NSW GOVERNMENT

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 6

Construction work

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6 Construction work

This chapter describes the proposed approach to construction of the project. It outlines the proposed construction program, footprint, methodology, working hours, materials, equipment, traffic management, site access routes, and temporary construction support sites.

The construction works described in this chapter may be refined in response to submissions received during exhibition of this environmental impact statement, to further minimise impacts on the community or environment and/or during further design development and construction planning once a construction contractor has been appointed.

Detailed construction planning would be carried out before construction of the project begins. This would include the identification of specific construction methods and program.

The Secretary's environmental assessment requirements as they relate to construction works, and where in the environmental impact statement these have been addressed, are detailed in Table 6-1.

Table 6-1 Secretary's environmental assessment requirements - Construction work

Secretary's requirement	Where addressed in EIS
Environmental impact statement	
1. The EIS must include, but not necessarily be limited to, the following: b. a description of the project and all components and activities (including ancillary components and activities) required to construct and operate it, including: - the proposed route	This chapter describes the key construction activities and shows the temporary construction support sites along the proposed route. **Chapter 5** (Project description), sections 5.1, 5.2 and 5.3, describe the proposed route.
- Design of the tunnels, interchanges (inclusive of tunnel portals and entry and exit ramps), road user, pedestrian and cyclist facilities, and lighting	**Section 6.4** describes the tunnel construction method. **Section 6.5** describes the construction method for surface road works and associated infrastructure. **Chapter 5** (Project description), sections 5.1, 5.2 and 5.3, describe the design of the tunnels, including tunnel-to-tunnel connections and entry and exit ramps as well as road user, pedestrian and cyclist facilities, lighting and other operational ancillary infrastructure.
- Surface road upgrade works, including road widening, intersection treatment and grade separation works, property access, parking, pedestrian facilities (including appropriate locations for overbridges) and public transport facilities	**Chapter 5** (Project description), sections 5.2 and 5.3, describe the surface road works and surface connections as well as pedestrian, cyclist and public transport facilities. **Section 6.5** describes the construction method for surface road works and associated infrastructure, including bridgeworks and pedestrian facilities. **Chapter 8** (Construction traffic and transport), **Chapter 9** (Operational traffic and transport), **Chapter 20** (Land use and property) and

Secretary's requirement	Where addressed in EIS
	Chapter 21 (Socio-economics) discuss property access.
- Ancillary infrastructure and operational facilities, such as operational and maintenance facilities, ventilation structures and systems, and fire and emergency services and infrastructure for the proposal, including (if required) additional infrastructure (such as tolling infrastructure)	**Chapter 5** (Project description), sections 5.2.7 and 5.3.4 describe operational facilities and ancillary infrastructure. **Section 6.8** describes the temporary construction support sites required to construct the project. Construction of operational facilities and ancillary infrastructure is described in **Section 6.4.6**.
- Location and operational requirements of construction ancillary facilities and access	**Chapter 5** (Project description), sections 5.2 and 5.3, describe operational facilities and ancillary infrastructure. The location and hours of construction at each temporary construction support site and their respective access arrangements are described in **Section 6.8.2**.
- Land use changes as a result of the proposal and the acquisition of privately owned, Council and Crown lands, and impacts to Council and Crown lands	Land use changes as a result of the project are described in **Chapter 20** (Land use and property).
- The relationship and/or integration of the project with existing public and freight transport services.	**Chapter 3** (Strategic context and project need) and **Chapter 8** (Construction traffic and transport) discuss the relationship and/or integration of the project with existing public and freight transport services. Additional information about the relationship and/or integration of the project with existing and proposed public and freight transport services is provided in **Chapter 9** (Operational traffic and transport) and **Chapter 27** (Cumulative impacts).

6.1 Overview of construction works

An overview of the temporary construction support sites required for the project is provided in Figure 6-1. Further detail on the key activities to be carried out at each site and typical construction hours for each location is provided in Section 6.8. An overview of the types of construction work required for the project is provided in Table 6-2. Detailed descriptions of each construction activity are also provided in sections 6.3 to 6.7.

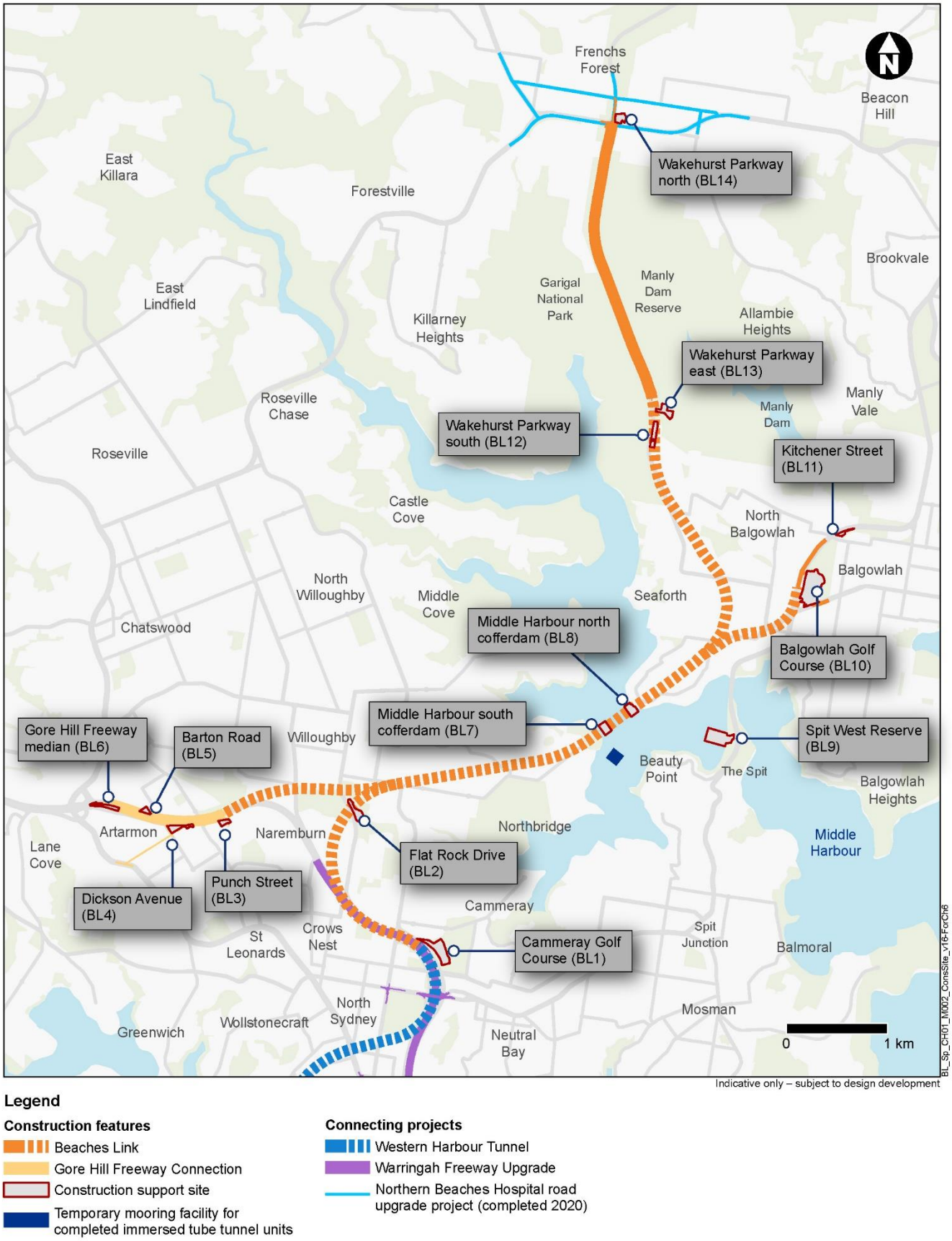


Figure 6-1 Overview of the temporary construction support sites for the project

Table 6-2 Overview of construction works

Component	Typical activities
Early works and site establishment	• Survey work and investigations (including geotechnical) • Property acquisitions and condition surveys • Utilities installation, protection, adjustment and relocation • Land remediation and heritage conservation and/or salvage works (where required) • Temporary relocation of swing moorings, where required • Provision of alternative facilities (swing mooring or marina berth) for users, where required • Installation of site fencing, environmental controls and traffic management controls • Vegetation clearing, earthworks and demolition of structures • Construction of minor access roads and the provision of access where required • Establishment of temporary construction support sites and acoustic sheds, where required.
Construction of the Beaches Link component	• Excavation of tunnel construction access declines • Construction of driven tunnels and surface connections • Construction of cut and cover and trough structures • Cofferdam construction and dredging activities in preparation for the installation of immersed tube tunnels (crossing of Middle Harbour) • Removal of temporary cofferdams • Installation of immersed tube tunnel piled supports and associated concrete headstocks • Casting and installation of immersed tube tunnels • Civil finishing works and tunnel fitout • Construction of operational facilities including: - A motorway control centre within the Artarmon industrial area, next to the Gore Hill Freeway - Motorway facilities and substations at Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway - Fitout of the Beaches Link ventilation outlet at Warringah Freeway. Civil construction of the ventilation outlet would form part of the Western Harbour Tunnel and Warringah Freeway Upgrade project (subject to separate environmental assessment and approval) - A wastewater treatment plant within the industrial area at Artarmon - Tunnel support facilities at Artarmon and Frenchs Forest - Installation of motorway tolling infrastructure (in tunnel).
Surface road works (Beaches Link and Gore	• Traffic staging works to enable access for the road works • Earthworks

Component	Typical activities
Hill Freeway Connection components)	• Bridgeworks • Construction of retaining walls • Construction of cut and cover and trough for connections to and from the Gore Hill Freeway, the Burnt Bridge Creek Deviation and the Wakehurst Parkway • Construction and installation of stormwater and cross drainage • Pavement works and linemarking • Utilities installation and relocation • Localised adjustment of a small section of Burnt Bridge Creek for road widening and existing culvert extension works • Tolling gantries and associated infrastructure • Installation of road furniture, fauna connectivity structure, lighting, signage and noise barriers • Construction of new active transport infrastructure.
New open space and recreation facilities at Balgowlah	• Staged construction of the new and improved open space and recreation facilities • Facilities may include shared user paths, open space areas, amenities, car park, playground, netball courts, soccer field, hockey field and new enlarged AFL/cricket oval.
Testing, commissioning and site rehabilitation	• Testing of plant and equipment • Commissioning of the project • Removal of infrastructure at temporary construction support sites • Backfill of access declines • Landscaping and rehabilitation of disturbed areas • Removal of temporary environmental and traffic controls.

