Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 23

Hazards and risks

transport.nsw.gov.au

DECEMBER 2020

23 Hazards and risks

This chapter assesses potential hazards arising from possible incidents during project construction and operation that could pose a risk to public safety, the surrounding community or the environment, and summarises the approaches taken to manage these risks. Other potential environmental hazards resulting from construction and operation of the project, and measures to avoid, mitigate and manage these risks are addressed in Chapter 8 (Construction traffic and transport) to Chapter 27 (Cumulative impacts) of this environmental impact statement. The impacts associated with human health risks are detailed in Chapter 13 (Human health).

The Secretary's environmental assessment requirements as they relate to hazard and risk impacts, and where in the environmental impact statement these have been addressed, are detailed in Table 23-1.

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 hazards and risks are included in Section 23.4.

Table 23-1 Secretary's environmental assessment requirements – hazards and risks

Secretary's requirement	Where addressed in EIS
Transport and traffic	
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 j. impacts to water-based traffic on Middle Harbour.	Within **Chapter 6** (Construction work), **Section 6.7** and **Section 6.8** show the land and maritime construction traffic/vessel movements for each temporary construction support site, as well as the operating hours of each site. Construction traffic routes are discussed in **Chapter 8** (Construction traffic and transport). **Section 8.4** discusses the proposed marine and land transport movements. **Section 23.2.4** outlines interactions between maritime traffic and tunnel infrastructure during construction.
Health and safety	

Secretary's requirement	Where addressed in EIS
2. The assessment must: 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.	An assessment of bushfire risks relating to construction and operation is presented in **Section 23.2.6** and **Section 23.3.5** respectively. The handling, transport and use of dangerous goods is described in **Section 23.2** and **Section 23.3**. An assessment of potential ground movement associated with the project is provided in **Chapter 16** (Geology, soils and groundwater). Ground movement due to construction activities is also discussed in **Section 23.2.3.** Pedestrian safety is discussed in **Chapter 8** (Construction traffic and transport). **Section 23.3.3** provides an assessment of the impacts of potential traffic incidents during operation.
Socio-economic, land use and property	
4. The Proponent must assess potential impacts on utilities (including communications, electricity, gas, fuel and water and sewerage) and the relocation of these utilities.	**Chapter 6** (Construction work) details utilities impacted during construction. **Chapter 5** (Project description) outlines utilities and services management for the project. **Appendix D** (Utilities management strategy) provides a detailed description of utilities likely to be impacted and a framework for utility adjustment, relocation and protection. The framework is outlined in **Section 23.2.5**.
Hazards	
1. The Proponent must describe the process for assessing the risk of emissions from ventilation facilities on aircraft operations taking into consideration the requirements of the *Airports Act 1996* (Commonwealth) and the Airports Regulations 1997.	The process for the assessment of risk of emissions from ventilation facilities on aircraft operation is described in **Chapter 2** (Assessment process). The findings of the assessment are summarised in **Section 23.3.6.**

23.1 Assessment methodology

An assessment was carried out to identify environmental hazards and risks that could arise during construction and operation of the project, as well as appropriate risk management measures.

The assessment focused on those hazards with the potential to adversely affect the surrounding environment, and general public. It took into account the following guidelines:

- *Hazardous and Offensive Development Application Guidelines: Applying SEPP 33* (Department of Planning, 2011)
- *Australian Code for the Transport of Dangerous Goods by Road and Rail* (7th edition) (National Transport Commission, 2007)
- *Storage and Handling of Dangerous Goods Code of Practice* (WorkCover, 2005)
- *Planning for Bushfire Protection* (Rural Fire Service (RFS), 2019)

- *Bush Fire Risk Management Planning Guidelines for Bush Fire Management Committees* (RFS, 2008)
- *Garigal National Park Fire Management Strategy* (Department of Environment and Conservation (DEC), 2006b)
- *Manly Warringah War Memorial Park Fire Regime Management Plan* (Eco Logical Australia, 2006)
- Bushfire prone land mapping developed and published by the relevant local councils
- Relevant Bush Fire Risk Management Plans including:
  - *Mosman North Sydney Willoughby Bush Fire Risk Management Plan 2017–2022* (Mosman North Sydney Willoughby Bush Fire Management Committee, 2017)
  - *Warringah Pittwater Bush Fire Risk Management Plan 2010–2015* (Warringah Pittwater Bush Fire Management Committee, 2010).

23.2 Assessment of potential construction impacts

During construction, potential hazards and risks to public safety, the surrounding community or the environment may be associated with:

- Storage and handling of dangerous goods and hazardous substances (Section 23.2.1)
- Transport of dangerous goods and hazardous substances (Section 23.2.2)
- Ground movement (settlement) or geotechnical uncertainty (Section 23.2.3)
- Interactions between maritime traffic and tunnel infrastructure (Section 23.2.4)
- Damage to, or disruption of, both underground and above ground utilities (Section 23.2.5)
- Bushfires (Section 23.2.6).

Other potential environmental hazards resulting from the construction of the project are considered and addressed in the relevant chapters of this environmental impact assessment.

23.2.1 Storage and handling of dangerous goods and hazardous substances

The anticipated types and quantities of dangerous goods and hazardous substances that would be stored and used at the temporary construction support sites are listed in Table 23-2. The types and quantities of dangerous goods and hazardous substances are indicative and would be confirmed during further design development and detailed construction planning, and if necessary, further screening of potential risks would be carried out at that time. The screening would be used to confirm that the project would not pose a substantial off-site risk.

State Environmental Planning Policy No 33 – Hazardous and Offensive Development (SEPP 33) presents a systematic approach to the assessment of development proposals for potentially hazardous and offensive industry or storage. SEPP 33 ensures that proposals can be built and operated with an adequate level of safety and pollution control. *Hazardous and Offensive Development Application Guidelines: Applying SEPP 33* (Applying SEPP 33) (Department of Planning, 2011) includes a screening method, based on the quantities of dangerous goods on a site, to assist in determining if a proposed development is considered potentially hazardous and offensive under SEPP 33.

A screening comparison of the indicative quantities of dangerous goods to be stored at the temporary construction support sites against the threshold quantities listed in Applying SEPP 33 has been carried out. These thresholds represent the level at which dangerous goods may present a credible off-site risk requiring further, more detailed assessment. The comparison against the screening thresholds in Applying SEPP 33 is included in Table 23-2. Other potentially dangerous goods and hazardous substances to be used during construction of the project and not listed in Applying SEPP 33 have also been included in Table 23-2 for completeness.

Table 23-2 demonstrates that the Applying SEPP 33 inventory thresholds would not be exceeded for any material at any temporary construction support site. The storage and use of dangerous goods and hazardous materials at the temporary construction support sites would therefore not pose an unacceptable risk of harm beyond the temporary construction support site boundary.

Environmental hazards and risks associated with the on-site storage and use of chemicals, fuels and materials would be managed through standard mitigation measures (refer to Section 23.4). Storage of dangerous goods and hazardous substances would be in accordance with the supplier's instructions, and would comply with applicable legislation, guidelines and Australian Standards.

Table 23-2 Indicative dangerous goods and hazardous substances stored at temporary construction support sites

Material	Australian Dangerous Goods Code class	Storage method	Assessment against Applying SEPP 33 inventory thresholds	Temporary construction support site
Explosives	1.1	No on site storage – delivery would be timed to avoid the need for on-site storage	Explosives would not be stored on site and would therefore not be subject to the Applying SEPP 33 thresholds.	N/A
Diesel	C1[1], 3 PG III[2]	Self-bunded fuel tank (up to 2.5 kilolitres) and 20 litre drums	Diesel would be less than five tonnes and would not be stored with Class 3 (flammable liquids) materials. It would therefore not be subject to the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Petrol	C1[1], 3 PG III[2]	Self-bunded fuel tank (up to 2.5 kilolitres) and 20 litre drums	Petrol would be less than five tonnes and would not be stored with Class 3 materials. It would therefore not be subject to the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Lubricating and hydraulic oils and grease	C2	20 litre drums	Lubricating and hydraulic oils and grease would not be stored with Class 3 materials and would therefore not be subject to the Applying SEPP 33 thresholds.	All temporary construction support sites.
Industrial grade acetylene	2.1	3.2 m^3 cylinders (13 kilograms)	Individual cylinders containing acetylene would not trigger the Applying SEPP 33 thresholds (100 kilograms). Maximum stored inventories (250 kilograms) would be located more than 25 metres away from the temporary construction support site boundary and would therefore also not trigger the Applying SEPP 33 thresholds if considered in aggregate.	All temporary construction support sites.

Material	Australian Dangerous Goods Code class	Storage method	Assessment against Applying SEPP 33 inventory thresholds	Temporary construction support site
Industrial grade oxygen	2.2	8.9 m^3 cylinders	Industrial grade oxygen is a class 2.2 dangerous good and is therefore not subject to the Applying SEPP 33 thresholds.	All temporary construction support sites.
Accelerator for shotcrete	3.2	1000 litre intermediate bulk containers (IBC)	Individual IBCs containing accelerator fluid would not trigger the Applying SEPP 33 thresholds (five tonnes). Maximum stored inventories (20,000 litres) would be located more than eight metres away from the temporary construction support site boundary and would therefore also not trigger the Applying SEPP 33 thresholds if considered in aggregate.	• Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13) • Wakehurst Parkway north (BL14).
Retardants for concrete	3 PGIII	205 litre drums	Retardants would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.	All land based temporary construction support sites.
Epoxies	3 PGIII	20 litre drums	Epoxies would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.	All temporary construction support sites.
Acids	8 PGIII	1000 litre IBC (and smaller containers)	Acids would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.	All temporary construction support sites.
Bases	8 PGIII	1000 litre IBC	Bases would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.	All temporary construction support sites.
Disinfectants	8 PGIII	500 litre IBC	Disinfectants would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.	All land based temporary construction support sites.

Material	Australian Dangerous Goods Code class	Storage method	Assessment against Applying SEPP 33 inventory thresholds	Temporary construction support site
General purpose Portland cement	N/A	20 kilogram bags	Cement is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Road and joint sealants	N/A	12 litre boxes	Road and joint sealants are not a dangerous good and therefore do not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites (except Spit West Reserve (BL9)).
Concrete curing compounds	N/A	1000 litre IBC	Concrete curing compounds are not a dangerous good and therefore do not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Pavement layers curing compound	N/A	1000 litre IBC	Pavement layers and curing compounds are not a dangerous good and therefore do not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Paint for tunnel roof	N/A	1000 litre IBCs	Paint is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	• Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).
Paints	N/A	50 litre drums	Paints are not a dangerous good and therefore do not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Coagulants	N/A	1000 litre IBCs	Coagulants are not a dangerous good and therefore do not trigger the Applying SEPP 33 thresholds.	• Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).

Material	Australian Dangerous Goods Code class	Storage method	Assessment against Applying SEPP 33 inventory thresholds	Temporary construction support site
Anti-scalent	N/A	100 litre drums	Anti-scalent is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	• Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).

Note 1: Classified as C1 if not stored with other Class 3 flammable liquids
Note 2: Classified as 3 PG III if stored with other Class 3 flammable liquids

23.2.2 Transport of dangerous goods and hazardous substances

Dangerous goods and hazardous materials that would be transported to each temporary construction support site are outlined in Table 23-3. Potential transportation hazards and risks have been considered through comparison of the likely type, quantity and frequency of dangerous goods and hazardous materials transportation with the thresholds presented in Applying SEPP 33. In all cases, the transportation of dangerous goods and hazardous materials to temporary construction support sites would be below the Applying SEPP 33 thresholds. This indicates that risks associated with transport of dangerous goods and hazardous materials would not be significant.

The proposed haulage routes outlined in Chapter 6 (Construction work) have been identified to avoid local roads where possible and would therefore minimise the risks associated with the transport of dangerous goods and hazardous materials.

Table 23-3 Indicative dangerous goods and hazardous substances transported to temporary construction support sites

Material	Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Assessment against Applying SEPP 33 transport thresholds	Temporary construction support site destination
Explosives	1.1	As required, if blasting is carried out.	As required	Not subject to the Applying SEPP 33 thresholds if not transported with Class 3 dangerous goods.	• Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).
Diesel[1]	C1[2], 3 PG III[3]	Daily	1500 litres	Not subject to the Applying SEPP 33 thresholds if not transported with Class 3 dangerous goods. Refuelling at cofferdams would be carried out by fit for purpose refuelling barges.	All temporary construction support sites.
Petrol[1]	C1[2], 3 PG III[3]	Weekly	50 litres	Not subject to the Applying SEPP 33 thresholds if not transported with Class 3 dangerous goods. Refuelling at cofferdams would be carried out by fit for purpose refuelling barges.	All temporary construction support sites.
Lubricating and hydraulic oils and grease	C2	Weekly	40 litres	Not subject to the Applying SEPP 33 thresholds if not transported with Class 3 dangerous goods.	All temporary construction support sites.
Industrial grade acetylene	2.1	Monthly	410 litres[4]	Transport quantities would not trigger the Applying SEPP 33 thresholds.	All temporary construction support sites.
Industrial grade oxygen	2.2	Monthly	410 litres[4]	Not subject to Applying SEPP 33 transport thresholds	All temporary construction support sites.

Material	Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Assessment against Applying SEPP 33 transport thresholds	Temporary construction support site destination
Accelerator for shotcrete	3PGII	Weekly	100 litres[4]	Transport quantities would not trigger the Applying SEPP 33 thresholds.	• Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13) • Wakehurst Parkway north (BL14).
Retardants for concrete	3PGIII	Monthly	205 litre drum	Transport quantities would not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Epoxies	3PGIII	Monthly	20 litres[4]	Transport quantities would not trigger the Applying SEPP 33 thresholds.	All temporary construction support sites.
Acids	8 PGIII	Monthly	20 litres[4]	Not subject to Applying SEPP 33 transport thresholds.	All temporary construction support sites.
Bases	8 PGIII	Monthly	20 litres[4]	Not subject to Applying SEPP 33 transport thresholds.	All temporary construction support sites.
Disinfectants	8 PGIII	Monthly	20 litres[4]	Not subject to Applying SEPP 33 transport thresholds.	All land based temporary construction support sites.
General purpose Portland cement	N/A	Monthly	72 bags[4]	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Road and joint sealants	N/A	Monthly	Four 12 litre boxes	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites (except Spit West Reserve (BL9)).

Material	Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Assessment against Applying SEPP 33 transport thresholds	Temporary construction support site destination
Concrete curing compounds	N/A	Monthly	50 litres	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Pavement layers curing compound	N/A	Monthly	100 litres	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Paint for tunnel roof	N/A	Five to six deliveries	50 litre drums	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	• Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).

Material	Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Assessment against Applying SEPP 33 transport thresholds	Temporary construction support site destination
Paints	N/A	Monthly (during the second half of construction program)	250 litres	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Coagulants	N/A	Monthly	150 kilograms	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	• Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).
Anti-scalent	N/A	Monthly	1000 litres	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	• Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).

Note 1: For some temporary construction support sites, the quantity of diesel and unleaded petrol delivered to site would be greater than the quantity stored within the facility at any time, because the delivery volume takes into the account fuel which is brought to the facility by mini-tanker and used to directly refuel plant. As this fuel is 'in use' in the plant it is not classified as 'stored'.
Note 2: Classified as C1 if not stored with other Class 3 flammable liquids.
Note 3: Classified as 3 PG III if stored with other Class 3 flammable liquids.
Note 4: Per temporary construction support site.

23.2.3 Ground movement and geological uncertainty

Ground movement (or settlement) refers to a localised lowering of the ground level due to construction activities involving excavation or disturbance below ground. If unmanaged, ground movement can present a risk to the stability of nearby buildings and other structures, including building basements and ground support structures.

Ground movement may occur as a result of:

- Tunnel induced movement caused by the relief of stress from the removal of intact rock during tunnelling
- Settlement induced by groundwater drawdown.

The construction of tunnels, even using the most modern machinery and control methods, results in some volume loss and corresponding ground movement. Geotechnical investigations have confirmed that high quality Hawkesbury Sandstone would be encountered for the majority of the proposed tunnel alignment. Furthermore, the alignment of the proposed tunnels means that they would be very deep for the majority of their length, with a substantial amount of sandstone between the tunnels and surface. Most of the induced settlement along the alignment due to tunnel excavation would therefore likely be as a result of stress redistribution within the rock mass.

An assessment of potential ground movement associated with the project is provided in Chapter 16 (Geology, soils and groundwater). Preliminary ground movement predictions indicate that there may be potential settlement of up to 40 millimetres around the Burnt Bridge Creek Deviation and Wakehurst Parkway portals. This would be considered 'slight' severity under relevant guidelines. Potential settlement at Flat Rock Creek Reserve could reach 85 millimetres, however no buildings are present at this location. This prediction assumes that groundwater inflows into the tunnel beneath Flat Rock Reserve are unconstrained. Additional modelling and settlement predictions at this location indicated that when reduced inflows and groundwater drawdown were taken into account, the maximum predicted total settlement reduced to 35 millimetres.

For most of the tunnelling works, the anticipated drawdown in the groundwater table would occur within the bedrock stratigraphy above the tunnel and this drawdown is assessed not to cause consolidation settlement in the overlying natural or filled soils, which are currently above the groundwater table. However, tunnelling works could potentially lower the groundwater table within poorly consolidated fill which could result in surface settlements where the tunnel crosses beneath the former Flat Rock Creek. At this location, the tunnelling works could drain the groundwater currently “ponded” within landfill in the former creek. Inflow of groundwater into the tunnels would result in a depressurisation of the groundwater surrounding the tunnels and could lead to ground settlement.

The groundwater and settlement modelling completed for this environmental impact statement is conservative in that it disregards the effects of the permanent concrete and waterproofing linings that will be installed within the tunnels. The tunnel will be designed to limit groundwater inflow into the tunnel, minimising the actual groundwater drawdown and associated settlement predicted to occur during construction.

A number of major design and construction method reviews have been carried out to better understand the Lane Cove Tunnel failure which occurred at Longueville in 2005. The causes of the failure are generally cited as a complex combination of factors, including the changing ground conditions and geological defects and the inadequacy of the tunnel support system.

The risks of a similar incident occurring during a Sydney tunnelling project are considered extremely low. The reasons for this include:

- Vastly improved geotechnical assessment and modelling
- Improved predictive two dimensional and three dimensional modelling of geology, excavation spans, temporary and permanent loads

- Fit for purpose design to develop the appropriate type of ‘support’ to match the ground conditions as the excavation progresses on a day to day basis
- Continuous independent review of the temporary and permanent works design and construction methods
- Continual construction verification that tunnel support is installed and performing as per the design
- Robust change management processes for conditions that are out of the ordinary or unexpected, including probe drilling and ground treatment through suspected poor ground zones
- Continuous assessment of likely excavation and groundwater conditions
- Detailed survey monitoring of surface roads, buildings and structures in the tunnel vicinity.

In addition to the consideration of the above, the project design and tunnel construction methods have been informed by early geotechnical investigations to reduce the construction risks associated with uncertain ground conditions (additional geotechnical investigations would be carried out during further design development to confirm ground conditions, where required). Primary support for the tunnels would be installed as the excavation progresses, as recommended by an appropriately qualified geotechnical or tunnel engineer, to ensure tunnel stability during construction.

23.2.4 Interactions between maritime traffic and tunnel infrastructure

The project would require marine vessel movements during construction of the immersed tube tunnels in Middle Harbour, including:

- Barges for construction activities including delivering construction materials, removing cofferdam spoil and removing dredged material
- Dredging vessels
- Barges with piling equipment and cranes
- Tugboats for manoeuvring barges
- Transport vessels for workers.

The steel shells for the immersed tube tunnel units for the Middle Harbour crossing would be prepared at a location outside of Middle Harbour. Once prepared, the immersed tube tunnel steel shells would be transported by sea either on a barge or directly towed and guided by several tug boats to Middle Harbour, through the Spit Bridge navigation channel and moored at Spit West Reserve construction support site (BL9) to be completed.

There is a shallow sand bar located near the entrance to Middle Harbour which would need to be navigated by the barge or tug boat and immersed tunnel unit steel shells. While the waterway at the Middle Harbour entrance is relatively wide, the water depths through the deepest part of the channel are about 4.5 metres, becoming shallower at low tide. The immersed tube tunnel units have been designed as incomplete steel shells so that they would be lighter during transportation into Middle Harbour. The steel shell design would enable the barge or floating immersed tube tunnel unit steel shells to float higher in the water, enabling their safe and efficient transport over the shallow sand bar and into Middle Harbour. This would minimise the potential for the vessel (barge or tug boat) transporting the immersed tube tunnel unit steel shells, or the floating steel shells, grounding on the shallow sand bar. Casting of the steel shells with reinforced concrete and fitout of the completed immersed tube tunnels would be carried out at Spit West Reserve construction support site (BL9) prior to immersion.

During immersion of the tube tunnel units, there is a risk that maritime traffic could collide with the units if they pass the location of the Middle Harbour crossing before the tube tunnel units are in their final position on the bed of the harbour. The timeframe for immersion would be very short

(less than two days per unit), and measures would be put in place to manage potential risks, including restrictions such as partial or full closures to marine vessel movements through the crossing location during immersion of the tube tunnels. As outlined in Chapter 8 (Construction traffic and transport), simulation modelling has demonstrated that the transportation of both steel shell and completed immersed tube tunnel units can be carried out safely.

23.2.5 Damage or disruption to underground and above ground utilities

The project has been designed, where possible, to avoid utilities, taking into account the results of utility investigations and consultation with utility providers carried out during the design process (refer to Chapter 7 (Stakeholder and community engagement)). Where the project is unable to avoid utilities, if possible, they would be adjusted, relocated or protected prior to the commencement of construction to avoid impacts. Alternatively, adjustment, relocation or protection would occur during construction.

Consultation with utility providers would continue during the further design development and construction planning phases of the project to mitigate the risk of unplanned and unexpected disturbance of utilities. In rare circumstances, the relocation of utilities may result in planned short term outages of some utilities to surrounding areas. Utilities which would be directly impacted and require adjustment, protection or relocation have been considered in Appendix D (Utilities management strategy).

23.2.6 Bushfires

A bushfire risk assessment was carried out to assess potential bushfire implications of the project. In accordance with *Planning for Bushfire Protection* (RFS, 2019) the predominant vegetation class (bushfire prone land) has been assessed to a distance of 140 metres from the project in all directions. Table 23-4 provides the assessed bushfire risk level for temporary construction support sites located on, or close to, bushfire prone land. The level of bushfire risk is determined using a combination of likelihood and consequence, with the likelihood of bushfire risk for all assets being defined as the chance of a bushfire igniting and spreading and the consequence being the outcome or impact of a bushfire event (RFS, 2008).

Table 23-4 Bushfire risk level for temporary construction support sites

Temporary construction support site(s)	Bushfire risk level	Proximity to bushfire prone land
Cammeray Golf Course (BL1)	Low	No bushfire prone land within 140 metres.
Flat Rock Drive (BL2)	Low	The northern, eastern and southern areas of the temporary construction support site would be within 10 metres of bushfire prone land.
Punch Street (BL3) Dickson Avenue (BL4) Barton Road (BL5) Gore Hill Freeway median (BL6)	Low	The northern portion of the Punch Street construction support site (BL3) would be located more than 70 metres from bushfire prone land (and separated by Gore Hill Freeway). Other temporary construction support sites would be located greater than 100 metres from bushfire prone land.
Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8)	N/A	Not applicable as the temporary construction support sites would be located within Middle Harbour.

Temporary construction support site(s)	Bushfire risk level	Proximity to bushfire prone land
Spit West Reserve (BL9)	Low	No land based structures are proposed within the temporary construction support site, with site access only proposed.
Balgowlah Golf Course (BL10) Kitchener Street (BL11)	Low	The northern portion of the Balgowlah Golf Couse construction support site (BL10) would be located within 60 metres of bushfire prone land.
Wakehurst Parkway south (BL12) Wakehurst Parkway east (BL13)	Medium	These two temporary construction support sites would be located in an area classified as bushfire prone land.
Wakehurst Parkway north (BL14)	High	This temporary construction support site would be located in an area classified as bushfire prone land.

The bushfire risk assessment identified that during construction, all areas of the project, with the exception of areas along the Wakehurst Parkway, would have a bushfire risk level of 'low'. With respect to the Wakehurst Parkway, the risk of bushfires would be considered higher, with the Wakehurst Parkway south (BL12) and Wakehurst Parkway east (BL13) temporary construction support sites assessed as having a bushfire risk level of 'medium' and Wakehurst Parkway north construction support site (BL14) having a rating of 'high'. The difference in these ratings is largely as a result of greater consequences should a bushfire occur.

Several areas associated with the project, including areas within Naremburn, Northbridge and Frenchs Forest are identified in the *Mosman North Sydney Willoughby Bushfire Risk Management Plan 2017-2022* (Mosman North Sydney Willoughby Bush Fire Management Committee, 2008) and the *Warringah Pittwater Bush Fire Risk Management Plan 2010–2015* (Warringah Pittwater Bush Fire Management Committee, 2010) as being subject to bushfire planning measures. Council management of these areas would contribute to the bushfire protection measures for the relevant temporary construction support sites.

Strategies to reduce risk from bushfire, such as site layout, setbacks from bushfire prone vegetation, access and emergency procedures along the Wakehurst Parkway would be developed and implemented during construction (refer to Section 23.4).

23.3 Assessment of potential operational impacts

During operation, potential hazards and risks to public safety, the surrounding community or the environment may be associated with:

- Storage and handling of dangerous goods and hazardous substances (Section 23.3.1)
- Transport of dangerous goods and hazardous substances (Section 23.3.2)
- Traffic incidents on surface roads and within tunnels (Section 23.3.3)
- Interactions between maritime traffic and tunnel infrastructure (Section 23.3.4)
- Bushfires (Section 23.3.5)
- Atmospheric turbulence caused by discharges from the ventilation outlets and motorway facilities at the Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and the Wakehurst Parkway and the interface with aviation (Section 23.3.6).

Other potential environmental hazards resulting from the operation of the project are considered and addressed in the relevant chapters of this environmental impact statement.

23.3.1 Storage and handling of dangerous goods and hazardous substances

Dangerous goods and hazardous materials would be stored at the operational facilities to be provided as part of the project and used during operation of the project. The types and quantities of dangerous goods and hazardous materials to be stored on-site during operation are summarised in Table 23-5. Additional small quantities of other materials may be required on-site from time to time to support maintenance activities. Managed in accordance with the measures in Section 23.4, these materials would not pose a substantial risk to the general public during operation of the project.

Comparison of the types and quantities of dangerous goods and hazardous materials to be stored on-site with the thresholds outlined in Applying SEPP 33, demonstrates that operational inventories would not pose a substantial risk of harm beyond the boundary of the operational facilities.

Table 23-5 Indicative dangerous goods and hazardous substances stored on site during operation

Material and Australian Dangerous Goods Code class	Storage method (amount stored at any one time)	Inventory thresholds in Applying SEPP 33	Assessment against Applying SEPP 33 inventory thresholds
Diesel C1[1], 3 PG III[2]	Bunded tanks on site.	N/A	Diesel would be less than five tonnes and would not be stored with Class 3 materials. It would therefore not be subject to the Applying SEPP 33 thresholds.
Grease C2	400-gram cartridge, 20 litre containers stored undercover on site.	N/A	Grease would not be stored with Class 3 materials and would therefore not be subject to the Applying SEPP 33 thresholds.
Adhesives C2, PGIII	375-gram cartridge, 20 litre containers stored on site.	Five tonnes	Adhesives would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.
Acetylene C2.1	Size G cylinders on site.	100 kilograms	Individual cylinders containing acetylene would not trigger the Applying SEPP 33 thresholds. Maximum stored inventories would not trigger the Applying SEPP 33 thresholds if considered in aggregate.
Linemarking aerosol C2.1	375 millimetre aerosol container stored undercover on site.	100 kilograms	Linemarking aerosol would not trigger the Applying SEPP 33 thresholds.
Oxygen C2.2	Size G cylinders on site.	N/A	Industrial grade oxygen is a Class 2.2 dangerous good and is not subject to the Applying SEPP 33 thresholds.
Kerosene C3, PGIII	20 litre containers stored in an undercover bunded area on site.	Five tonnes	Kerosene would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.
Oxygen (subsidiary risk) C5.1	Size G cylinders on site.	Five tonnes	Oxygen has a subsidiary risk Class of 5.1. It would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.

Material and Australian Dangerous Goods Code class	Storage method (amount stored at any one time)	Inventory thresholds in Applying SEPP 33	Assessment against Applying SEPP 33 inventory thresholds
Sodium hydroxide C8, PGII	10,000 litre feed tank in an undercover bunded area on site.	25 tonnes	Sodium hydroxide would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.
Bitumen C9	12,000 litre tanker (brought onto site as required).	N/A	Bitumen is a Class 9 dangerous good and is not subject to the Applying SEPP 33 thresholds.
Coagulant N/A	12,000 litre feed tank in an undercover bunded area on site.	N/A	Coagulant is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.
Polymers N/A	20 kilogram bags stored in a container and undercover on site.	N/A	Polymers are not classified as a dangerous good and would not trigger the Applying SEPP 33 thresholds.
Non-shrink grout N/A	20 kilogram bags stored undercover on site.	N/A	Non-shrink grout is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.
Release agent (lanolin-based) N/A	20 litre drums stored undercover on site.	N/A	Release agent (lanolin-based) is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.

Note 1: Classified as C1 if not stored with other Class 3 flammable liquids
Note 2: Classified as 3 PG III if stored with other Class 3 flammable liquids

23.3.2 Transport of dangerous goods and hazardous substances

Dangerous goods and hazardous materials that would be transported to the project during operation are outlined in Table 23-6. The risks associated with transport of dangerous goods and hazardous materials would not be high.

Prior to opening to traffic, the mainline tunnels would be listed as prohibited areas under Road Rules 2014 – Rule 300-2: NSW rule: carriage of dangerous goods in prohibited areas (Regulation 300-2). The transport of dangerous goods in prohibited areas, including the mainline tunnels, would be prohibited. Signage would be provided near tunnel entry points advising of applicable restrictions to ensure compliance with Rule 300-2.

Table 23-6 Indicative dangerous goods and hazardous substances transported during operation

Material and Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Transport thresholds in Applying SEPP 33	Assessment against Applying SEPP 33 transport thresholds
Diesel C1[1], 3 PG III[2]	As required	As required	N/A	Diesel would not be transported with Class 3 materials and would therefore not be subject to the Applying SEPP 33 thresholds.
Grease C2	Weekly	50 cartridges (20 kilograms)	N/A	Grease would not be transported with Class 3 materials and would therefore not be subject to Applying SEPP 33 thresholds.
Adhesives C2, PGIII	Weekly	50 cartridges (19 kilograms)	Minimum transport load or transport frequency of 10 tonnes, more than 60 times per week	Adhesives would not trigger the Applying SEPP 33 thresholds.
Acetylene C2.1	Weekly	50 cylinders	Minimum transport load or transport frequency of two tonnes, more than 30 times per week	Industrial grade acetylene would not trigger the Applying SEPP 33 thresholds for minimum transport load or transport frequency of two tonnes, more than 30 times per week.
Line-marking aerosol C2.1	Quarterly	50 cans	Minimum transport load or transport frequency of two tonnes, more than 30 times per week	Line-marking aerosol would not trigger the Applying SEPP 33 thresholds.
Oxygen C2.2	Weekly	50 cylinders	N/A	Industrial grade oxygen is a Class 2.2 dangerous good and is not subject to the Applying SEPP 33 thresholds.
Kerosene C3, PGIII	Monthly	80 litres	Minimum transport load or transport frequency of 10 tonnes, more than 60 times per week	Kerosene would not trigger the Applying SEPP 33 thresholds.
Oxygen (subsidiary risk) C5.1	Weekly	50 cylinders	Minimum transport load or transport frequency of two tonnes, more than 30 times per week	Oxygen has a subsidiary risk Class of 5.1. It would not trigger the Applying SEPP 33 thresholds.

Material and Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Transport thresholds in Applying SEPP 33	Assessment against Applying SEPP 33 transport thresholds
Sodium hydroxide C8, PGII	Six monthly	10,000 litres	Minimum transport load of 25 tonnes	Sodium hydroxide would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.
Bitumen C9	Quarterly	12,000 litres	Minimum transport frequency of more than 60 times per week	Bitumen would not trigger the Applying SEPP 33 thresholds.
Coagulant N/A	Quarterly	10,000 litres	N/A	Coagulant is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.
Polymers N/A	Quarterly	1000 kilograms	N/A	Polymers are not classified as a dangerous good and would not trigger the Applying SEPP 33 thresholds.
Non-shrink grout N/A	Monthly	1900 kilograms	N/A	Non-shrink grout is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.
Release agent (lanolin-based) N/A	Twice monthly	180 litres	N/A	Release agent (lanolin-based) is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.

Note 1: Classified as C1 if not stored with other Class 3 flammable liquids
Note 2: Classified as 3 PG III if stored with other Class 3 flammable liquids

23.3.3 Traffic incidents

The project has been designed to provide efficient, free flowing traffic conditions with capacity to safely accommodate forecast traffic volumes. The project design incorporates all feasible and reasonable traffic safety measures including those related to geometry, pavement, lighting, signage and shared user infrastructure consistent with current Australian Standards, road design guidelines and industry best practice. In doing so, the design of the project inherently minimises the likelihood of incidents and accidents.

Each project tunnel would be one-directional, reducing the risk of crashes through head on collisions and simplifying smoke management and egress requirements. The transport of dangerous goods and hazardous substances would be prohibited through the mainline and ramp tunnels and on and off ramps, reducing the risk of very large fires or the release of toxic materials in the tunnels.

Notwithstanding, human factors in particular cannot be entirely removed during operation of the project and there would remain a residual risk of incidents and accidents. In the event of incidents and accidents, the project has been designed to meet appropriate fire and life safety requirements. The key fire and life safety aspects of the project are described in Chapter 5 (Project description), and would include maintenance and emergency breakdown bays, fire and incident detection equipment, communications systems, fire suppression systems, emergency lighting, smoke management and power systems, cross passages or longitudinal egress passages, and tunnel closure systems. The fire and life safety systems would be installed in accordance with Australian Standard *AS 4825:2011 Tunnel Fire Safety*, applicable Austroads and Transport for NSW guidelines, and the outcomes of consultation with emergency services.

In the event of an incident, approaching traffic would be prevented from entering the mainline and ramp tunnels. Vehicle occupants upstream of the fire or incident would be instructed to stop their vehicles, and exit in the opposite direction through the section of carriageway that would be protected by the smoke management system, or through an exit door to a pressurised and fire rated cross-passage leading to the other non-incident tunnel.

Occupants downstream of the fire or incident would be encouraged to continue driving out of the tunnel. If this is not possible and they are forced to evacuate on foot, egress would be provided via exit doors to pressurised and fire rated cross-passages leading to the non-incident tunnel. Emergency services would be able to reach the fire or incident via the non-incident tunnel, or from the upstream direction in the affected tunnel. Emergency vehicle cross passages have also been included in the design at key locations.

During emergency conditions the ventilation system would extract smoke from the affected tunnels. Depending on the location of the incident, smoke would be emitted from one or more of the ventilation outlets and from the ramp tunnel portals at the ramp tunnel surface connections.

23.3.4 Interactions between maritime traffic and tunnel infrastructure

The crossing of Middle Harbour would comprise two immersed tube tunnels between Northbridge and Seaforth. The immersed tube tunnels would be located within a tunnel trench on the bed of Middle Harbour. The immersed tube units would be placed to provide sufficient clearance for all maritime traffic in Middle Harbour.

With respect to maritime traffic, the immersed tube tunnel units would be appropriately designed including with an additional layer of concrete to protect against:

- Falling and dragging anchors
- Sinking vessels
- High currents
- Propeller wash and vessel wake.

As such, it is not expected that there would be any risk to the tunnels during operation of the project as a result of maritime traffic.

23.3.5 Bushfires

Most of the project's operational facilities would not be vulnerable to bushfire attack due to its incombustible nature (road surface materials, retaining walls, road barriers), fire safety ratings and/or location underground.

However, some operational facilities would be located on or close to bushfire prone land. These facilities and their associated bushfire risk are listed in Table 23-7.

Table 23-7 Bushfire risk level for operational sites

Operational facilities	Bushfire risk level	Proximity to bushfire prone land
Ventilation outlet and motorway facilities at Warringah Freeway	Low	The ventilation outlet and motorway facilities would not be located within 140 metres of bushfire prone land.
Motorway control centre at the Gore Hill Freeway at Artarmon	Low	The motorway control centre would not be located within 140 metres of bushfire prone land.
Ventilation outlet and motorway facilities at the Gore Hill Freeway	Low	The ventilation outlet and motorway facilities would not be within 140 metres of bushfire prone land (separated by the Gore Hill Freeway).
Tunnel support facilities at the Gore Hill Freeway	Low	The tunnel support facilities would not be located within 140 metres of bushfire prone land.
Ventilation outlet and motorway facilities at the Burnt Bridge Creek Deviation	Low	The ventilation outlet and motorway facilities would not be located within 140 metres of bushfire prone land.
Ventilation outlet and motorway facilities at the Wakehurst Parkway	Medium	The ventilation outlet and motorway facilities would be located in an area classified as bushfire prone land.
Tunnel support facilities at the Wakehurst Parkway	High	The tunnel support facilities would be located in an area classified as bushfire prone land.

Operational facilities along the Wakehurst Parkway were assessed as having a medium or high bushfire risk level. The difference in bushfire risk ratings is largely as a result of greater consequences should there be the occurrence of bushfires. Bushfire risks associated with operational infrastructure along the Wakehurst Parkway would be minimised through continued application of bushfire management practises on the adjoining National Parks land, in accordance with the *Garigal National Park Fire Management Strategy* (DEC, 2006b) administered by the National Parks and Wildlife Service, Crown Land in accordance with the *Manly Warringah War Memorial Park Fire Regime Management Plan* (Eco Logical Australia, 2006) administered by Northern Beaches Council, and routine maintenance within the road reserve.

Strategies to reduce risk from bushfire during operation of the project are included in Section 23.4.

