	62
	Total	**178**	**134**
Seaforth to Frenchs Forest			
53.1	Seaforth	15	11
53.4	North Balgowlah	1	1
54.1	Seaforth	36	30
55.1	Forestville	14	11
56.1	Frenchs Forest	14	12
57.1	Frenchs Forest	15	2
58.2	Frenchs Forest	6	1
	Total	**101**	**68**
Project Total		**371**	**247**

Note 1: Number of receivers considered for at-property treatment would be subject to further design development and confirmation of all proposed mitigations measures, and would be based on the resultant predicted road traffic noise levels
Note 2: Refer to Figure 10-1 in Chapter 10 (Construction noise and vibration) for location of noise catchment areas
Note 3: Receiver floors represent the individual receiver floor levels of a multi-level building. For example, a ten-storey residential apartment block would have ten receiver floors and one receiver building.

11.5.4 Maximum road traffic noise level

Where road traffic noise dominates the noise environment, maximum noise levels (mainly generated by heavy vehicles) have the potential to cause disturbance to sleep.

Changes in the maximum noise levels and the number of events generating these levels would depend on changes in traffic volumes and changes on road alignment or width. The project is predicted to increase maximum noise level events at sensitive receivers within the following noise catchment areas:

- NCA 23.1 located in Neutral Bay– sensitive receivers to the east of the Warringah Freeway are predicted to experience an increase in maximum noise levels and the number of events compared to the existing situation due to the widening of the Warringah Freeway resulting in the southbound carriageway moving closer to receivers in this NCA
- NCAs 49.1 and 50.1 located in Seaforth and Balgowlah – sensitive receivers to the west and east of the new access road which forms part of the connections to and from Burnt Bridge

Creek Deviation are predicted to experience an increase in maximum noise levels and the number of events compared to the existing levels due to traffic along the new access road between Sydney Road and the Burnt Bridge Creek Deviation. The new access road would include traffic lights at Sydney Road and the Burnt Bridge Creek Deviation, which would contribute to the increase in maximum noise levels and the number of events. Furthermore, new bus stops along the new access road would also introduce maximum noise levels and events to these receivers

- NCA 48.1 located in Balgowlah – sensitive receivers to the south of the new access road intersection with Sydney Road are predicted to experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the new traffic lights on Sydney Road impacting receivers in this NCA
- NCA 55.1 located in Frenchs Forest– sensitive receivers to the west of the new access road intersection with the Burnt Bridge Creek Deviation are predicted to experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the new traffic lights on the Burnt Bridge Creek Deviation impacting receivers in this NCA
- NCAs 54.1 and 55.1 located in Seaforth, Allambie Heights, Killarney Heights and Frenchs Forest – sensitive receivers to the east and west of Wakehurst Parkway are predicted to experience an increase in maximum noise levels and the number of events compared to the existing situation. This is due to the realignment and upgrade of Wakehurst Parkway resulting in both the northbound and southbound carriageways moving closer to receivers and the introduction of new traffic light intersections or new bus stops in these NCAs, which in turn are likely to increases maximum noise levels and the number of events at the affected receivers.

Maximum noise levels are not expected to significantly change as a result of the project within other noise catchment areas where no major road realignments or widening would be carried out.

Changes in maximum noise levels are a consideration when prioritising and ranking mitigation strategies and will be considered during further design development. Mitigation measures to be considered are described in Section 11.8.

11.5.5 Operational facilities

Table 11-10 compares predicted fixed facility noise levels with *Noise Policy for Industry* (NSW EPA, 2017a) intrusiveness and amenity criteria. No criteria exceedances are predicted. Noise predictions and assessment of operational fixed facilities will be updated when actual types, makes and models of the plant and equipment are confirmed.

Table 11-10 Predicted noise levels ($L_{Aeq(15\ minute)}$)[1] from fixed facilities, dB(A)

Fixed facility location	NCA[2]	Project noise criteria[3]		Predicted noise level
		Intrusiveness	Amenity	
Warringah Freeway	NCA 23.1	49	43	39
	NCA 23.2	42	43	39
	NCA 24.1	42	43	37
	NCA 25.1	48	43	36
	NCA 26.1	46	43	38
	NCA 26.2	42	43	40
	NCA 29.1	52	43	35

Fixed facility location	NCA[2]	Project noise criteria[3]		Predicted noise level
		Intrusiveness	Amenity	
Gore Hill Freeway	NCA 32.1	45	43	<35
	NCA 33.1	51	43	38
	NCA 33.2[4]	N/A	68	45
Burnt Bridge Creek Deviation	NCA 49.1	36	43	<35
	NCA 50.1	40	43	<35
	NCA 51.1	41	43	38
Wakehurst Parkway	NCA 54.1	35	43	<35

Note 1: $L_{Aeq(15\ minute)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a period of 15 minutes
Note 2: Refer to Figure 10-1 in Chapter 10 (Construction noise and vibration) for location of noise catchment areas
Note 3: Project noise levels based on night-time period. Most stringent criteria used for assessment is shown in bold font
Note 4: Noise catchment area 33.2 in Artarmon comprises industrial premises only.

11.6 Assessment of open space and recreation facilities at Balgowlah

Noise impacts from the proposed new and improved open space and recreation facilities at Balgowlah have been determined through noise modelling of typical activities associated with the facilities. The indicative layout of these facilities at Balgowlah provided in Chapter 5 (Project description) was subject to assessment, and noise predictions are based on all the playing fields, courts, playgrounds and carpark areas operating concurrently (conservative).

The indicative layout of these facilities at Balgowlah would comply with the noise criterion at sensitive receivers in NCA 48.1 located in Balgowlah south of Sydney Road. However, some sensitive receivers in NCA 50.1 located in Balgowlah north of Sydney Road and east of the Burnt Bridge Creek Deviation may potentially experience noise exceedances during periods where all activities at the facilities are occurring concurrently.

A dedicated consultation process, jointly led by Transport for NSW and Northern Beaches Council will, is proposed to give the community an opportunity to provide input into the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation would be separate to the consultation for the Beaches Link environmental impact statement. The final layout would be designed to meet intrusive noise criteria derived in accordance with the *Noise Guide for Local Government* (NSW EPA, 2013b) where reasonable and feasible. The final layout would be subject to further noise assessment to confirm the need for and details of any noise additional attenuation required.

Refer to Annexure U of Appendix G (Technical working paper: Noise and vibration) for the location of receiver buildings identified in Table 11-11.

Table 11-11 Predicted noise levels ($L_{Aeq(15\ minute)}$)[1] from the new and improved open space and recreation facilities, dB(A) and potential exceedances based on indicative layout

NCA	Location	Noise criteria	Predicted noise level	Number of exceedances
48.1	Balgowlah	55	52	-
50.1	Balgowlah	50	56	6

Note 1: $L_{Aeq(15\ minute)}$ is the A-weighted "equivalent noise level". It is the summation of noise events and integrated over a period of 15 minutes

11.7 Assessment of operational impacts – vibration

The potential for operational ground-borne noise and tactile vibration impacts on nearby sensitive receivers from traffic on project surface roads and tunnels has been reviewed.

Vehicles operating on a roadway are unlikely to cause a perceptible level of vibration unless there are significant road irregularities (eg potholes), particularly if the affected receiver is more than 20 metres from the roadway.

As the new and upgraded roads on the surface and in the tunnels associated with the project would be designed and constructed to avoid road irregularities, operational ground-borne noise and tactile vibration impacts from operation traffic are not expected.

Vibration impacts from traffic travelling on the proposed surface roads, through tunnels and portals are considered negligible and are unlikely to result in ground-borne noise or tactile vibration impacts to sensitive receivers directly adjacent to surface roads, tunnels and portals.

Similarly, vibration from operational fixed facilities is not anticipated to exceed objectives given the distance between these facilities and the nearest sensitive receiver.

11.8 Environmental management measures

Environmental management measures for potential noise and vibration impacts during operation are outlined in Table 11-12. Additional measures to address cumulative impacts are included in Chapter 27 (Cumulative impacts).

Table 11-12 Environmental management measures – operational noise and vibration

Ref	Phase	Impact	Environmental management measure	Location
ONV1	Operation	Operational road traffic noise	The operational noise performance of the project will be reviewed during further design development and functionally appropriate operational noise mitigation (quieter pavements eg open grade asphalt, noise barriers, at-property treatments or a combination of treatments) will be confirmed in accordance with *NSW Road Noise Policy* (DECCW, 2011), *Noise Criteria Guideline* (Roads and Maritime Services, 2015f) and *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g).	BL/GHF
ONV2	Operation	Operational road traffic noise	Within 12 months of the commencement of the operation of the project, actual operational noise performance will be compared to predicted operational noise performance (as reviewed during further design development) to analyse the effectiveness of the operational road traffic noise mitigation measures. Additional reasonable and feasible mitigation will be considered where any additional receivers are identified as qualifying for consideration of noise mitigation in accordance with the *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g).	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
ONV3	Design and construction	Operational road traffic noise	For local roads in Balgowlah, North Balgowlah and Seaforth where predicted increases in traffic are likely to result in exceedances of the relevant road traffic noise criteria, traffic calming measures with the aim of limiting potential road traffic noise increases to no more than 2 dB(A) will be investigated in consultation with Northern Beaches Council and implemented. As a minimum, traffic calming measures will be investigated for Wanganella Street at Balgowlah, Woodbine Street at Balgowlah and Judith Street at Seaforth. The need for at-property treatments will be confirmed during further design development and will consider the potential impact of the proposed traffic calming measures on traffic volumes and speeds.	BL
ONV4	Operation	Operational facilities noise	Operational fixed facilities will be designed to meet project specific noise criteria derived in accordance with the *Noise Policy for Industry* (NSW EPA, 2017a).	BL/GHF
ONV5	Operation	Sporting and recreation noise impacts	Open space and recreation facilities at Balgowlah will be designed to meet intrusive noise criteria derived in accordance with the *Noise Guide for Local Government* (NSW EPA, 2013b) where reasonable and feasible. The final layout will be subject to further noise assessment to confirm the need for and details of any additional noise attenuation required.	BL

BL = Beaches Link, GHF = Gore Hill Freeway Connection

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 12

Air quality

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DECEMBER 2020

12 Air quality

This chapter outlines the potential air quality impacts associated with the project and identifies measures which address these impacts. A detailed air quality impact assessment has been carried out for the project and is included in Appendix H (Technical working paper: Air quality).

An assessment of potential human health impacts associated with air quality is provided in Chapter 13 (Human health).

The Secretary's environmental assessment requirements as they relate to air quality, and where in the environmental impact statement these have been addressed, are detailed in Table 12-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to air quality are included in Section 12.7.

Table 12-1 Secretary's environmental assessment requirements – air quality

Secretary's requirements	Where addressed in EIS
Air quality	
1. The Proponent must undertake an air quality impact assessment (AQIA) for construction and operation of the project in accordance with the current guidelines.	**Appendix H** (Technical working paper: Air quality) documents the air quality impact assessment undertaken for the project in accordance with current guidelines. **Chapter 12** provides the air quality impacts related to the project. **Section 12.5** and **Section 12.6** outline the potential air quality impacts of the construction and operation of the project respectively.
2. The Proponent must ensure the AQIA also includes the following: a. Demonstrated ability to comply with the relevant regulatory framework, specifically the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Operations (Clean Air) Regulation 2010;	**Section 12.1** outlines information in respect to the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Operations (Clean Air) Regulation 2010. **Section 12.6** outlines the compliance of the project with relevant criteria and regulatory requirements.
b. The identification of all potential sources of air pollution including details of the location, configuration and design of all potential emission sources including ventilation systems and tunnel portals;	The methodology for identifying all potential sources of air pollution during construction and operation are outlined in **Section 12.2**. Details of potential sources of air pollution are provided in **Section 12.4**, **Section 12.5** and **Section 12.6**. The configuration and design of ventilation systems and tunnel portals are described and shown in **Chapter 5** (Project description).
c. A review of vehicle emission trends and an assessment that uses or sources	Best available information on vehicle emission trends are presented in **Section 12.4**.

Secretary's requirements	Where addressed in EIS
best available information on vehicle emission factors;	
d. An assessment of impacts (including human health impacts) from potential emissions from PM_{10}, $PM_{2.5}$, CO, NO_2, and other nitrogen oxides and volatile organic compounds (eg BTEX) including consideration of short and long term exposure periods;	An assessment of impacts of air pollutants during short and long term exposure periods are outlined in **Section 12.6**. Impacts to human health due to the operation of the project is provided in **Section 13.5** of **Chapter 13** (Human health).
e. Consider the impacts from the dispersal of these air pollutants on the ambient air quality along the proposal route, proposed ventilation outlets and portals, surface roads, ramps and interchanges and the alternative surface road network;	An assessment of impacts from the dispersal of air pollutants on ambient air quality along the project alignment is outlined in **Section 12.6**.
f. A qualitative assessment of the redistribution of ambient air quality impacts compared with existing conditions, due to the predicted changes in traffic volumes;	A qualitative assessment of the redistribution of ambient air quality impacts in comparison to existing conditions is presented in **Section 12.6.3**.
g. Assessment of worst case scenarios for in-tunnel and ambient air quality, including a range of potential ventilation scenarios and range of traffic scenarios, including worst case design maximum traffic flow scenarios (variable speed) and the worst case breakdown scenario, and discussion of the likely occurrence of each;	**Section 12.6** outlines the assessment of in-tunnel air quality in addition to the assessment of issues related to ambient air quality.
h. Details of the proposed tunnel design and mitigation measures to address in-tunnel air quality and the air quality in the vicinity of portals and any mechanical ventilation systems (ie ventilation outlets and air inlets) including details of proposed air quality monitoring (including frequency and criteria);	Details of the proposed tunnel design and monitoring are presented in **Chapter 5** (Project description), while mitigation and management measures in relation to in-tunnel air quality and air quality in the vicinity of portals and mechanical ventilation systems are outlined in **Section 12.7.2**.
i. A demonstration of how the project and ventilation design ensures that concentrations of air emissions meet NSW, national and international best practice for in-tunnel and ambient air quality, and taking into consideration the approved criteria for the M4 East project, New M5 project and the In-Tunnel Air Quality (Nitrogen Dioxide) Policy;	Information relating to the design standard of the proposed ventilation system for the project is provided in **Chapter 5** (Project description). Criteria applied in this assessment are discussed in **Section 12.1** and **Section 12.3**. The project and ventilation system have been designed to meet in-tunnel criteria and ambient air quality goals and criteria as outlined in **Section 12.3**.
j. Details of any emergency ventilation systems, such as air intake/exhaust outlets, including protocols for the operation of these systems in	Details of any emergency ventilation systems, such as air intake/ventilation outlets, including protocols for the operation of these systems in emergency situations, potential emission of air

Secretary's requirements	Where addressed in EIS
emergency situations, potential emission of air pollutants and their dispersal, and safety procedures;	pollutants and their dispersal, and safety procedures are presented in **Chapter 5** (Project description).
k. Details of in-tunnel air quality control measures considered, including air filtration, and justification of the proposed measures or for the exclusion of other measures;	Details of in-tunnel air quality control measures considered, including air filtration, and justification of the proposed measures or for the exclusion of other measures are outlined in **Section 12.7.2** and expanded upon in **Chapter 5** (Project description). **Chapter 4** (Project development and alternatives), **Section 4.5** provides the ventilation system design alternatives.
l. A description and assessment of the impacts of potential emission sources relating to construction, including details of the proposed mitigation measures to prevent the generation and emission of dust (particulate matter and TSP) and air pollutants (including odours) during the construction of the proposal, particularly in relation to ancillary facilities (such as concrete batching plants), dredge and tunnel spoil handling and storage, the use of mobile plant, stockpiles and the processing and movement of spoil; and	A description and assessment of impacts relating to potential emission sources relating to construction are outlined in **Section 12.5**, while mitigation measures to prevent the generation and emission of dust and other air pollutants (including odours) are presented in **Section 12.7.1** of this chapter.
m. A cumulative assessment of the in-tunnel, local and regional air quality impacts from the operation of the project and due to the operation of and potential continuous travel through motorway tunnels and surface roads.	The cumulative assessment of the in-tunnel, local and regional air quality impacts, as well as consideration of continuous travel through motorway tunnels, is outlined in **Section 12.6**.

12.1 Legislative and policy framework

The *Protection of the Environment Operations Act 1997* (NSW) allows the NSW Environment Protection Authority to regulate air emissions in NSW. Further, it specifies that road tunnel emissions are regulated by the NSW Environment Protection Authority. The Secretary's environmental assessment requirements for the project refer to the *Protection of the Environment Operations Act 1997* and the Protection of the Environment Operations (Clean Air) Regulation 2010. Although the Protection of the Environment Operations (Clean Air) Regulation 2010 specifies concentration limits for air emissions, these limits are designed primarily for industrial activities and the limit values are much higher than those imposed for motorway tunnels in Sydney.

The monitoring and management of dust emissions during construction and the ventilation outlet emissions during operation would be regulated under an Environment Protection Licence prescribed under the *Protection of the Environment Operations Act 1997*.

In February 2018, the NSW Government announced stronger measures on emissions from motorway tunnels and then established a new process for the assessment, determination, and compliance of significant road tunnels (and associated ventilation systems). The process, which applies to this project, is summarised below:

- Prior to public exhibition of the environmental impact statement:

- The Office of the Chief Scientist and Engineer (OCSE) provides a scientific review of a project's air emissions from ventilation outlets for the Minister of Planning and Public Spaces' consideration
- The NSW Chief Health Officer releases a statement on the potential health impacts of emissions from the tunnel ventilation outlets informed by the review by the OCSE

- The NSW Environment Protection Authority provides technical advice to the Department of Planning, Industry and Environment on operational air quality impacts during the assessment of the environmental impact statement
- The Department of Planning, Industry and Environment seeks advice from an independent air quality expert during the assessment of the environmental impact statement, if required
- If the project is approved, the Department of Planning, Industry and Environment regulates the construction and operation of the project in accordance with the project approval
- The NSW Environment Protection Authority licenses emissions from the ventilation outlets under the *Protection of the Environment Operations Act 1997*.

As part of the preparation of the air quality impact assessment for the project, Appendix H (Technical working paper: Air quality) was issued to the Office of the Chief Scientist and Engineer on 26 October 2020, and the Advisory Committee on Tunnel Air Quality (ACTAQ) coordinated a scientific review of the project's air emissions from ventilation outlets.

For the operating years of the project, nitrogen dioxide (NO_2) would be the pollutant that determines the required airflow and drives the design of the tunnel ventilation system. In February 2016, the ACTAQ issued a policy entitled *'In-tunnel air quality (nitrogen dioxide) policy'* (ACTAQ, 2016). The policy consolidates the approach taken for similar projects (NorthConnex, New M4 and M8 Motorway), and requires tunnels to be 'designed and operated so that the tunnel average NO_2 concentration is less than 0.5 parts per million (ppm) as a rolling 15 minute average'. In 2018, ACTAQ released *Technical Paper TP07: Criteria for In-tunnel and Ambient Air Quality* (ACTAQ, 2018a), which concluded that the NO_2 criterion is the most stringent in Australia and compares favourably to the international in-tunnel NO_2 design guidelines which range from between 0.4 ppm to 1 ppm. The ventilation system would be designed to achieve this criterion.

With regards to regional air quality, the NSW Environment Protection Authority has developed a *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON, 2011). This procedure was applied to the air quality impact assessment of the project to give an indication of the likely significance of the project's effect on ozone concentrations in the broader Sydney region.

The in-tunnel and ambient air quality assessment was carried out against criteria, or levels of pollutants, that have been adopted by the NSW Government. Schedule 4 of the Protection of the Environment Operations (Clean Air) Regulation 2010 specifies standards of concentrations for general activities and plant. The project was assessed against the air quality criteria listed in the *Modelling and Assessment of Air Pollutants in NSW* (NSW EPA, 2016) (NSW EPA Approved Methods) as the statutory method used for assessing air pollution from stationary sources.

Odour emissions would be assessed and managed in accordance with the *Technical framework for the assessment and management of odour from stationary sources in NSW* (DEC, 2006a). This framework introduces a system that protects the environment and the community from the impacts of odour emissions, while promoting fair and equitable outcomes for the operators of activities that emit odour.

12.2 Assessment methodology

12.2.1 Overview

The assessment methodology for air quality impacts has included the following key tasks:

- Assessment of potential dust impacts and odour impacts on sensitive receivers during construction of the project
- Assessment to ensure the tunnel ventilation system can achieve acceptable in-tunnel air quality outcomes for carbon monoxide, nitrogen dioxide and visibility during operation of the project
- Modelling of changes in the concentrations of key pollutants at community, residential, workplace and recreational receiver locations for expected traffic and operation of the project under a number of worst case operational scenarios
- Assessment of regional air quality impacts associated with the operation of the project
- Prediction of changes in the levels of three representative odorous pollutants (toluene, xylenes, and acetaldehyde) at receivers with the operation of the project.

The methodology for the assessment of both construction and operational air quality impacts, as well as the modelling inputs and assumptions used to carry out this assessment is provided in full at Appendix H (Technical working paper: Air quality).

12.2.2 Construction air quality assessment methodology

Air quality impacts as a result of construction of the project include those associated with exhaust emissions from tunnelling operations, and from the generation of dust and odour.

Exhaust emissions during construction would occur due to the use of some plant and equipment. These impacts are considered to be minor and unlikely to have a noticeable impact on the surrounding environment including sensitive receivers. Any impacts associated with exhaust emissions would be managed through the environmental management measures described in Section 12.7.

Some construction activities could also result in the generation of dust and odours. The assessment methodology for the air quality impacts associated with the generation of dust and odour are described below.

Dust assessment

For the purpose of the construction dust assessment, construction activities have been categorised into four types to reflect their potential impacts:

- Demolition is any activity that involves the removal of existing structures
- Earthworks covers the processes of topsoil stripping, ground levelling, excavation (including blasting) and landscaping and primarily involves excavating, loading, hauling, tipping and compaction of material including stockpiling where required
- Construction is any activity that involves the provision of new structures, or modification or refurbishment of existing structures, including buildings, ventilation outlets and roads
- Track-out involves the transport of dust and dirt from the construction/demolition site onto the public road network using construction vehicles. These materials may then be deposited and re-suspended by vehicles using the road network.

It is difficult to quantify dust emissions from construction activities since it is not possible to predict the weather conditions that would prevail during specific construction activities. The effects of construction on airborne particulate matter would generally be temporary and of relatively short duration, and mitigation should be straightforward since dust suppression measures are routinely employed as ‘good practice’ at most construction sites.

A semi-quantitative, risk-based approach was used for the assessment in accordance with the United Kingdom Institute of Air Quality Management’s *Guidance on the assessment of dust from demolition and construction* (Institute of Air Quality Management (IAQM), 2014). The IAQM guidance has been adapted for use in NSW, taking into account factors such as the assessment criteria for ambient PM_{10} (being particulate matter less than or equal to 10 micrometres in diameter) concentrations. The potential construction air quality impacts were assessed based on the proposed works, plant and equipment, and the potential emission sources and levels. The assessment considered the risk of dust deposition and elevated concentrations of dust (as PM_{10}) in the air from construction activities, and potential impacts on amenity, human health and the environment.

The IAQM guidance (IAQM, 2014) specifies that a dust assessment is required where:

- Human receivers are within 350 metres of the assessment zone boundary. A human receiver refers to any location where a person or property may experience the adverse effects of airborne dust or dust settlement, or exposure to dust emissions over a time period that is relevant to air quality standards and goals
- Ecological receivers are within 50 metres of the boundary of the assessment zone. An ecological receiver refers to any sensitive habitat or fauna affected by dust settlement.

Key steps in the assessment included:

- An initial screening to identify whether there is a risk of construction dust impacts based on the proximity of human and ecological receivers to construction activities
- A risk assessment to determine which construction activities have the potential to generate a dust impact based on the scale and nature of the activities, and the sensitivity of nearby human and ecological receivers
- Identification of appropriate dust mitigation and management measures depending on the level of assessment risk of impact.

Further details of the construction dust assessment methodology are provided in Appendix H (Technical working paper: Air quality) of this environmental impact statement. The assessment of construction dust using the IAQM guidance (IAQM, 2014) is outlined in Figure 12-1. The construction dust assessment carried out for the project is summarised in Section 12.5.1.

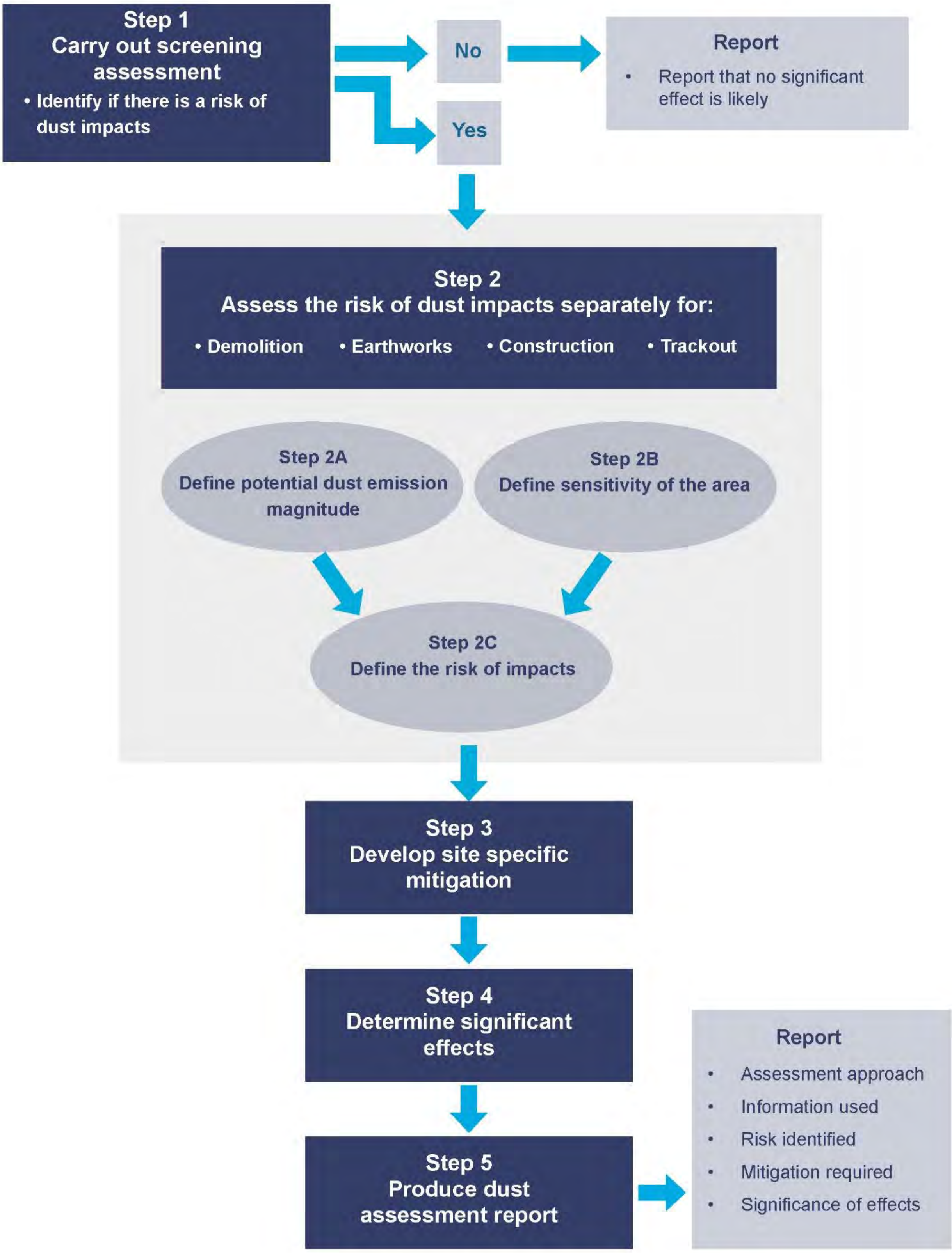

Figure 12-1 Construction dust assessment procedure (IAQM, 2014)

Odour assessment

During construction, there is the potential for odour impacts due to emissions from dredged or excavated material being exposed to air, temporarily stored and transported for treatment or disposal to landfill. As a location for temporary storage would be determined during detailed design, a qualitative assessment of odour impacts has been carried out and is discussed in Section 12.5.

12.2.3 Operational air quality assessment methodology

Air quality impacts from the operation of the project are associated with emissions from vehicles using the project. The impact of vehicle emissions was considered in terms of effects on in-tunnel air quality, local air quality, regional air quality and odour.

In-tunnel air quality

The tunnel ventilation system would be operated to achieve acceptable in-tunnel air quality outcomes for carbon monoxide (CO), NO_2 and visibility (as a measure of in-tunnel particulate matter concentrations) (refer to Section 12.3.2 for additional information relating to air quality criteria).

In-tunnel air quality modelling was carried out using IDA Tunnel software. The modelling considered traffic volumes, tunnel air flow and vehicle emission levels. The modelling incorporated the Beaches Link, Western Harbour Tunnel and WestConnex projects and considered the following scenarios:

- Expected traffic – 24-hour operation of the project ventilation system under day-to-day conditions of expected traffic demand in 2027 (planned opening date) and 2037
- Worst case traffic – the most onerous traffic conditions for the ventilation system (refer below)
- Travel route scenarios – a worst case trip scenario for in-tunnel exposure to NO_2.

Operational worst case scenarios

Operational worst case scenarios consider emissions from traffic within the tunnels and represent the theoretical maximum pollutant concentrations for all potential traffic operations in the tunnel, including unconstrained traffic conditions from an emissions perspective, as well as vehicle breakdown situations. The operational worst case scenarios are conservative and result in pollutant emission concentrations that are much higher than those that could occur under any foreseeable operational conditions in the tunnel.

The operational worst case assessments of in-tunnel air quality considered worst case (variable speed) traffic operations and worst case (breakdown or major incident) operations.

The worst case (variable speed) traffic operation scenario represents the upper limit of daily operations on the ventilation system of the mainline and ramp tunnels, regardless of the year of operation and is based on the traffic flow splits of the predicted traffic peak periods with the tunnels reaching a theoretical maximum lane capacity traffic flow rate. This scenario also includes the highest predicted number of buses using the tunnels. The worst case (variable speed) traffic operation scenario was considered under four different average speeds for lane capacity; 20, 40, 60 and 80 kilometres per hour.

The worst case (breakdown or major incident) operation scenario assesses the most conservative case from a traffic perspective, where congestion that occurs as a result of a breakdown affects the longest length within the mainline and ramp tunnels. This worst case operational scenario assumes a breakdown would result in a complete blockage on the specific ramp causing traffic that would ordinarily use the mainline tunnel to take other routes.

In-tunnel air quality for extended journeys

The assessment for in-tunnel air quality for extended journeys considers the estimated average concentration of NO_2 for the longest potential journey that could be taken by motorists in the connected motorway network. This was identified as a journey that used the project, the Western Harbour Tunnel, WestConnex and the M6 Motorway (Stage 1) tunnel network.

Provided that each project satisfies the air quality criteria (which requires NO_2 concentrations to be below an average of 0.5 ppm over the trip length through each tunnel), the average through the entire network would remain at, or below, 0.5 ppm under all traffic conditions. For this assessment, the estimated journey assessment completed as part of the *WestConnex M4-M5 Link environmental impact statement* (Roads and Maritime Services, 2017a) has been combined with the in-tunnel modelling completed for the 'Do something cumulative 2037' scenario.

Ambient air quality

The potential impacts of the project on ambient air quality during operation were assessed in relation to CO, NO_2, PM_{10} and $PM_{2.5}$ (particulate matter less than or equal to 2.5 micrometre diameter) and air toxics (benzene, polycyclic aromatic hydrocarbons (PAHs), formaldehyde, 1,3-butadiene and ethylbenzene), in accordance with the NSW EPA Approved Methods or the *National Environment Protection (Ambient Air Quality) Measure* (National Environment Protection Council (NEPC), 2003b) as relevant. The pollutants and criteria considered are provided in Section 12.3.3.

The following terms have been used to describe the concentration of pollutants at a specific location or receiver:

- Background concentration describes all contributing sources of a pollutant concentration other than road traffic. It includes contributions from natural sources, industry and domestic activity
- Surface road concentration describes the contribution of pollutants from the surface road network. It includes not only the contribution of the nearest road at the receiver, but also the net contribution of the rest of the modelled road network at the receiver
- Tunnel portal concentration is the contribution from the portals of existing tunnels for which portal emissions are permitted (Sydney Harbour Tunnel and Eastern Distributor tunnel)
- Ventilation outlet concentration describes the contribution of pollutants from tunnel ventilation outlets
- Total concentration is the sum of the sources defined above: background, surface road and ventilation outlet concentrations. It may relate to conditions with or without the project under assessment
- The change in concentration due to the project is the difference between the total concentration with the project and the total concentration without the project (increase or decrease), depending on factors such as the redistribution of traffic on the network as a result of the project.

The modelling scenarios, modelling process, receivers considered and approach to the analysis of results are discussed below.

Modelling scenarios

Seven expected traffic scenarios were included in the operational air quality assessment and considered future changes in the composition and performance of the vehicle fleet, as well as predicted traffic speeds, traffic volumes and the distribution of traffic on the road network. Each expected traffic scenario is set out in Chapter 9 (Operational traffic and transport) and has been modelled from an air quality perspective in order to assess the potential air quality impacts of the traffic scenario. The expected traffic scenarios that were modelled are summarised in Table 12-2.

Table 12-2 Operational air quality assessment modelling – expected traffic scenarios

Scenario	Existing network	Western Harbour Tunnel and Warringah Freeway Upgrade	Beaches Link and Gore Hill Freeway Connection	WestConnex	Other projects		
					Sydney Gateway	M6 Motorway (Stage 1)	M6 Motorway (full project)
Scenario in the base year (2016)							
Base year (existing conditions)	✓	-	-	-	-	-	-
Scenarios at project opening (2027)							
‘Do minimum 2027’ (without the project)	✓	-	-	✓	-	-	-
‘Do something 2027’ (with the project)	✓	Warringah Freeway Upgrade only	✓	✓	-	-	-
‘Do something cumulative 2027’ (with the project and other projects)	✓	✓	✓	✓	✓	✓	-
Scenarios ten years after the project opening (2037)							
‘Do minimum 2037’ (without the project)	✓	-	-	✓	-	-	-
‘Do something 2037’ (with the project)	✓	Warringah Freeway Upgrade only	✓	✓	-	-	-
‘Do something cumulative 2037’ (with the project and other projects)	✓	✓	✓	✓	✓	-	✓

Modelling process

The modelling process involved an emissions model, a meteorological model (Graz Mesoscale Model – GRAMM) and a dispersion model (Graz Langrangian Model – GRAL). The relationship between these models is illustrated in Figure 12-2.

For each expected traffic scenario, a spatial emissions inventory (emissions model) was developed for road traffic sources within the domain of the dispersion model. The following components were treated separately to take into account potential changes in traffic emissions across the road network:

- Emissions from existing and proposed tunnel ventilation outlets for tunnels where portal emissions are, or would not be, conducted
- Emissions from the portals of a small number of existing tunnels, where these are currently conducted
- Emissions from the traffic on the surface road network, including any new surface roads associated with the project.

The GRAMM meteorological model predicted wind fields (three-dimensional spatial pattern of winds). Predicted wind fields then became an input into the dispersion model following alignment with meteorological observations.

The GRAL dispersion model predicted ground-level pollutant concentrations by simulating the movement of individual 'particles' of a pollutant emitted from an emission source in a three-dimensional wind field.

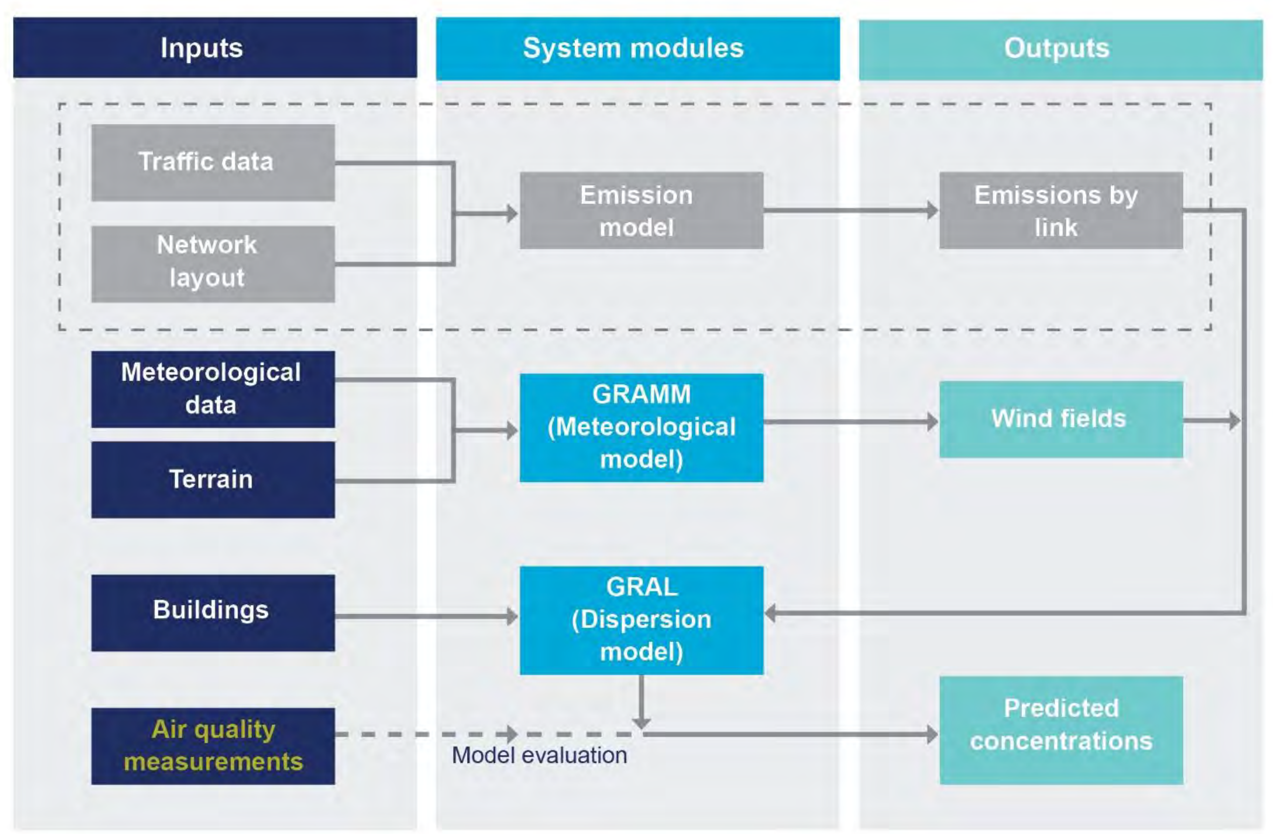

Figure 12-2 Overview of operational air quality modelling process

Receivers

Receivers are defined as anywhere someone works or resides, or may work or reside, including residential areas, hospitals, hotels, shopping centres, playgrounds and recreational centres. Due to its location in a highly built-up area, the dispersion modelling domain for the project contains many receivers.