6.2 Construction program

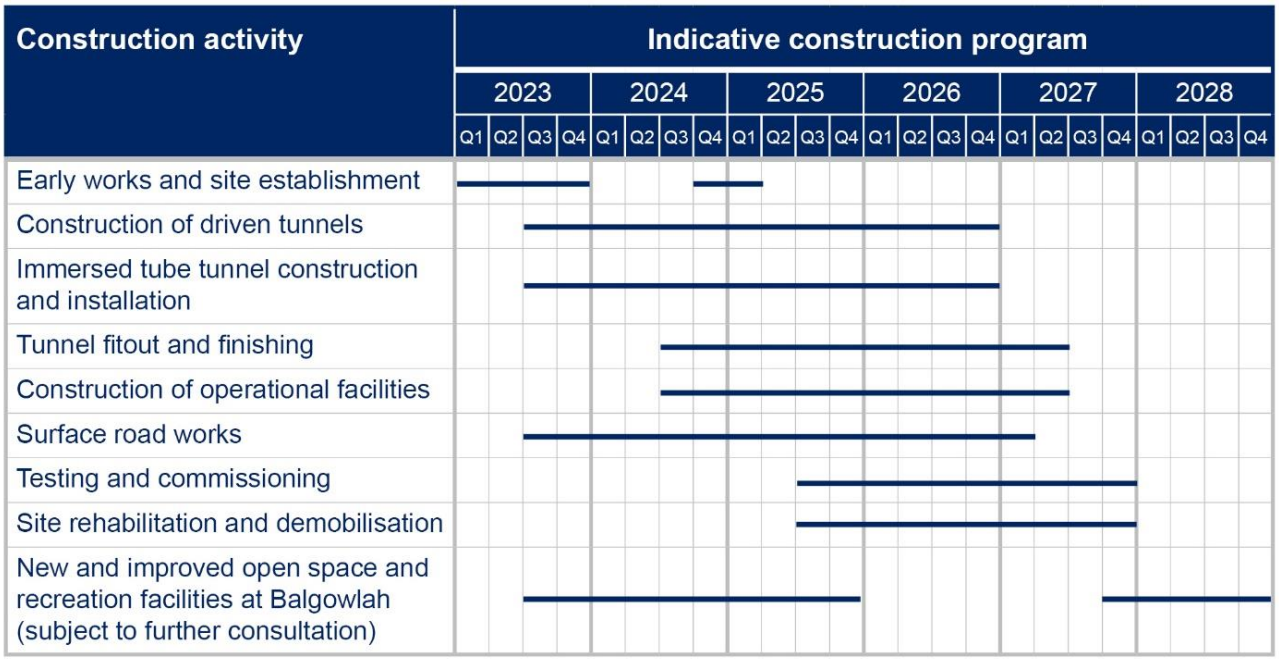
6.2.1 Program overview

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

Construction associated with the Gore Hill Freeway Connection component comprises early works and site establishment, surface works and bridgework activities, which would run concurrently from 2023 to around end 2027.

The indicative construction program of the project, including the Gore Hill Freeway Connection component, is shown in Table 6-3. Construction activities outlined in Table 6-3 may not occur continuously during the time period outlined.

Table 6-3 Beaches Link and Gore Hill Freeway Connection project indicative construction program



The final construction program for the project would depend on future project procurement and packaging decisions. This may include one or multiple construction contractors.

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

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

Works could include but may not be limited to cut and cover and trough works at Cammeray, construction of motorway facilities and ventilation tunnels at Warringah Freeway and traffic staging enabling works for the Gore Hill Freeway Connection.

6.3 Early works and site establishment

6.3.1 Early works, preparatory investigations and surveys

Early works, preparatory investigations and surveys for major infrastructure projects are carried out prior to substantial construction to prepare sites to facilitate the main construction activities. Typically, these works are of low environmental impact. Subject to conditions of approval some early works, preparatory investigations and surveys would take place prior to the formal approval of the main works construction management plans, and would include but are not limited to:

- Survey work and investigations including investigative drilling
- Carrying out existing condition surveys of buildings and infrastructure
- Property acquisitions and adjustment works including installation of property fencing

- Further contamination testing and land remediation subject to the recommendations of a remediation action plan (where required)
- Relocation, adjustment and protection of utilities and services affected by the project (utility works would be ongoing during the main works to suit staging of surface works)
- Road work adjustments to facilitate access to various temporary construction support sites
- Carrying out detailed heritage investigations, protections, salvage and/or conservation works (where required)
- Carrying out maritime heritage and submerged Aboriginal site investigations, protections, salvage and/or conservation works (where required)
- Upgrade of Spit Bridge pier protection fenders, including piling (if required, subject to condition survey)
- Temporary relocation of swing moorings from within Middle Harbour as close to their existing position as possible (details on swing moorings requiring temporary relocation are provided in Chapter 8 (Construction traffic and transport))
- Provision of alternative facilities (swing mooring or marina berth) for the users of a small number of fixed jetties below Seaforth Bluff that would have access restricted during construction (details on jetties requiring temporary closure are provided in Chapter 8 (Construction traffic and transport)).

6.3.2 Site establishment

Site establishment would occur prior to the main construction activities commencing. Similar to the early works described above, subject to conditions of approval (and approval of relevant site establishment plans), site establishment activities also include works which are of low environmental impact and could be carried prior to the formal approval of the main works construction management plans. Site establishment would include, but is not limited to:

- Installation of site environmental management controls (including site fencing, exclusion fencing for sensitive areas, noise attenuation measures and erosion and sediment controls)
- Vegetation clearing, chipping and mulching, where required
- Traffic management controls, including adjustments to road signage where required (showing changes to traffic movements and speed limits)
- Construction of minor access roads and provision of access including the temporary relocation of pedestrian and cycle paths and bus stops
- Earthworks to level the temporary construction support sites in preparation for site work and installation of site facilities
- Building structures and/or erection of demountable buildings within temporary construction support sites including temporary site accesses, acoustic sheds and associated access decline acoustic enclosures, where required
- Demolition of existing structures which require removal to enable construction of the project.

6.4 Construction of Beaches Link

Construction of the Beaches Link component would include the following activities:

- Excavation of the tunnel construction access declines
- Construction of driven tunnels
- Construction of cut and cover and trough structures

- Construction of temporary cofferdams in Middle Harbour
- Construction of interface structures between driven tunnel and immersed tube units
- Construction of immersed tube tunnel units
- Dredging to form the trench for installation of immersed tube tunnel units
- Installation of immersed tube tunnel piled supports and associated concrete headstocks
- Installation of immersed tube tunnels for the crossing of Middle Harbour
- Civil finishing and fitout of the tunnels, including drainage, pavement construction, barrier construction, architectural panel installation and other works required to finish the civil works
- Surface works to tie-in to surface roads in Cammeray, Artarmon, Balgowlah, Seaforth, Killarney Heights and Frenchs Forest
- Realignment and upgrade of Wakehurst Parkway between Killarney Heights and Frenchs Forest
- Construction of operational facilities
- Testing and commissioning.

More information on each of these activities is provided in the following sections.

6.4.1 Excavation of tunnel construction access declines

To enable construction of the driven tunnels, construction accesses would need to be created from temporary construction support sites to intersect the tunnel alignment. Tunnel construction accesses can take the form of shafts or declines, depending on constraints and construction context. All of the accesses for construction of the Beaches Link tunnels are currently proposed to be declines.

Excavated access declines would be required at the Cammeray Golf Course (BL1), Flat Rock Drive (BL2), Punch Street (BL3), Balgowlah Golf Course (BL10) and Wakehurst Parkway east (BL13) construction support sites.

The access decline provides access for workers, equipment, material supply, and spoil removal, and would be big enough for construction vehicles, including roadheaders, concrete trucks, spoil removal trucks and other equipment to drive in and out of the tunnel. The temporary tunnel ventilation and services such as compressed air, potable water and drainage return lines would also be installed through the access decline.

The access decline would typically be sized to allow for two-way vehicular traffic and a separated walkway for construction workers. An example of an access decline is shown in Figure 6-2.

While the majority of these tunnel declines would be driven tunnels, trough structures are required where these declines reach the surface. These trough structures are ultimately enclosed within the acoustic shed or covered with their own acoustic enclosure.

The access declines at Cammeray Golf Course (BL1) (partial), Flat Rock Drive (BL2), Punch Street (BL3), Balgowlah Golf Course (BL10) and Wakehurst Parkway east (BL13) construction support sites would be backfilled at the completion of construction. Part of the access decline at Cammeray Golf Course construction support site (BL1) would be used for a permanent ventilation tunnel connecting to the motorway facilities at this location.

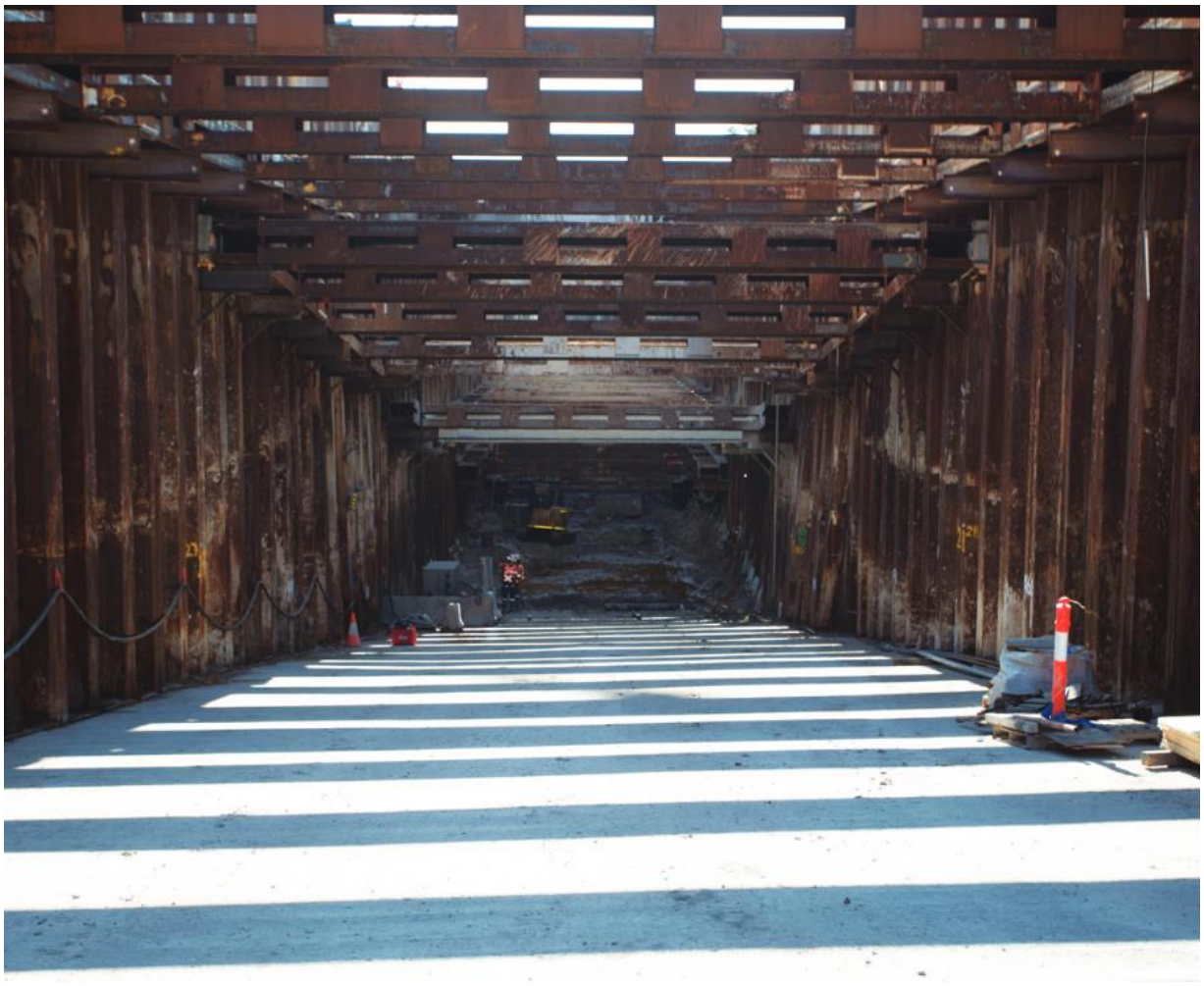


Figure 6-2 Example tunnel access decline

Acoustic sheds

An acoustic shed is an enclosed noise mitigation structure constructed over access declines that access the tunnel for construction. Noisy works required to support out of hours tunnelling, including spoil handling, would take place within the acoustic shed, reducing impacts on nearby receivers. Acoustic sheds would be designed with consideration of the activities that would occur within them and the noise management levels applicable at nearby receivers. They would also be designed to accommodate stockpiled tunnel spoil within the shed thereby removing the requirement for spoil haulage outside of standard hours. An example of an acoustic shed is shown in Figure 6-3.