23.3.6 Aviation risks

The operational design of the project has considered airspace protection and associated risks and hazards. As discussed in Chapter 2 (Assessment process), under the *Airports Act 1996*, a 'controlled activity' in relation to a prescribed airspace must not be carried out or caused to be

carried out without the approval of the Secretary of the Department of Infrastructure, Transport, Regional Development and Communications or otherwise exempt under the Airspace Regulations 2007.

Regulations define the 'prescribed airspace' for Sydney Airport as the airspace above any part of either an obstacle limitation surface (OLS) or procedures for air navigation systems operations (PANS-OPS) surface for Sydney Airport.

The OLS is an invisible level that defines the limits to which objects may project into the airspace around an aerodrome so that aircraft operations may be conducted safely. The OLS defines the airspace to be protected for aircraft operating during the initial and final stages of flight, or manoeuvring near Sydney Airport. This has been established in accordance with International Civil Aviation Organisation specifications, as adopted by the Civil Aviation Safety Authority.

PANS-OPS surfaces are conceptual surfaces in space that establish the airspace that is to remain free of any potential disturbance (including physical objects and other disturbances such as emissions from ventilation outlets) so that aircraft operations may be conducted safely. Where structures may (under certain circumstances) be permitted to penetrate the OLS, they would not normally be permitted to penetrate any PANS-OPS surface.

Operational buildings and structures that form part of the project, including the ventilation outlets and motorway facilities at the Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway are designed to be below the prescribed airspace heights.

The Civil Aviation Safety Authority stipulates requirements for the construction and operation of new infrastructure that has the potential to influence aviation safety. The Civil Aviation Safety Authority may determine that exhaust from a ventilation outlet is a hazardous object if the vertical velocity of the emissions exceeds 4.3 metres per second within the OLS and/or PANS-OPS surfaces.

A plume rise assessment was carried out in accordance with the *Civil Aviation Safety Authority Advisory Circular Plume Rise Assessments AC 139-5(1) November 2012* to determine whether plume rise resulting from the operation of the ventilation outlet and motorway facilities at the Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway would be a controlled activity as defined in section 183 of the *Airports Act 1996*. The modelling considered an expected case, based on predicted typical operational conditions of the project, and a capacity case, based on the maximum theoretical airflow that can be discharged from each ventilation outlet. The capacity case scenario is conservative and represents the upper bound of potential plume rise extents from the ventilation outlets. It is noted that the ventilation outlets are not expected to operate at design capacity on a regular basis. In addition, the cumulative case was modelled, which considered the merged ventilation outlets at the Warringah Freeway for the Western Harbour Tunnel and Beaches Link program of works.

The plume rise assessment found that air exhausted from the majority of the ventilation outlets and motorway facilities would not exceed a vertical velocity of 4.3 metres per second, nor penetrate the OLS and PANS-OPS surfaces under the expected and capacity case scenarios. At the Warringah Freeway, under the capacity case when the ventilation outlet is considered in conjunction with the ventilation outlet for the Western Harbour Tunnel at the Warringah Freeway, the combined exhausted air from the ventilation outlets is predicted to penetrate the OLS at a vertical velocity of greater than 4.3 metres per second about 0.5 per cent of the time. There would be no penetration of the PANS-OPS surface or exceedance of the critical vertical velocity of 4.3 metres per second at the PANS-OPS surface under this scenario.

The design of the ventilation outlets and motorway facilities would be finalised during further design development and designed to satisfy requirements set by the Department of Infrastructure, Transport, Regional Development and Communications in relation to erected structures (such as ventilation outlets), equipment manoeuvring and lighting. A plume rise application would be prepared for approval under the *Airports Act 1996* for the Warringah Freeway ventilation outlet and motorway facilities where they may constitute a controlled activity.

23.4 Environmental management measures

The implementation of environmental management measures for the project would avoid, to the greatest extent possible, risks to public safety and achieve the desired performance outcomes in relation to the hazards identified in this chapter. Environmental management measures relating to hazards and risks identified in this chapter are outlined in Table 23-8. Management measures relating to other potential environmental hazards resulting from the construction or operation of the project are outlined in Chapter 8 (Construction traffic and transport) to Chapter 27 (Cumulative impacts) of this environmental impact statement.

Table 23-8 Environmental management measures – hazards and risks

Ref	Phase	Impact	Environmental management measure	Location
HR1	Construction and operation	Storage of dangerous goods and hazardous substances	Dangerous goods and hazardous materials will be stored in accordance with supplier's instructions and relevant legislation, Australian Standards, and applicable guidelines and may include bulk storage tanks, chemical storage cabinets/containers or impervious bunds.	BL/GHF
HR2	Construction	Transportation of dangerous goods and hazardous substances	Dangerous goods and hazardous substances will be transported in accordance with relevant legislation and codes, including the *Dangerous Goods (Road and Rail Transport) Act 2008*, Road and Rail Transport (Dangerous Goods) (Road) Regulation 1998 and the *Australian Code for the Transport of Dangerous Goods by Road and Rail* (National Transport Commission, 2007).	BL/GHF
HR3	Construction	Bushfire	Adequate access and egress for fire fighting vehicles and staff will be provided at the Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites. Access roads will have a minimum width of four metres to allow passage of fire fighting vehicles.	Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.
HR4	Construction	Bushfire	Adequate setbacks from bushfire prone vegetation to allow for fire fighting vehicle access will be provided for the Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.	Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.

Ref	Phase	Impact	Environmental management measure	Location
HR5	Construction	Bushfire	An emergency response plan will be prepared for the construction of the project at the Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites, including a bushfire risk matrix.	Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.
HR6	Construction	Bushfire	First response capabilities, including fire extinguishers, water carts and hoses will be assessed and provided at the Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites, where needed.	Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.
HR7	Operation	Bushfire	Adequate access and egress for fire fighting vehicles and operation vehicles will be provided at the Beaches Link tunnel support facilities at the Wakehurst Parkway at Frenchs Forest.	Beaches Link tunnel support facilities at Wakehurst Parkway at Frenchs Forest.
HR8	Operation	Bushfire	Adequate setbacks from bushfire prone vegetation will be provided for the Beaches Link tunnel support facilities at the Wakehurst Parkway at Frenchs Forest and ventilation outlet at the Wakehurst Parkway at Killarney Heights.	Beaches Link tunnel support facilities at the Wakehurst Parkway at Frenchs Forest and ventilation outlet at the Wakehurst Parkway at Killarney Heights.

Ref	Phase	Impact	Environmental management measure	Location
HR9	Operation	Fire and life safety	The fire and safety systems and measures adopted for the project will be equivalent to or exceed the fire safety measures recommended by NFPA502 (American) (National Fire Protection Association (NFPA), 2020), Permanent International Association of Road Congresses (PIARC) (European), AS4825-2011 (Standards Australia, 2011) and AS3959-2018 (Standards Australia, 2018), and Transport for NSW standards.	BL/GHF
HR10	Operation	Transportation of dangerous goods and hazardous substances	The transport of dangerous goods and hazardous substances will be prohibited through the mainline and ramp tunnels.	BL/GHF
HR11	Operation	Incident response	The response to incidents within the motorway will be managed in accordance with the memorandum of understanding between Transport for NSW and the NSW Police Service, NSW Rural Fire Service, NSW Fire Brigade and other emergency services.	BL/GHF
HR12	Operation	Aviation risks	The ventilation outlet and motorway facilities at the Warringah Freeway will be operated in accordance with any conditions of approval from the Secretary of Department of Infrastructure, Transport, Regional Development and Communications to manage penetration of the OLS layers.	BL

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 24

Resource use and waste management

transport.nsw.gov.au

DECEMBER 2020

24 Resource use and waste management

This chapter describes the resources and materials, including potential sources and expected quantities that would be used to construct and operate the project, and identifies measures which address these impacts.

Construction and operation of the project would generate waste streams which would require management and disposal in accordance with relevant state policies and guidelines. This chapter also provides a description of likely waste streams, expected quantities, and waste management strategies.

The Secretary's environmental assessment requirements as they relate to resource use and waste management, and where in the environmental impact statement these have been addressed, are detailed in Table 24-1.

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 resource use and waste management are discussed in Section 24.6.

Table 24-1 Secretary's environmental assessment requirements – resource use and waste management

Secretary's requirement	Where addressed in EIS
Spoil	
1. The Proponent must identify and assess spoil generation and reuse including: a. type and quantity	Spoil balance and management is outlined in **Section 24.3.3**. Estimates of the type and quantities of spoil are provided in **Section 24.3.3**.
b. onsite storage (including capacity to minimise amenity impacts);	Indicative stockpile locations, volumes and descriptions of onsite storage is provided in **Section 24.3.3**.
c. reuse potential and disposal sites;	The reuse of construction spoil is discussed in **Section 24.3.3**. Waste disposal locations are discussed in **Section 24.5.**
d. transport and handling options (including traffic, distance, road safety and related amenity and environmental impacts); and	Spoil transport alternatives that were considered for the project are outlined in Section 4.5.8 of **Chapter 4** (Project development and alternatives).
e. illegal dumping	The potential for illegal dumping of spoil generated by the project is discussed in **Section 24.3.3**. Management of waste disposal is outlined in **Section 24.6.2**.
Waste	
1. The Proponent must assess predicted waste generated from the project during construction and operation, including:	Waste streams are classified in **Section 24.3.2** and **Section 24.4.2**.

Secretary's requirement	Where addressed in EIS
a. classification of the waste in accordance with the current guidelines;	
b. estimates/details of the quantity of each classification of waste to be generated during the construction of the project, including bulk earthworks and spoil balance;	Estimates of the quantities of waste are provided in **Sections 24.3.2** and **24.4.2**. Spoil balance and management is outlined in **Section 24.3.3**.
c. handling of waste including measures to facilitate segregation and prevent cross contamination;	Construction waste management measures are provided in **Section 24.6**.
d. management of waste including estimated location and volume of stockpiles;	Indicative stockpile locations and volumes is provided in **Section 24.3**.
e. waste minimisation and reuse;	The reuse of construction and operational waste is discussed in **Section 24.3.1** and **Section 24.4.1**.
f. lawful disposal or recycling locations for each type of waste; and	Disposal and recycling options are outlined in **Section 24.3.2** and **Section 24.6**.
g. contingencies for the above, including managing unexpected waste volumes.	Contingencies for managing unexpected waste are discussed in **Section 24.6**.
2. The Proponent must assess potential environmental impacts from the excavation, handling, storage on site and transport of the waste particularly with relation to sediment/leachate control, noise and dust.	Potential environmental impacts associated with the handling, storage and transport of waste are discussed in **Section 24.3** and **Section 24.4**. Dust impacts and management are discussed in **Chapter 12** (Air quality). Noise impacts and management are discussed in **Chapter 10** (Construction noise and vibration). Sediment control and potential environmental impacts associated with the excavation of waste are described in **Chapter 16** (Geology, soils and groundwater) and **Chapter 17** (Hydrodynamics and water quality).

24.1 Legislative and policy framework

Waste management and recycling is regulated in NSW through the *Protection of the Environment Operations Act 1997*, the Protection of the Environment Operations (Waste) Regulation 2014 (including the requirement to track certain types of waste) and the *Waste Avoidance and Resource Recovery Act 2001*.

The *Waste Avoidance and Resource Recovery Act 2001* aims to promote efficient use of resources, and avoidance and minimisation of waste through the following resource management hierarchy:

- Avoidance of unnecessary resource consumption
- Resource recovery, including reuse, reprocessing, recycling and energy recovery
- Disposal.

By minimising consumption and encouraging the efficient use of resources, the *Waste Avoidance and Resource Recovery Act 2001* aims to reduce the generation and impacts of waste.

The following guidelines inform or respond to the regulatory framework and have been applied to the assessment of the project:

- *Waste Classification Guidelines* (NSW EPA, 2014a)
- *Technical Guide: Management of Road Construction and Maintenance Wastes* (Roads and Maritime Services, 2016b)
- *Sustainable Design Guidelines*, Version 4.0 (Transport for NSW, 2017)
- *Managing Urban Stormwater: Soils and Construction Volume 1* (Landcom, 2004) and *Volume 2* (DECC, 2008).

A number of policies and strategic documents are relevant to the project's resource use and waste management. The *NSW Government Resource Efficiency Policy* (Office of Environment and Heritage (OEH), 2019) aims to drive resource efficiency by NSW Government agencies and reduce harmful air emissions from government operations. As a government agency, Transport for NSW has a responsibility under this policy to incorporate resource-efficiency considerations in all major decisions to address rising costs for energy, water, clean air and waste management.

The *NSW Waste Avoidance and Resource Recovery Strategy 2014–21* (NSW EPA, 2014b) supports the avoidance and minimisation of waste and provides a framework and targets for waste management and recycling in NSW until 2021–2022.

Transport for NSW, as a NSW Government agency, supports these targets by:

- Implementing complementary policies and programs, including sustainable procurement policies
- Incorporating resource recovery and waste reduction objectives into its operations
- Complying with relevant regulations.

The aims of these policies are incorporated into the *Environmental Sustainability Strategy 2019–2023* (Roads and Maritime Services, 2019), which outlines specific focus areas for integrating sustainability into Transport for NSW road projects and services. Under the *Environmental Sustainability Strategy 2019–2023,* resource use and waste reduction initiatives include:

- Consideration of earthworks in project design and construction, including the recovery of materials for reuse
- Recycling materials
- Reducing resource use through appropriate project design and operation.

The Department of Planning, Industry and Environment is leading the development of a 20-year waste strategy for NSW with a focus on sustainability, reliability and affordability. The *20-Year Waste Strategy Issues Paper* and complementary NSW Plastics Plan Discussion Paper *Cleaning Up Our Act: Redirecting the Future of Plastic* were released for public consultation in early 2020. The Department of Planning, Industry and Environment is currently reviewing the feedback received through the consultation process.

24.2 Assessment methodology

The assessment of resource use and waste management comprised:

- A review of the likely resources required for the construction and operation of the project, including construction materials, water and power
- A review of the likely waste streams, volumes and classifications
- Identification of opportunities for the avoidance, minimisation and reuse of waste, including targets for the beneficial reuse of solid waste, wastewater and other waste consistent with the project's sustainability framework (refer to Chapter 25 (Sustainability))
- Identification of the environmental impacts associated with resource use and the generation (and subsequent disposal) of residual waste materials
- Management strategies for waste during construction and operation, including:
  - Managing construction waste through the resource management hierarchy established under the *Waste Avoidance and Recovery Act 2001*
  - Developing procedures for the assessment, handling, stockpiling and disposal of potentially contaminated materials and wastewater, in accordance with the *Waste Classification Guidelines* (NSW EPA, 2014a).

24.3 Assessment of potential construction impacts

Potential impacts during construction of the project relate to:

- Construction resource use, including construction materials, water and electricity
- Generation and management of waste (non-spoil)
- Generation and management of spoil, including dredged and excavated materials from Middle Harbour.

24.3.1 Construction resource use

Construction materials

Given the scale of the project, substantial quantities of materials would be used for construction. Indicative quantities and the potential sources of construction materials are provided in Table 24-2. Other items such as timber, electrical materials and landscaping materials would also be required.

Table 24-2 Indicative quantities of resources required for construction

Material	Estimated quantity required	Anticipated source/origin
Asphalt	124,400 tonnes	Sydney suppliers
Sprayed bitumen	500 tonnes	Sydney suppliers
Ready-mixed concrete	322,100 cubic metres	Sydney suppliers located close to the project and on-site concrete batching plants
Precast concrete	8600 cubic metres	Sydney, NSW Central and Mid North Coast
Aggregates – gravel/sand	25,400 cubic metres	NSW South Coast and Central Coast

Material	Estimated quantity required	Anticipated source/origin
Aggregates – general fill	183,400 cubic metres	Reuse spoil from tunnelling works if timing permits, or imported fill from the Greater Sydney region
Steel	58,400 tonnes	Australia and/or overseas
Aluminium	20 tonnes	Overseas
Glass	2 tonnes	Australia and/or overseas
PVC piping	3000 tonnes	Australia and/or overseas
Concrete piping	2100 tonnes	Australia
Plastic sheeting	30 cubic metres	Australia and/or overseas
Composites – cement fibreboard	500 tonnes	Australia
Coatings and finishes	less than 1 tonne	Australia and/or overseas
Water treatment chemicals	1 tonne	Australia and/or overseas

Construction material requirements for the project are typical for a motorway project of this scale. While the resource requirements of the project do have the potential to impact resource availability within the Sydney metropolitan region over the construction period, the concurrent construction of NorthConnex, M8, M4-M5 Link and Sydney Metro City & Southwest demonstrates that the market is able to manage the concurrent construction of major infrastructure projects given sufficient opportunity to forward plan. The period between the approval of the project and the start of major construction would be sufficient to allow the market to prepare for the needs of the project in conjunction with the concurrent infrastructure projects listed in Chapter 27 (Cumulative impacts).

The design of the project has included careful consideration of the construction methodology and selection of materials and resources to ensure fit for purpose and minimise resource consumption. Consistent with the resource management hierarchy of the *Waste Avoidance and Resource Recovery Act 2001*, resource consumption would be further minimised during construction through reuse, where possible. For example, temporary work structures such as road plates and tunnel formwork would be reused, and asphalt from decommissioned pavements would be reused in temporary and new pavements, where technically feasible.

Water

Water would be required during construction activities including:

- Tunnelling activities such as dust suppression and equipment wash down
- Surface works such as during compaction of earthworks and pavement materials and for dust suppression and equipment wash down
- Concrete batching
- Site offices and ablutions
- Irrigation for landscaping.

Measures to avoid and minimise water consumption, particularly of potable water, have been included in the design and construction planning for the project. Examples of these measures include:

- Use of dust extraction and ventilation systems to control dust in tunnels during construction to minimise the use of water as a dust suppressant
- Collection, treatment and use of wastewater and rainwater at temporary construction support sites to minimise the use of potable water sources during construction.

Water for construction of the project would be sourced according to the following hierarchy, where feasible and reasonable, and where water quality and volume requirements are met:

- Stormwater harvesting (non-potable water)
- On-site construction water treatment and reuse, including groundwater sourced from infiltration into tunnelling works (non-potable water)
- Mains supply (potable water).

The average total water demand during construction is estimated to be 2645 kilolitres per day. About 1442 kilolitres per day would be sourced from mains supply (potable water) with the remainder coming from treated groundwater or harvested rainwater (non-potable water).

A summary of the indicative construction water balance is presented in Chapter 17 (Hydrodynamics and water quality). Connection to, and supply of, mains water would be confirmed during further design development, in consultation with Sydney Water.

Electricity

Electricity supply would be required at all temporary construction support sites, including high voltage supply for tunnelling support sites. Table 24-3 summarises the indicative electricity demand at temporary construction support sites where tunnelling is proposed.

Infrastructure required to connect each temporary construction support site with the electricity supply network outside the project corridor would be subject to separate design, assessment and approval. Further information on the coordination and management of electricity infrastructure delivery is provided in Appendix D (Utilities management strategy).

Measures to avoid and minimise electricity consumption have been included in the design and construction planning for the project. Examples of these measures include:

- Use of guidance systems for tunnel excavation and rock bolting to ensure efficient use of tunnelling equipment to minimise excessive electricity consumption
- Use of energy efficient site buildings and equipment at temporary construction support sites, including use of solar powered lights and signage, where feasible and reasonable
- Efficient design of electricity transmission systems to supply power as efficiently as possible.

Table 24-3 Indicative construction electricity demand for tunnel support sites

Temporary construction support site	Indicative temporary power requirement (megavolt ampere (MVA))
Cammeray Golf Course (BL1)	3
Flat Rock Drive (BL2)	7
Punch Street (BL3)	3
Balgowlah Golf Course (BL10)	3
Wakehurst Parkway east (BL13)	3

24.3.2 Construction waste generation and management (non-spoil)

This section details the solid and liquid waste, and the wastewater expected to be generated during construction of the project. Generation and management of spoil, including dredged and excavated materials, is considered in Section 24.3.3.

Solid and liquid waste

Measures to minimise the generation of waste and maximise resource recovery have been included in the design and construction planning for the project. Examples of these measures include:

- Prioritisation of pre-cast concrete structural elements to improve efficiency and minimise waste
- On-site sorting of materials like timber, steel and concrete to maximise resource reuse on site or near to the site where possible
- Chipping and mulching of cleared vegetation for reuse on site as a preference to disposal where appropriate or reusing salvaged logs for fauna connectivity structures and habitat enhancement measures.

Table 24-4 summarises indicative solid and liquid waste streams that would be generated during construction, including examples of these waste streams, indicative waste stream quantities and anticipated waste classifications.

These waste streams are typical of construction and demolition activities and can be adequately managed with the implementation of well-established environmental management measures (refer to Section 24.6). Consistent with the resource management hierarchy under the *Waste Avoidance and Resource Recovery Act 2001*, solid waste would be reused and recycled where feasible and reasonable. Construction waste would be disposed of at appropriate licenced facilities.

Table 24-4 Indicative solid and liquid waste streams generated during construction

Waste stream	Examples of waste	Indicative quantity	Likely waste classification
Demolition waste	Concrete, bricks, tiles, timber, metals, plasterboard, carpets, electrical and plumbing fittings, furnishings	12,585 cubic metres	General solid waste (non-putrescible)
Aggregates – crushed rock/concrete	Concrete	3,206,710 cubic metres	General solid waste (non-putrescible)
Hazardous waste	Asbestos, heavy metals	1000 tonnes (subject to further investigation)	Hazardous waste and/or special waste
Vegetation waste	Trees, shrubs, ground cover	Up to 12,552 tonnes[1] (noting vegetation waste would be reused on site if possible)	General solid waste (putrescible)
General construction waste	Timber formwork, scrap metal, steel, concrete, plasterboards, packaging materials	19,600 tonnes	General solid waste (non-putrescible)
Waste from the operation and maintenance of construction vehicles and equipment	Adhesives, lubricants, waste fuels, oils, engine coolant, batteries, hoses, tyres	5 tonnes	Hazardous waste

Waste stream	Examples of waste	Indicative quantity	Likely waste classification
General waste from site offices	Putrescibles (food waste), paper, cardboard, plastics, glass, printer cartridges	960 tonnes	General solid waste (putrescible and non-putrescible)

Note 1: Vegetation waste has been assumed as 600 tonnes per hectare of vegetation removal.

Wastewater

Wastewater volumes generated during construction would vary depending on the types of construction activities being carried out and the stage of construction. The majority of wastewater generated during construction would be through groundwater infiltration in the tunnels.

The average infiltration rate across the project tunnels is expected to be less than the design standard of an average one litre per second per kilometre applied to other recent motorway tunnel projects, including NorthConnex and M4-M5 Link. Further information on groundwater infiltration and groundwater effects is provided in Chapter 16 (Geology, soils and groundwater).

Smaller volumes of wastewater would be generated by other construction activities, such as dust suppression and equipment washdown.

Opportunities for wastewater reuse would be investigated and pursued, where feasible and reasonable, and subject to meeting water reuse quality requirements. Options for wastewater reuse may include on-site reuse for construction purposes, such as dust suppression and compaction of earthworks and pavement materials.

The anticipated generation of wastewater from tunnel construction would be greater than the potential for reuse. Therefore, treatment of surplus wastewater and off-site discharge would be required. Chapter 2 (Assessment process) outlines the requirement for an environment protection licence for road construction under Chapter 3 of the *Protection of the Environment Operations Act 1997.* The wastewater collected from tunnelling activities would be tested and treated at construction wastewater treatment plants prior to reuse or discharge. Discharges from wastewater treatment plants during the construction phase would be required to meet the following discharge criteria:

- The relevant physical and chemical stressors set out in of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000)
- The ANZG (2018) 90 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which will be treated to meet the ANZG (2018) 95 per cent species protection levels
- The ANZG (2020) default guideline values for iron (in fresh and marine water) and zinc (in marine water).

Indicative wastewater treatment plant discharge volumes at the temporary construction support sites used to support tunnelling are summarised in Table 24-5. These volumes conservatively assume that all wastewater would be treated and discharged, and do not take into account the opportunities for wastewater reuse identified above. Further information on water treatment and discharge water quality, as well as the complete water balance for the project is provided in Chapter 17 (Hydrodynamics and water quality).

Table 24-5 Indicative daily average wastewater discharge volumes

Temporary construction support site	Estimated daily discharge (kilolitres)	Treated wastewater available for reuse daily (kilolitres)	Discharge point
Cammeray Golf Course (BL1)	296	127	Willoughby Creek via stormwater system
Flat Rock Drive (BL2)	711	305	Flat Rock Creek via stormwater system
Punch Street (BL3)	308	130	Flat Rock Creek via stormwater system
Balgowlah Golf Course (BL10)	428	263	Burnt Bridge Creek via stormwater system
Wakehurst Parkway east (BL13)	10	199	Drainage pit on the eastern boundary of the support site. Discharge would subsequently flow into nearby golf course dam via overland flow, for reuse by the golf course.
Surface works	0	185	N/A
Total	1754	1208	

24.3.3 Spoil generation and management

About three million cubic metres of spoil would be produced from land-based construction activities (terrestrial spoil) during construction, made up of:

- Soil and rock from construction of the project tunnels underground
- Soil and rock from bulk excavation works on the surface.

The majority of land-based spoil generated by the project would be crushed sandstone from tunnelling. This material is generally considered a desirable engineering fill and is typically reused in development sites and major earthworks projects across Greater Sydney.

In addition, marine construction works for the project within Middle Harbour would produce around 163,000 cubic metres of dredged and excavated materials, made up of:

- Soft soils, sediment and rock excavated from the two temporary cofferdams in Middle Harbour
- Soft soils, sediment and rock dredged for the installation of the immersed tube tunnels.

The management of spoil and dredged and excavated materials during construction of the project would depend on its composition, the location from which it was removed (ie land-based or marine-based construction), and whether it is considered to be suitable or unsuitable for reuse. The approach to management of land-based spoil and dredged and excavated materials is shown in Figure 24-1.

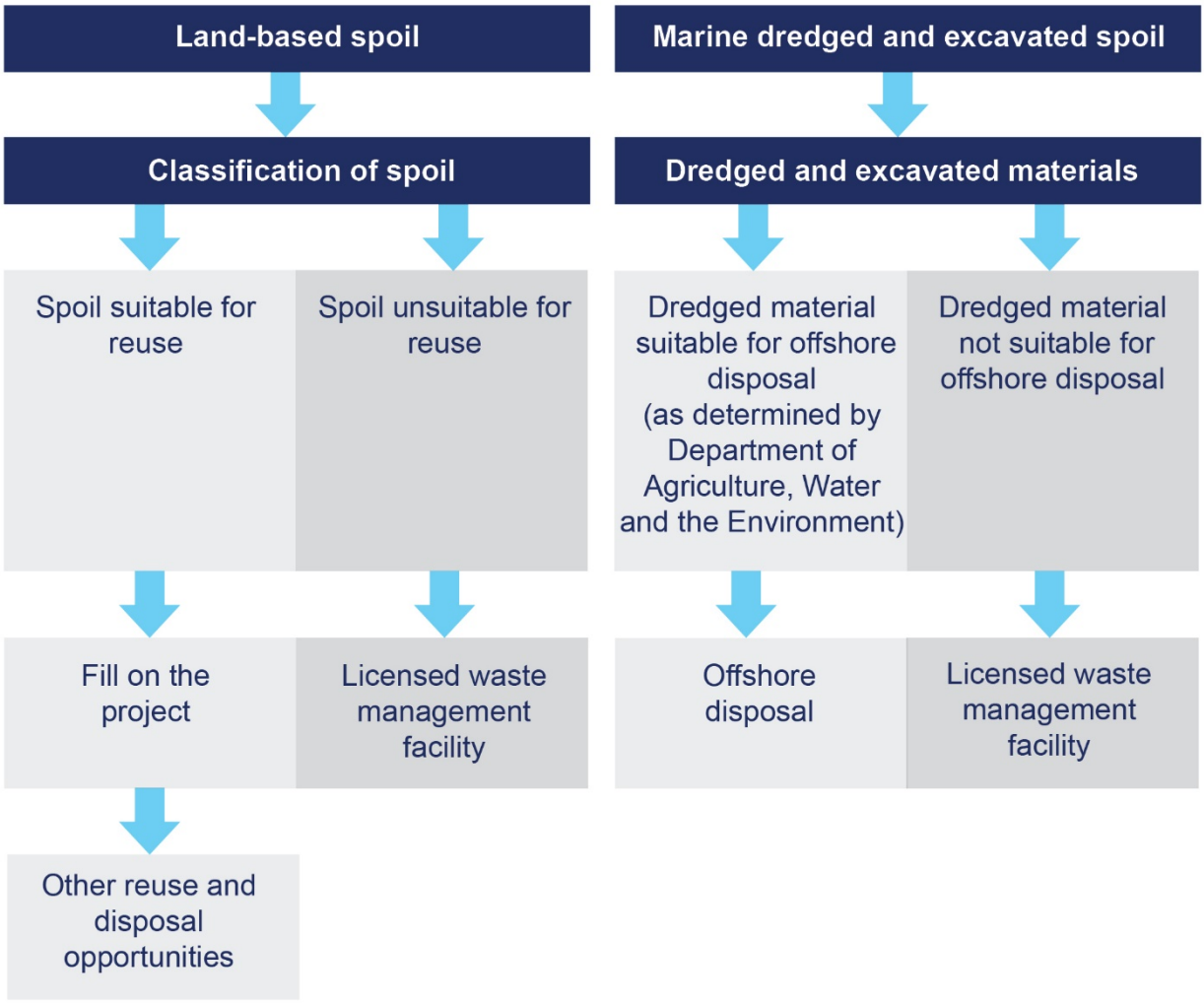

Figure 24-1 Spoil management approach

Spoil from land-based construction activities

Land-based spoil generation

The project's land-based construction activities would generate about three million cubic metres of spoil.

The temporary construction support sites supporting tunnelling operations would be the main generators of spoil during construction. Additional, smaller quantities of spoil would be generated at other construction areas along the project alignment, associated with surface road works. The indicative volume of surplus land-based spoil to be extracted and managed through each of the temporary construction support sites is summarised in Table 24-6.

Table 24-6 Indicative land-based spoil generation

Construction site	Spoil volume (cubic metres)	Spoil composition
Cammeray Golf Course (BL1)	222,000	Sandstone
Flat Rock Drive (BL2)	929,880	Sandstone
Punch Street (BL3)	450,860	Sandstone
Balgowlah Golf Course (BL10)	673,940	Sandstone and soil
Wakehurst Parkway surface works	157,120	Sandstone and soil

Construction site	Spoil volume (cubic metres)	Spoil composition
Wakehurst Parkway east (BL13)	564,850	Sandstone
Gore Hill Freeway surface works	32,080	Sandstone and soil
Total land-based spoil generation	3,030,730	-

Spoil from tunnelling works would be transported from the tunnel face to the surface using dump trucks. Where required, tunnel spoil stockpiles would be largely contained within acoustic sheds or below ground within the tunnels being excavated. This would also minimise the potential for impacts from runoff (including from contaminated materials) and sedimentation associated with stockpiling. Storage of stockpiles within the acoustic sheds would also minimise amenity impacts to the surrounding area.

Spoil would be classified prior to leaving the site in accordance with NSW and Australian standards and guidelines. It is anticipated that the majority of this material would be used at development, construction or remediation sites across Greater Sydney.

Other earthworks, such as those required for surface road works, cut and cover and trough structures may require the stockpiling of material on site if the material cannot be loaded directly into trucks. These stockpiles would be located outside of acoustic sheds; however, appropriate measures, including bunding, would be in place to avoid potential impacts associated with runoff, sedimentation and leachate. Environmental management measures provided for construction noise and vibration (Chapter 10), air quality (Chapter 12) and urban design and visual amenity (Chapter 22) would minimise potential amenity impacts from the proposed stockpiles. Several of the temporary construction support sites that would require stockpiling outside of acoustic sheds are large sites that are located away from residential receivers or within industrial areas which would further minimise potential amenity impacts. Construction stockpiles would also allow for contingency management of unexpected waste materials, including contaminated materials. The indicative location and volume of spoil stockpiles located outside of acoustic sheds is provided in Table 24-7.

Potential impacts from runoff and sedimentation would be further minimised through the implementation of the environmental management measures described in Chapter 17 (Hydrodynamics and water quality).

Potential impacts related to leachate (ie contaminated liquid that drains from a landfill or stockpile) are considered to be unlikely during construction as the project does not involve the excavation or disturbance of known historical landfill areas with the exception of the Flat Rock Drive construction support site (BL2). In this instance, it is anticipated that excavated materials would generally be building type waste and non-putrescible waste. Further information is provided in Chapter 16 (Geology, soils and groundwater).

Table 24-7 Indicative stockpile locations and volumes – outside of acoustic sheds

Location	Indicative stockpile volume
Cammeray Golf Course (BL1)	4500 cubic metres
Flat Rock Drive (BL2)	500 cubic metres
Dickson Avenue (BL4)	2500 cubic metres
Balgowlah Golf Course (BL10)	1000 cubic metres per stockpile (up to five stockpiles, totalling 5000 cubic metres) 3300 cubic metre stockpiles for concrete batch plants
Wakehurst Parkway south (BL12)	500 cubic metres
Wakehurst Parkway upgrade	Multiple stockpiles of varying volumes up to 2500 cubic metres

The design of the project and preferred construction methodology has taken into consideration the waste hierarchy by aiming to reduce the volume of excess spoil generated, as far as practical. Where possible, the project would maximise reuse of spoil generated during construction before alternative off-site spoil disposal options are pursued.

The geochemistry of the spoil material as well as its consistency and quality would determine the reuse options. The spoil produced by the project would have the following potential reuse opportunities:

- Granular sandstone fill is likely to be suitable for use as engineering fill
- Excavated clay and clayey sand material is likely to be suitable for use as general fill following moisture conditioning
- Excavated weathered shale and sandstone could be suitable for use as engineering fill following moisture conditioning to reduce the shrink-swell capacity of the material
- Medium strength or better quality shale is likely to be suitable for use as engineering fill
- Medium to high strength sandstone may be suitable for use as engineering fill
- Wet clay and wet shale spoil is unlikely to be suitable for reuse on site without substantial moisture conditioning.

Where spoil cannot be reused for the project, opportunities to reuse this material on other projects (preferably within the Sydney region to reduce transport distances) would be identified.

The following sites are potential options for spoil reuse/disposal:

- Western Sydney Airport (about 60 kilometres from the project)
- Moorebank Intermodal Terminal Precinct (about 40 kilometres from the project)
- Kurnell Landfill (about 40 kilometres from the project)
- Penrith Lakes Scheme (about 60 kilometres from the project).

These sites have a need for spoil or fill material and represent viable reuse locations. Other reuse or disposal sites may be used depending on need at the time the spoil is generated. The final destination(s) for excess spoil from construction of the project would be planned prior to construction commencing.

With the consideration of the above commitment to maximising reuse of spoil generated during construction, the potential options for off-site spoil reuse/disposal, and the environmental management measures included in Section 24.6, the potential risk for illegal dumping of spoil generated by the project is considered negligible.

Disposal of contaminated material

There is potential to discover contaminated material during excavation works for the project. A Stage 1 contamination assessment has been carried out to determine the potential for encountering contaminated material during construction (refer to Chapter 16 (Geology, soils and groundwater)).

The contamination assessment identified twelve locations within or adjacent to the construction footprint of the project that are considered to be potential areas of interest. These locations and types of potential contaminated material are provided in Chapter 16 (Geology, soils and groundwater). Further investigations of these sites including a Stage 2 contamination assessment are required to quantify the exposure risk. These investigations would be carried out prior to construction activities so that contamination (if present) can be adequately planned for and managed.

Management of contaminated spoil would be in accordance with the measures outlined in Chapter 16 (Geology, groundwater and soils). 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.

Dredged and excavated materials from harbour construction activities

About 163,000 cubic metres of soft soil, sediments and rock would need to be removed from Middle Harbour during the dredging activities required for the installation of the immersed tube tunnels and associated transition structures. The indicative volume and composition of dredged and excavated materials to be removed as part of marine construction activities is included in Table 24-8.

Table 24-8 Indicative dredged and excavated material volumes

Construction area	Dredged and excavated material volume (cubic metres)	Indicative composition of dredged and excavated materials
Middle Harbour south cofferdam (BL7) Middle Harbour north cofferdam (BL8)	5000	Soft soils and sediment suitable for offshore disposal under Australian Government permit
	30,000	Sandstone suitable for offshore disposal under Australian Government permit
Middle Harbour immersed tube tunnel construction	58,000	Soft soils and sediment suitable for offshore disposal under Commonwealth permit
	60,000	Sandstone suitable for offshore disposal under Australian Government permit
	10,000	Soft soils and sediment not suitable for offshore disposal
Total material	163,000	

Dredged and excavated materials suitable for offshore disposal

Transport for NSW has submitted an application to the Australian Government Department of Agriculture, Water and Environment for an offshore disposal permit relating to sediments dredged and excavated from Middle Harbour. Dredged and excavated materials suitable for offshore disposal would be transported from Middle Harbour on split hopper barges and disposed of at a designated offshore disposal site (in accordance with legislative requirements). The appropriateness of offshore disposal would be assessed in accordance with the Australian Government *National Assessment Guidelines for Dredging* (NAGD) (Department of Environment, Water, Heritage and the Arts, 2009). Offshore disposal would only be appropriate for material that meets the requirements outlined in the NAGD. Offshore disposal would reduce the number of heavy vehicle movements required to transport dredged and excavated materials. As detailed in Chapter 2 (Assessment process), assessment for offshore disposal of dredged and excavated materials is subject to a separate assessment process by the Australian Government Department of Agriculture, Water and the Environment.

The potential impacts to marine water quality from the transport, treatment and/or temporary storage of dredged and excavated materials is assessed in Chapter 17 (Hydrodynamics and water quality). The potential impact of shipping movements is discussed further in Chapter 8 (Construction traffic and transport).

Dredged and excavated materials unsuitable for offshore disposal

Some soft soils and sediments in Middle Harbour contain high concentrations of metallic and non-metallic contaminants (refer to Chapter 16 (Geology, soils and groundwater)). Most of the harbour's contamination results from a combination of historical inputs that remain in the sediments and other ongoing sources of input such as stormwater.