Two types of receivers were considered in the air quality assessment:

- ‘Community receivers’. These were taken to be representative of particularly sensitive locations such as schools, child care centres and hospitals within a zone up to 1.5 kilometres either side of the Western Harbour Tunnel and Beaches Link program of works corridor, and generally near significantly affected roadways. In total, 42 community receivers were included in the assessment (refer to Figure 12-3)
- ‘Residential, workplace and recreational receivers’. These were all discrete receiver locations along the Western Harbour Tunnel and Beaches Link program of works corridor, and mainly covered residential and commercial land uses. A maximum of 35,484 residential, workplace and recreational receiver locations were considered in the assessment of project air quality impacts.

The identified community and residential, workplace and recreational receiver locations were representative and not exhaustive. They have been selected using professional judgement to demonstrate potential impacts at a more detailed level. While some sensitive locations might not have been selected as representative community receivers, they have still been assessed as residential, workplace and recreational receivers in the model. For example, while the Northern Beaches Secondary College – Balgowlah Boys Campus has not been included as a community receiver, the potential air quality impacts at that location have been predicted and are considered in the discussion of results for residential, workplace and recreational receivers below in Section 12.5 and Section 12.6.

The main emphasis in the assessment was on ground-level concentrations (as specified in the NSW EPA Approved Methods). However, at several locations there are existing multi-storey residential and commercial buildings, or the land zoning permits the construction of such buildings, and the potential impacts of the project at these elevated points are likely to be different to the impacts at ground level. Elevated receivers were therefore evaluated separately.

Based on a review of available building height information, four elevated receiver heights were selected to cover both existing buildings and future developments: 10 metres, 20 metres, 30 metres and 45 metres.

The modelling extent extended beyond the project to allow for the traffic interactions between the Western Harbour Tunnel and Warringah Freeway Upgrade and the WestConnex M4-M5 Link projects, as well as changes along affected surface roads. A large model extent also increased the number of meteorological and air quality monitoring stations that could be included for model evaluation purposes.

Regional air quality

The potential impacts of the project on air quality more widely across Greater Sydney were assessed through consideration of the changes in emissions across the road network. The regional air quality impacts of a project can also be considered in terms of its capacity to influence ozone production. As noted in Section 12.1, The NSW Environment Protection Authority has developed a *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON, 2011). Although this procedure does not relate specifically to road projects, it was applied here to give an indication of the likely significance of the project’s effect on ozone concentrations in the Greater Sydney region.

Odour

The generation of odours from motor vehicle emissions tend to be very localised and short-lived, and there are unlikely to be any significant, predictable or detectable changes in odour due to the project. Odour was assessed based on the maximum change in 1-hour total hydrocarbon concentrations as a result of the project, which was converted into an equivalent change for three of the odorous pollutants identified in the NSW EPA Approved Methods (toluene, xylenes and acetaldehyde). These pollutants were taken to be representative of other odorous pollutants from motor vehicles.

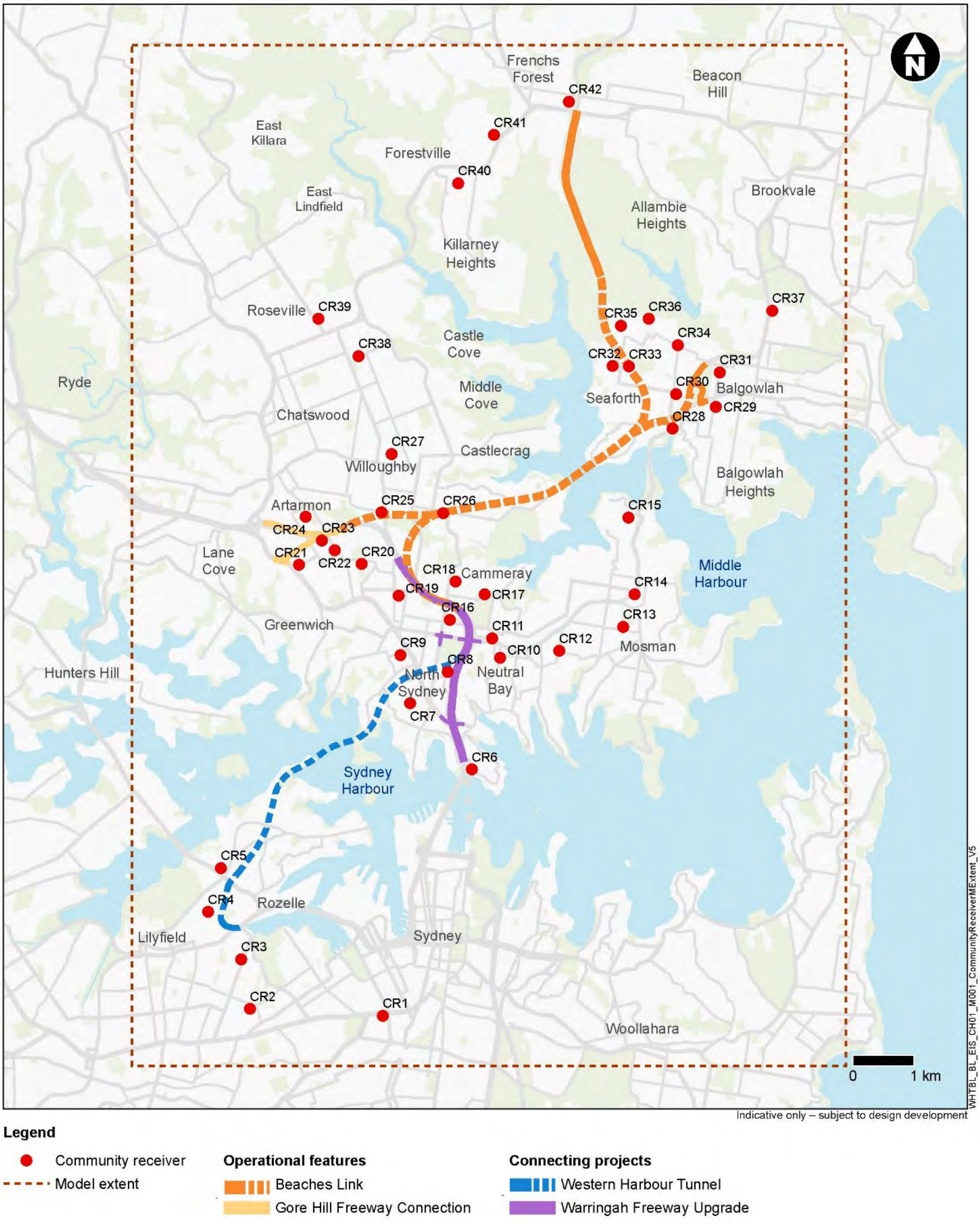

Figure 12-3 Location of community receivers and model extent

12.3 Criteria and standards

12.3.1 Overview

There are two types of criteria and standards that are relevant to the assessment of air quality impacts from construction and operation of the project:

- In-tunnel air quality criteria, which apply to the air quality inside the mainline tunnels
- Ambient air quality criteria and standards, which apply to outdoor air quality.

Air quality criteria and standards applied to the assessment of the project are outlined in the following sections, with further details provided in Appendix H (Technical working paper: Air quality).

12.3.2 In-tunnel air quality criteria

The project has been designed to achieve in-tunnel air quality that is protective of human health and amenity and provides a safe travel environment. Further details of the project's ventilation system design are provided in Chapter 5 (Project description).

The project's ventilation system would be operated to achieve the in-tunnel air quality criteria summarised in Table 12-3. The in-tunnel air quality limits for the project reflect those identified by the ACTAQ (ACTAQ, 2016; ACTAQ, 2018a) and are consistent with the limits provided in planning approvals for recent motorway tunnel projects in NSW.

Table 12-3 In-tunnel operational limits for CO, NO_2 and visibility

Parameter	Averaging period	Criteria
CO	3-minute (rolling), single point exposure limit	200 ppm
	15-minute (rolling), average along tunnel length	87 ppm
	30-minute (rolling), average along tunnel length	50 ppm
NO_2	15-minute (rolling), average along tunnel length	0.5 ppm
Visibility	15-minute (rolling), at any point in the tunnel	0.005 m^{-1}

12.3.3 Ambient air quality criteria

Air quality criteria and standards applied to the assessment of the project are outlined in the following sections, with further details provided in Appendix H (Technical working paper: Air quality), including Annexure B of that report.

Air pollutant criteria

The ambient air quality criteria applied to the assessment of the project are set in the NSW EPA Approved Methods and summarised in Table 12-4. Some of these criteria are among the lowest in the world (see Annexure B of Appendix H (Technical working paper: Air quality)). For example, the annual average $PM_{2.5}$ criterion used, on which a key health metric is based, is lower than any other $PM_{2.5}$ standard in the world, including the World Health Organisation guideline.

Table 12-4 Ambient air quality criteria applied to the assessment of the project

Pollutant	Criteria	Averaging period
CO	30 mg/m^3	1 hour
	10 mg/m^3	8 hours (rolling)

Pollutant	Criteria	Averaging period
NO_2	246 µg/m³	1 hour
	62 µg/m³	1 year
PM_{10}	50 µg/m³	24 hours
	25 µg/m³	1 year
$PM_{2.5}$	25 µg/m³	24 hours
	20 µg/m³ (goal by 2025)	24 hours
	8 µg/m³	1 year
	7 µg/m³ (goal by 2025)	1 year
Benzene[1]	0.029 mg/m³	1 hour
Polycyclic aromatic hydrocarbons (PAHs) (as benzo(a)pyrene)[1]	0.0004 mg/m³	1 hour
Formaldehyde[1]	0.02 mg/m³	1 hour
1,3-butadiene[1]	0.04 mg/m³	1 hour
Ethylbenzene[1]	8 mg/m³	1 hour

Note 1: These compounds were taken to be representative of the much wider range of air toxics associated with motor vehicles

Odour criteria

The NSW EPA Approved Methods provides assessment criteria for complex mixtures of odorous compounds, as summarised in Table 12-5. These criteria are 99th percentile values, meaning that they must not be exceeded more than one per cent of the time.

Table 12-5 Assessment criteria for odour

Population of affected community	Criterion for complex mixtures of odour (OU)
≤~2	7
~10	6
~30	5
~125	4
~500	3
Urban (>2000) and/or schools and hospitals	2

For the assessment of operational odour impacts, the change in the maximum 1-hour total hydrocarbon concentration as a result of the project was calculated at each of the residential, workplace and recreational receiver locations. The hydrocarbon pollutants were taken to be representative of other odorous pollutants from motor vehicles. The odorous pollutants assessed along with their relevant criteria include:

- Toluene (360 µg/m³)
- Xylene (190 µg/m³)
- Acetaldehyde (42 µg/m³).

12.4 Existing environment

Air quality in a region is influenced by a number of factors including the terrain, meteorology (weather patterns), historical trends in road traffic emissions and the current (ambient) and historical air quality environment.

12.4.1 Meteorology

Analysis of meteorological data found that the Randwick station (operated by the Department of Planning, Industry and Environment (Environment, Energy and Science)) was the most representative of the project corridor. At Randwick, the wind speed and wind direction patterns over the five-year period between 2011 and 2016 were reasonably consistent. Average wind speeds ranged from 2.4 to 2.6 meters per second.

12.4.2 Vehicle emissions

The most comprehensive source of information on current and future air pollutant emissions in the Sydney area is the emissions inventory that is compiled periodically by the NSW Environment Protection Authority.

For 2016, the emissions inventory identifies that road transport, including cars, light duty vehicles, heavy duty vehicles such as buses and trucks and other transport such as motorbikes, was the second largest sectoral contributor to emissions of CO (34 per cent) and the largest contributor to NO_X (47 per cent) in Sydney. The sector was also responsible for substantial proportions of emissions of volatile organic compounds (13 per cent), PM_{10} (nine per cent) and $PM_{2.5}$ (10 per cent). Road transport contributed only two per cent of total sulfur dioxide (SO_2) emissions in Sydney, reflecting the reduced sulfur in road transport fuels in recent years.

Petrol passenger vehicles (mainly cars) accounted for a large proportion of the vehicle kilometres travelled in Sydney and exhaust emissions from these vehicles were responsible for 65 per cent of CO from road transport in Sydney in 2016, 37 per cent of NO_X, and 71 per cent of SO_2. Non-exhaust processes, such as brake wear, tyre wear, road surface wear and resuspension of road dust during on-road vehicle usage, were the largest source of road transport PM_{10} (71 per cent) and $PM_{2.5}$ (57 per cent), whereas exhaust emissions from petrol passenger vehicles were only a minor source of road transport PM_{10} (three per cent) and $PM_{2.5}$ (four per cent).

The road transport contribution to CO, volatile organic compounds and NO_X emissions is projected to decrease substantially between 2011 and 2036 due to improvements in emission-control technology. For PM_{10}, $PM_{2.5}$ and SO_2 the road transport contributions are also expected to decrease, but their smaller contributions to these pollutants mean that these decreases would have only a minor impact on total emissions.

12.4.3 Ambient air quality

Air quality in Sydney is monitored across a network of monitoring stations operated by the Department of Planning, Industry and Environment (Environment, Energy and Science), and at project-specific monitoring stations operated by Transport for NSW. A summary of ambient air quality in Sydney is provided in Table 12-6, based on data from these monitoring stations from 2004 to 2019.

Table 12-6 Ambient air quality in Sydney (2004 to 2019)

Air pollutant	Ambient air quality
CO (maximum 1-hour)	All monitoring data shows ambient concentrations well below the air quality criteria of 30 mg/m^3 (1-hour) and 10 mg/m^3 (8-hour). With the exception of 2019, there is a general downward trend in maximum concentrations over time.
CO (rolling 8-hour)	

Air pollutant	Ambient air quality
NO_2 (maximum 1-hour)	Although variable from year to year, maximum 1-hour NO_2 concentrations are relatively stable in the longer term. Data from all monitoring stations typically range from 80 µg/m^3 to 140 µg/m^3, and continue to be well below the criterion of 246 µg/m^3.
NO_2 (annual mean)	Concentrations at all monitoring stations are well below the air quality criterion of 62 µg/m^3. There is a general downward trend in annual mean concentrations over time.
PM_{10} (maximum 24-hour)	Maximum 24-hour mean PM_{10} concentrations show a slight downward until 2015, but there is a large variation from year to year. In 2016 the concentrations recorded at the Transport for NSW monitoring stations were about 40 µg/m^3, below the air quality criterion of 50 µg/m^3. Since 2018, maximum 24-hour PM_{10} concentrations at Department of Planning, Industry and Environment (Environment, Energy and Science) stations exhibited an upward trend due to extended drought conditions and widespread bushfires.
PM_{10} (annual mean)	Concentrations at the Department of Planning, Industry and Environment (Environment, Energy and Science) stations show a downward trend between 2004 and 2016, by as much as 21 to 23 per cent in the case of the Chullora and Earlwood stations. In recent years the annual mean PM_{10} concentration at the Department of Planning, Industry and Environment (Environment, Energy and Science) stations has increased, from around 20 µg/m^3 in 2018 to close to or above the air quality criterion of 25 µg/m^3 in 2019. This is largely due to drought conditions worsening and then severe bushfire activity in 2018 and 2019. The monitoring station at Lindfield shows substantially lower concentrations, about 15 to 16 µg/m^3. Monitoring data from stations operated by Transport for NSW away from busy roads is generally about 15 µg/m^3, which is well below the air quality criterion of 25 µg/m^3.
$PM_{2.5}$ (maximum 24-hour)	There has been no trend in the maximum 24-hour $PM_{2.5}$ concentration. The maximum 24-hour concentrations are often close to or above the air quality criterion of 25 µg/m^3, and were generally above the long-term goal of 20 µg/m^3. Exceedances are largely due to hazard reduction burns and bushfires.
$PM_{2.5}$ (annual mean)	$PM_{2.5}$ has only been measured over several years at three of the Department of Planning, Industry and Environment (Environment, Energy and Science) stations reviewed (ie Chullora, Earlwood and Liverpool). Concentrations show a similar pattern, with a steady reduction between 2004 and 2012 being followed by a substantial increase in 2013. The main reason for the increase was a change in the measurement method. The increases in measured concentrations meant that background $PM_{2.5}$ concentrations between 2013 and 2016 were already very close to or above the air quality criterion of eight µg/m^3, and above the long-term goal of seven µg/m^3. In 2018 and 2019, the annual mean $PM_{2.5}$ concentrations exceeded the air quality criterion at all three monitoring stations.

12.5 Assessment of potential construction impacts

Potential sources of air quality impacts during construction of the project would include:

- Dust generated at construction sites and temporary construction support sites
- Emissions from vehicles, plant and equipment used on construction sites and temporary construction support sites
- Emissions during blasting
- Odour generated during handling and management of harbour sediments and material excavated from the former landfill site at the Flat Rock Drive construction support site (BL2).

Environmental management measures that are proposed to address these impacts are outlined in Section 12.7.

12.5.1 Dust

Overall, dust generated as a result of construction works, with best practice management measures in place, is unlikely to represent a serious ongoing problem. Any effects would be temporary and relatively short-lived and would likely only arise during dry weather where the wind is blowing towards a receiver at a time when dust is being generated and environmental management measures are not fully effective.

Screening assessment

The construction dust assessment considered potential dust impacts across five assessment zones. The assessment zones, and their associated temporary construction support sites and surface construction areas are summarised in Table 12-7. As shown in Figure 12-4, there are a large number of human receivers located within 350 metres, as well as ecological receivers located within 50 metres, of the assessment zones. This has triggered the need for further assessment of potential dust impacts.

Table 12-7 Assessment zones

Assessment zone	Construction support sites within assessment zone	Surface construction areas within assessment zone
Zone 1	Punch Street (BL3), Dickson Avenue (BL4), Barton Road (BL5), Gore Hill Freeway median (BL6)	Beaches Link and Gore Hill Freeway works. This includes tunnel decline structures and construction of tunnel portals and ramps, construction of operational ancillary infrastructure and adjustments to other infrastructure (eg active transport infrastructure).
Zone 2	Cammeray Golf Course (BL1), Flat Rock Drive (BL2)	Beaches Link tunnel decline structures and tunnel portals at Cammeray Golf Course (BL1) and Flat Rock Drive (BL2), and connections to Warringah Freeway, including fitout of the ventilation outlet and motorway facility. Note: The majority of this construction assessment zone would have already undergone significant disturbance during the construction of the Western Harbour Tunnel and Warringah Freeway Upgrade. The construction activities assessed in this zone therefore assumes that much of the works have already been completed as part of that project.

Assessment zone	Construction support sites within assessment zone	Surface construction areas within assessment zone
Zone 3	Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8), Spit West Reserve (BL9)	Harbour crossing including cofferdam excavation, dredging and handling of dredged material.
Zone 4	Balgowlah Golf Course (BL10), Kitchener Street (BL11)	Connections and integration of Beaches Link to the surrounding road network at Balgowlah. This includes construction of portals and the new access road, modifications to existing surface roads and construction of the Burnt Bridge Creek Deviation ventilation outlet and motorway facility.
Zone 5	Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13), Wakehurst Parkway north (BL14)	Connections and integration of Beaches Link with Wakehurst Parkway at Seaforth, Killarney Heights and Frenchs Forest. This includes surface road works associated with the realignment and upgrade of Wakehurst Parkway and minor changes to intersections, as well as the construction of the Wakehurst Parkway motorway facility and ventilation outlet.

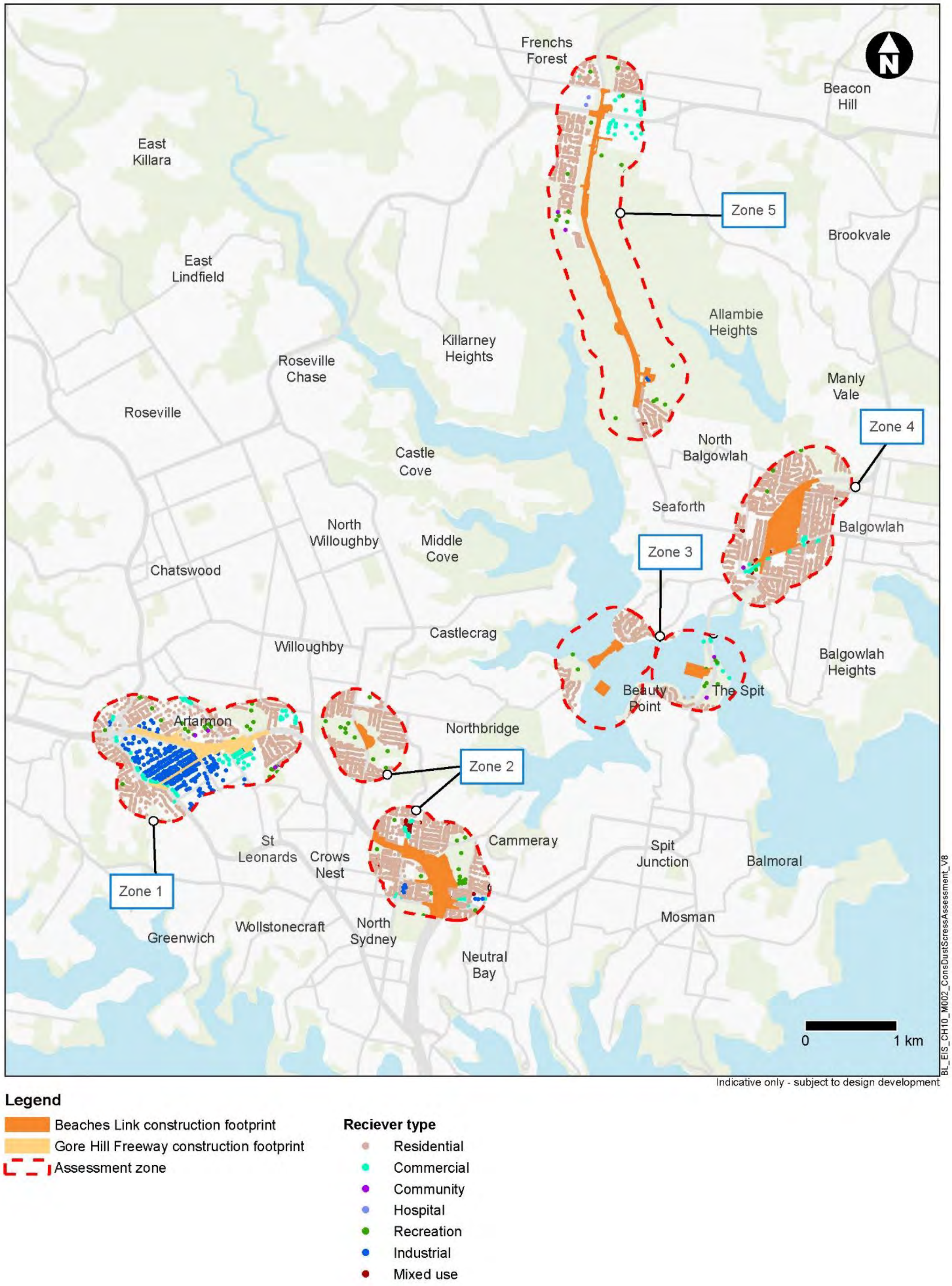

Figure 12-4 Construction dust screening assessment – receivers near the construction footprint

Risk assessment

The risk of potential dust impacts, without mitigation, is determined by combining the following to provide an overall summary of potential risk:

- The scale and nature of the works, which determined the magnitude of potential dust emissions (refer to Table 12-8)
- The sensitivity of the surrounding area to dust settlement effects, human health impacts and ecological impacts (refer to Table 12-9).

Potential for dust emissions from surface construction works

The potential magnitude of dust emissions for the construction works that would be carried out for demolition, earthworks, construction, and track-out (as defined in Section 12.2.2) is shown in Table 12-8, and is based on the scale and nature of the works.

Table 12-8 Potential magnitude of dust emissions of construction works in each assessment zone

Type of activity	Site category by assessment zone				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Demolition	Large	Small	N/A	Medium	Small
Earthworks	Large	Medium	Small	Large	Large
Construction	Large	Medium	Small	Large	Large
Track-out	Large	Medium	Medium	Large	Large

Sensitivity of receivers during construction

The sensitivity of an area to dust settlement effects, human health impacts and ecological impacts during construction takes into account factors such as the number of receivers in the area, the proximity of receivers from construction activities and the local annual mean background PM_{10} concentration. The sensitivity of receivers to dust settlement effects, human health impacts and ecological impacts (without mitigation) within the five surface construction zones assessed is provided in Table 12-9. The results in Table 12-9 show that:

- For construction dust settlement effects:
  - Zone 1, zone 2, zone 4 and zone 5 were considered to have a high sensitivity to dust settlement effects due to the high number of receivers, located near the surface construction works
  - Zone 3 was considered to have a medium sensitivity to dust settlement effects as there were fewer receivers located near construction works. No demolition or track-out dust settlement effects would occur within zone 3.
- For human health impacts,
  - The sensitivity of receivers in zone 1, zone 2, zone 4 and zone 5 would be considered high, due to the high number of receivers located near surface construction works
  - Zone 3 would have a low sensitivity to human health impacts during all construction works. Demolition would not occur in this zone.
- For ecological impacts, sensitive ecological receivers within all the zones are located within 20 metres of the construction disturbance footprint. As a result, the sensitivity of these ecological receivers to construction dust would be considered high at all locations.

Risk of dust impacts

The summary of potential risk relating to construction dust, without mitigation, is provided in Table 12-9.

Without mitigation, sites and works that were determined to have a high and medium risk of dust impacts include:

- Punch Street (BL3), Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6) construction support sites: High risk of dust settlement, human health and ecological impacts as a result of demolition, earthworks, construction and track-out activities
- Cammeray Golf Course (BL1) and Flat Rock Drive (BL2) construction support sites: Medium risk of dust settlement, human health and ecological impacts as a result of demolition, earthworks, construction and track-out activities
- Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and Spit West Reserve (BL9) construction support sites: Medium risk of ecological impacts and a low risk of dust settlement and human health impacts as a result of track-out activities. Low risk of dust settlement and ecological impacts as a result of earthworks and construction activities
- Balgowlah Golf Course (BL10) and Kitchener Street (BL11) construction support sites: Medium risk of dust settlement, human health and ecological impacts as a result of demolition activities. High risk of dust settlement, human health and ecological impacts as a result of earthworks, construction and track-out activities
- Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites: Medium risk of dust settlement, human health and ecological impacts as a result of demolition activities. High risk of dust settlement, human health and ecological impacts as a result of earthworks, construction and track-out activities.

The effects of airborne dust during construction works would likely be temporary and of relatively short duration. For all construction works, the aim would be to prevent dust related impacts on receivers, through the implementation of best management practices routinely used on construction sites. The proposed environmental management measures are outlined in Section 12.7 and would include measures such as:

- Suppressing dust with water
- Covering stockpiles of loose materials
- Cleaning up loose materials from hard surfaces
- Stabilising unsealed areas
- Selection of equipment and materials handling techniques that minimise the potential for dust generation
- Ceasing dust generating activities during unfavourable weather conditions or changing how they are managed to minimise dust emission
- Site inspections and activity supervision to monitor the effectiveness of implemented measures and identify any additional measures to be implemented.

However, even with rigorous air quality management in place and the effective best practice management measures described above, there is the risk that nearby residences, commercial premises and schools near construction works might experience occasional dust impacts. This does not imply that impacts are likely, or that if they did occur, that they would be frequent or persistent. Overall dust generated as a result of construction works is unlikely to represent a serious ongoing problem.

Table 12-9 Summary of potential risk relating to construction dust (without mitigation)

Zone	Activity	Step 2A: Potential for dust emissions	Step 2B: Sensitivity of area			Step 2C: Risk of dust impacts		
			Dust settlement	Human health	Ecological	Dust settlement	Human health	Ecological
Zone 1 (BL3, BL4, BL5 and BL6)	Demolition	Large	High	High	High	High	High	High
	Earthworks	Large	High	High	High	High	High	High
	Construction	Large	High	High	High	High	High	High
	Track-out	Large	High	High	High	High	High	High
Zone 2 (BL1, BL2)	Demolition	Small	High	High	High	Medium	Medium	Medium
	Earthworks	Medium	High	High	High	Medium	Medium	Medium
	Construction	Medium	High	High	High	Medium	Medium	Medium
	Track-out	Medium	High	High	High	Medium	Medium	Medium
Zone 3 (BL7, BL8 and BL9)	Demolition	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Earthworks	Small	Medium	Low	High	Low	Negligible	Low
	Construction	Small	Medium	Low	High	Low	Negligible	Low
	Track-out	Medium	Low	Low	High	Low	Low	Medium
Zone 4 (BL10 and BL11)	Demolition	Medium	High	High	High	Medium	Medium	Medium
	Earthworks	Large	High	High	High	High	High	High
	Construction	Large	High	High	High	High	High	High
	Track-out	Large	High	High	High	High	High	High
Zone 5 (BL12, BL13 and BL14)	Demolition	Small	High	High	High	Medium	Medium	Medium
	Earthworks	Large	High	High	High	High	High	High
	Construction	Large	High	High	High	High	High	High
	Track-out	Large	High	High	High	High	High	High

Dust emissions containing contaminants

There is the potential for dust emissions to contain contaminants mobilised through the disturbance of contaminated soils, and other hazardous materials (such as asbestos fibres or organic matter) during demolition of buildings and other structures. These issues would be considered on a site-by-site basis and would be effectively managed through standard air quality mitigation and management measures as outlined in Table 12-11.

Areas identified as potentially containing contaminated soils and other hazardous substances, which may be disturbed during construction, include:

- Warringah Freeway, North Sydney to Cammeray
- Punch Street, Artarmon
- Freeway Hotel, Artarmon
- Flat Rock Reserve, Northbridge
- Spit West Reserve, Mosman
- Balgowlah Golf Course, Balgowlah
- Dudley Street, Balgowlah
- Judith Street and Kirkwood Street, Seaforth
- Sydney Water Bantry Bay Reservoir site, Killarney Heights
- Burnt Bridge Creek Deviation, Balgowlah
- Wakehurst Parkway, Seaforth to Frenchs Forest.

These areas are described in more detail in Chapter 16 (Geology, soils and groundwater). These areas would be investigated further in accordance with requirements of guidance endorsed under Section 105 of the *Contaminated Land Management Act 2008* to confirm the contamination present, and the implementation of Remedial Action Plans prepared in accordance with *Managing Land Contamination: Planning Guidelines SEPP 55 – Remediation of Land* (Department of Urban Affairs and Planning and Environment Protection Authority, 1998). Remedial Action Plans consider all potential risk pathways for exposure to contaminants and specify the controls required to reduce those risks to acceptable levels. This includes potential emissions of contaminated dust. Refer to Chapter 16 (Geology, soils and groundwater) for more details.

12.5.2 Emissions from vehicles, plant and equipment

The use of on-site diesel-powered vehicles, generators and construction equipment, and the handling and/or on-site storage of fuel and other chemicals, would result localised increased concentrations of airborne particle matter, CO, NO_X, sulfur dioxide and volatile organic compounds. Minor emissions from these sources would be localised and would be managed with standard environmental management measures.

12.5.3 Emissions during blasting

As discussed in Chapter 6 (Construction work), it is anticipated that controlled blasting might be used to excavate bedrock along sections of Wakehurst Parkway, as an alternative to ripping or hammering of rock, to minimise the duration of this activity and potential noise and amenity impacts. In addition, controlled blasting may also be carried out during construction of the driven tunnels.

Controlled underground blasting would not result in direct emissions to the external air. The potential for impacts to sensitive receivers due to dust from surface-based blasting would depend on the location where the blasting is proposed, the blasting approach, and whether there are any sensitive receivers in the vicinity that could be impacted. Emissions to air from any blasting required at Wakehurst Parkway would be managed to ensure safe working conditions for workers and minimise potential impacts to sensitive receivers in the vicinity.

12.5.4 Odour

This section assesses impacts associated with potential odours due to dredging activities, stockpiling and transport of dredged material at Middle Harbour, as well as excavation activities within a former landfill site at the Flat Rock Drive construction support site (BL2).

Environmental management measures such as odour supressing additives, use of sealed trucks and the development of an odour management strategy (where required) would be implemented to minimise the potential for odour during construction.

Excavated material from Middle Harbour

As part of the tunnelling activities for the project, a significant amount of material would be excavated from beneath the water. This would be done using mechanical dredging, bringing potentially odorous material to the surface. While on the barges in the vicinity of the dredging activity or while in transit to the sea disposal location or onshore disposal area, dredged material would be covered with water which would significantly reduce any odour emissions. Any odour impacts from this material would be negligible to low, given it would remain wet and located at some distance from any sensitive receiver.

For dredged material that is determined to be unsuitable for sea disposal, the material would be transported by barge to land, made spadable and then transported by truck to an appropriately licensed waste management facility for disposal. The unloading location for the dredged material would be determined during detailed design, and necessary environmental planning approvals obtained to operate the facility to accept and, if required, treat the material. Odour measurements carried out on dredged material from Middle Harbour showed extremely low concentrations. Modelling for the same material for the Western Harbour Tunnel air quality assessment showed if handled in manageable quantities, it is unlikely that emissions from dredged material would result in detectable levels of odour at any sensitive receivers.

Excavation at Flat Rock Drive construction support site (BL2)

The Flat Rock Drive construction support site (BL2) is a tunnel support site and would have an access decline to the tunnels underground.

The area to the west of Flat Rock Drive and east of Willoughby Road at Willoughby was used extensively as a municipal landfill prior to redevelopment as recreation facilities. Following the construction of Flat Rock Drive in 1968, and prior to 1971, areas to the east of the road were filled with material comprising of putrescible waste. Since that time the majority of fill has been non-putrescible, predominantly consisting of building debris and so the material most likely to be encountered during excavation in this area would the more recent non-putrescible waste. A geotechnical investigation carried out within the construction footprint at this location identified clayey material with some building debris but did not encounter any putrescible waste.

There is some potential that landfill gases might be present in the soils underneath the Flat Rock Drive construction support site (BL2) from any putrescible waste present, or that might have migrated from the landfilled areas to the west.

To manage the potential risks associated with the historic use of the area, the Flat Rock Drive construction support site (BL2) has been designed to minimise excavations. The main excavations that would be required are associated with piling for structures and excavation of the tunnel access decline. The location of the decline has been chosen to minimise the amount of excavation required to reach bedrock. As such, there is limited potential to encounter putrescible landfilled waste (if present) that could generate odour. Additionally, the potential for the release of significant volumes of landfill gases (if present) is also limited.

As there is a low potential for significant amounts of putrescible waste materials and landfill gases to be present beneath the proposed Flat Rock Drive construction support site (BL2) site, the potential for significant odour issues during excavation is very low. However, prior to excavations at the temporary construction support site, further investigations would be carried out to confirm the potential to encounter odorous materials and gases and need for any site-specific management measures (refer to environmental management measures SG14 in Chapter 16 (Geology, soils and groundwater) and AQ4 in Section 12.7.1).

12.6 Assessment of potential operational impacts

Key areas of consideration with regards to air quality impacts during the operation of the project would include:

- In-tunnel air quality, including protection of amenity and motorist health when using the project tunnels and during longer trips through other parts of the motorway network
- Ambient air quality for receivers at ground level, as a result of changes in the distribution of surface traffic and operation of the project's ventilation facilities
- Ambient air quality for elevated receivers in existing and potential future high rise buildings, as a result of operation of the project's ventilation facilities
- Odour caused by odorous compounds in vehicle emissions.

12.6.1 In-tunnel air quality

The project's ventilation systems have been designed to achieve the in-tunnel air quality criteria summarised in Section 12.3.2 under all traffic conditions, and to effectively manage smoke in the event of a fire in the project tunnels. The tunnel ventilation system would include:

- Jet fans installed in the ceiling of the tunnels
- Axial fans within the motorway facilities to extract air from the tunnel via ventilation tunnels
- Axial fans within the motorway facilities to supply air to the tunnel via ventilation tunnels
- Ventilation outlets to effectively disperse tunnel air into the atmosphere
- Air quality monitoring systems in the tunnels and ventilation outlets to monitor and control the ventilation system.

The design and operation of the tunnel ventilation system is shown in Figure 5-1 of Chapter 5 (Project description) and described in Section 5.2.7 of that chapter and Appendix H (Technical working paper: Air quality).

The design of the tunnel ventilation system would ensure there would be no emissions from the tunnel portals. This would involve using jet fans close to the exit portals to draw air back into the tunnel, to be emitted via the ventilation outlets.

Simulations have been carried out to demonstrate that in-tunnel air quality criteria would not be exceeded. The simulations consider in-tunnel air quality based on:

- Expected traffic volumes using the project tunnels
- Maximum traffic volumes based on the design capacity of the tunnels at different average traffic speeds
- Congestion due to a breakdown or incident in the project tunnels.