Figure 6-3 Example from within an acoustic shed constructed for the New M4 tunnels

6.4.2 Construction of driven tunnels

The project would involve the construction of two mainline tunnels, as well as on and off ramps, cross passages and ventilation tunnels. The majority of this tunnelling work is expected to be carried out in Hawkesbury sandstone using electrically powered machines known as roadheaders.

A roadheader is an excavation machine that has a rotating, rock-cutting head on the front, mounted to a boom. When the underground rock is cut using a roadheader, a loading device typically transfers the rock onto a conveyor belt which runs the spoil onto haulage trucks. An example of a roadheader working underground to construct the New M4 tunnels is shown in Figure 6-4.

Ground support for tunnels excavated using roadheaders would typically consist of cement grouted rock anchors and/or rock bolts and shotcreting as shown in Figure 6-5. In areas which require control of higher levels of groundwater ingress or to accommodate poorer geology, the permanent tunnel lining would include a thicker reinforced concrete lining and waterproofing membrane. Ground support would be installed progressively following tunnel excavation.

In addition to the mainline tunnels and on and off ramp tunnels, cross passages would be excavated between the tunnels at intervals to facilitate emergency egress. These cross passages would be excavated using smaller roadheaders, rock hammers, rock saws or controlled blasting.

Figure 6-4 Example of a roadheader in the New M4 tunnels loading tunnel spoil into a spoil haulage truck

Figure 6-5 Example of tunnel shotcreting

It is anticipated that tunnel excavation would be carried out using a number of roadheaders, supported from multiple temporary construction support sites, including:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Balgowlah Golf Course (BL10)
- Wakehurst Parkway east (BL13).

Each of these temporary construction support sites would require additional surface infrastructure to support tunnel construction, such as acoustic sheds, workshops, material and equipment storage areas, heavy and light vehicle parking areas, air intake facilities to supply air for workers, power and water supply, temporary construction wastewater treatment plants, and worker amenities.

Temporary construction wastewater treatment plants would be designed to treat wastewater generated from tunnel construction activities and groundwater inflow during construction (refer to Chapter 17 (Hydrodynamics and water quality) for more detail).

Rock hammering (see Figure 6-6) and rock saws may be used in some areas for excavation of the tunnels, cross passages and areas of sandstone within the cut and cover and trough structures.

Figure 6-6 Example of rock hammering

Controlled underground blasting may also be used to improve the efficiency of excavation activities and shorten the overall excavation program. Areas likely to require controlled blasting would be confirmed during detailed construction planning. Refer to Chapter 10 (Construction noise and vibration) for further information on the management of blasting impacts from the project.

6.4.3 Construction of cut and cover and trough structures

Cut and cover tunnels would typically be constructed at locations where the tunnel alignment connects to and from the surface and does not have enough rock cover or quality of rock cover for construction using roadheaders. Cut and cover is a tunnel excavation methodology that generally involves excavating downwards from the surface of the ground, and installing a tunnel structure including a base, walls and a roof. Once the roof is in place, the structure is either used for permanent surface roads or covered over with soil and revegetated. These structures can also be constructed by installing the walls and roof and subsequently excavating out the material below from underneath the roof.

Cut and cover structures typically transition to open trough structures which connect to and from the surface (see Figure 6-7). Construction of trough structures is similar to cut and cover, except a roof is not installed (see Figure 6-8).

Figure 6-7 New M4 tunnel cut and cover structures

Figure 6-8 Trough structure for New M4 tunnel ramp at Haberfield

Cut and cover tunnels and trough structures are anticipated to be constructed at the following locations:

- The Beaches Link connections to the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project
- The eastbound on ramp from the Gore Hill Freeway to Beaches Link
- The westbound off ramps from Beaches Link to both the Gore Hill Freeway and Reserve Road
- The Wakehurst Parkway on and off ramps
- The Burnt Bridge Creek Deviation on and off ramps.

The Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project would provide the structural works for the cut and cover and trough structures for the Beaches Link ramps to and from the Warringah Freeway. This would allow maximum use of the road corridor by the Warringah Freeway Upgrade contractor and minimise disruption. The structural works would largely comprise the construction of the 'roof' and supporting piles for these structures. The construction impacts of these works have been assessed in the Western Harbour Tunnel and Warringah Freeway Upgrade environmental impact statement (Transport for NSW, 2020b).

The excavation and fitout (including pavement works to tie-in to the Warringah Freeway Upgrade) of the trough and cut and cover structures connecting Beaches Link mainline tunnels and the Warringah Freeway would be carried out as part of the Beaches Link component of this project.

6.4.4 Construction process for immersed tube tunnels

An overview of the construction process for the immersed tube tunnel crossing of Middle Harbour is shown in Figure 6-9 and Figure 6-10. During the construction process, temporary anchors for plant associated with marine works would be required to ensure stability and safety.

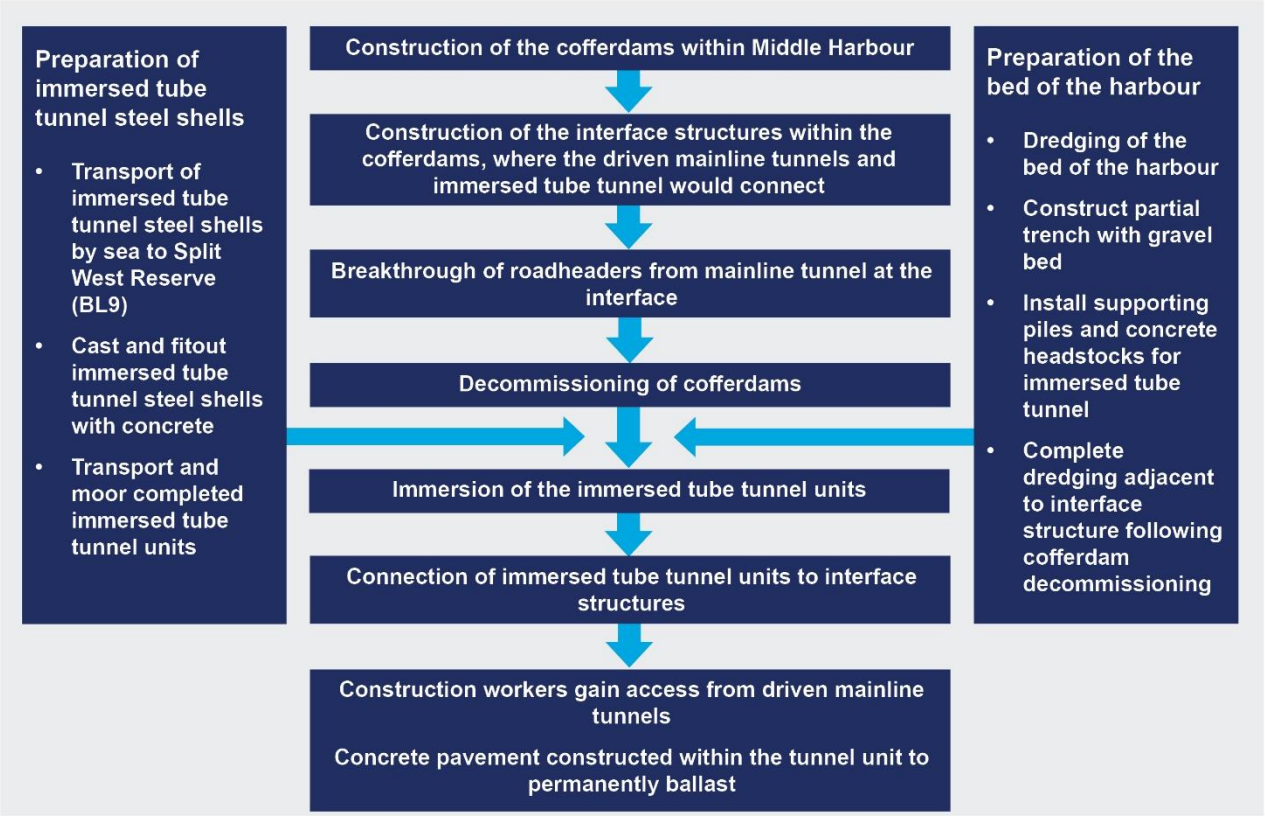
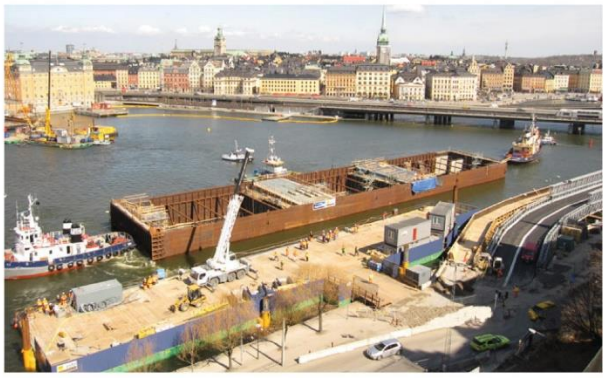


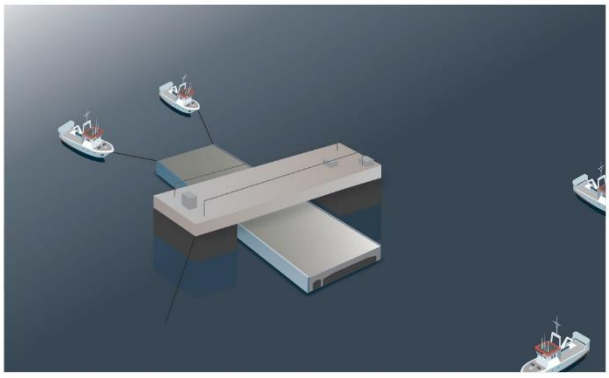
Figure 6-9 Indicative construction process for the immersed tube tunnels

Transport of steel shell units through Spit Bridge.