Of the 163,000 cubic metres of material requiring removal from Middle Harbour, it is expected that about 10,000 cubic metres from the top 0.5 metre to one metre of the bed of the harbour may not be suitable for offshore disposal. The nature of existing contamination within Middle Harbour is described in more detail in Chapter 16 (Geology, soils and groundwater).

Dredged and excavated materials not suitable for offshore disposal would be loaded onto hopper barges and transferred to a suitable onshore facility for treatment (if required) and disposal.

Dredged and excavated materials would be subject to waste classification under the *Waste Classification Guidelines 2014* (NSW EPA, 2014a) and would be treated to make the material spadable (a consistency which allows the material to be spaded or shovelled). During this process, additives such as lime or absorbent polymers would be mixed into the material to assist in mitigating potential odour and to neutralise acid sulfate soils. This process is widely used on marine construction projects and has been applied on recent projects in Sydney Harbour, including Garden Island dredging works completed in 2010 and 2019.

Once treated, materials would be loaded into sealed and covered trucks for transport to a suitably licensed facility.

24.4 Assessment of potential operational impacts

Potential impacts during operation of the project relate to:

- Operational resource use, including operational materials, water and electricity
- Generation and management of waste.

24.4.1 Operational resource use

Operational materials

Materials used for the operation of the project would be limited to those required for ongoing maintenance activities, and the operation of the motorway control centre and tunnel support facilities. As outlined in Chapter 5 (Project description), ongoing maintenance activities are not included as part of the project and would be considered separately at the relevant time in the future.

Water

During operation of the project, water would be required for:

- Testing and operation of the tunnel deluge system, which forms part of the fire and life safety system
- Tunnel cleaning systems
- Motorway control centre ablutions
- Landscape irrigation.

Measures to avoid and minimise water use, particularly of potable water, have been included in the project design. An example of these measures includes the reuse of groundwater entering the project tunnels where possible to satisfy the project's operational water requirements and reduce the demand for potable water.

Water for operation of the project would be sourced according to the following hierarchy, where feasible and reasonable, and where water quality and volume requirements are met:

- Groundwater which has been treated after infiltrating into tunnels (non-potable water)
- Rainwater harvesting (non-potable water)
- Mains supply (potable water).

Indicative volumes and potential sources of water for each operational activity are provided in Table 24-9. Connection to and supply of mains water would be confirmed during further design development, in consultation with Sydney Water.

Table 24-9 Indicative operational water requirements

Activity	Total water demand
Washdown	730 kilolitres/year
Deluge testing	2920 kilolitres/year

Electricity

An operational electricity supply would be required for the mainline and ramp tunnels (including associated mechanical and electrical equipment), traffic control facilities (including the motorway control centre, tunnel support facilities and electronic signage) and surface street lighting. As described in Chapter 5 (Project description), the project includes underground substations at regular intervals within the tunnel and aboveground substations at the Beaches Link motorway facilities.

The project would likely be connected to the Warringah sub-transmission substation. Initial discussions with Ausgrid indicate that this substation would have sufficient capacity to supply the project without negative impacts on the local power supply.

Measures to minimise energy consumption and maximise energy efficiency have been included in the project design. Examples of these measures include:

- Use of low heat emission LED lighting to reduce operational energy requirements
- Efficient and effective longitudinal ventilation system design with outlets located in close proximity to tunnel portals, taking advantage of the movement of vehicles within tunnels to reduce fan usage and reducing energy needed to move exhaust to outlet locations
- Opportunities to install solar panels at the tunnel portals and on tunnel support and traffic control facility buildings to supplement non-renewable power sources, where feasible and reasonable.

Opportunities to further minimise energy consumption and maximise energy efficiency would be considered during further design development, where feasible and reasonable.

The anticipated operational electricity consumption of the project would be about 28 MVA.

24.4.2 Operational waste generation

This section details the solid and liquid waste, and the wastewater expected to be generated during operation of the project.

Solid and liquid waste

The types and volumes of waste generated from the operation of the motorway would depend on the nature of the activity but would predominantly consist of minor volumes of general office waste (paper, plastics, food waste).

The volumes and types of waste would be typical of motorway operations and could be accommodated by existing metropolitan licenced facilities. With the implementation of standard waste management practices, the overall impact of operational waste streams would be minimal.

Maintenance and repair activities would be subject to separate assessment processes, which would include the assessment of waste impacts associated with these activities.

Wastewater

The project tunnels would include drainage infrastructure to collect groundwater, stormwater, maintenance wastewater, fire deluge and other potential water sources. The tunnel drainage streams would receive water containing a variety of potential pollutants (such as fuel, oil grease, and fire suppressants) requiring different treatment before discharge.

Tunnel wastewater (including collected groundwater) would be pumped to an operational wastewater treatment facility at the Gore Hill Freeway (refer to Chapter 5 (Project description)). Volumes of tunnel wastewater to be pumped and treated would be minimised through the installation of tunnel linings which would minimise the ingress of groundwater. On average, the project tunnels would generate about 551 megalitres per year of treated groundwater in the first year of operation, falling to about 436 megalitres per year after 100 years of operation. Tunnel water would be treated to comply with (ANZECC/ARMCANZ, 2000), ANZG (2018) and ANZG (2020) guidelines (refer to Section 17.1.3), and spill controls and water quality monitoring would be implemented to manage operational impacts on ambient water quality within the receiving waterways.

Following treatment, discharges would enter into the local stormwater network. Further information is provided in Chapter 17 (Hydrodynamics and water quality) including potential impacts associated with operational stormwater runoff and water discharge.

24.5 Waste disposal locations

There are a number of options for recycling and disposal of construction and operational waste generated by the project. A large number of waste facilities in Greater Sydney are licensed to accept general solid waste (putrescible) and general solid waste (non-putrescible). Specific facilities and collection contractors for the disposal of putrescible and non-putrescible general solid waste would be selected during the later stages of the project and documented in the construction waste management plan.

Recyclables generated during construction and operation of the project would be collected by an authorised contractor for off-site recycling. There are a number of resource recovery facilities in Sydney. Recycling facilities for the project would be determined by the contractor engaged to collect the material.

Special and hazardous wastes would be disposed of at appropriately licensed waste management facilities to be selected during the later stages of the project and documented in the construction waste management plan.

24.6 Environmental management measures

24.6.1 Contingency management of waste

Contingency measures would be implemented to manage unexpected waste volumes and types of waste materials generated from the construction of the project. Suitable areas would be identified, where feasible, to allow for contingency management of unexpected waste materials, including contaminated materials. These areas would be hardstand or lined areas that are appropriately stabilised and bunded, with sufficient area for stockpile storage and segregation.

As detailed in Chapter 16 (Geology, soils and groundwater), in the event of discovery of previously unidentified contaminated material, all relevant work would cease in the vicinity of the discovery and the unidentified contaminated material would be managed in accordance with an unexpected contaminated lands discovery procedure, as outlined in the *Guideline for the Management of Contamination* (Roads and Maritime Services, 2013a).

The environmental management measures outlined in Table 24-10 would be consistently implemented in the event of unexpected waste volumes and materials generated from the construction of the project, along with adherence to all waste principles and relevant legislation and regulations.

24.6.2 Management of waste

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* and as described in Section 24.1. Where feasible and reasonable, resources would be managed according to the following hierarchy:

- Avoidance of unnecessary resource consumption through design, efficient construction methodologies and management
- Resource recovery, including reuse, reprocessing, recycling and energy recovery within the project
- Resource recovery, including reuse, reprocessing, recycling and energy recovery outside the project
- Where resource recovery is not feasible or reasonable, disposal would be the last resort.

As described in Section 28.5, the construction environmental management plan would outline the management of waste and resources during construction. Waste and resource management would include waste monitoring, reporting and compliance tracking of construction waste generated by the project.

Measures to avoid, minimise or manage resource consumption and waste generation as a result of the project are detailed in Table 24-10. Environmental management measures relating to contamination, including acid sulfate soils, are provided in Chapter 16 (Geology, soils and groundwater).

Table 24-10 Environmental management measures - resource use and waste management

Ref	Phase	Impact	Environmental management measure	Location
WM1	Construction	Resource use	Construction materials will be sourced in accordance with the project's Sustainability Framework and with a preference for Australian materials and prefabricated products with low embodied energy, where feasible and reasonable.	BL/GHF
WM2	Construction	Resource management	The resource management hierarchy principles established under the *Waste Avoidance and Recovery Act 2001* of avoid/ reduce/ reuse/recycle/dispose will be applied.	BL/GHF
WM3	Construction	Waste generation and disposal	Any surplus material requiring offsite disposal to land, including marine sediments unsuitable for offshore disposal, will be classified in accordance with *Waste Classification Guidelines* (NSW EPA, 2014).	BL/GHF
WM4	Construction	Storage and transport of waste	Wastes will be appropriately transported, stored and handled according to their waste classification and in a manner than prevents pollution of the surrounding environment.	BL/GHF
WM5	Construction	Waste generation and disposal	Opportunities for terrestrial spoil reuse within the project corridor, so as to minimise the quantity of material disposed to land will be investigated and implemented where feasible and reasonable.	BL/GHF
WM6	Construction	Wastewater generation and disposal	Opportunities for wastewater reuse and recycling, including use of stormwater from sediment basins and recirculating water during tunnel excavation to use for dust suppression or off-site reuse, will be investigated and implemented where feasible and reasonable.	BL/GHF
WM7	Construction	Management of mulch	Mulch stockpiles and the potential generation of tannin leachates will be managed through the implementation of *Environmental Direction for the Management of Tannins from Vegetation Mulch* (Roads and Maritime Services, 2012).	BL/GHF
WM8	Construction	Reuse of vegetation waste	Where reasonable and feasible, salvaged logs from the clearing process will be reused on site and/or reused as part of the fauna	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			connectivity structures with consideration of the *Guide 5: Re-use of woody debris and bushrock of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011).	
WM9	Construction	Waste disposal	Further investigations will be carried out at the Flat Rock Drive (BL2), Balgowlah Golf Course (BL10) construction support sites and surface works and construction support site locations along the Wakehurst Parkway (BL12, BL13 and BL14) to determine the feasibility of encapsulation of contaminated materials on site. Where contaminated soils and other materials are to be encapsulated on-site, encapsulation will be designed in accordance with the requirements detailed in the *Guidelines for the Assessment of On-site Containment of Contaminated Soil* (ANZECC, 1999).	Flat Rock Drive (BL2), Balgowlah Golf Course (BL10), Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites
WM10	Operation	Resource use and waste generation	The project will be operated in accordance with the relevant aims of the project's Sustainability Framework to optimise resource efficiency and waste management.	BL/GHF
WM11	Operation	Waste generation and disposal	Waste will be managed and disposed of in accordance with relevant applicable legislation, policies and guidelines, including the *Waste Avoidance and Resource Recovery Act 2001* and the *NSW Waste Avoidance and Resource Recovery Strategy 2014–21* (NSW EPA, 2014b).	BL/GHF
WM12	Operation	Water use and discharge	Opportunities to reuse treated groundwater during project operation will be considered where feasible and reasonable.	BL/GHF

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection

NSW GOVERNMENT

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 25

Sustainability

transport.nsw.gov.au

DECEMBER 2020

25 Sustainability

This chapter describes the overall approach to sustainability through design, construction and operation of the project, and identifies management measures relating to sustainability. A sustainability framework has been prepared for the project (refer to Section 25.2).

The Secretary's environmental assessment requirements as they relate to sustainability, and where in the environmental impact statement these have been addressed, are detailed in Table 25-1.

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 sustainability are discussed in Section 25.4.

Table 25-1 Secretary's environmental assessment requirements – sustainability

Secretary's requirement	Where addressed in EIS
Sustainability	
1. The Proponent must assess the sustainability of the project in accordance with the Infrastructure Sustainability Council of Australia (ISCA) Infrastructure Sustainability Rating Tool and recommend an appropriate target rating for the project.	The assessment of the sustainability of the project in accordance with the ISCA *Infrastructure Sustainability Rating Tool* is discussed in **Section 25.2**. A Sustainability Management Plan would be developed during further design development. The Sustainability Management Plan would detail measures to meet the sustainability objectives and targets.
2. The Proponent must assess the project against the current guidelines including targets and strategies to improve Government efficiency in use of water, energy and transport.	Discussion of the sustainability framework and relevant legislation, policies and guidelines is provided in **Table 25-2**. The sustainable use of water and energy resources is discussed in **Chapter 24** (Resource use and waste management).

25.1 Overview

Sustainable development refers to "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987).

The Infrastructure Sustainability Council of Australia provides a definition specific to sustainable infrastructure development, being that which is "designed, constructed and operated to optimise environmental, social and economic outcomes over the long term" (Infrastructure Sustainability Council of Australia, 2016c).

This chapter describes how sustainability principles have been applied to the design, construction and operation of the project including:

- The sustainability framework that has been developed for the project, including the application of the Infrastructure Sustainability Council of Australia's Infrastructure Sustainability rating scheme to the project

- Legislation and policies relevant to the project
- Application of the principles of ecologically sustainable development to the project.

25.2 Beaches Link and Gore Hill Freeway Connection sustainability framework

A sustainability framework has been developed for the project. The sustainability framework has been prepared to ensure that sustainability is embedded in project planning, design, construction and operation. The sustainability framework provides the overarching vision, objectives, targets and implementation approaches for the project.

Figure 25-1 shows the key elements of the sustainability framework. Each element is described in detail in the following sections.

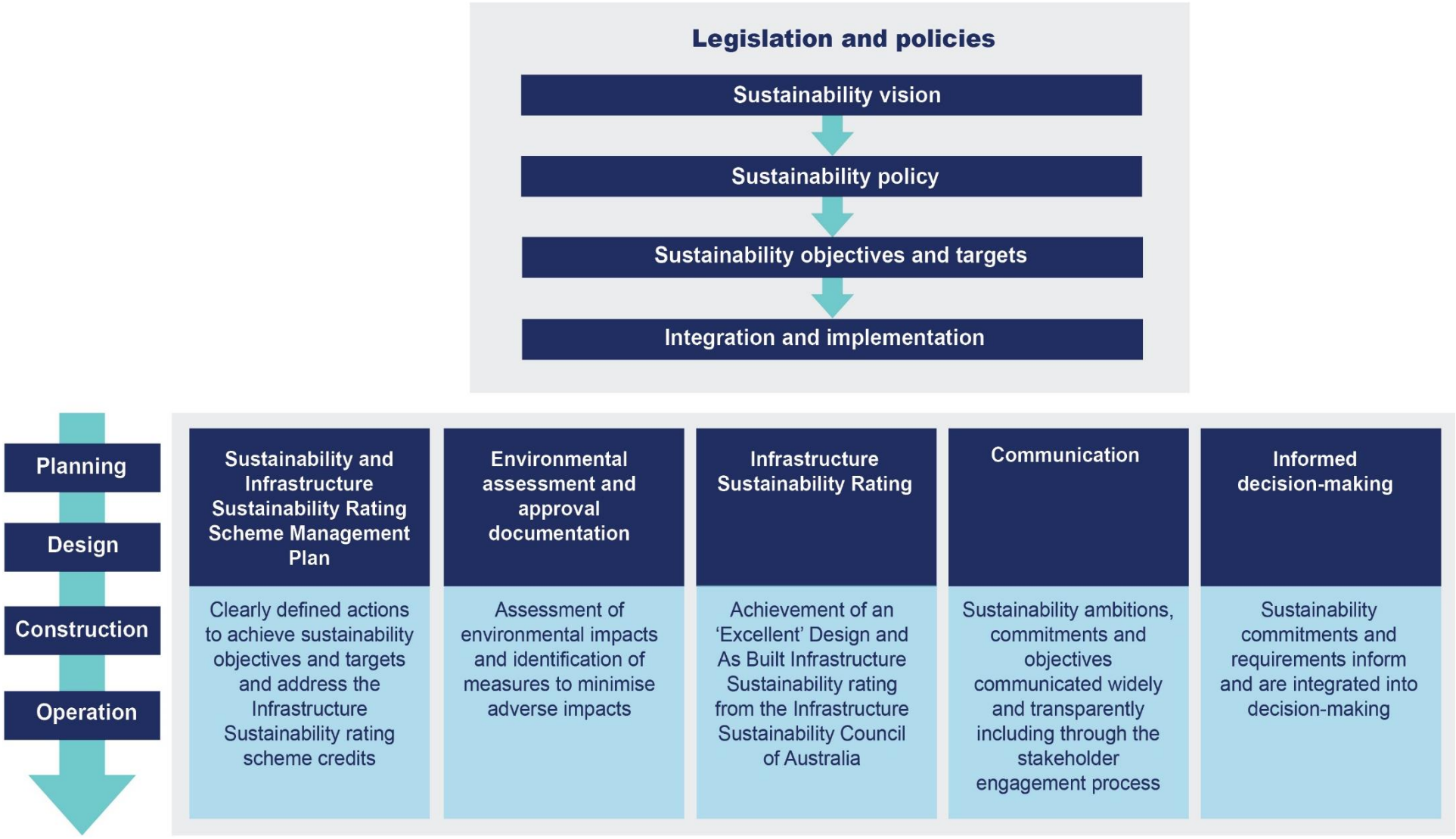

Figure 25-1 Beaches Link and Gore Hill Freeway Connection sustainability framework

25.2.1 Legislative and policy framework

The sustainability framework is underpinned by sustainability principles outlined in applicable legislation, policies and guidelines. The NSW Government, Transport for NSW, and the Infrastructure Sustainability Council of Australia each set sustainability principles, objectives and targets within their respective policies.

Key legislation, policies and guidelines that have directed the consideration and integration of sustainability in the project design and assessment are summarised in Table 25-2. Other relevant legislation, policies and guidelines that include sustainability outcomes relevant to the project are outlined in Table 25-3. Table 25-3 shows the recurring sustainability themes found in these documents and where specific principles, objectives and targets are set.

Table 25-2 Key legislation, policies and guidelines

Legislation, policy or guideline	Overview
Environmental Planning and Assessment Act 1979	The *Environmental Planning and Assessment Act 1979* facilitates ecologically sustainable development in NSW by integrating relevant economic, environmental and social considerations in decision making about environmental planning and assessment. As an object of the Act, ecologically sustainable development must be incorporated in the planning of the project (refer to Section 25.3).
Transport Environment and Sustainability Policy (Transport for NSW, 2020c)	The *Transport Environment and Sustainability Policy* outlines the commitment of Transport for NSW and key transport agencies to deliver transport projects and services in a manner that balances economic, environmental and social issues.
Environmental Sustainability Strategy 2019-23 (Roads and Maritime Services, 2019)	The *Environmental Sustainability Strategy 2019-2023* (Roads and Maritime Services, 2019) aligns with the *Transport Environment and Sustainability Policy* and outlines specific focus areas for integrating sustainability into Transport for NSW road projects and services.
Infrastructure Sustainability Rating Tool version 1.2 (Infrastructure Sustainability Council of Australia, 2016a)	The Secretary's environmental assessment requirements for the project require the assessment of the project in accordance with the *Infrastructure Sustainability Rating Tool* and recommendation of an appropriate target rating. The Infrastructure Sustainability rating scheme was developed by the Infrastructure Sustainability Council of Australia as a comprehensive process for evaluating sustainability across the design, construction and operation of infrastructure.
Sustainable Design Guidelines version 4.0 (Transport for NSW, 2017)	The Transport for NSW *Sustainable Design Guidelines version 4.0* are aimed at embedding sustainability initiatives across seven key themes, into the planning, design, construction, operations and maintenance of infrastructure projects. The Secretary's environmental assessment requirements for the project reference the *Sustainable Design Guidelines version 4.0* as the current guidelines to be considered as part of the preparation of this environmental impact statement.

Table 25-3 Relevant sustainability legislation, policies and guidelines

Sustainability theme	NSW Government legislation, policies and guidelines								Transport for NSW's policies and guidelines						Infrastructure Sustainability Council of Australia
✓ Principle ✓ Objective ✓ Target	*Environmental Planning and Assessment Act 1979*	Future Transport 2056 plan	NSW Sustainable Design Guidelines v4.0	NSW Government Resource Efficiency Policy	NSW Waste avoidance and Resource recovery Strategy	NSW Government Training Management Guidelines	Aboriginal Participation in Consultation Guidelines	Aboriginal Participation in Construction Policy	Transport Social Procurement Policy	Transport Environment and Sustainability Policy	Sydney's Cycling Future, Cycling for everyday transport	Sydney's Walking Future, Connecting people and places	Roads and Maritime Services Sustainability Strategy	Beyond the Pavement	
Management and participation		✓ ✓	✓ ✓						✓	✓ ✓			✓ ✓	✓ ✓	✓ ✓
Energy, carbon and materials	✓ ✓	✓	✓ ✓	✓ ✓					✓	✓ ✓			✓ ✓		✓ ✓
Resources and waste	✓	✓	✓ ✓	✓	✓					✓			✓	✓	✓ ✓
Climate change		✓ ✓	✓ ✓							✓			✓ ✓		✓ ✓
Communities and liveability		✓	✓ ✓ ✓						✓	✓ ✓	✓ ✓	✓ ✓ ✓	✓ ✓	✓ ✓	✓ ✓
Water			✓ ✓	✓						✓ ✓			✓		✓ ✓
Pollution and emissions	✓ ✓	✓	✓ ✓	✓						✓ ✓			✓ ✓ ✓		✓ ✓
Ecology	✓	✓	✓ ✓							✓			✓	✓	✓ ✓
Employment and opportunities						✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓							

25.2.2 Sustainability vision and policy

The sustainability framework establishes the sustainability vision and policy for the project (refer to Figure 25-2). The sustainability vision and policy set the overall direction for implementing sustainability initiatives during the delivery of the project. The vision and policy reflect and align with NSW Government legislation and policies and Transport for NSW's strategic sustainability policy (refer to Section 25.2.1). The policy acknowledges the need to deliver services and infrastructure that benefit the community and minimise negative environmental, social and economic impacts while maximising positive outcomes. The vision and policy may continue to be refined as the project progresses.

Vision	The Beaches Link and Gore Hill Freeway Connection project is committed to improving quality of life for current and future generations by maximising social, economic and environmental value. The project will achieve excellence in sustainability, and embed sustainability thinking across all stages, moving industry forward by setting the bar higher for both the process and delivery of sustainability.

Policy

The Beaches Link and Gore Hill Freeway Connection project is committed to:

- Aligning with the *Transport Environment and Sustainability Policy* (Transport for NSW, 2020)
- Aligning with, supporting and, wherever feasible, exceeding the ambitions of the Environmental Sustainability Strategy 2019-2023 (Roads and Maritime, 2019)
- Optimising sustainability outcomes, transport service quality, and cost effectiveness
- Being environmentally responsible by avoiding pollution, enhancing the natural environment and maintaining or reducing the project ecological footprint
- Using resources (energy, water and materials) efficiently and reducing waste
- Providing a safe and accessible motorway integrated into the urban environment and transport system
- Raising awareness of environmental issues and sharing sustainability knowledge with the community and broader industry
- Creating desirable places, promoting liveability and cultural heritage, and optimising both community and economic benefit

To deliver these commitments, the Beaches Link and Gore Hill Freeway Connection project will:

- Establish robust sustainability objectives and targets
- Ensure balanced consideration of environmental, social and economic costs and benefits during decision making
- Encourage innovation and setting high environmental and sustainability standards
- Establish positive relationships with community and stakeholders to maximise opportunities to add value to local communities
- Develop and maintain an environmental management framework to embed best practice pollution management and sustainable outcomes during construction
- Apply effective assurance processes to monitor performance against the project environment and sustainability objectives and identify appropriate reward or corrective action, as required
- Integrate environment and sustainability-specific processes into the procurement of delivery activities and suppliers
- Hold employees and contractors accountable for proactively meeting their environmental and sustainability responsibilities
- Provide local training, education, apprenticeships and employment opportunities

The project will comply with environmental legislation and regulations, and proactively support initiatives that go beyond compliance requirements. The project will also exhibit leadership in environmental practices and sustainability, supporting innovation, creating beneficial social and environmental impacts, and creating a positive economic legacy.

Figure 25-2 Beaches Link and Gore Hill Freeway Connection sustainability vision and policy

25.2.3 Sustainability objectives and targets

To achieve the sustainability vision for the project and to contribute to the desired outcomes of the relevant NSW Government and Transport for NSW policies and guidelines (refer to Section 25.2.1) the project would establish robust sustainability objectives and targets. The process being followed to develop the objectives and targets is shown in Figure 25-3.

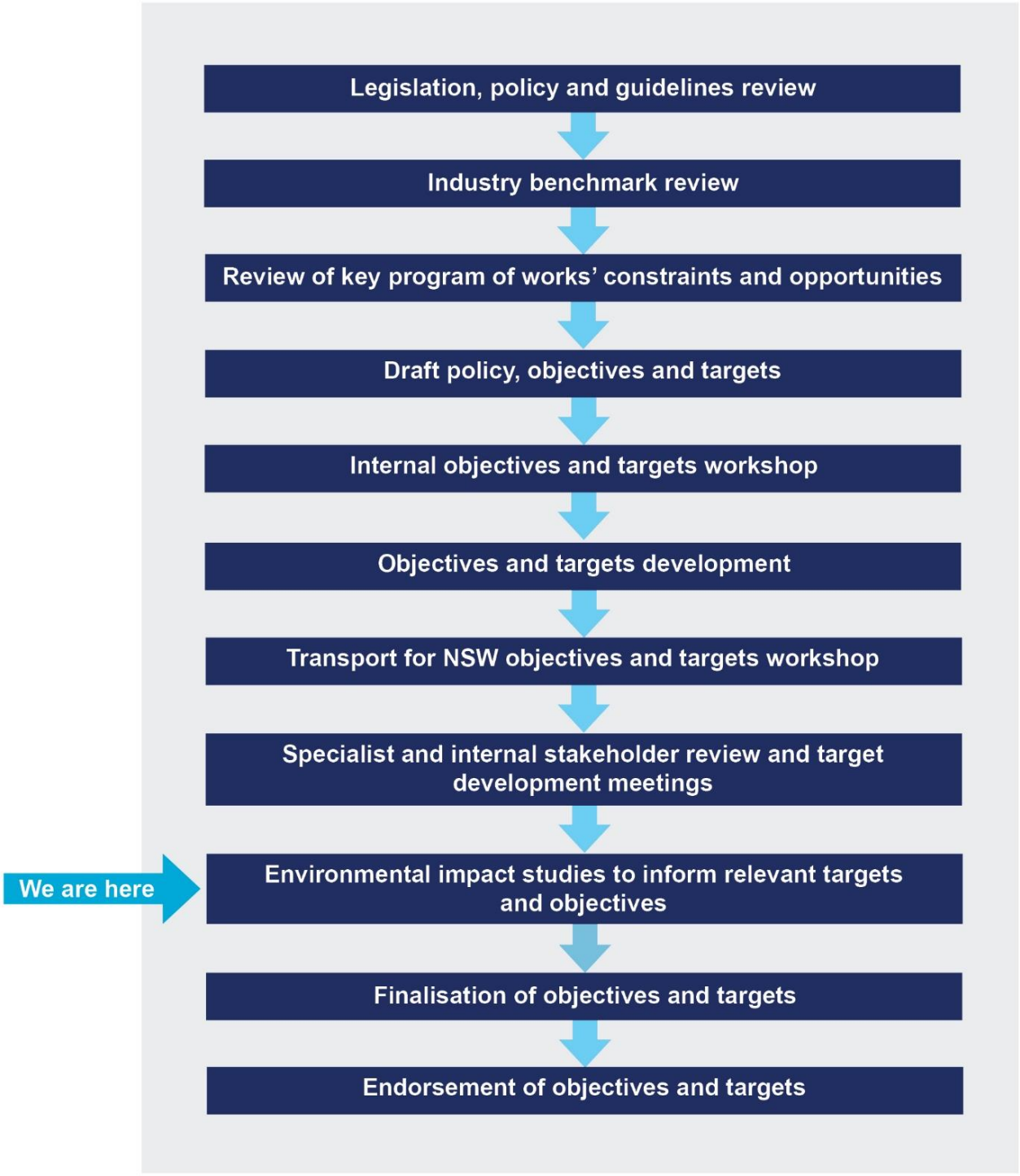

Figure 25-3 Beaches Link and Gore Hill Freeway Connection sustainability objectives and targets development process

The outcomes from this environmental impact statement, including any relevant conditions that may be applied to the project by the Minister for Planning and Public Spaces, would be used to finalise the sustainability objectives and targets for the project. Indicative objectives and targets (subject to later refinement to allow for incorporation of any relevant approval conditions) are outlined in Table 25-4.

Table 25-4 Indicative sustainability objectives and target themes

Objective	Target themes
Maximise sustainability knowledge and awareness	• Sustainability commitments (including procurement commitments) • Sharing of sustainability outcomes with the community/stakeholders and industry • Sustainability awareness training.
Minimise energy use and greenhouse gas emissions	• Embodied energy within construction materials • Construction greenhouse gas emissions • Operational greenhouse gas emissions • Energy efficient lighting.
Optimise resource efficiency and waste management	• Resource recovery of virgin excavated natural material • Reuse of topsoil • Diversion of office waste from landfill • Resource recovery of concrete and reclaimed asphalt • Encapsulation of contaminated material on site where appropriate • Cementitious substitution materials • Recycled content in road base • Recycling of other waste and wastewater • Recycled paper use • Avoidance of single use kitchen items.
Maximise resilience to climate change impacts	• Climate change risk mitigation and/or adaptation measures.
Enhance liveability of local communities	• Heritage values • Community benefit initiatives • Public open space • Urban design.
Maximise employment and training opportunities for young people, Aboriginal and Torres Strait Islanders, disadvantaged groups, long term unemployed and people who live along the project's alignment	• Apprenticeships • Training and development • Workforce participation.

Objective	Target themes
Efficiently manage water	• Water use during construction • Water use during operation • Use of non-potable water.
Minimise pollution generated by the project	• Air quality • Noise and vibration • Water quality • Reporting and tracking of environmental incidents.
Minimise impacts on biodiversity	• Ecological value and biodiversity.
Maximise sustainable procurement	• Sustainability and social aspects selection criteria • Labour practices • Procurement of sustainable timber.

25.2.4 Integration and implementation of sustainability framework

The sustainability framework would continue to be developed and refined in future phases of the project's delivery. The key implementation tools and processes that have been, and would continue to be, applied to the delivery of the sustainability framework are shown in Figure 25-1.

Activities to implement the sustainability framework, including requirements from the Infrastructure Sustainability rating scheme, would be implemented through a Sustainability Management Plan. The management plan would detail measures to meet the sustainability objectives and targets and Infrastructure Sustainability rating scheme credit requirements (refer to Section 25.4).

The project would seek to achieve an 'Excellent' 'Design' and 'As Built' Infrastructure Sustainability rating under version 1.2 of the Infrastructure Sustainability Council of Australia rating scheme.

25.3 Ecologically sustainable development

Facilitating ecologically sustainable development is adopted as an object of the *Environmental Planning and Assessment Act 1979*. This object requires the integration of "relevant economic, environmental and social considerations in decision making about environmental planning and assessment".

Ecologically sustainable development is defined under the *Protection of the Environment Administration Act 1991* (NSW) and includes four principles:

- The precautionary principle
- Intergenerational equity
- Conservation of biological diversity and ecological integrity
- Improved valuation and pricing of environmental resources.

The principles of ecologically sustainable development have been an integral part of the design and assessment of the project. This has included the integration of relevant economic, environmental and social considerations in project design and assessment decisions, as summarised in Table 25-5.

The environmental impact statement has been prepared with regard to the key issues associated with the project and the integration of biophysical, economic and social considerations, including the principles of ecologically sustainable development and cumulative impacts (refer to Chapter 28 (Synthesis of the environmental impact statement) for additional information).

Table 25-5 Application of the principles of ecologically sustainable development to the project

Principle	Application to the project
Precautionary principle If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.	Applied during the design and development of the project: • Potential environmental impacts associated with the project considered in the alternatives and options analysis • Opportunities identified to avoid and minimise surface disturbance • Sustainability workshops and meetings held during design development with planning and design teams to develop draft sustainability targets and objectives for the project. Applied during the preparation of this environmental impact statement: • Prepared with a conservative approach, including assessment of worst case impacts and scenarios • Carried out using the best available technical information and has adopted best practice environmental standards, goals and measures • Potential environmental risks associated with the project identified and considered, with safeguards and management measures developed to manage and reduce identified risks • Sustainability workshops and meetings held during the development of the environmental impact statement with planning and design teams to inform relevant sustainability targets and objectives for the project.
Intergenerational equity The present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations.	• Project designed to meet with needs of both current and future generations with a design life of 100 years • Support for Sydney's long term economic growth through improved motorway access and connections across Sydney's Global Economic Corridor, particularly the strategic centres of Sydney CBD and North Sydney and the Northern Beaches, with improved connection to Macquarie Park and north-west Sydney • Contribution to improving the capacity, functionality and safety of the road network servicing the Northern Beaches for motorists, buses and freight • Contribution to the increased resilience of the road network servicing the Northern Beaches through the provision of an additional crossing of Middle Harbour • Reduction of operational greenhouse gas emissions on Sydney's road network when compared to the project not being built • The project's resilience to future climate change is considered in Chapter 26 (Climate change and greenhouse gas), which identifies potential climate change risks to the project, and adaptation measures incorporated into the design or options for further consideration during further design development

Principle	Application to the project
	• Management measures for potential environmental impacts have been provided throughout this environmental impact statement to protect the future health, diversity and productivity of the environment • During construction and operation of the project, opportunities would be taken to reduce material use and maximise the use of materials with low embodied environmental impact, where feasible • The mainline tunnel ventilation system has been designed for coordinated operation with the adjacent and connecting Western Harbour Tunnel and Warringah Freeway Upgrade project. The tunnel ventilation would meet the in-tunnel air quality criteria and would be operated in accordance with licensing requirements.
Conservation of biological diversity and ecological integrity Conservation of biological diversity and ecological integrity should be a fundamental consideration of the project.	• As outlined in Chapter 4 (Project development and alternatives), five different alignment alternatives were considered as part of the project development process to avoid and minimise potential impacts • Through this process, consideration was given to avoiding and minimising biodiversity impacts by way of locating project elements away from areas of biodiversity value as far as practicable. Where this was not possible, project elements were situated in areas with lower biodiversity values • The design of the project within the preferred corridor was then refined and assessed with the aim of further identifying, avoiding, minimising and mitigating impacts. The construction methodology has also been developed to avoid and minimise adverse impacts on biodiversity • The project would require the removal of native vegetation and potential fauna habitat. Detailed terrestrial and marine biodiversity assessments were carried out for the project to identify potential impacts on biodiversity and to provide a range of mitigation measures to further avoid and minimise potential impacts • A Biodiversity development assessment report (BDAR) was prepared in accordance with the Biodiversity Assessment Method (BAM) to establish how biodiversity impacts could be avoided and minimised and to identify the biodiversity credits that would need to be offset to achieve no net loss of biodiversity • Residual biodiversity impacts would be offset in accordance with the requirements of the *Biodiversity Conservation Act 2016* and relevant guidelines. The offsets required for the project were calculated using the BAM Calculator. A total of 391 ecosystem credits and 1099 species credits are required to offset the direct impacts of the project. An additional 50 ecosystem credits may be required to offset indirect impacts; these would be in addition to BAM credit obligations and are at the discretion of the Minister for Planning and Public Spaces.

Principle	Application to the project
Improved valuation and pricing of environmental resources Environmental factors should be included in the valuation of assets and services.	Value placed on avoiding and minimising environmental impacts demonstrated by: • The opportunities identified in the design development to improve local amenity, improve public transport access and active transport connections, and create new open space and recreation facilities • The opportunities identified to avoid and minimise environmental impacts in the project development and alternatives analysis • The extent of environmental investigations carried out to inform this environmental impact statement • The measures developed to further avoid and minimise potential impacts of the project detailed in this environmental impact statement • The inclusion of costs associated with planning, design and implementation of avoidance and mitigation measures in the overall project costs.

25.4 Environmental management measures

Environmental management measures relating to sustainability are outlined in Table 25-6.

Table 25-6 Environmental management measures – sustainability

Ref	Phase	Impact	Environmental management measure	Location
SU1	Design	Project sustainability outcomes	Project sustainability objectives and targets will be finalised during further design development, informed by the requirements of the project planning approval.	BL/GHF
SU2	Construction	Project sustainability outcomes	Activities to implement the sustainability framework, including requirements from the Infrastructure Sustainability rating scheme, will be implemented through a Sustainability Management Plan. The management plan will detail measures to meet the sustainability objectives and targets as well as achieving 'Design' and 'As Built' ratings of Excellent under the Infrastructure Sustainability Council of Australia (ISCA) rating scheme.	BL/GHF

Note: BL = Beaches Link, Gore Hill Freeway Connection = GHF

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 26

Climate change and greenhouse gas

26 Climate change and greenhouse gas

This chapter assesses the potential impacts of climate change on the project and adaptation measures that have been incorporated into the design of the project. Greenhouse gas emissions generated by the construction and operation of the project are also assessed within this chapter. Detailed greenhouse gas calculations and climate change projections are provided in Appendix X (Technical working paper: Climate change and greenhouse gas calculations).

The Secretary's environmental assessment requirements relating to climate change and greenhouse gas emissions, and where in the environmental impact statement these have been addressed, are detailed in Table 26-1.

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 adaptation for climate change risk and greenhouse gas emissions are included in Section 26.1.5 and Section 26.2.5 respectively.

Table 26-1 Secretary's environmental assessment requirements – climate change risk

Secretary's requirement	Where addressed in EIS
Climate change risk	
1. The Proponent must assess the risk and vulnerability of the project to climate change in accordance with the current guidelines.	This chapter and **Appendix X** (Technical working paper: Climate change and greenhouse gas calculations), present a climate change risk assessment for the project in accordance with current guidelines as listed in **Section 26.1.1**.
2. The Proponent must quantify specific climate change risks with reference to either the NSW Government's climate projections at 10 km resolution (or lesser resolution if 10 km projections are not available) or equivalent projection tool (such as the Climate Futures Tool from CSIRO and BoM (attenuated for project region)) and incorporate specific adaptation actions in the design.	Climate change risks to the project are identified in **Section 26.1.4**, and **Appendix X** (Technical working paper: Climate change and greenhouse gas calculations), with reference to current climate change projections presented in **Section 26.1.3**.