In-tunnel air quality under expected traffic conditions

The change in the peak in-tunnel NO_2 (rolling 15-minute average) emissions throughout the project tunnel and the adjoining tunnels confirm that the tunnel ventilation system would maintain in-tunnel air quality well within operational limits. The predicted in-tunnel NO_2 levels modelled for all 'Do something' and 'Do something cumulative' scenarios in 2027 and 2037 are provided in Section 7 of

Annexure K of Appendix H (Technical working paper: Air quality). The in-tunnel operational air quality limits for CO and visibility would also be achieved under all expected traffic scenarios.

In-tunnel air quality under worst case variable speed operation

In-tunnel air quality was assessed with the mainline tunnels operating at theoretical maximum lane capacity over the full length of the tunnels (which is not expected to actually occur). Four variable speed scenarios were assessed along all northbound and southbound routes: 20 kilometres per hour, 40 kilometres per hour, 60 kilometres per hour and 80 kilometres per hour. Vehicles travelling at 20 kilometres per hour are predicted to result in the highest pollutant levels in the tunnel, due to less air moving through the tunnel. This is considered the worst case variable speed operation scenario.

The predicted in-tunnel NO_2 (rolling 15-minute average) emissions for the worst case northbound route through the tunnel confirms that the tunnel ventilation system would achieve the NO_2 emissions criteria during all variable speed operation scenarios. The in-tunnel operational air quality limits for CO and visibility would also be achieved during all variable speed operation scenarios (refer to Annexure K of Appendix H (Technical working paper: Air quality)).

In-tunnel air quality under worst case breakdown or major incident

The tunnel ventilation system would be designed to cater for various traffic scenarios, including a case where there is a breakdown or major incident at a point along the tunnel. The worst case scenario from a traffic perspective would be where the resulting congestion due to a breakdown affects the longest length within the tunnel operating at capacity. The assessment considered breakdowns in a range of plausible locations.

The highest trip average NO_2 concentration for the breakdown scenarios considered was 0.29 ppm. This was predicted during a breakdown or major incident along the route for traffic originating in Killarney Heights and Balgowlah and exiting at the Warringah Freeway exit ramp (prior to the Western Harbour Tunnel). The predicted in-tunnel trip average NO_2 concentration for the worst case vehicle breakdown or major incident scenario in the tunnel confirms that the tunnel ventilation system would achieve the NO_2 emissions criteria during all breakdown scenarios. The in-tunnel operational air quality limits for NO_2, CO and visibility would also be achieved during all breakdown or major incident scenarios (refer to Annexure K of Appendix H (Technical working paper: Air quality)).

In-tunnel air quality for extended journeys

The extended journey assessment considered the longest potential journey that could be taken by motorists in the connected motorway network in 2037. This was identified as a journey that used the project, the proposed Western Harbour Tunnel, WestConnex and the M6 Motorway (Stage 1) tunnel network. It is expected that the in-tunnel trip average NO_2 concentrations would remain below the 0.5 ppm criterion under all traffic conditions, provided that NO_2 emissions criteria are achieved in every tunnel (which is expected). Further detail can be found in Section 5.2.7 of Annexure K of Appendix H (Technical working paper: Air quality).

12.6.2 Ambient air quality (receivers at ground level)

The predicted ambient air quality for the expected traffic scenarios are presented, by pollutant in this section. All results, including tabulated concentrations and contour plots are provided in Appendix H (Technical working paper: Air quality).

For the pollutants assessed, the following has been determined for over 35,000 residential, workplace and recreational receiver locations and 42 community receivers:

- The total ground-level concentrations for comparison against the NSW impact assessment criteria and international air quality standards

- The change in the total ground-level concentrations. This was calculated as the difference in concentration between the 'Do something' and 'Do minimum' scenarios, ie the difference in ground-level concentrations as a result of the project
- The contributions of the background, surface road and ventilation outlet sources to the total ground-level concentrations.

Due to the number of residential, workplace and recreational receiver locations, ranked plots for pollutant concentrations at each receiver location have been included. In each figure the background concentration, maximum contributions from each source (ventilation outlets and surface roads) and the maximum total concentration have been included for all the 'Do something' and 'Do something cumulative' scenarios.

For community receivers, a figure showing the pollutant concentrations (background plus the project scenario contribution) at each receiver relative to the air quality criterion has been provided. A second figure showing the change in pollutant concentration as a result of the different project scenario contributions at each receiver has also been provided.

Nitrogen dioxide (maximum 1-hour mean)

Residential, workplace and recreational receiver locations

There are some predicted exceedances of the NSW 1-hour NO_2 criterion (246 µg/m^3), both with and without the project at residential, workplace and recreational receiver locations. In the 'Do minimum 2027' scenario, the maximum concentration of NO_2 exceeds the NSW criterion at 201 receivers (0.6 per cent of all receivers). With the introduction of the project in the 'Do something 2027' scenario, the number of receivers experiencing exceedances of the maximum concentration of NO_2 decreases to 153 receivers. In the 'Do something cumulative 2027' scenario, the number of receivers experiencing exceedances of the maximum 1-hour mean concentration of NO_2 further decreases to 88 receivers (0.2 per cent of all receivers).

In the 'Do minimum 2037' scenario, there are predicted to be exceedances at 234 receivers (0.7 per cent of all receivers), and this remained the same for the 'Do something 2037' scenario. In the 'Do something cumulative 2037' scenario, the number decreases to 75 receivers (0.2 per cent of all receivers).

Most exceedances in all scenarios were located along Warringah Freeway (and the Warringah Freeway Upgrade) in future years. There were also a small number of exceedances close to Victoria Road in Rozelle and along Manly Road at The Spit. These exceedances reduced even further in the cumulative scenarios when the Western Harbour Tunnel is introduced.

Figure 12-5 shows the predicted contributions of the project to the maximum 1-hour mean NO_2 concentration at all of the residential, workplace and recreational receiver locations.

The maximum contribution of ventilation outlets to NO_2 at any receiver was 60 µg/m^3 in the 'Do something cumulative 2037' scenario. Since this contribution would not coincide with maximum contributions from surface roads, this would not lead to an exceedance of the 1-hour NO_2 criterion.

Community receivers

Figure 12-6 shows the maximum 1-hour NO_2 concentrations at all the community receivers in the project and cumulative scenarios. At all these receiver locations in all scenarios assessed, the maximum concentration is predicted to be below the impact assessment criterion of 246 µg/m^3, and in most cases below 200 µg/m^3.

Figure 12-7 shows the predicted change in maximum 1-hour mean NO_2 concentration as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. There was a mixture of small (relative to the NSW criterion) increases and decreases across the scenarios assessed and some notable increases in the maximum concentration at a small number of receivers, but as noted above, these did not result in any exceedances of the criterion.

In the hour in which the maximum 1-hour NO_2 concentration occurred, the background concentration was the most important source of NO_2, with generally a small contribution from surface roads. The main exceptions were CR06 (St Aloysius College, Milsons Point) and CR11 (Neutral Bay Public School, Neutral Bay), which had a large contribution from surface roads in the ‘Do something’ scenario and the ‘Do something cumulative’ scenario respectively. The tunnel ventilation outlet contribution to the maximum 1-hour mean NO_2 concentration was either zero or negligible.

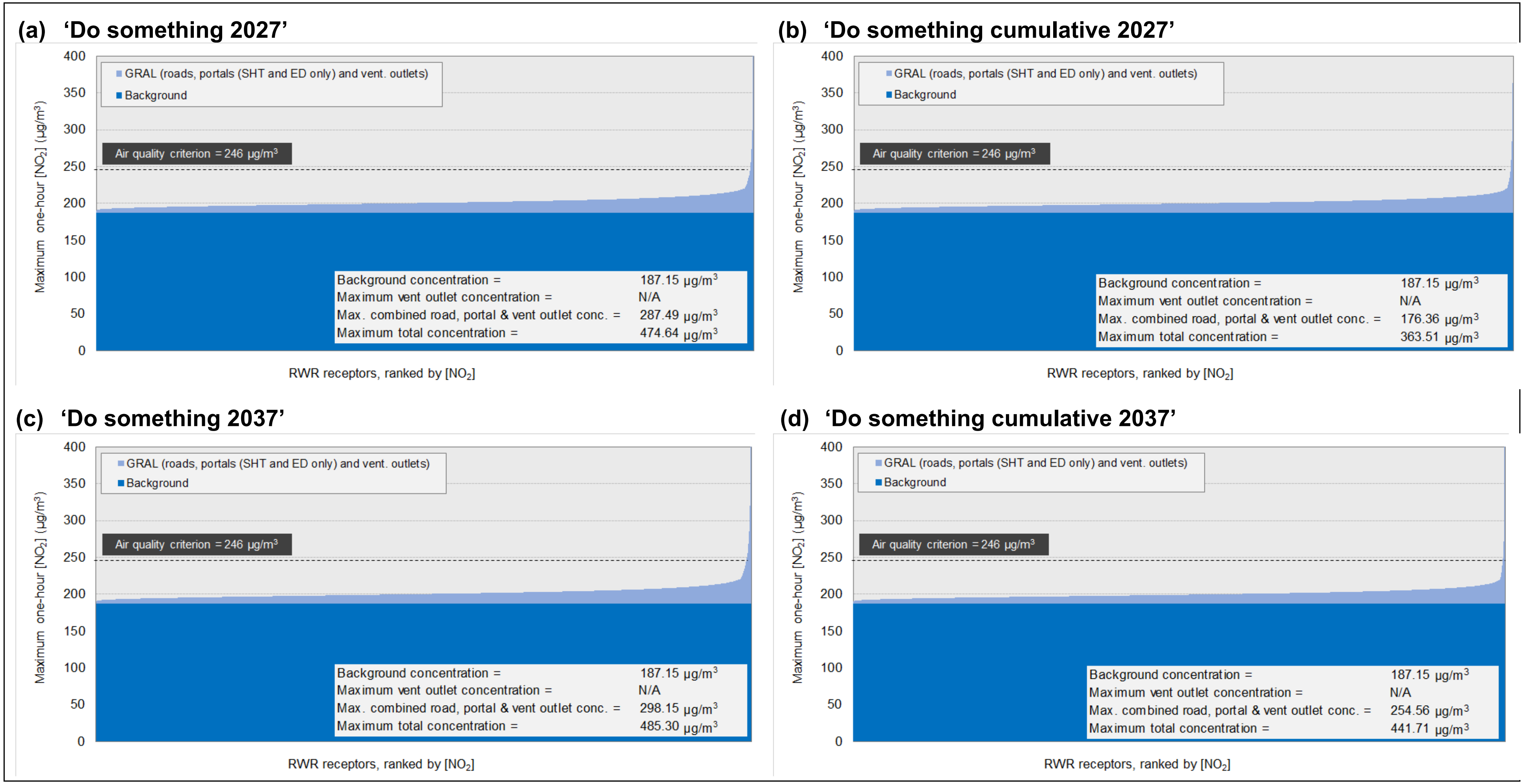

Figure 12-5 Contributions to maximum 1-hour mean NO_2 concentration at residential, workplace and recreational receivers

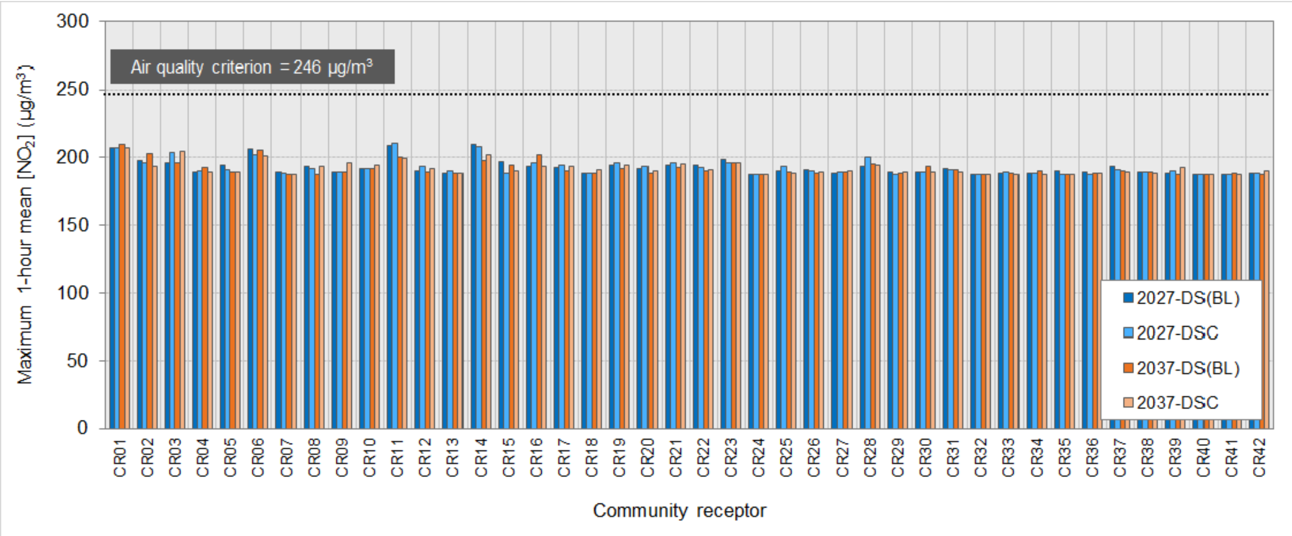

Figure 12-6 Maximum 1-hour mean NO_2 concentration at community receivers

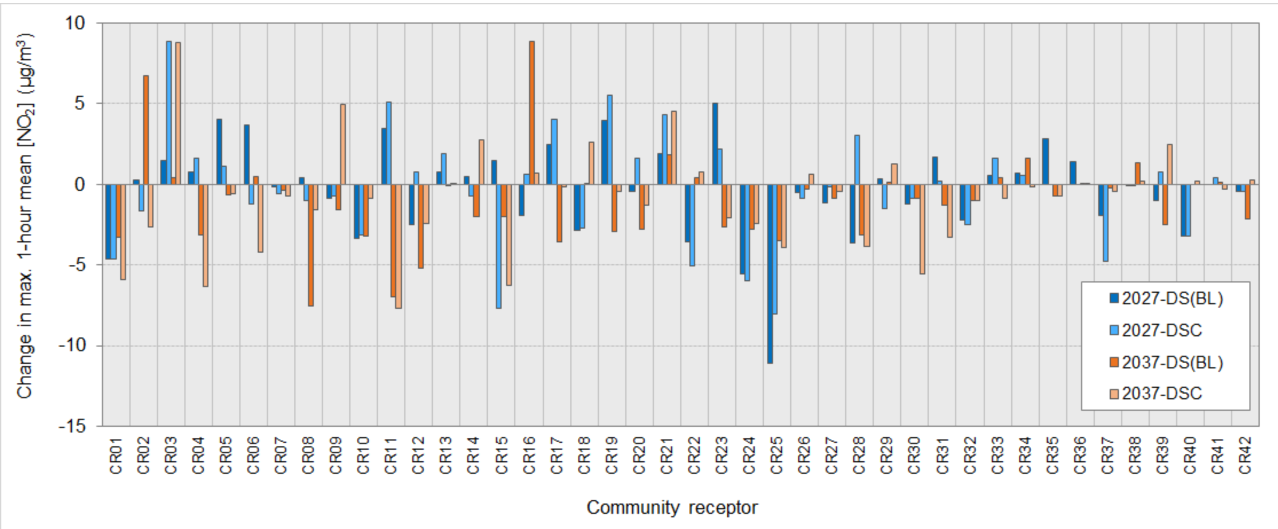

Figure 12-7 Change in maximum 1-hour mean NO_2 concentration at community receivers

Nitrogen dioxide (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-8 shows the predicted contribution of the 'Do something' and 'Do something cumulative' scenarios to annual mean NO_2 concentration at residential, workplace and recreational receiver locations. The predicted annual mean NO_2 concentrations at most (more than 97 per cent) of the receiver locations are between about 13 μg/m^3 and 25 μg/m^3. The annual mean NO_2 criterion of 62 μg/m^3 would not be exceeded at any receiver locations under all scenarios assessed.

The maximum predicted NO_2 contribution at ground level from the ventilation outlets would be 0.7 μg/m^3, and the maximum predicted surface road contribution would be 24.3 μg/m^3, under all scenarios assessed. Given that annual mean NO_2 concentrations at most receiver locations would be well below the criterion, the contribution of the ventilation outlets at ground level is considered negligible.

Community receivers

Figure 12-9 shows the predicted annual mean NO_2 concentrations for the project and cumulative scenarios at community receivers. At all these locations the concentration is predicted to be below 40 μg/m^3, and well below the annual mean NO_2 criterion of 62 μg/m^3 for all scenarios assessed.

Figure 12-10 shows the predicted change in annual mean NO_2 concentration at all of the community receivers. There is a small predicted increase (<2 μg/m^3) in the NO_2 concentration at some community receivers. The largest increase with the project under the scenarios assessed would be about 1.3 μg/m^3 in the 2037 'Do something' scenario, equating to less than three per cent of the criterion. There would also be some notable decreases in the annual mean NO_2 concentration at some receivers (in North Sydney, Mosman and Seaforth) in both the 'Do something' and 'Do something cumulative' scenarios in 2027 and 2037.

For the scenarios assessed, the background component at the community receivers is likely to be responsible for, on average, about 80 to 90 per cent of the predicted total annual mean NO_2, with most of the remainder being due to surface roads. At most receivers, surface roads would contribute between 10 and 30 per cent of the total annual mean NO_2 concentration. The contributions of tunnel ventilation outlets were less than three per cent in all scenarios.

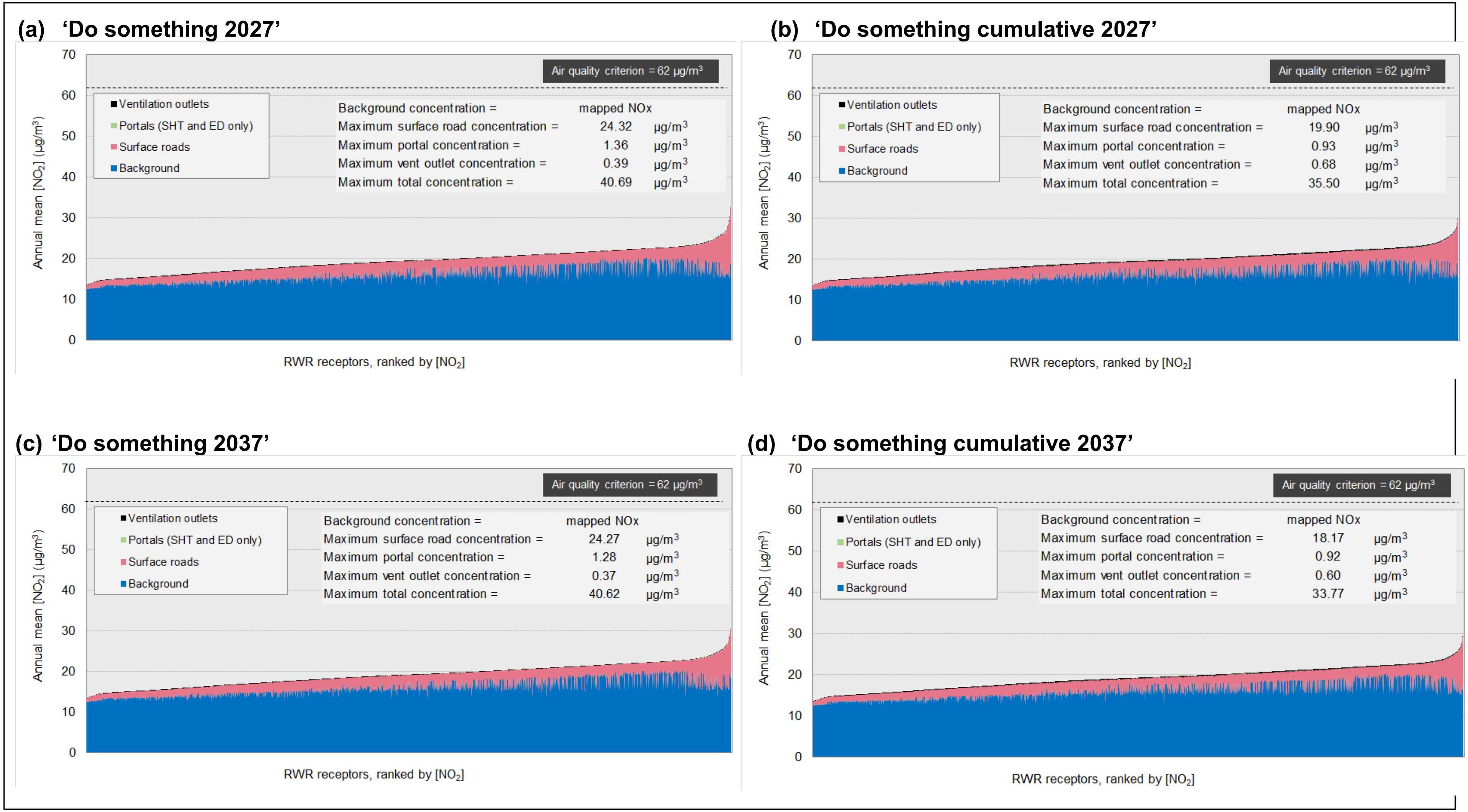

Figure 12-8 Contributions to annual mean NO_2 concentration at residential, workplace and recreational receivers

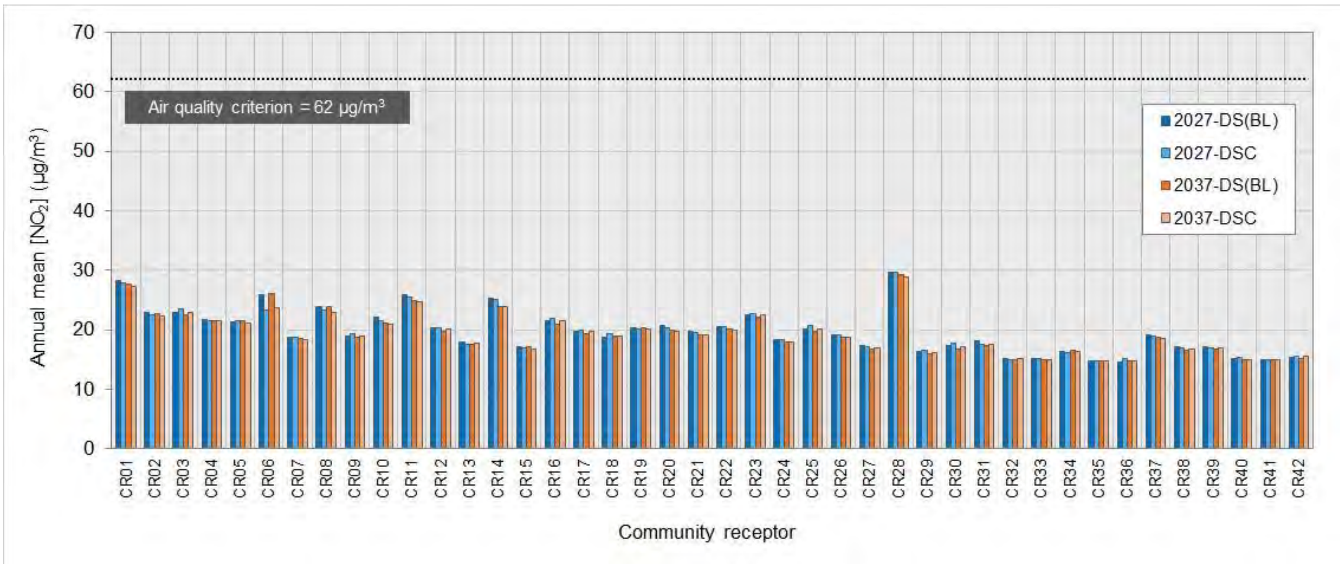

Figure 12-9 Annual mean NO_2 concentration at community receivers

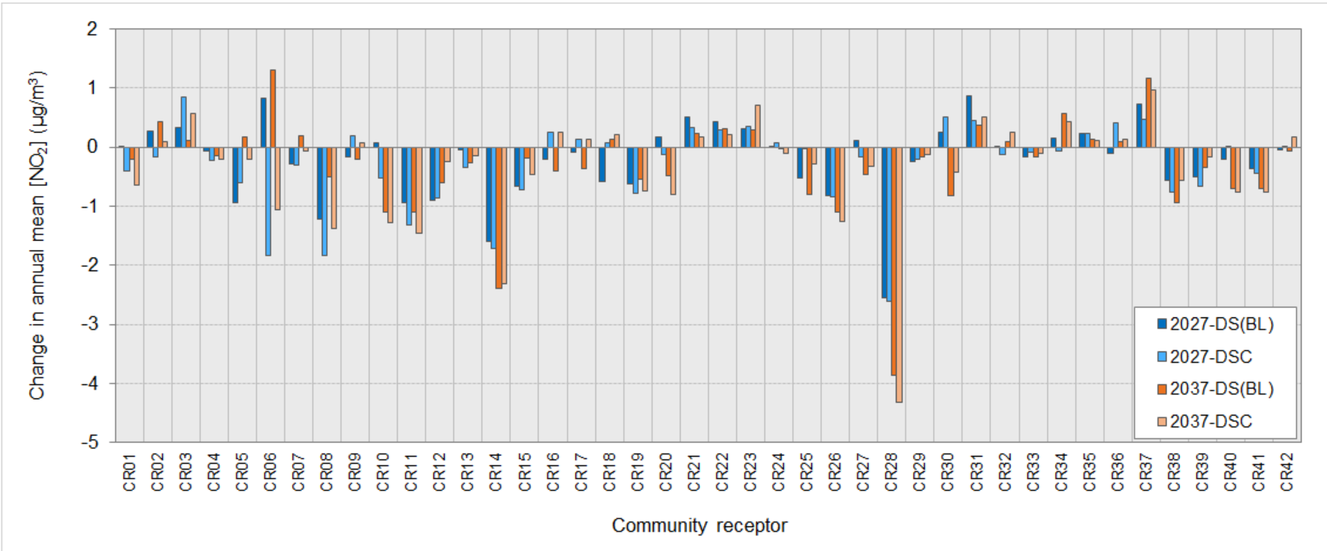

Figure 12-10 Change in annual mean NO_2 concentration at community receivers

PM_{10} (maximum 24-hour mean)

Residential, workplace and recreational receiver locations

Figure 12-11 shows predicted contributions of the project to maximum 24-hour mean PM_{10} concentrations at all the residential, workplace and recreational receiver locations. The results are highly dependent on the assumption for the background concentration (48.04 µg/m^3), which is driven by extreme events such as dust storms, bushfires and hazard reduction burns that occurred in 2016. Accordingly many of the receivers in the ‘Do something’ and ‘Do something cumulative’ scenarios (around 63 per cent) are predicted to be above the criterion of 50 µg/m^3. For the ‘Do something’ and ‘Do something cumulative’ scenarios, the maximum predicted contribution at ground level from the project’s tunnel ventilation outlets at any receiver location would be between 0.7 µg/m^3 and 1.8 µg/m^3.

The largest predicted increase in concentration at any receiver as a result of the project was 6.1 µg/m^3, and the largest predicted decrease was 9.8 µg/m^3. The number of receivers for which a concentration above the criterion is predicted to reduce as a result of the project are as follows:

- From 23,065 in the ‘Do minimum 2027’ scenario to 21,795 in the ‘Do something 2027’ scenario and to 21,083 in the ‘Do something cumulative 2027’ scenario
- From 24,341 in the ‘Do minimum 2037’ scenario to, 23,236 in the ‘Do something 2037’ scenario and 22,507 in the ‘Do something cumulative 2037’ scenario.

Community receivers

Figure 12-12 shows the predicted maximum 24-hour mean PM_{10} concentrations at all of the community receivers in the project and cumulative scenarios. The predicted maximum 24-hour mean PM_{10} concentration is predicted to exceed the criterion of 50 µg/m^3 under all modelled scenarios, due to elevated background concentrations which occur during extreme events such as dust storms, bushfires and hazard reduction burns.

The background concentration is the largest contributor to predicted peak 24-hour PM_{10} concentrations under all modelled scenarios. For the majority of community receivers, the maximum total 24-hour concentration occurred on one day of the year, which coincided with the highest 24-hour background concentration in the PM_{10} profile (126.2 µg/m^3), recorded during a hazard reduction burn. The predicted surface road contribution to the maximum 24-hour PM_{10} concentration at each community receiver is relatively small (less than 4.2 µg/m^3). In the ‘Do something’ scenarios (ie with the operation of the project), the ventilation outlet contributions at all community receivers were less than 0.3 µg/m^3.

Figure 12-13 shows the predicted change in maximum 24-hour mean PM_{10} concentration as a result of the project and cumulatively with other projects (the difference between the ‘Do something’ scenarios and the ‘Do minimum’ scenarios) in 2027 and 2037. The changes were variable and there was no systematic changes by year or by scenario. At several receivers, there would be a predicted increase in concentration, but this would be less than about one µg/m^3.

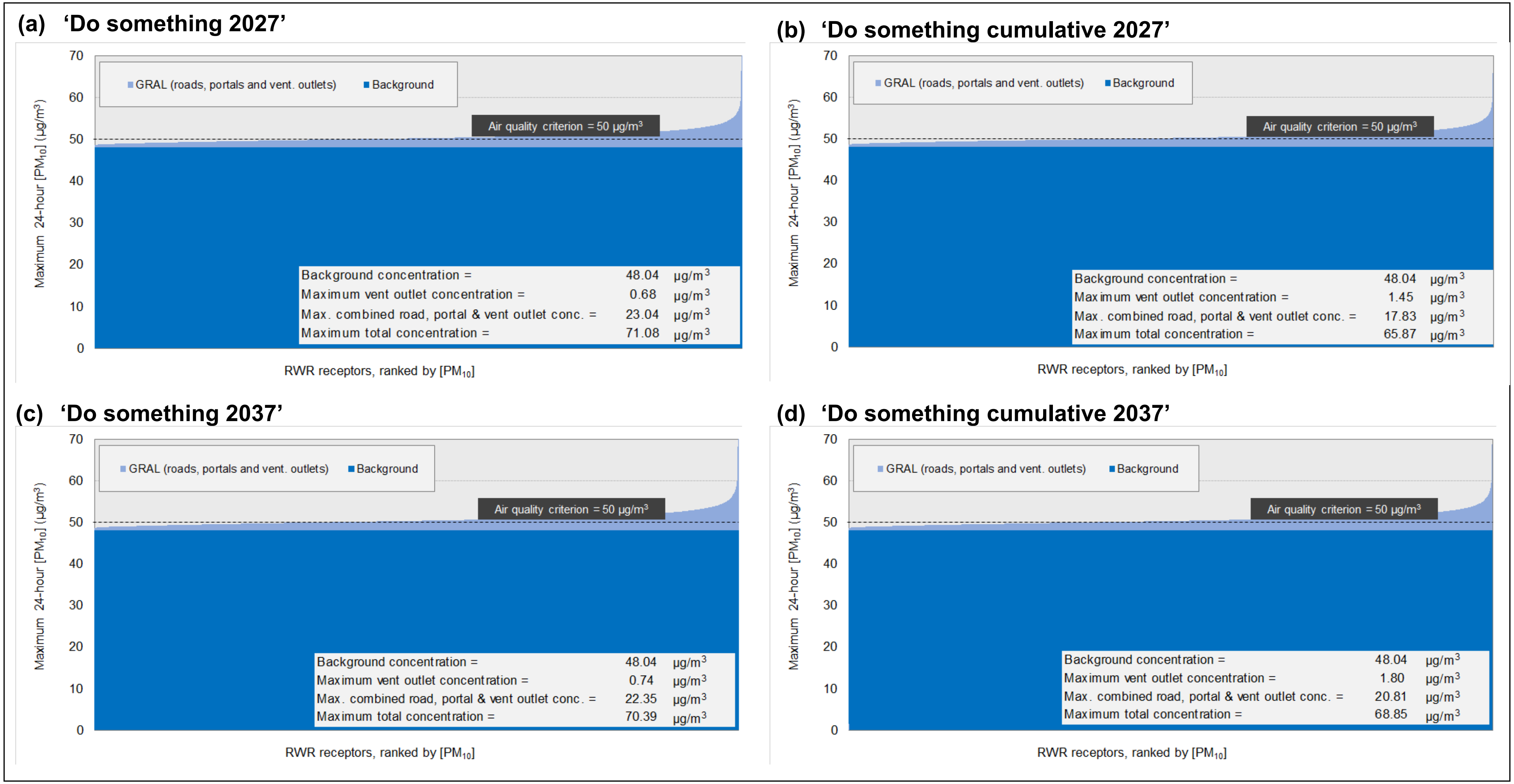

Figure 12-11 Contributions to maximum 24-hour mean PM_{10} concentration at residential, workplace and recreational receivers

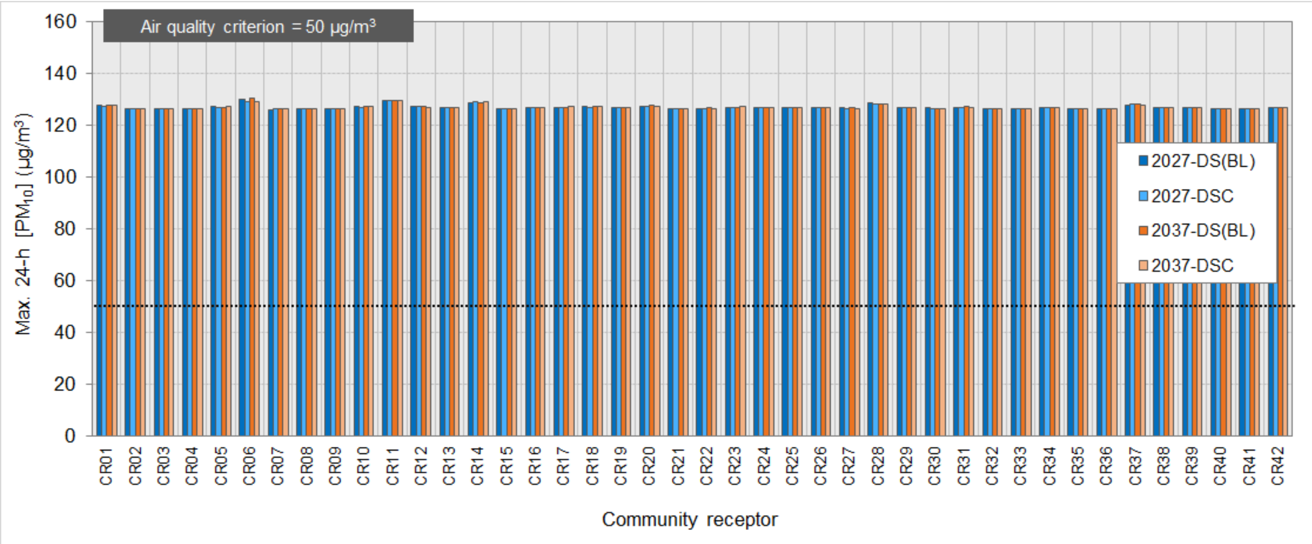

Figure 12-12 Maximum 24-hour mean PM_{10} concentration at community receivers

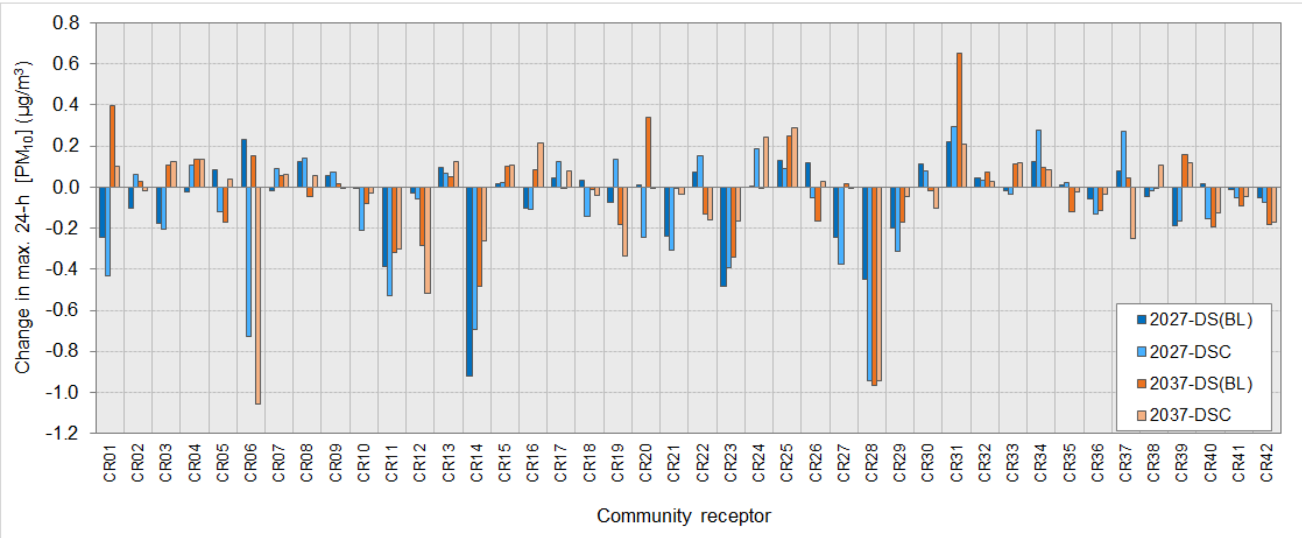

Figure 12-13 Change in maximum 24-hour mean PM_{10} concentration at community receivers

PM_{10} (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-14 shows the ‘Do something’ and ‘Do something cumulative’ scenarios predicted contributions to the annual mean PM_{10} concentration at all the residential, workplace and recreational receiver locations. It demonstrates that the concentration at most receivers is predicted to be below 20 µg/m^3, and only one receiver is predicted to have a concentration above the criterion of 25 µg/m^3 under all scenarios assessed. The receiver is a commercial property (the control centre for Sydney Harbour Tunnel), located in the middle of the Bradfield Highway. This receiver had exceedances in the ‘Do minimum’ and ‘Do something’ scenarios.