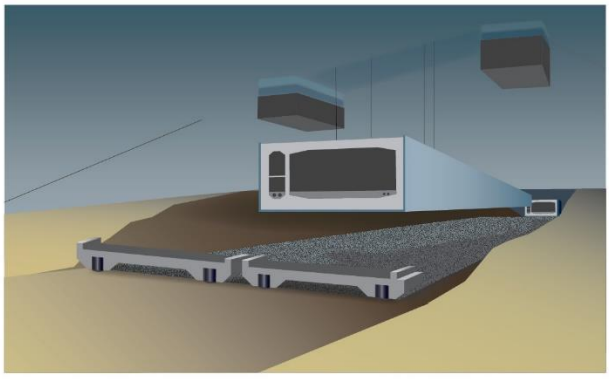
Steel shell unit arrives at Spit West Reserve construction support site (BL9) casting facility.



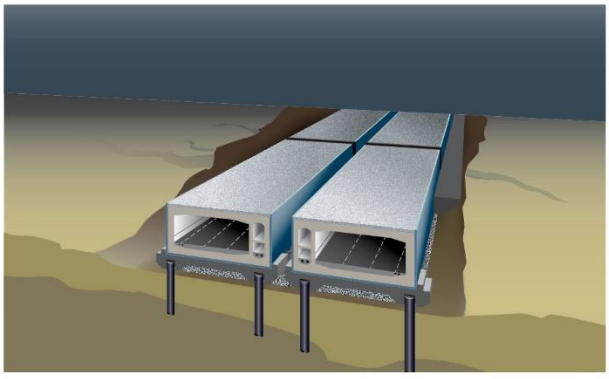
Floating steel shell unit arriving at casting facility for concrete construction. *



Transport completed unit to immersion site.



Immersion of completed tunnel units.



Completed units partially within a trench with locking fill.

*Note: Example of a casting facility for the Soderstrom Tunnel, Stockholm (TunnelTalk, 2013)

Figure 6-10 Indicative construction sequence for the immersed tube tunnels

Cofferdam construction

A cofferdam is a temporary enclosure within a body of water that is constructed to allow dewatering of an enclosed area. The purpose of the cofferdams is to create a relatively dry environment to allow the construction of the interface structures which would connect the driven tunnel and the immersed tube tunnels at each end of the Middle Harbour crossing.

Two temporary cofferdams would be constructed to facilitate construction of the concrete interface structures to enable the connection of the immersed tube tunnels to the driven tunnels off the shoreline at Northbridge and Seaforth. The cofferdams would be about 63 metres wide and 25 metres long. The location and indicative layout of the Middle Harbour cofferdams are shown in Figure 6-36. The cofferdams would be supported (with labour, plant, materials) from both the Spit

West Reserve construction support site (BL9) and Balgowlah Golf Course construction support site (BL10).

The method for the construction of the cofferdams within Middle Harbour is summarised below:

- Ground treatment – before the construction of the cofferdam can occur, the upper layer of the bed of the harbour would be injected with a permanent grouting material to improve its strength and make relatively water-tight. Ground treatment would be carried out by drilling holes into the bed of the harbour. These holes would then be injected with grout by a grouting machine located on a flat top barge. An example of a flat top barge is shown in Figure 6-12
- Piling – the cofferdam structure would be made up of a series of interlocking, tubular piles. Each pile would be driven into the underlying sandstone within the areas that were subject to ground treatment. Piling would take place from a flat top barge (or similar barge) using a crane fitted with a hydraulic vibrating hammer, offshore pile driving hammer and/or a similar piece of construction equipment
- Dewatering and installation of structural support – once all piles have been installed, the water level within the cofferdam would be progressively lowered (dewatered). Structural steel supports would be installed within the cofferdams from a flat top barge so that the cofferdams remain structurally sound.

The construction sequence for the cofferdam and interface structure is provided in Figure 6-11.

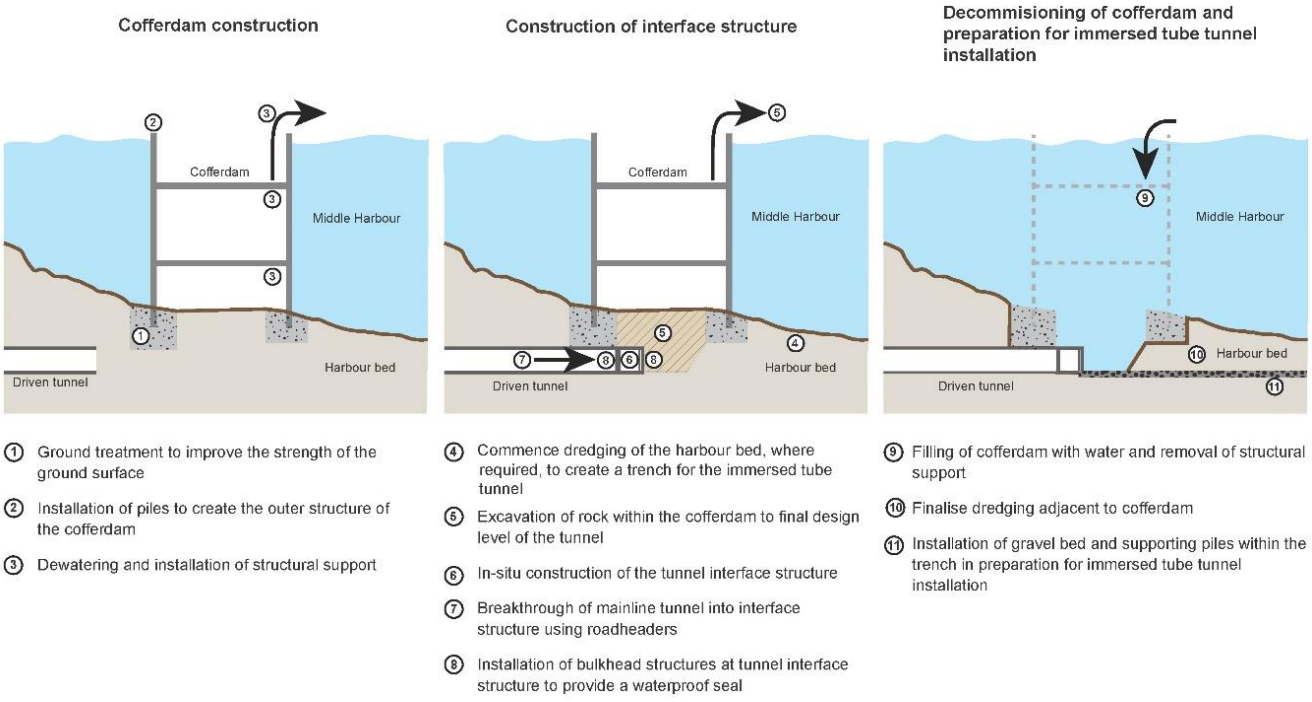


Figure 6-11 Indicative process for constructing cofferdams and interface structures

Figure 6-12 Example of a flat top barge

Construction of the interface structures within the cofferdams

The immersed tube tunnels would be connected to the mainline driven tunnels by an interface structure, which would be built within the cofferdams. The interface structure is essentially a structural adaptor between the driven tunnel cross section and the rectangular immersed tube tunnel cross section. Construction of the interface structures within the cofferdams would require excavation of overlying soft sediments and rock from within the cofferdam.

Excavation works within the cofferdams would be carried out using excavators that would be lowered into the cofferdam. The excavators would use both buckets, hydraulic hammers and steel cutter blades where required, to load out soft sediments and fracture and load out the underlying rock. To facilitate fracturing of the rock, some pre-cutting may be required using a large steel cutting blade fitted to the excavator. The sediment and fractured rock would be loaded into bins within the cofferdam, and lifted out by a crane, which would be located on the cofferdam work platform. An application for offshore disposal of dredged material will be submitted to the Australian Government Department of Agriculture, Water and the Environment. It is proposed that suitable dredged material would be loaded in a hopper barge and transported to the designated offshore disposal site (refer to Chapter 24 (Resource use and waste management) for further information). Any material not suitable for offshore disposal would be barged to a loadout facility for treatment to be made spadable and then loaded onto trucks and disposed of at a licensed land-based facility.

Construction of the interface structure would be supported by work barges that would be moored at the cofferdams for the duration of construction works (refer to Section 6.8.2 for location of cofferdams). A ferry barge would be used to transport the construction materials and plant, and smaller boats would transfer the workforce, from the Spit West Reserve construction support site (BL9) for the construction of the interface structure.

Decommissioning of cofferdams

Following completion of the interface structures, the cofferdams would be refilled with seawater pumped from Middle Harbour. As the cofferdams are filled with water, the structural support within the cofferdams would be removed. Once the water levels inside the cofferdams match the water level outside, the tubular piles would be removed, and the marine environment rehabilitated, where required. Where the tubular piles remain fixed in the bed of the harbour, they would be cut off at the harbour bed level and the marine environment rehabilitated where required.

Dredging

The construction of the immersed tube tunnels would require dredging of the bed of the harbour to create a trench for the installation of the immersed tube tunnels.

Dredging depths would range from 10 metres below the existing bed of the harbour near to the cofferdams, reducing to the existing bed level of the harbour at the mid-harbour section. Most of the mid-harbour section of the immersed tube tunnels would be located on the existing bed of the harbour and would not require substantial dredging. The tunnel trench beyond the mid-harbour section, would be designed to provide a solid foundation for placement of the immersed tube tunnel units.

The immersed tube tunnel units would need to be installed on a piled foundation in the mid-harbour section, due to the very soft marine sediments of lower strength which occur in Middle Harbour.

The method of dredging would depend on the material being dredged and would be carried out for the project using a combination of methods (refer to Table 6-4).

During dredging operations, floating silt curtains would be used to minimise impacts on the surrounding marine environment. Silt curtains are designed and installed to restrict and contain suspended sediments which can be spread into the water column during dredging operations. Dredging operations would be carried out within a localised floating silt curtain enclosure to a depth of two to three metres (sometimes referred to as a ‘moon pool’). Additional containment of suspended sediments would be provided by installation of large enclosed silt curtains extending to a depth of 10 to 12 metres enclosing the broader dredging site. An additional shallow silt curtain would also be installed where required next to any nearshore ecologically sensitive areas to provide additional protection.

Dredging of the sand bar at the entrance to Middle Harbour would not be required. Transport of dredged material, marine construction equipment and steel shell immersed tube tunnel units would be planned to use high tide periods to allow safe travel over this relatively shallow area.

Table 6-4 Dredging methods for installation of the immersed tube tunnels

Type of material to be dredged	Type of dredge to be used	Description
Soft sediments not suitable for offshore disposal (anticipated to be the top 0.5 – 1.0 metre of the bed of the harbour, subject to further testing (refer to Chapter 16 (Geology, soils and groundwater)))	Backhoe dredge with a closed environmental clamshell	A backhoe dredge consists of a hydraulic excavator that is fixed to a pontoon or work barge (refer to Figure 6-13). A closed environmental clamshell is a closed bucket which is used to minimise the spread of excavated material into the water column (refer to Figure 6-14). This material would be loaded directly into nearby self-propelled split hopper barges (with no overflow allowed). Once fully loaded, the vessel would transport the dredged material to a load out facility. This material would be made spadable, loaded onto trucks and then disposed of at a suitable land-based licensed facility.