26.1 Climate change risk assessment

This section outlines the legislation, policies and climate change projections relevant to the project, assesses the risks of climate change to the project and outlines adaptations to manage those risks.

26.1.1 Legislative and policy framework

The climate change risk assessment has been conducted in line with the following relevant standards and current guidelines:

- *National Climate Resilience and Adaptation Strategy* (Department of the Environment and Energy, 2015)
- *NSW Climate Change Policy Framework* (Office of Environment and Heritage (OEH), 2016a)

- *Environmental Sustainability Strategy 2019-2023* (Roads and Maritime Services, 2019)
- Australian Standard *AS 5334-2013 Climate change adaptation for settlements and infrastructure – A risk-based approach* (Standards Australia, 2013)
- Australian and New Zealand Standard *AS/NZ ISO 31000:2009 Risk management – Principles and guidelines* (Australian and New Zealand Standard, 2009)
- *Climate Change Impacts and Risk Management – A Guide for Business and Government* (Australian Government, 2006)
- *Technical Guide for Climate Change Adaptation for the State Road Network* (Roads and Maritime Services, 2015e)
- *Guideline for Climate Change Adaptation, Revision 2.1* (Australian Green Infrastructure Council, 2011)
- *Climate Risk Assessment Guideline* (Transport for NSW, 2019b).

26.1.2 Assessment methodology

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

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

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

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

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

A hazard-receiver pathway model has been applied to identify and analyse risks to the project with respect to climate change. Climate or climate influenced attributes with potential to influence the project were identified (hazards), along with the component of the project, user or surrounding environment that would be impacted by the hazard (receivers).

The appropriate risk rating level was identified by:

- Determining the likelihood of each risk occurring
- Determining the consequences of each risk occurring
- Considering what is already inherent in the design, and the business as usual controls expected to be applied through design, construction, maintenance and operation

- Determining the residual risk, incorporating the above factors.

The risk assessment matrix in Appendix X (Technical working paper: Climate change and greenhouse gas calculations) was applied to determine risk ratings for the identified hazards and receivers.

26.1.3 Climate change projections

Climate change projections used for the climate change risk assessment are summarised below in Table 26-2.

The projections were developed for three periods, broadly reflecting the operating timeframes of different elements of the project:

- Year 2030: assets and systems with short operating timeframes, such as communications and other electronic systems, landscaping and road surfaces
- Year 2050: assets and systems with long operating timeframes, such as drainage structures and barriers/rails
- Year 2090: 'permanent' assets, which would become fixed and ongoing features of project, such as tunnel civil structures (including rock bolts), bridges, embankment culverts (and other inaccessible drainage), and buildings.

Projections were derived from the Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5) (IPCC, 2013) which are incorporated into the Climate Futures Tool by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Department of Agriculture, Water and Environment. Projections are provided for a number of emissions and pathway scenarios for a range of climate parameters. The projections are based on the 'worst-case' scenario (Representative Concentration Pathways 8.5), which reflects the highest emissions projected for the time period.

Table 26-2 Summary of climate change projections – Sydney region

Climate variable	Baseline (1986 - 2005)	2030	2050	2090
Temperature				
Mean minimum temperatures (°C) – annual	14.4	15.5	16.3	18.4
Mean maximum temperatures (°C) – annual	22.4	24.3	24.4	26.5
Days over 35°C – annual	3.5	5.6	5.9	11.3
Rainfall				
Mean precipitation (mm) – annual	1238	1206	1151	1049
Extreme rainfall events – max 1-day rainfall	Projected to increase 2 – 22%			
Extreme rainfall events – 20-year return level of max. 1-day rainfall	Projected to increase 5 – 42%			
Evapotranspiration				
Annual change in potential evapotranspiration (% change)	375 mm (1961-1990)	4.2	No data	14.3
Fire regimes				
The number of days where the fire danger rating is 'severe' or 'extreme'	0.9	1.3	No data	2.1

Climate variable	Baseline (1986 - 2005)	2030	2050	2090
Severe wind				
Average maximum daily wind speed (% change)	120 km/h	-0.2 to 1.9	1.8 to 3.2	0.3 to 5.7
Sea conditions				
Sea level rise (m)	0	0.14	No data	0.66
Sea surface temperature (°C)	Varies	1.0	No data	3.1
Atmospheric CO_2				
Atmospheric CO_2 concentration	401 ppm	No data	No data	940 ppm (2100)

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

26.1.4 Climate change risk evaluation

Climate change risks with a medium or high rating (based on the design presented in this environmental impact statement), prior to the implementation of further treatment measures, are summarised in Table 26-3 (ie 'initial rating'). These 'initial ratings' assume the incorporation of business as usual design, construction and operational controls. Treatment methods have been identified and are proposed for those 'initial ratings', based on the current design, or are proposed to be carried out as part of future investigations during further design development.

The 'final rating' (ie post-treatment), incorporating further additional treatment options and investigations, is also presented in Table 26-3.

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

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

Table 26-3 Climate change risk assessment

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

26.1.5 Adaptation for climate change

Table 26-4 lists the actions that would be carried out during further design development to mitigate the effects of climate change.

Table 26-4 Environmental management measures – climate change risks

Ref	Phase	Risks	Environmental management measure	Location
CC1	Design	Climate change risks and flood modelling projections	The following actions will be carried out during further design development to ensure climate change is adequately addressed: a) Flood modelling will continue to use sea level rise projections and future climate change rainfall projections b) The extent of scour protection will be refined c) Sensitivity testing for future climate change will be carried out in the detailed design of drainage channels and culverts. Increased capacity will be provided where feasible and reasonable.	BL/GHF

Beaches Link = BL, Gore Hill Freeway = GHF

26.2 Greenhouse gas

Atmospheric greenhouse gases absorb and re-radiate heat from the sun, trapping heat in the lower atmosphere and influencing global temperatures. This is known as the greenhouse effect and is linked to climate change.

The emission of greenhouse gases into the atmosphere occurs as a result of both natural processes (eg bushfires) and human activities (eg burning of fossil fuels to generate electricity).

This section outlines the legislation and policies relevant to the project, and the greenhouse gas emissions and potential impacts caused by the construction and operation of the project.

26.2.1 Legislative and policy framework

This assessment was prepared according to the principles and objectives outlined in the following legislation and policies:

- *Kyoto Protocol to the United Nations Framework Convention on Climate Change* (the Kyoto Protocol) (UNFCCC, 1998)
- *Doha Amendment to the Kyoto Protocol* (UNFCCC, 2012)
- *Paris Agreement* (UNFCCC, 2015)
- *National Greenhouse and Energy Reporting Act 2007* (Cwlth)
- *Direct Action Plan* (Australian Government, 2014)
- *NSW Climate Change Policy Framework* (OEH, 2016a)
- *Environmental Sustainability Strategy 2019-2023* (Roads and Maritime Services, 2019).

26.2.2 Assessment methodology

The methodology for this greenhouse gas and energy assessment is based on the following tools and protocols:

- *Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard* (World Resources Institute & World Council for Sustainable Business Development (WRI & WBCSD), 2004)
- *Greenhouse Gas Assessment Workbook for Road Projects* (the TAGG Workbook) (Transport Authorities Greenhouse Group (TAGG), 2013)
- *Infrastructure Sustainability Materials Calculator* (Infrastructure Sustainability Council of Australia, 2016b)
- *Tools for Roadside Air Quality* (Roads and Maritime Services, 2012).

Greenhouse gas emissions are reported as kilotonnes of carbon dioxide equivalent (kt CO_2-e).

Emissions are categorised into three different scopes in accordance with the Greenhouse Gas Protocol.

The three greenhouse gas scopes are:

- Scope 1 emissions – direct emissions generated by the project, eg emissions generated by the use of diesel fuel in project construction plant, equipment or vehicles
- Scope 2 emissions – indirect emissions from the consumption of purchased electricity for project equipment or operation of the project
- Scope 3 emissions – all other indirect emissions (not included in Scope 2) generated as a consequence of the project, eg emissions associated with the mining, production and transport of materials used in construction.

26.2.3 Assessment of potential construction impacts

The primary sources of construction greenhouse gas emissions and the indicative Scope 1, 2 and 3 emissions for the project are presented in Table 26-5 and Figure 26-1.

The construction stage of the project is expected to generate about 724 kt CO_2-e of greenhouse gas emissions. As shown in Figure 26-1, about 38 per cent of emissions are expected to be contributed from terrestrial electricity consumption, and about 42 per cent by construction materials.

The estimated construction stage emissions represent about 0.6 per cent of NSW emissions and about 0.13 per cent of Australia's national emissions in 2018. Due to the indirect nature of Scope 3 emissions, a proportion of these emissions may be generated interstate or internationally. While these percentage contributions are small within the NSW and national contexts, measures have been outlined in Section 26.2.5 to further minimise greenhouse gas emissions during the construction of the project.

Table 26-5 Indicative construction phase greenhouse gas emissions by scope

Emission source	Emissions (kt CO_2-e)			
	Scope 1	Scope 2	Scope 3	Total
Diesel combustion (plant and equipment)	23.9	-	1.2	25.1
Diesel combustion (generators for marine construction)	4.5	-	0.2	4.7
Diesel combustion (transport of materials to terrestrial temporary construction support sites)	-	-	9.6	9.6
Diesel combustion (transport of waste and spoil from terrestrial and harbour temporary construction support sites)	-	-	98.6	98.6

Emission source	Emissions (kt CO_2-e)			
	Scope 1	Scope 2	Scope 3	Total
Vegetation removal	2.9	-	-	2.9
Electricity consumption (terrestrial)	-	249.5	27.7	277.2
Construction materials	-	-	305.6	305.6
Total	31.3	249.5	442.9	723.7

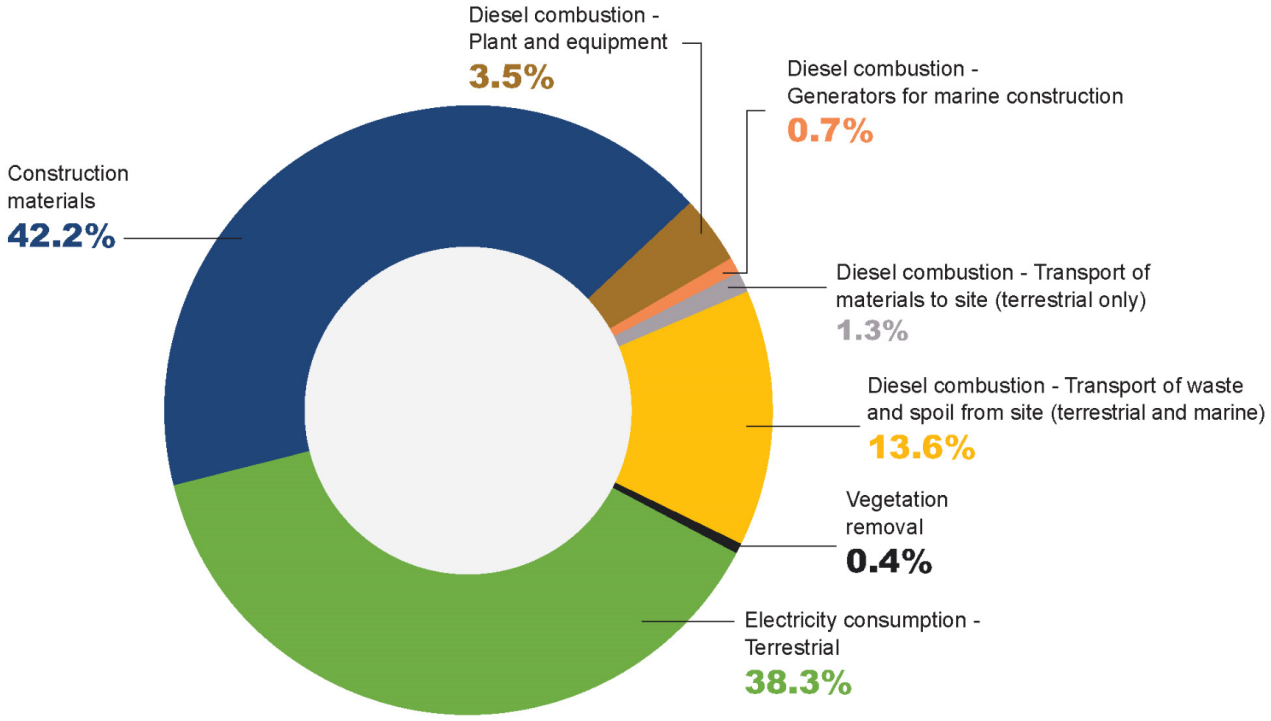

Figure 26-1 Estimated greenhouse gas emissions by source for construction

26.2.4 Assessment of potential operational impacts

The primary sources of operational greenhouse gas emissions and the indicative Scope 1, 2 and 3 emissions for the project are presented in Table 26-6. Emissions estimates are provided for operational scenarios in 2027 (opening) and 2037 (10 years after opening).

Electricity

Operational greenhouse gas emissions would be associated with the electricity consumption required to power operational infrastructure and facilities, including:

- Tunnel ventilation
- Surface and tunnel lighting
- Motorway control centre
- Wastewater treatment plant
- Substations.

Operational electricity consumption is projected to increase over time, due to the projected increase in traffic volumes using the roads, increasing tunnel ventilation requirements.

Maintenance

Greenhouse gas emissions generated from the maintenance of road infrastructure would be relatively small in comparison with other operational sources. Emissions would result from the use of diesel fuel maintenance vehicles and equipment, and are embedded in the construction materials used for maintenance activities.

Traffic

Operational greenhouse gas emissions would be associated with fuel consumed by vehicles using the road network. Greenhouse gas emissions are also projected to increase as traffic numbers across the road network grow. However, the expected reduction in congestion as a result of the project and expected improvements in fuel efficiency and increases in electric vehicles, are projected to result in improvements to the overall efficiency of emissions. The project would increase the number of road links across the network, but would result in fewer vehicle stop and start movements, less congestion and a greater average vehicle speed, which would further increase the efficiency of vehicles and assist in reducing emissions. Table 26-6 outlines the difference, with and without the project, between operational greenhouse gas emissions associated with traffic.

Emission estimates

The estimated operational emissions would represent about 0.03 and 0.04 per cent of projected NSW emissions in 2027 and 2037 respectively, and 0.01 per cent of Australia's projected national emissions in both 2027 and 2037. While these percentage contributions are small within the NSW and national contexts, the environmental management measures outlined in Section 26.2.5 would be implemented to further minimise greenhouse emissions during the operation of the project.

Table 26-6 Indicative operational phase greenhouse gas emissions by scope

Source	Emissions (kt CO_2-e)			
	Scope 1	Scope 2	Scope 3	Total
2027				
Operational electricity	-	27.9	3.1	31.0
Maintenance	0.3	-	0.3	0.6
Traffic (difference between existing levels and levels with the project)	-	-	13.7	13.7
Total	0.3	27.9	17.1	45.3
2037				
Operational electricity	-	29.2	3.2	32.4
Maintenance	0.3	-	0.3	0.6
Traffic (difference between existing levels and levels with the project)	-	-	19.5	19.5
Total	0.3	29.2	24.1	52.5

26.2.5 Environmental management measures

Environmental management measures relating to greenhouse gas emissions are outlined in Table 26-7.

Table 26-7 Environmental management measures – greenhouse gas

Ref.	Phase	Risks	Environmental management measure	Location
GHG1	Design	Energy efficiency	Energy efficiency will be considered during further design development with energy efficient systems installed where reasonable and practicable.	BL/GHF
GHG2	Construction	Emission of greenhouse gases during construction	Greenhouse gas emissions will be managed and minimised as part of the Sustainability Management Plan and will be implemented to assist in achieving 'Design' and 'As Built' ratings of Excellent under the Infrastructure Sustainability Council of Australia rating scheme (Version 1.2).	BL/GHF

Beaches Link = BL, Gore Hill Freeway = GHF

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 27

Cumulative impacts

transport.nsw.gov.au

DECEMBER 2020

27 Cumulative impacts

This chapter provides an overview of the potential cumulative impacts associated with the construction and operation of the project and identifies measures which address these impacts.

The Secretary's environmental assessment requirements as they relate to cumulative impacts and where in the environmental impact statement these have been addressed, are detailed in Table 27-1.

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 cumulative impacts are discussed in Section 27.5.

Table 27-1 Secretary's environmental assessment requirements – cumulative impacts

Secretary's requirement	Where addressed in EIS
Environmental Impact Statement	
1. The EIS must include, but not necessarily be limited to, the following: o. an assessment of the cumulative impacts of the project taking into account other projects that have been approved but where construction has not commenced, projects that have commenced, and projects that have recently been completed	Projects that have been assessed and may have potential cumulative impacts are identified in **Section 27.2**. Potential cumulative impacts are described in **Section 27.3** and **Section 27.4**.
Assessment of Key Issues	
2. For each key issue the Proponent must: c. identify, describe and quantify (if possible) the impacts associated with the issue, including the likelihood and consequence of the impact (comprehensive risk assessment), and the cumulative impacts of: a) concurrent project construction activities; and b) proposed and approved projects (where information is available at the time of writing)	Potential cumulative impacts during construction and operation for the key issues discussed in **Chapters 8** to **26** are described in **Section 27.3** and **Section 27.4**.
Consultation	
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 project and other major projects in the local area.	The potential for complaint fatigue to occur and proposed mitigation measures and complaint handling procedures are described in **Chapter 7** (Stakeholder and community engagement). Potential impacts of construction and complaint fatigue are described in **Section 27.3.7**.

27.1 Assessment methodology

Cumulative impacts can occur when impacts from the project interact or overlap with impacts from other projects and potentially result in a larger overall effect 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, resulting in construction fatigue for local receivers. Construction fatigue incorporates the potential for complaint fatigue, which may impact communication of community concerns during construction.

This section provides:

- A description of how projects were initially identified for consideration of cumulative construction or operational impacts with the project
- The screening criteria applied to determine whether the identified projects should be assessed for cumulative impacts
- An overview of the type of assessment carried out for the relevant cumulative impacts.

The cumulative impact assessment in this environmental impact statement is based on the broad requirements set out by the Secretary's environmental assessment requirements.
The methodology is shown in Figure 27-1.

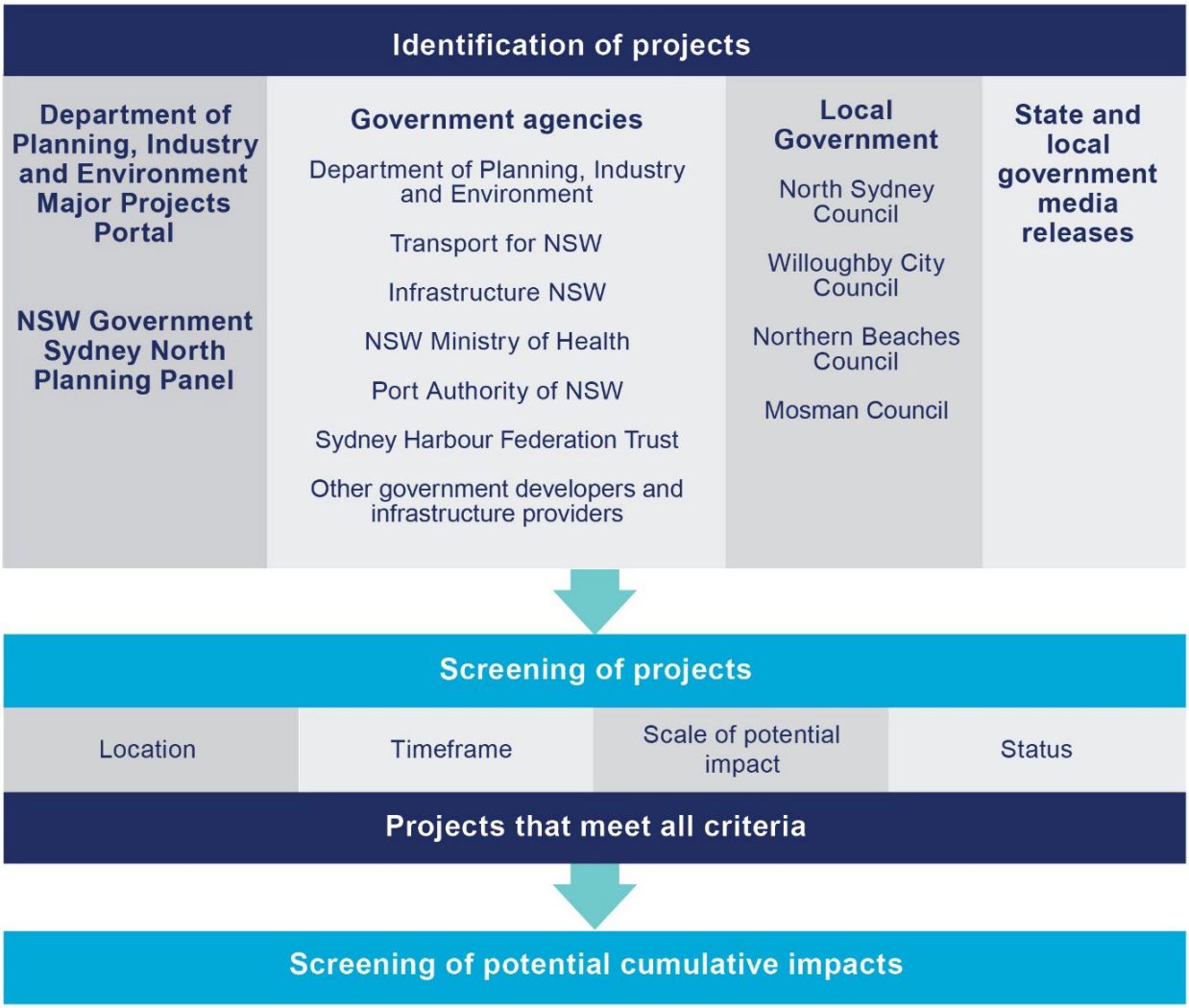

Figure 27-1 Overview of the cumulative impact assessment methodology

27.1.1 Identification of projects

An initial list of projects for potential inclusion in the cumulative impact assessment was identified from the sources outlined in Figure 27-1.

Projects identified for inclusion in the screening assessment were those likely to meet at least one of the screening criteria described in Table 27-2. The list of projects identified can be broadly categorised as:

- **Category 1:** The Western Harbour Tunnel and Beaches Link program of works, including the Western Harbour Tunnel and Warringah Freeway Upgrade
- **Category 2:** Other major transport infrastructure projects, including related Transport for NSW projects and public transport projects
- **Category 3:** Other projects and strategic development, including urban development, other infrastructure projects, and consideration of local strategic planning documents where they may result in future development and lead to potential cumulative impacts with the project.

27.1.2 Screening of projects

The screening criteria shown in Table 27-2 were applied to determine whether a project or strategic plan should be included in the cumulative impact assessment. Projects and plans that satisfied all of these criteria were included and are described in Section 27.2.

Table 27-2 Screening criteria for cumulative impact assessment

Criteria	Relevance
Location A project was considered relevant where that project was within one of the following areas:	• Direct overlap: construction footprints intersect
	• In close proximity: within 500 metres of the construction footprint
	• In the locality: within two kilometres of the construction footprint
Timeframe A project was considered relevant where that project involved one of the following timeframes:	• Concurrent construction programs
	• Consecutive construction programs (ongoing or recently completed projects resulting in construction fatigue considerations)
Scale of potential impact A project was considered relevant where that project involved one or more of the following impacts:	• Substantial temporary changes to existing traffic conditions
	• Substantial temporary changes to the existing noise environment
	• Impacts on numerous heritage items and/or heritage items with State, National, Commonwealth or World significance
	• Substantial changes to the existing land use
	• Substantial changes to the existing urban landscape and/or changes to biodiversity

Criteria	Relevance
Status A project was considered relevant where that project was at one of the following stages of the statutory assessment and approval process:	• Approved projects (statutory approvals received), including approved projects that have not started construction, projects currently under construction, and recently completed projects
	• Proposed projects (currently under statutory environmental impact assessment)
	• Future strategic government projects (where commitment on construction program and methodology has been made)

27.1.3 Screening of potential cumulative impacts

The assessment of potential cumulative impacts has considered the following key locations:

- North Sydney and Cammeray
- Artarmon
- Naremburn and Willoughby
- Middle Harbour
- Balgowlah
- Seaforth, Killarney Heights and Frenchs Forest.

Potential cumulative impacts have been considered based on likely interactions of the Beaches Link and Gore Hill Freeway Connection project with other projects and plans listed in Table 27-3 and Table 27-4.

Where potential cumulative impacts may occur, these could relate to:

- Additional impacts due to concurrent construction periods
- Prolonged impacts due to consecutive construction periods.

The assessment of potential cumulative impacts has considered the key issues identified in Chapters 8 to 26 of this environmental impact assessment. In locations where cumulative impacts relating to a key issue has been assessed as negligible, the issue is not considered further.

The potential cumulative impacts during construction and operation are described in sections 27.3 and 27.4 respectively.

27.2 Projects assessed

Following the application of the screening criteria to identified projects, the projects included in Table 27-3 have been considered in the cumulative impact assessment. The location of these projects is shown in Figure 27-2.

Local strategic plans listed in Table 27-4 have been considered in the assessment where relevant, as they will influence development that has the potential to result in cumulative impacts with the project. The potential impacts are not able to be considered in detail given the uncertainty of the status and timing of associated projects, construction methodologies, and the existing coordination arrangements between Transport for NSW and Sydney Metro for works in North Sydney and Artarmon.

Table 27-3 Projects assessed in the cumulative impact assessment

Project name, status and expected construction period	Brief project description	Relevant locations where cumulative impacts might occur[1]
Category 1: Western Harbour Tunnel and Beaches Link program of works		
Western Harbour Tunnel and Warringah Freeway Upgrade Proposed 2020 – 2026	The Western Harbour Tunnel and Warringah Freeway Upgrade project 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 connect to the Beaches Link and Gore Hill Freeway Connection project.	• North Sydney and Cammeray • Artarmon • Naremburn and Willoughby
Category 2: Other major transport infrastructure projects		
Sydney Metro City & Southwest (Chatswood to Sydenham) Approved 2017 – 2024	The Chatswood to Sydenham component of Sydney Metro City & Southwest involves the construction and operation of a 15.5 kilometre metro line from Chatswood, under Sydney Harbour and through Sydney's CBD out to Sydenham. Components of the project relevant to this assessment include: • Chatswood dive site • Artarmon substation • Crows Nest Station • Victoria Cross Station.	• North Sydney and Cammeray • Artarmon • Naremburn and Willoughby
Northern Beaches Hospital road upgrade project Completed 2015 – August 2020	This recently completed project involved staged construction works to enhance connectivity to the new Northern Beaches Hospital and to improve the broader road network capacity. The following locations were upgraded as part of the works: • Warringah Road from its intersection with Maxwell Parade to its intersection with Courtley Road • Naree Road/Frenchs Forest Road from its intersection with Forest Way to its intersection with Warringah Road	• Seaforth, Killarney Heights and Frenchs Forest

Project name, status and expected construction period	Brief project description	Relevant locations where cumulative impacts might occur[1]
	• Wakehurst Parkway from about 500 metres north of Frenchs Forest Road to about 500 metres south of Warringah Road • Forest Way from around Adams Street about 750 metres south to its intersection with Warringah Road.	
Category 3: Other projects and strategic developments		
Sydney Metro Victoria Cross over station development Approved 2021 – 2024[2]	This project involves the construction of a 40-storey (plus two storey rooftop plant) commercial office building above the southern entrance of Victoria Cross station.	• North Sydney and Cammeray
Marist Catholic College North Shore Proposed Prepare EIS 2020 – 2026	This project involves the demolition of existing buildings and construction of a new six storey building to accommodate teaching facilities, early learning centre and premises for independent tertiary education.	• North Sydney and Cammeray
Channel 9 site staged residential redevelopment Part 3A concept plan approved Construction stages 1 and 2 under assessment No timeframe information (construction overlap assumed)	Redevelopment of the Channel 9 site (14 Artarmon Road, Willoughby) for up to 400 residential dwellings with non-residential land uses such as retail/commercial space and landscaping and public domain works.	• Naremburn and Willoughby

Note 1: Relevant locations where cumulative impacts might occur includes locations where surface works for the Beaches Link and Gore Hill Freeway Connection project occur within two kilometres of a Category 1, 2 or 3 project

Note 2: Dates as per the Concept Development Application for the Victoria Cross over Station Development

Table 27-4 Strategic plans considered in the cumulative impact assessment

Strategic plan	Brief description	Relevant locations where cumulative impacts might occur
Northern Beaches Sportsground Strategy	The *Northern Beaches Sportsground Strategy* (Northern Beaches Council, 2017a) is a 15 year plan to provide a single approach to the management and long term planning of sporting facilities on the Northern Beaches. The *Northern Beaches Sportsground Strategy* has been informed by the *Northern Beaches Sportsgrounds and Golf Courses Discussion Paper* (Northern Beaches Council, 2017c) which was prepared in response to independent analyses commissioned by Northern Beaches Council to review sportsgrounds supply and demand, and assess the feasibility of golf courses on the Northern Beaches. The discussion paper included strategic directions for addressing a shortfall in sporting fields across the local area including the potential conversion of existing golf courses to provide additional sporting grounds and parkland areas.	• Balgowlah
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 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 plan provides the strategic land use planning framework for Frenchs Forest for the next 20 years. The plan includes proposed land use rezoning around the Northern Beaches Hospital to the north and west of the Wakehurst Parkway/Warringah Road intersection as part of a strategy to support long term growth in the area (including a proposed 5360 new dwellings in the next 20 years).	• Seaforth, Killarney Heights and Frenchs Forest
North Sydney Integrated Transport Program	The *North Sydney Integrated Transport Program* (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 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 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,	• North Sydney and Cammeray

Strategic plan	Brief description	Relevant locations where cumulative impacts might occur
	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 timing for deliverables in the North Sydney Program would be cognisant of the Western Harbour Tunnel and Beaches Link program of works delivery timeframes. Further information on the North Sydney Program is provided in Section 9.1.1	

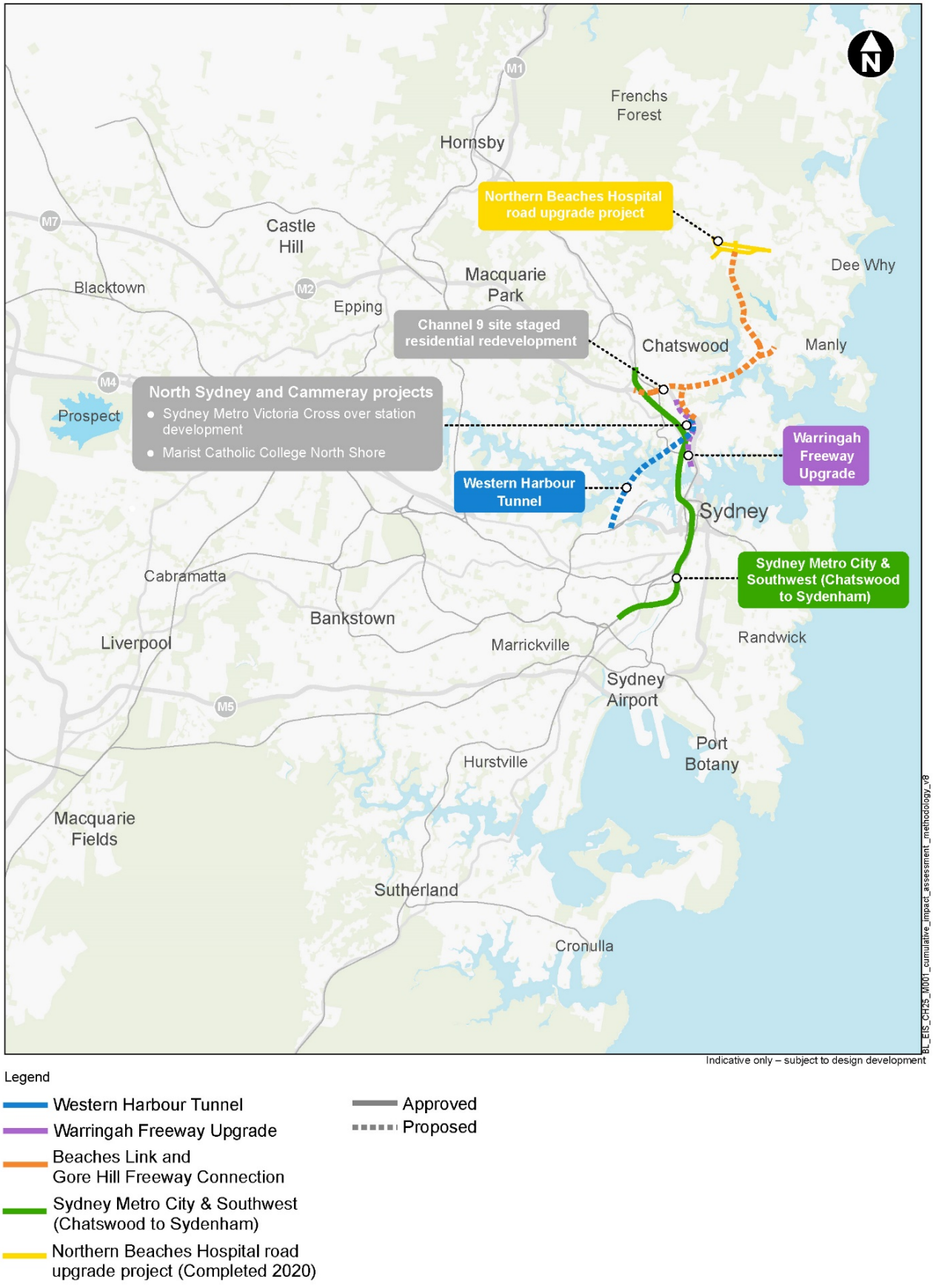

Figure 27-2 Projects assessed in the cumulative impact assessment

27.3 Assessment of potential cumulative construction impacts

The following sections describe the potential cumulative impacts during construction of the project based on likely interactions with the projects and plans listed in Table 27-3 and Table 27-4.

Impacts outlined in each section are unmitigated potential cumulative impacts. Mitigation measures are included in Section 27.5.

27.3.1 North Sydney and Cammeray

Projects

Construction activities at North Sydney and Cammeray would occur in close proximity to the following projects:

- Western Harbour Tunnel and Warringah Freeway Upgrade
- Sydney Metro City & Southwest (Chatswood to Sydenham) – Victoria Cross and Crows Nest stations
- Marist Catholic College North Shore
- Sydney Metro Victoria Cross over station development.

Potential cumulative impacts

Potential cumulative construction impacts at North Sydney and Cammeray are identified in Table 27-5.

In summary, cumulative impacts are most likely to be experienced by receivers around Cammeray Golf Course and the Warringah Freeway corridor in North Sydney and Cammeray as a result of interactions with the Western Harbour Tunnel and Warringah Freeway Upgrade project.

Cumulative traffic impacts have the potential to be experienced at Cammeray due to the interaction of the project with the Western Harbour Tunnel and Warringah Freeway Upgrade project. In particular, the wider road network at the Warringah Freeway and surrounds, including the suburb of Cammeray, is likely to be affected due to the consecutive use of Cammeray Golf Course as temporary construction support sites for the Western Harbour Tunnel and Beaches Link program of works.

Cumulative temporary construction noise, visual amenity, and social and economic impacts may also be experienced by receivers at North Sydney and Cammeray due to the proximity of the project's construction sites to construction sites for the Western Harbour Tunnel and Warringah Freeway Upgrade. It is likely that some construction sites for the two projects would operate both concurrently and consecutively, with prolonged impacts to residential, commercial and recreational receivers.

The concurrent and/or consecutive use of Cammeray Golf Course as temporary construction support sites for the Western Harbour Tunnel and Beaches Link program of works also has the potential to result in prolonged cumulative land use and heritage impacts, and impacts to public open space.

However, these projects may provide cumulative benefits for local construction workers and to local business and services in these areas by increasing passing trade and demand for services during construction periods.

The potential for construction fatigue and complaint fatigue at North Sydney and Cammeray is discussed in Section 27.3.7.

Potential cumulative impacts resulting from the construction of the projects considered are expected to be negligible for the following issues:

- Air quality
- Aboriginal heritage
- Geology, groundwater and soils
- Hydrology and water quality
- Flooding
- Biodiversity
- Hazards and risks
- Resource use and waste management
- Sustainability
- Climate change and greenhouse gases.

As such, these issues are not considered further in Table 27-5.

Negligible cumulative impacts are expected to result from construction activities at North Sydney and Cammeray from the following projects:

- Marist Catholic College North Shore
- Sydney Metro City & Southwest (Chatswood to Sydenham) – Victoria Cross and Crows Nest stations
- Sydney Metro Victoria Cross over station development.

Additional cumulative construction impacts at North Sydney may be generated by future projects associated with the North Sydney Program (refer to Table 27-4). As discussed in Chapter 9 (Operational traffic and transport), the development of the North Sydney Program is ongoing, with validation of the vision for North Sydney currently underway. 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.

As such, these projects and strategic plan have not been considered further in Table 27-5.