An increase in annual mean PM_{10} concentration is predicted at less than half of receivers (between around 39 per cent and 45 per cent of receivers), with the increase considered to be negligible at the majority of receivers. The largest predicted surface road contribution was about 10.7 µg/m^3, with an average about 0.8 to 0.9 µg/m^3. The largest predicted contribution at ground level from the project’s ventilation outlets would be 0.3 µg/m^3 in the ‘Do something cumulative 2037’ scenario.

Community receivers

Figure 12-15 shows the predicted annual mean PM_{10} concentrations at all the community receivers in the project and cumulative scenarios. PM_{10} concentrations are predicted to be below the criterion of 25 µg/m^3 at all receivers in all scenarios.

Figure 12-16 shows the predicted changes in annual mean PM_{10} concentration as a result of the project and cumulatively with other projects (the difference between the ‘Do something’ and ‘Do something cumulative’ scenarios and the ‘Do minimum’ scenarios) in 2027 and 2037. The largest predicted increase would be about 0.5 µg/m^3 (two per cent of the criterion) at receiver CR03 (St Basil’s, Annandale), and the largest decrease would be 1.5 µg/m^3 at receiver CR28 (Peek A Boo Cottage, Seaforth).

Annual mean PM_{10} concentrations in the ‘Do something’ and ‘Do something cumulative’ scenarios for 2027 and 2037 would be dominated by existing PM_{10} concentrations (background). The predicted contribution from surface roads at most receivers would be small (up to three µg/m^3) and the contribution from the project’s ventilation outlets would be negligible (less than about 0.2 µg/m^3).

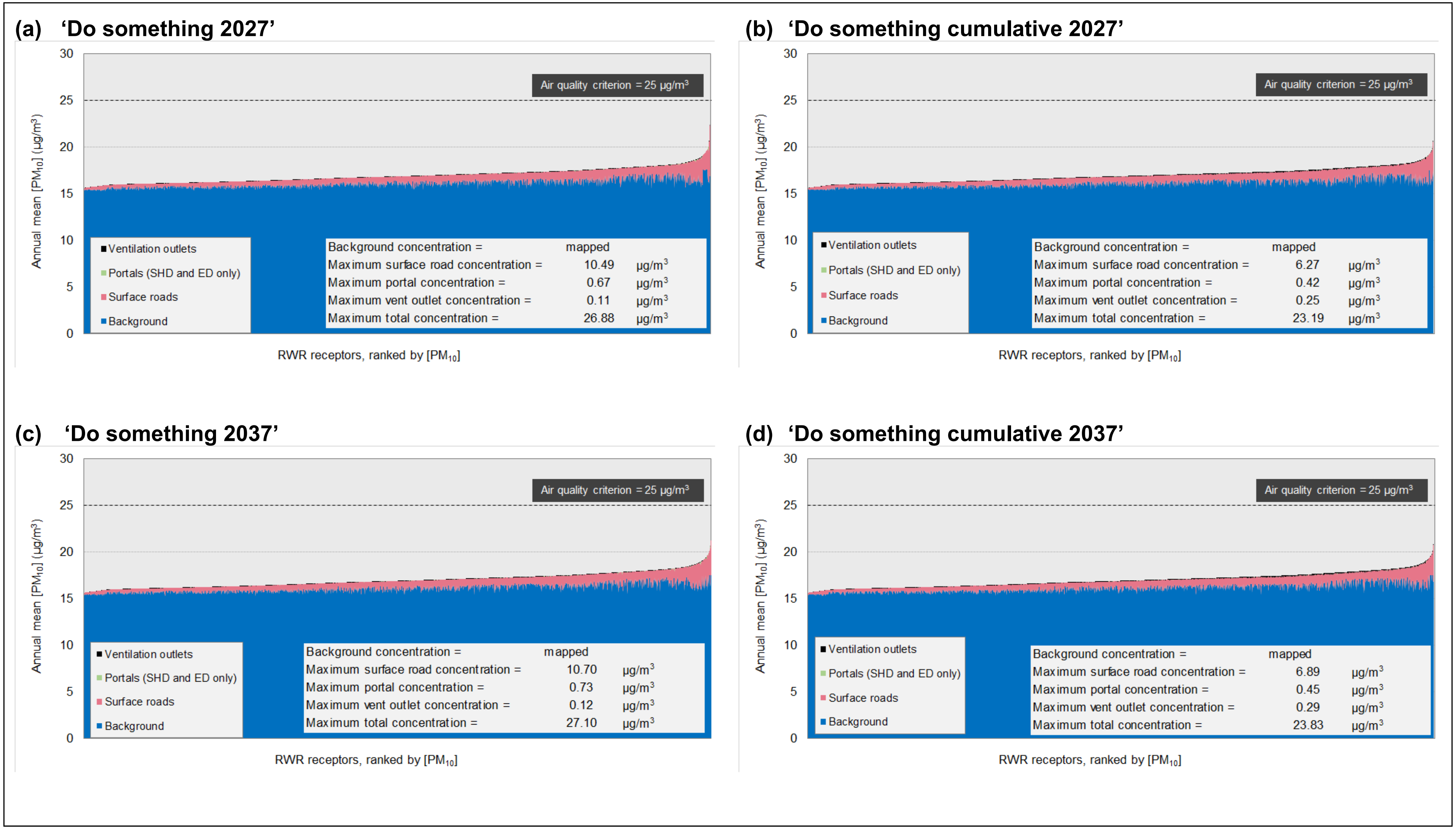

Figure 12-14 Contributions to annual mean PM_{10} concentration at residential, workplace and recreational receivers

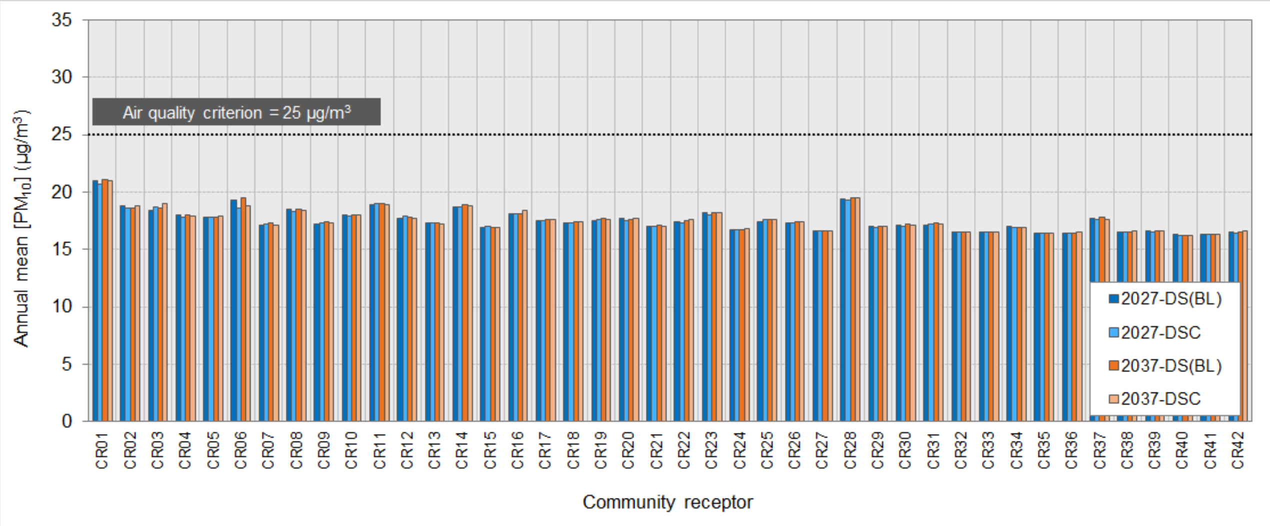

Figure 12-15 Annual mean PM_{10} concentration at community receivers

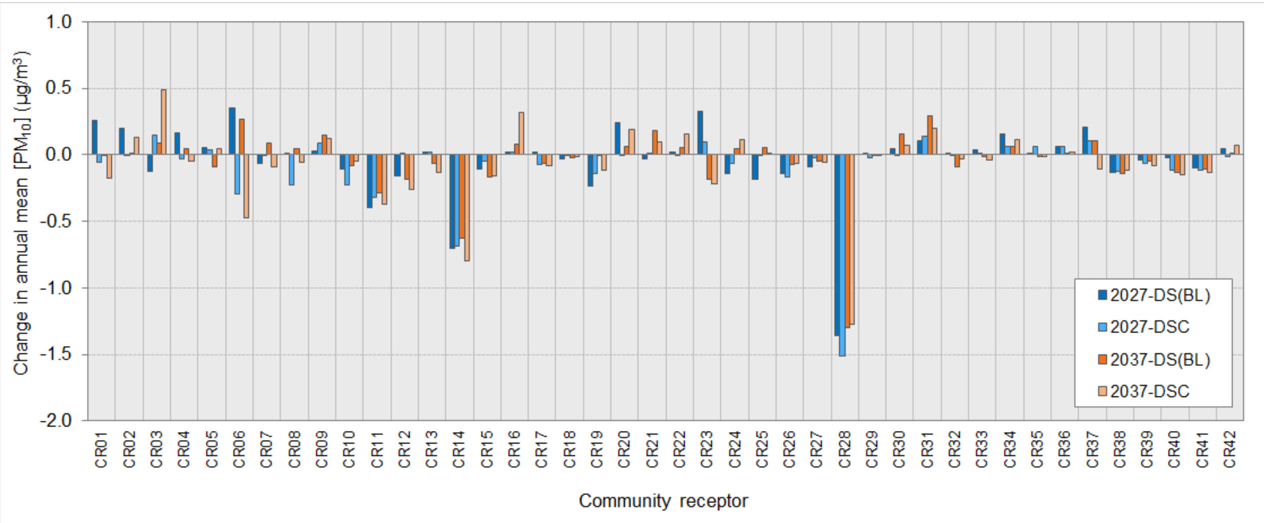

Figure 12-16 Change in annual mean PM_{10} concentration at community receivers

$PM_{2.5}$ (maximum 24-hour mean)

Residential, workplace and recreational receiver locations

Figure 12-17 shows predicted contributions of the project to the maximum 24-hour mean $PM_{2.5}$ concentration at all of the residential, workplace and recreational receiver locations. The main contributor to the predicted maximum 24-hour mean $PM_{2.5}$ concentration was elevated background concentrations that occur during extreme events such as dust storms, bushfires and hazard reduction burns. Consequently, the predicted maximum 24-hour mean $PM_{2.5}$ concentration at a large proportion of receivers was above the criterion of 25 µg/m^3, although this decreased slightly with the project. The proportion of exceedances decreased from 8.6 per cent in the ‘Do minimum 2027’ scenario to 7.1 per cent in the ‘Do something 2027’ scenario and 5.9 per cent in the ‘Do something cumulative 2027’ scenario. The proportion of exceedances are slightly higher in the 2037 scenarios, likely due to predicted increases in traffic. The predicted maximum contribution of the project’s ventilation outlets would be 1.1 µg/m^3 in the ‘Do something cumulative 2037’ scenario at Rozelle.

At most receivers, the changes in the maximum 24-hour mean $PM_{2.5}$ concentration would be very small. The largest predicted increase in concentration at any receiver as a result of the project is predicted to be 4.2 µg/m^3, near Mowbray Road West in Lane Cove North and the largest predicted decrease is 6.3 µg/m^3, at North Sydney near Little Alfred Street. Where increases are predicted, they are greater than one µg/m^3 at less than one per cent of receivers.

Community receivers

Figure 12-18 shows the maximum 24-hour mean $PM_{2.5}$ concentrations at all the community receivers in the ‘Do something’ and ‘Do something cumulative’ scenarios. At all receiver locations, the predicted maximum concentrations were above the criterion of 25 µg/m^3, as exceedances were already predicted without the project. At all community receivers, the maximum total 24-hour concentration coincided with the highest 24-hour background concentration in the $PM_{2.5}$ profile at 49.4 µg/m^3, which is due to the extreme events described above. The combined non-background contributions to the predicted maximum 24-hour mean $PM_{2.5}$ concentration at community receivers would be relatively small. On the days when the maximum total concentration occurred, the project’s ventilation outlet contributions would be small in all cases (less than 0.2 µg/m^3).

Figure 12-19 shows the predicted changes in maximum 24-hour mean $PM_{2.5}$ concentration as a result of the project and cumulatively with other projects (the difference between the ‘Do something’ scenarios and the ‘Do minimum’ scenarios) in 2027 and 2037. All of the increases in concentration were less than one µg/m^3. The largest predicted increase in maximum 24-hour mean $PM_{2.5}$ concentrations is 0.54 µg/m^3 at a receiver CR25 in Willoughby (Sue’s Childcare Castlevale, Willoughby East) in the ‘Do something cumulative 2037’ scenario, which is less than two per cent of the criterion for $PM_{2.5}$.

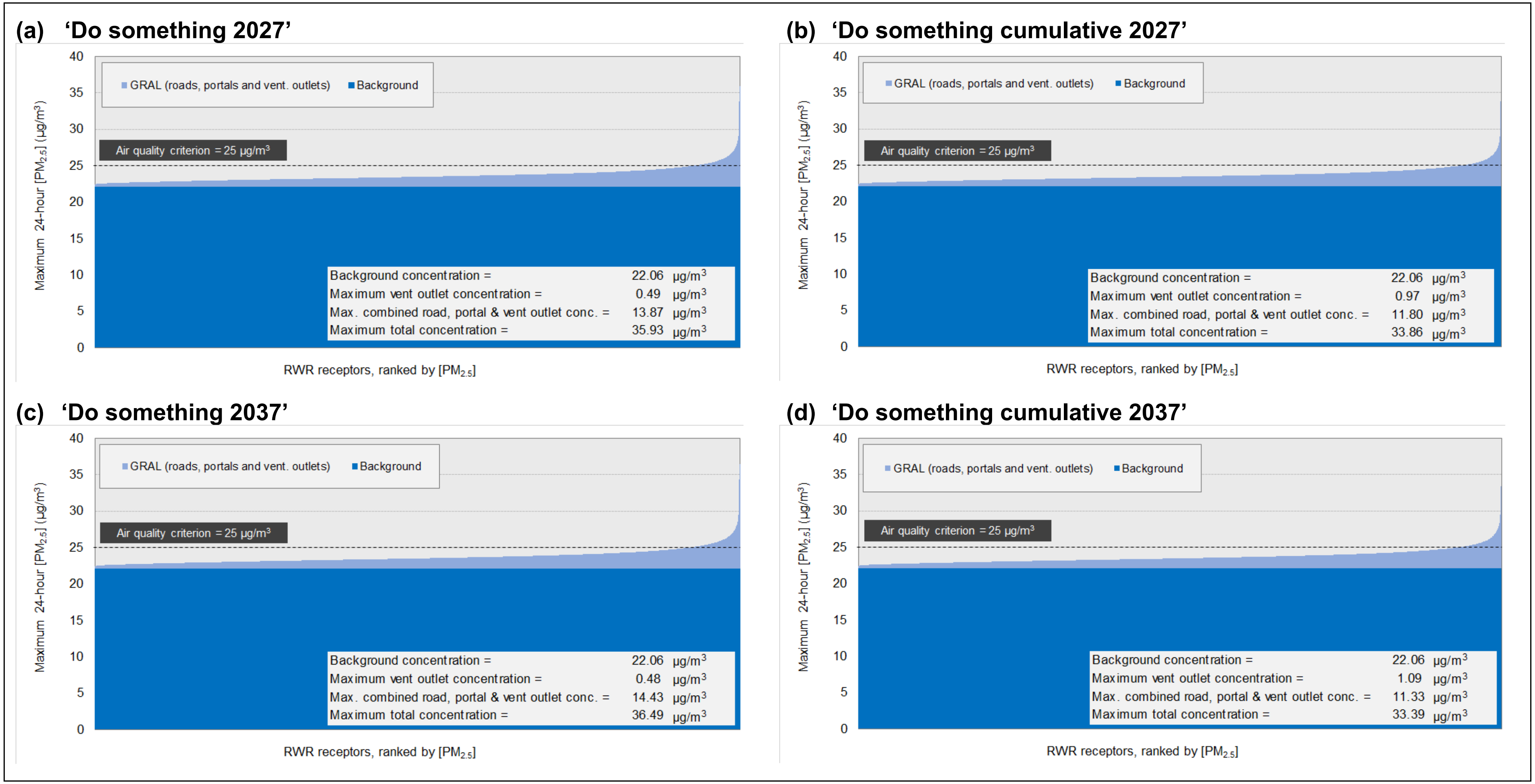

Figure 12-17 Contributions to maximum 24-hour $PM_{2.5}$ mean concentration at residential, workplace and recreational receivers

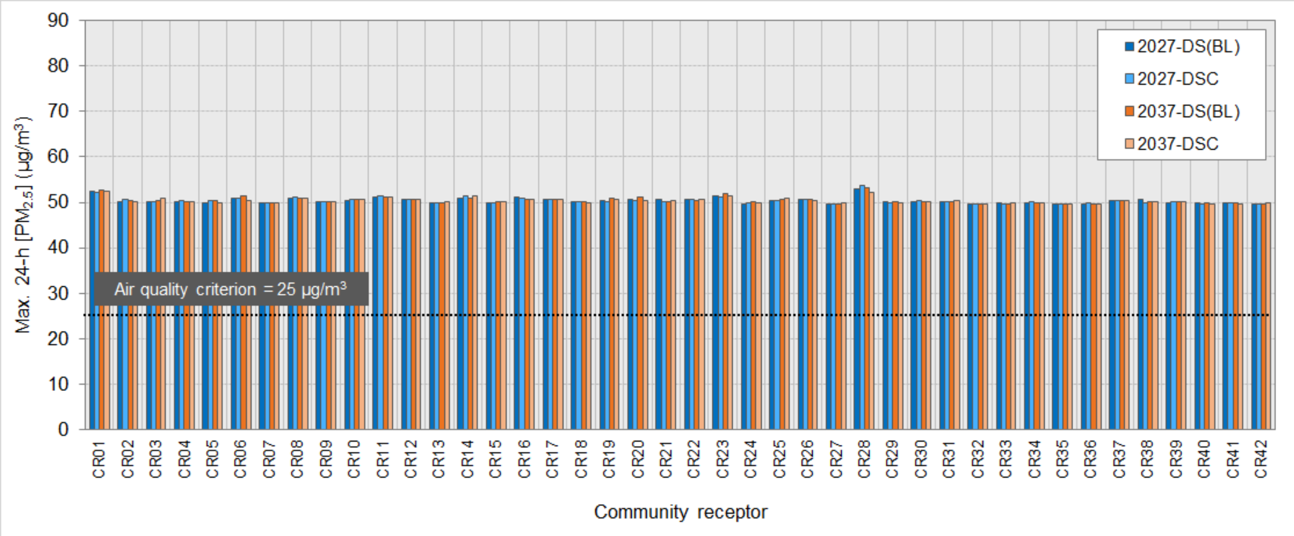

Figure 12-18 Maximum 24-hour $PM_{2.5}$ mean concentration at community receivers

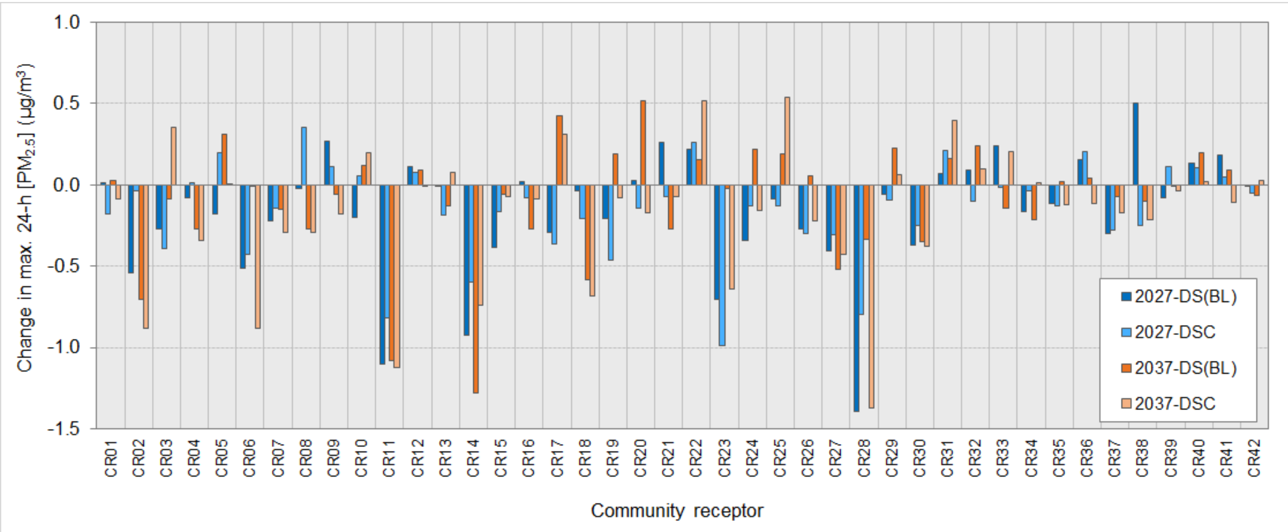

Figure 12-19 Change in maximum 24-hour $PM_{2.5}$ mean concentration at community receivers

$PM_{2.5}$ (annual mean)

Residential, workplace and recreational receiver locations

Figure 12-20 shows predicted contributions of the project to the annual mean $PM_{2.5}$ concentration at all the residential, workplace and recreational receiver locations. Elevated background levels of $PM_{2.5}$ currently exist at these receiver locations that often exceed the criterion of eight µg/m^3, as well as the 2025 goal of seven µg/m^3. Therefore, the background $PM_{2.5}$ concentration was the main contributor to predicted annual mean $PM_{2.5}$ concentrations in the 'Do something' and 'Do something cumulative' scenarios. Nevertheless, the annual mean $PM_{2.5}$ concentration was unchanged or slightly lower at the majority of residential, workplace and recreational receiver locations in the 'Do something' and 'Do something cumulative' scenarios.

The highest predicted annual mean $PM_{2.5}$ concentration at any receiver location would be 14.5 µg/m^3. In the 'Do something' and 'Do something cumulative' scenarios, the largest surface road contribution at any receiver is predicted to be 6.7 µg/m^3. The largest predicted contribution from the project's ventilation outlets in these scenarios would be 0.18 µg/m^3, at Rozelle.

The largest predicted increase in concentration at any receiver location as a result of the project would be 1.6 µg/m^3, in Kirribilli at the northern end of the Sydney Harbour Bridge. The largest predicted decrease would be 2.3 µg/m^3, at North Sydney near Little Alfred Street. The increases were mainly along the Warringah Freeway Upgrade, north east of the Burnt Bridge Creek Deviation, along Wakehurst Parkway and particularly near the Sydney Harbour Bridge and Cammeray. The predicted increases in concentration along Wakehurst Parkway are limited to within the road corridor and do not extend out to the nearby residential, workplace and recreational receivers. There were also increases at Gore Hill Freeway, Manly Road and Rozelle.

Community receivers

Figure 12-21 shows the annual mean $PM_{2.5}$ concentrations at all the community receivers. As with the residential, workplace and recreational receivers, the annual mean $PM_{2.5}$ concentrations in the 'Do something' and 'Do something cumulative' scenarios for 2027 and 2037 would be dominated by background $PM_{2.5}$ concentrations. Given that the predicted background concentration at some community receivers (up to 7.9 µg/m^3) is already close to the air quality criterion (eight µg/m^3) under the 'Do minimum' scenario, some exceedances of the 2025 goal (seven µg/m^3) are predicted with the project under the scenarios assessed for 2027 and 2037. These exceedances also occur in the 'Do minimum' scenarios.

The contribution from surface roads is predicted to be between 0.1 µg/m^3 and 2.1 µg/m^3 whereas the largest predicted contribution from the project's ventilation outlets at any receiver would be 0.1 µg/m^3.

Figure 12-22 shows the predicted change in the annual mean $PM_{2.5}$ as a result of the project and cumulatively with other projects (the difference between the 'Do something' scenarios and the 'Do minimum' scenarios) in 2027 and 2037. Overall, the changes would generally be less than 0.3 µg/m^3. The largest predicted increase in annual mean $PM_{2.5}$ concentration at any community receiver as a result of the project would be 0.3 µg/m^3 at receiver CR03 (St Basil's, Annandale) in the 'Do something cumulative 2037' scenario. This increase is less than four per cent of the air quality criterion. The largest reduction in the annual mean $PM_{2.5}$ concentration (up to 1.1 µg/m^3) is predicted at receiver CR28 (Peek A Boo Cottage, Seaforth) with the project.

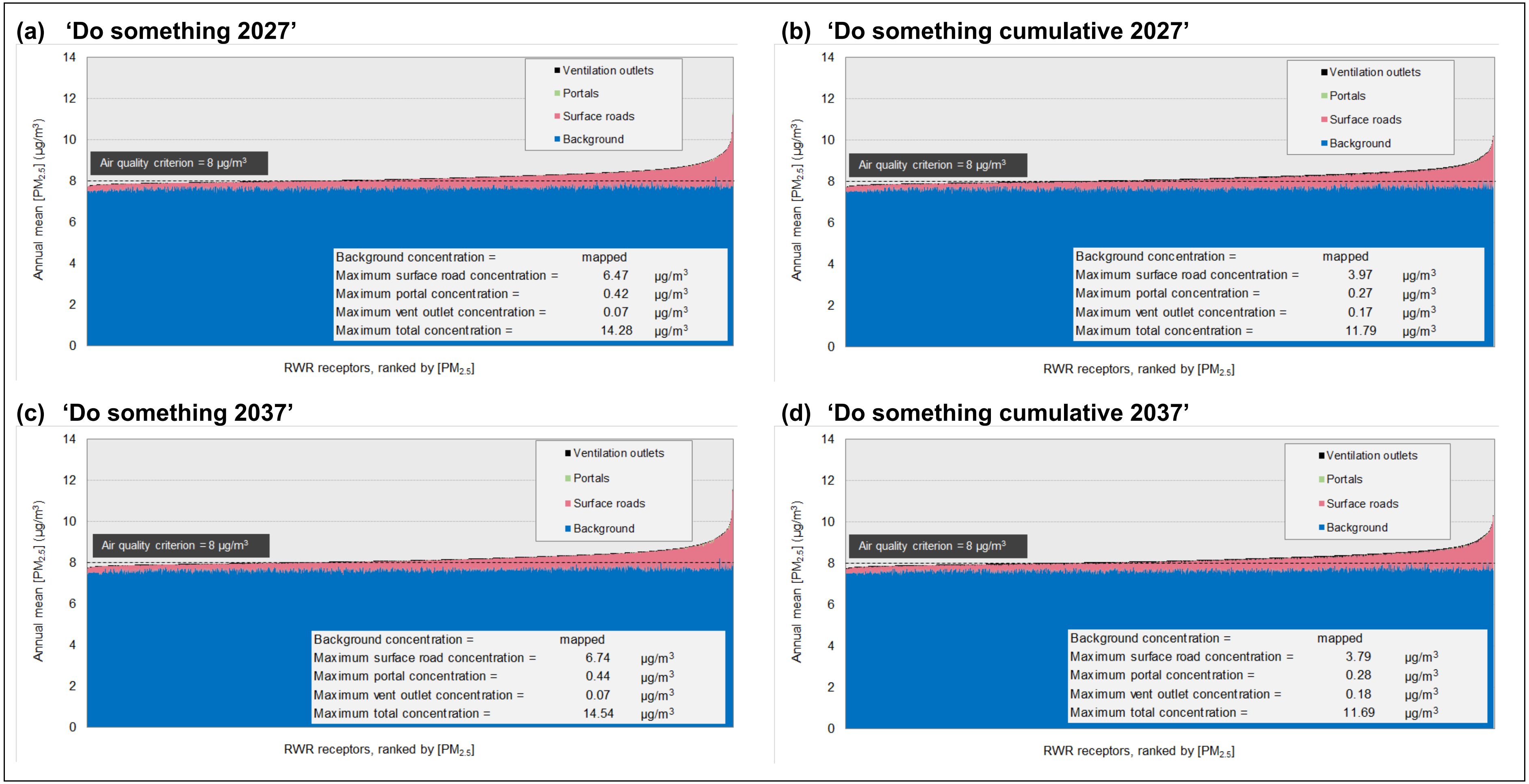

Figure 12-20 Contributions to annual mean $PM_{2.5}$ concentration at residential, workplace and recreational receivers

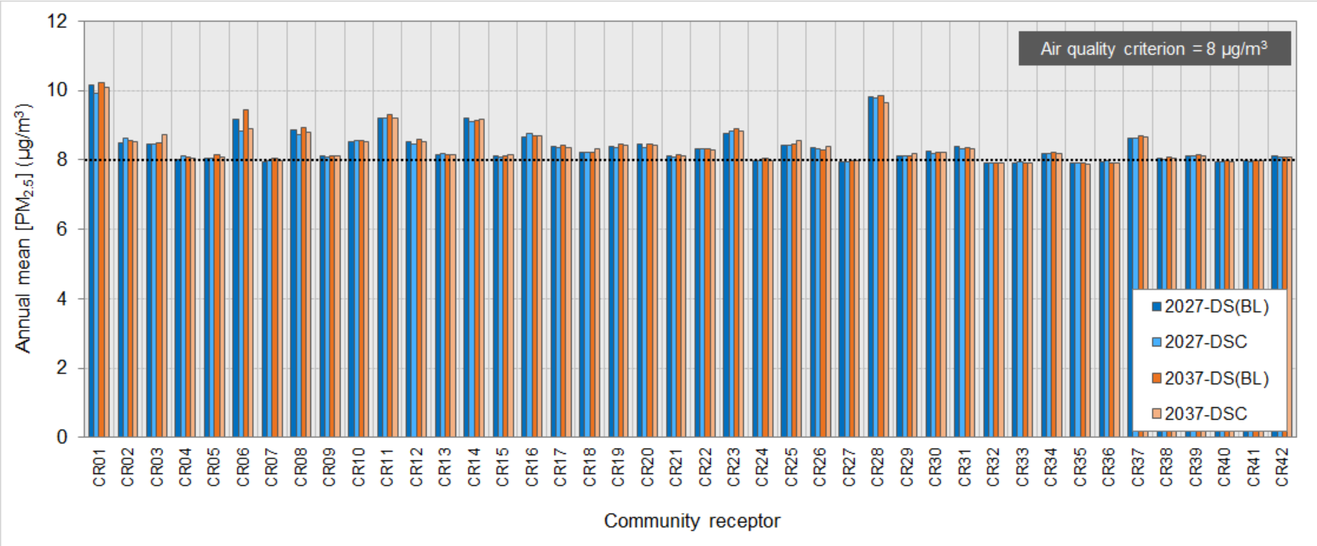

Figure 12-21 Annual mean $PM_{2.5}$ concentration at community receivers

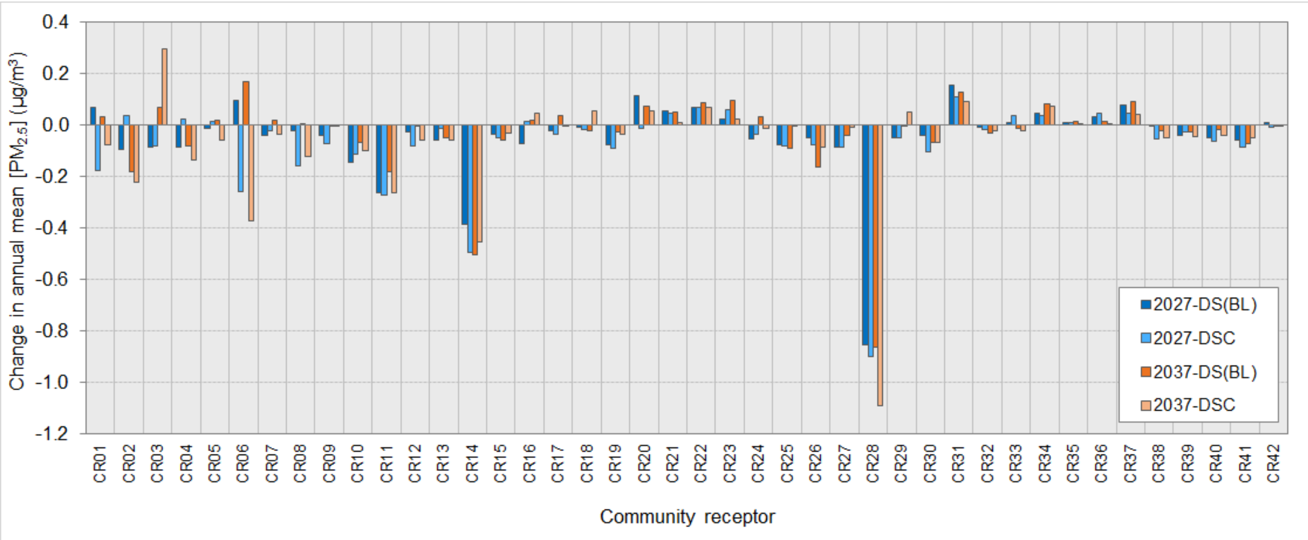

Figure 12-22 Change in annual mean $PM_{2.5}$ concentration at community receivers

Carbon monoxide (CO)

Residential, workplace and recreational receiver locations

The maximum 1-hour and rolling 8-hour mean CO concentrations are predicted to be below the 1-hour and rolling 8-hour CO criteria at all the receiver locations for all the scenarios. The highest total 1-hour CO concentration in any of the 'Do something' or 'Do something cumulative' scenarios is predicted to be 5.5 mg/m^3, in Rozelle. The largest predicted contribution from ventilation outlets at any receiver is predicted to be less than 0.1 mg/m^3, also in Rozelle. Rolling 8-hour mean CO concentrations at all of the residential, workplace and recreational receiver locations are predicted to be similar to those obtained for maximum 1-hour concentrations.

Community receivers

The CO concentration at all of the community receiver locations, is predicted to be well below the impact assessment criterion for both the maximum 1-hour and maximum rolling 8-hour mean CO concentrations.

The largest contribution of surface roads to the maximum total concentration in any of the 'Do something' and 'Do something cumulative' scenarios is predicted to be small for both the maximum 1-hour and maximum rolling 8-hour mean CO concentrations (1.2 mg/m^3 at receiver CR01 (University of Notre Dame, Broadway)). The contribution of the project's ventilation outlets to the maximum CO concentration is zero or negligible (ie less than 0.01 mg/m^3) for all receivers.

Air toxics

Five compounds, benzene, polycyclic aromatic hydrocarbons, formaldehyde, 1,3-butadiene and ethylbenzene, were considered in the assessment. These compounds were taken to be representative of the much wider range of air toxics associated with motor vehicles and have commonly been assessed for road projects.

The predicted changes in the maximum 1-hour concentrations for these compounds showed that there would be minor increases in concentrations as a result of the project, however, all air toxic concentrations would be well below their respective assessment criterions. The increases (and decreases) for the most affected residential, workplace and recreational receiver locations would be higher for those that are in close proximity to the surface roads, but in all 'Do something' and 'Do something cumulative' scenarios for all five compounds considered in the assessment, the total predicted concentrations would be well below their respective criteria. For example, the largest increase in benzene concentrations at any residential, workplace and recreational receiver location for a 'Do something cumulative' scenario is predicted to be 3.7 µg/m^3, but the total concentration of 8.7 µg/m^3 still remains well below the criterion of 29 µg/m^3 (0.029 mg/m^3).

12.6.3 Redistribution of air quality impacts

Spatial changes in air quality

The spatial changes in pollutant concentrations are assessed with respect to annual mean $PM_{2.5}$ concentration, given its importance in terms of human health risks. However, the spatial changes would be qualitatively similar for all pollutants.

The annual mean $PM_{2.5}$ concentration as a result of the project ('Do something 2027' scenario relative to the 'Do minimum 2027' scenario) is predicted to decrease along Military Road, Spit Road, Manly Road and Warringah Road. These reductions would be associated with the reductions in traffic and would result in improved amenity along these built-up road corridors. The human health benefits associated with the decrease in $PM_{2.5}$ concentration as a result of the project is discussed in Chapter 13 (Human health).

There would be increases in the $PM_{2.5}$ concentration along Sydney Harbour Bridge and Wakehurst Parkway. In the case of Wakehurst Parkway there would be a large increase in traffic (about 140 per cent) as a result of the project. However, the section of Wakehurst Parkway that is affected crosses bushland, and there are no sensitive receivers close to the road. Predicted increases in pollutant concentrations along Wakehurst Parkway are also limited to the road corridor and do not extend out to nearby receivers. There would be broadly similar changes in the ‘Do something 2037’ scenario.

For the cumulative scenarios, there would be some additional changes as a result of the Western Harbour Tunnel and Warringah Freeway Upgrade project, including reductions in the $PM_{2.5}$ concentration along the Western Distributor, Sydney Harbour Bridge and Warringah Freeway.

Overall, there would be no marked redistribution of air quality impacts, and there would generally be a shift towards lower concentrations. Most notably, there would be no significant increase in concentration at receiver locations which already had high concentrations in the ‘Do minimum’ scenarios.

12.6.4 Ambient air quality (elevated receivers)

Modelling of all pollutants at elevated receivers, for the ‘Do something cumulative 2037’ scenario was carried out at heights of 10 metres, 20 metres, 30 metres and 45 metres above ground level. The changes in the annual mean and maximum 24-hour mean PM_{10} and $PM_{2.5}$ concentrations were considered in addition annual average and maximum 1-hour average NO_2 concentrations and air toxics (only the incremental (ventilation outlet) contribution).The aim of this assessment is to provide an evaluation of impacts at elevated receivers within 300 metres of the project’s ventilation outlets.

It should be noted that existing buildings at receiver locations are not as tall as the heights discussed above (eg at a receiver location, an existing building may be up to 10 metres in height but was assessed at all four selected heights).