Type of material to be dredged	Type of dredge to be used	Description
Soft sediments suitable for offshore disposal	Backhoe dredge with a closed environmental clamshell	A closed environmental clamshell would be used for the removal of soft clay, silt or silty sand material. Dredged material would be loaded directly into nearby self-propelled split hopper barges (with no overflow allowed). Once fully loaded, the vessel would transport and dispose of the dredged material at the designated offshore disposal site.
Rock layer suitable for offshore disposal	Backhoe dredge with a set of drum cutters or steel cutting blade and a standard open bucket	The underlying soft rock would be removed using a backhoe dredge with standard open bucket. The underlying hard rock would be crushed with a very large backhoe dredge fitted with a set of rotating drum cutters on a boom (instead of a bucket) (refer to Figure 6-15). The drum cutter would be lowered by the backhoe dredger to crush the rock into small fragments. The fragmented rock would be removed by a backhoe dredge fitted with a standard open bucket. The backhoe dredge would then load the fragmented rock into the self-propelled split hopper barges (with no overflows) for transport and disposal of the dredged material at the designated offshore disposal site. To facilitate crushing of the rock, some pre-cutting of the harder rock may be required using a large steel cutting blade fitted to the backhoe dredge.

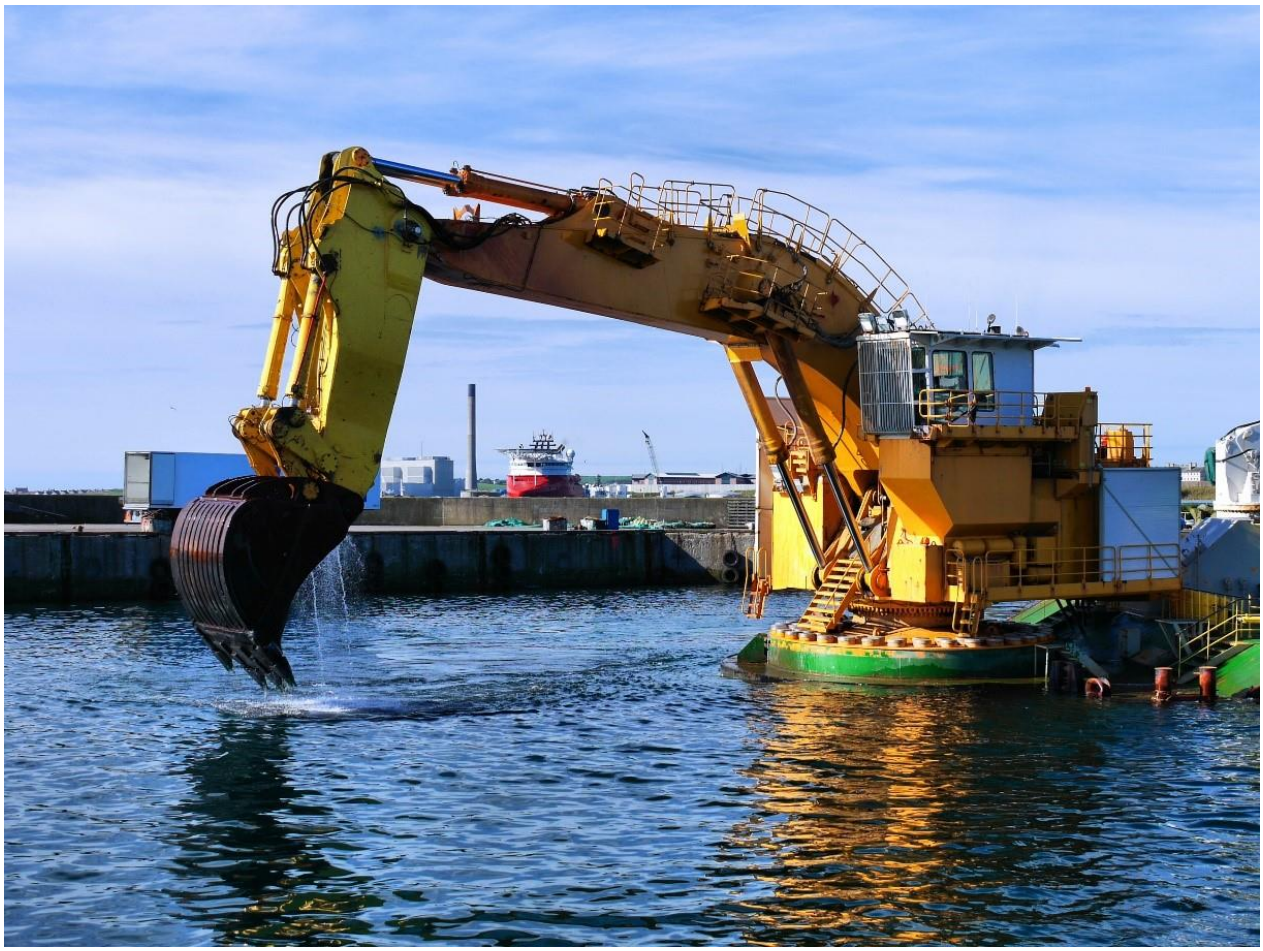


Figure 6-13 Example of backhoe dredger with an open bucket (Royal Haskoning DHV, 2020)

Figure 6-14 Example of an excavator fitted with a closed environmental clamshell loading into a hopper barge (Source: supplied by Royal Haskoning DHV, 2020)

Figure 6-15 Example of drum cutters which can be used in a marine situation

Installation of the gravel bed

The immersed tube tunnel trench would be lined with gravel to a depth of about 0.8 metres. The gravel bed would be installed using a pontoon with a fall pipe which levels the gravel materials supplied via a conveyor belt from a barge moored against the pontoon.

Installation of immersed tube tunnel units on support piles

Immersed tube tunnel units would need to be placed on supporting piles due to the soft marine sediments on the bed of the Middle Harbour. Installation of the piles would be carried out using similar sized equipment to the cofferdam construction. The piles would be tubular steel liners, vibrated through the upper sediments and screwed into the underlying rock. The piles would then be filled with reinforced concrete after reaching their final depth. The piles would be cut off to level and a concrete headstock would be cast below water on top of the piles. Alternatively, a pre-cast concrete headstock may be placed on the installed piles and locked in place.

Construction of the immersed tube tunnel units

The immersed tube tunnels would be about 340 metres in overall length and would each consist of three individual units for each carriageway (six units in total). Refer to Figure 6-16 for an example of an immersed tube tunnel casting facility and Figure 6-17 for an example of a completed immersed tube tunnel unit.

The steel shell immersed tube tunnel units would be transported by sea from a location outside of Middle Harbour (either on a barge or directly towed by a tug) to the Spit West Reserve construction support site (BL9) to be completed. Works to complete the units at the Spit West Reserve construction support site (BL9) would include installation of internal formwork and reinforcement, pouring of concrete in stages to form the permanent immersed tube structure. The cast concrete units would then have fitout works completed prior to immersion. An additional concrete layer would be provided to protect the top of the completed tunnel units from marine activities during operation, including falling or dragging anchors.

Once the casting and fitout of the immersed tube tunnel units is complete, the units would be towed by tug boats to the temporary mooring location east of Clive Park in Middle Harbour (refer to Figure 6-26). The temporary mooring location would enable storage of the first four completed

immersed tube tunnel units prior to installation. The final two completed units would be towed directly to the immersion site.

Figure 6-16 Example of a casting facility for the Soderstrom Tunnel, Stockholm (Source: TunnelTalk, 2013)

Figure 6-17 Example of completed immersed tube tunnel unit for the Amsterdam Metro moored ahead of installation (Source: ITA, n.d.)

Immersion of tube tunnels

The immersion of the immersed tube tunnel units would be carried out using pontoons (refer to Figure 6-18). Temporary anchors would be placed prior to the immersion process to position the tunnel units (refer to Figure 6-19).

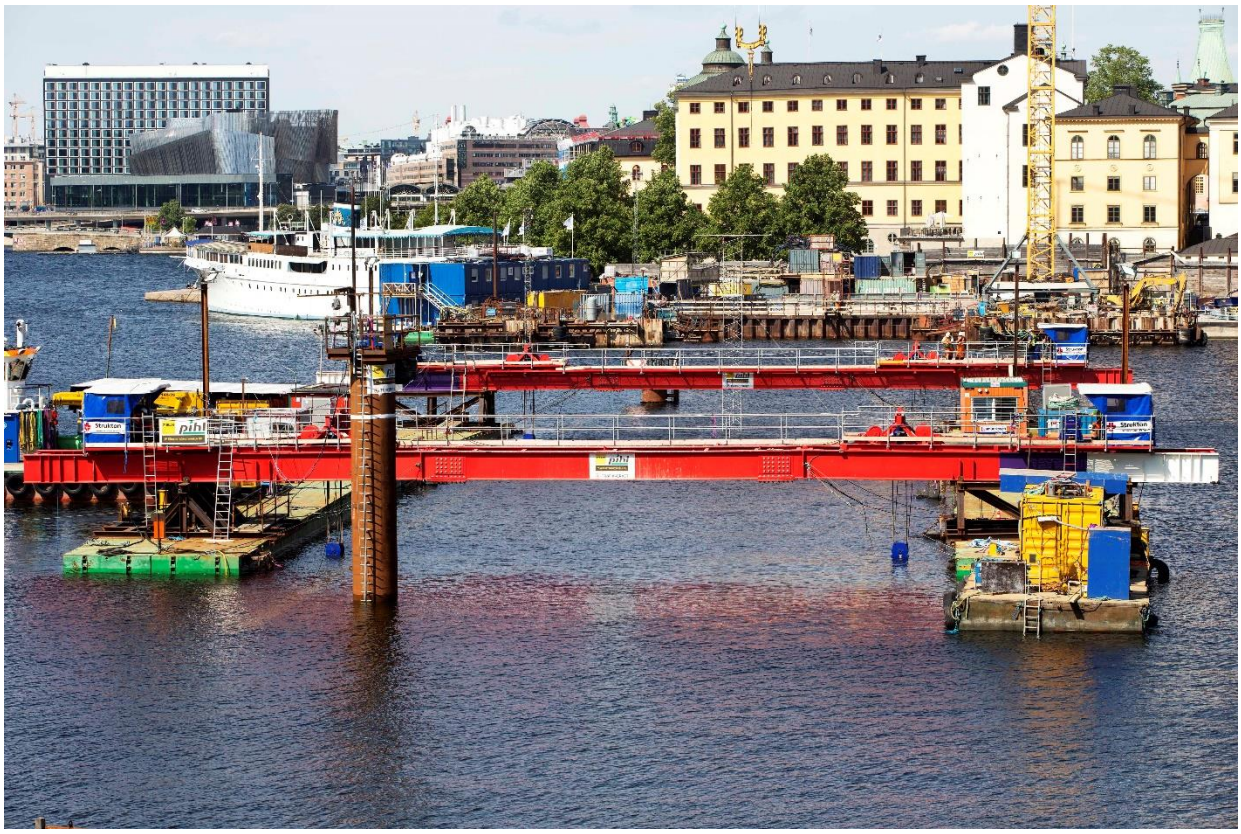


Figure 6-18 Example of immersed tube tunnel unit being immersed for the Soderstrom tunnel in Stockholm (Source: provided by Strukton)