Table 27-5 Potential cumulative construction impacts – North Sydney and Cammeray

Environmental impact	Potential cumulative construction impacts
	Category 1 projects
	Western Harbour Tunnel and Warringah Freeway Upgrade
Traffic and transport[1]	Additional and prolonged reduction in level of service Ernest Street, Falcon Street and Miller Street at Cammeray due to construction traffic volumes. Increase in delays at intersections including Brook Street/Warringah Freeway ramps due to introduction of construction traffic. Increases in bus travel times on the Warringah Freeway due to increased traffic demand across the southbound bus lane south of Falcon Street[1].
Health and safety	Health effects for residential receivers around Cammeray from stress and anxiety from changes in the urban environment.
Noise and vibration	Additional and prolonged temporary increase in construction noise from construction work at Cammeray Golf Course construction support site (BL1) and temporary construction support sites at Cammeray Golf Course for the Western Harbour Tunnel and Warringah Freeway Upgrade project[2].
Urban design and visual amenity	Additional and prolonged moderate to high landscape and visual impacts for receivers around the Warringah Freeway corridor, residential receivers around Cammeray, North Cremorne and Neutral Bay, and recreational receivers at Cammeray Park.
Socio-economic, land use and property	Additional temporary and permanent loss of open space, parks and recreation facilities at Cammeray Golf Course. Additional and prolonged: • Increase in passing trade for local businesses and services in North Sydney and Cammeray, particularly along Miller Street • Land use impacts at Cammeray Golf Course due to consecutive construction periods • Amenity impacts for receivers around the Warringah Freeway and for residential and recreational receivers at Cammeray • Impacts to community perceptions of public health and safety due to increases in construction traffic for residential and recreational receivers at Cammeray • Increase in demand for construction workers, providing benefits for local workers.
Non-Aboriginal heritage	• Additional and prolonged moderate impacts on Cammeray Park (including golf course) • Minor temporary impacts to additional heritage items in the vicinity of North Sydney and Cammeray.

Note 1: Quantitative cumulative assessment presented in Chapter 8 (Construction traffic and transport)
Note 2: Cumulative assessment presented in Chapter 10 (Construction noise and vibration)

27.3.2 Artarmon

Projects

Construction activities for the Gore Hill Freeway Connection component of the project would occur in close proximity to the following projects:

- Western Harbour Tunnel and Warringah Freeway Upgrade
- Sydney Metro City & Southwest (Chatswood to Sydenham) – Chatswood dive site and Artarmon substation site. The works at Artarmon substation are anticipated to conclude at the beginning of 2022 and are therefore considered in terms of construction fatigue only.

Potential cumulative impacts

Potential cumulative construction impacts at the Gore Hill Freeway Connection component of the project are identified in Table 27-6.

In summary, cumulative impacts are most likely to be experienced by receivers in the Artarmon area near the Gore Hill Freeway corridor as a result of interactions with the identified projects. The volume of traffic associated with construction works at the Gore Hill Freeway temporary construction support sites has the potential to result in cumulative impacts to the local road network at Artarmon, primarily at Dickson Avenue and Reserve Road.

There is potential that cumulative temporary construction noise, visual amenity, social and economic impacts may also be experienced by receivers at Artarmon due to the number of nearby projects under construction both concurrently and consecutively. Cumulative construction impacts would most likely be experienced by receivers near the Warringah Freeway and Gore Hill Freeway road corridors and around the Artarmon industrial area. There would be around a one year break between the completion of works for the Artarmon substation site as part of Sydney Metro City & Southwest (Chatswood to Sydenham) at the beginning of 2022 and the commencement of construction at the Gore Hill Freeway connections. Works prior to completion are likely associated with the testing/commissioning phase of the project and subsequently construction fatigue impacts may be reduced. These projects may also provide cumulative benefits for local construction workers and to local businesses and services in these areas by increasing passing trade and demand for services during construction periods.

The potential for construction fatigue and complaint fatigue at Artarmon is discussed in Section 27.3.7.

Potential cumulative impacts resulting from the construction of the projects considered are expected to be negligible for the following issues:

- Air quality
- Health and safety
- Non-Aboriginal heritage
- Aboriginal heritage
- Geology, groundwater and soils
- Hydrology and water quality
- Flooding
- Biodiversity
- Hazards and risks
- Resource use and waste management
- Sustainability
- Climate change and greenhouse gases.

As such, these issues are not considered further in Table 27-6.

Table 27-6 Potential cumulative construction impacts – Artarmon

Environmental impact	Potential cumulative construction impacts	
	Category 1 projects	Category 2 projects
	Western Harbour Tunnel and Warringah Freeway Upgrade	Sydney Metro City & Southwest
Traffic and transport	Negligible[1]	Prolonged heavy and light vehicle traffic on the local road network at Artarmon, including Dickson Road and Reserve Road.
Noise and vibration	Additional and prolonged temporary increase in construction noise for commercial, industrial and residential receivers from construction work at the Gore Hill Freeway temporary construction support sites and temporary construction support sites at the Warringah Freeway for the Western Harbour Tunnel and Warringah Freeway Upgrade project[2].	Prolonged temporary increase in construction noise for commercial and industrial receivers near construction works at the Gore Hill Freeway temporary construction support sites[2].
Urban design and visual amenity	Additional and prolonged minor landscape and visual impacts for motorists using the Warringah Freeway and Gore Hill Freeway.	Prolonged minor landscape and visual impacts for industrial and commercial receivers near Dickson Avenue and Reserve Road.
Socio-economic, land use and property	Additional and prolonged: • Increase in passing trade for local businesses and services in Artarmon near the Warringah Freeway and Gore Hill Freeway corridors • Amenity impacts in Artarmon near the Warringah Freeway and Gore Hill Freeway corridors, primarily due to works outside standard construction hours • Impacts to community perceptions of public health and safety due to increases in construction traffic • Increase in demand for construction workers, providing benefits for local workers.	Additional and prolonged: • Increase in passing trade for local businesses and services in the Artarmon industrial area • Amenity impacts in the Artarmon industrial area • Increase in demand for construction workers, providing benefits for local workers.

Note 1: Quantitative cumulative assessment presented in Chapter 8 (Construction traffic and transport)
Note 2: Cumulative assessment presented in Chapter 10 (Construction noise and vibration).

27.3.3 Naremburn and Willoughby

Projects

Construction activities at the Flat Rock Drive construction support site (BL2) would occur in close proximity to the following projects:

- Western Harbour Tunnel and Warringah Freeway Upgrade
- Sydney Metro City & Southwest (Chatswood to Sydenham) – Artarmon substation site. The works at Artarmon substation site are anticipated to conclude at the beginning of 2022 and are therefore considered in terms of construction fatigue only
- Channel 9 site staged residential redevelopment.

Potential cumulative impacts

Potential cumulative construction impacts at Naremburn and Willoughby are identified in Table 27-7.

Cumulative impacts associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project would be limited to potential temporary increases in construction noise for residential and recreational receivers in the Naremburn and Willoughby area resulting from concurrent and consecutive construction programs with the project. Cumulative construction impacts would most likely result from works at the Flat Rock Drive construction support site (BL2) and temporary construction support sites at the Warringah Freeway for the Western Harbour Tunnel and Warringah Freeway Upgrade project.

The construction of the proposed Channel 9 site staged residential development (14 Artarmon Road, Willoughby) is assumed to overlap with construction of the project. Cumulative construction impacts would most likely be experienced by residential receivers in Willoughby and Naremburn and would be associated with concurrent construction activities of the development and the project. Potential cumulative construction impacts for surrounding residents are likely to be associated with increased construction traffic, urban design, visual amenity and social and economic impacts associated with vegetation removal and demolition activities given the proximity of the development to the Flat Rock Drive construction support site (BL2).

The potential for construction fatigue and complaint fatigue at Naremburn and Willoughby is discussed in Section 27.3.7.

Potential cumulative impacts resulting from the construction of the projects considered are expected to be negligible for the following issues:

- Air quality
- Health and safety
- Non-Aboriginal heritage
- Aboriginal heritage
- Geology, groundwater and soils
- Hydrology and water quality
- Flooding
- Biodiversity
- Hazards and risks
- Resource use and waste management
- Sustainability
- Climate change and greenhouse gases.

As such, these issues are not considered further in Table 27-7.

Cumulative impacts expected to result from construction activities at Naremburn and Willoughby due to the Sydney Metro City & Southwest (Chatswood to Sydenham) – Artarmon substation site would be due to construction fatigue. Impacts are considered likely to be negligible and as such this project has not been considered further in Table 27-7.

Table 27-7 Potential cumulative construction impacts – Naremburn and Willoughby

Environmental impact	Potential cumulative construction impacts	
	Category 1 projects	Category 3 projects
	Western Harbour Tunnel and Warringah Freeway Upgrade	Channel 9 site staged residential redevelopment
Traffic and transport	Negligible[1]	Potential for prolonged heavy and light vehicle traffic on the local road network at Naremburn and Willoughby during assumed construction overlap.
Noise and vibration	Additional and prolonged temporary increase in construction noise for residential and recreational receivers from construction works at the Flat Rock Drive construction support site (BL2) and temporary construction support sites at the Warringah Freeway for the Western Harbour Tunnel and Warringah Freeway Upgrade project[2].	Negligible
Urban design and visual amenity	Negligible	Prolonged temporary minor landscape and visual impacts for residential receivers at Naremburn and Willoughby due to demolition and vegetation clearing works at the Channel 9 site and establishment of the Flat Rock Drive construction support site (BL2).
Socio-economic, land use and property	Negligible	Additional and prolonged amenity impacts: • In the Naremburn and Willoughby residential area during assumed construction overlap • To public open space and recreation facilities.

Note 1: Quantitative cumulative assessment presented in Chapter 8 (Construction traffic and transport.

Note 2: Cumulative assessment presented in Chapter 10 (Construction noise and vibration)

27.3.4 Middle Harbour

Works at the Middle Harbour cofferdams and the Spit West Reserve construction support site (BL9) would be unlikely to produce cumulative impacts with the projects identified in Table 27-3 and strategic plans in Table 27-4.

27.3.5 Balgowlah

Construction of the project in Balgowlah would be unlikely to produce cumulative impacts with the projects identified in Table 27-3 and strategic plans in Table 27-4.

Additional cumulative construction impacts at Balgowlah may be generated by future projects associated with the *Northern Beaches Sportsground Strategy* (Northern Beaches Council, 2017a) (refer to Table 27-4), however construction programs and specific scopes for individual projects have not yet been released.

27.3.6 Seaforth, Killarney Heights and Frenchs Forest

Construction of the project in Seaforth, Killarney Heights and Frenchs Forest would be unlikely to produce cumulative impacts with the projects identified in Table 27-3 and strategic plans in Table 27-4.

Additional cumulative construction impacts at Frenchs Forest may be generated by future projects associated with the *Northern Beaches Hospital Precinct Structure Plan* (Northern Beaches Council, 2017b) (refer to Table 27-4), however construction programs and specific scopes for individual projects have not yet been released.

27.3.7 Construction and complaint fatigue

Construction fatigue

There is potential for construction fatigue to be experienced by receivers near the project. Construction fatigue may be experienced by receivers that are near 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.

Areas considered most likely to experience sustained impacts to receivers that may result in construction fatigue include residential receivers in North Sydney and Cammeray near the Cammeray Golf Course and the Warringah Freeway, and receivers in Artarmon near the Warringah Freeway and Gore Hill Freeway. Construction fatigue in the above areas may occur as a result of the close proximity of multiple construction sites for the project, and from construction activities associated with the following projects:

- North Sydney and Cammeray
  - Western Harbour Tunnel and Warringah Freeway Upgrade
- Artarmon
  - Western Harbour Tunnel and Warringah Freeway Upgrade
  - Sydney Metro City & Southwest (Chatswood to Sydenham) – Artarmon substation site.

Based on the environmental impact assessment for the project and those projects listed above, potential impacts that are considered most likely to result in construction fatigue include traffic and parking, 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 the Western Harbour Tunnel and Warringah Freeway Upgrade project. Construction fatigue at this location is likely to be limited to

temporary increases in construction noise and are expected to be minor. Work would be coordinated between the various project construction sites, where feasible and reasonable, to minimise construction fatigue.

There would be around a one year break between the completion of works at the Sydney Metro City & Southwest (Chatswood to Sydenham) – Artarmon substation site at the beginning of 2022, and the commencement of construction of the connections to and from the Gore Hill Freeway. Works prior to completion are likely associated with the testing/commissioning phase of the project and as a result, construction fatigue impacts may be reduced.

Community consultation would be carried out to understand key impacts and issues, and identify any unknown impacts from concurrent or consecutive sets of construction work. The community consultation framework is presented in Chapter 7 (Stakeholder and community engagement) and Appendix E (Community consultation framework).

Complaint fatigue

Complaint fatigue may occur where community perceptions of project complaint management systems result in failure to report concerns about construction impacts. Complaint fatigue may be compounded where multiple proponents are responsible for issues in the same area where construction of multiple projects occurs.

Areas considered most likely to generate complaint fatigue include North Sydney and Cammeray, and Artarmon, due to the proximity of the project to the following projects:

- North Sydney and Cammeray
  - Western Harbour Tunnel and Warringah Freeway Upgrade
- Artarmon
  - Western Harbour Tunnel and Warringah Freeway Upgrade
  - Sydney Metro City & Southwest (Chatswood to Sydenham) – Artarmon substation site.

A complaints management system would be implemented for the duration of construction, which would include a number of different complaint mechanisms to cater to different needs and preferences of the community (refer to Chapter 7 (Stakeholder and community engagement)). The complaints management system for the project is outlined in Appendix E (Community consultation framework).

The community relations team for the project would build a working relationship with the project teams for other major projects under construction at the same time as the project to identify stakeholders and community members who may be susceptible to complaint fatigue.

27.3.8 Summary

In summary, 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. Potential cumulative impacts would be generated by interactions between the project and the Western Harbour Tunnel and Warringah Freeway Upgrade project at North Sydney and Cammeray, Sydney Metro City & Southwest (Chatswood to Sydenham) at Artarmon, and the Western Harbour Tunnel and Warringah Freeway Upgrade project and Channel 9 staged residential redevelopment at Naremburn and Willoughby.

Without mitigation, key potential cumulative impacts would likely include minor temporary increases in traffic volumes, construction noise and vibration, decreased visual amenity and land use impacts. There is also potential for construction fatigue and complaint fatigue to be experienced by surrounding receivers at these locations as a result of concurrent and consecutive construction programs.

The project design and construction methodology has been developed with consideration of these issues and attempts to mitigate many of these issues 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 possible. Potential cumulative construction impacts would be managed in accordance with the measures outlined in Section 27.5.

27.4 Assessment of potential cumulative operational impacts

Potential cumulative impacts during the operation of the project are included in the operational modelling and assessment of various issues. This has been used to inform the assessment of key issues, including for traffic and transport, noise and vibration, air quality and human health.

The operational modelling scenarios have considered cumulative impacts associated with the Category 1 and 2 projects listed in Table 27-3. Category 3 projects were excluded as they were considered unlikely to generate cumulative operational impacts. In addition to Category 1 and 2 projects, some additional projects have been considered outside the two-kilometre radius as they are considered to be relevant to some operational models, which operate on a wider scale to the cumulative assessment in this chapter.

Table 27-8 identifies the projects considered in the operational cumulative impact assessments carried out for some of the key individual issues in the environmental impact statement.

Table 27-8 External projects included in the operational modelling scenarios for the environmental impact assessment

Projects included in operational model	Traffic and transport	Noise and vibration	Air quality	Human health
WestConnex program of works	✓	✓	✓	✓
Sydney Gateway[3]	✓	✓	✓	✓
M6 Motorway (Stage 1)[1, 3]	✓	✓	✓	✓
M6 Motorway (full project)[2, 3]	✓	✓	✓	✓
NorthConnex	✓			
Northern Beaches Hospital road upgrade project	✓			

Note 1: M6 Motorway (Stage 1) is considered as part of the 2027 'Do something – cumulative' scenario
Note 2: M6 Motorway (full project) is considered as part of the 2037 'Do something – cumulative' scenario
Note 3: Since the commencement of this assessment, the M6 Motorway (Stage 1) and Sydney Gateway projects have been approved. As these projects would not have a substantial influence on the current traffic network that would be impacted by the Beaches Link and Gore Hill Freeway Connection project, these projects have not been assumed in the 'Do minimum' scenarios.

The operational modelling considered the following scenarios:

- Without the project ('Do minimum')
- With the project ('Do something')
- With the project and other planned or proposed projects ('Do something cumulative').

Within the operational models:

- The 'Do minimum' scenarios include 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. It also reflects the operational effects of approved, under construction and/or recently completed major projects (eg Sydney Metro City & Southwest and Northern Beaches Hospital road upgrade projects)

- The ‘Do something’ scenarios include 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. It also includes Sydney Metro City & Southwest and Northern Beaches Hospital road upgrade projects
- The ‘Do something cumulative’ scenarios include NorthConnex, WestConnex, Western Harbour Tunnel and Warringah Freeway Upgrade, Beaches Link and Gore Hill Freeway Connection, Sydney Gateway and M6 Motorway projects. It also includes Sydney Metro City & Southwest and Northern Beaches Hospital road upgrade projects.

The Warringah Freeway Upgrade is considered as part of the ‘Do something’ scenarios (ie with the project) as the Warringah Freeway Upgrade component would need to be constructed and operational to facilitate Beaches Link connections to the Warringah Freeway at Cammeray.

The cumulative assessments for the issues identified in Table 27-8 are discussed in detail in their respective assessment chapters and technical working papers, as listed below, and are therefore not considered further in this chapter:

- Traffic and transport: Chapter 9 (Operational traffic and transport) and Appendix F (Technical working paper: Traffic and transport)
- Noise and vibration: Chapter 11 (Operational 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).

Excluding the assessments identified in Table 27-8, the potential cumulative operational impacts are expected to be limited to social and economic, and visual amenity issues.

Potential cumulative social and economic impacts would be generated by Category 1 and 2 projects. The Category 3 projects identified in Table 27-3 were considered unlikely to generate cumulative operational social and economic impacts. Cumulative operational impacts would be associated with improved travel benefits for communities, business and industry, including freight, across the Sydney transport network. The project, in conjunction with the Western Harbour Tunnel and Warringah Freeway Upgrade project, would help to reduce traffic on major roads, including Military Road/Spit Road/Manly Road, Eastern Valley Way, Brook Street, Miller Street, Warringah Road, Ourimbah Road, Frenchs Forest Road (at Seaforth town centre), Pacific Highway and Western Distributor, supporting local environment and amenity improvements in areas surrounding the project. By providing new underground bypass routes, the Western Harbour Tunnel and Beaches Link program of works would enable express bus services to travel to and from the Northern Beaches region via the new tunnel and motorway network to destinations like North Sydney, the Sydney CBD, Macquarie Park and St Leonards, freeing up surface roads for local buses and local traffic, supporting amenity improvements for town centres and businesses.

In addition, the Western Harbour Tunnel and Beaches Link program of works would result in improved access and connectivity for residents, business and industry between the Northern Beaches and destinations across the Greater Sydney region, including the Sydney CBD.

Through the re-purposing of land at Balgowlah as new and improved open space and recreation facilities for the community, the project would support the implementation of the *Northern Beaches Sportsground Strategy* (Northern Beaches Council, 2017a). The strategy aims to increase sporting fields and recreational facilities in response to a growing shortfall in sporting fields and recreation facilities in the Northern Beaches local government area. Converting existing open space such as golf courses to sports fields was identified as one of six actions to address the need for more sportsgrounds and new and improved facilities. 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 at Balgowlah.

Potential adverse cumulative visual amenity impacts at Cammeray would be generated by the Western Harbour Tunnel and Beaches Link program of works. Operational facilities for both projects introduce new built forms into existing open space at Cammeray Golf Course and generate cumulative landscape character and visual amenity impacts for residential receivers at Cammeray and motorists on the Warringah Freeway and Ernest Street.

There would be no cumulative impacts to geology, groundwater and soils, hydrology and water quality, flooding, hazards and risks, resource use and waste management, sustainability, Aboriginal heritage, non-Aboriginal heritage, climate change and greenhouse gases, and biodiversity during the operation of the project, as impacts related to these aspects would generally be limited to the construction phase of the project.

27.5 Environmental management measures

The implementation of environmental management measures for the project would avoid, to the greatest extent possible, negative cumulative impacts with surrounding development. As each of the study disciplines presented in this environmental impact statement have identified management measures to reduce potential impacts to acceptable levels, cumulative mitigation measures have focused on broader opportunities around inter-project coordination and communication with stakeholders.

Construction fatigue is recognised as an important issue for communities near large construction projects that overlap in time or space. Substantial effort to coordinate with other projects during construction would be made to further manage construction fatigue impacts where possible.

Further opportunities to more effectively manage construction fatigue would be considered during further design development and construction of the project.

Environmental management measures relating to cumulative impacts are outlined in Table 27-9.

Table 27-9 Environmental management measures – cumulative impacts

Ref	Phase	Impact	Environmental management measure	Location
CI1	Pre-construction	Cumulative impacts	Considered and tailored multi-party engagement and cooperation will be established prior to construction to ensure all contributors to impacts are working together to minimise adverse impacts or enhance benefits of multiple projects occurring concurrently or consecutively. Haulage routes and road occupancy will be coordinated with other major transport projects via Greater Sydney Operations.	BL/GHF
CI2	Pre-construction	Construction fatigue	Multi-party engagement and cooperation will be established prior to construction to coordinate with the following projects to manage construction fatigue impacts where possible: • Western Harbour Tunnel and Warringah Freeway Upgrade • Sydney Metro City & Southwest • Channel 9 site staged residential redevelopment.	BL/GHF
CI3	Construction	Cumulative impacts	Communication strategies for the project will be managed consistently across the NSW Government transport portfolio and in	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			accordance with the Community consultation framework for the project.	
CI4	Construction	Complaint fatigue	Complaint fatigue will be managed as outlined in Chapter 7 (Stakeholder and community engagement). Complaint management tools for the project are outlined in Appendix E (Community consultation framework).	BL/GHF
CI5	Construction	Spoil management	Co-ordination and engagement with proponents of other major projects, including external to Transport for NSW, will be undertaken prior to construction to identify the opportunity for beneficial reuse of construction spoil where it cannot be reused on site and prior to consideration of disposal options.	BL/GHF

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 28

Synthesis of the environmental impact statement

transport.nsw.gov.au

DECEMBER 2020

28 Synthesis of the environmental impact statement

This chapter provides a synthesis of the findings of the environmental impact statement for the project, in response to the Secretary's environmental assessment requirements issued for the project. The main body of the environmental impact statement and appendices should be referred to for further details.

The Secretary's environmental assessment requirements as they relate to the synthesis of the environmental impact statement, and where in the environmental impact statement these have been addressed, are detailed in Table 28-1.

A summary of the proposed environmental management measures relevant to the project are included in Section 28.4.

Table 28-1 Secretary's environmental assessment requirements –synthesis of the environmental impact statement

Secretary's requirement	Where addressed in EIS
1. The EIS must include, but not necessarily be limited to, the following: q. a chapter that synthesises the environmental impact assessment and provides:	This **Chapter 28** (Synthesis of the environmental impact statement) provides the following:
- a succinct, but full, description of the project for which approval is sought;	A full description of the project in **Section 28.1.**
- a description of any uncertainties that still exist around design, construction methodologies and/or operational methodologies and how these will be resolved in the next stages of the project;	A description of any uncertainties related to the design, construction methodologies and/or operational methodologies and their proposed resolution in **Section 28.3.**
- a compilation of the impacts of the project that have not been avoided;	A compilation of the impacts of the project that have not been avoided in **Section 28.4.**
- a compilation of the proposed measures associated with each impact to avoid or minimise (through design refinements or ongoing management during construction and operation) or offset these impacts;	A compilation of the proposed measures associated with each impact to avoid or minimise (through design refinements or ongoing management during construction and operation) or offset these impacts in **Section 28.4.**
- a compilation of the outcome(s) the proponent will achieve; and	A compilation of the outcome(s) the project would achieve in **Section 28.6**.
- the reasons justifying carrying out the project as proposed, having regard to the biophysical, economic and social considerations, including ecologically sustainable development and cumulative impacts;	Project justification and conclusions in **Section 28.1** and **Section 28.7**. **Section 27.2** of **Chapter 27** (Cumulative impacts), presents the projects that have been assessed and may have potential cumulative impacts. Potential cumulative impacts are described in **Section 27.3** and **Section 27.4** of **Chapter 27** (Cumulative impacts)**.**

28.1 Overview and key features of the project

28.1.1 Overview of project need

Existing arterial road connections to Sydney's Northern Beaches, including Military Road/Spit Road, Mona Vale Road, Warringah Road and Eastern Valley Way, currently experience high levels of traffic congestion. This congestion adversely affects transport connectivity, travel times, economic prosperity and local amenity for both road users and local communities. These connections are integral to the economic growth of Sydney's Eastern Economic Corridor. As Sydney's population and economy continues to grow, so would the pressure on access to these connections. Consequently, improvements to transport networks would be essential for Sydney to continue to be competitive.

The Greater Sydney Region Plan – A Metropolis of Three Cities (Greater Sydney Commission, 2018a) identifies the importance of investing in and delivering efficient and effective transport systems including road infrastructure that would relieve congestion, improve travel times, improve road safety and enhance and expand capacity on key road corridors. The project would reduce congestion and improve road network performance and efficiency, enabling sustained growth and productivity across Sydney's Eastern Economic Corridor. By providing a new underground motorway bypass of existing surface arterial roads and a third Middle Harbour crossing, the project would also enhance the resilience of the road network across the Eastern Harbour City.

The public transport network connecting the Northern Beaches to destinations such as North Sydney, the Harbour CBD and Chatswood provides many people with direct access to employment hubs, as well as access to education facilities, health centres and hospitals, and sporting, cultural and entertainment facilities. The project would improve the capacity, journey times and reliability of bus services for the Northern Beaches region through reduced congestion on existing surface routes and would facilitate opportunities to expand the express bus service network through allowing express buses to travel within the new tunnels. This would improve access to key centres and result in more people having better access to jobs, goods and services.

The Beaches Link and Gore Hill Freeway Connection project is identified as a *priority initiative* by Infrastructure Australia's *Australian Infrastructure Plan: The Infrastructure Priority List* (Infrastructure Australia, 2018) in recognition of its importance in addressing urban congestion on Sydney's road network, enhancing critical cross-harbour capacity and Northern Beaches connectivity. This new connection would improve travel times to the international gateways of Sydney Airport and Port Botany, and strategic commercial and industrial centres including North Sydney, St Leonards and Macquarie Park. Increased network capacity and connectivity as a result of the project would also result in travel time savings for freight movements, further servicing the growth of Sydney's Eastern Economic Corridor.

In addition to addressing the transport challenges created by the limited arterial roads servicing the Northern Beaches region, by relieving congestion, through traffic and 'rat running' on arterial roads, the project would also deliver benefits for urban amenity in local centres. Improved amenity in town centres along and next to key road corridors such as Mosman, Cremorne, Neutral Bay, Forestville and Seaforth would be expected as a result of reduced through traffic due to 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, 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).

Key features of the project are described in Section 28.1.3.

28.1.2 Project objectives

The project objectives were developed to respond to the current and future network challenges and include:

- Providing greater capacity on the road network by reducing congestion and through traffic on arterial roads in northern Sydney
- Creating faster, more reliable journeys for freight services, public transport and other road users between the Northern Beaches region and other strategic centres across Greater Sydney
- Creating opportunities to expand and improve the public transport network connecting the Northern Beaches and key centres across Greater Sydney
- Improving productivity and access to services by facilitating faster and more reliable journeys for commuters and freight to reach their destinations
- Increasing the resilience of the Northern Beaches and North Shore road network to traffic incidents
- Improving urban amenity.

28.1.3 Key features of the project

Key features of the Beaches Link component of the project 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 between Seaforth and the surface at Wakehurst Parkway, Killarney Heights (about 2.8 kilometres in length)
    - Eastbound and westbound connections between Northbridge and the surface at the Gore Hill Freeway and Reserve Road, Artarmon (about 2.1 kilometres in length).
- New and improved public open space and recreation facilities at Balgowlah
- A new 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 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 the Wakehurst Parkway in Frenchs Forest

- Other operational infrastructure including groundwater and tunnel drainage management and treatment systems, surface drainage, signage, tolling infrastructure, fire and life safety systems, roadside furniture, lighting, emergency evacuation and emergency smoke extraction infrastructure, Closed-Circuit Television (CCTV) and other traffic management systems.

Key features of the Gore Hill Freeway Connection component of the project would include:

- 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 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.

The location of the project is shown in Figure 28-1 and key features are shown in Figure 28-2 and Figure 28-3.

The residual land created as a result of the project would largely continue to remain suitable for future development in accordance with the relevant land use zonings and applicable development standards. 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. Any future development of residual land would be subject to separate assessment and approval in accordance with the *Environmental Planning and Assessment Act 1979* and is beyond the scope of the project.

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

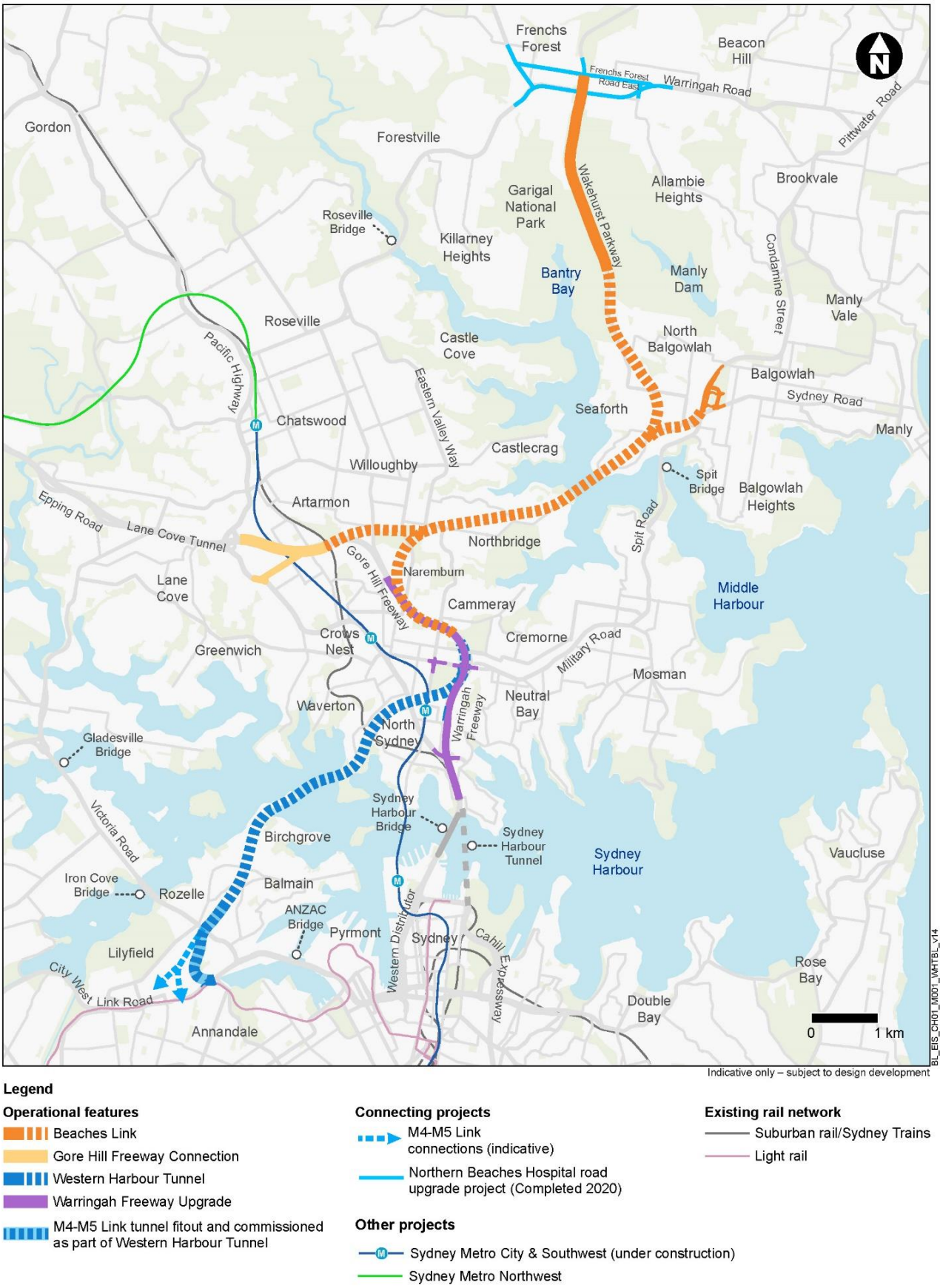

Figure 28-1 The Western Harbour Tunnel and Beaches Link program of works

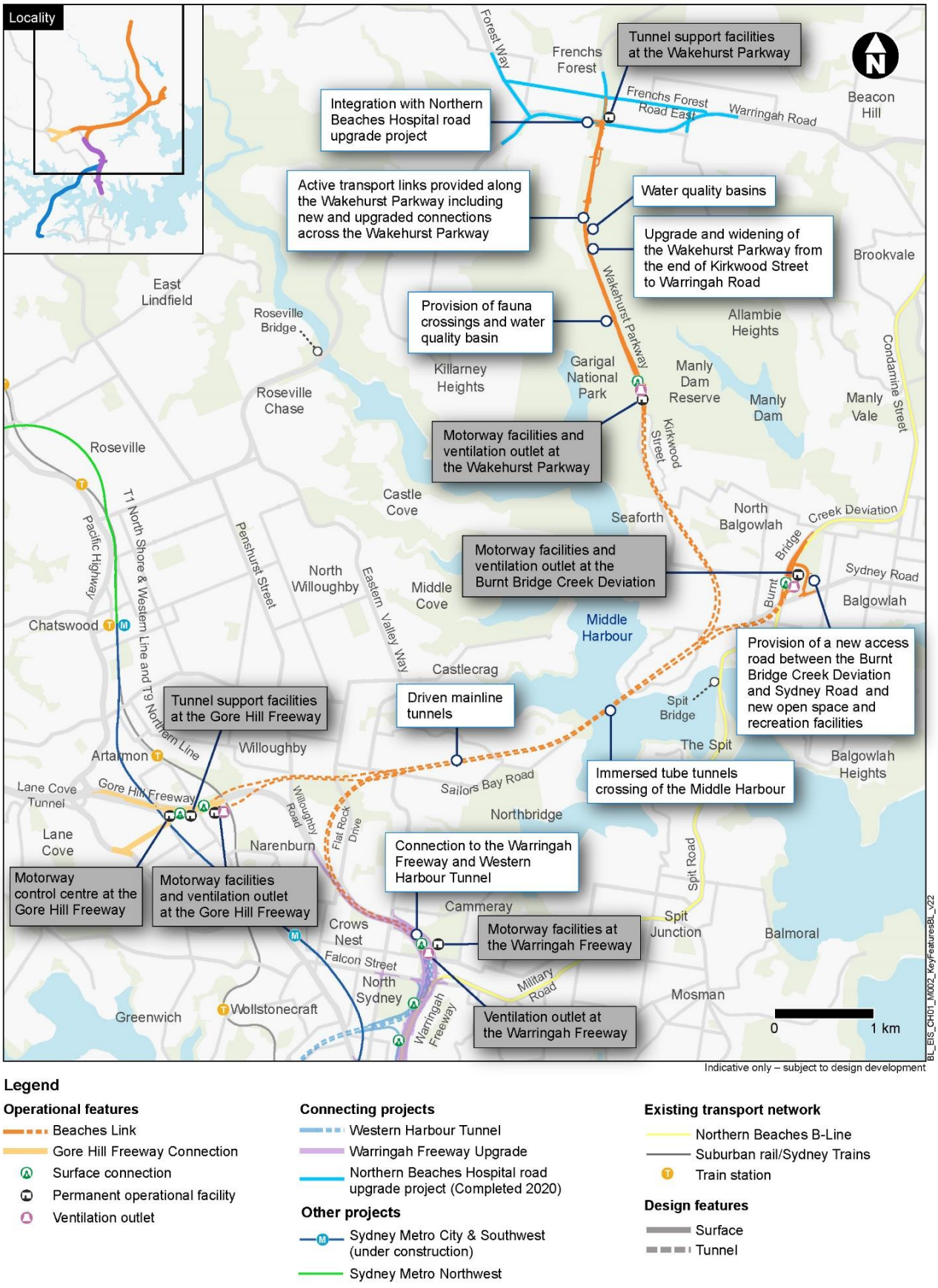

Figure 28-2 Key features of the Beaches Link component of the project

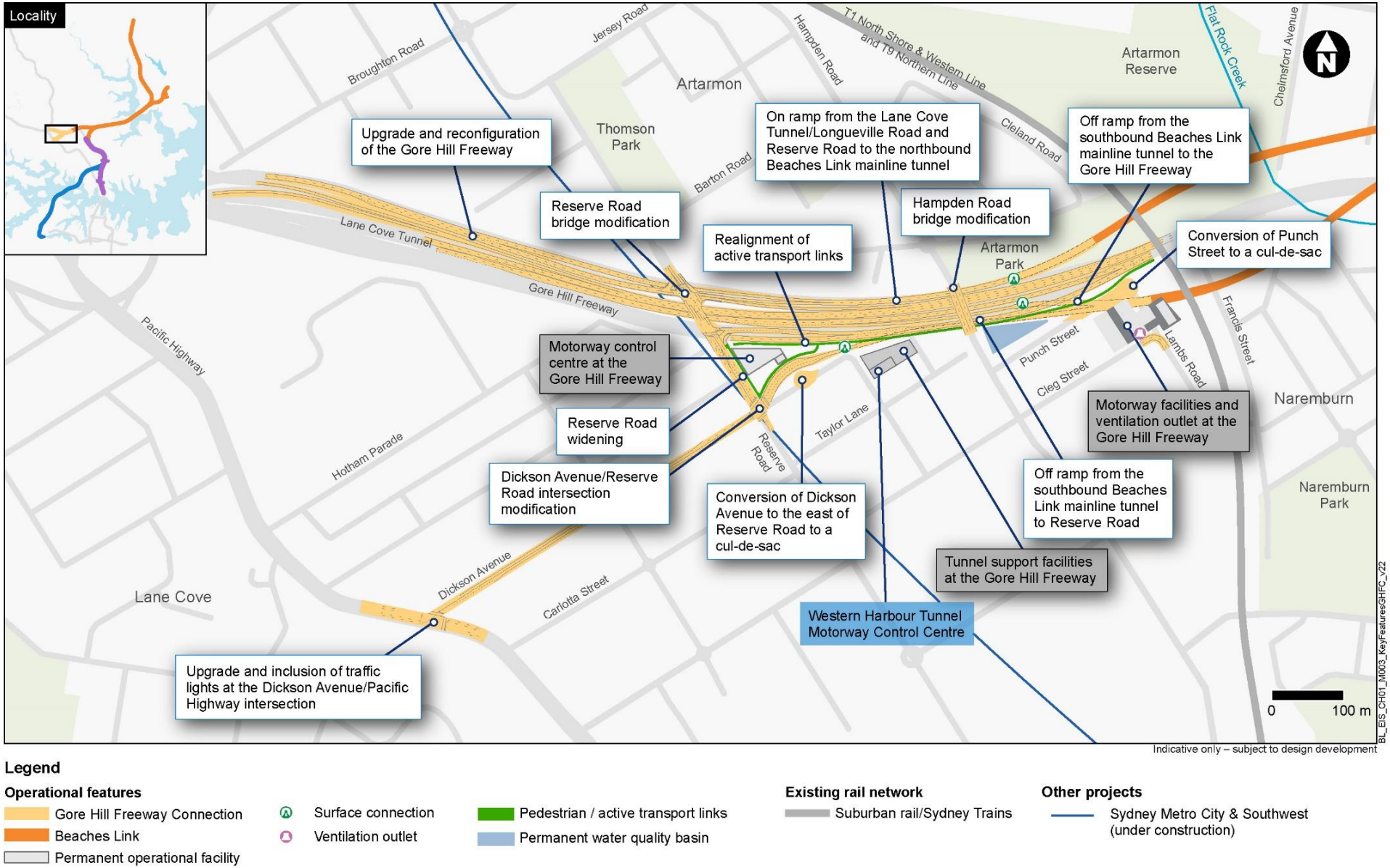

Figure 28-3 Key features of the Gore Hill Freeway component of the project

28.2 Construction of the project

A substantial amount of the work for the project would occur underground with the mainline and ramp tunnels being constructed using roadheaders. Where the tunnels cross Middle Harbour construction would involve excavation of the bed of the harbour and the placement of twin immersed tube tunnel units installed both on supporting piles and within a trench. The middle third of the tunnels 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 tunnels would be installed within a trench of varying depth.