As summary of the outcomes of the elevated receivers assessment for existing buildings is provided below with the full methodology and results provided in Section 8.4.9 of Appendix H (Technical working paper: Air quality):

- For the annual average PM_{10} and $PM_{2.5}$ concentrations, there are no predicted exceedances of the respective criteria at any modelled height
- For the maximum 24-hour average PM_{10} concentrations, there are no predicted exceedances of the criterion of 50 $\mu g/m^3$ at any height for the buildings present
- For the maximum 24-hour average $PM_{2.5}$ concentrations, there are no predicted exceedances of the criterion of 25 $\mu g/m^3$ at any height for the buildings present
- For the annual average and maximum 1-hour average NO_2 concentrations, there are no predicted exceedances of the criterion at any modelled height
- For the maximum 1-hour average benzene, PAHs, formaldehyde, 1,3-butadiene and ethylbenzene concentrations, there are no predicted exceedances of the criteria at any modelled height.

Considering the above, it can be concluded that no adverse impacts are predicted at any existing buildings.

The modelling predicted no exceedances at any modelled height for concentrations for annual average PM_{10} and $PM_{2.5}$, annual average and maximum 1-hour average NO_2 and air toxics. The assessment predicted some exceedances at heights above 30 metres within 300 metres of the project’s ventilation outlets for $PM_{2.5}$ and PM_{10} maximum 24-hour average concentrations, which might impact any future buildings at these heights. This would not necessarily preclude such development and further consideration at rezoning or development application stage would be required.

In addition, land use considerations would be required to manage any interaction between the project and future development for buildings with habitable structures above 20 metres and within 300 metres of a ventilation outlet.

Transport for NSW would assist councils and the Department of Planning, Industry and Environment (as appropriate) in determining relevant land use considerations applicable to future development in the immediate vicinity of the project's ventilation outlets for inclusion in Local Environmental Plans or Development Control Plans, where required, to manage interactions between the project and future development. This may include procedures for identifying the requirement for consultation with Transport for NSW for proposed rezoning or development applications.

12.6.5 Regional air quality

The absolute changes in the total emissions resulting from the project can be viewed as a proxy for the project's regional air quality impacts which, based on the results, are likely to be negligible. For example:

- Changes in NO_X emissions for the assessed road network for the 'Do something' scenarios in a given assessment year ranged from an increase of around one tonne per year to a decrease of around four tonnes per year, depending on the scenario. In the 'Do something cumulative' scenarios, changes in NO_X emissions ranged from an increase of around 29 tonnes to 125 tonnes per year. These values equated to small proportions of human activity related NO_X emissions in the Greater Sydney airshed in 2016 (about 53,700 tonnes)
- The projected reduction in the NO_X emission rate between 2016 and 2037 (about 2000 tonnes per year) exceed the relatively small increases in the NO_X emission rate due to the project in a given year.

The regional air quality impacts of a project can also relate to its capacity to influence ozone production. The project's impact on ozone concentrations in the Greater Sydney region was assessed in accordance with the NSW Environment Protection Authority's *Tiered Procedure for Estimating Ground Level Ozone Impacts from Stationary Sources* (ENVIRON, 2011). The assessment indicated that the largest increase in NO_X emissions due to the project (125 tonnes per year in the 'Do something cumulative 2037' scenario) would be above the 90 tonnes per year threshold for conducting a further detailed assessment. Further assessment using the NSW Environment Protection Authority Level 1 screening tool indicated that the maximum 1-hour and 4- hour incremental ozone concentrations due to the project in the 'Do something cumulative 2037' scenario would not exceed the screening impact level of 0.5 parts per billion, and therefore no further consideration is required.

Overall, the regional impacts of the project would be negligible, and undetectable in ambient air quality measurements at background locations.

12.6.6 Odour

For each of the residential, workplace and recreational receivers, the change in the maximum one hour total hydrocarbon concentration as a result of the project was calculated. The largest change in the maximum one hour total hydrocarbon concentration across all receivers was then determined, and this was converted into an equivalent change for three of the odorous pollutants identified in the NSW EPA Approved Methods (toluene, xylenes, and acetaldehyde). Some hydrocarbons emitted from the burning of fuel by motor vehicles create odour. These pollutants were taken to be representative of other odorous pollutants from motor vehicles.

The changes in the levels of three odorous pollutants as a result of the project, and the corresponding odour assessment criteria from the NSW EPA Approved Methods, are shown in Table 12-10.

Table 12-10 Changes in odorous pollutant concentrations

Scenario	Largest predicted increase in maximum 1-hour hydrocarbon concentration		
	Toluene ($\mu g/m^3$)	Xylenes ($\mu g/m^3$)	Acetaldehyde ($\mu g/m^3$)
'Do something 2027'	6.7	5.6	1.5
'Do something cumulative 2027'	5.9	4.8	1.3
'Do something 2037'	3.9	3.2	1.3
'Do something cumulative 2037'	3.5	2.9	1.2
Odour criterion ($\mu g/m^3$)	360	190	42

12.7 Environmental management measures

12.7.1 Management of construction impacts

Environmental management measures relating to air quality impacts are outlined in Table 12-11.

Table 12-11 Environmental management measures – air quality

Ref	Phase	Impact	Environmental management measure	Location
AQ1	Pre-construction and construction	General	Standard construction air quality mitigation and management measures will be detailed in construction management documentation and implemented during construction, such as: a) Reasonable and feasible dust suppression and/or management measures, including the use of water tanks and/ or carts, sprinklers, site exit controls (eg wheel washing systems and rumble grids), stabilisation of exposed areas or stockpiles, and surface treatments b) Selection of construction equipment and/or materials handling techniques that minimise the potential for dust generation c) Management measures to minimise dust generation during the transfer, handling and on site storage of spoil and construction materials (such as sand, aggregates or fine materials) (eg the covering of vehicle loads) d) Adjustment or management of dust generating activities during unfavourable weather conditions, where reasonable and feasible e) Minimisation of exposed areas during construction f) Measures for managing odour generation likely to result in odour impacts at sensitive receivers in the vicinity during the	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			disturbance, handling and storage of potentially odorous materials, including any contingency measures g) Internal project communication protocols to ensure dust-generating activities in the same area are coordinated and mitigated to manage cumulative dust impacts of the project h) Site inspections will be carried out to monitor the effectiveness of implemented measures and identify any additional measures to be implemented.	
AQ2	Pre-construction and construction	Odour	Further site investigations will be carried out during the detailed design and construction planning phase to determine the potential to encounter odorous gases or materials during the proposed excavations at the Flat Rock Drive construction support site (BL2). If the investigations indicate that there is potential for odorous materials to be uncovered or odorous gases to be released, the potential for off-site impacts (informed by meteorological studies and modelling as required) will be investigated. If unacceptable off-site impacts are predicted, appropriate mitigation and management measures will be identified to minimise potential impacts, with consideration of the investigation results, proposed site activities and meteorological conditions, and the identified measures will be implemented during relevant site activities. Odour monitoring will be carried out during relevant site activities and mitigation and management measures adjusted as required to minimise potential off-site impacts.	BL
AQ3	Construction	General	Dust and air quality complaints will be managed in accordance with the overarching complaints handling process for the project. Appropriate corrective actions; if required, will be taken to reduce emissions in a timely manner.	BL/GHF
AQ4	Construction	Odour	Any areas of exposed material at the Flat Rock Drive construction support site that have the potential to generate odour will be kept to a minimum during site establishment works and while the area is uncovered. If odorous areas are to remain uncovered at the end of the work shift, temporary cover or other suitable measures to minimise odour emissions will be implemented.	BL

Ref	Phase	Impact	Environmental management measure	Location
AQ5	Construction	Odour	If the dredged materials require some form of land-based processing prior to disposal, an assessment of potential odour impacts will be carried out for the proposed processing site in accordance with the *Technical framework for the assessment and management of odour from stationary sources in NSW* (DEC, 2006). This will include modelling to assess whether the use of the site and the proposed processing and treatment activities for the dredged material can comply with a criterion of 2 odour units at all sensitive receivers in the vicinity.	BL
AQ6	Construction	Odour	Where the assessment carried out in environmental management measure AQ5 indicates that compliance is not likely, an odour management strategy will be developed. The strategy will describe appropriate mitigation and management measures to ensure that the 2 odour units criterion is met, odour survey requirements and contingency actions that will be implemented if significant odour issues are observed in the vicinity of sensitive receivers. The strategy will be developed prior to accepting dredged material at the site and implemented for the duration of the processing of dredged material at the site.	BL

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection

12.7.2 Management of operational impacts

The Secretary's environmental assessment requirements for the project require details of, and justification for, the air quality management measures that were considered for the project. This section reviews the environmental management measures that are available for improving tunnel-related air quality, and then describes their potential application in the context of the project. The measures are categorised as follows:

- Tunnel design
- Ventilation design and control
- Air treatment systems
- Emission controls and other measures.

Tunnel design

Tunnel infrastructure is designed in such a way that the generation of pollutant emissions by traffic using the tunnel is minimised. Tunnel design provisions for this project include:

- Minimal gradients as far as reasonably practicable
- Large tunnel cross-sectional area to reduce the pollutant concentration for a given emission into the tunnel volume, and to permit greater volumetric air throughput
- Increased height to reduce the risk of incidents involving high vehicles blocking the tunnel and disrupting traffic. This would reduce the risk of higher pollutant concentrations associated with flow breakdown.

Ventilation design and control

The project ventilation system has been designed and would be operated so that it would achieve some of the most stringent standards in the world for in-tunnel air quality, and would be effective at maintaining local air quality. The design of the ventilation system would ensure zero portal emissions.

The ventilation system would be automatically controlled using real-time air velocity and air quality sensor data to ensure that in-tunnel conditions are managed effectively in accordance with the agreed criteria. Furthermore, specific ventilation modes would be developed to manage breakdown, congested and emergency situations.

There are several reasons why a tunnel needs to be ventilated. The main reasons are:

- Control of the internal environment: It must be safe and comfortable to drive through the tunnel. Vehicle emissions must be sufficiently diluted so as not to be hazardous during normal operation, or when traffic is moving slowly or stationary
- Protection of the external environment: Ventilation, and the dispersion of pollutants, is the most widely used method for minimising the impacts of tunnels on ambient air quality. Collecting emissions and venting them via elevated ventilation outlets is a very efficient way of dispersing pollutants. Studies show that the process of removing surface traffic from heavily trafficked roads and releasing the same amount of pollution from an elevated location results in substantially lower concentrations at sensitive receivers (Permanent International Association of Road Congress (PIARC), 2008)
- Emergency situations: When a fire occurs in a tunnel, the ventilation system is able to control the heat and smoke in the tunnel so as to permit safe evacuation of occupants, and to provide the emergency services with a safe route to deal with the fire and to rescue any trapped or injured persons.

The ventilation system design options that were considered for the project are discussed in Chapter 4 (Project development and alternatives) and the system adopted for the project is described in Chapter 5 (Project description).

Air treatment systems

In November 2018, the ACTAQ, chaired by the NSW Chief Scientist and Engineer, published a review of lessons learnt from other major road tunnel projects in NSW (ACTAQ, 2018c). The review found that emissions from well designed ventilation outlets have little, if any, impact on surrounding communities and, as such, there is little health benefit in installing filtration and air treatment systems.

There are several air treatment options for mitigating the effects of tunnel operation on both in-tunnel and ambient air quality. Where in-tunnel treatment technologies have been applied to road tunnels, these technologies have focused on the management and treatment of particulates.

ACTAQ's review of options for treating road tunnel emissions (ACTAQ, 2018b) demonstrated that the appropriate design of ventilation outlets would achieve the same (or better) outcomes as installing air filtration systems – that is, the contribution of tunnel ventilation outlets to pollutant concentrations would be negligible for all receivers. In Australia, tunnel projects therefore generally implement the primary approach of dilution of air pollution (through ventilation systems) (PIARC, 2008; Centre d'Etudes des Tunnels (CETU), 2016).

Emission controls and other measures

In addition to the operation and management of the tunnel ventilation system, there are various operational measures available to manage in-tunnel emissions and air quality. These include the following:

- Traffic management: Traffic management will be employed by tunnel operators to control exposure to vehicle-derived air pollution. Measures can include (PIARC, 2008):

- Allowing only certain types of vehicle
- Regulating time of use
- Tolling (including differential tolling by vehicle type, emission standard, time of day, occupancy)
- Reducing traffic throughout
- Lowering the allowed traffic speed

- Incident detection: Early detection of incidents and queues is essential to enable tunnel operators and the highway authority to put effective traffic management in place. Monitoring via CCTV cameras is normally a vital part of the procedure for minimising congestion within tunnels and allowing timely operator response to changes in traffic flow
- Public information and advice: Traffic lights, barriers, variable message signs, radio broadcasts, public address systems (used in emergencies) and other measures can help to provide driver information and hence influence driver behaviour in tunnels
- Cleaning the tunnel regularly assists in reducing concentrations of small particles (PIARC, 2008), as is common practice in Sydney tunnels.

Further design development of the in-tunnel air quality monitoring system will be carried out during future project development phases and will include the following:

- Air quality monitoring of key pollutants will be carried out throughout the tunnel. The locations of monitoring equipment will generally be at the beginning and end of each ventilation section. This will include, for example, monitors at each entry ramp, exit ramp, merge point and ventilation exhaust and supply point. The location of monitors will be governed by the need to meet in-tunnel air quality criteria for all possible journeys through the tunnel system, especially for NO_2. This will require sufficient, appropriately placed monitors to calculate a journey average
- Velocity monitors will be placed in each tunnel ventilation section and at portal entry and exit points. The velocity monitors in combination with the air quality monitors will be used to modulate the ventilation within the tunnel to manage air quality and to ensure net air inflow at all tunnel portals.

During operation, air quality monitoring data will be made publicly available on the new motorway website.

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 13

Human health

DECEMBER 2020

13 Human health

This chapter outlines the potential human health impacts associated with the project and identifies measures to address these impacts. A human health impact assessment has been carried out for the project and is included in Appendix I (Technical working paper: Health impact assessment).

The Secretary's environmental assessment requirements as they relate to human health impacts, and where in the environmental impact statement these have been addressed, are detailed in Table 13-1 (Secretary's environmental assessment requirements checklist).

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The proposed environmental management measures relevant to human health impacts are discussed in Section 13.6.

Table 13-1 Secretary's environmental assessment requirements – human health

Secretary's requirement	Where addressed in EIS
Health and Safety	
1. The Proponent must assess the potential health risks from the construction and operation of the project.	**Section 13.4** and **Section 13.5** describe the potential human health risks from the construction and operation of the project.
2. The assessment must: a. describe the current known health status of the potentially affected population;	**Section 13.3** describes the potentially affected community and their current health status.
b. describe how the design of the proposal minimises adverse health impacts and maximises health benefits;	**Section 2.3** of **Appendix I** (Technical working paper: Health impact assessment) outlines how health issues have been considered and benefits maximised in project design. Adverse and beneficial impacts associated with the project are discussed in **Section 13.4** and **Section 13.5**.
c. assess human health risks from the operation and use of the tunnel under a range of conditions, including worst case operating conditions and the potential length of motorway tunnels in Sydney;	**Section 13.5** assesses the human health risks associated with the operation and use of the project.
d. human health risks and costs associated with the construction and operation of the proposal, including those associated with air quality, odours, noise and vibration (including residual noise following application of mitigation measures), construction fatigue, and social impacts (including from acquisitions) on the adjacent and surrounding areas as well as opportunity costs (such as those from	**Section 13.4** and **Section 13.5** outline the construction and operational impacts including those related to air quality, noise and vibration, construction fatigue, social impacts and cumulative impacts associated with the project. **Appendix I** (Technical working paper: Health impact assessment) includes consideration of opportunity costs for particulates, noting there are no methods to quantify health costs other than particulates.

Secretary’s requirement	Where addressed in EIS
social infrastructure and active transport impacts) during the construction and operation of the proposal;	
e. include both incremental changes in exposure from existing background pollutant levels and the cumulative impacts of project specific and existing pollutant levels at the location of the most exposed receivers and other sensitive receptors (including public open space areas child care centres, schools, hospitals and aged care facilities);	Health related air quality impacts during operation, including cumulative impacts, are discussed in **Section 13.5**.
f. assess the likely risks of the project to public safety, paying particular attention to pedestrian safety, subsidence risks, bushfire risks and the handling and use of dangerous goods;	**Section 13.4** and **Section 13.5** considers pedestrian/public safety during construction and operation. Subsidence is considered in **Chapter 16** (Geology, soils and groundwater). **Chapter 23** (Hazards and risks) includes an assessment of bushfire risks and the handling and use of dangerous goods.
g. assess the opportunities for health improvement;	Beneficial impacts associated with the project are discussed in **Section 13.4** and **Section 13.5**.
h. assess the distribution of the health risks and benefits; and	The distribution of the health related risks and benefits are presented in **Section 13.4** and **Section 13.5**. Consideration of the distribution of noise and air quality impacts are presented in **Chapter 10** (Construction noise and vibration), **Chapter 11** (Operational noise and vibration) and **Chapter 12** (Air quality).
i. include a cumulative human health risk assessment inclusive of in-tunnel, local and regional impacts due to the operation of and potential continuous travel through motorway tunnels and surface roads.	Health related air quality impacts are discussed in **Section 13.5.1** and **Section 13.5.2**.
Air Quality	
2. The Proponent must ensure the AQIA also includes the following: d. an assessment of impacts (including human health impacts) from potential emissions of PM_{10}, $PM_{2.5}$, CO, NO_2 and other nitrogen oxides and volatile organic compounds (eg BTEX) including consideration of short and long term exposure periods;	Health related air quality impacts are discussed in **Section 13.5.1** and **Section 13.5.2**.

Secretary's requirement	Where addressed in EIS
Water – Quality	
1. The Proponent must: c. identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Potential pollutants of concern are identified in **Chapter 17** (Hydrodynamics and water quality) and **Appendix O** (Technical working paper: Surface water quality and hydrology). An assessment of the potential for construction to introduce pollutants into receiving waterways and discharge quantities and locations are provided in **Chapter 17** (Hydrodynamics and water quality). Practical management measures to be adopted for the project are provided in **Chapter 17** (Hydrodynamics and water quality). Management measures to ensure the protection of human health are outlined in **Section 13.6.**
h. demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Potential pollutants of concern are identified in **Chapter 17** (Hydrodynamics and water quality) and **Appendix O** (Technical working paper: Surface water quality and hydrology). An assessment of the potential for construction to introduce pollutants into receiving waterways and discharge quantities and locations are provided in **Chapter 17** (Hydrodynamics and water quality). Practical management measures to be adopted for the project are provided in **Chapter 17** (Hydrodynamics and water quality). Management measures to ensure the protection of human health are outlined in **Section 13.6.**
Soils	
3. The Proponent must assess whether the land and harbour sediment is likely to be contaminated and identify if remediation is required, having regard to the ecological and human health risks posed by the contamination in the context of past, existing and future land uses.	**Section 13.4** discusses human health risks and impacts due to potential contaminated soil/groundwater exposure. Further details are presented in **Appendix I** (Technical working paper: Health impact assessment). **Section 16.4**, **Chapter 16** (Geology, soils and groundwater) considers areas of potential and known land and harbour sediment contamination, having regard to risks to human and environmental receivers. Further details are presented in **Appendix M** (Technical working paper: Contamination).

13.1 Legislative and policy framework

The human health impact assessment was carried out in accordance with national and international guidance that is endorsed or accepted by Australian health and environmental authorities and is described below.

13.1.1 Principal guidance

Principle guidance used for the assessment of human health impacts included the following:

- *Health Impact Assessment: A Practical Guide* (Harris et al., 2007)
- *Health Impact Assessment Guidelines*, Environmental Health Committee (enHealth, 2001)
- *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards: 2012* (enHealth, 2012)
- *Schedule B8 Guideline on Community Engagement and Risk Communication, National Environment Protection (Assessment of Site Contamination Contamination) Measure* (National Environment Protection Council (NEPC), 2013).

13.1.2 Supporting guidance

Supporting guidance for the health implications of air quality impacts included the following:

- *National Environmental Protection (Air Toxics) Measure, Impact Statement for the National Environment Protection (Air Toxics) Measure,* National Environment Protection Council (NEPC), 2003a
- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment),* United States Environmental Protection Agency (USEPA), 2009
- *Building Better Health, Health considerations for urban development and renewal in the Sydney Local Health District*, NSW Health, 2016
- *Healthy Urban Development Checklist, A guide for health services when commenting on development policies, plans and proposals*, NSW Health, 2009
- *Methodology for Valuing the Health Impacts of Changes in Particle Emissions*, NSW Environment Protection Authority (EPA), 2013a
- *Air Quality in and Around Traffic Tunnels*, National Health and Medical Research Council (NHMRC, 2008a)
- State Environmental Planning Policy No. 33 – Hazardous and Offensive Development
- Assessing the environmental burden of disease at national and local levels, Ostro, 2004 (World Health Organisation).

13.2 Assessment methodology

The methodology for the human health impact assessment is aimed at assessing impacts and risks to human health from the construction and operation of the project. The human health assessment has focused on health related impacts associated with key air quality, noise and vibration and social aspects.

13.2.1 Air quality

The assessment methodology for health impacts related to air quality involved:

- Review of Appendix F (Technical working paper: Traffic and transport) and Appendix H (Technical working paper: Air quality (including the in-tunnel ventilation report which is Annexure K to Appendix H)
- Identification of sensitive receivers within potentially impacted communities surrounding the project, and assessment of the current health metrics for those communities
- Assessment of potential human health impacts from key pollutants during construction and operation of the project.

When evaluating human health risks with respect to air quality, the quantification of risk involves the calculation of an increased probability of some adverse health effect, disease or mortality occurring, over and above the baseline incidence of that health effect, disease or mortality in the community. A one in a million chance of developing a certain health effect due to exposure to a substance is considered negligible. The risk scale used for the assessment of incremental air quality exposure is as follows:

- Negligible health related risks – less than one chance in a million
- Tolerable or acceptable health related risks – between one chance in a million and one chance in ten thousand
- Unacceptable health related risks – more than one chance in ten thousand.

Further details of the assessment guidelines adopted is provided in the relevant sections below.

13.2.2 Noise and vibration

The assessment methodology for health impacts related to noise and vibration involved:

- Review of technical assessments including Appendix F (Technical working paper: Traffic and transport) and Appendix G (Technical working paper: Noise and vibration)
- Identification of sensitive receivers within potentially impacted communities surrounding the project, and assessment of the current health metrics for those communities
- Assessment of potential human health impacts associated with the generation of noise during construction and operation of the project.

For the following noise guidelines, the noise assessment criteria adopted relate to levels of noise that can be tolerated or permitted above background before some adverse effect (annoyance, discomfort, sleep disturbance or complaints) occurs:

- *Interim Construction Noise Guideline* (Department of Environment and Climate Change (DECC), 2009a),
- *NSW Road Noise Policy* (Department of Environment, Climate Change and Water (DECCW), 2011)
- *NSW Noise Policy for Industry* (NSW Environment Protection Agency (EPA), 2017a)
- *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016a)
- *Noise Criteria Guideline* (Roads and Maritime Services, 2015f).

As annoyance would usually occur before physiological and other health-based impacts, annoyance-based criteria are considered to be conservative from a human health impact perspective. Some of the other criteria are based on specific health impacts such as sleep disturbance for the assessment of night-time noise.

13.2.3 Social

The assessment methodology for health impacts related to social aspects involved:

- Review of all available information relevant to the assessment including:
  - Appendix U (Technical working paper: Socio-economic assessment)
  - Data from the Australian Bureau of Statistics
  - Information relevant to local government areas and health districts (in particular Sydney Local Health District and Northern Sydney Local Health District)
- Identification of sensitive receivers within potentially impacted communities surrounding the project, and assessment of the current health metrics for those communities
- Assessment of potential human health impacts associated with public safety, traffic changes, property acquisitions, impacts on open space, changes in community access and connectivity, visual amenity, construction fatigue, economic access and stress and anxiety issues during construction and operation of the project, including short-term and long-term impacts.

13.3 Existing environment

This section outlines the existing environment as it relates to human health including:

- Potentially impacted receivers within the communities surrounding the project
- The current health status of these communities.

The existing environment for air quality, noise and vibration and social aspects are detailed in the following chapters:

- Chapter 12 (Air quality)
- Chapter 10 (Construction noise and vibration)
- Chapter 11 (Operational noise and vibration)
- Chapter 21 (Socio-economics).

13.3.1 Health status of the community

The health of the community is influenced by a complex range of interacting factors including age, socio-economic status, social networks, behaviours, beliefs and lifestyle, life experiences, country of origin, genetic predisposition and access to health and social care.

Information in relation to health related behaviours (that are linked to poorer health status and chronic disease including cardiovascular and respiratory diseases, cancer, and other conditions that account for much of the burden of morbidity and mortality in later life) is available for the larger populations within the local area health services in Sydney and NSW. This includes excessive alcohol consumption, smoking, inadequate consumption of fruit and vegetables, being overweight or obese, and inadequate physical activity.

The study population is largely located within the Northern Sydney, Sydney and South Eastern Sydney Area Health Services. Review of this data generally indicates that, when compared to NSW as a whole, the population in the Northern, Sydney and South Eastern Sydney Area Health Service areas (that include the study area) have the following characteristics:

- Lower rates of physical inactivity and of being overweight and obese
- Lower rates of smoking (Northern Sydney Local Health District)
- Lower rates of mortality, except for lung cancer, which was lower in the Northern Sydney Health District only

- Lower rates of hospitalisations, except for cardiovascular disease hospitalisations in the South Eastern Sydney District, which are similar to the rates for NSW
- High or very high rates of psychological distress reported in 2015 in the Sydney Local Health District (13.9 per cent) where rates are slightly higher than the state average. In Northern Sydney (10 per cent) and South Eastern Sydney local health districts (9.3 per cent) rates are slightly lower than the state average (11.8 per cent), however none were substantially different
- High or very high rates of psychological distress in Northern Sydney Local Health District has varied between eight and 15 per cent while in the Sydney Local Health District it has varied between 10 and 15 per cent between 2003 and 2015. In the South Eastern Sydney Local Health District, the rate has declined from around 14 per cent in 2003 to less than 10 per cent in 2015.

Section 3.5 of Appendix I (Technical working paper: Health impact assessment) provides further detail on health related behaviours and health indicators for the study area.

13.3.2 Potentially impacted communities

The potentially impacted communities considered in the assessment include those who live or work within the vicinity of the proposed temporary construction support sites, surface connections (ie where the tunnels would interface with the surface road network), motorway facilities, ventilation facilities and the road network associated with the combined Western Harbour Tunnel and Beaches Link program of works as well the adjoining WestConnex M4-M5 Link. The human health impact assessment study area is an amalgamation of the air quality, noise and vibration, and social and economic study areas.

The human health impact assessment considers community receivers identified in the suburbs close to the project. Community receivers are locations in the local community where more sensitive members of the population, such as infants and young children, the elderly or those with existing health conditions or illnesses, may spend a significant period of time. Community receiver locations include hospitals, child care facilities, schools and aged care homes/facilities. Details of the sensitive or community receivers included in the assessment are provided in Chapter 12 (Air quality) and Appendix H (Technical working paper: Air quality).

13.4 Assessment of potential construction impacts

Potential impacts on human health during construction have been assessed below in relation to:

- Air quality
- Noise and vibration
- Social impacts.

The following sections provide a high-level overview of the key considerations in these areas, with further detail provided in referenced environmental impact assessment chapters and appendices.

13.4.1 Health related air quality impacts during construction

Air quality impacts and details of the distribution of impacts in the construction period are presented in Chapter 12 (Air quality).

The assessment of construction air quality was carried out using a qualitative assessment approach for dust, emissions and odour impacts.

The construction air quality assessment found that for almost all construction activities, substantial impacts on receivers would be avoided through project design and the implementation of effective, industry standard mitigation and management measures. However, dust management measures may not be fully effective all the time. In situations where the construction air quality management measures are not fully effective, impacts on the community would generally be temporary and short-term and are not considered to be significant.

Measures to manage dust impacts include site management, preparing and maintaining temporary construction support sites and disturbance areas, use of water carts, maintenance and controls on vehicles and machinery, waste management and modifying of site activities during atmospheric conditions conducive to dust generation and emission. The effectiveness of dust control measures would be monitored and adjusted as required to ensure impacts on the health of the community are minimised.

Air quality impacts during construction also include exhaust emissions from the use of plant and equipment. These impacts would be minor and unlikely to have a noticeable impact on the surrounding environment and would be managed through standard management measures.

As part of the marine construction activities for the project, a large amount of material would be dredged from the harbour bed, bringing potentially odorous material to the surface, which has the potential to generate odour once exposed to air. However, odours from dredged material from Middle Harbour are unlikely to be detectable at any sensitive receptor.

For tunnelling works proposed at Flat Rock Reserve, there is a risk of encountering odorous waste material and landfill gases from historical waste landfilling activities in the locality. Detailed investigations have not been carried out to confirm the presence and extent of potentially odorous materials and landfill gases within the project site at this location. The investigation that was carried out, however, did not identify putrescible waste and landfill gases in the vicinity of the locations that would be excavated as part the project. This indicates that the risk of encountering odorous materials and landfill gases is low. Further investigations are proposed prior to commencement of excavations to confirm the potential for odour issues based on the detailed construction methodology and identify appropriate mitigation and management measures (if required) to reduce the potential for odour impacts at sensitive receivers in the vicinity. Further landfill gas investigations should be carried out within these areas to assess the potential presence or absence of gas which could potentially impact upon construction and/or operation of the project if not managed appropriately.

Overall, potential air quality impacts during construction are unlikely to result in any health related impacts.

13.4.2 Health related noise and vibration impacts during construction

Potential noise and vibration impacts during construction are presented in Chapter 10 (Construction noise and vibration). Noise impacts in relation to human health have been considered in relation to sleep disturbance, annoyance, hearing impairment, interference with speech and other daily activities, children’s cognitive function, and cardiovascular health.

Noise that may be generated during construction has been modelled based on the type of equipment to be used, the proximity of community receivers, the hours of work, the duration of the activities carried out and the local terrain. Worst case predicted construction noise levels would occur at any one receiver only infrequently, if at all. Typical construction noise levels would be significantly lower than worst case predictions.

This assessment has considered ground-borne noise from tunnelling and rock-hammering, construction vibration generated from tunnelling, surface works, piling and heavy equipment, and underwater noise impacts associated with the construction of the tunnel in Middle Harbour.

This modelling has identified areas where, if unmitigated, potential noise levels may exceed:

- Day, evening or night noise management levels
- Sleep disturbance criteria, including the criteria for awakening.

Results from this modelling, and associated assessments including distribution of potential impacts, are provided in Appendix G (Technical working paper: Noise and vibration) and discussed in Chapter 10 (Construction noise and vibration).

The measures to manage and mitigate potential health impacts associated with noise and vibration during construction include:

- Location and activity specific assessments to confirm ground-borne noise potential impacts
- Proactive engagement with the community including water users for underwater noise
- Noise and vibration monitoring including during piling activities
- Respite periods.

The following sections describe potential impacts related to noise and vibration criteria, possible human health impacts and proposed environmental management measures.

Construction noise impacts from the movement of construction vehicles

Potential increases in noise for sensitive receivers due to construction traffic have been assessed separately from the assessment of noise from other construction activities. Temporary construction support sites have been configured such that heavy vehicles involved in construction are expected to travel via existing major roadways with minimal use of local roads. Use of the temporary construction support sites is unlikely to increase road traffic noise levels by more than 2 dB(A). This change represents a minor impact that is likely to be barely perceptible.

Ground-borne construction noise

Ground-borne noise occurs when vibration is transmitted through the ground and into building structures, where it then produces an audible noise. The project would involve tunnelling using vibration intensive equipment such as roadheaders and rock hammers that have the potential to generate ground-borne noise. Many of the more significant activities with the potential to generate ground-borne noise would take place at depth (with a large proportion of the mainline and ramp tunnels at depths of 10 metres to greater than 50 metres).

Modelling carried out for potential ground-borne noise impacts contemplated the worst case scenario when the tunnelling is occurring immediately beneath a sensitive receiver. The roadheader excavation would typically progress at around 20 to 30 metres per week subject to local geology and confirmation of the tunnel excavation methods. Roadheader advance rates would reduce to two to five metres a day around the tunnel portals, which may slightly increase the duration of exposure for receivers in these areas. Ground-borne noise would typically increase as the roadheader nears a receiver and decrease as the roadheader moves way. It is noted that receivers might also experience ground-borne noise on multiple occasions, associated with excavation of different (adjacent) tunnel tubes and other subsurface elements such as ventilation shafts, cross-passages and niches for motorway operational equipment.

Ground-borne noise from excavation by the roadheaders may be noticeable in some areas during the evening and during the night for one to two weeks at each affected receiver as the roadheader passes below them. Ground-borne noise from roadheader activity is predicted to exceed the night time noise criteria at about 107 residential receiver buildings. Worst case impacts are likely to occur in locations where the tunnel would be relatively shallow, such as in the immediate vicinity of tunnel on ramps and off ramps or tunnel access declines at Cammeray, Northbridge, Balgowlah, Seaforth and Killarney Heights.

Following the excavation by roadheaders, rock hammers would then be required for sub-surface activities that include tunnel floor (bench) excavation, utility and stormwater trench excavation and excavation of niches for tunnel operational equipment. When rock hammers are in use within the tunnel, there is potential for intermittent audible ground-borne noise within buildings at the surface. The potential ground-borne levels would be influenced by the separation distance between the building and work location, the underlying geology and the structure of building. Where rock hammering has the potential to exceed the relevant criteria for ground-borne noise, it would be scheduled during standard construction hours where feasible and reasonable, reducing the potential for associated amenity impacts during the more sensitive evening and night time period. If rock hammering is required outside standard daytime construction hours, ground-borne noise levels could exceed the night time criteria for up to 638 residential receiver buildings and could exceed the evening criteria for 419 residential receiver buildings, depending on the location of works. It is noted that there are locations in Cammeray, Naremburn, Northbridge Artarmon and Seaforth where it is predicted that rock hammers could be used outside standard construction hours without exceeding the evening and night time ground-borne noise criteria.

Measures to manage and mitigate potential impacts associated with ground-borne noise include location and activity specific assessments to confirm potential impacts, scheduling, and community notification and engagement to confirm that actual ground-borne noise levels and impacts are not worse than predicted.

Airborne construction noise

Chapter 10 (Construction noise and vibration) identifies residential receiver buildings that are predicted to experience noise levels above the noise management levels, in the absence of additional environmental management measures. In some instances, maximum noise levels are also predicted to exceed the sleep disturbance screening level and awakening reaction levels at several receivers.

Where criteria cannot be met there is the potential for annoyance and adverse health effects, such as sleep disturbance, for the receivers in the vicinity of construction sites, particularly where noise increases of greater than 5 dB(A) over extended periods (over a year or more).

Exceedances of the noise management levels and the number of impacted residential receiver buildings would vary over the duration of construction. For example, the predicted worst case airborne noise levels are only likely to occur when works are at the closest point to each receiver building. However, for many work areas, construction activities are mobile and so construction noise levels might routinely be lower than predicted, reducing the potential for annoyance and health impacts. Further, the mitigation and management measures identified in Chapter 10 (Construction noise and vibration) would be implemented to minimise potential health related impacts on the surrounding community. This includes noise management approaches for works that would occur outside of standard construction hours.

Where the recommended noise management levels cannot be achieved, reasonable and feasible mitigation measures would be implemented to reduce potential impacts. Monitoring would also be carried out periodically throughout all stages of construction to ensure that noise and vibration impacts are being appropriately managed, and the effectiveness of implemented mitigation and management measures. Refer to Chapter 10 (Construction noise and vibration) for environmental management measures.

Construction vibration

Some items of equipment to be used during construction have the potential to cause unacceptable levels of vibration. Managing the potential for such vibration to cause discomfort or structural damage at sensitive receiver locations is based on selecting site-specific suitable plant and methods as well as observing suitable separation distances between the equipment and receiver locations for highly vibration-intensive activities.

Vibration monitoring would be carried out to confirm that the adopted controls are effective and respite periods would be offered to affected residents where human comfort levels are to be exceeded for an extended period during any one day.

Underwater noise impacts

Piling and dredging in Middle Harbour would generate underwater noise. Noise can propagate for long distances underwater.

Piling would be required in Middle Harbour to install immersed tube tunnel unit supporting piles and for the construction of cofferdams adjacent to each shore line. Piling would predominately consist of vibratory piling (in harbour sediments), however impact piling would be required to ensure that piles are adequately bedded into the underlying bedrock. Piling has the potential to generate significant underwater noise levels. Impact piling has the potential to generate significantly higher underwater noise levels than vibratory piling and other proposed underwater construction activities.

Dredging also generates underwater noise levels. The potential for dredging to generate significant noise levels is less than for piling.

Underwater sound pressure levels would likely exceed the precautionary guideline of 145 dB re 1μPa in the vicinity of the proposed piling and dredging locations Middle Harbour (Jasco, 2019). The locations in the vicinity of the piling activities that could experience underwater noise levels in excess of this guideline value would vary depending on the type of equipment and operation being carried out and the bathymetry in the vicinity of the activity location. The precautionary guideline value could exceeded at distances of around two kilometres for impact pile driving. The piling program would be refined during detailed construction planning with the consideration of reasonable and feasible alternatives to reduce potential underwater noise levels. It is, however, unlikely there is a feasible alternative construction methodology that does not involve some impact piling.

For divers, a sudden increase in sound pressure levels could startle, or cause discomfort, dizziness and vertigo. Excessive underwater noise can lead to life-threatening situations.

CNV14 (refer to Section 10.7) commits that impact piling in any given week will be carried out over durations of no more than either two hours each work day or six hours on a single work day, to provide respite to noise affected receivers in the vicinity. This would also limit the frequency of potential underwater noise impacts.

The areas affected by elevated underwater noise levels due to project activities would be managed during construction to minimise the risk of potential amenity and health impacts divers and swimmers. This would include monitoring during the early stages of impact piling activities at each location to measure underwater noise levels and compare against acoustic thresholds to confirm the affected areas and appropriate management measures, and a proactive communication strategy to inform water users and other potential stakeholders of the potential impacts and risks. Management measures would be informed by the final construction methodologies and mitigation measures, and management areas. Environmental management measure HH1 would be reviewed and, if required, amended over the course of the piling program to reflect monitoring outcomes.