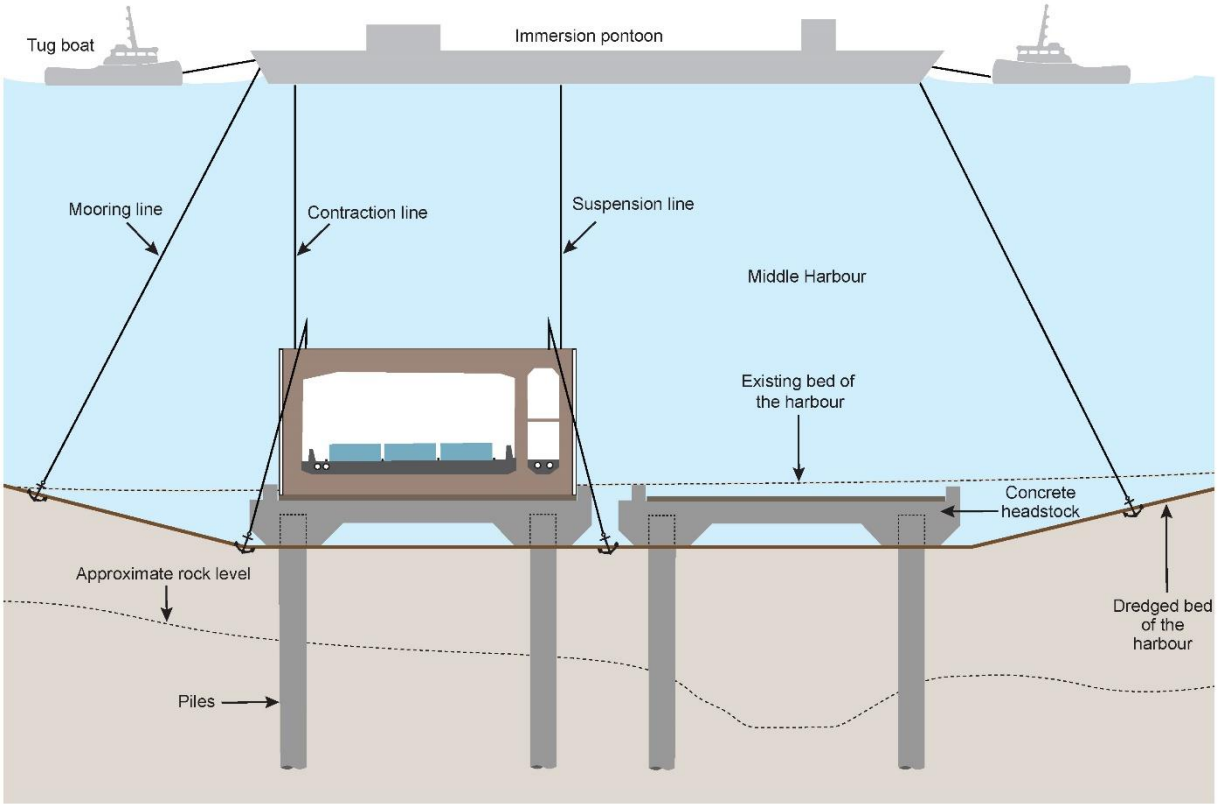


Figure 6-19 Positioning of immersed tube tunnel units in Middle Harbour

Immersion would be carried out by pumping water into temporary ballast tanks within the immersed tube tunnel unit. The water ballast tank would be used to control the buoyancy (ie the amount they float) and balance of each unit. A guidance system would be installed on the pontoon deck to guide the immersed tube tunnel unit to the previous immersed unit and/or to the interface structure.

The immersed tube tunnel units would be installed both on supporting piles and within a trench. The middle third of the tunnel would be installed on supporting piles and would sit generally just above the nominally dredged bed of the harbour. The northern and southern thirds of the tunnel would be installed within a trench of varying depth.

Once the immersed tube tunnel units have been placed into their final location in the section within the trench, locking fill would be placed between the sides of the tunnel units and the trench wall to provide initial stability and to prevent it from moving.

Immersed tube tunnel units placed on supporting piles would be founded securely on concrete headstocks installed on the supporting piles.

Following immersion of each unit, and connection to the either the interface structure or an adjacent tunnel unit, the immersion joint would be dewatered and steel bulkhead barriers at the connected end safely removed. Construction workers would then be able to gain access to the unit through the mainline tunnel to complete fit out works within the units. Concrete pavement would be cast within the immersed tube tunnel unit to replace the weight provided by the temporary ballast tanks, allowing them to be removed.

This configuration is shown schematically in Figure 6-20.

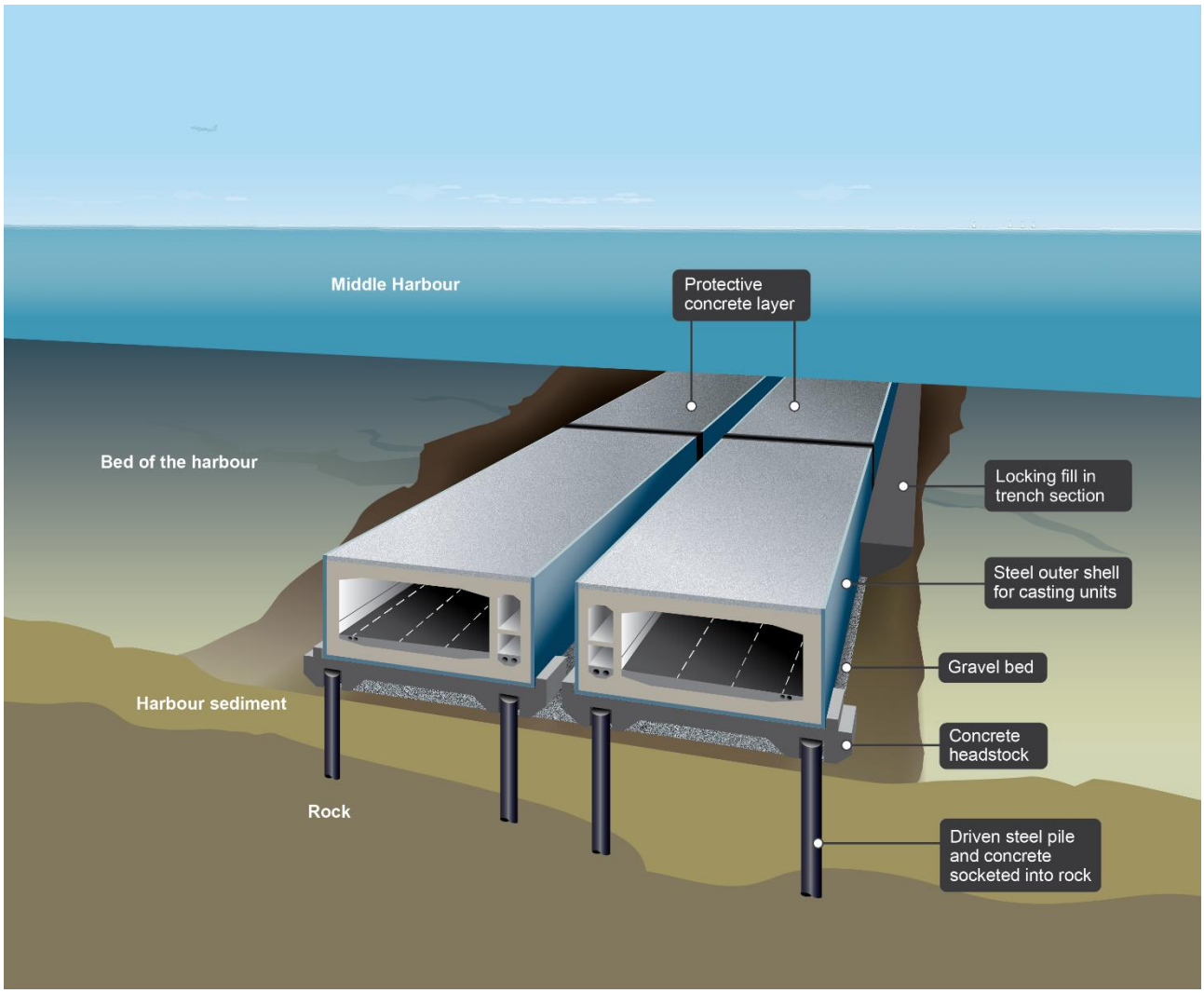
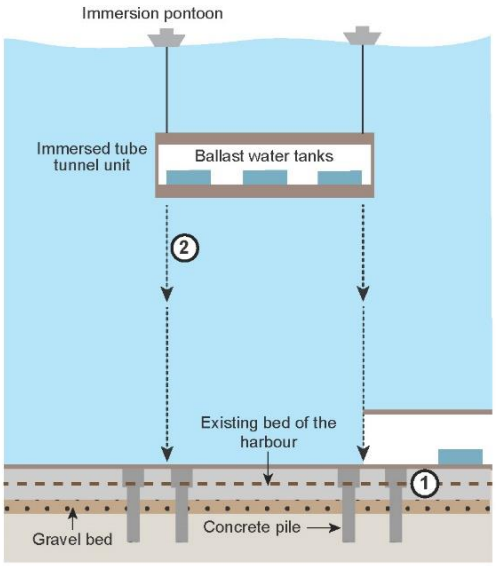


Figure 6-20 Example of an immersed tube tunnel

A typical immersion process for one immersed tube tunnel unit would take 24 to 48 hours. Partial harbour closures in the vicinity of the site would be required while each unit is immersed. Full harbour closures may be required during immersion of the two middle units.

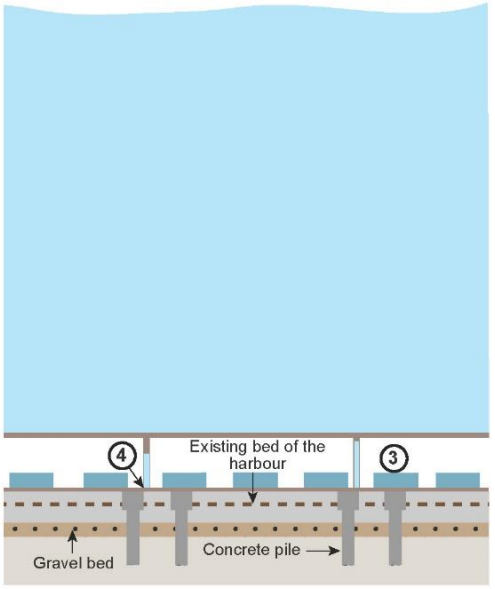
The installation sequence for the immersed tube tunnels is shown in Figure 6-21.