Large surface areas would be required to support underground construction activities and to support and construct the surface connections, tunnel portals, surface road works, active transport facilities (pedestrian and cyclist facilities) and operational facilities.

Construction activities for the Gore Hill Freeway Connection would generally include surface earthworks, bridgeworks, construction of retaining walls, installation of stormwater drainage and pavement construction.

Subject to planning approval and procurement, construction of the Beaches Link and Gore Hill Freeway Connection project (the project) is currently planned to commence in early 2023. On that basis, completion of the main construction works would be around around the end of 2027 with a likely opening to traffic in early 2028. Construction works for the new and improved open space and recreation facilities are planned to commence in 2023 and progressively staged to be fully completed in late 2028.

28.2.1 Key construction activities

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

Key construction activities would include:

- Early works and site establishment, with typical activities being property acquisition and condition surveys, utilities installation, protection, adjustments and relocations, installation of site fencing, environmental controls (including noise attenuation and erosion and sediment control), traffic management controls, vegetation clearing, earthworks, demolition of structures, building temporary construction support sites including acoustic sheds and associated access decline acoustic enclosures (where required), construction of minor access roads and the provision of property access, temporary relocation of pedestrian and cycle paths and bus stops, temporary relocation of swing moorings and/or provision of alternative facilities (mooring or marina berth) within Middle Harbour
- Construction of the Beaches Link, with typical activities being excavation of tunnel construction access declines, construction of driven tunnels, cut and cover and trough structures, construction of surface upgrade works, construction of cofferdams, dredging and immersed tube tunnel piled support activities in preparation for the installation of immersed tube tunnels, casting and installation of immersed tube tunnels and civil finishing and tunnel fitout
- Construction of operational facilities comprising:
    - A motorway control centre at the Gore Hill Freeway in Artarmon
    - Tunnel support facilities at the Gore Hill Freeway in Artarmon and at the Wakehurst Parkway in Frenchs Forest
    - Motorway facilities and ventilation outlets at the Warringah Freeway in Cammeray (fitout only of the Beaches Link ventilation outlet at Warringah Freeway (the outlet structure being constructed by Western Harbour Tunnel and Warringah Freeway Upgrade

project)), the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights

  - A wastewater treatment plant at the Gore Hill Freeway in Artarmon
  - Installation of motorway tolling infrastructure

- Staged construction of the Gore Hill Freeway Connection at Artarmon and upgrade and integration works at Balgowlah and along the Wakehurst Parkway with typical activities being vegetation clearing, earthworks, bridgeworks, construction of retaining walls, stormwater drainage, pavement works and linemarking and the installation of road furniture, lighting, signage and noise barriers
- Testing of plant and equipment and commissioning of the project, backfill of access declines, removal of temporary construction support sites, landscaping and rehabilitation of disturbed areas and removal of environmental and traffic controls.

Further details are provided in Chapter 6 (Construction work).

28.2.2 Temporary construction support sites

Temporary construction support sites would be required as part of the project and would include tunnelling and tunnel support sites, civil surface sites, cofferdams, mooring sites, wharf and berthing facilities, laydown areas, parking and workforce amenities. Temporary construction support sites would include:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Dickson Avenue (BL4)
- Barton Road (BL5)
- Gore Hill Freeway median (BL6)
- Middle Harbour south cofferdam (BL7)
- Middle Harbour north cofferdam (BL8)
- Spit West Reserve (BL9)
- Balgowlah Golf Course (BL10)
- Kitchener Street (BL11)
- Wakehurst Parkway south (BL12)
- Wakehurst Parkway east (BL13)
- Wakehurst Parkway north (BL14).

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

28.3 Project uncertainties

As with any project of the nature and scale of this project, the project design presented in this environmental impact statement would continue to be refined during further design development. This design development would be guided by the key principles adopted during the planning and assessment phase of the project. Some flexibility has been provided in the design to:

- Allow for refinement during further design and construction planning phase to consider alternative construction techniques

- Allow for refinement in response to submissions received following the exhibition of this environmental impact statement
- Respond to improved technologies or materials
- Improve value for money.

The final design may vary from that described in Chapter 5 (Project description). If approval is granted, any changes to the project would be reviewed for consistency with the assessment contained in the environmental impact statement including relevant environmental management measures, environmental performance outcomes and any future conditions of approval. If design refinements are not consistent with the approval issued by the Minister for Planning and Public Spaces, approval would be sought from the Minister for any such modifications in accordance with the requirements of Division 5.2 of the *Environmental Planning and Assessment Act 1979*.

Areas where further work would be carried out to optimise the design outcomes and construction planning include refinements to:

- Avoid utilities that present substantial construction difficulties in terms of logistics, time and/or cost
- Reduce the duration of construction
- Avoid areas of environmental sensitivity
- Reduce impacts on the community during construction and/or operation
- Improve operation of the project without increasing the potential environmental impacts.

For any future design refinements, a screening assessment would be carried out to consider whether the refinement would result in:

- Any inconsistency with the conditions of approval
- Any inconsistency with the objectives and operation of the project as described in the environmental impact statement
- A change to the approved project that may require a modification of the approval
- Any potential environmental or social impacts of a greater scale or impact on previously unaffected receivers than that considered by the environmental impact statement or the submissions and preferred infrastructure report.

Table 28-2 outlines key project components that have been identified as requiring resolution during further design development, construction and/or operation of the project and references where these uncertainties are discussed in this environmental impact statement.

Table 28-2 Resolution of project uncertainties

Project uncertainties	Proposed resolution	Timing	Where discussed
Tunnel design and operational facilities	• Confirmation of the final tunnel alignment would be carried out by the construction contractor, once appointed • Future consultation to engage with communities and affected stakeholders about the final alignment of the mainline and ramp tunnels would be carried out to explain any differences between the design presented and assessed in this environmental impact statement and the design refined during further development, as required • The final configuration and design requirements for the tunnel electricity supply and substations and mains water connection (if required) would be determined during further design development in consultation with relevant utility providers.	Design	Chapter 5 (Project description)
New and improved open space and recreation facilities	• 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 at Balgowlah. This consultation would be separate to consultation for the Beaches Link environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting.	Design	Chapter 5 (Project description)
Local road changes	The need for, design and location of traffic calming measures as part of the surface connections and road works to be provided at the Burnt Bridge Deviation at Balgowlah would be confirmed during further design development in consultation with Northern Beaches Council.	Design	Chapter 5 (Project description)

Project uncertainties	Proposed resolution	Timing	Where discussed
Utilities	Confirmation of the extent of installation, relocation, adjustment and/or protection of utilities would be carried out during further design development and in consultation with the relevant utility providers. To confirm the extent of utility works, additional utility tracing and/or potholing investigations may be required and may result in the need to carry out works outside of the construction footprint, particularly within and around surface connections and road works. As described in Chapter 5 (Project description), Appendix D (Utilities management strategy) provides the framework for how these utility relocations and adjustments would be identified, assessed and managed.	Design	Chapter 5 (Project description) Appendix D (Utilities management strategy)
Temporary construction support sites – location, layout and facilities	The final location and layout of temporary construction support sites would be confirmed during construction planning, with consideration of the final construction methodologies for the project and in accordance with the conditions of approval, once determined.	Design	Chapter 6 (Construction work)
Cofferdams and extent of dredging works in Middle Harbour	• The final location and layout of the Middle Harbour cofferdams (BL7 and BL8) would be confirmed during further design development and construction planning, with consideration of geotechnical conditions, the final construction methodologies for the project and in accordance with the conditions of approval • The final extent of dredging works for the construction of the immersed tube tunnels would be confirmed during further design development and construction planning for the project, with consideration of additional geotechnical investigations and the final construction methodologies for the project.	Design	Chapter 6 (Construction work)

Project uncertainties	Proposed resolution	Timing	Where discussed
Spoil disposal management and encapsulation opportunities for contaminated material encountered on site	• Further site investigations during the further design development and construction planning phases would inform contamination management including determining where encapsulation is appropriate • Any material that is not suitable for encapsulation would be loaded into sealed and covered trucks for disposal at a suitably licensed facility that would be confirmed during development of the detailed construction method for the project by the construction contractor, once appointed • A review of encapsulation, spoil transport and disposal options identified in the environmental impact statement would be carried out by the construction contractor, once appointed • Spoil transport options would be adjusted as required and the relevant construction management plans updated, in accordance with the relevant requirements of the conditions of approval • Confirmation of the location for a loadout facility for any dredged material not suitable for offshore disposal would be confirmed during further construction planning, in accordance with the relevant requirements of the conditions of approval • The location, design and configuration for encapsulating contaminated materials encountered on site during earthworks at Flat Rock Drive construction support site (BL2) and surface works associated with Balgowlah and Wakehurst Parkway would be confirmed during further design development and construction planning.	Design and construction	Chapter 6 (Construction work) Chapter 24 (Resource use and waste management)

Project uncertainties	Proposed resolution	Timing	Where discussed
Construction method and staging	• Final construction methodologies and staging plans including road possessions would be prepared by the construction contractor, once appointed. The staging plans would be based on further design development and refinement of the construction method. The plans would describe how construction areas associated with road works would be established to safely maintain traffic flows in areas of reduced traffic capacity, and to minimise delays to motorists, public transport, pedestrians and cyclists.	Construction	Chapter 6 (Construction work) Chapter 8 (Construction traffic and transport)
Final noise mitigation requirements	• Further noise modelling would be carried out during further design development to confirm the receivers eligible for at-property treatments. • The operational noise performance of the project would be reviewed during further design development and operational noise mitigation (ie quieter noise pavement, noise barrier, at-property treatment or a combination) would be confirmed subject to a reasonable and feasible assessment in accordance with the *Noise Mitigation Guideline* (Roads and Maritime Services, 2015g) • Ongoing community and stakeholder consultation to assist in informing and determining appropriate noise mitigation would be carried out during further design development and construction.	Design	Chapter 11 (Operational noise and vibration)
The boundary and potential impacts to the Frenchs Bullock Track	• Further detailed survey would be completed to confirm the heritage curtilage of the southern section of Frenchs Bullock Track prior to construction to determine if this section would be directly impacted • Where the heritage curtilage of the Frenchs Bullock Track is within the construction footprint or the boundary of proposed permanent infrastructure, the track would be avoided where possible through further design development.	Design	Chapter 14 (Non-Aboriginal heritage)

Project uncertainties	Proposed resolution	Timing	Where discussed
Extent and final design for fauna fencing along the Wakehurst Parkway	The extent and final alignment of fauna fencing along the Wakehurst Parkway would be confirmed during further design development by the construction contractor, once appointed.	Design	Chapter 5 (Project description)
The presence of, and potential impacts on registered Aboriginal Heritage Information Management System (AHIMS) sites and sites containing potential Aboriginal heritage significance	• Further consultation with Department of Premier and Cabinet (Heritage), the Metro Local Aboriginal Land Council (LALC) and Registered Aboriginal Parties would be carried out to determine appropriate management measures for previously recorded Aboriginal sites not assessed during archaeological surveys due to site accessibility constraints • Terrestrial Aboriginal site condition surveys would be completed using photogrammetry and 3D capture techniques employed to confirm where vibration monitoring at terrestrial AHIMS sites would be required.	Design and construction	Chapter 15 (Aboriginal cultural heritage)
The presence of, and potential impacts on maritime heritage	• Any pre-dredge clearance of the bed of the harbour to include involvement by a maritime archaeologist to minimise the risk of impact to potential maritime heritage remains such as maritime infrastructure, shipwrecks or submerged heritage sites and items • Complete and review the sidescan sonar survey for areas to be affected by project works to identify any additional potential heritage items requiring investigation and assessment • Carry out high-resolution geophysical survey(s) to further investigate potential submerged cultural heritage material in consultation with a maritime archaeology advisor • Carry out controlled archaeological investigations to recover any artefacts if required and feasible.	Design and construction	Chapter 14 (Non-Aboriginal heritage) Chapter 15 (Aboriginal cultural heritage)

Project uncertainties	Proposed resolution	Timing	Where discussed
Location and degree of contamination	• Further investigations of potentially contaminated sites are required to quantify the exposure risk. These investigations would be carried out prior to construction activities so contamination (if present) can be adequately planned for and managed.	Pre-construction and construction	Chapter 16 (Geology, soils and groundwater)
The potential presence of landfill generated gas which could impact on the construction and/or operation of the project	• Ground gas investigations would be carried out in Flat Rock Reserve to assess for the potential presence of landfill generated gas which could impact on the construction and/or operation of the project • Ground gas investigations would be carried out in accordance (where applicable) with the *Guideline for the Assessment and Management of Sites Impacted by Hazardous Ground Gases* (NSW EPA, 2012).	Pre-construction and construction	Chapter 16 (Geology, soils and groundwater)
Groundwater inflow rates and water table drawdown associated with tunnelling in proximity to Middle Harbour	• A tunnelling procedure that details a methodology to determine when and what type of waterproofing is required to be installed would be implemented during the further design development phase and outcomes monitored • Groundwater inflows into the tunnels would be monitored during construction and compared to predictions from the updated groundwater model • The groundwater model would be updated based on the results of the monitoring and if required, feasible and reasonable management measures to minimise groundwater inflows would be implemented to ensure that groundwater inflow performance criteria are met.	Design and construction	Chapter 16 (Geology, soils and groundwater)

Project uncertainties	Proposed resolution	Timing	Where discussed
The locations and extent of potential settlement impacts	• Further assessment would be carried out with regards to settlement, including groundwater and geotechnical modelling during further design development to refine the level of predicted settlement, where required • Efforts to minimise impacts in areas where higher ground movement in excess of settlement limits is predicted would be carried out • Building condition surveys and monitoring of settlement during construction would be carried out by the construction contractor.	Design and construction	Chapter 16 (Geology, soils and groundwater)
Construction and operational water treatment plant design local stormwater discharge capacity	• The local stormwater system capacity to receive construction and operational wastewater treatment plant inflows would be confirmed during further design development, and environmental management measures implemented in the event of a capacity issue.	Design	Chapter 17 (Hydrodynamics and water quality)
Surface water drainage and management infrastructure	• The drainage design for the project would be continued to be refined during further design development and would include confirmation of capacity requirements and extent of scour protection • The type and design of the stormwater management system including permanent water quality basins, would continue to be refined and modelled as part of further design development with the aim of meeting or improving the existing water quality of receiving waters. This would also include consideration of best management practice guidelines including Transport for NSW's Water sensitive urban design guideline (Roads and Maritime Services, 2017d).	Design	Chapter 17 (Hydrodynamics and water quality)

Project uncertainties	Proposed resolution	Timing	Where discussed
Flood behaviour during operation	• Further flood modelling would be carried out during further design development to confirm the level of predicted impacts and ensure appropriate mitigation measures identified for areas where higher flooding is predicted, eg provision of flood walls and/or increased flood storage capacity. Further flood modelling would also include the consideration of future climate change and a partial blockage of the local stormwater drainage system.	Design	Chapter 18 (Flooding)
Groundwater drawdown impact on groundwater dependent ecosystems and stream flows	• A focused study confirming the potential groundwater drawdown and associated baseflow reductions at Burnt Bridge Creek, Flat Rock Creek and Quarry Creek due to tunnelling would be carried out. Where unacceptable ecological impacts are predicted, feasible and reasonable mitigation measures to address the impacts would be identified, incorporated into the detailed design, and implemented during construction. • Monitoring of the vegetation within the mapped groundwater dependent ecosystem adjoining Flat Rock Creek and Quarry Creek would be carried out to assess how its health may be impacted by water table drawdown. This would be carried out in conjunction with monitoring of groundwater levels, groundwater quality and surface water flows • If monitoring identifies potential long term detrimental effects to groundwater dependent ecosystem health, adaptive management measures would be implemented.	Design and construction	Chapter 16 (Geology, soils and groundwater) Chapter 19 (Biodiversity)

Project uncertainties	Proposed resolution	Timing	Where discussed
Design details for motorway facilities and ventilation outlets	• Refinement of the architectural design of the project motorway facilities and ventilation outlets would be confirmed during further design development. A design for the motorway facilities and ventilation outlets would be developed to incorporate the infrastructure component as an integral part of surrounding land use in accordance with the project's strategic urban design framework (refer to Appendix V (Technical working paper: Urban design, landscape character and visual impact) for more information).	Design	Chapter 22 (Urban design and visual amenity)
Urban design detail of fixed infrastructure (motorway facilities, ventilation outlets, substations, portals, water treatment facilities and bridges) and other key features	• The urban design for project infrastructure and key features would be refined during further design development in accordance with performance requirements for elements such as the motorway facilities and ventilation outlets, the objectives and principles for urban design and landscaping developed for the project, and the outcomes of consultation • An urban design and landscape plan would be prepared during further design development and implemented in line with the strategic urban design framework for the project. The urban design and landscape plan would detail built and landscape features to be implemented during construction and rehabilitation of disturbed areas during construction of the project.	Design	Chapter 22 (Urban design and visual amenity)

28.4 Summary of project impacts and management measures

This section provides a summary of the impacts of the project that could not be avoided. These impacts are discussed in detail in Chapter 8 (Construction traffic and transport) to Chapter 27 (Cumulative impacts) of this environmental impact statement.

28.4.1 Key impact avoidance

Many potential impacts have been avoided through the project development process which included input from key stakeholders and the community. A number of corridor alternatives were evaluated to identify the most technically, environmentally and socially acceptable alternative with the most efficient transport connections (refer to Chapter 4 (Project development and alternatives) for more information on the alternatives considered).

Following identification of the preferred corridor for the project, further design development and refinement has been carried out which has resulted in the avoidance or minimisation of environmental impacts; these include:

- Selection of roadheaders instead of tunnel boring machines for construction of the land-based tunnels, resulting in lower spoil volumes and fewer heavy vehicle movements
- The selection of precast immersed tube tunnel units on top, or within the top layers, of harbour rock and sediments as the preferred harbour crossing method, rather than the use of driven tunnel, thereby avoiding the need for tunnelling in challenging geology and enabling better grades and journey experience (eg safety, lower emissions)
- Refinements to the location of the Warringah Freeway, Gore Hill Freeway and Balgowlah surface connections, resulting in improved connectivity and network performance, improved constructability and design, and minimising environmental, community and traffic impacts
- Temporary construction support site location and layout alternatives were considered to minimise impacts to sensitive environments and community facilities, while minimising property impacts and acquisitions. Locations were also selected to maximise opportunities for direct access to arterial roads or water transport opportunities for construction traffic, to avoid use of local streets where possible
- Ventilation system design alternatives. A longitudinal system with elevated ventilation outlets was selected as the preferred option as it is able to meet the requirement to avoid portal emissions, most effectively manage smoke in the tunnel in the event of a fire, ensure emissions are dispersed and diluted so there is minimal or no effect on ambient air quality
- Alternatives for the transport of spoil were considered, including the use of rail, barge or truck. A combination of trucks and some barging was selected as the preferred spoil transport option for the project as it reduces the amount of double or triple handling of spoil required (ie transfer spoil to a loading facility) while also providing the ability to move large volumes of spoil, thereby reducing the number of heavy vehicle movements on the wider road network
- Dredged material management alternatives were considered. An application for offshore disposal of suitable 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 transported by barge and disposed of at a designated offshore disposal site (in accordance with legislative requirements). Disposal of suitable dredged material at the designated offshore disposal site would minimise some environmental impacts at sensitive receivers and avoid the creation of a large volume of waste to be disposed on land
- Identification of the potential for residual land at Balgowlah to be repurposed as new and improved open space and recreation facilities in line with the *Northern Beaches Sportsground Strategy* (Northern Beaches Council, 2017a) and addressing the current under supply of sporting grounds available for public use in the local area

- Further refinement of the design including consideration of community issues through the environmental impact statement exhibition process may further reduce and if possible, avoid impacts.

Potential impacts would be further avoided and minimised, where possible, through the implementation of the environmental management measures complying with the performance outcomes identified in Chapter 4 (Project development and alternatives).

28.4.2 Key project impacts

The environmental impact statement has assessed the potential environmental impacts that may occur as a result of the project and recommends measures to manage these impacts. Table 28-3 provides a summary of potential impacts of the project that could not be avoided and the associated environmental management measures. Table 28-3 is not a comprehensive list of all environmental management measures proposed in this environmental impact statement. For further details refer to the individual chapters. Unavoidable impacts would be addressed through design refinements or ongoing management during construction and operation.

Table 28-3 Summary of key project impacts and management measures

Summary of key impact	Timing	Management measure
Traffic and transport • Increased heavy vehicle movements around work sites during construction • Increased traffic volumes and delays for traffic in the North Sydney, Balgowlah and Frenchs Forest areas during construction • Temporary, partial closures of the Pacific Highway, Wakehurst Parkway and roads within the Gore Hill Freeway and Artarmon area, for short periods of time to carry out key construction activities which are located within the road corridor • Temporary closures and detours of footpaths and shared user paths at Flat Rock Reserve, and within the Gore Hill Freeway, Artarmon, Spit West Reserve, Balgowlah and Wakehurst Parkway areas • Temporary impacts on maritime traffic associated with the six closures (likely two full closures and four partial closures) of Middle Harbour for recreational, commercial and government users between Northbridge and Seaforth to enable construction works for the crossing of Middle Harbour.	Construction	• 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 • Directional signage, barriers and/or line marking 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 • Any adjustments to existing bus stops will be determined in consultation with relevant stakeholders including other divisions of Transport for NSW and advanced notification will be provided to affected bus customers. Relocations will be as close to their existing position where feasible and reasonable • 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 • 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 • Direct impacts to existing pedestrian and cycle facilities will be minimised where reasonable and feasible. Any detours and adjustments will be designed with consideration of user safety and convenience • Construction marine traffic activities will be scheduled to avoid times and locations of high recreational marine traffic where feasible and reasonable

Summary of key impact	Timing	Management measure
		• Harbour closures scheduling will be carried out in consultation with Port Authority of NSW, other divisions of Transport for NSW and other relevant stakeholders.
Noise and vibration • Construction noise levels predicted to exceed noise management levels at some sensitive receiver locations • Potential for sleep disturbance impacts during the night • Construction traffic movements has the potential to result in road traffic noise levels above the relevant criteria.	Construction	• Monitoring will be carried out to confirm construction noise and vibration levels in relation to noise and vibration management levels • Where construction activities are predicted to exceed noise management levels at receivers mitigation measures will be implemented where feasible and reasonable including community consultation and engagement, detailed programming and respite protocols and the early implementation of operational noise barriers • An out-of-hours works protocol will be developed for the construction of the project. The protocol will be prepared in consultation with the 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.
Human health and air quality • Underwater noise and vibration impacts affecting water-based recreational users • Dust generated during works carried out for demolition, earthworks, construction and track-out • Odours potentially generated during handling and management of harbour sediments and material excavated from a former landfill site • Blast emissions generated by blasting, if required during construction • Potential impacts on ambient air quality due to changes in the distribution of surface traffic and operation of the tunnel ventilation facilities:	Construction/ operation	• Opportunities to coordinate the piling program with the planned activities of key recreational stakeholders to minimise interaction with planned or peak activity periods of these stakeholders, where feasible and reasonable • An underwater noise monitoring program will be carried out during the early stages of impact piling activities at each location 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. • 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

Summary of key impact	Timing	Management measure
– Generally minor increases in common ambient air quality air pollutants (CO, NO_2, PM_{10}, $PM_{2.5}$, benzene, polycyclic aromatic hydrocarbons, formaldehyde, 1,3-butadiene and ethylbenzene) predicted, with only a very small proportion of receivers predicted to experience larger increases – Some of the current exceedances of short-term NSW EPA ambient air quality criteria (1-hour NO_2, 24-hour $PM_{2.5}$ and 24-hour PM_{10} and annual mean PM_{10} and $PM_{2.5}$) predicted to continue when the project is in operation, although total numbers of receivers experiencing exceedances predicted to decrease as a result of the project – Exceedances of PM_{10} and $PM_{2.5}$ air quality criteria predicted at potential future buildings above 30 metres in height within 300 metres of the Gore Hill Freeway ventilation outlet, but would not necessarily preclude such development – Odours generated by vehicle emissions.		• Standard construction air quality mitigation and management measures will be detailed in construction management documents including minimisation and management of dust generation during construction. • 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 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 • 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 impact to structures and sensitive receivers. Prior to any blasting all potentially affected sensitive receivers and features in the vicinity will be identified. The potentially affected community will be kept informed about proposed blasting activities.
Non-Aboriginal heritage • Direct and indirect impacts to non-Aboriginal heritage items near of the project including: – Moderate and permanent impacts to Cammeray Park (including Golf Course) as a result of the construction activities and the installation of permanent operational infrastructure within the heritage boundary – Major impacts at Balgowlah Golf Course as a result of the temporary establishment and operation of Balgowlah Golf Course construction support site (BL10) and the construction of	Construction/ operation	• 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 • 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 • Delineation of restricted zones will be implemented to avoid inadvertent works occurring within the curtilage of heritage items

Summary of key impact	Timing	Management measure
permanent road infrastructure and operational facilities - Direct impacts to maritime heritage items near of the project		• 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 and implemented during construction.
Aboriginal heritage • Direct and indirect impacts to Aboriginal heritage items near of the project including: – Five Aboriginal sites located within 50 metres of surface works including two sites that may be subject to indirect impacts associated with vibration and settlement – Five Aboriginal sites located above or within 50 metres of the tunnel alignment and may be subject to indirect impacts associated with vibration and settlement • Direct impacts from construction activities such as dredging, piling and excavation within the cofferdams to submerged sites • Indirect impacts associated with construction vibration generated by construction activities in proximity to Aboriginal sites.	Construction	• Cultural and historic heritage awareness training will be carried out for personnel engaged in work that may impact heritage items before commencing works for the project. • Vibration monitoring will be carried out where required at terrestrial AHIMS sites. Where monitoring identifies vibration levels exceed 2.5 millimetres per second or following vibration intensive activities, a subsequent condition survey will be carried out to record any changes to the integrity of the site that may have resulted from construction vibration • The effectiveness of using high resolution geophysical survey to identify rock overhangs concealed by marine sediments will be assessed. If determined to be appropriate geophysical survey will be conducted to identify potential rock overhangs concealed by marine sediments.

Summary of key impact	Timing	Management measure
Hydrodynamics and water quality • Discharges from construction and operation wastewater treatment facilities affecting fresh and marine water quality. • Construction works leading to water quality and sedimentation issues in surrounding waterways.	Construction/ Operation	• Construction and operation wastewater treatment plants will be designed to meet the relevant requirements of ANZECC/ARMCANZ (2000) and ANZG (2018) • Operational phase monitoring will be described in the operational water quality monitoring program, for both surface water and groundwater as appropriate, and carried out in line with the post construction phases requirements of the *Guideline for Construction Water Quality Monitoring* (RTA, 2003a). Should any of the discharge criteria be exceeded, a management response will be triggered and appropriate mitigation measures to address the exceedance will be identified and implemented • A freshwater quality monitoring program for the construction of the project will be developed and implemented, with consideration of the freshwater monitoring being carried out for the Western Harbour Tunnel and Warringah Freeway Upgrade project and the completed Northern Beaches Hospital road upgrade project. If exceedances of the criteria established under the freshwater monitoring program are detected, a management response will be triggered and appropriate mitigation measures to address the exceedance will be identified and implemented • Erosion and sediment control measures will be implemented at all work sites and surface road upgrades in accordance with the principles and requirements in *Managing Urban Stormwater – Soils and Construction, Volume 1* (Landcom, 2004), *Managing Urban Stormwater: Soils and Construction, Volume 2D Main Road Construction* (Department of Environment and Climate Change (DECC), 2008) and relevant guidelines, procedures and specifications of Transport for NSW.

Summary of key impact	Timing	Management measure
Biodiversity • Removal of native remnant and planted individuals of Netted Bottle Brush (*Callistemon linearifolius*) and Magenta Lilly Pilly (*Syzygium paniculatum*) listed under the *Biodiversity Conservation Act 2016* and EPBC Act • Removal of about 15.4 hectares of native vegetation and native revegetation • Fragmentation of habitat and removal of hollow-bearing trees due to the realignment and upgrade of the Wakehurst Parkway. The fragmentation of vegetation would potentially adversely affect the movement patterns of a number of threatened terrestrial fauna species known or likely to occur in the area • Potential edge effects to vegetated habitats next to the Wakehurst Parkway • Potential for short-term noise impacts from surface works at Balgowlah to the Grey-headed Flying-fox (*Pteropus poliocephalus*) camp identified in the vegetated area between Balgowlah Road and Burnt Bridge Creek Deviation, about 120 metres from the construction footprint • Potential noise and vibration impacts to Large-eared Pied Bat during the realignment and upgrade of the Wakehurst Parkway, particularly during blasting and/or rock hammering • Potential impacts to key fish habitats in Middle Harbour due to the removal of medium/high relief rocky reef habitat, turbidity and sedimentation from dredging, and underwater noise from dredging and piling	Construction	• Vegetation removal including the clearing of native vegetation and fauna habitat will be further minimised during further design development and construction planning, where feasible and reasonable • Credits will be required as part of the biodiversity offsets for the project for the removal of native vegetation and threatened species habitat impacted by the project • Vegetation removal along the Wakehurst Parkway will be timed to avoid the winter breeding period for the Eastern Pygmy-possum (May to July), where possible • Connectivity measures will be designed during further design development in accordance with the *Wildlife Connectivity Guidelines: Managing wildlife connectivity of road projects* (Draft) (Roads and Maritime Services, 2011c) and consider measures to facilitate the crossing of native fauna species • Adaptive management measures to minimise impacts on Grey-headed Flying-foxes will be developed prior to construction. Where feasible and reasonable, noise intensive works with the potential of impacting the Grey-headed Flying-fox camp (ie demolition involving rock hammering or resurfacing works) should be programmed to avoid September to February. A person experienced in flying-fox behaviour will monitor disturbance levels within the Grey-headed Flying-fox camp at Balgowlah during construction activities • Activity-specific controls will be developed to manage impacts from high noise and vibration generating activities (eg controlled blasting and rock hammering) on Large-eared Pied Bat along the Wakehurst Parkway. The controls will be developed by a suitably qualified and experienced microbat specialist and implemented during surfaced road works as required • Exclusion zones will be implemented to avoid disturbance to sensitive marine habitats not proposed to be directly impacted by the project. Routine inspections and maintenance of exclusion measures will be carried out

Summary of key impact	Timing	Management measure
• Potential impacts on marine threatened species in Middle Harbour, such as the Black Rockcod and White's seahorse that reside in habitat affected during construction • Potential impacts on some marine mammals, turtles and sharks, which may forage or transit through seagrass, rocky reef or deepwater soft sediment habitats • Potential underwater noise impacts to marine fauna generated through construction dredging and piling activities.		• Silt curtains will be installed around seagrass patches and subtidal rocky reef contained within the Zone of Influence as described in Appendix T (Technical working paper: Marine ecology) • Pre-construction surveys of potentially affected marine habitat areas will be carried out as close as practicable to 24 hours prior to commencement of works by suitably qualified and experienced marine ecologists to search for White's seahorses (and other Syngnathids) and relocate to nearby unaffected habitat • Salvage of live fish and other native marine organisms (eg large, mobile macroinvertebrates) will occur during cofferdam dewatering and will be carried out by suitably qualified and experienced marine ecologists. All salvaged organisms will be immediately relocated to similar habitat nearby • A stop-work procedure will be developed in accordance with the recommendations in Appendix T (Technical working paper: Marine ecology) to mitigate potential impacts to marine mammals and reptiles within the vicinity of impact piling works.
Land use and property • Temporary leasing of properties and land during construction • Temporary land use changes to some areas associated with construction activities or construction support sites • Temporary relocation of boat moorings to provide safe access to temporary construction support sites • Permanent full or partial acquisition of properties and land • Permanent land use changes where permanent project infrastructure is established	Construction/ operation	• Land subject to temporary use, including areas of public open space, will be rehabilitated as soon as practicable to an appropriate condition, taking into consideration the location, land use characteristics, area and adjacent land uses or in accordance with the urban design and landscape plan where applicable. Rehabilitation will be carried out in consultation with the relevant land owner, the local council and community (where appropriate) • Transport for NSW will consult with existing lease holders of properties that will be directly affected by the project regarding any changes to lease arrangements • Land acquisition for the project will be carried out in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW), the *Roads and Maritime Services Land Acquisition Information Guide* (Roads and Maritime Services, 2014b) and

Summary of key impact	Timing	Management measure
• Permanent closure of Balgowlah Golf Course and repurposing of the land for new and improved open space and recreation facilities for the community • Permanent land use change for part of Cammeray Golf Course used for operational facilities • Air quality impacts for future elevated receivers above 20 metres in height located within 300 metres of ventilation outlets.		*Fact sheet: Property acquisition of subsurface lands* (Roads and Maritime Services, 2015b) and in accordance with the land acquisition reforms announced by the NSW Government in 2016 • Identification of residual land of the project will be confirmed during further design development and construction planning. Appropriate strategies for the ongoing management and/or divestment of the residual land will consider the location, land use characteristics, area and adjacent land uses. • Transport for NSW will assist Northern Beaches Council, North Sydney Council, Willoughby City Council 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 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.
Urban design and visual amenity • Visual impacts during construction as a result of the presence of construction works, plant and equipment and construction vehicles • Loss of vegetation providing screening and amenity • Temporary increases in exposure to built form.	Construction	• Construction support sites will be developed to minimise visual impacts for adjacent receivers where feasible and reasonable • Existing trees adjacent to the works will be retained and protected where reasonable and feasible to screen construction works • Early planting works will be considered to provide a screening buffer that has time to mature before the project is fully operational. • The urban design and landscape plan will be further developed during further design development and implemented in line with the strategic urban design framework for the project. It will include appropriate operational mitigation measures • All areas disturbed by construction and not required for operation of the project will be restored as soon as practicable to their existing condition or in accordance with the urban design and landscape plan where applicable.

Summary of key impact	Timing	Management measure
Geology, soils and groundwater • Ground movement may occur as a result of the construction of the project or from settlement induced by groundwater drawdown • The project is situated adjacent to areas that are considered to have a 'moderate' or 'high' risk rating of containing contaminated material • Disturbance of sediments in Middle Harbour during dredging activities which could potentially pose a contamination risk due to the contamination associated with historical industrial use of the harbour.	Construction	• Detailed predictive settlement models will be developed for areas of concern to guide tunnel design and construction methodology, including the selection of options to minimise settlement where required • Pre-construction building structure condition surveys will be offered and prepared 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 • Potentially contaminated areas directly affected by the project will be investigated and managed in accordance with the requirements of guidance endorsed under section 105 of the *Contaminated Land Management Act 2008* • The dredging methodology has been designed to minimise impacts on the marine environment and would include the use of a backhoe dredge with closed environmental bucket.
Resource use and waste management • About three million cubic metres of spoil would be produced from land-based construction activities (terrestrial spoil) during construction. In addition, marine construction works for the project within Middle Harbour would produce around 163,000 cubic metres of dredged and excavated material.	Construction	• The resource management hierarchy principles established under the *Waste Avoidance and Recovery Act 2001* of avoid/reduce/reuse/recycle/dispose will be applied • Wastes will be appropriately transported, stored and handled according to their waste classification and in a manner than prevents pollution of the surrounding environment.

Summary of key impact	Timing	Management measure
Socio-economic • Loss of open space, parks and recreational facilities, due to use for temporary construction support sites and permanent project facilities • Property impacts and acquisitions affecting residential properties and businesses • Potential reduction in amenity at social infrastructure due to reduced visual amenity and increased air-borne construction noise, dust and traffic • Potential impacts on community cohesion due to temporarily restricting access to some social infrastructure and meetings places, which may reduce opportunities for social and community interaction • Changes in passing trade to business, employee and customer access, servicing and deliveries, business visibility, demand for services, displacement of business and potential impacts on maritime businesses and freight and efficiency.	Construction/ operation	• Ongoing engagement will be carried out with representatives of user groups and managers of social infrastructure located near to surface construction works/construction support sites and sensitive social infrastructure above the tunnel alignment about the timing and duration of construction works and management of potential impacts • Where businesses are affected by property acquisition, or lease cessation, the acquisition and compensation process will be implemented in line with the *Determination of compensation following the acquisition of a business guideline*. Compensation for a business conducted on land that is acquired should be determined in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* as relevant • Where feasible and reasonable, the extent of permanent impact on public open space areas will be minimised during further design development • Specific consultation will be carried out with businesses potentially impacted during construction. Consultation will aim to identify specific potential construction impacts for individual businesses.
Cumulative impacts • There is the potential for construction fatigue and complaint fatigue to be experienced by surrounding receivers as a result of concurrent and consecutive construction programs.	Construction	• Multi-party engagement and cooperation will be established prior to construction to coordinate with the following projects to manage construction fatigue impacts where possible: - Western Harbour Tunnel and Warringah Freeway Upgrade project - Sydney Metro City & Southwest - Channel 9 site staged residential redevelopment • Complaint fatigue will be managed in accordance with Appendix E (Community consultation framework).