13.4.3 Health related social impacts during construction

Social impacts in the construction period are presented in Chapter 21 (Socio-economics).

Health related social impacts are discussed below in terms of:

- Changes in traffic, public transport, access and connectivity
- Public safety and contamination
- Property acquisition
- Open space
- Visual amenity
- Construction fatigue
- Economic aspects.

Measures to manage and mitigate potential health related impacts during construction include:

- Use of communication and traffic control management measures to limit delays and disruptions to road users and for the safety of motorists, cyclists and pedestrians
- Use of silt curtains and a backhoe dredge with a closed bucket attachment to minimise the risk of sediment and contaminants within the sediments being mobilised into the water during dredging
- Management of property acquisition impacts through a property acquisition support service and in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW) and the land acquisition reforms announced by the NSW Government in 2016.

- Design of the project to optimise opportunities for the repurposing of remaining project land at Balgowlah to provide new open space and recreation facilities for the community. The residual land would progressively become available through the construction period for use by the community
- Consideration of construction fatigue as when developing the detailed project design and construction methodology to mitigate these impacts where possible.

The following sections describe the potential impacts, possible human health impacts and proposed environmental management measures.

Changes in traffic, public transport, access and connectivity

Changes in traffic, access and connectivity during construction are presented in Chapter 8 (Construction traffic and transport). During construction, potential short-term impacts may include:

- Temporary changes to road conditions, which could include partial and full road closures, diversions and access changes, removal of some on-street parking and reductions in speed limits, changes to property accesses
- Temporary increased construction traffic on roads leading to longer travel times and potentially impacting on community perceptions of safety for motorists, cyclists and pedestrians if not appropriately managed
- Temporary disruptions to public transport services, and changes to road conditions and the temporary relocation of some bus stops near construction works for safety, resulting in possible delays and disruptions for bus users and changes in bus access for some people
- Temporary changes to pedestrian and cycle access near to construction works, resulting in possible disruptions which may result in delays and disruptions to commuters
- Temporary changes to property access near construction works, with suitable access arrangements to be implemented
- Temporary relocation of moorings in the vicinity of works in Middle Harbour, with relocated moorings to be placed as close as possible to their original locations during construction and restored where possible to the original position on completion of construction
- Temporary adjustments to bus priority infrastructure on Burnt Bridge Creek Deviation in Balgowlah would also be required, resulting in a minor increase in bus travel times
- Temporary changes and diversions to pedestrian and cyclist networks have the potential to affect commuter departure times, travel durations, movement patterns and accessibility.

Changes to traffic, access and connectivity during construction have the potential to result in short-term increased levels of stress and anxiety in the local community. Traffic impacts would be managed through standard communication and traffic control management measures, which would limit delays and disruptions to road users as well as ensuring the safety of motorists, cyclists and pedestrians, in consultation with the relevant road authorities.

Public safety and contamination

A range of potential hazards were considered that have the potential to affect public safety during construction of the project. There would be no issues related to construction that have the potential to result in significant safety risks to the community.

Known and potentially contaminated sites, and potential contamination impacts are discussed in Chapter 16 (Geology, Soils and Groundwater). Contamination risk issues to the community would be associated with construction phase of the project, when exposure to contaminated soil, sediment or groundwater would most likely occur during the excavation and construction works. If contamination is identified in construction, measures including the development of appropriate Remediation Action Plans would be put in place so the health of the local community is not impacted.

Sediment sampling was carried out within the proposed locations of Middle Harbour crossing and temporary construction support sites (Douglas Partners and Golder Associates, 2017, Appendix M (Technical working paper: Contamination)). Where sediments require excavation and removal to facilitate construction, the use of silt curtains and a backhoe dredge with a closed bucket attachment would minimise the risk of sediment and contaminants within the sediments being mobilised into the water during dredging. This control in conjunction with the behaviour of sediment bound contaminants means it is unlikely that water quality would be significantly impacted by contaminants mobilised from dredging and marine construction activities (Appendix Q (Technical working paper: Marine water quality).Provided the proposed management measures are adopted, it is expected there would be negligible impacts to human health associated with recreational exposures in areas surrounding the proposed works.

Property acquisition

Property acquisition impacts are presented in Chapter 20 (Land use and property).

The project has been designed to minimise the need for property acquisitions. Wherever possible, temporary construction support sites have been located to minimise the overall property acquisition requirements, as well as impacts on heritage items and ecologically sensitive areas.

The acquisition and relocation of households and businesses due to property acquisition could disrupt social networks and affect health and wellbeing due to raised levels of stress and anxiety. Both a house and a workplace are central to daily routines and the location of these premises influences how a person may travel to/from work or study, the social infrastructure and businesses they visit and the people they interact with.

Impacts associated with property acquisition would be managed through a property acquisition support service and in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW) and the land acquisition reforms announced by the NSW Government in 2016.

Loss of open space

Open space (also referred to as green space) within urban areas includes green corridors (paths, rivers and canals), grassland, parks and gardens, outdoor sporting facilities, playing fields and children play areas. Epidemiological studies have been carried out that show a positive relationship between open space and health and wellbeing (de Vries et al. 2003, Health Scotland et al. 2008, Kendal et al. 2016, Maas et al. 2006, Mitchell & Popham 2007). The health benefits of open space in urban areas include the following:

- Protection of people from environmental exposures associated with air pollution and extreme temperature (by regulating microclimates and reducing the urban heat island effect)
- Reduced morbidity
- Improved opportunities for physical activity and exercise
- Improved mental health and feelings of wellbeing, particularly lower stress levels
- Improved opportunities for social interactions.

There are several existing sporting/recreation facilities and parks in the project area that would be impacted by the project including sporting fields, parks and reserves and playgrounds. Impacts on these open spaces include:

- Temporary and permanent loss of a portion of land, including recreation land at Artarmon Park and Cammeray Golf Course, noting that works have been designed to ensure that the golf course can continue to function as a nine hole golf course, subject to some reconfiguration during the construction phase that would temporarily affect golf activities
- Permanently acquiring or temporarily leasing parts of the Balgowlah Golf Course, with construction resulting in the permanent closure of the golf course. However, the project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities

- Temporary use of parks and open space areas for temporary construction support sites (for example parts of Artarmon Park adjacent to Gore Hill Freeway, Flat Rock Reserve and the Spit West Reserve) resulting in the temporary loss of access to and use of land within the construction footprint
- Reduced amenity due to construction activities and temporary construction support sites and changes in noise, dust and visual environment, detracting from the use and enjoyment for users of social infrastructure near the project.

The loss of open space associated with construction of the project would be short term, except for permanent land loss at Balgowlah Golf Course. Other golf courses are accessible in the area and hence, while some additional travel may be required, recreational golf activities are not expected to be substantially affected overall. Alternative open space is located in the area and can be easily accessed by the community, and so the potential effects on community health associated with the temporary use of parks and open space areas during construction would be minimal. The reduced amenity may affect the desirability of active recreational use of some areas. Other recreation areas are available and accessible in the community, hence the potential impact on community health is considered to be minimal. The project has been designed to optimise opportunities for the repurposing of remaining project land at Balgowlah. Residual land, primarily to the east and north of the new access road, would progressively become available through the construction period, which would facilitate re-purposing it to the new and improved open space and recreation facilities. This would allow it to be handed over progressively for use by the community. The new open space and recreation facilities to the west of the proposed access road, between the access road and Burnt Bridge Creek Deviation, would be constructed and handed over to Northern Beaches Council after completion of the project.

Visual amenity

Landscape and visual impacts are presented in Chapter 22 (Urban design and visual amenity).

Visual amenity can be described as the pleasantness of the view or outlook of an identified receiver or group of receivers (eg residences, recreational users). Visual amenity is an important part of an area’s identity and offers a wide variety of benefits to the community in terms of quality of life, wellbeing and economic activity.

During construction, visual amenity throughout the project area has the potential to be affected by factors such as the removal of established vegetation, the installation of construction hoardings and noise barriers and/or the visual appearance of temporary construction support sites. In some areas, the acoustic sheds, hoardings and noise barriers required to manage noise impacts during construction are large and may cause overshadowing. Further factors affecting visual amenity may include the temporary change of view corridors to heritage, open space, water bodies or the city skyline.

For some individuals, changes in visual amenity can increase levels of stress and anxiety. These impacts, however, are typically of short duration as most people adapt to changes in the visual landscape, particularly within an already urbanised area. As a result, most changes in visual impacts are not expected to have a significant impact on the health of the community. Design development has been influenced by urban design principles that have been established for the project, including integrating the project elements and infrastructure into the surrounding environment.

Construction fatigue

Construction fatigue relates to receivers that experience construction impacts from a variety of projects over an extended period with few or no breaks between construction periods. Construction fatigue typically relates to traffic and access disruptions, noise and vibration, air quality, visual amenity and social impacts from projects that have overlapping construction phases or are back to back.

The assessment of construction fatigue in this report includes the following projects that may immediately precede or overlap with the construction phase of the project:

- Western Harbour Tunnel and Warringah Freeway Upgrade (North Sydney, Cammeray and Artarmon)
- Sydney Metro City & Southwest (Chatswood to Sydenham).

As outlined in Chapter 27 (Cumulative impacts), the potential cumulative impacts during construction of the project based on likely interactions with other projects may occur around North Sydney and Cammeray, Artarmon, and Naremburn and Willoughby. Cumulative impacts could be generated by interactions between the project and the Western Harbour Tunnel and Warringah Freeway Upgrade at North Sydney, Cammeray and Artarmon and the Sydney Metro City & Southwest (Chatswood to Sydenham) at Artarmon. Potential impacts considered most likely to result in construction fatigue include construction traffic and parking, construction noise and vibration, visual and amenity impacts, and impacts to community perceptions of public health and safety. There is also potential for residential receivers around Naremburn and Willoughby to experience construction fatigue as a result of the project and its proximity to Western Harbour Tunnel and Warringah Freeway Upgrade construction sites. Construction fatigue at this location is likely to be limited to temporary increases in construction noise and are expected to be minor.

The project design and construction methodology has been developed with consideration of these impacts and attempts to mitigate many of these where possible. The community consultation framework presented in Chapter 7 (Stakeholder and community engagement) and Appendix E (Community consultation framework) has also been developed with consideration of complaint fatigue and includes procedures to proactively manage this issue where feasible and reasonable. Potential cumulative construction impacts would be managed in accordance with the measures outlined in Chapter 27 (Cumulative impacts).

Economic aspects

The construction expenditure of the project would be of significant benefit to the economy. This expenditure would inject economic stimulus benefits into the local, regional and state economies. Ongoing or improved economic vitality is of significant health benefit to the community. Employment opportunities would grow in the region through the potential increase in business customers and through the increase in demand for construction workers. The increase in demand for labour may increase wages in the region, particularly for construction workers, who would be in high demand.

It is noted that both positive and negative effects may occur for some businesses during construction activities. While construction activities may bring greater demand from construction workers, lack of access to businesses through reduced parking and physical barriers could impact on local economies. Specific consultation would be carried out with businesses potentially impacted during construction. Consultation would aim to identify specific potential construction impacts for individual businesses. Based on consultation with businesses potentially impacted, feasible and reasonable measures would be identified and implemented to minimise business impacts.

13.5 Assessment of potential operational impacts

Impacts on human health during operation have been assessed below in relation to:

- Air quality impacts outside the tunnels
- Air quality impacts inside the tunnels
- Noise and vibration impacts
- Social impacts.

Some of the key findings of the assessments, as discussed below, indicate:

- There would be no significant changes in the incidence of health impacts associated with exposure to NO_2 in the community as a result of the project

- Concentrations of total particulate matter ($PM_{2.5}$ and PM_{10}) within the local community would essentially remain unchanged in most cases with the operation of the project. The potential incident of health impacts associated with exposure to particulate matter is anticipated to remain unchanged as a result of the project
- No health impacts due to exposures to CO are anticipated in the local area surrounding the project as a result of the project
- No significant health impacts are anticipated within the tunnel due to exposures to vehicle emissions under any plausible traffic and tunnel operational scenarios
- For most receivers assessed, the project would result in either reduced or relatively minor changes in traffic noise levels. In areas where there is a reduction in traffic noise there would be associated health benefits in these communities
- Where traffic noise levels are predicted to increase, additional mitigation measures would be implemented to reduce potential amenity and associated health impacts
- Public safety is anticipated to improve as a result of improvements to road safety with reduced traffic volumes along key road transport corridors
- New or upgraded pedestrian and cyclist infrastructure is anticipated to encourage increased active transport, with associated improvements in community health and wellbeing
- Most changes in visual impacts are not expected to have a significant impact on the health of the community.

13.5.1 Health related ambient air quality impacts during operation

Air quality impacts and details of the distribution of impacts outside of the tunnel during operation, are presented in Chapter 12 (Air quality). The tunnel ventilation system and tunnel operational parameters for the project have been designed to ensure the in-tunnel air quality concentration limits are not exceeded under any plausible tunnel operation scenarios, including major breakdowns, and to control the concentration of pollutants discharged to the external environment.

The assessment of impacts on air quality associated with the operation of the project considered a range of expected traffic scenarios that includes the operation of the project in 2027 and 2037 ('Do something'), both with and without the project and including other projects ('Do something cumulative'). For further details of the scenarios considered, refer to Chapter 12 (Air quality).

This assessment included a calculation of the emissions from vehicles using the tunnel and surface roads in the vicinity under expected traffic conditions (ie operating normally with traffic volumes fluctuating over the day to reflect peak and out of peak periods).

In addition, a regulatory worst case scenario has been evaluated. The regulatory worst case assumes the emissions from the ventilation outlets are at the maximum levels permitted by regulatory criteria at all hours of the day. While not a realistic scenario, it is used to demonstrate that contributions from the ventilation outlets to air quality at ground level under even the most extreme of conditions would still be negligible. Further detail is available in Section 5.10 of Appendix I (Technical working paper: Health impact assessment).

Health related air quality impacts outside of the tunnel have been assessed for nitrogen dioxide, particulate matter, carbon monoxide and air toxics. Health related air quality impacts associated with particulate matter on elevated receivers have also been assessed.

Nitrogen dioxide

Motor vehicles, along with industrial, commercial and residential (for example gas heating or cooking) combustion sources, are primary producers of nitrogen oxides, including nitrogen dioxide (NO_2). In Sydney, it was estimated that on-road vehicles account for about 55 per cent of emissions of nitrogen oxides, industrial facilities account for 13 per cent, other mobile sources account for about 27 per cent with the remainder from domestic/commercial sources (NSW EPA, 2019).

NO_2 is the only oxide of nitrogen that may be of concern to health (World Health Organisation (WHO), 2000). NO_2 can cause inflammation of the respiratory system and increase susceptibility to respiratory infection. The health effects associated with exposure to NO_2 depend on the duration of exposure as well as the concentration.

Guidelines are available from the NSW Environment Protection Authority and National Environment Protection Council (NEPC) (NEPC, 2003b) that indicate acceptable concentrations of NO_2. The assessment of acute exposures relates to the maximum predicted total one-hour average concentration in air and considers the 'Do minimum', 'Do something' and 'Do something cumulative' scenarios. An acute exposure guideline of 246 micrograms per cubic metre of NO_2 in air over a one-hour average period has been adopted for the project. The assessment of chronic exposures relates to the maximum predicted annual average concentration in air, and considers the 'Do minimum', 'Do something' and 'Do something cumulative' scenarios. A chronic exposure guideline of 62 micrograms per cubic metre of NO_2 in air, averaged over a year, has been adopted for the project. An uncertainty factor of two was applied to both the acute and chronic exposure guidelines to account for susceptible people (ie asthmatic children). On this basis, the acute and chronic exposure guidelines are protective of adverse health effects in all individuals, including sensitive individuals like asthmatics, children and the elderly.

Potential health effects associated with NO_2 consider both comparison with guidelines for cumulative exposure (acute and chronic) and an assessment of incremental impacts on health (associated with changes in air quality from the project).

Assessment of acute exposures

As there is no clear community threshold established for acute exposures to NO_2, the assessment of incremental exposures is of most relevance to potential human health impacts and is discussed further below.

Assessment of chronic exposures

The National Environment Protection Council ambient air quality guideline for the assessment of chronic (long-term) exposures to NO_2 relates to the maximum predicted total (cumulative) annual average concentration in air (NEPC, 2003b).

The assessment completed for the project indicates that all concentrations of NO_2 would be below the chronic guideline by more than 15 micrograms per cubic metre for all scenarios. Therefore, no adverse health impacts would be expected as a result of chronic exposures to NO_2 from the project.

Assessment of incremental exposures

The assessment indicates that the individual risks (ie of mortality (respiratory and all causes) and asthma admissions) calculated for changes in NO_2 levels associated with the project would be less than one in ten thousand for residential areas, commercial/industrial areas, childcare centres, schools, aged care homes and open space areas and all community receivers and would therefore be considered tolerable and acceptable.

Review of the calculated impacts in terms of the change in incidence of the relevant health impacts associated with exposure to NO_2 in the whole community, associated with the 'Do something' and 'Do something cumulative' scenarios, indicates the following:

- The total change in the number of cases relevant to the health impacts evaluated, for both 2027 and 2037 ('Do something' and 'Do something cumulative') is negative, meaning a decrease in incidence as a result of the project (due to the redistribution of traffic on surface roads). The change, however, is small, with a decrease of approximately one case, this change would not be measurable within the community
- Review of the incidence calculated for the individual suburbs indicates that these predominantly relate to small decreases in health incidence with some suburbs showing an increase. Overall, there are no individual suburbs within the Local Government Areas (LGAs) where there is a change in incidence that is of significance or would be measurable.

Overall, there would be no significant changes in the incidence of health impacts associated with exposure to NO_2 in the community as a result of the project.

Particulate matter

Particulate matter is a widespread air pollutant with a mixture of physical and chemical characteristics that vary by location, source and substance. Particulates can be derived from natural sources such as soil dust, pollen and moulds, and other sources that include combustion and industrial processes.

Particulate matter has been linked to adverse health effects after both short-term and long-term exposure. The health effects associated with exposure to particulate matter vary widely (with the respiratory and cardiovascular systems most affected) and include mortality and morbidity effects. The potential for particulate matter to result in adverse health effects is dependent on the size and composition of the particulate matter.

The particle sizes addressed in the human health risk assessment relate to the particulates most commonly measured in the urban air environment studies, including:

- PM_{10} (particulate matter below 10 micrometres in diameter)
- $PM_{2.5}$ (particulate matter below 2.5 micrometres in diameter).

The current National Environment Protection Council and NSW Environment Protection Authority air quality goals and guidelines/standards for particulate matter are presented in Chapter 12 (Air quality).

The assessment of potential health impacts associated with particulate matter generated by vehicles using the tunnel considered both total exposure impacts and incremental exposure impacts associated with changes in $PM_{2.5}$ and PM_{10} concentrations as a result of the project.

The assessment of total exposures involves the assessment of total concentrations of particulate matter in the air from all sources including the project and considers background air quality data for the project.

To assess potential risks to human health that may be associated with localised changes (or redistribution) in exposures to $PM_{2.5}$ and PM_{10} that relate to the project, an assessment of incremental impacts was carried out.

Consideration of opportunity costs associated with particulate matter impacts is provided in Section 5.12 of Appendix I (Health Impact Assessment).

Assessment of total exposures

Due in large part to the existing levels of $PM_{2.5}$ in the air within the urban environment, the maximum total concentrations of $PM_{2.5}$ are above the guidelines for both the 24-hour average and the annual average (including the 2025 goal set by NEPC (2016) with or without the operation of the project. These elevated background levels would be present in the community regardless of the construction and operation of the project. Concentrations of total $PM_{2.5}$, however, would be essentially unchanged or slightly lower in most cases within the study area with the operation of the project only (‘Do something’) and in conjunction with other road tunnel projects by 2037 (‘Do something cumulative’).

Similarly, the maximum total concentrations of PM_{10} would exceed the 24-hour average guidelines. The maximum total concentrations of PM_{10} would also exceed the annual average guideline in most cases with or without the operation of the project but would be below the guideline in the cumulative scenario (‘Do something cumulative’). The elevated levels of total PM_{10} is due to the existing levels of PM_{10} in the air within the existing urban environment. These elevated background levels would be present in the community regardless of the operation of the project. Concentrations of total PM_{10}, however, are essentially unchanged in most cases within the local community with the operation of the project in 2027 and 2037.

Assessment of incremental exposures

The calculated changes in risk (associated with individual mortality, cardiovascular illness, respiratory or asthma hospitalisations, and lung cancer) associated with the expected operation of the project in 2027 and 2037 ('Do something'), including the cumulative scenarios ('Do something cumulative') indicates the maximum risks associated with the changes to $PM_{2.5}$ and PM_{10} concentrations would be less than or equal to one in ten thousand, for exposures in residential, commercial and industrial areas, childcare centres, schools, aged care homes and open space areas. This is considered to be tolerable or acceptable.

A review of the calculated impacts in terms of the change in incidence of the relevant health impacts for $PM_{2.5}$ in the community (being the change in the number of cases per year of mortality, hospital or emergency department admissions), indicates the following:

- The total change in the number of cases (totals for each local government area considered) relevant to the health impacts evaluated for the project in 2027 ('Do something') are mostly negative, meaning an overall decrease in incidence as a result of the project. The number of cases, however is small, with a decrease of approximately one case. This change would not be measurable within the community
- Within these local government areas there are several smaller suburbs. The incidence calculated for the individual suburbs indicates that these predominantly relate to small decreases in health incidence, with some suburbs showing an increase. The largest increase in health incidence for any individual suburb would be less than one case per year. Therefore, there would be no individual suburbs within the LGAs assessed for which the increased health incidence would be of significance or measurable.

Assessment of elevated receivers

The air quality impact assessment (Appendix H (Technical working paper: Air quality)) carried out a screening assessment of potential issues related to exposures that may occur at elevated receivers to model concentrations of $PM_{2.5}$ at 10 metres, 20 metres, 30 metres and 45 metres above ground level in the 'Do something cumulative 2037' scenario. These heights were chosen as a representative of potential exposures that may occur in multi-storey buildings. The assessment has evaluated the impacts at these heights across the study area, regardless of whether a multi-storey building is present or not, as well as receivers that do currently exist at these heights. For existing receivers, more than 90 per cent of the receiver buildings assessed have a height of less than 10 metres, with less than 0.5 per cent having a height of 40 metres or more.

The calculated health risks associated with changes in annual $PM_{2.5}$ concentrations for elevated receivers at 10, 20 and 30 metre heights would range from negligible to acceptable and are not in areas where elevated receptors are currently present.

Further assessment (see Annexure H of Appendix I (Technical working paper: Health impact assessment)) was carried out relating to exposure to NO_2 and volatile organic compounds within in 300 metres of the ventilation outlets for the project, at the Warringah Freeway, the Gore Hill Freeway, the Burnt Bridge Creek Deviation and Wakehurst Parkway. Based on the assessment carried out, the following was identified:

- The assessment of potential health risks for elevated receptors is dominated by the assessment of individual risks relevant to changes in NO_2 and $PM_{2.5}$
- No unacceptable risks have been identified considering existing and expected traffic emissions
- For the regulatory worst case emissions, unacceptable risks have been identified for elevated receptors in the 300 metres adjacent to ventilation outlets at the Warringah Freeway, the Gore Hill Freeway and the Wakehurst Parkway for elevated receptors that may be present at 45 metres height.

The implications of this assessment on surrounding land use is discussed in considered in Chapter 20 (Land use and property). Land use considerations would be required to manage any interaction between the project and future development for buildings with habitable structures above 20 metres within 300 metres of the ventilation outlet.

Carbon monoxide

Motor vehicles are the dominant source of carbon monoxide (CO) in the air (NSW Department of Environment, Climate Change and Water (DECCW, 2010a)). Adverse health effects of exposure to CO are linked with carboxyhaemoglobin (COHb) in blood. In addition, association between exposure to CO and cardiovascular hospital admissions and mortality, especially in the elderly for cardiac failure, myocardial infarction and ischemic heart disease and some birth outcomes (such as low birth weights), have been identified (NEPC, 2010).

The assessment completed for this project indicates that all concentrations would be below the relevant health-based guidelines presented in the *National Environment Protection (Ambient Air Quality) Measure* (NEPC, 2003b), which is consistent with international guidelines currently prescribed by the WHO (2005) and USEPA (2011). Therefore, no acute or chronic health impacts are expected as a result of the project for all scenarios in relation to exposures to CO in the local area surrounding the project.

Volatile organic compounds and polycyclic aromatic hydrocarbons

Air toxics assessed for the project include volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) and are associated with emissions from vehicles using the mainline tunnels and adjacent surface road network. From a toxicity perspective, the key VOCs from vehicle emissions that have been considered are benzene, toluene, ethylbenzene, and xylenes (BTEX), 1,3-butadiene, acetaldehyde and formaldehyde (consistent with those identified and targeted in studies conducted in Australia on vehicle emissions (NSW EPA, 2019).

The assessment of acute and chronic exposures of air toxics involves calculating a hazard index for each pollutant, which is the ratio of the maximum predicted concentration of the pollutant to their respective guidelines. Each individual hazard index is added up to obtain a total hazard index for all the air toxics considered. The total hazard index is a sum of the potential hazards associated with all the air toxics together assuming the health effects are additive, and is evaluated as follows (enHealth, 2012):

- A total Hazard Index less than or equal to one means all the maximum predicted concentrations are below the health based guidelines and there are no additive health impacts of concern
- A total Hazard Index greater than one means the predicted concentrations (for at least one individual compound) are above the health based guidelines, or there are at least a few individual air toxics where the maximum predicted concentrations are close to the health based guidelines such that there is the potential for the presence of all these together (as a sum) to result in adverse health effects.

Assessment of acute exposure

The assessment indicates the total Hazard Index predicted for acute exposures to VOCs would be less than one for the ‘Do something’ and ‘Do something cumulative’ scenarios for 2027 and 2037. Based on this, there would be no acute risk issues predicted in the local community as a result of the project.

Assessment of chronic exposure and incremental lifetime carcinogenic risk

For the assessment of chronic exposures to VOCs and PAHs, the total Hazard Index associated with exposure to the predicted maximum concentrations would be less than one for the ‘Do something’ and ‘Do something cumulative’ scenarios for 2027 and 2037. The calculated lifetime cancer risks associated with the maximum change in benzene, 1,3-butadiene and carcinogenic PAHs (as benzo(a)pyrene TEQ) are less than or equal to four in one hundred thousand and are considered to be tolerable. The approach adopted is expected to overestimate concentrations of PAHs in air. Hence the calculations presented are a conservative upper limit estimate. Based on this, there would be no chronic health risk issues predicted in the local community as a result of the project.

13.5.2 Health related in-tunnel air quality impacts during operation

Air quality in-tunnel impacts in the operational period are presented in Chapter 12 (Air Quality). The tunnel ventilation system would be designed and operated so that the operational in-tunnel air quality limits would not be exceeded. The ventilation report is provided as Annexure K to Appendix H (Technical working paper: Air quality).

Health related in-tunnel air quality impacts in operation have been assessed for nitrogen dioxide, particulate matter, carbon monoxide and carbon dioxide. This includes cumulative exposures for users of the project and connected tunnel network, or frequent users of the tunnel network.

Nitrogen dioxide

A study of nitrogen dioxide (NO_2) concentrations inside vehicles travelling in Sydney and using existing road tunnels was commissioned by Roads and Maritime Services (now Transport for NSW) in 2016 (Pacific Environment Limited (PEL), 2016) to better understand the relationship between NO_2 outside the vehicle, and inside the vehicle. Within existing tunnels investigated in the study, trip average concentrations of NO_2 were generally less than 0.15 parts per million (ppm) (PEL, 2016). During periods of high traffic volumes and a high proportion of heavy vehicles, the trip average concentrations inside the M5 East tunnels have been recorded in excess of the 0.5 ppm criterion, with levels up to 0.7 ppm. The average concentrations inside the vehicles when ventilation was on recirculation, however, were less than 0.2 ppm. The most recent tunnels in Sydney are designed to ensure that trip average concentrations of NO_2 do not exceed the 0.5 ppm criterion.

The project's ventilation systems have been designed to achieve the in-tunnel air quality criteria for NO_2 of 0.5 ppm (tunnel average as a rolling 15-minute average) for all traffic scenarios, including the worst case variable speed and breakdown scenarios. Recent reviews of health effects of exposure to NO_2 supports the NO_2 criteria for up to 60 minutes of exposure (NSW Health, 2018).

The average concentration in the tunnels considered in the 'Do something cumulative' scenario in 2037 would vary throughout the day, with the average concentration through the entire tunnel (trip average) would be expected to be (at most) around 0.25 ppm, which is less than the in-tunnel limit of 0.5 ppm. Lower average concentrations may occur within vehicles with windows up and ventilation on recirculation. A summary of the health effects of short-term exposures to NO_2 is provided in Section 6.3 of Appendix I (Technical working paper: Health impact assessment). As discussed in Appendix I, no significant health impacts are expected as a result of the project from exposures to NO_2 within vehicles using the tunnels, as the trip average concentrations would be below 0.5 ppm.

Individuals using motorbikes would not have the opportunity to reduce exposure inside the tunnel through the use of vehicle ventilation controls. However, the time spent inside tunnels under congested conditions would be less than other users given their ability to lane filter during heavy traffic.

The in-tunnel NO_2 criterion may not be protective of all health effects for all individuals. For severe asthmatic individuals travelling by motorcycle or within vehicles where advice to keep windows up and ventilation on recirculation is not adopted, there is the potential for these individuals to experience some minor change in respiratory response after using the tunnels following prolonged exposure (refer to Section 6.3 of the Appendix I (Health impact assessment)).

For individuals involved in occupations that may require more regular use of the road network, such as point to point transport and courier drivers, there is the potential for these individuals to make more frequent and varied trips over different travel segments in any one day. For these drivers, it is important that they keep their windows up and vehicle ventilation on recirculation to minimise exposures throughout the day.

Particulate matter

Potential concentrations of particulate matter inside the tunnel are derived from exhaust as well as non-exhaust sources. Non-exhaust sources include tyre and brake wear and dust from surface road wear and the resuspension of road dust. The modelling of particulate matter and visibility issues within the tunnel has considered both sources.

There are no health-based guidelines available for the assessment of short-duration exposures to particulate matter within a tunnel. In-tunnel criteria relate to visibility (and safety in using the tunnels). It is expected the concentration of particulate matter within the tunnels would be higher than ambient air concentrations, and the concentration of particulate matter would increase with increasing distance travelled through the tunnels.

Exposures that may occur within the tunnels would be consistent with expected variability of exposure to particulate matter throughout any day where a range of activities are carried out in an urban setting. Keeping windows closed and switching ventilation to recirculation has been shown to reduce exposures inside the vehicle by up to 80 per cent (NSW Health, 2003). While noting no guidelines are available for very short duration exposures, this would further reduce exposure to motorists.

In congested conditions inside the tunnels, it is not considered likely that significant adverse health impacts would occur.

Carbon monoxide

The operational in-tunnel limits for CO have been adopted based on the conditions of approval for other Sydney road projects. The assessment indicates there would be no health issues of concern related to in-tunnel exposures to CO. Furthermore, closing vehicle windows and switching the ventilation to recirculation can reduce exposures by about 70 to 75 per cent for CO.

Carbon dioxide

A study was carried out on behalf of Transport for NSW (enRiskS, 2017) to determine carbon dioxide (CO_2) levels for passengers in vehicles travelling through tunnels (ie to represent the likely conditions for the project). This study found that for passengers in vehicles travelling through tunnels for a period of up to an hour, levels of CO_2 would not be expected to adversely affect driver safety. However, for periods of exposure up to two hours where ventilation is left on recirculation, levels of CO_2 inside a vehicle where there are one or more passengers may affect an already fatigued driver.

The assessment indicates that where Transport for NSW provides specific advice to drivers entering road tunnels to put vehicle ventilation on recirculation, further advice may need to be provided that recirculation should be switched off at some point after using the tunnel network and not left on for an extended period of time. However, this situation would be considered rare as travel time in the tunnels is unlikely to be for such extended periods.

Overall, no significant health impacts related to exposure to CO_2 would be expected in the operation of the project.

13.5.3 Health related noise and vibration impacts during operation

Noise and vibration impacts in the operational period are presented in Chapter 11 (Operational noise and vibration). Sound is a natural phenomenon that only becomes noise when it has some undesirable effect on people or animals. Noise and vibration can potentially have both short-term and long-term adverse effects on people. These health effects include:

- Sleep disturbance (sleep fragmentation that can affect psychomotor performance, memory consolidation, creativity, risk-taking behaviour and risk of accidents)
- Annoyance
- Hearing impairment

- Interference with speech and other daily activities
- Children's school performance (through effects on memory and concentration)
- Cardiovascular health.

Other potential effects which may occur, but for which the evidence is weaker, include:

- Effects on mental health (usually in the form of exacerbation of existing issues for vulnerable populations rather than direct effects)
- Tinnitus (which manifests as a ringing in the ears when no physical noise is present, can also result in sleep disturbance, anxiety, depression, communication and listening problems, frustration, irritability, inability to work, reduced efficiency and a restricted participation in social life)
- Cognitive impairment in children (including deficits in long term memory and reading comprehension)
- Some evidence of indirect effects such as impacts on the immune system.

Annoyance can be a major consideration because it reflects the community's dislike of noise and their concerns about the full range of potential negative effects from a project. It also affects the greatest number of people in the population.

The assessment of potential health impacts relating to noise has focused on whether the guidelines/criteria that have been established can be met. The NSW noise policies and guidelines against which this project is assessed are designed to protect the most sensitive receivers from annoyance and sleep disturbance. Where the guidelines cannot be met there is the potential to interfere with communication, disturb sleep and cause annoyance. Further, communities subjected to long-term exposure of acute noise levels may experience impairment of cardiovascular health and reduced cognitive performance in children.

The noise modelling for the project has been carried out to address impacts associated with the operation of the project in 2027 and 2037 ('Do something'), including a cumulative scenario ('Do something cumulative'). The modelling has evaluated noise impacts at the façade of all buildings, including on all floors of multi-storey buildings. An assessment was carried out to determine how well the model estimated noise impacts based on a current scenario. The modelled and measured results were found to be within acceptable tolerances, which are ± 2 dB(A).

For most receivers assessed, the project would result in either reduced or relatively minor changes in traffic noise levels. In areas where there is a reduction in traffic noise, as a result of the project due to a decrease in traffic volumes on parts of the surface road network, there would be associated health benefits in these communities. However, the assessment also predicts that without mitigation, incremental noise increases greater than 2 dB(A) would be experienced at several properties adjacent to the project during operation, which may result in health impacts if not appropriately mitigated. Additionally, many properties have been identified where cumulative noise levels exceed the relevant guidelines, with and without the project.

Mitigation measures considered to address potential road traffic noise levels during operation would principally involve the use of quieter pavements, noise barriers and at-property treatments. The use of the use of quieter pavements and noise barriers are favoured, as they provide a benefit to external and internal spaces. Even with appropriate mitigation measures in place, however, 616 buildings under the 'Do something cumulative' scenario are still predicted to be eligible for consideration for at-property treatment. It is noted, however, that most receivers predicted to experience exceedances of the operational road traffic noise criteria already experience exceedances (ie the reason for additional mitigation is existing noise levels, rather than predicted increases due to the project). In this regard, installation of at-property treatments would also be addressing existing road traffic noise and amenity issues and the project would have a positive impact on community amenity and health. Further details are presented in Chapter 11 (Operational noise and vibration).

Where there are predicted increases in road traffic noise and the specific individuals impacted do not take up the recommended at-property treatments, there is the potential for adverse health effects including increased levels of noise annoyance and sleep disturbance. While of at-property treatments can reduce impacts within a dwelling, they do not generally reduce noise levels in external areas. The number of properties subject to increases in noise levels which may be of concern to health as a result of the project, however, is very small. If at-property treatments area appropriate and are installed at the properties, the impact on road traffic noise levels within dwelling will be adequately reduced and no significant health impacts are expected.

13.5.4 Health related social impacts during operation

Social impacts in the operation period are presented in Chapter 21 (Socio-economics).

Health related social impacts are discussed below in terms of:

- Changes in traffic, public transport, access and connectivity
- Public safety
- Open space
- Visual amenity
- Economic aspects and
- Road tolling.

Changes in traffic, public transport, access and connectivity

Changes in traffic, access and connectivity during operation are presented in Chapter 9 (Operational traffic and transport).

The project would improve regional access and connectivity for road based public transport, freight and servicing, private vehicles and other road users by providing an alternate crossing of Middle Harbour. The project would improve travel times on the Military Road/Spit Road corridor, Warringah Road and Eastern Valley Way. It would enable better access to jobs and businesses, with direct access to the new Northern Beaches Hospital at Frenchs Forest, and better access to businesses on the Northern Beaches from Greater Sydney. The project would also enhance the resilience of the road network due to reduced demand on other surface roads, including Frenchs Forest Road and the Ourimbah Road, and would enable a major reduction of heavy vehicle traffic on the Warringah Road, Spit Road and Military Road corridor. The substantial additional travel that would be facilitated by the project would also increase localised traffic demands at either ends of the project where it would be integrated with the existing transportation network. At some locations there would be some residual delay at these interface precincts. This includes some increases in localised delays for traffic through French Forest, particularly on Warringah Road and Wakehurst Parkway as a result of changes to traffic patterns caused by the project. In such cases localised delays at these precincts would be offset by the strategic travel time benefits provided by the project at the broader network level.

Traffic congestion and long commuting times can contribute to increased levels of stress and fatigue, more aggressive behaviour and increased traffic and accident risks on residential and local roads as drivers try to avoid congested areas (Hansson et al., 2011). Increased travel times reduce the available time to spend on heathy behaviours such as exercise, or engage in social interactions with family and friends. Long commute times are also associated with sleep disturbance, low self-rated health and absence from work (Hansson et al., 2011). Reducing travel times and road congestion is expected to reduce these health impacts. From a public transport network perspective, the project, once complete, is expected to improve access to public transport and improve journey times for buses for local and regional communities.