Immersion of tube tunnel units

① Installation of gravel bed and/or supporting piles

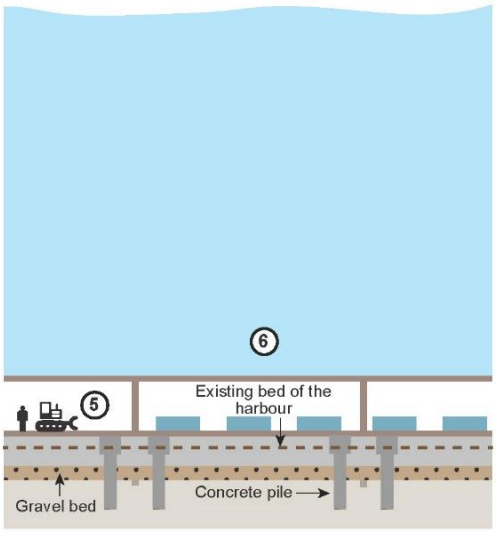
② Immersion of immersed tube tunnel element against previous element



Connection and dewatering of immersed tube tunnel units

③ Connection of immersed tube tunnel unit with interface structure or adjacent immersed tube tunnel unit and installation of waterproof joint between units/structures

④ Dewatering of immersion joint



Fitout and finishing works

⑤ Removal of water ballast tanks, ballast concrete and fitout

⑥ Placement of backfill between tunnel units and the tunnel trench to close any voids

Figure 6-21 Indicative immersed tube tunnel installation sequence

6.4.5 Tunnel fitout and finishing works

On completion of the tunnelling works, a variety of fitout and finishing works would be required. Fitout refers to the construction works that need to be carried out after excavation of the tunnels.

Fitout and finishing works to be completed within the Beaches Link tunnels are described in Table 6-5.

Table 6-5 Tunnel fitout and finishing works

Construction activity	Description
Service conduits	Trenches would be constructed along the inner wall of the mainline and ramp tunnels under the shoulder of the roadway using a saw mounted on an excavator. Rock would be broken up by an excavator with a hydraulic hammer and loaded out for disposal. Conduits would then be installed within the trench, and the trench then backfilled to cover the conduits.
Roadway drainage	Trenches would be constructed in the same way as the service conduits but positioned on the low side of the road pavement where water runoff would be directed during operation. Drainage pipes would be placed within the trench and held in place, and the trench would then be backfilled with concrete.
Pavement works	Continuously reinforced concrete pavement would be installed within the tunnels.
Traffic barriers	Traffic barriers would be constructed from concrete using a specialised barrier placement machine or alternative hand placement methods where the machine is unable to access that location.
Mechanical and electrical infrastructure	The mechanical and electrical infrastructure would include the installation of: • Tunnel lighting and surveillance cameras • Operations management and traffic management equipment • Toll points within the mainline tunnels • Cross passages and equipment rooms, including lighting, power, exit lights and signage • Emergency and surveillance systems • Fire systems and protection equipment • Underground pump stations • Ventilation system, jet fans and support frames • Cabling including high voltage and low voltage cables, power supply cables from substations, power and control cables from jet fans to substations and communications cables • Substation equipment.
Finishing works	Finishing works within the tunnels would include: • Testing and commissioning all equipment and systems • Installation of architectural wall panels above the concrete traffic barriers • Painting sections of the tunnels as required • Linemarking • Signage.

6.4.6 Construction of operational facilities and ancillary infrastructure

Permanent operational infrastructure would be required for the ongoing management and operation of the project. Operational infrastructure would be located at Cammeray, Artarmon, Balgowlah, Killarney Heights and Frenchs Forest. The construction methods employed for operational facilities and ancillary infrastructure are summarised in Table 6-6.

Table 6-6 Construction of operational facilities and ancillary infrastructure

Operational	Construction method
Tunnel ventilation systems	Construction of the tunnel ventilation systems would involve: • Excavation and fitout of the ventilation tunnels to connect the ventilation outlet to the mainline or ramp tunnels (where required) • Construction and fitout of the Beaches Link motorway facilities buildings at the Warringah Freeway, the Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway • Connections to utilities, including sewerage, power, potable water and stormwater • Construction of car parking, hardstand areas, and access to the public road network • Fitout of the ventilation outlets • Internal fitout of plant areas, equipment installation and commissioning. The civil construction of the Beaches Link ventilation outlet at the Warringah Freeway would be carried out as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project, which is subject to separate environmental assessment and approval. As such, only fitout and commissioning works for this particular ventilation outlet would be carried out as part of this project. All other ventilation outlets for the project would be constructed as part of the Beaches Link and Gore Hill Freeway Connection project.
Motorway control	Construction of the motorway control centre at Artarmon would include: • Demolition of existing structures • Connections to utilities, including sewerage, power, potable water and stormwater • Excavation, footing and base slab installation • Construction of concrete columns, deck and roof • Enclosure of the building • Construction of car parking, hardstand areas, and access to the public road network • Internal fitout of control rooms, computer rooms, offices and workshop and associated staff amenities • Security fencing.

Operational facilities	Construction method
Tunnel support facilities	Construction of the tunnel support facilities at Artarmon and Frenchs Forest would include: • Demolition of existing structures • Connections to utilities, including sewerage, power, potable water and stormwater • Excavation, footing and base slab installation • Construction of columns and deck to the first floor • Construction of columns to support the roof • Cladding of the building • Internal fitout of control rooms, computer rooms, offices and workshop and associated staff amenities • Construction of car parking, hardstand areas, and access to the public road network • Security fencing.
Operational wastewater treatment plant	The operational wastewater treatment plant would be constructed at Artarmon using prefabricated components which would be assembled on site as follows: • Mechanical assembly of operational wastewater treatment plant components, including rising main and discharge pipework • Complete electrical connections between the operational wastewater treatment plant components and incoming power supply • Commission the operational wastewater treatment plant • Connection of the wastewater treatment plant to the local stormwater network for the discharge of treated wastewater.
Substations	The substations area located adjacent to the motorway facilities at the Warringah Freeway, the Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway would be constructed using prefabricated components where feasible.

6.5 Surface road works

Surface road works are required to connect and integrate the new tunnels with the existing road network. The main areas of surface road works for the project include:

- Integration works to connect the new tunnels into the Warringah Freeway
- Upgrade and integration works along the Gore Hill Freeway
- Upgrade and integration works at Balgowlah
- Upgrade and integration works along Wakehurst Parkway, between Seaforth and Frenchs Forest.

This would also include new and upgraded public and active transport infrastructure at Artarmon, Balgowlah, Killarney Heights and Frenchs Forest.

The construction of the surface road works would typically involve the following activities:

- Traffic staging works to enable access for the surface road works
- Demolition of existing kerbs, structures and pavements

- Utility relocation works to suit staging of surface works
- Earthworks
- Bridgeworks at Artarmon and Frenchs Forest
- Construction of retaining walls, noise barriers, traffic barriers and flood walls
- Stormwater drainage
- Road pavement works
- Signage and linemarking
- Installation of new and modification of existing, lighting and lighting structures
- Fauna connectivity structures
- Surface finishing works.

These activities are described in detail in the following sections with utility relocation works detailed in Appendix D (Utilities management strategy).

6.5.1 Earthworks

Earthworks would be required for the surface works of the project including:

- The tunnel portals at Warringah Freeway, Gore Hill Freeway, Wakehurst Parkway and Burnt Bridge Creek Deviation
- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore and Western Line and T9 Northern Line and the Pacific Highway
- Widening of Burnt Bridge Creek Deviation
- Realignment and upgrading of Wakehurst Parkway between Seaforth and Frenchs Forest
- Construction of the new access road at Balgowlah to connect the tunnel portals to Sydney Road and provide access to the new and improved open space and recreation facilities
- The staged construction of the new and improved open space and recreation facilities at Balgowlah
- Local road works at Artarmon, Balgowlah, Seaforth and Frenchs Forest in the vicinity of surface road works.

Earthworks would include bulk excavation, excavation for new pavement or pavement widening, and placement and compaction of general fill and select fill. Excavation work would be carried out using excavators and bulldozers.

Where earthworks are required, excavated material would be loaded directly into trucks and removed from site or unloaded and compacted directly into new fill areas or stockpiled for future reuse on the project.

It is expected that excavated material would consist of a combination of:

- Virgin excavated natural material
- Roadbuilding materials from within existing road corridors, such as concrete, roadbase and asphalt.

Material required for filling and compaction works would typically be imported to temporary construction support sites and/or the construction footprint as this material is required to have specific engineering properties. Tunnelling spoil would be used as fill material if it is available at the time required for surface earthworks. Earthworks in sections of Wakehurst Parkway would potentially be constructed as local cut to fill operations utilising locally sourced materials for reuse where it is practical. This is likely to involve stockpiling to ensure locally sourced materials could be

utilised on site at the appropriate times rather than needing to be transported off site as spoil or to site from other sources.

Fill material imported to site would typically be placed directly from trucks and would be spread with a grader and/or excavator and compacted using vibratory rollers. Where fill material cannot be placed directly from trucks, stockpile areas would be established within temporary construction support sites and/or the construction footprint as required. Watercarts would be used to add moisture to aid compaction and control the generation of dust.

It is anticipated that sections of Wakehurst Parkway may require controlled blasting during bulk earthworks as an alternative to ripping or hammering of rock so as to minimise the duration of this activity. Controlled blasts would not take place during peak hour traffic periods, on Sundays or public holidays. Traffic control measures related to blasting are detailed in Section 6.9.2. Refer to Chapter 10 (Construction noise and vibration) for further information on the management of blasting impacts from the project.

During the earthworks identified above, a number of erosion and sediment controls would be required to mitigate and manage potential erosion and sedimentation impacts from the project, including impacts to water quality. Temporary sediment basins would be used in catchments where the erosion hazard exceeds 150 cubic metres/year (200 tonnes/year) of soil loss. The final location and size of all sediment basins would be determined during further design development and construction planning. Alternative erosion and sediment control measures would be implemented in locations where sediment basins cannot be provided because of site, soil and drainage constraints to constructing large scale sediment basins. For these catchments, smaller sediment basins, sediment sumps, mulch bunds, sediment fences or combinations of these would be used. However, to manage potential associated risks, these catchments would also be subject to enhanced erosion control measures and best management practice, such as limiting the size of disturbed land at any one time and ensuring disturbed areas are re-landscaped progressively. Refer to Chapter 17 (Hydrodynamics and water quality) for further information on the management of potential erosion and sedimentation impacts from the project.

6.5.2 Bridgeworks

Bridgeworks required for the project include:

- Modification of the existing Reserve Road bridge and Hampden Road bridge in Artarmon
- Replacement and upgrade of the existing pedestrian bridge across Wakehurst Parkway, south of Aquatic Drive
- Construction of a new shared user bridge over an existing combined fauna underpass/drainage culvert south of Warringah Road at Frenchs Forest.

Typical bridge construction methods are described in Table 6-7. Chapter 5 (Project description) provides more information on the types of new, modified and relocated bridges.

Table 6-7 Bridge construction methods

Bridgeworks	Construction method
Bridge modification works at Artarmon	Reserve Road bridge and Hampden Road bridge would generally remain operational during construction but may require lane closures or short-term closures. Modification of Reserve Road bridge would involve: • Traffic staging works to enable access for the bridge modification works • Relocation of utilities as required • Existing bridge lane closures as required • Existing bridge barriers removed down to the existing bridge deck slab

Bridgeworks	Construction method
	• Existing asphalt removed from the bridge deck • New pre-cast sections positioned with the use of cranes and fixed to the bridge deck • Asphalt applied to the bridge deck to form the roadway surface • Installation of any required barriers, drainage infrastructure, throw screens • Signage, linemarking and lighting adjustments • Footpaths periodically closed to allow for reinstalment of utilities within the bridge prior to reopening. Works at Hampden Road bridge are generally limited to the underside of the bridge at the two abutments. Surface works at Hampden Road bridge would involve piling behind and strengthening of the existing northern abutment.
Replacement and upgrade of the existing pedestrian bridge across Wakehurst Parkway and construction of a new shared user bridge over drainage culvert south of Warringah Road	Replacement of the existing pedestrian bridge and construction of the new shared user bridge would generally include: • Relocation of utilities as required • Construction of the substructure, likely to be cast in-situ concrete in the following sequence: - Piling works, such as bored piles - Pile cap construction including localised excavation around the piles - Abutment construction including localised excavation around the piles - Pier or column construction • Headstock construction • Construction of the new superstructure (including the new bridge deck), likely to be through the placement of pre-cast concrete segments • New pre-cast sections positioned with the use of cranes • Construction of access ramps and integration of these with the surface path network • Installation of any required handrails, drainage infrastructure, throw screens • Demolition of the existing bridge. The new replacement shared user bridge would be constructed just to the north of the existing bridge so the existing bridge can remain operational during construction of the replacement bridge.