28.4.3 Residual impacts

An environmental risk analysis for the project has been carried out and is detailed in Appendix C (Environmental risk analysis). The risk analysis identifies an initial risk rating for each of the environmental issues and the residual risk rating derived after the application of environmental management measures developed and recommended by this environmental impact statement. It involved:

- Rating the risk of each identified potential impact by identifying the consequences of the impact and likelihood of each impact occurring
- Considering the probable effectiveness of the proposed environmental management measures to determine the likely residual risk of each impact.

The risk analysis outlined in Appendix C (Environmental risk analysis) has identified several 'medium' level residual risks. No potential impacts with a residual risk rating of 'high' were identified for the project. During further design development, opportunities would be identified for 'medium' level residual risks to:

- Resolve residual impacts and risks through further design refinement
- Develop suitable construction methodologies and carry out construction planning with the construction contractor to ensure that environmental management measures can be implemented effectively
- Implement a process of review, correction and audit for the management measures that were identified in this environmental impact statement and summarised in Appendix Y (Compilation of environmental management measures). This would be a process of continuous improvement that would form part of the construction environmental management plan and operational environmental management plan and would allow for environmental management measures to be updated or improved during the construction and operational phases, where practical.

Where 'medium' level residual risks are considered to still be likely after further design development, additional refined environmental management measures would be developed, where appropriate, to ensure those risks are suitably mitigated.

Where 'low' level residual risks are identified, an appropriate process of continuous improvement would be applied to address these potential impacts during construction and operation as far as is reasonable and feasible.

28.5 Environmental management plan framework

The implementation of environmental management measures during further design development, construction and operation of the project would minimise potential adverse impacts arising from the proposed work on the surrounding environment.

28.5.1 Construction environmental management

The environmental management framework provides a whole-of-construction life-cycle approach to construction environmental management and sets out the environmental requirements for construction. Construction environmental management documentation that would be prepared in accordance with the planning approval documents includes:

- Construction environmental management plan
- Construction environmental management plan sub-plans
- Performance and compliance reports.

This approach is illustrated in Figure 28.5 and has been developed to be consistent with legislative and regulatory requirements, including those described in Chapter 2 (Assessment process).

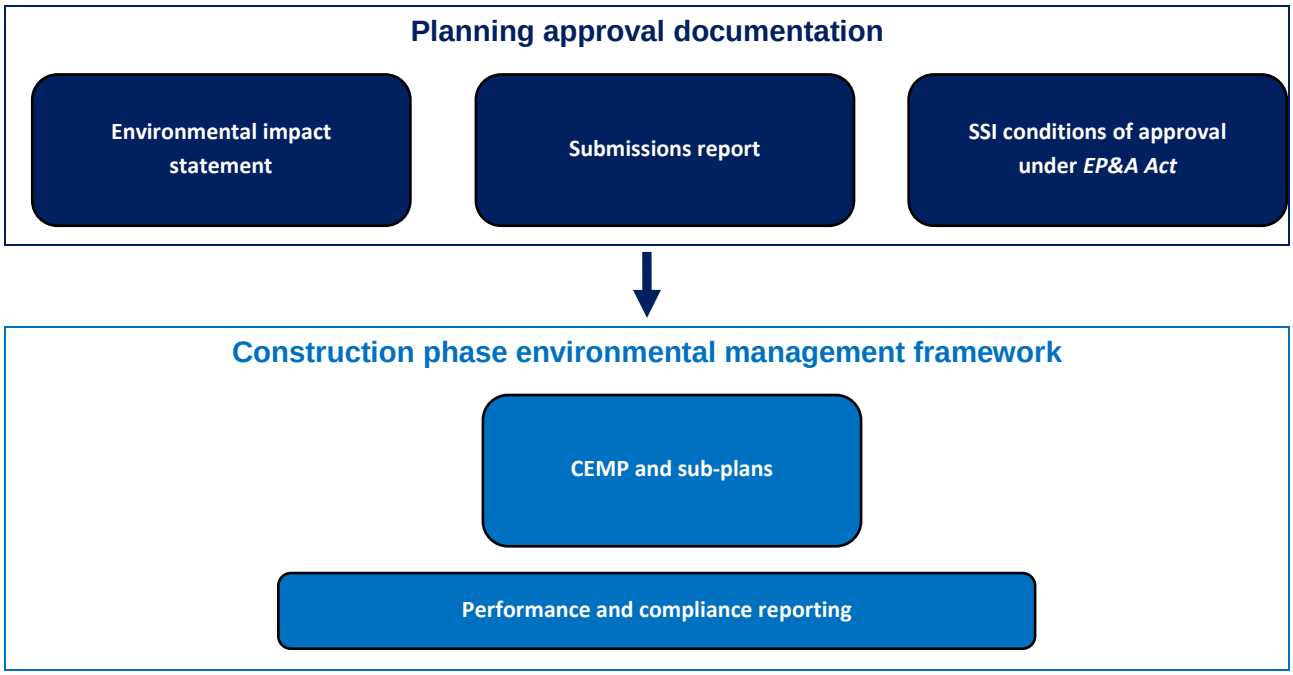

Figure 28.5 Construction environmental management approach

Construction environmental management plan

A construction environmental management plan would be prepared for the project in accordance with *QA Specification G36: Environmental Protection* (Transport for NSW, 2020h) prior to construction of the project and would be reviewed and approved by Transport for NSW and the Department of Planning, Industry and Environment, prior to the commencement of main construction work. It would provide the overarching framework for construction environmental management and would include the following:

- A description of applicable activities to be carried out during construction
- Construction methodologies and incorporation of relevant environmental management measures for applicable activities during construction
- An environmental risk and opportunities methodology
- A matrix of the relevant conditions of approval, as well as project specific commitments including environmental management measures, referencing where each requirement is addressed
- Outline the objectives and targets, in defined performance outcomes
- Environmental accountabilities or responsibilities
- Induction and training requirements
- Management strategies for reviewing the effectiveness of environmental management measures
- Processes and methodologies for surveillance and monitoring, auditing and reviewing and reporting on environmental and sustainability performance including compliance tracking
- Procedures for emergency and incident management, non-compliance management and corrective and preventative action
- Procedures for the control of environmental documents and records
- Environmental management measures table.

The construction environmental management plan would be a working document, subject to ongoing change and updated as necessary to respond to specific requirements.

Construction environmental management sub-plans

The construction environmental management plan would provide the overarching framework for construction environmental management. The following sub-plans which would likely be required to manage specific environmental impacts during construction:

- Traffic and transport management plan
- Marine works and marine traffic management plans
- Noise and vibration management plan
- Heritage management plan
- Air quality management plan
- Waste and resource management plan
- Soil and water management plan
- Groundwater management plan
- Flora and fauna management plan
- Dredge management plan.

The sub-plan structure identified above may be modified slightly during detailed construction planning to respond more effectively to particular contractor or stakeholder requirements.

In addition, a number of other management plans and strategies are likely to be required separate to the construction environmental management plan. These may include, but are not limited to:

- Site establishment management plan
- Utilities management strategy which would be prepared in accordance with Appendix D (Utilities management strategy)
- Blasting management strategy
- Sustainability management plan
- Community communication strategy which would be prepared in accordance with Appendix E (Community consultation framework).

28.5.2 Operational environmental management

Maintenance of the project and its environmental performance during operation would be managed under the existing Transport for NSW environmental management system for asset maintenance (or similar) prepared in accordance with the AS/*NZS ISO 14000 Environmental Management System* series and developed to be consistent with the broad environmental objectives and policies set out in the Transport for NSW environmental management system. Transport for NSW is committed to managing its impacts on the environment and carrying out its activities so as to avoid, minimise or mitigate environmental impacts. Accordingly, any project-specific operational environmental management practices and procedures would be incorporated into the existing environmental management system.

28.6 Performance outcomes

The project's performance outcome as measured against those identified for key issues in the Secretary's environmental assessment requirements is provided in Table 28-4, along with a summary of how each performance outcome would be achieved by the project.

Table 28-4 Design performance outcomes and project outcome

Desired performance outcome	How performance outcomes would be achieved
Environmental impacts assessment process • The process for assessment of the proposal is transparent, balanced, well focussed and legal.	• This environmental impact statement has been prepared in accordance with Part 3 of Schedule 2 of the Environmental Planning and Assessment Regulation 2000 • Based on the results of the environmental investigations carried out for this environmental impact statement, it is considered that matters of national environmental significance set out in the *Environment Protection Biodiversity Conservation Act 1999* are not likely to be significantly impacted by the project. Accordingly, Transport for NSW has decided a referral to the Commonwealth is not required at this stage.
Environmental impact statement • The project is described in sufficient detail to enable clear understanding that the project has been developed through an iterative process of impact identification and assessment and project refinement to avoid, minimise or offset impacts so the project, on balance, has the least adverse environmental, social and economic impact, including its cumulative impacts.	• The project has been described in detail in Chapter 5 (Project description) • The merits of the project, and the design options were considered in the context of a range of alternatives based on how well they performed with reference to transport, environmental, engineering, social and economic factors (refer to Chapter 4 (Strategic context and project need)). The preferred design provides a combination of benefits compared with other options assessed, including improved access, minimised impacts on properties and on future development potential.
Assessment of key issues • Key issue impacts are assessed objectively and thoroughly to provide confidence the project would be constructed and operated within acceptable levels of impact.	• The assessment of key issues has been conducted objectively and thoroughly. The implementation of environmental management measures would ensure the project is constructed and operated within acceptable levels of impact. Refer to Chapter 8 (Construction traffic and transport) to Chapter 26 (Climate change risk and greenhouse gas) for further details.
Consultation • The project is developed with meaningful and effective engagement during project design and delivery.	• Consultation has been carried out to inform the design process and project development (refer to Chapter 7 (Stakeholder and community engagement)) • The construction contractor would respond to complaints in a timely and appropriate manner, to ensure all stakeholders' concerns are addressed effectively and promptly.

Desired performance outcome	How performance outcomes would be achieved
Transport and traffic • Network connectivity, safety and efficiency of the transport system near of the project are managed to minimise impacts • The safety of transport system customers is maintained • Impacts on network capacity and the level of service are effectively managed • Works are compatible with existing infrastructure and future transport corridors.	With respect to transport and traffic, the project has been developed such that it would: • Minimise impacts to local streets from loss of parking, road closures and heavy vehicle movements during construction • Minimise impacts to road network efficiency during construction • Enable access to properties to be maintained during construction and operation • Improve the performance and capacity of Sydney's road network • Provide an efficient motorway link which improves traffic flow on Sydney's motorway network • Relocate a substantial volume of through traffic underground • Improve traffic conditions, and ease future congestion on the road network • Provide functional connectivity between the subsurface and surface road network • Provide future motorway connections to support a growing Sydney • Maintain pedestrian and cyclist safety along surface roads near the project • Provide considerable travel time savings for motorists and freight vehicles using Sydney's motorway network • Provide opportunity to develop faster and more reliable express bus services to connect the Northern Beaches to strategic centres such as North Sydney, St Leonards, Sydney CBD and Macquarie Park, with the potential for links to strategic stations on the rail network • Improved travel times and reliability for buses travelling along existing key corridors including Warringah Freeway, Warringah Road, Eastern Valley Way and Military Road due to a reduction in traffic • Enable long-term development of Sydney's motorway network, including connections to and from the Northern Beaches.
Air quality • The project is designed, constructed and operated in a manner that minimises air quality impacts (including nuisance dust and odour) to minimise risks to human health and the environment to the greatest extent	With respect to air quality, the project has been developed that it would: • Provide effective management of dust, odour and other emissions during construction • Result in zero portal emissions during normal operations • Provide effective dispersion of emissions from the tunnels to ensure negligible contributions to air quality at ground level. Tunnel ventilation design would be developed to maintain in-tunnel air quality in accordance with relevant criteria.

Desired performance outcome	How performance outcomes would be achieved
Health and safety • The project avoids or minimises any adverse health impacts arising from the project • The project avoids, to the greatest extent possible, risk to public safety.	With respect to health and safety, the project has been developed that: • Incidents, crashes and risks to public safety would be minimised during construction • The motorway design would achieve safe and efficient road user movements including diverting many heavy vehicles into the tunnels and off the surface road network • Establishment and operation of temporary construction support sites and ancillary infrastructure would ensure the protection of road users and the public • The project avoids, to the greatest extent possible, risk to public safety • Hazardous materials within project areas would be managed to protect human health.
Noise and vibration – Amenity • Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on acoustic amenity • Increases in noise emissions and vibration affecting nearby properties and other sensitive receivers during operation of the project are effectively managed to protect the amenity and well-being of the community.	With respect to noise and vibration (amenity), the project has been developed that it would: • Relocate a considerable volume of through traffic on surface arterial roads underground, improving surface road noise • Divert many heavy vehicles into the tunnels and off the surface road network • Comply with the relevant criteria from the *NSW Industrial Noise Policy* • Minimise increases in road traffic noise, where possible • Include effective implementation of noise management measures during operation • Include effective management of construction noise and vibration in accordance with relevant guidelines, for example through the use of acoustic sheds • Minimise surface activity and associated noise at tunneling sites, as once tunneling starts the majority of the work at these sites would be underground • Minimise impacts to the local community by: - Controlling noise and vibration at the source - Controlling noise and vibration on the source to receiver transmission path - Controlling noise and vibration at the receiver - Implementing practicable and reasonable measures to minimise the noise and vibration impacts of construction activities on local sensitive receivers.

Desired performance outcome	How performance outcomes would be achieved
Noise and vibration – Structural • Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on the structural integrity of buildings and items including Aboriginal places and environmental heritage • Increases in noise emissions and vibration affecting environmental heritage as defined in the *Heritage Act 1977* during operation of the project are effectively managed.	With respect to noise and vibration (structural), the project would minimise impacts to structures by: • Controlling vibration at the source • Controlling vibration on the source to receiver transmission path • Implementing practicable and reasonable measures to minimise vibration impacts of construction activities on structures • Carrying out building/structure condition surveys for properties (and heritage assets) within the zone of influence of tunnel settlement prior to the commencement of construction.
Biodiversity • The project design considers all feasible measures to avoid and minimise impacts on terrestrial and aquatic biodiversity • Offsets and/or supplementary measures are assured which are equivalent to any remaining impacts of project construction and operation.	With respect to biodiversity, the project has been developed that: • It would minimise impacts on biodiversity • Where practicable, the design minimises the need to clear vegetation • Potential impacts on biodiversity would be managed in accordance with relevant legislation, including the *Environmental Planning and Assessment Act 1979* and the *Biodiversity Conservation Act 2016* and relevant guidelines • Offsets would be provided for the project in accordance with NSW Biodiversity Offsets Scheme, established under Part 6 of the *Biodiversity Conservation Act 2016* and the *Policy and guidelines for fish habitat conservation and management* (NSW Department of Primary Industries (DPI), 2013).
Place Making and Urban Design • The project design complements the visual amenity, character and quality of the surrounding environment • The project contributes to the accessibility and connectivity of communities.	With respect to place making and urban design, the project has been developed that: • It would connect disconnected communities • A substantial volume of through traffic on surface arterial roads would be diverted underground, improving urban amenity • Sympathetic urban design would integrate with adjacent and historical land uses • It would establish and operate ancillary infrastructure to minimise adverse impacts on the visual amenity of the local community • It would provide for new and improved active transport links • It would provide for new and improved open space and recreation facilities at Balgowlah.

Desired performance outcome	How performance outcomes would be achieved
Socio-economic, land use and property • The project minimises adverse social and economic impacts and capitalises on opportunities potentially available to affected communities • The project minimises impacts to property and business and achieves appropriate integration with adjoining land uses, including maintenance of appropriate access to properties and community facilities, and minimisation of displacement of existing land use activities, dwellings and infrastructure.	With respect to socio-economics, land use and property, the project has been developed to: • Minimise property acquisition • Manage the property acquisition process to minimise impacts to community and businesses • Minimise impacts to businesses during construction • Make provision for social infrastructure • Reduce congestion on the road network, supporting future urban regeneration • Avoid barriers and division of the community through the tunnel solution.
Water – Hydrology • Long term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised • The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved) • Sustainable use of water resources.	With respect to water (hydrology), the project has been developed that: • Design and construction of the tunnels minimises groundwater inflow • Opportunities for reuse of treated water during construction have been considered throughout project development • The environmental values of nearby, connected and affected water sources would be improved and/or maintained.
Water – Quality • The project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable).	With respect to water (quality), the project has been developed to: • Operate under water quality discharge criteria with consideration of the NSW Water Quality Objectives • Effectively treat water to meet water quality discharge criteria.

Desired performance outcome	How performance outcomes would be achieved
Flooding • The project minimises adverse impacts on existing flooding characteristics • Construction and operation of the project avoids or minimises the risk of, and adverse impacts from, infrastructure flooding, flooding hazards, or dam failure.	With respect to flooding, the project has been developed that: • Construction would be carried out in a manner that minimises the potential for adverse flooding impacts, through staging of works and the implementation of mitigation measures • Temporary construction support sites and construction sites would be laid out so flows are not substantially impeded • Flood levels would be maintained or reduced at residential, commercial and industrial properties adjacent to the alignment during a 1% AEP event.
Soils • The environmental values of land, including soils, subsoils and landforms, are protected • Risks arising from the disturbance and excavation of land and disposal of soil are minimised, including disturbance to acid sulfate soils and site contamination.	With respect to soils, the project has been developed that: • Erosion and sediment controls would be implemented in accordance with *Managing Urban Stormwater – Soils and Construction, Volume 1* (Landcom 2004) and *Managing Urban Stormwater: Soils and Construction, Volume 2D: Main Roads* (DECC 2008), commonly referred to as the 'Blue Book' • Acid sulfate soils would be managed in accordance with good practice measures • Contamination would be managed to protect environmental values and human health.
Heritage • The design, construction and operation of the project facilitates, to the greatest extent possible, the long term protection, conservation and management of the heritage significance of items of environmental heritage and Aboriginal objects and places.	With respect to heritage, the project has been developed that it would: • Establish archival recording of items of heritage significance that would be subject to change • Minimise impacts on heritage items during construction • Incorporate key heritage values and stories into the final urban design and landscaping outcome • Minimise impacts to features of heritage conservation significance from vibration. The design would be sympathetic to the heritage significance of surrounding listed heritage items, and where practicable, avoid and minimise impacts to heritage. Impacts on heritage would be managed in accordance with relevant legislation, including the *Environmental Planning and Assessment Act 1979*, the *Heritage Act 1977*, and relevant guidelines.

Desired performance outcome	How performance outcomes would be achieved
Sustainability • The project reduces the NSW Government's operating costs and ensures the effective and efficient use of resources • Conservation of natural resources is maximised.	With respect to sustainability, the project has been developed that: • Sustainability considerations would be integrated throughout design, construction, and operation • The project would seek to achieve an 'Excellent' Design and 'As Built' Infrastructure Sustainability rating • The project would be carried out in accordance with the Sustainability Framework developed for the project • Activities to implement the sustainability framework, including requirements from the Infrastructure Sustainability rating scheme, would be implemented through a Sustainability Management Plan.
Waste • All wastes generated during the construction and operation of the project are effectively stored, handled, treated, reused, recycled and/or disposed of lawfully and in a manner that protects environmental values.	With respect to waste, the project has been developed that: • Where feasible and reasonable, the project would recycle or reuse clean spoil either on site or off site • Disturbed contaminated material would be encapsulated on site where appropriate and in accordance with relevant regulatory requirements. • Off-site waste reuse would be managed in accordance with relevant NSW Environment Protection Authority resource recovery exemptions and requirements • Waste would be disposed of at appropriately licensed facilities.
Climate change risk • The project is designed, constructed and operated to be resilient to the future impacts of climate change.	With respect to climate change risk, the project has been developed that it: • Would incorporate climate change and sea level rise adaptation measures into the further design development and construction planning for the project.

28.7 Project justification and conclusion

28.7.1 Biophysical, economic and social considerations

The environmental impact statement has been prepared with regard to the key issues associated with the project and the integration of biophysical, economic and social considerations.

While the development of the project would have some unavoidable impacts (associated with, for example, construction impacts from heavy vehicle traffic, noise, vibration and dust, access disruptions and visual impacts) overall, the project would deliver a large number of benefits and opportunities including:

- Reducing pressure on congested road corridors, leading to faster and more reliable journeys to, from and around the Northern Beaches and North Shore
- Improving public transport journey times, travel time reliability and connectivity between the Northern Beaches and strategic centres, enabling new express bus service routes
- Improving access for local businesses to Greater Sydney, making it easier and safer to move goods and provide services
- Increasing the resilience of the Northern Beaches road network to traffic incidents by providing a new alternate underground bypass route of existing congested arterial road corridors

- Improving the amenity of local streets and local town centres by freeing up local streets for local traffic
- Creating opportunities to enhance local communities by improving active transport links and providing new and improved public open space.

28.7.2 Sustainable development

Facilitating ecologically sustainable development is adopted as an object of the *Environmental Planning and Assessment Act 1979*. This object requires the integration of ”relevant economic, environmental and social considerations in decision making about environmental planning and assessment”.

Ecologically sustainable development is defined under the *Protection of the Environment Administration Act 1991* (NSW) and Environmental Planning and Assessment Regulation 2000 and includes four principles. The project is consistent with these principles of ecologically sustainable development:

- **Precautionary principle:** The environmental impact statement was prepared adopting a conservative approach, which includes an assessment of the worst case impacts and scenario and using the best available technical information and has adopted best practice environmental standards, goals and measures. The design and development of the project included consideration of potential environmental impacts associated with the project alternatives and options analysis, and opportunities were identified to avoid and minimise surface disturbance. In addition, sustainability workshops and meetings were held during design development with planning and design teams to develop draft sustainability targets and objectives for the project
- **Intergenerational equity**: The project is designed to meet the needs of both current and future generations with a design life of about 100 years and would contribute to an increase in the resilience and capacity of the Sydney transport network. During construction and operation of the project, opportunities would be taken to reduce resource and material use and maximise the use of materials with low embodied environmental impact, where feasible
- **Conservation of biological diversity and ecological integrity:** The design and assessment of the project has been carried out with the aim of identifying, avoiding, minimising and mitigating impacts to biodiversity and ecological integrity. Consistent with the *Biodiversity Conservation Act 2016* and the Secretary’s environmental assessment requirements, a biodiversity offset strategy has been developed to compensate for the unavoidable loss of ecological values as a result of the project
- **Improved valuation and pricing and incentive mechanisms:** The value placed on avoiding and minimising environmental impacts is demonstrated in the design features incorporated into the project (for example identifying opportunities to improve local amenity, improve public transport access and active transport connections, and create additional green spaces). The costs of planning, design and implementation of avoidance and environmental management measures have been incorporated into the project cost.

28.7.3 Objects of the *Environmental Planning and Assessment Act 1979* (NSW)

A consideration of the project against the objects of the *Environmental Planning and Assessment Act 1979* is outlined in Table 28-5.

Table 28-5 Objects of the *Environmental Planning and Assessment Act 1979* (NSW)

Objects of the *Environmental Planning and Assessment Act 1979*	Project attributes
(a) To promote the social and economic welfare of the community and a better environment by the proper management, development and conservation of the State's natural and other resources,	The project would provide benefits for local businesses and commuters by enabling better and more efficient access between the Northern Beaches region and major 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 including Chatswood, St Leonards and Macquarie Park, as well as the international gateways of Sydney Airport and Port Botany. Increased network capacity and connectivity as a result of the project would result in travel time savings for freight movements, further servicing the growth of Sydney's Eastern Economic Corridor. The combination of freight and business travel time savings would be integral to the economic growth of Sydney's Eastern Economic Corridor, enabling sustained growth and productivity. During construction and operation, the following opportunities would be taken to reduce material use and maximise the use of materials with low embodied environmental impact, where practical: • Water efficiency measures would be implemented where possible, with the reuse of non-potable water from stormwater harvesting and on-site reuse of treated water from groundwater inflows, where water quality and volume requirements are met • The design of the project has included careful consideration of the construction methodology and selection of materials and resources to minimise resource consumption • Consistent with the resource management hierarchy under the *Waste Avoidance and Resource Recovery Act 2001*, solid wastes would be reused and recycled where feasible and reasonable. Where possible, the project has been designed to avoid impacts on the natural environment and to minimise the need for land acquisition, as well as impacts on existing development and local communities.
(b) to facilitate ecologically sustainable development by integrating relevant economic, environmental and social considerations in decision-making about environmental planning and assessment,	The project is consistent with the principles of ecologically sustainable development as outlined in Section 28.7.2.

Objects of the *Environmental Planning and Assessment Act 1979*	Project attributes
(c) to promote the orderly and economic use and development of land,	The project has been designed to: • Provide improved efficiency of the road network, in particular for freight and commercial users, resulting in economic benefits for NSW • Provide an additional underground motorway alternative, enhancing the resilience of the road network, supporting wider network improvements • Minimise impacts to the surrounding natural and built environments where possible, for example by integrating design features such as tunnel portals and motorway facilities and ventilation outlets into the existing road corridors as far as practical • Integrate with, and thereby minimise disruption to, existing development and other projects.
(d) to promote the delivery and maintenance of affordable housing,	Not applicable to this project. The residual land created as a result of the project would largely continue to remain suitable for future development in accordance with the relevant land use zonings and applicable development standards. 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 ventilation outlets.
(e) to protect the environment, including the conservation of threatened and other species of native animals and plants, ecological communities and their habitats,	Construction would result in the clearing of native vegetation, and some areas of planted vegetation would also be removed. Management measures have been proposed to minimise the potential for direct and indirect impacts. Some terrestrial fauna species would be impacted by the project. Management measures including pre-clearing surveys and monitoring to minimise the risk of impacts to native species. Mitigation and rehabilitation works would be carried out to protect and restore subtidal rocky reef and intertidal rocky shore habitat removed along the shoreline. In accordance with the Secretary's environmental assessment requirements and the requirements of the *Biodiversity Conservation Act 2016,* a biodiversity offset strategy has been developed to compensate for the loss of ecological values as a result of the project.
(f) to promote the sustainable management of built and cultural heritage (including Aboriginal cultural heritage),	Impacts on heritage items would be minimised during construction where possible, and works would be carried out in accordance with relevant management strategies where impacts are unavoidable. Possible indirect impacts associated with vibration and settlement from tunnelling works or surface works beneath or near to Aboriginal sites would be managed in accordance with relevant management measures.

Objects of the *Environmental Planning and Assessment Act 1979*	Project attributes
(g) to promote good design and amenity of the built environment,	The project would provide: • New and upgraded active transport infrastructure (pedestrian and cyclist facilities) • Reduction in traffic noise at receivers surrounding the project surface road works, due to the redistribution of traffic. The project is expected to lead to an overall improvement in noise levels within the community (compared with the existing situation). Noise mitigation (such as at-property treatment) would be implemented where required • Improved access and connectivity through improved travel time and improved travel time reliability, including to local and regional infrastructure within and near the project • New and improved open space and recreation facilities at Balgowlah.
(h) to promote the proper construction and maintenance of buildings, including the protection of the health and safety of their occupants,	The construction of the project, including motorway facilities, ventilation outlets and tunnel portals would be completed in line with the applicable Australian and international safety standard as well as any applicable Transport for NSW Safety in Design guidelines.
(i) to promote the sharing of the responsibility for environmental planning and assessment between the different levels of government in the State,	Consultation has been carried out with the relevant local councils and government agencies throughout the development of the project and the preparation of this environmental impact statement. All levels of government have been encouraged to be actively involved in and to contribute to the evolution of the project through consultation to date and continuing consultation activities.
(j) to provide increased opportunity for community participation in environmental planning and assessment.	Consultation has been carried out through all stages of the project development, with targeted community consultation periods carried out in 2017 and 2018, consultation with key community and interest groups, and a business survey carried out in November 2017 across ten local centres potentially affected by the project. Community feedback has been considered at each stage of the project development to inform the selection of the preferred corridor alignment and subsequent design development and refinements. Community consultation would continue through public exhibition of this environmental impact statement and during further design development and construction, should the project be approved, in accordance with the Community consultation framework. 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.

28.7.4 Cumulative impacts

Once operational, the Western Harbour Tunnel and Beaches Link program of works is expected to deliver beneficial cumulative impacts including substantial increases in travel speeds through sections of the surface road network, increased reliability, and a reduction in average travel times.

Adverse cumulative impacts could occur when impacts from the project interact or overlap with impacts from other projects and potentially result in a larger overall impact. Cumulative impacts may also occur when there are projects that are constructed consecutively, resulting in construction fatigue for local receivers. Cumulative impacts for the project are presented in Chapter 27 (Cumulative impacts).

The implementation of environmental management measures for the project would avoid, to the greatest extent possible, cumulative impacts with surrounding development. In particular, the design of the project has carefully considered minimising construction fatigue as far as practical. The intent is to reduce the overall cumulative or consecutive impacts on the community over a longer period.

28.7.5 Conclusion

This environmental impact statement addresses the key issues identified in the Secretary's environmental assessment requirements issued under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* and the relevant provisions of Schedule 2 of the Environmental Planning and Assessment Regulation 2000.

The project is part of the NSW Government's commitment to investing in and delivering efficient and effective transport systems including road infrastructure that would relieve congestion, improve travel times, improve road safety and enhance and expand capacity on key road corridors. In particular, the project would provide additional capacity across Middle Harbour, relieving congestion on existing key routes and providing connections including via planned new express bus services within the tunnels to other key existing and future proposed transport projects.

The merits of the project were considered in the context of a range of other alternatives including do-nothing, based on the extent to which they could meet the project objectives and how well they performed with reference to other transport, environmental, engineering, social and economic factors. No other alternative would satisfy the need and objectives as effectively as the project.

As for any major infrastructure project to be constructed through the middle of a major urban area, there are expected to be impacts. Designing and constructing the project mainly underground has considerably reduced impacts and largely confined these to the construction stage. The design and construction method would continue to be developed with the objective of further minimising potential impacts taking into account the input of stakeholders and the local community.

Notwithstanding there would be a range of residual impacts. With the implementation of the proposed environmental management measures, the potential residual environmental impacts of the project are considered manageable and the project would be in the public interest.

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 29

References

29 References

ACTAQ (Advisory Committee on Tunnel Air Quality) (2016), *In-tunnel air quality (nitrogen dioxide) policy,* Advisory Committee on Tunnel Air Quality, NSW Government, Sydney.

ACTAQ (Advisory Committee on Tunnel Air Quality) (2018a), *Technical Paper TP07: Criteria for In-tunnel and Ambient Air Quality,* Advisory Committee on Tunnel Air Quality, NSW Government, Sydney.

ACTAQ (Advisory Committee on Tunnel Air Quality) (2018b), *Technical Paper TP06: Options for Treating Road Tunnel Emissions*, Advisory Committee on Tunnel Air Quality, NSW Government, Sydney.

ACTAQ (Advisory Committee on Tunnel Air Quality) (2018c), *Technical Paper TP09: Evolution of Road Tunnels in Sydney*, Advisory Committee on Tunnel Air Quality, NSW Government, Sydney.

ACTAQ (Advisory Committee on Tunnel Air Quality) (2019), *Technical Paper TP04: Road Tunnel Ventilation Systems*, Advisory Committee on Tunnel Air Quality, NSW Government, Sydney.

AECOM (2015), *New M5 environmental impact statement – Technical working paper: Groundwater Appendix Q*, Prepared for the Roads and Maritime Services, Sydney.

AECOM (2017), *M4-M5 environmental impact statement – Technical working paper: Groundwater Appendix T*, Prepared for the Roads and Maritime Services, Sydney.

Ahern, CR, Stone, Y & Blunden, B (1998), *Acid Sulfate Soils Assessment Guidelines*, Acid Sulfate Soil Management Advisory Committee, Wollongbar, NSW.

AMOG (2012), *M5 East Tunnel Filtration Trial Evaluation Program – Review of Operational Performance*, AMOG, Notting Hill, Victoria.

ANZEC (Australian and New Zealand Environment Council) (1990), *Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration.*

ANZECC (Australian and New Zealand Environment and Conservation Council) (1999), *Guidelines for the Assessment of On-site Containment of Contaminated Soil.*

ANZECC/ARMCANZ (Australian and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand) (2000), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand, Australia.

ANZG (2018), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Retrieved 27 November 2020 from https://waterquality.gov.au/anz-guidelines.

Arup & WSP (2020), *Western Harbour Tunnel and Beaches Link: Tunnels – Settlement assessment. Document No WHTBL-BL20-TU-MEM-0066. Revision 1.0*. Prepared for Roads and Maritime Services, Sydney.

ASSMAC (Acid Sulfate Soils Management Advisory Committee) (1998), *Acid Sulfate Soil Manual*, Acid Sulfate Soils Management Advisory Committee, Wollongbar, NSW.

Attenbrow, V (2010), *Sydney's Aboriginal past: Investigating the archaeological and historical records*, University of New South Wales Press Ltd, Sydney, NSW.

Australia ICOMOS (International Council on Monuments and Sites) (2013), *The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance*, Australia International Council on Monuments and Sites, Burwood, Victoria.

Australian and New Zealand Standard (2009), *AS/NZ ISO 31000:2009 Risk management – Principles and guidelines*.

Australian Geomechanics Society (2007), *Landslide risk management guidelines*. Retrieved 27 November 2020 from https://landsliderisk.org/resources/guidelines/.

Australian Government (2006), *Climate Change Impacts and Risk Management – A Guide for Business and Government,* Australian Greenhouse Office, in the Department of the Environment and Heritage, Canberra, ACT.

Australian Government (2014), *Direct Action Plan.*

Australian Green Infrastructure Council (2011), *Guideline for Climate Change Adaptation, Revision 2.1*, Australian Green Infrastructure Council.

Australian Institute for Disaster Resilience (2017), *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia,* Commonwealth of Australia, Canberra, ACT.

Australian Institute for Maritime Archaeology Inc. and the Australian Cultural Development Office (1994), *Guidelines for the Management of Australia's Shipwrecks*, Australian Institute for Maritime Archaeology Inc. and the Australian Cultural Development Office, Canberra, ACT.

Ball, J, Babister, M, Nathan, R, Weeks, W, Weinmann, E, Retallick, M & Testoni, I (2019), *Australian Rainfall and Runoff: A guide to flood estimation,* Commonwealth of Australia, Canberra, ACT.

Birch, G & O'Hea, L (2007), 'The chemistry of suspended particulate material in a highly contaminated embayment of Port Jackson (Australia) under quiescent, high-wind and heavy-rainfall conditions*', Environmental Geology*, vol. 53*,* pp. 501–516*.*

Birch, G & Rochford, L (2010), 'Stormwater metal loading to a well mixed / stratified estuary (Sydney Estuary, Australia) and management implications', *Environmental Monitoring and Assessment*, vol. 169, no. 1–4, pp. 531–551.

BMT WBM (2018), *Greater Sydney Harbour Estuary Coastal Management Program Scoping Study*, Greater Sydney Local Land Services, Office of Environment and Heritage and City of Sydney Council.

BOM (Bureau of Meteorology) (2018), *Groundwater Dependent Ecosystems Atlas*. Retrieved 16 November 2020 from: http://www.bom.gov.au/water/groundwater/gde/map.shtml.

Boscardin, MD & Cording, EG (1989), 'Building response to excavation-induced settlement', *Journal of Geological Engineering*.

British Standards Institution (1993), *BS 7385-2:1993 Evaluation and Measurement for Vibration in Buildings – Guide to Damage Levels from Ground Borne Vibration*.

Bureau of transport statistics (2016), *Employment Data 2016*.

Burland, JB, Broms, B & De Mello, VFB (1977), Behaviours of foundations and structures – SOA Report, *Proceedings of Ninth International Conference on Soil Mechanics and Foundation Engineering (SMFE)*, Tokyo, Japan.

Cardno (2010). *Manly Lagoon Dredging Project – Review of Environmental Factors*. Prepared for Manly and Warringah Councils.

Cardno Lawson Treloar (2008), *Parramatta River Estuary Data Compilation and Review Study*. Prepared for Parramatta City Council, Department of Environment and Climate Change & Sydney Metropolitan Catchment Management Authority.

CETU (Centre d'Etudes des Tunnels) (2016), *The treatment of air in road tunnels: state-of-the-art studies and works*, Centre d'Etudes des Tunnels, Bron, France. Retrieved 16 November 2020 from http://www.cetu.developpement-durable.gouv.fr/IMG/pdf/cetu_di_traitement_de_l_air-en-19_07_2017.pdf.

Chapman, GA & Murphy, CL (1989), *Soil landscapes of the Sydney 1:100,000 sheet 9130*. Soil Conservation Services of NSW, Sydney.

City of Sydney (2016a), *Community Profile - Crows Nest - St Leonards*. Retrieved 16 November 2020 from http://profile.id.com.au/north-sydney/about?WebID=130.

City of Sydney (2016b), *Community Profile - Seaforth*. Retrieved 16 November 2020 from http://profile.id.com.au/northern-beaches/about?WebID=450.

City of Sydney, (2016c), *North Balgowlah*. Retrieved 25 16 October November 2020 from https://dictionaryofsydney.org/place/north_balgowlah.

City of Sydney, (2016d), *Community Profile - Balgowlah*. Retrieved 25 16 October November 2020 from http://profile.id.com.au/northern-beaches/about?WebID=120.

City of Sydney, (2016e), *Community Profile - North Balgowlah*. Retrieved 25 16 October November 2020 from http://profile.id.com.au/northern-beaches/about?WebID=400.

City of Sydney, (2016f), *Community Profile - Frenchs Forest*. Retrieved 26 16 October November 2020 from http://profile.id.com.au/northern-beaches/about?WebID=290.