Public safety

A range of potential hazards were considered that have the potential to affect public safety during the operation of the project, principally in relation to traffic accidents. It was identified there are no issues related to operation that have the potential to result in significant safety risks to the community.

Improvements to road safety with reduced traffic volumes along key road transport corridors, and new or upgraded pedestrian and cyclist infrastructure would improve pedestrian and cyclist safety. Therefore, there would be a beneficial health impact in terms of public safety.

Open space

The health benefits of greenspace are described in Section 13.4.3. Impacts on greenspace during operation are summarised below.

Cammeray Golf Course

The project would occupy parts of the golf course acquired as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project to accommodate a temporary construction support site and Beaches Link motorway facilities (including an access road) (see Section 13.4.3). This would require the reconfiguration of the golf course to allow its ongoing use, noting that golf activities would likely be temporarily affected during the reconfiguration. The site would initially be established as a temporary construction support site for the Western Harbour Tunnel and Warringah Freeway Upgrade project. Potential impacts to the golf course were assessed as part of the environmental impact statement for Western Harbour Tunnel and Warringah Freeway Upgrade (Transport for NSW, 2020b).

The establishment of the operational facilities would change the visual setting of this location, when viewed from within the golf course and adjoining sporting facilities, and surrounding locations, including the Warringah Freeway and Ernest Street.

Landscaping and other architectural treatments would be provided to reduce the visual impacts of these facilities when viewed from some locations.

Artarmon Park

The project would require the permanent acquisition of a portion of land at Artarmon Park to accommodate road infrastructure associated with the Gore Hill Freeway Connection. This is not expected to impact on the ongoing use or functioning of the park and facilities within the park.

Balgowlah Golf Course

Acquisition and temporary leasing of Balgowlah Golf Course during construction (see Section 13.4.3) would result in the permanent closure of the golf course (and club). This would require members and visitors to access golf courses elsewhere, impacting on social networks associated with the club. It is likely some members would use the closure of the club as a reason to stop playing golf. This is most likely to be long-term members or older golfers, potentially impacting individuals' general levels of physical activity, and overall wellbeing associated with the possible loss of social networks and personal relationships.

However, engagement with Northern Beaches Council has identified potential for the residual land to be returned as new and improved open space and recreation facilities. Use of the residual land for such facilities would align with the Northern Beaches Sportsground Strategy (Northern Beaches Council, 2017a) and address the current under supply of sporting grounds available for public use in the local area.

A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation would be separate to the consultation for the environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting. As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space. The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities.

Spit West Reserve

Land within Spit West Reserve affected by the project during construction would be rehabilitated and reinstated and no operational impacts would be expected.

Flat Rock Reserve

Land affected by the project at Flat Rock Reserve during construction would be rehabilitated and reinstated. The final land use of the temporary construction support site after project completion would be subject to further consultation with Willoughby City Council and the community. No operational impacts would be expected.

Visual amenity

The operational project would include changes to local visual amenity due to the presence of new and amended infrastructure (including motorway facilities, ventilation outlets, water treatment plants, substations, bridges, retaining walls, flood walls, noise walls and drainage channels), landscaping and urban design features.

Changes in visual amenity have the potential to increase levels of stress and anxiety, however, most people adapt to changes in the visual landscape, particularly within an already urbanised area. Where long term visual impacts would be negative, mitigation measures including landscape screening would be utilised where feasible to reduce these impacts. Design development has been influenced by urban design principles that have been established for the project including integrating the project elements and infrastructure into the surrounding environment. A detailed review and finalisation of architectural treatment of the project operational infrastructure would be carried out during further design development.

As a result, most changes in visual impacts are not expected to have a significant impact on the health of the community.

Economic aspects

Economic impacts are presented in Chapter 21 (Socio-economics). The operational impacts on business would be beneficial for employee and customer access, servicing and delivery and demand for services across most business centres. Some business centres would also benefit from improvements in passing trade, character and amenity and business visibility. However, any impact is considered to be moderate to low, given the sensitivity of the centre and the magnitude of change by the project. Further changes are also expected in this area as associated with the development of the Northern Beaches Hospital Precinct Structure Plan.

Freight and commercial vehicle movements are an important component of the economy. Numerous industries are dependent upon efficient transport to service operational requirements. Transport for NSW estimated that freight and logistics contributed $66 billion to NSW State Gross Product (GSP) in 2011, this represented 13.8 per cent of NSW GSP at the time.

The project would encourage heavy and commercial vehicle movements into the tunnel, due to increased efficiencies and reducing freight costs through increased travel speeds and reliability and reduced travel distances.

The transport modelling carried out for the project highlighted that the project would result in substantial potential benefits for freight and commercial vehicle movements. Improvements in the efficiency and reliability of these transport networks would likely result in increased productivity, reduced costs and broader economic benefits for these workforces. Ongoing or improved economic vitality is of significant health benefit to the community. Employment opportunities would grow in the region through the potential increase in business customers and improved regional connectivity as a result of the project.

Road tolling

The implementation of road tolls can have direct impacts on the management of congestion, which has an impact on economic productivity, and social elements such as stress, time with family and friends, cost and environmental amenity such as reduced traffic emissions.

One impact is the potential to increase congestion volumes on surrounding roads as a result of toll avoidance. The use of a toll road can also increase the cost of living and can exacerbate social inequality. Specifically, the impact of roads tolls on households can be assessed as a function of household income, urban spatial structure, and available mobility choices. Depending on the travel routes of individuals, and the individual economic situation, there would be a proportion of the population that avoid the use of tollways due to affordability. In July 2018, the NSW Government implemented a toll relief initiative to ease the cost of living for frequent NSW toll road users through the provision of free vehicle registration. This was expanded in July 2019 to also provide half-priced vehicle registration for eligible road users.

13.6 Environmental management measures

Key environmental management measures specific to human health impacts are provided in Table 13-2. In addition, environmental management measures relating to human health impacts are also provided in other chapters within this environmental impact statement, particularly:

- Transport and travel management measures – Chapter 8 (Construction traffic and transport and Chapter 9 (Operational traffic and transport)
- Air quality management measures – Chapter 12 (Air quality)
- Noise and vibration management measures – Chapter 10 (Construction noise and vibration) and Chapter 11 (Operational noise and vibration)
- Contamination management measures – Chapter 16 (Geology, soils and groundwater)
- Property acquisition and relocation services – Chapter 20 (Land use and property)
- Social impact management measures – Chapter 21 (Socio-economics)
- Visual amenity measures – Chapter 22 (Urban design and visual amenity)
- Cumulative impact measures – Chapter 27 (Cumulative impacts).

Table 13-2 Environmental management measures – human health

Ref	Phase	Impact	Environmental management measure	Location
HH1	Construction	Underwater noise impacts	Monitoring during the early stages of impact piling activities at each location will be carried out to measure underwater noise levels and compare against acoustic thresholds to confirm the extent of areas that need to be managed with respect to underwater noise, and to confirm appropriate management measures (as required). Appropriate management measures will be implemented during impact piling. The monitoring results, management areas and proposed management measures will be peer-reviewed to ensure they adequately address potential health impacts. Monitoring will be carried out following implementation of management measures (as required) to confirm they are appropriate and to	BL (Middle Harbour)

Ref	Phase	Impact	Environmental management measure	Location
			identify any additional management measures required.	
HH2	Construction	Underwater noise impacts	Communication and management measures will be implemented during construction to manage potential underwater noise impacts to water-based recreational users during dredging and piling activities in Middle Harbour. The communication tools and management measures that would be contemplated within the management zone include: a) Coordination of piling programs with the planned activities of key recreational stakeholders to minimise interaction with planned or peak activity periods of these stakeholders, where feasible and reasonable b) Communication of the piling program and management area so recreational users know when the piling, dredging and other noise generating activities will be taking place, what they can expect, and the zones to minimise the possibility of being startled from a sudden increase in sound pressure underwater c) Direct communication with key local recreational stakeholders during the piling and dredging program to provide up-to-date scheduling d) Use of advertisements, signage, letter box drops and project updates to communicate the implementation of a management area during the works. This could include floating markers or signage on approach to the construction work e) Surveillance within the areas in which precautionary guideline level is exceeded to proactively monitor users in the prior to and during relevant activities that could pose a risk to recreational users.	BL (Middle Harbour)

Note: BL = Beaches Link

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Beaches Link and Gore Hill Freeway Connection

Chapter 14

Non-Aboriginal heritage

14 Non-Aboriginal heritage

This chapter describes the potential non-Aboriginal heritage impacts associated with the project and identifies measures which address these impacts. Detailed non-Aboriginal heritage assessments have been carried out for the project and are included in Appendix J (Technical working paper: Non-Aboriginal heritage) and Appendix K (Technical working paper: Maritime heritage).

The Secretary's environmental assessment requirements as they relate to non-Aboriginal heritage, and where in the environmental impact statement these have been addressed, are detailed in Table 14-1 (Secretary's environmental assessment requirements checklist).

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures.

The proposed environmental management measures relevant to non-Aboriginal heritage are included in Section 14.5.

Table 14-1 Secretary's environmental assessment requirements – Non-Aboriginal heritage

Secretary's requirement	Where addressed in EIS
1. The Proponent must identify and assess any direct and/or indirect impacts (including cumulative, vibration and visual impacts) to the heritage significance of listed (and nominated) heritage items inclusive of: c. environmental heritage, as defined under the *Heritage Act 1977* (including potential items of heritage value, conservation areas, open space heritage landscapes, build heritage landscapes and archaeology); d. items listed on the State, National and World Heritage lists; e. heritage items and conservation areas identified in local regional planning environmental instruments covering the project area; and f. marine items of potential heritage significance within Middle Harbour, such as any shipwrecks.	A summary of listed heritage items within the study area is presented in **Section 14.3**. Consideration of direct and/or indirect impacts (including potential item of heritage value, conservation areas, open space heritage landscapes, built heritage landscapes and archaeology) to the heritage significance of listed (and nominated) heritage items are presented in **Section 14.4.2**. Further details are provided in **Appendix J** (Technical working paper: Non-Aboriginal heritage). **Section 14.4.3** includes assessment of maritime items of potential heritage significance within Middle Harbour. Further details are provided in **Appendix K** (Technical working paper: Maritime heritage).
2. Where impacts to State or locally significant heritage items or archaeology are identified, the assessment must: a. Include a significance assessment and statement of heritage impact for all heritage items (including any unlisted places that are assessed of heritage value); b. Provide a discussion of alternative locations and design options that have	Significance assessment and statements of heritage impact are presented in **Section 14.4**, and **Section 4** of **Appendix J** (Technical working paper: Non-Aboriginal heritage). A discussion of alternative locations and design options are outlined in **Section 14.4.1,** and **Section 5.1**, **Section 5.2** and **Section 5.4** of **Appendix J** (Technical working paper: Non-Aboriginal heritage) and **Section 4.4** and

Secretary's requirement	Where addressed in EIS
been considered to reduce heritage impacts; c. in areas identified as having potential archaeological significance, undertake a comprehensive archaeological assessment and management plan in line with Heritage Council guidelines which includes a methodology and research design to assess the impact of the works on the potential archaeological resource and to guide physical archaeological test excavations and include the results of these excavations. This is to be carried out by a suitably qualified archaeologist and is to discuss the likelihood of significant historical, maritime and Aboriginal archaeology on the site, how this may be impacted by the project, and includes measures to mitigate any impacts; d. consider impacts to the item of significance caused by, but not limited to, vibration, demolition, archaeological disturbance, altered historical arrangements and access, increased traffic, visual amenity, landscape and vistas, curtilage, subsidence and architectural noise treatment (as relevant); e. provide a comparative analysis to inform the rarity and representative value of any heritage places proposed for demolition; f. outline mitigation measures to avoid and minimise identified impacts in accordance with the current guidelines; and g. be undertaken by a suitably qualified heritage consultant(s) (note: where archaeological excavations are proposed the relevant consultant must meet the NSW Heritage Council's Excavation Director criteria).	**Section 4.5** of **Chapter 4** (Project development and alternatives). Mitigation measures are presented in **Section 14.5** which includes consideration of areas identified as having potential archaeological significance. Discussion of impacts as a result of vibration, demolition, archaeological disturbance, altered historical arrangements and access, increased traffic, visual amenity, landscape and vistas, curtilage, subsidence and architectural noise treatment (as relevant) are provided in **Section 14.4** and **Section 5.2** to **Section 5.4** of **Appendix J** (Technical working paper: Non-Aboriginal heritage). A comparative analysis is not required for the reasons stated in **Appendix J** (Technical working paper: Non-Aboriginal heritage). This is summarised in **Section 14.4.2**. Environmental management measures are presented in **Section 14.5**. **Section 14.2** and **Section 1.4** of **Appendix J** (Technical working paper: Non-Aboriginal heritage) provides details of qualification held by heritage consultants.

14.1 Legislative and policy framework

The *Heritage Act 1977* (the Heritage Act) is the primary piece of State legislation affording protection to all items of environmental heritage (natural and cultural) in NSW. Under the Heritage Act, "items of environmental heritage" include places, buildings, works, relics, moveable objects and precincts identified as having heritage significance based on historical, scientific, cultural, social, archaeological, architectural, natural or aesthetic values. Items of identified heritage at a level of State significance are listed on the NSW State Heritage Register and are afforded automatic protection against any activities that may damage an item or affect its heritage significance under the Heritage Act.

The Heritage Act also provides protection for ‘relics’, which includes archaeological material or deposits. Sections 139 to 145 of the Heritage Act prevent the excavation or disturbance of land known or likely to contain relics, unless under an excavation permit. However, the project is subject to Division 5.2 (State significant infrastructure) provisions of the *Environmental Planning and Assessment Act 1979*, and therefore excavation or exception permits would not be required.

For the purposes of the Heritage Act, the State of NSW also includes the bed of the harbour and the water column up to three nautical miles from the coast. Shipwrecks currently under the jurisdiction of the Heritage Act are identified in the Historic Shipwrecks Register, maintained by the NSW Heritage Council. Part 3C of the Heritage Act also contains specific provisions for the protection of shipwrecks more than 75 years old. This section is included in the Act to provide a link to and consistency with the *Historic Shipwrecks Act 1976* (Commonwealth).

The *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Commonwealth) applies to those items which are of World, Commonwealth or National heritage significance. Significant impact to World or National heritage items constitute a matter of national environmental significance and require a referral to the Minister for Environment and Energy.

The *Environmental Planning and Assessment Act 1979* establishes the framework for cultural heritage values to be formally assessed in the land use planning and development consent process. The *Environmental Planning and Assessment Act 1979* requires that environmental impacts are considered before land development; this includes impacts on cultural heritage items and places as well as archaeological sites and deposits.

The requirement to consider potential impacts on Non-Aboriginal heritage is given effect through the following guidelines:

- United Nations Educational, Scientific and Cultural Organisation Convention on the Protection of the Underwater Cultural Heritage (UNESCO, 2001)
- Australia International Council on Monuments and Sites *Charter for Places of Cultural Significance (Burra Charter)* (Australia ICOMOS, 2013)
- *NSW Heritage Manual* (NSW Heritage Office and Department of Urban Affairs and Planning, 1996) including the following sections:
    - *Investigating History* – used in carrying out research into historical context and history of individual heritage items
    - *Investigating Fabric* – used in surveying and recording individual heritage items
- *Assessing Heritage Significance* (NSW Heritage Office, 2001) – updated section of 1996 *NSW Heritage Manual* used to review existing significance assessment and carry out significance assessment for new heritage items
- *Investigating Heritage Significance* (draft guideline) (NSW Heritage Office, 2004) – updated section of *NSW Heritage Manual* used to carry out significance assessment for new heritage items
- *Statements of Heritage Impact* (NSW Heritage Office, 2002) – used in preparation of Statements of Heritage Impact
- *Guidelines for the Management of Australia’s Shipwrecks* (Australian Institute for Maritime Archaeology Inc. and the Australian Cultural Development Office, 1994)
- *Criteria for the Assessment of Excavation Directors* (NSW Heritage Council, 2011)
- *Cultural Heritage Guidelines* (Roads and Maritime Services, 2015a).

14.2 Assessment methodology

Impacts on heritage are defined as either:

- Direct impacts, resulting in a planned and intentional physical change to a heritage item from project activities within the heritage item boundary
- Potential direct impacts, resulting from incidental physical impacts occurring as a result of activities adjacent to or within the heritage item boundary
- Indirect impacts, resulting in changes to the heritage item or its surroundings from project activities outside of the heritage boundary, such as vibration, settlement, visual impacts, social impacts, impacts to landscapes and vistas, changes to ongoing use, changed associations, or change to access.

The level of impact on the heritage significance of each heritage item in the study area has been assessed as major, moderate, minor or negligible based on the definitions and framework for assessing severity of impacts from the *EPBC Act Significant Impact Guidelines 1.2* (Department of Sustainability Environment Water Population and Communities, 2013). Where the heritage significance of an item is unknown, such as for potential maritime heritage items identified during field surveys and investigations, items have been assigned a heritage sensitivity level which combines heritage potential of the item with its potential significance.

A Statement of Heritage Impact has been prepared for each State or locally significant terrestrial heritage item impacted by the project in accordance with the *Statements of Heritage Impact guidelines* (NSW Heritage Office, 2002). Where relevant, the impact assessment has incorporated Commonwealth heritage guidelines including *Matters of National Environmental Significance Significant Impact Guidelines 1.1* (Commonwealth of Australia Department of the Environment, 2013).

For the purpose of the heritage assessments, all areas within 50 metres of the project construction footprint have been considered (the study area). The maritime heritage assessment is limited to the immersed tube tunnel alignment between Northbridge and Seaforth, the area around the Middle Harbour south and Middle Harbour north cofferdams (BL7 and BL8), the area around the Spit West Reserve construction support site (BL9) and the temporary mooring facility east of Clive Park in Middle Harbour (refer to Chapter 6 (Construction work)).

The terrestrial and maritime heritage assessments have been informed by searches of NSW and Commonwealth heritage registers and supplemented by a literature review of previous assessments and heritage studies. Heritage items and areas of archaeological potential not already identified on registers are also identified as part of the assessment. Field surveys were carried out in May, June, September and December 2017, August 2018, and March 2020 by qualified heritage specialists to inspect items of known heritage value and areas of potential heritage value.

Further detail on the assessment methodology is provided in Appendix J (Technical working paper: Non-Aboriginal heritage) and Appendix K (Technical working paper: Maritime heritage).

14.3 Existing environment

14.3.1 Historical context of the project area

North Sydney to Cammeray

At the time of European arrival, the North Shore area of Sydney was inhabited by the *Cammeraygal* (also known as *Gamaraigal* and *Kameragal*) with groups camped at Milsons Point, Manly and Lane Cove (Morris, 1986). The first record of contact with Aboriginal people in this area was on the Lane Cove River in 1788 and later in Middle Harbour.

Between the 1790s and 1831, thousands of hectares of land were granted to politicians, merchants, ex-convicts, and settlers (North Sydney Council, n.d.-a). The Township of St Leonards (now North Sydney) was gazetted in 1838, and its town centre was established in the same year. By the mid-1880s, the township had a commercial and civic centre, a tramline, and a ferry wharf at Milsons Point, which boosted development. A tramline extension was added along Falcon Street from North Sydney to Crows Nest in 1893, which was replaced by an electric tramline in 1898, attracting a larger population to the area (Godden Mackay, 1994).

The opening of the Sydney Harbour Bridge in 1932 transformed the township into a large commercial area and a popular shopping destination, and saw a marked increase in land values (City of Sydney, 2016a; Warne, 2005). By the 1960s, many townhouses and apartments were built in an effort to house the population. During the 1970s and 1980s, commercial growth accompanied residential development, and the 1990s and 2000s saw a substantial increase in population (City of Sydney, 2016a).

The Cammeray area was slow to develop due to its steep topography and remote location, with little growth in the area until the early 1900s when the tramline was extended along Miller Street (North Sydney Council, 2012a; 2012b; n.d.-b). In 1886, the mayor of St Leonards dedicated a portion of land as a reserve, comprising present-day Cammeray Park, Cammeray Golf Course, Green Park, and ANZAC Park (North Sydney Council, 2016).

Cammeray and Artarmon to Northbridge

The first land grant in Artarmon was made in 1810, with new settlers establishing farms, market gardens, and orchards in the area during the 1850s. Brick making began in the area in 1828 and laid the foundation for the 1950s establishment of the Artarmon Industrial Area (City of Sydney, 2016b; Fallowfield, 2008).

The Municipality of North Willoughby was formally proclaimed in October 1865 and by the 1880s, several tanneries and brickworks had been established in the area (LandArc Pty Limited, 2002; Willoughby District Historical Society Inc, 2011a). Land near Naremburn was one of the first areas settled from 1853, followed by land on the Northbridge Peninsula in the vicinity of Sailors Bay Road in 1855 and 1856 (Willoughby District Historical Society Inc, 2011c).

In the late 19th century and early 20th century, subdivision and development took off first around Artarmon, predominantly driven by the opening of the North Shore Railway (City of Sydney, 2016b; Willoughby District Historical Society Inc, 2011b). Development around Naremburn, Northbridge and Willoughby during the 1920s was driven by the prospective opening of the Sydney Harbour Bridge (Willoughby District Historical Society Inc, 2011c; Willoughby Leisure, n.d.).

More intensive development in the area occurred from the 1960s, and in response, the Willoughby Council initiated the West Artarmon Residential Area Redevelopment Plan to open the way for 0medium and high density buildings, including high-rise residential towers and public housing developments (City of Sydney, 2016b; Willoughby District Historical Society Inc, 2011b). The opening of the Gore Hill Freeway in 1992 separated Artarmon's industrial area in the south from its residential area in the north (Willoughby City Library Services, 2013).

Middle Harbour

The first recorded European visitation of Middle Harbour occurred soon after the arrival of the First Fleet, however settlement in the surrounding area was slow to develop as it was not attractive for agricultural activities (Godden Mackay, 1991).

The waterway gradually became a thoroughfare and crossing point for people travelling between Sydney and settlements in the Manly area in the 19th century, and for the transportation of goods such as timber logs and harvested oysters (Technical working paper: Maritime heritage (2020); Godden Mackay, 1991). The first ferry service across Middle Harbour from The Spit to Clontarf was established in 1849 and was taken over by the Government in the late 1880s (Sturrock, 1982). The first Spit Bridge was constructed in 1924 and was later replaced with the present bridge in 1958 as development on the northern side of Middle Harbour increased.

Modest commercial maritime activities in Middle Harbour developed through the second half of the 19th century but slowly declined as rail and road networks diverted trade away from small jetties and landings along the foreshore. At this time, the upper areas of Middle Harbour around Bantry Bay were largely undeveloped and were used by the Government as an explosives storage area. From the early 20th century until the mid-1970s, explosives were regularly towed in lighters or barges to and from a storage facility at Bantry Bay to a specially dedicated wharf at The Spit (Godden Mackay, 1991).

In the early 20th century, Middle Harbour became popular for recreational purposes, with a corresponding increase in the presence of recreational boats, timber jetties, slips, boatsheds and swimming enclosures (Godden Mackay, 1991).

Seaforth to Balgowlah and Frenchs Forest

Initial land grants were made in the 1810s and were typically used for farming. Settlements had been developed around Manly Cove and North Harbour by the 1820s (City of Sydney, 2016c; Manly and Northern Beaches, 2017). Balgowlah was used for the village of North Harbour as early as 1828, although the population remained minimal until the 1880s (City of Sydney, 2016d; 2016e; MacRitchie, 2008). The first Manly Wharf was built in 1856 with a regular ferry service from 1859. Rapid growth took place in the 1880s, and the area became a popular seaside resort (City of Sydney, 2016d).

Settlement in the Frenchs Forest area first began in the 1850s, driven by major timber and milling operations around Bantry Bay (City of Sydney, 2016f; City of Sydney, 2017; City of Sydney, 2016g). Traces of the 1856 bullock track used to haul logs from the sawmills to the wharf are still extant today along a bushwalking track within the Garigal National Park between Bantry Bay and the Wakehurst Parkway (NSW National Parks and Wildlife Service, 2017).

Land within the Warringah area remained rural until the 1880s when some growth occurred and Warringah Council established in 1906 (Warringah Council, 1998). Growth in this area primarily consisted of subdivision for weekenders and holiday homes for tourism and recreational purposes, which was further driven by the early 1900s extension of the tramline and the construction of the Spit and Roseville bridges in 1924 (City of Sydney, 2016h).

There was population expansion in the 1920s after the opening of the Spit Bridge, and the Balgowlah Golf Course was formed in 1925 (Jobling IF, 1996; Manly Library, n.d). Significant development did not occur in the area until the post-war years of the 1950s, when the remaining dairy farms disappeared as the area urbanised (MacRitchie, 2008).

Many apartments and units were constructed in the 1960s and 1970s, and industrial development centred around Frenchs Forest (City of Sydney, 2016g; 2016h). New buildings were established during the mid-1990s, attracting a larger population, (City of Sydney, 2016i).

14.3.2 Heritage items and conservation areas

Listed terrestrial heritage items and conservation areas

Seventy-three items with heritage listings were identified within the study area. This includes four items listed on the State Heritage Register (North Sydney Sewer Vent and St Leonards Park at North Sydney, Tarella (house) at Cammeray, and the Walter Burley Griffin Incinerator at Willoughby), with the remainder being of local heritage significance. There are no heritage items listed on the World Heritage List, National Heritage List or Commonwealth Heritage List in or adjacent to the study area. Heritage items listed within the study area are shown in Figure 14-1 to Figure 14-3. Further detail on heritage items and heritage listings of each item are provided in Appendix J (Technical working paper: Non-Aboriginal heritage).

Additional potential terrestrial heritage items

Four additional items of potential heritage significance were identified during the field investigations. These were ANZAC Park at Cammeray, Henry Lawson's Cave within Flat Rock Gully, Balgowlah Golf Course and Burnie (House) at Balgowlah. ANZAC Park was assessed as being of social value due to the location of the war memorial within the park, and its association with the former North Sydney Tramway Depot and its personnel who served during World Wars I and II. Henry Lawson's Cave was assessed as being of historical and social value due to its association with Henry Lawson and as an amphitheatre for recreational community use. Balgowlah Golf Course was assessed as being of historical value as an example of Sydney's post-World War l suburban expansion and community desire for recreational activities, and its association with one if its founders, James Sydney Wallace Eve, an Olympic swimmer and Australian sports administrator. The impact of the project on these items is assessed in Section 14.4.2. Burnie (House) did not meet the thresholds for heritage significance for local or state listing.

No additional areas of archaeological potential were identified during the field surveys.

Listed maritime heritage items

Two of the listed heritage items identified within the study area have a maritime heritage component. These are Clive Park Tidal Pool, listed on the Willoughby Local Environment Plan 2013, and Harbour foreshores (Seaforth), listed on the Manly Local Environment Plan 2012.

Further detail on heritage items and heritage listings of each item are provided in Appendix K (Technical working paper: Maritime heritage).

Additional potential maritime heritage items

Three unidentified shipwrecks of potential heritage significance were identified during field surveys at Clive Park, Pearl Bay and Middle Harbour (refer to Figure 14-3). These are considered to be of local heritage significance for their rarity and research potential. As such, the impact of the project on these items has been assessed in Section 14.4.3.

Seven unverified anomalies were identified between Northbridge and Seaforth through review of remote sensing data from field surveys and from review of existing sources (refer to Figure 14-3). These are considered to have low to medium potential heritage sensitivity. As the heritage significance cannot be verified, the impact of the project on these items has been assessed in Section 14.4.3 for completeness.

There is potential within the project construction footprint for archaeological remains to occur, associated with maritime infrastructure, shipwrecks and vessel activity that were not identified during the field surveys due to the limitations of visual and remote sensing investigations. A summary of maritime archaeological potential is provided in Table 14-2.

Table 14-2 Maritime archaeological potential within the study area

Potential archaeological site type	Location		
	Middle Harbour between Northbridge and Seaforth	Middle Harbour and Pearl Bay, west of The Spit	Middle Harbour between Northbridge and Beauty Point
Maritime infrastructure	Certain	Certain	Very unlikely
Shipwrecks	Certain	Certain	Unlikely
Discard	Certain	Certain	Very likely

14.4 Assessment of potential impacts

14.4.1 Impact avoidance and minimisation

As detailed in Chapter 4 (Project development and alternatives), the project has avoided or minimised impacts to heritage in the following ways:

- The majority of the project would be constructed and located underground, avoiding impacts through the subsurface tunneling of the project

- At Cammeray, the construction and permanent footprint for the program of works has been designed to utilise as much as possible the existing Warringah Freeway corridor and to enable the remaining land to continue to function as a recreational area (golf course). Residual land (ie outside operational requirements) would be returned to enable incorporation into the golf course at the completion of constructionAt Middle Harbour, the construction methodology for the project has been selected to avoid direct impacts on foreshore areas, such as Clive Park. Specifically, the use of cofferdams has minimised temporary and permanent impacts to the shoreline and avoids direct impacts to the park
- At the Wakehurst Parkway, project work has been contained within the existing road reserve to avoid direct impact to Bantry Bluff, which is listed on the Manly Local Environmental Plan 2013 as locally significant, and Upper Middle Harbour Area and the Narrabeen Catchment Lagoon, which are listed on the Register of the National Estate for landscape values
- The Wakehurst Parkway east construction support site (BL13) has been designed to avoid direct impacts to key heritage elements of the Bantry Bay Water Pumping Station and the Bantry Bay Reservoir
- Permanent direct impacts to the Manly Dam and surrounds have been avoided. Less than one per cent of the heritage item would be impacted during a short period of the construction phase to reconnect the upgrade works to an existing fire trail / high voltage powerline maintenance access track.

14.4.2 Potential terrestrial heritage impacts

Of the 76 heritage items identified within the study area, 48 items have been identified as not being impacted by the project. These items are located within 50 metres of surface works for the project along the Warringah Freeway corridor and Balgowlah connections in proximity to minor works within the existing road reserve. Impacts on these 48 items would be limited to temporary noise, vibration and/or visual impacts during construction, and managed through the implementation of minimum working distances for vibration intensive construction activities and other standard construction management measures. As such, impacts to these heritage items have not been carried forward for further detailed assessment.

Of the 28 heritage items that would be potentially impacted:

- Three heritage items (Henry Lawson’s Cave, Commercial building, and Grant’s Wharf (remains)) would be in the vicinity of low impact work and impact to these items from settlement and vibration would be negligible. There would be no impact to one item in the vicinity of low impact work. Temporary and permanent visual impact is also unlikely as the distance to permanent infrastructure and the retained mature vegetation provides a visual barrier to the majority of the project-related infrastructure
- Three heritage items (Bantry Bluff, The Upper Middle Harbour Area, and The Narrabeen Catchment Lagoon) within the study area, that are listed for landscape and natural values, have been identified as subject to negligible impact by the construction or operation of the project. In each case, the work is outside, or just within the curtilage of the item and work would be contained within previously disturbed areas. Mature vegetation would be retained between the construction footprint and heritage curtilage and any impact on the heritage items and their significance would be negligible.

As such, impact to these heritage items has not been carried forward for further detailed assessment.

A heritage assessment for the remaining 22 heritage items and conservation areas that would be potentially impacted is included in Table 14-3, with items shown in Figure 14-1. Heritage items situated above the tunnel alignment or adjacent to surface works have been assessed as groups of heritage items due to their proximity to each other, the similarity of impacts and similarity of mitigation measures.

Two terrestrial heritage items considered in Table 14-3 have maritime heritage elements. These items include:

- Clive Park Tidal Pool
- Harbour foreshores (Seaforth).

These items have been considered in their entirety in Table 14-3, and do not appear in the maritime heritage assessment in Section 14.4.3.

It is noted that as no whole heritage places are proposed for demolition, no comparative analysis was carried out.

Table 14-3 Potential impacts on terrestrial heritage items

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
1	ANZAC Park, Cammeray	Unlisted	Local	Direct impacts: • Planned physical impacts to the heritage item due to the construction of permanent operational infrastructure within the heritage boundary as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project and Beaches Link and Gore Hill Freeway Upgrade program of works.	**Negligible** All work within the heritage boundary would be contained within previously disturbed areas associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project, and would be minor in nature. Views of permanent operational infrastructure would be partially filtered by vegetation and would not affect the visual setting around the war memorial within the park. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be negligible.
				Potential direct impacts: • Potential physical impacts to the heritage item due to operation of construction vehicles and equipment within and in proximity to the heritage boundary.	
				Indirect impacts: • Temporary vibration impacts due to construction activities within the heritage boundary • Temporary and permanent visual impacts due to the construction of permanent operational infrastructure within and adjacent to the heritage boundary.	

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
2	Cammeray Park (including Golf Course), Cammeray	North Sydney Local Environmental Plan 2013	Local	Direct impacts: • Planned physical impacts to the heritage item due to the construction of permanent operational infrastructure within the heritage boundary. Potentially direct impacts: • Potential physical impacts to the heritage items due to operation of construction vehicles and equipment within and in proximity to the heritage boundary. Indirect impacts: • Temporary and permanent visual impacts due to the construction of permanent operational infrastructure within the heritage boundary • Permanent social impacts due to the repurposing of a large section of the heritage item for permanent operational infrastructure • Temporary vibration impacts due to construction activities within the heritage boundary • Slight permanent settlement and ground movement impacts to the heritage item caused by tunnel excavation.	**Moderate** Direct impacts of the project would be contained within areas previously disturbed by the Western Harbour Tunnel and Warringah Freeway Upgrade project. The proposed works would be of small-medium scale and of moderate intensity, with the changes to the heritage item being permanent and irreversible. The heritage item would lose a large portion of its significance as a relatively intact open space. The implementation of the management measures described in Section 14.5 would provide landscape treatments to screen views to operational infrastructure, however the level of impact would still be moderate.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
3	Cammeray Conservation Area, Cammeray	• North Sydney Local Environmental Plan 2013 • Register of the National Estate.	Local	Direct impacts: • Planned physical impacts to the heritage item due to the construction of permanent road infrastructure within and adjacent to the heritage boundary. Potential direct impacts: • Potential physical impacts to the heritage item due to operation of construction vehicles and equipment within and in proximity to the heritage boundary. Indirect impacts: • Temporary and permanent visual impacts due to the construction of permanent operational infrastructure within and adjacent to the heritage boundary • Temporary vibration impacts due to construction activities within and adjacent to the heritage boundary • Very slight permanent settlement and ground movement impacts to the heritage item caused by tunnel excavation.	**Minor** Direct impacts of the project to the heritage item would be minor and would be contained within areas previously disturbed by the Western Harbour Tunnel and Warringah Freeway Upgrade project. However, temporary and permanent visual impacts along the boundary of the conservation area would be moderate to high due to landscape impacts at Cammeray Golf Course and the presence of project-related infrastructure. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be minor.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
4	Tarella, Cammeray	• State Heritage Register • North Sydney Local Environmental Plan 2013 • Register of the National Estate • National Trust of Australia (NSW) Register.	State	Direct impacts: • Physical impact due to the implementation of architectural noise treatments for the heritage item.	**Negligible** Eligibility for architectural noise treatment for the heritage item would be confirmed during further design development and in consultation with the landowner. Should architectural noise treatment be required, this would be done in such a way to minimise heritage impacts, while preserving owner amenity and heritage values of the item. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be negligible.
				No potential direct impacts	
				Indirect impacts: • Temporary and permanent visual impacts due to the construction of permanent operational infrastructure within and adjacent to the heritage boundary • Temporary vibration impacts due to construction activities within and adjacent to the heritage boundary • Very slight permanent settlement and ground movement impacts to the heritage item caused by tunnel excavation.	

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
5	St Thomas Rest Park, Crows Nest	• North Sydney Local Environmental Plan 2013 • National Trust of Australia (NSW).	Local	No direct impacts No potential direct impacts Indirect impacts: • Temporary vibration impacts due to construction activities within and adjacent to the heritage boundary • Very slight permanent settlement and ground movement impacts to the heritage item caused by tunnel excavation.	**Negligible** With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be negligible, as the proposed works would remain outside the heritage boundary.
6	Holtermann Estate A Conservation Area, Crows Nest	• North Sydney Local Environmental Plan 2013 • Register of the National Estate.	Local	Direct impacts: • Physical impact due to the implementation of architectural noise treatments for a number of residences within the conservation area. No potential direct impacts Indirect impacts: • Temporary and permanent visual impacts due to the construction of permanent operational infrastructure in proximity to the conservation area • Very slight to slight permanent settlement and ground movement impacts to heritage item within the conservation area caused by tunnel excavation.	**Negligible** Eligibility for architectural noise treatment at a number of residences within the conservation area would be confirmed during further design development and in consultation with the landowner. Should architectural noise treatment be required, this would be done in such a way to minimise heritage impacts, while preserving owner amenity and heritage values of the conservation area. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be negligible.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
7	Artarmon heritage conservation area, Artarmon	Willoughby Local Environmental Plan 2012	Local	Direct impacts: • Physical impacts to the conservation area due to the construction of permanent infrastructure within the heritage boundary.	**Negligible** Temporary and permanent works within the heritage conservation area would be limited to minor pavement and drainage works and be restricted to previously disturbed areas. Areas impacted by vibration and settlement would be vegetated open space (Artarmon Reserve), with no structures relevant to the heritage listing present. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be negligible.
				No potential direct impacts	
				Indirect impacts: • Temporary and permanent visual impacts due to the construction of permanent operational infrastructure within and adjacent to the heritage boundary • Temporary vibration impacts due to construction activities within and adjacent to the heritage boundary • Settlement and ground movement impacts to the heritage item caused by tunnel excavation.	