City of Sydney (2016g), *Frenchs Forest*. Retrieved 16 November 2020 from https://dictionaryofsydney.org/place/frenchs_forest.

City of Sydney, (2016h), *Community Profile - Warringah Council area*. Retrieved 25 16 October November 2020 from http://profile.id.com.au/northern-beaches/about?WebID=520.

City of Sydney, (2016i), *Community Profile - Allambie Heights*. Retrieved 25 16 October November 2020 from http://profile.id.com.au/northern-beaches/about?WebID=100.

City of Sydney (2017), *Australia For Everyone - Frenchs Forest*. Retrieved 16 November 2020 from http://www.visitsydneyaustralia.com.au/frenchs-forest.html.

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

Cumberland County Council (1948), *County of Cumberland: Planning Scheme.*

de Vries, S, Verheij, RA, Groenewegen, PP & Spreeuwenberg, P (2003), 'Natural Environments—Healthy Environments? An Exploratory Analysis of the Relationship between Greenspace and Health', *Environment and Planning A: Economy and Space*, vol. 35, no. 10, pp. 1717-31.

DEC (Department of Environment and Conservation) (2006a), *Technical framework for the assessment and management of odour from stationary sources in NSW*, Department of Environment and Conservation NSW, Sydney.

DEC (Department of Environment and Conservation) (2006b), *Garigal National Park Fire Management Strategy*, Department of Environment and Conservation, Parks and Wildlife Division, Sydney North Region.

DEC (Department of Environment and Conservation) (2007), *Approved Methods for the sampling and analysis of air pollutants in New South Wales*. Department of Environment and Conservation NSW, Sydney.

DECC (Department of Environment and Climate Change) (2006), *Assessing Vibration: a technical guideline,* Department of Environment and Climate Change, Sydney.

DECC (Department of Environment and Climate Change) (2007), *Flood risk management guideline: Practical Consideration of Climate Change,* State of New South Wales through the Department of Environment and Climate Change, NSW.

DECC (Department of Environment and Climate Change) (2008), *Managing Urban Stormwater: Soils and Construction Volume 2 (A. Installation of Services; B. Waste Landfills; C. Unsealed Roads; D. Main Roads; E. Mines and Quarries),* Department of Environment and Climate Change, Sydney.

DECC (Department of Environment and Climate Change) (2009a), *Interim Construction Noise Guideline,* Department of Environment and Climate Change, Sydney.

DECC (Department of Environment and Climate Change) (2009b), *NSW Threatened Species Survey and Assessment Guidelines: Field survey methods for fauna (Amphibians),* Department of Environment and Climate Change, Sydney.

DECCW (Department of Environment, Climate Change and Water) (2006a), *NSW Water Quality and River Flow Objectives. – Sydney Harbour and Parramatta River,* Department of Environment, Climate Change and Water, Sydney.

DECCW (Department of Environment, Climate Change and Water) (2006b), *NSW Water Quality and River Flow Objectives – Gosford and Northern Beaches Lagoons,* Department of Environment, Climate Change and Water, Sydney.

DECCW (Department of Environment, Climate Change and Water) (2010a), *Current air quality in New South Wales: A technical paper supporting the Clean Air Forum 2010*, Department of Environment, Climate Change and Water, Sydney.

DECCW (Department of Environment, Climate Change and Water) (2010b), *Aboriginal Cultural Heritage Consultation Requirements for Proponents,* Department of Environment, Climate Change and Water, Sydney.

DECCW (Department of Environment, Climate Change and Water) (2010c), *Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW,* Department of Environment, Climate Change and Water, Sydney.

DECCW (Department of Environment, Climate Change and Water) (2010d), *Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales,* Department of Environment, Climate Change and Water, Sydney.

DECCW (Department of Environment, Climate Change and Water) (2011), *NSW Road Noise Policy,* Department of Environment, Climate Change and Water, Sydney.

Department of Environment, Water, Heritage and the Arts (2009), *National Assessment Guidelines for Dredging,* Commonwealth of Australia, Canberra, ACT.

Department of Planning (2007), *Guideline on development controls on low risk flood areas*. Issued as part of Planning Circular PS 07-003, NSW Government Department of Planning and Department of Natural Resources.

Department of Planning (2011), *Hazardous and Offensive Development Application Guidelines: Applying SEPP 33*, State of New South Wales through the Department of Planning, Sydney.

Department of the Environment (2013), *Matters of National Environmental Significance Significant Impact Guidelines 1.1*, Commonwealth of Australia, Australia.

Department of the Environment and Energy (2015), *National Climate Resilience and Adaptation Strategy,* Commonwealth of Australia, Australia.

Department of Urban Affairs and Planning and Environment Protection Authority (1998), *Managing Land Contamination: Planning Guidelines SEPP 55 – Remediation of Land*.

DIPNR (Department of Infrastructure Planning and Natural Resources) (2002), *Map of salinity potential in Western Sydney 2002,* Department of Infrastructure, Planning and Natural Resources, Sydney.

DLWC (Department of Land and Water Conservation) (2000), *Soil and Landscape Issues in Environmental Impact Assessment*, Technical Report No. 34, 2nd edition, NSW Department of Land and Water Conservation, Sydney.

DLWC (Department of Land and Water Conservation) (2002), *Site Investigations for Urban Salinity*, Department of Land and Water Conservation, Sydney.

Douglas Partners and Golder Associates (2017), *Western Harbour Tunnel and Beaches Link Geotechnical Investigation, Contamination Factual Report – Marine Investigations*. Prepared for Roads and Maritime Services, Sydney.

DPIE (Department of Planning, Industry and Environment) (2019), *Biodiversity Assessment Method Operational Manual - Stage 2*, Department of Planning, Industry and Environment, Environment, Energy and Science, Sydney.

DPIE (EES) (Department of Planning, Industry and Environment) (Environment, Energy and Science) (2020a), *Threatened Biodiversity Data Collection.* Available from (with registered login): https://www.environment.nsw.gov.au/AtlasApp/UI_Modules/TSM_/Default.aspx?a=1.

DPIE (EES) (Department of Planning, Industry and Environment (Environment, Energy and Science)) (2020b), Vegetation Information System Classification database. Available from: www.environment.nsw.gov.au/NSWVCA20PRapp/LoginPR.aspx.

Eco Logical Australia (2006), *Manly Warringah War Memorial Park Fire Regime Management Plan*.

enHealth (2001), *Health Impact Assessment Guidelines*, Commonwealth Department of Health and Aged Care.

enHealth (2012), *Environmental Health Risk Assessment*: *Guidelines for assessing human health risks from environmental hazards*, Commonwealth of Australia, Canberra. Retrieved 16 November 2020 from https://www1.health.gov.au/internet/main/publishing.nsf/Content/A12B57E41EC9F326CA257BF0001F9E7D/$File/Environmental-health-Risk-Assessment.pdf.

enRiskS (2017), *Review of In-Cabin Carbon Dioxide Levels*, Prepared for Roads and Maritime Services.

ENVIRON (2011), *Tiered Procedure for Estimating Ground-Level Ozone Impacts from Stationary Sources*, ENVIRON Australia Pty Ltd.

Fallowfield (2008), *Artarmon*. Retrieved 16 November 2020 from https://dictionaryofsydney.org/entry/artarmon.

Forest Coach Lines (2019), *Forest Coach Lines Sydney Region Network Map*. Retrieved 16 November 2020 from https://forestcoachlines.com.au/network-map/.

FTA (Federal Transit Administration) (2018), *United States Department of Transportation Federal Transit Administration Noise and Vibration manual*, U.S. Department of Transportation, Washington DC.

Geotechnical Assessments (2015), *Sediment Quality Assessment: Sydney Metro Harbour Tunne*l. Prepared for Roads and Maritime Services, Sydney.

German Institute for Standardisation (1999), *DIN 4150–3:1999 Vibration in Buildings – Part 3: Effects on Structures*.

GHD (2015), *M4 East environmental impact statement – Technical working paper: Groundwater Appendix R,* Prepared for Roads and Maritime Services, Sydney.

Godden Mackay (1991), *Sydney and Middle Harbours Heritage Study*, Prepared for NSW Department of Planning.

Godden Mackay (1994), *Tramway Workshops, Depots and Substations*, Report prepared for the National Trust.

Greater Sydney Commission (2016), *Towards our Greater Sydney 2056*, State of New South Wales through the Greater Sydney Commission, Parramatta.

Greater Sydney Commission (2017), *Directions for a Greater Sydney 2017-2056*, Greater Sydney Commission, Sydney.

Greater Sydney Commission (2018a), *Greater Sydney Region Plan – A Metropolis of Three Cities*, State of New South Wales through the Greater Sydney Commission.

Greater Sydney Commission (2018b), *North District Plan – Connecting Communities,* State of New South Wales through the Greater Sydney Commission.

Greater Sydney Commission (2018c), *Eastern City District Plan - Connecting Communities,* State of New South Wales through the Greater Sydney Commission.

Greater Sydney Local Land Services (2015), *Sydney Harbour Water Quality Improvement Plan*, Local Land Services.

Hansson, E, Mattisson, K, Björk, J, Östergren, PO & Jakobsson, K (2011), 'Relationship between commuting and health outcomes in a cross-sectional population survey in southern Sweden', *BMC Public Health*, vol. 11, no. 1, pp. 834.

Harris, P, Harris-Roxas, B, Harris, E & Kemp, L (2007), *Health Impact Assessment: A Practical Guide*, Centre for Health Equity Training, Research and Evaluation (CHETRE). Part of the UNSW Research Centre for Primary Health Care and Equity, University of New South Wales, Sydney.

Harrison, D (2012), *Water Quality Sampling of Parramatta River, Methods and Sampling Protocol*.

Hatje, V, Apte, SC, Hales, LT & Birch, G (2003), 'Dissolved trace metal distributions in Port Jackson estuary (Sydney Harbour), Australia', *Marine Pollution Bulletin*, vol. 46, pp. 719-730.

Hatje, V, Rae, K & Birch, G (2001), 'Trace metal and total suspended solids concentrations in freshwater: The importance of small-scale temporal variation', *Journal of environmental monitoring*, vol. 3, pp. 251-256.

Health Scotland, greenspace scotland, Scottish Natural Heritage and Institute of Occupational Medicine (2008), *Health Impact Assessment of greenspace, A Guide*, greenspace scotland, Stirling, United Kingdom.

Hedge, LH, Johnston, EL, Ayong, ST, Birch, GF, Booth, DJ, Creese, RG, Doblin, MA, Figueira, WF, Gribben, PE, Hutchings, PA, Mayer Pinto, M, Marzinelli, EM, Pritchard, TR, Roughan, M & Steinberg, PD (2013), *Sydney Harbour: A systematic review of the science*, Sydney Institute of Marine Science, Sydney, Australia.

HEPA (Heads of EPAs Australia and New Zealand) (2020), *PFAS National Environmental Management Plan Version 2.0 – January 2000*, National Chemicals Working Group of the Heads of EPAs Australia and New Zealand.

Herbert, C (1983), *Sydney 1:100 000 Geological Sheet 9130, 1st edition,* Geological Survey of New South Wales, Sydney.

IAQM (Institute of Air Quality Management) (2014), *Guidance on the assessment of dust from demolition and construction,* Institute of Air Quality Management. Retrieved 16 November 2020 from http://iaqm.co.uk/text/guidance/construction-dust-2014.pdf.

Infrastructure Australia (2015), *Australian Infrastructure Audit Report. Our Infrastructure Challenges. Report – Volume 1*, Infrastructure Australia, Sydney.

Infrastructure Australia (2016), *Australian Infrastructure Plan: Priorities and Reforms for Our Nation's Future*, Infrastructure Australia.

Infrastructure Australia (2018), *Australian Infrastructure Plan: The Infrastructure Priority List – Project and Initiative Summaries*, Infrastructure Australia.

Infrastructure Australia (2019), *The Australian Infrastructure Audit 2019*. Urban Transport Crowding and Congestion, June 2019.

Infrastructure NSW (2014), *State Infrastructure Strategy Update 2014*.

Infrastructure NSW (2017), *The NSW Infrastructure Pipeline,* NSW Government.

Infrastructure NSW (2018), *Building momentum: The State Infrastructure Strategy 2018-2038*.

Infrastructure Sustainability Council of Australia (2016a), *Infrastructure Sustainability Rating Tool*, *Version 1.2.*

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

Infrastructure Sustainability Council of Australia (2016c), *Infrastructure Sustainability*. Retrieved 16 November 2020 from https://www.isca.org.au/infrastructure_sustainability.

Institution of Engineers Australia (1987), *Australian Rainfall and Runoff: A Guide to Flood Estimation, Vol. 1* (Rev. ed.), Editor-in-chief Pilgrim, DH, Institution of Engineers, Barton, ACT.

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

Jacobs (2016), *Sydney Metro Chatswood to Sydenham environmental impact statement – Technical Paper 7: Groundwater Assessment* . Prepared for Transport for NSW, Sydney.

Jacobs (2020), *Western Harbour Tunnel and Warringah Freeway Upgrade Project environmental impact statement – Technical Working Paper: Stage 1 Contamination Investigation Appendix M,* Prepared for Transport for NSW, Sydney.

Jasco (2019), *Beaches Link and Gore Hill Freeway Connection Technical working paper: Underwater acoustic modelling report,* Prepared for Roads and Maritime Services.

Jobling, IF (1996), 'Eve, Sydney James Wallace (Jim) (1899–1978)', *Australian Dictionary of Biography*, Australian National University, Canberra.

Kendal, D, Lee, K, Ramalho, C, Bower, K & Bush, J (2016), *Benefits of Urban Green Space in the Australian Context, A synthesis review for the Clean Air and Urban Landscapes Hub*, National Environmental Science Programme, Clean Air and Urban Landscape NESP hub.

LandArc Pty Limited (2002), *Willoughby Natural Heritage Register - Appendix VI: Historic Context*, Willoughby City Council, Avalon.

Landcom (2004), *Managing Urban Stormwater: Soils and construction – Volume 1*, New South Wales Government.

Laxton, JH (1997), *Water Quality of the Upper Parramatta River. Analysis of data collected between 1990 and 1996*. Prepared for Shell Refining (Australia) Pty Ltd.

Lend Lease (2017), Barangaroo Resource Centre water quality reports 2012 to 2017. Retrieved 26 November 2020 from https://resource.barangaroo.com/hc/en-us/categories/115001198747-Publications#air-and-water-quality-reports.

Lyall and Associates (2017), *Flat Rock Creek Catchment Flood Study and Overland Flow Mapping Volume 1. Draft Report for Public Exhibition.* Prepared for Willoughby City Council.

Maas, J, Verheij, RA, Groenewegen, PP, de Vries, S & Spreeuwenberg, P (2006), 'Green space, urbanity, and health: how strong is the relation?', *J Epidemiol Community Health*, vol. 60.

MacRitchie (2008), *Balgowlah*. Retrieved 16 November 2020 from https://dictionaryofsydney.org/entry/balgowlah.

Manly Council (2008), *Draft Clontarf/Bantry Bay Estuary Management Plan*.

Manly Library, n.d., *Balgowlah Golf Club*. Manly: Manly Library.

ManlyAustralia.com (2017), *Manly and Northern Beaches - Manly History*. Retrieved 16 November 2020 from https://www.manlyaustralia.com.au/info/history/.

Mitchell, R & Popham, F (2007), 'Greenspace, urbanity and health: relationships in England', *Journal of Epidemiology and Community Health*, vol. 61, no. 8, pp. 681-83.

Morris, A (1986), *An Archaeological Survey of North Port Jackson*, Prepared for NSW National Parks and Wildlife Service.

Mosman Council (2013), *Mosman Council Community Strategic Plan 2013-2023*.

Mosman Council (2020), *Mosman Local Strategic Planning Statement.*

Mosman North Sydney Willoughby Bush Fire Management Committee (2008), *Mosman North Sydney Willoughby Bush Fire Risk Management Plan 2017-2022* (Policy No. 1/2008).

National Transport Commission (2007), *Australian Code for the Transport of Dangerous Goods by Road and Rail, 7th edition.*

NEPC (National Environment Protection Council) (1999 amended 2013), *National Environment Protection (Assessment of Site Contamination) Measure Schedule B8 Guideline on Community Engagement and Risk Communication*.

NEPC (National Environment Protection Council) (2003a), *National Environment Protection (Air Toxics) Measure*, *Impact Statement for the National Environment Protection (Air Toxics) Measure*.

NEPC (National Environment Protection Council) (2003b), *National Environment Protection (Ambient Air Quality) Measure*.

NEPC (National Environment Protection Council) (2010*), Review of the National Environment Protection (Ambient Air Quality) Measure*, Discussion Paper, Air Quality Standards.

NEPC (National Environment Protection Council) (2016), *National Environment Protection (Ambient Air Quality) Measure*, Federal Register of Legislative Instruments F2016C00215.

NFPA (National Fire Protection Association) (2020), *NFPA 502 - Standard for Road Tunnels, Bridges, and Other Limited Access Highways.*

NHMRC (National Health and Medical Research Council) (2008a), *Air Quality in and Around Traffic Tunnels*, National Health and Medical Research Council, Australia.

NHMRC (National Health and Medical Research Council) (2008b), *Guidelines for Managing Risks in Recreational Waters*, Australian Government, Australia*.*

North Sydney Council (2012a), *Draft North Sydney Development Control Plan 2012 - Section 3: St Leonards / Crows Nest Planning Area*. North Sydney Council, Sydney.

North Sydney Council (2012b), *Draft North Sydney Development Control Plan 2012 - Section 4: Cammeray Planning Area*. North Sydney Council, Sydney.

North Sydney Council (2013), *North Sydney Community Strategic Plan 2013-2023*.

North Sydney Council (2016), *Cammeray Park*. Retrieved 16 November 2020 from https://www.northsydney.nsw.gov.au/Recreation_Facilities/Sports_Sportsgrounds/Sportsgrounds/Cammeray_Park.

North Sydney Council (2020a), *Local Strategic Planning Statement.*

North Sydney Council (2020b), *Military Road Corridor Planning Study.*

North Sydney Council, n.d.-a, *Estates*. Retrieved 16 November 2020 from http://www.athomeinnorthsydney.com.au/estates.html.

North Sydney Council, n.d.-b, *North Sydney Heritage Leaflet 22: Greencliffe*. North Sydney Heritage Centre, North Sydney.

Northern Beaches Council (2017a), *Northern Beaches Sportsground Strategy*.

Northern Beaches Council (2017b), *Northern Beaches Hospital Precinct Structure Plan.*

Northern Beaches Council (2017c), *Northern Beaches Sportsgrounds and Golf Courses Discussion Paper.*

Northern Beaches Council (2018a), *Move: Northern Beaches Transport Strategy 2038*.

Northern Beaches Council (2018b), *Shape 2028 Northern Beaches Draft Community Strategic Plan 2017*-2028.

Northern Beaches Council (2020), *Towards 2040 – Local Strategic Planning Statement*.

NSW Department of Industry (2018), *Guidelines for controlled activities on waterfront land - Riparian corridors*, Natural Resources Access Regulator.

NSW DPI (Department of Primary Industries) (2013), *Policy and guidelines for fish habitat conservation and management*, NSW Department of Primary Industries, a part of the Department of Trade and Investment, Regional Infrastructure and Services.

NSW DPI (Department of Primary Industries) (Office of Water) (2011a), *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources*.

NSW DPI (Department of Primary Industries) (Office of Water) (2011b), *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources*.

NSW DPI (Department of Primary Industries) (Office of Water) (2012a), *NSW Aquifer Interference Policy: NSW Government policy for the licensing and assessment of aquifer interference activities,* NSW Department of Primary Industries, a division of NSW Department of Trade and Investment, Regional Infrastructure and Services.

NSW DPI (Department of Primary Industries) (Office of Water) (2012b), *Risk assessment guidelines for groundwater dependent ecosystems*, NSW Department of Primary Industries, Office of Water, Sydney.

NSW DPIE (Department of Planning, Industry and Environment) (2020), *Threatened Biodiversity Data Collection*. Retrieved 16 November 2020 from (with registered login) https://www.environment.nsw.gov.au/AtlasApp/UI_Modules/TSM_/Default.aspx?a=1.

NSW EPA (Environment Protection Authority) (1997), *Draft Managing Urban Stormwater: Council Handbook,* Environment Protection Authority, Sydney.

NSW EPA (Environment Protection Authority) (2012), *Guideline for the Assessment and Management of Sites Impacted by Hazardous Ground Gases*, NSW Environment Protection Authority, Parramatta.

NSW EPA (Environment Protection Authority) (2013a), M*ethodology for Valuing the Health Impacts of Changes in Particle Emissions,* Prepared by PAE Holmes on behalf of NSW Environment Protection Authority.

NSW EPA (Environment Protection Authority) (2013b), *Noise guide for local government,* Environment Protection Authority, Sydney South.

NSW EPA (Environment Protection Authority) (2014a), *NSW Waste Avoidance and Resource Recovery Strategy 2014–21*, Environment Protection Authority, Sydney.

NSW EPA (Environment Protection Authority) (2014a), *Waste Classification Guidelines,* NSW Environment Protection Authority, Sydney South.

NSW EPA (Environment Protection Authority) (2014b), *NSW Waste Avoidance and Resource Recovery Strategy 2014–21*, Environment Protection Authority, Sydney.

NSW EPA (Environment Protection Authority) (2015a), *Guidelines on the duty to report contamination under the Contaminated Land Management Act 1997*, NSW Environment Protection Authority, Sydney South.

NSW EPA Environment Protection Authority) (2015b), *Cultural Heritage Guidelines*.

NSW EPA (Environment Protection Authority) (2016), A*pproved Methods for the Modelling and Assessment of Air Pollutants in NSW*, Environment Protection Authority, Sydney.

NSW EPA (Environment Protection Authority) (2017a), *Noise Policy for Industry*, Environment Protection Authority, Sydney.

NSW EPA (Environment Protection Authority) (2017b), *Contaminated Land Management: Guidelines for the NSW Site Auditor Scheme*, Third Edition.

NSW EPA (Environment Protection Authority) (2019), *Sources of air pollution in NSW: Air Emissions Inventory for the Greater Metropolitan Region in NSW - 2013*, Environment Protection Authority, Sydney.

NSW EPA (Environment Protection Authority) (2020), *NSW EPA Contaminated Sites Record of Notices*. Retrieved 16 March 2020 from https://apps.epa.nsw.gov.au/prclmapp/searchregister.aspx.

NSW Government Architect (2017), *Better Placed*, NSW Government Architect, Sydney.

NSW Government (1983), *Commission of Inquiry into the Warringah Transport Corridor*.

NSW Government (2005), *NSW Floodplain Development Manual 2005*, Department of Infrastructure, Planning and Natural Resources, Sydney.

NSW Government (2014), *A Plan for Growing Sydney.*

NSW Government (2015), *State and Premier priorities.*

NSW Government (2017), *Western Harbour Tunnel and Beaches Link. Project Definition and Delivery Report.*

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

NSW Health (2003), *M5 East Tunnels Air Quality Monitoring Project*, South Eastern Sydney Public Health Unit & NSW Department of Health.

NSW Health (2009), *Healthy Urban Development Checklist, A guide for health services when commenting on development policies, plans and proposals*, NSW Department of Health, North Sydney.

NSW Health (2016), *Building Better Health, Health considerations for urban development and renewal in the Sydney Local Health District*, NSW Health, Sydney Local Health District.

NSW Health (2018), *Technical Paper: TP03: Health Effects of Traffic-related Air Pollution*, Advisory Committee on Tunnel Air Quality.

NSW Heritage Council (2005), *Heritage Interpretation Policy*, Heritage Office, Department of Planning, Parramatta.

NSW Heritage Council (2011), *Criteria for the Assessment of Excavation Directors.*

NSW Heritage Office (2001), *Assessing Heritage Significance*.

NSW Heritage Office (2002), *Statements of Heritage Impact*.

NSW Heritage Office (2004), *Investigating Heritage Significance (draft guideline).*

NSW Heritage Office (2005), *Interpreting Heritage Places and Items: Guidelines,* NSW Heritage Office, Parramatta.

NSW Heritage Office and Department of Urban Affairs and Planning (1996), *NSW Heritage Manual.*

NSW National Parks and Wildlife Service (2017), *Seaforth Oval to Natural Bridge track: Garigal National Park*. Retrieved 16 November 2020 from https://www.nationalparks.nsw.gov.au/things-to-do/walking-tracks/seaforth-oval-to-natural-bridge-track.

OEH (Office of Environment and Heritage) (2011a), *Guide to Investigating, Assessing and Reporting on Aboriginal Cultural Heritage in NSW*, Office of Environment and Heritage, Sydney South.

OEH (Office of Environment and Heritage) (2011b), *Guidelines for Consultants Reporting on Contaminated Sites*, Office of Environment and Heritage, Sydney.

OEH (Office of Environment and Heritage) (2014a). *Framework for Biodiversity Assessment – NSW Biodiversity Offsets Policy for Major Projects*, Office of Environment and Heritage, Sydney.

OEH (Office of Environment and Heritage) (2016a), *NSW Climate Change Policy Framework,* Office of Environment and Heritage, Sydney.

OEH (Office of Environment and Heritage) (2016b*), The Native Vegetation of the Sydney Metropolitan Area, Version 3.0.*

OEH (Office of Environment and Heritage) (2017), *Biodiversity Assessment Method*, Office of Environment and Heritage, Sydney.OEH (Office of Environment and Heritage) (2019), *NSW Government Resource Efficiency Policy,* Office of Environment and Heritage, Sydney.

Ostro, B (2004), *Outdoor Air Pollution: Assessing the environmental burden of disease at national and local levels*, World Health Organisation, Geneva.

PEL (Pacific Environment Limited) (2016), *Road tunnels: reductions in nitrogen dioxide concentrations in-cabin using vehicle ventilation systems*. Prepared for Roads and Maritime Services.

PIARC (Permanent International Association of Road Congress) (2008), *Road tunnels: a guide to optimising the air quality impact upon the environment, PIARC Report 2008R04,* World Road Association, Paris.

Roads and Maritime Services (2011a), *Procedure for Aboriginal Cultural Heritage Consultation and Investigation*, Roads and Maritime Services, North Sydney*.*

Roads and Maritime Services (2011b), *Technical Guideline: Temporary Stormwater Drainage for Road Construction*, Roads and Maritime Services*.*

Roads and Maritime Services (2011c), *Wildlife Connectivity Guidelines: Managing wildlife connectivity of road projects (Draft).*

Roads and Maritime Services (2012), *Tools for Roadside Air Quality (TRAQ)*.

Roads and Maritime Services (2013a), *Guideline for the Management of Contamination*, September 2013.

Roads and Maritime Services (2013b), *Environmental Impact Assessment Practice Note – Social and economic assessment (EIA-N05).*

Roads and Maritime Services (2014a), *Northern Beaches Hospital Road Connectivity and Network Enhancement Project environmental impact statement*, October 2014. Prepared by SMEC Australia for Roads and Maritime Services*.*

Roads and Maritime Services (2014b), *Roads and Maritime Services land acquisition information guide*.

Roads and Maritime Services (2015a), *Cultural Heritage Guidelines*, Environment Branch, Roads and Maritime Services, North Sydney.

Roads and Maritime Services (2015b), *Fact sheet: Property acquisition of subsurface lands*.

Roads and Maritime Services (2015c), *Northern Beaches Hospital Road Connectivity and Network Enhancement Project - Stage 2 environmental impact statement*, July 2015. Prepared by SMEC Australia for Roads and Maritime Services.

Roads and Maritime Services (2015d), *Standard Management Procedure: Unexpected Heritage Items*, Road and Maritime Services, North Sydney*.*

Roads and Maritime Services (2015e), *Technical Guide for Climate Change Adaptation for the State Road Network.*

Roads and Maritime Services (2015f), *Noise Criteria Guideline*, Road and Maritime Services, North Sydney*.*

Roads and Maritime Services (2015g), *Noise Mitigation Guideline*, Road and Maritime Services, North Sydney*.*

Roads and Maritime Services (2016a), *Construction Noise and Vibration Guideline*, Roads and Maritime Services, North Sydney*.*

Roads and Maritime Services (2016b), *Noise Wall Design Guideline*, Roads and Maritime Services, North Sydney

Roads and Maritime Services (2016c), *Technical Guide: Management of Road Construction and Maintenance Wastes,* Roads and Maritime, North Sydney.

Roads and Maritime Services (2017a), *WestConnex M4-M5 Link environmental impact statement,* August 2017. Prepared by AECOM for Roads and Maritime Services.

Roads and Maritime Services (2017b), *Traffic survey data 2017*.

Roads and Maritime Services (2017c), *Beaches Link and Gore Hill Freeway Connection Scoping Report*.

Roads and Maritime Services (2017d), *Water sensitive urban design guideline: Applying water sensitive urban design principles to NSW transport projects*.

Roads and Maritime Services (2019), *Environmental Sustainability Strategy 2019-2023*.

Robinson GRC Consulting (1999), *Mid Parramatta (North) River Stormwater Management Plan*. Prepared for City of Ryde and Parramatta City Council, July 1999: pp. 97.

Rochford, L (2008), *Stormwater heavy metal loading to Port Jackson estuary*, NSW, Australia. M.Sc. Thesis (unpubl), School of Geosciences, University of Sydney.

RTA (Roads and Traffic Authority) (1999), *Roads and Maritime Code of Practice for Water Management.*

RTA (Roads and Traffic Authority) (2001), *Environmental Noise Management Manual*, Roads and Traffic Authority of New South Wales, Surry Hills.

RTA (Roads and Traffic Authority) (2002), *Guide to Traffic Generating Developments, Version 2.2*, Roads and Traffic Authority, NSW.

RTA (Roads and Traffic Authority) (2003a), *Guideline for Construction Water Quality Monitoring*.

RTA (Roads and Traffic Authority) (2003b), *'Section 8 Erosion and Sediment', Road Design Guideline.*

RTA (Roads and Traffic Authority) (2009), *RTA Procedures 143P: Erosion and Sediment Management Procedure*.

RTA (Roads and Traffic Authority) (2011), *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects*.

Rural Fire Service (2008), *Bush Fire Risk Management Planning Guidelines for Bush Fire Management Committees.*

Rural Fire Service (2019), *Planning for Bush Fire Protection*, NSW Rural Fire Service, Granville, SNW.

Salkavich, L, Cumbo, B and Ku, S (2002), *Manly Dam Galaxias Action Plan*, prepared by the Manly Dam Action Team for the Save Manly Dam Catchment Committee.

SCCG (Sydney Coastal Council Group) (2015), *Sydney Harbour Coastal Zone Management Plan Scoping Study: Literature and Data Review*. Prepared by GHD for the Sydney Coastal Council Group.

SLR Consulting Australia (2015), *Northern Beaches Hospital Connectivity and Network Enhancements Stage 2 Noise and Vibration Assessment.* Prepared for Roads and Maritime Services, Parramatta.

SMEC (2011). *Narrabeen Lagoon Plan of Management*. Prepared for the NSW Department of Primary Industries and Warringah Council.

SMEC (2017), *Northern Beaches Hospital Road Connectivity and Network Enhancements Project Factual Baseline Water Quality Monitoring Report (24 Months)*.

Standards Australia (1984), *AS 2702–1984 Acoustic methods of measurement of road traffic noise*.

Standards Australia (2001), *AS 2601-2001 The demolition of structures.*

Standards Australia (2006), *AS 2187.2-2006 Explosives: Storage and use – Part 2 Use of explosives.*

Standards Australia (2011), *AS 4825-2011 Tunnel fire safety.*

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

Standards Australia (2018), *AS 3959:2018 Construction of a Building in Bush Fire Prone Areas*.

Standards Australia (2019), *4282-2019 Control of the obtrusive effects of outdoor lighting.*

Sturrock, R (1982), *A Pictorial History of Mosman*, self-published, Mosman, NSW.

Sydney Trains (2015), *Our Performance: Train Loads.*

Sydney Water (2016), *Water Quality Monitoring Program for Willoughby City Council: Spring 2015-Autumn 2016*.

Sydney Water (2020), *Stormwater quality targets (Version 2)*.

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

Taylor, SE & Birch, GF (1999), 'Contaminant dynamics in offchannel embayments of Port Jackson, New South Wales', *AGSO Journal of Australian Geology and Geophysics*, vol. 17, pp. 233-237.

Terrill, M, Batrouney, H, Etherington, S & Parsonage, H (2017), *Stuck in traffic? Road congestion in Sydney and Melbourne*. Grattan Institute.

Transport for NSW (2012a), *NSW Long Term Transport Master Plan*. TfNSW, Sydney.

Transport for NSW (2012b), *North West Rail Link environmental impact statement - Stage 1 Major Civil Construction Works*. Prepared by AECOM for Transport for NSW, Sydney.

Transport for NSW (2013a), *Sydney's Bus Future,* Transport for NSW, Chippendale, NSW.

Transport for NSW (2013b), *Sydney's Cycling Future,* Transport for NSW, Chippendale, NSW.

Transport for NSW (2013c), *Sydney's Walking Future,* Transport for NSW, Chippendale, NSW.

Transport for NSW (2016b), *Northern Beaches Transport Action Plan.*

Transport for NSW (2017), *Sustainable Design Guidelines, Version 4.0,* Transport for NSW, Chippendale, NSW.

Transport for NSW (2018), *NSW Freight and Ports Plan 2018-2023*, Transport for NSW, Chippendale, NSW.

Transport for NSW (2019a), *Walking and Cycling Program 2020–2021 Funding Guidelines*, Transport for NSW.

Transport for NSW (2019b), *Climate Risk Assessment Guideline.*

Transport for NSW (2020a), *State Transit - Northern Beaches and Lower North Shore bus network map*. Retrieved 16 November 2020 from https://transportnsw.info/document/1695/region-guide-sydney-northern-beaches-lower-north-shore_0.pdf.

Transport for NSW (2020b), *Western Harbour Tunnel and Warringah Freeway Upgrade environmental impact statement*, January 2020. Prepared by Jacobs for Transport for NSW, Chippendale, NSW.

Transport for NSW (2020c), *Transport Environment and Sustainability Policy*, Transport for NSW, Chippendale, NSW.

Transport for NSW (2020d), *Environmental Impact Assessment Practice Note – Guidelines for Landscape Character and Visual Impact Assessment*, Transport for NSW, Rozelle, NSW.

Transport for NSW, (2020e). *Environmental Impact Assessment Practice Note N05 – Socio-economic assessment, January 2020.*

Transport for NSW (2020f), *QA Specification G38 – Soil and Water Management, Edition 2/Revision 4*.

Transport for NSW (2020g), *Beyond the Pavement 2020*.

Transport for NSW (2020h), *QA Specification G36 – Environmental Protection, Edition 4/Revision 6*.

UNESCO (United Nations Educational, Scientific and Cultural Organization) (2001), *Convention on the Protection of the Underwater Cultural Heritage*.

UNFCCC (United Nations Framework Convention on Climate Change) (1998), *Kyoto Protocol to the United Nations Framework Convention on Climate Change.*

UNFCCC (United Nations Framework Convention on Climate Change) (2012), *Doha Amendment to the Kyoto Protocol.*

UNFCCC (United Nations Framework Convention on Climate Change) (2015), *Paris Agreement.*

USEPA (United States Environmental Protection Agency) (2009), *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part F*, *Supplemental Guidance for Inhalation Risk Assessment)*.

USEPA (United States Environmental Protection Agency) (2011), *Review of National Ambient Air Quality Standards for Carbon Monoxide,* published by the USEPA in the Federal Register Volume 76, No. 169. Retrieved 16 November 2020 from http://www.gpo.gov/fdsys/pkg/FR-2011-08-31/html/2011-21359.htm.

Warne, C (2005), *Pictorial History Lower North Shore,* Kingsclear Books, Alexandria, NSW.

Warringah Council (1998), *History of Warringah*. Retrieved 16 November 2020 from https://web.archive.org/web/20060209043301/http://www.warringah.nsw.gov.au/lstudies.htm.

Warringah Pittwater Bush Fire Management Committee (2010), *Warringah Pittwater Bush Fire Risk Management Plan 2010 – 2015.*

Watson, PJ and Lord, DB (2008), *Fort Denison Sea Level Rise Vulnerability Study*. Prepared by the Coastal Unit, NSW Department of Environment and Climate Change.

WHO (World Health Organisation) (2000), *WHO air quality guidelines for Europe*, 2nd edition, 2000 (CD ROM version), World Health Organisation.

WHO (World Health Organisation) (2005), *WHO air quality guidelines global update 2005*, Report on a Working Group meeting, Bonn, Germany, 18-20 October 2005, World Health Organisation.

Willoughby City Council (2013), *Willoughby City Strategy*.

Willoughby City Council (2019), *Draft Local Strategic Planning Statement*.

Willoughby City Library Services (2013), *History @ Willoughby - Fact Sheet No. 1: Artarmon*. Retrieved 16 November 2020 from https://libraries.willoughby.nsw.gov.au/History-at-Willoughby/Resources-and-Publications/Fact-Sheet-1.0-Artarmon.

Willoughby District Historical Society Inc (2011a), *Short history of Willoughby*. Retrieved 16 November 2020 from http://willoughbydhs.org.au.

Willoughby District Historical Society Inc (2011b), *Artarmon*. Retrieved 16 November 2020 from https://abc17603.wordpress.com/history/suburbs/artarmon/.

Willoughby District Historical Society Inc (2011c), *Northbridge*. Retrieved 16 November 2020 from https://abc17603.wordpress.com/history/suburbs/northbridge/.

Willoughby Leisure, n.d., *Northbridge Baths*. Retrieved 16 November 2020 from https://www.willoughby.nsw.gov.au/Council/Venues/Northbridge-Baths.

WMA Water (WMA) (2016), *North Sydney LGA Flood Study*. Prepared for North Sydney Council.

WMA Water (WMA) (2018), *Manly Lagoon Floodplain Risk Management Study and Plan*. Prepared for Northern Beaches Council.

WorkCover NSW (2005), *Storage and Handling of Dangerous Goods Code of Practice*, WorkCover NSW, Gosford, NSW.

World Commission on Environment and Development (1987), *Our Common Future.*

WRI & WBCSD (World Resources Institute and World Business Council for Sustainable Development) (2004), *Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard.*