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
8	Clive Park and Tidal Pool, Northbridge	Willoughby Local Environmental Plan 2012	Local	No direct impacts Potential direct impacts • Potential physical impact to the heritage item from anchoring of project maritime vessels on or around the item. Indirect impacts: • Temporary visual impacts due to the construction infrastructure in Middle Harbour in proximity to the heritage item, including cofferdams, cranes and maritime construction vessels • Temporary vibration impacts due to construction activities (eg piling) adjacent to the heritage boundary • Slight permanent settlement and ground movement impacts to heritage item within the conservation area caused by tunnel excavation.	**Minor** The construction methodology for the project has been selected to avoid direct impacts on Clive Park and its immediate foreshore. There is potential for the site to be physically impacted from anchoring by construction related vessels, however this is highly improbable as the area would be marked as a restricted zone. Indirect impacts would occur due to vibration, settlement and temporary changes to the visual setting of the item. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be minor.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
9	Harbour foreshores	Manly Local Environmental Plan 2012	Local	No direct impacts Potential direct impacts: • Potential physical impact to the heritage item from anchoring of project marine vessels on or around the item. Indirect impacts: • Temporary visual impacts due to the construction infrastructure in Middle Harbour in proximity to the heritage item, including cofferdams, cranes and marine construction vessels • Temporary vibration impacts due to construction activities (eg piling) adjacent to the heritage boundary • Slight permanent settlement and ground movement impacts to heritage item within the conservation area caused by tunnel excavation.	**Minor** The construction methodology for the project has been selected to avoid direct impacts on the heritage item. There is potential, for the site to be physically impacted from anchoring by construction related vessels, however this is highly improbable as the harbour foreshores would be marked as restricted zones. Indirect impacts would occur due to vibration, settlement and temporary changes to the visual setting of the item. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be minor.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
10	Balgowlah Golf Course, Balgowlah	Unlisted	Local	Direct impacts: • Physical impacts to significant portions of the heritage item due to the temporary establishment and operation of the Balgowlah Golf Course construction support site (BL10) and the construction of permanent road infrastructure and operational facilities and new and improved open space and recreation facilities. No potential direct impacts Indirect impacts: • Temporary and permanent visual impacts due to the location of the Balgowlah Golf Course construction support site (BL10) and the location of permanent operational facilities within the heritage boundary • Permanent social impacts due to repurposing of the heritage item for construction and operational use, and for use as new and improved open space and recreation facilities.	**Major** The proposed works would be of large scale and major intensity, with portions of the golf course being modified through the construction of the permanent access road, operational infrastructure and new and improved open space and recreation facilities. Changes to the heritage item would be permanent and irreversible as the heritage item would potentially no longer demonstrate its original character as an interwar period golf course. It is noted that for the purposes of the non-Aboriginal heritage impact assessment (see Appendix J (Technical working paper: Non-Aboriginal heritage)), a worst-case scenario approach of demolition has been assumed for the Golf Course club house building. However, further opportunities to retain and repurpose the club house would be investigated through the dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council during further design development which would give the community the opportunity to provide input on the final layout of the new and improved open space and recreation facilities at Balgowlah. The implementation of the management measures described in Section 14.5 would ensure information about the physical nature of the heritage item is recorded, however the level of impact would still be major.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
11	Frenchs Bullock Track, Killarney Heights	Warringah Local Environmental Plan 2011	Local	Direct impacts: • Physical impacts to part of the heritage item due to the construction of permanent road infrastructure within the heritage boundary. Potential direct impacts: • Potential physical impacts to the heritage item due to operation of construction vehicles and equipment within and in proximity to the heritage boundary. Indirect impacts: • Temporary and permanent visual and aesthetic impacts to the heritage item due to roadworks within and in proximity to the heritage boundary • Vibration impacts to the heritage item due to construction activities within the heritage boundary.	**Minor** The proposed works would be of small and localised scale, and low intensity, with a small section of the Frenchs Bullock Track potentially being permanently modified by a slope associated with roadworks extending into the curtilage of the item. If required, works could result in a permanent and irreversible change of up to 20 per cent of the track, the changes would not detrimentally impact the historical and aesthetic significance of the heritage item as the greater majority of the track remains in-situ and would continue to display its historical and aesthetic significance. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be minor. During detailed design and construction planning, the impacts would be re-assessed with a view to redesign shared path connections to the track, thereby minimising the level of impact.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
12	Bantry Bay Water Pumping Station (WPS 122), Killarney Heights	• Warringah Local Environmental Plan 2011 • Sydney Water Section 170 Heritage and Conservation Register	Local	Direct impacts: • Physical impacts within the heritage boundary due to site establishment works and operation of the Wakehurst Parkway east construction support site (BL13). Potential direct impacts: • Potential physical impacts to the heritage item due to operation of construction vehicles and equipment within proximity to the pumping station building. Indirect impacts: • Temporary visual impacts due to the location of the Wakehurst Parkway east construction support site (BL13).	**Minor** The proposed works would be restricted to avoid direct impact to the historic pumping station building. Within the heritage boundary the proposed works would be restricted to small to medium scale low-intensity temporary and reversible activities. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be minor.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
13	Bantry Bay Reservoir (WS 0008), Killarney Heights	• Warringah Local Environmental Plan 2011 • Sydney Water Section 170 Heritage and Conservation Register	Local	Direct impacts: • Physical impacts within the heritage boundary due to site establishment works and operation the Wakehurst Parkway east construction support site (BL13).	**Minor** The proposed works would be restricted to avoid direct impact to the significant concrete reservoir which is the key heritage element of the heritage item. Within the heritage boundary, the proposed works would be of small-medium scale of low intensity, with the majority of the area being subject to works which are temporary and reversible. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be minor.
				Potential direct impacts: • Potential physical impacts to the heritage item due to operation of construction vehicles and equipment within and in proximity to the heritage boundary.	
				No indirect impacts	

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
14	Manly Dam and Surrounds, Allambie Heights	• Warringah Local Environmental Plan 2011 • Register of the National Estate.	Local	Direct impacts: • Physical impacts within the heritage boundary due to the construction of permanent road infrastructure within and adjacent to the heritage boundary. Potential direct impacts: • Potential physical impacts within the heritage boundary due to operation of construction vehicles and equipment within and in proximity to the heritage boundary. Indirect impacts: • Temporary and permanent visual impacts due to the location of the Wakehurst Parkway South construction support site (BL13) and the location of permanent operational facilities adjacent to the heritage boundary • Temporary vibration impacts due to construction activities within and adjacent to the heritage boundary • Slight permanent settlement and ground movement impacts within the heritage boundary caused by tunnel excavation.	**Negligible** The vast majority of the heritage item would not be impacted by the project, beyond the single small section of the boundary along the Wakehurst Parkway. Additionally, none of the significant built heritage elements are within close proximity to the Wakehurst Parkway east construction support site (BL13) and are not predicted to experience vibration impacts. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be negligible, as there would be little or no physical impact to the heritage item.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
n/a	Three heritage items situated above the tunnel alignment with potential settlement impacts – Naremburn Central Township (Conservation Area), Walter Burley Griffin Incinerator, street trees along Alan Avenue within Seaforth	Various	State (Walter Burley Griffin Incinerator) / Local (all other items)	No direct impacts	**Negligible** With the implementation of the management measures described in Section 14.5, the level of impact on the heritage items would be negligible.
				No potential direct impacts	
				Indirect impacts: • Temporary vibration impacts due to construction activities within and adjacent to the heritage boundaries • Slight permanent settlement and ground movement impacts to heritage items caused by tunnel excavation.	

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating
n/a	Five heritage items situated immediately adjacent to surface works – five houses on Ernest Street in Neutral Bay	Various	Local	No direct impacts Potential direct impacts: • Potential physical impacts to the heritage items due to operation of construction vehicles and equipment within and in proximity to the heritage boundary. Indirect impacts: • Temporary and permanent visual impacts due to changes in land use and the construction of permanent operational infrastructure in the vicinity of the heritage items • Temporary vibration impacts due to construction activities within and adjacent to the heritage boundary.	**Negligible** Temporary and permanent visual impacts along the boundary of the conservation area would be moderate to high due to landscape impacts at Cammeray Golf Course and the presence of project-related infrastructure. Permanent impacts would likely reduce over time as replacement landscape planting matures. It is noted there may be direct impacts to the heritage items due to the implementation of architectural noise treatments however, these would be carried out as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage items would be negligible.

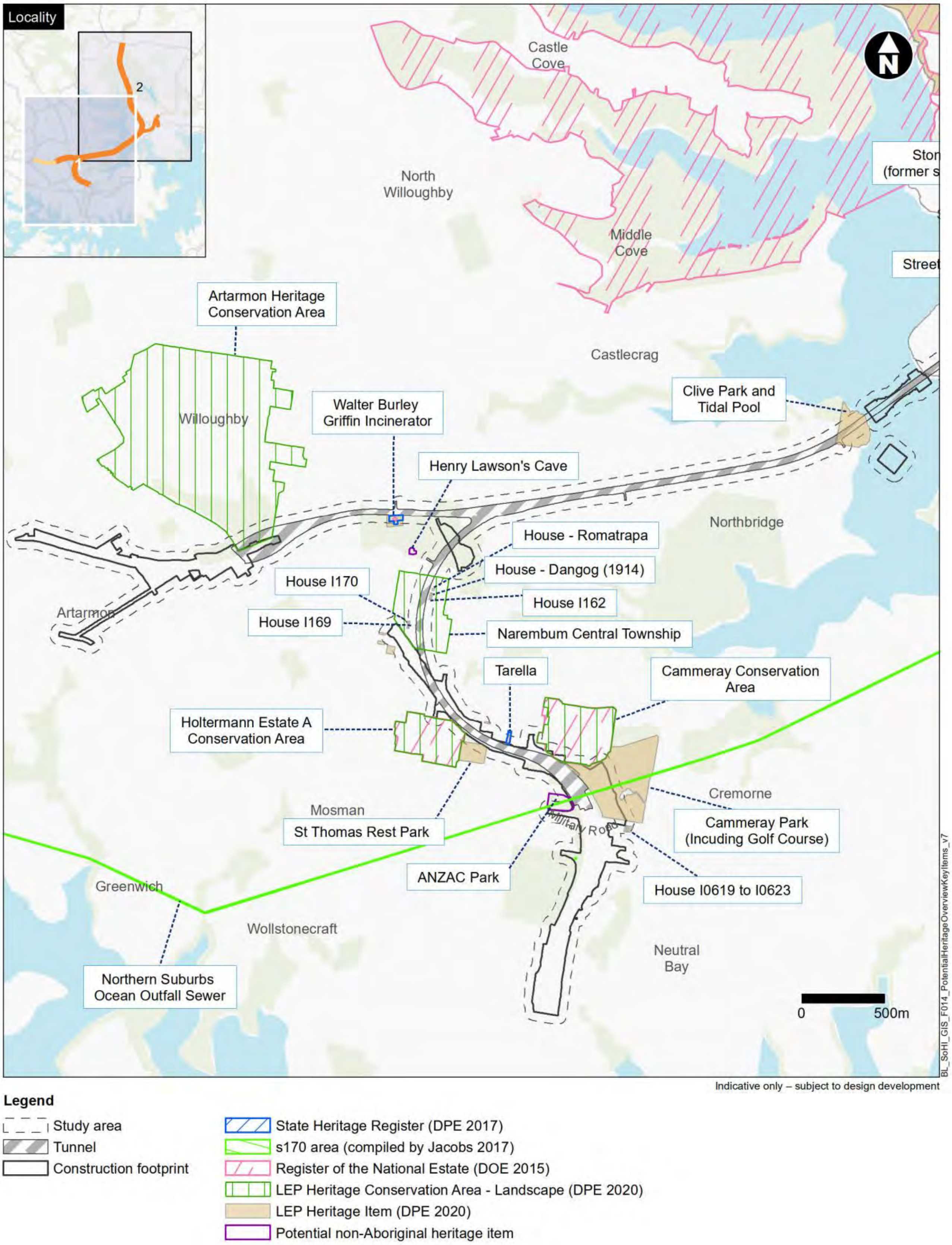


Figure 14-1 Location of terrestrial heritage items impacted by the project

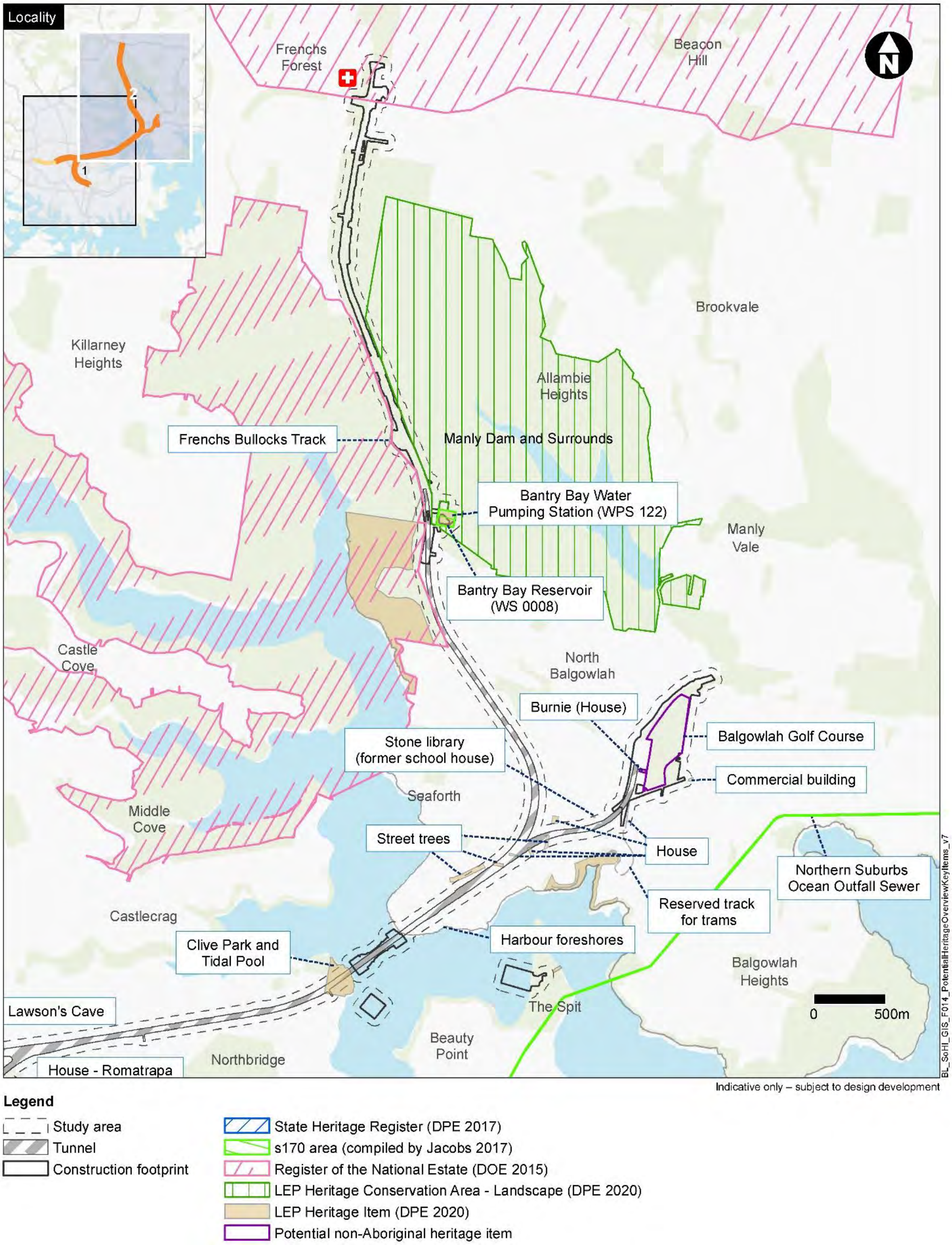


Figure 14-2 Location of terrestrial heritage items impacted by the project

14.4.3 Potential maritime heritage impacts

Of the 10 maritime heritage items identified within the study area with cultural heritage significance, one item, the Side scan sonar anomaly (18W-003), would not be impacted by the project (refer Figure 14-3).

A heritage assessment for the remaining nine heritage items that would be potentially impacted is included in Table 14-4 and shown in Figure 14-3. Areas of archaeological potential have also been assessed (Items 10, 11 and 12).

Note that Clyde Park Tidal Pool and Harbour foreshores (Seaforth) have been assessed as terrestrial items in Section 14.4.2.

Table 14-4 Potential impacts on maritime heritage sites

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating (with mitigation)
Heritage items					
1	Clive Park Unidentified Shipwreck No. 1	Unlisted	Local	No direct impacts	**Minor** The proposed works may result in loss of site integrity and reduction in heritage values. Potential direct and indirect impacts to the heritage item would be minimised with the implementation of the management measures described in Section 14.5 to collect archaeological information from the site before construction.
				Potential direct impacts: • Physical impact to the heritage item from anchoring of project vessels on or around the item • Physical impact to the heritage item by propeller jet turbulence of project vessels.	
				Indirect impacts: • Temporary vibration impacts to the heritage item due to the construction of the Middle Harbour south cofferdam (BL7).	
2	Middle Harbour Unidentified Shipwreck No. 1	Unlisted	Local	No direct impacts	**Negligible** With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be negligible.
				No potential direct impacts	
				Indirect impacts: • Temporary vibration impacts to the heritage item due to the construction of the Middle Harbour south cofferdams (BL7).	

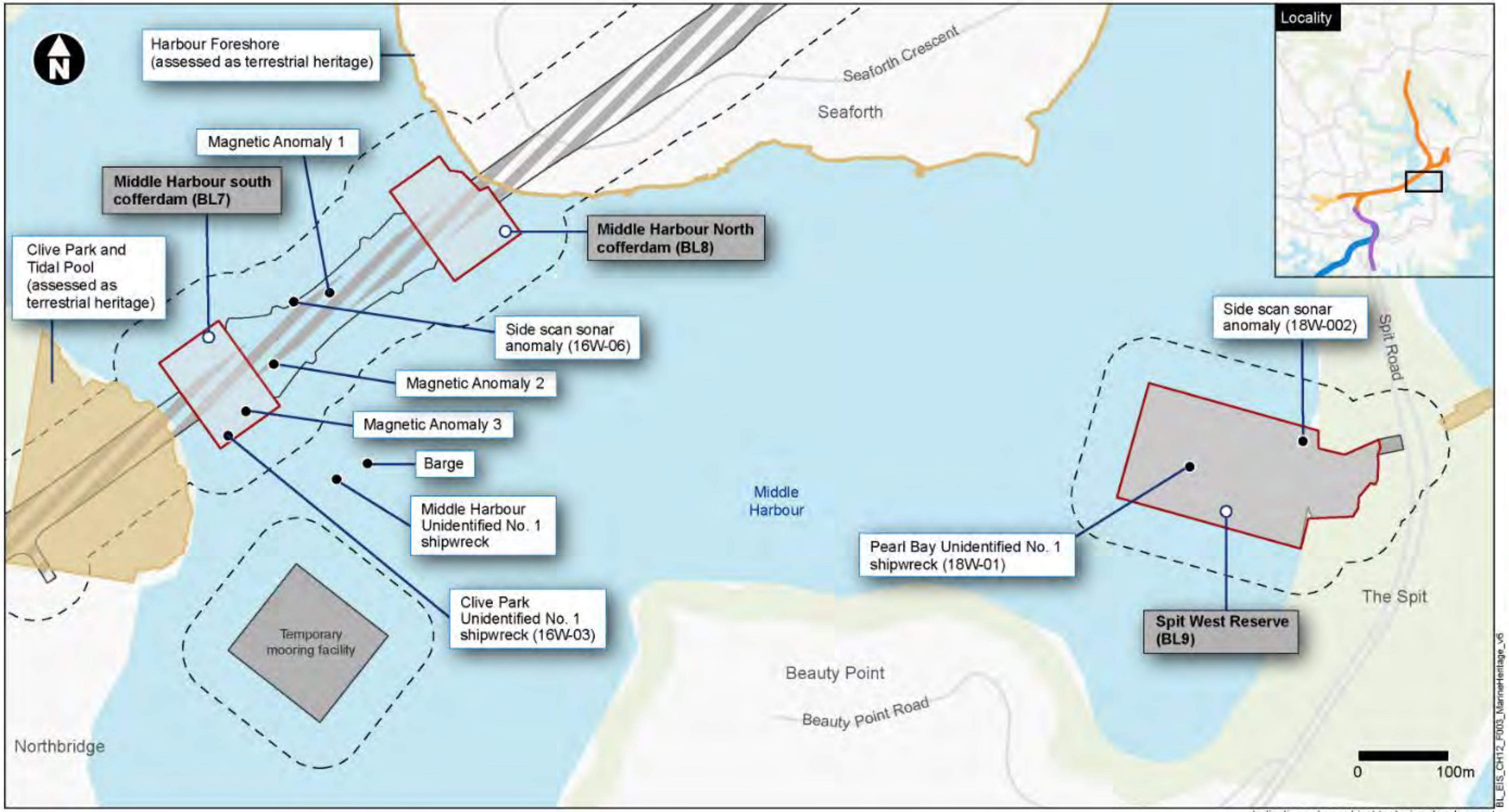
Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating (with mitigation)
3	Pearl Bay Unidentified No. 1 Shipwreck (18W-01)	Unlisted	Local	Direct impacts: • Physical impact to the heritage item from piling activities associated with the construction of the Spit West Reserve construction support site (BL9). Potential direct impacts • Physical impact to the heritage item from anchoring of project vessels on or around the item. No indirect impacts	**Minor** The proposed works may result in loss of site integrity and reduction in heritage values. Potential direct and indirect impacts to the heritage item would be minimised with the implementation of the management measures described in Section 14.5 to collect archaeological information from the site before construction and to establish a restricted zone before construction to avoid potential direct impacts.
Unverified anomalies – potential heritage items					
4	'Barge'	Unlisted	Unknown – low heritage sensitivity	No direct impacts No potential direct impacts Indirect impacts: • Temporary vibration impacts to the heritage item due to the construction of the Middle Harbour south cofferdam (BL7).	**Negligible** It is expected there would be no discernible change to the existing natural and human impacts to this site. With the implementation of the management measures described in Section 14.5, the level of impact on the heritage item would be negligible.
5	Side scan sonar anomaly 16W-06	Unlisted	Unknown – low heritage sensitivity	Direct impacts: • Planned physical impacts to the entire item due to dredging for the immersed tube tunnels. No potential direct impacts No indirect impacts	**Minor** The proposed dredging works for the immersed tube tunnels would result in loss of site integrity and reduction in heritage values. As the expected heritage sensitivity of the site is low, the implementation of the pre-dredge management measures described in Section 14.5 would result in a minor impact.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating (with mitigation)
6	Magnetic anomaly 1	Unlisted	Unknown – low heritage sensitivity	Direct impacts: • Physical impacts to the entire item due to dredging for the immersed tube tunnels. No potential direct impacts No indirect impacts	**Minor** The proposed dredging works for the immersed tube tunnels would result in loss of site integrity and reduction in heritage values. As the expected heritage sensitivity of the site is low, the implementation of the pre-dredge management measures described in Section 14.5 would result in a minor impact.
7	Magnetic anomaly 2	Unlisted	Unknown – low heritage sensitivity	Direct impacts: • Physical impacts to the entire item due to dredging for the immersed tube tunnels. No potential direct impacts No indirect impacts	**Minor** The proposed dredging works for the immersed tube tunnels would result in loss of site integrity and reduction in heritage values. As the expected heritage sensitivity of the site is low, the implementation of the pre-dredge management measures described in Section 14.5 would result in a minor impact.
8	Magnetic anomaly 3	Unlisted	Unknown – medium heritage sensitivity	No direct impacts Potential direct impacts: • Physical impact to the heritage item from anchoring of project vessels on or around the item • Physical impact to the heritage item by propeller jet turbulence of project vessels. Indirect impacts: • Temporary vibration impacts to the heritage item due to the construction of the Middle Harbour south and Middle Harbour north cofferdams (BL7 and BL8).	**Minor** The proposed works may result in loss of site integrity and reduction in heritage values, which is suspected to be associated with the Clive Park Unidentified Shipwreck No 1. Potential direct and indirect impacts to the heritage item would be minimised with the implementation of the management measures described in Section 14.5 to collect archaeological information from the site before construction.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating (with mitigation)
9	Side scan sonar anomaly 18W-002	Unlisted	Unknown – low heritage sensitivity	Direct impacts: • Physical impact to the heritage item from piling activities associated with the construction of the Spit West Reserve construction support site (BL9).	**Minor** The proposed works may result in loss of site integrity and reduction in heritage values. Potential direct and indirect impacts to the heritage item would be minimised with the implementation of the management measures described in Section 14.5.
				Potential direct impacts: • Physical impact to the heritage item from anchoring of project vessels on or around the item • Physical impact to the heritage item by propeller jet turbulence of project vessels.	
				No indirect impacts	

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating (with mitigation)
Potential archaeological sites					
10	Potential archaeological sites in Middle Harbour between Northbridge and Seaforth	Unlisted	Unknown – low heritage sensitivity	Direct impacts: • Physical impacts to the bed of the harbour in this area due to dredging for the immersed tube tunnels and construction of the Middle Harbour south and Middle Harbour north cofferdams (BL7 and BL8). Potential direct impacts: • Physical impact to the bed of the harbour in this area from anchoring of project vessels on or around the item • Physical impact to the bed of the harbour in this area by water turbulence from the operation of project vessels. Indirect impacts: • Temporary vibration impacts to the bed of the harbour in this area due to the construction of the Middle Harbour south and Middle Harbour north cofferdams (BL7 and BL8).	**Minor** The proposed works may result in loss of site integrity and reduction in heritage values of potential archaeological sites. Impacts to potential archaeological sites would be minimised with the implementation of the management measures described in Section 14.5 to identify any further heritage items before construction.

Item No.	Item name	Listing	Heritage significance	Impact type	Impact rating (with mitigation)
11	Potential archaeological sites in Middle Harbour and Pearl Bay, west of The Spit	Unlisted	Unknown – low to medium heritage sensitivity	Direct impacts: • Physical impact to the bed of the harbour in this area from piling activities associated with the construction of the Spit West Reserve construction support site (BL9).	**Minor** The proposed works may result in loss of site integrity and reduction in heritage values of potential archaeological sites. Impacts to potential archaeological sites would be minimised with the implementation of the management measures described in Section 14.5 to identify any further heritage items before construction.
				Potential direct impacts: • Physical impact to the bed of the harbour in this area from anchoring of project vessels on or around the item • Physical impact to the bed of the harbour in this area by water turbulence from the operation of project vessels.	
				No indirect impacts	
12	Potential archaeological sites in Middle Harbour between Northbridge and Beauty Point	Unlisted	Unknown – low heritage sensitivity	No direct impacts	**Minor** The proposed works may result in loss of site integrity and reduction in heritage values of potential archaeological sites. Impacts to potential archaeological sites would be minimised with the implementation of the management measures described in Section 14.5 to identify any further heritage items before construction.
				Potential direct impacts: • Physical impact to the bed of the harbour in this area from anchoring of project vessels on or around the item.	
				No indirect impacts	



Indicative only – subject to design development

Legend

Construction features

- Study area
- Tunnel
- Construction footprint
- Construction support site

Heritage and potential heritage items

- LEP Heritage Items (DPE 2017)
- Potential maritime heritage item

Figure 14-3 Location of maritime heritage items impacted by the project

14.5 Environmental management measures

Environmental management measures relating to non-Aboriginal heritage for the project are outlined in Table 14-5.

Table 14-5 Environmental management measures – Non-Aboriginal heritage

Ref	Phase	Impact	Environmental management measure	Location
NAH1	Design	Ongoing non-Aboriginal heritage impacts	Appropriate heritage interpretation will be incorporated into the urban design for the project in accordance with the *NSW Heritage Manual* (NSW Heritage Office and Department of Urban Affairs and Planning, 1996), *Interpreting Heritage Places and Items: Guidelines* (NSW Heritage Office, 2005), and the *Heritage Interpretation Policy* (NSW Heritage Council, 2005).	BL/GHF
NAH2	Pre-construction	Impacts on specific non-Aboriginal heritage items	Archival recording will be carried out in accordance with the *Photographic Recording of Heritage Items Using Film or Digital Capture* guideline for areas/items subject to change within the following items, in accordance with Appendix J (Technical working paper: Non-Aboriginal heritage): • Item 10: Balgowlah Golf Course, Balgowlah • Item 11: Frenchs Bullock Track, Killarney Heights (pending further detailed survey and detailed design development confirming direct impact). Archival recording will be completed prior to any works that have the potential to impact upon the items and deposited with appropriate stakeholders as determined during further design development (eg local councils).	BL/GHF
NAH3	Pre-construction	Maritime non-Aboriginal heritage impacts	A Maritime Heritage Management Plan that details the objectives and methodologies to conserve maritime heritage and mitigate impacts will be prepared in consultation with a qualified and experienced maritime archaeologist. The Maritime	BL

Ref	Phase	Impact	Environmental management measure	Location
			Heritage Management Plan will specify: a. Unexpected finds protocols relevant to each type of activity such as dredging or piling b. Artefact management procedures, including identification of approved submerged reburial locations c. Relevant work method requirements and maritime heritage inductions tailored for each type of work activity such as dredging or piling d. Restricted zone, archival, baseline and periodic monitoring protocols including before and during construction, and final site inspections within three months of completion of works for the following maritime heritage sites: • Clive Park Tidal Pool • Clive Park Unidentified No. 1 • Pearl Bay Unidentified No. 1. e. An archaeological research design to guide the investigation of Clive Park Unidentified No 1.	
NAH4	Pre-construction	Maritime non-Aboriginal heritage impacts	Any pre-dredge bed of the harbour clearance by divers in Middle Harbour will be carried out in the presence of a maritime archaeologist, who will identify any additional inspection or documentation that should be carried out during the clearance dive. This may include inspecting the locations of known or potential submerged maritime heritage sites and items, either recording in situ or recovery and/or relocation.	Middle Harbour
NAH5	Pre-construction	Maritime archival recording	An archival recording of Clive Park Unidentified No. 1 will be carried out to mitigate the likely loss of information resulting from a breakdown of site integrity. The archival recording will have the	Clive Park Unidentified No. 1

Ref	Phase	Impact	Environmental management measure	Location
			following objectives or research questions: • Identifying and recording the extent of the site • Identifying the type and function of the vessel (which would mean determining its construction) • Identifying what the vessel was carrying at the time of loss • Re-assessing the cultural heritage significance of the site. The archival recording of the wreck would require limited excavation of the site to recover and examine its contents. This excavation will be carried out in accordance with the research design (refer to NAH3) and any artefacts recovered from the site will be buried, after analysis, in an approved location nearby.	
NAH6	Pre-construction	Maritime archival recording	A detailed archival recording of the following maritime heritage items will be prepared, consistent with relevant NSW Heritage Council approved standards and guidelines: • Clive Park Tidal Pool • Pearl Bay Unidentified No. 1. The archival records will also capture any relevant information needed to serve as a baseline for monitoring during the project, as identified in the Maritime Heritage Management Plan (see NAH3). The final archival record will be updated with any changes identified during monitoring or investigation prior to lodgement.	Clive Park Tidal Pool, Pearl Bay Unidentified No.1
NAH7	Pre-construction	Maritime non-Aboriginal heritage impacts	A side scan sonar survey will be carried out for the following areas, where they are not already covered by existing surveys: • Project construction footprint between Northbridge and	Middle Harbour south cofferdam (BL7), Middle Harbour

Ref	Phase	Impact	Environmental management measure	Location
			Seaforth in the vicinity of the immersed tube tunnels and the Middle Harbour cofferdams (BL7 and BL8) • Project construction footprint in the vicinity of the Spit West Reserve construction support site (BL9). A qualified maritime archaeologist will assess the results of the side scan survey to identify any additional potential heritage items requiring investigation and assessment.	north cofferdam (BL8), Spit West Reserve construction support site (BL9)
NAH8	Pre-construction	Maritime non-Aboriginal heritage impacts	A dive team under the supervision of a maritime archaeologist will inspect the location of each proposed piled mooring to assess the maritime heritage value of any cultural object present and either relocate the object or, if significant, relocate the proposed mooring.	Temporary mooring facility east of Clive Park in Middle Harbour
NAH9	Pre-construction	Non-Aboriginal heritage impacts to Frenchs Bullock Track	The northern section of the Frenchs Bullock Track potentially impacted directly by construction works will be reformed if impacted, as close as possible to the existing alignment. Further detailed survey will be completed to confirm the heritage curtilage of the southern section of Frenchs Bullock Track prior to construction to determine if this section will be directly impacted. Where the heritage curtilage of the Frenchs Bullock Track is within the construction footprint or boundary of proposed permanent infrastructure, impacts to the track will be avoided where possible through further design development.	BL
NAH10	Pre-construction and construction	Vibration impacts to non-Aboriginal heritage	A structural survey will be prepared for all maritime infrastructure within the Seaforth 'Harbour Foreshores' that could be subject to vibrational impact to determine minimum working distances and vibration limits to be observed to prevent cosmetic damage. Vibration	Harbour foreshores (Seaforth)

Ref	Phase	Impact	Environmental management measure	Location
			monitoring will be carried out during works to ensure vibration levels do not exceed appropriate limits. The recommended actions in Appendix G (Technical working paper: Noise and vibration) will be followed.	
NAH11	Construction	Non-Aboriginal heritage impacts during construction	Delineation of restricted zones will be implemented to avoid inadvertent works occurring within the curtilage of heritage items.	BL/GHF
NAH12	Construction	Unexpected discovery of historical heritage materials, features or deposits	If at any time during construction of the project, historical materials, features and/or deposits are encountered, the *Standard Management Procedure: Unexpected Heritage Items* (Roads and Maritime Services, 2015d) will be followed.	BL/GHF
NAH13	Construction	Unexpected discovery of human remains	In the event that construction of the project reveals possible human skeletal material (remains), *Standard Management Procedures – Unexpected Heritage Items* (Roads and Maritime Services, 2015d) will be implemented.	BL/GHF
NAH14	Construction	Non-Aboriginal heritage impacts during construction	Non-Aboriginal heritage awareness training will be provided for contractors prior to commencement of construction works to ensure understanding of potential heritage items that may be impacted during the project, and the procedure required to be carried out in the event of discovery of non-Aboriginal heritage materials, features or deposits, or the discovery of human remains. This includes relevant work method requirements and maritime heritage inductions tailored for each type of work activity such as dredging or piling.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
NAH15	Construction	Non-Aboriginal heritage impacts	Should at-property noise treatment be required at a premise that is heritage listed, this will be carried out in a manner to minimise heritage impact, and advice of a heritage conservation architect will be sought prior to carrying out the works. Any treatments will be sympathetic to the heritage values of the item, designed with heritage architect input and be reversible where feasible.	BL/GHF

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection.

Environmental management measures identified in previous sections of this environmental impact statement will also mitigate potential impacts to non-Aboriginal heritage. These are identified in Table 14-6.

Table 14-6 Environmental management measures for non-Aboriginal heritage impacts identified in other sections of the environmental impact statement

Ref	Phase	Impact	Environmental management measure	Location
SG7	Pre-construction, construction	Ground movement impacts	Pre-construction building structure condition surveys will be offered and prepared (where the offer is accepted by the owner) for properties (and heritage assets) within the zone of influence of tunnel settlement where the degree of severity has been assessed as 'slight' or above and within the minimum working distances for cosmetic and structural damage due to vibration. The surveys will be carried out by a suitably qualified person prior to the commencement of the tunnelling and vibration-intensive activities in the vicinity with the potential to affect the building/structure. Within three (3) months of the completion of construction activities that have the potential to cause settlement or vibration-related damage to the subject surface/subsurface structure, all property owners of buildings for which a pre-construction building condition survey was carried out will be offered a second building condition survey. Where an offer is accepted, a post-construction building condition surveys will be carried out by a suitably qualified person. The results of the surveys will be documented in a post-construction building condition survey report for each building surveyed. Copies of building condition survey reports will be provided to the owners of the buildings surveyed within one (1) month of the survey being completed. Any building and/or property damage from settlement caused by the project will be repaired at no cost to the owner. Any repairs to listed heritage items required as a result of the settlement damage, will be carried out under the guidance of a suitably qualified and experienced heritage professional.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
CNV7	Construction	Construction vibration impacts	Vibration generating activities will be managed through the establishment of minimum buffer distances to achieve screening levels. Where vibration levels are predicted to exceed the screening levels, a more detailed assessment of the impacted structure will be carried out to assess the susceptibility of the structure to damage from vibration due to the project. Appropriate mitigation and management measures, such as equipment substitution and alternative methods, will be identified and implemented to avoid damage. Attended vibration monitoring will be carried out during vibration intensive activities in the vicinity to ensure vibration levels remain below appropriate limits for that structure. For heritage items, the more detailed assessment will specifically consider the heritage values of the structure in consultation with a heritage specialist to ensure sensitive heritage fabric is adequately monitored and managed. Pre-construction building structure condition surveys will be carried out in accordance with environmental management measure SG7. Any building and/or structure damage from vibration caused by the project would be repaired at no cost to the owner.	BL/GHF

There are environmental management measures that would contribute to the mitigation and management of non-Aboriginal heritage impacts associated with the Western Harbour Tunnel and Beaches Link program of works, which are committed to within the Submissions report for the Western Harbour Tunnel and Warringah Freeway Upgrade project. The implementation of these management measures would also mitigate potential non-Aboriginal heritage impacts associated with this project. These include:

- A thematic heritage study of golf courses in Sydney will be prepared for the region north of the Sydney Harbour. This study will assist in identifying other potential heritage items in the region that demonstrate the same or similar significance as the Cammeray Golf Course (Revised environmental management measure NAH8)
- Archival recording will be carried out in accordance with the *Photographic Recording of Heritage Items Using Film or Digital Capture* guideline for areas/items subject to change within the following items, in accordance with Appendix J (Technical working paper: Non-Aboriginal heritage):
  - f) Cammeray Park (including the Golf Course), Cammeray
  - g) Cammeray Conservation Area, Cammeray (Revised environmental management measure NAH5).