6.5.3 Retaining walls

Retaining walls would be required at Cammeray, Artarmon, Balgowlah, Killarney Heights and Frenchs Forest.

The type of retaining wall required would depend on the location and the ground conditions and would be determined during further design development. The choice of retaining wall would consider the urban design principles and objectives developed for the project (Appendix V (Technical working paper: Urban design, landscape character and visual impact assessment)). The types of retaining walls used on the project could include:

- Piled retaining wall – generally used in areas where the face of the retaining wall is within an area that has been excavated or is to be excavated
- Reinforced soil wall – used where retaining walls would be constructed in areas of fill
- L-shape retaining wall – used where retaining walls would be constructed in areas of fill and are lower in height or where reinforced soil walls are not suitable for structural and/or geometric reasons
- Soil nail retaining wall – used in areas with stable ground conditions where the cut is reinforced with ground anchors and the cut face is stabilised using shotcrete.

The method for constructing retaining walls would vary depending on the type of wall required but could include:

- Excavation
- Piling, installation of concrete footings, provision of structural support (ie rock anchors or soil nails)
- Shotcreting
- Drainage at the base or behind the retaining wall
- Installation of either pre-cast or cast in-situ panels or segments
- Backfilling the retaining walls
- Safety railings
- Planting and architectural finishes (where required).

6.5.4 Stormwater drainage

The project would require construction of new drainage infrastructure and alterations to existing drainage infrastructure, including:

- Construction of new pits, pipes, culverts and associated outlet structures for the surface roads
- Alterations to existing drainage infrastructure to suit new road alignments on existing surface roads including Sydney Road at Balgowlah
- Alterations to the existing drainage infrastructure in the vicinity of tunnel connections to the Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway
- Localised adjustment of a small section Burnt Bridge Creek and provision of scour protection adjacent the downstream side of the culvert extension
- Construction of stormwater basins and associated outlet structures along Wakehurst Parkway.

Stormwater drainage would generally consist of pre-cast concrete pipes or culverts which would be placed in trenches and then backfilled with select material that meets engineering specifications. Where pipes and culverts need to be installed under existing roadways, underboring or pipejacking may be used to avoid the need to trench across live traffic lanes, where this work cannot be feasibly carried out in stages across existing carriageways. In this instance, a pit would be excavated to one side of the roadway, and the drainage pipes installed by drilling horizontally underneath the roadway.

During construction of new drainage infrastructure and alterations to existing drainage infrastructure, there may be a need to carry out temporary drainage works. This could include temporary diversions and drainage line crossings to enable earthworks and for installation of culverts. Temporary diversions and drainage line crossings would be managed to avoid impact on any sensitive receiving environments, including any changes to flow conditions. Depending on local site conditions, temporary diversions may also be required to extend outside the construction

footprint to ensure appropriate connection to existing drainage lines and ensure flow conditions are maintained or impacts minimised where possible.

Due to establishment of the Flat Rock Drive construction support site (BL2), there would also be a need to carry out box culvert drainage works associated with an aboveground constructed drainage line of Flat Rock Creek. This would include construction of a culvert and minor redirection of the drainage line at this location (refer to Figure 6-31).

Scour protection measures would be installed downstream of culverts and disturbed drainage line/creek banks to avoid erosion of the watercourse. Depending on local site conditions, scour protection and/or drainage work may be required to extend outside the construction footprint to ensure appropriate connection to existing waterways and/or drainage lines and ensure hydrologic conditions are maintained or impacts minimised where possible.

Indicative construction methods for permanent stormwater drainage are outlined in Table 6-8.

Table 6-8 Indicative stormwater drainage construction methods

Drainage type	Construction method
Drainage pipes	• Excavation of a trench in the existing ground surface • Installation of pre-cast concrete pipes placed in sections onto a bedding layer • Placement and compaction of select material around the pipes using hand-propelled compaction equipment, such as rammers or vibrating plates.
Installation of drainage pits and lids	• Excavation of pit location • Installation of pre-cast concrete pits, or casting the pit in-situ • Connection of pipes into concrete pits, which would be backfilled similar to the drainage pipes • Lids and inlets would be installed onto the pits and later incorporated into the kerbs and slabs • Installation of associated outlet structures.
Construction of box culverts	• Excavation of a trench in the existing ground surface • Concrete casting of culvert base slab in-situ • Installation of pre-cast culvert units • Backfilling, where required, using select material around the culverts and hand-propelled compaction equipment, such as rammers or vibrating plates • Installation of associated outlet structures.
Installation of flood walls	• Excavation of a foundation for the floodwall • Pour concrete foundation • Form, reinforce and pour concrete floodwall in panel sections.
Localised adjustment of a small section Burnt Bridge Creek and scour protection	• Localised diversion and protection of existing waterway • Excavation works including lowering and regrading of the creek channel to the required depth • Installation of box culvert base slab • Installation of box culvert units and redirect waterway into new box culvert • Backfill of installed box culvert units • Placement of scour protection • Landscaping and rehabilitation of the localised creek area.

6.5.5 Road pavement works

In areas where existing road pavements would be realigned and/or widened, pavements would be constructed to consist of similar pavement types to the existing road, and to meet Transport for NSW design standards.

Construction of areas of new surface roads would consist of both flexible and rigid pavements. Flexible pavements generally comprise the installation of an upper asphalt base layer (including an asphalt wearing course), placed on a granular or concrete sub-base. Installation of the sub-base pavement layer would involve the placement of material using trucks, excavators and graders, and compacted by vibratory rollers. A bitumen seal would be sprayed onto this layer of material, and aggregate would then be spread and rolled on top of the sprayed bitumen to create a waterproof seal.

Asphalt would be laid on top of the bitumen seal. Hot asphalt material would be transported to site in trucks from an off-site batching plant. Asphalt would be unloaded into paving machines, which would spread the asphalt to the required thickness. The asphalt surface would then be compacted by vibrating rollers and allowed to cool.

Rigid pavements generally comprise a concrete base (this may also include an asphalt wearing course), placed on a granular sub-base or concrete sub-base. The base or sub-base could be constructed using concrete pavers or they could be formed, with fixed forms set at the required pavement levels. Reinforcement would also be placed if required by the design. The concrete would be poured directly from agitator trucks into the concrete paver or into the forms.

Existing road pavements would be modified to integrate with the project where required. This may require milling and resurfacing of the existing pavements to tie-in with new road surfaces. These works are often required to be carried out at night when traffic numbers are reduced to enable the required lane closures.

Shared user path and cycleway pavements would be constructed to consist of similar pavement types to the existing paths, and to meet Transport for NSW design standards

Construction of the three shared user underpasses beneath the Wakehurst Parkway would be staged as part of the surface road works along the Wakehurst Parkway with further planning to include the potential of early access to one or more of the new underpasses. Controlled shared user access across Wakehurst Parkway would be limited but still available at all times with final access to all three underpasses available at the completion of construction works.

The extension of the existing shared user underpass beneath the Burnt Bridge Creek Deviation at Burnt Bridge Creek would be staged to maintain access at all times. Subject to final planning for staging of these works, short term detours may be required due to construction access restrictions.

6.5.6 Fauna connectivity structures

Three new fauna underpasses would be constructed along the Wakehurst Parkway as shown in Figure 6-28 and Figure 6-29. Fauna underpasses would be constructed using inverted U-shaped pre-cast concrete units placed on a cast concrete base slab. Following placement of the pre-cast units, the underpasses would be backfilled to the required new roadway level with select backfill material. An example of a fauna underpass is shown in Figure 6-22.

Additionally, three new fauna rope canopy bridges would be constructed about 910 metres and 1370 metres north of Kirkwood Street and 885 metres south of Aquatic Drive along Wakehurst Parkway. Three existing fauna rope canopy bridges would also be replaced by the project due to the widening of the Wakehurst Parkway. One of the fauna rope canopy bridges is located about 330 metres north of Kirkwood Street and the other two are located about 110 metres and 200 metres south of Aquatic Drive which were constructed as part of the Northern Beaches Hospital road upgrade project. Refer to Chapter 19 (Biodiversity) for further information on the management of biodiversity impacts from the project including measures to maintain the function of the existing fauna underpass on the Wakehurst Parkway north of Aquatic Drive during construction.

Figure 6-22 Example of a fauna underpass (Pacific Highway Upgrade, Woolgoolga to Ballina upgrade)

6.5.7 Surface finishing works

Surface finishing works would be carried out progressively during construction as areas are near completion and would include:

- Linemarking of new road pavement
- Installation of directional signage and other roadside furniture
- Final landscape treatments and rehabilitation works
- Local commercial and residential property adjustments required due to surface road changes
- Local road traffic calming measures.

6.6 New open space and recreation facilities at Balgowlah

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

Construction of the new and improved open space and recreation facilities at Balgowlah would be delivered progressively. Commencement of the staged works for the new open space and recreation facilities would be subject to completion of the consultation process described above.

Residual land, primarily to the east and north of the new access road, would progressively become available through the construction period, which would facilitate re-purposing it to the new open space and recreation facilities. This would allow it to be handed over progressively for use by the community. The new open space and recreation facilities to the west of the proposed access road, between the access road and Burnt Bridge Creek Deviation, would be constructed after completion of the project and then handed over to Northern Beaches Council.

An indicative layout of the new and improved open space and recreation facilities at Balgowlah is provided in Figure 5-28 of Chapter 5 (Project description).

6.7 Testing, commissioning and demobilisation

Testing and commissioning works would be carried out towards the completion of construction to validate the correct operation and integration of tunnel systems prior to road opening.

Site clean-up and demobilisation works would be carried out once construction activities have been completed at that location. This would include:

- Site demobilisation and rehabilitation of temporary construction support sites
- Post construction condition surveys
- Removal of construction-related signage
- Removal of construction-related environmental controls and traffic management infrastructure. In some instances, controls will remain in place until the environment has stabilised (eg vegetation is established).

Residual land refers to those lots that would be wholly or partially occupied during construction of the project but would not be required for operational infrastructure or other operational activities. Where land is leased for construction of the project, reinstatement and rehabilitation of the land would be carried out as part of demobilisation works, in consultation with and to meet the requirements of the relevant landowner.

Any future development of residual land would be subject to separate assessment and approval in accordance with the *Environmental Planning and Assessment Act 1979*. Additional detail about residual land not required following construction of the project is provided in Chapter 20 (Land use and property).

6.8 Construction footprint and temporary construction support sites

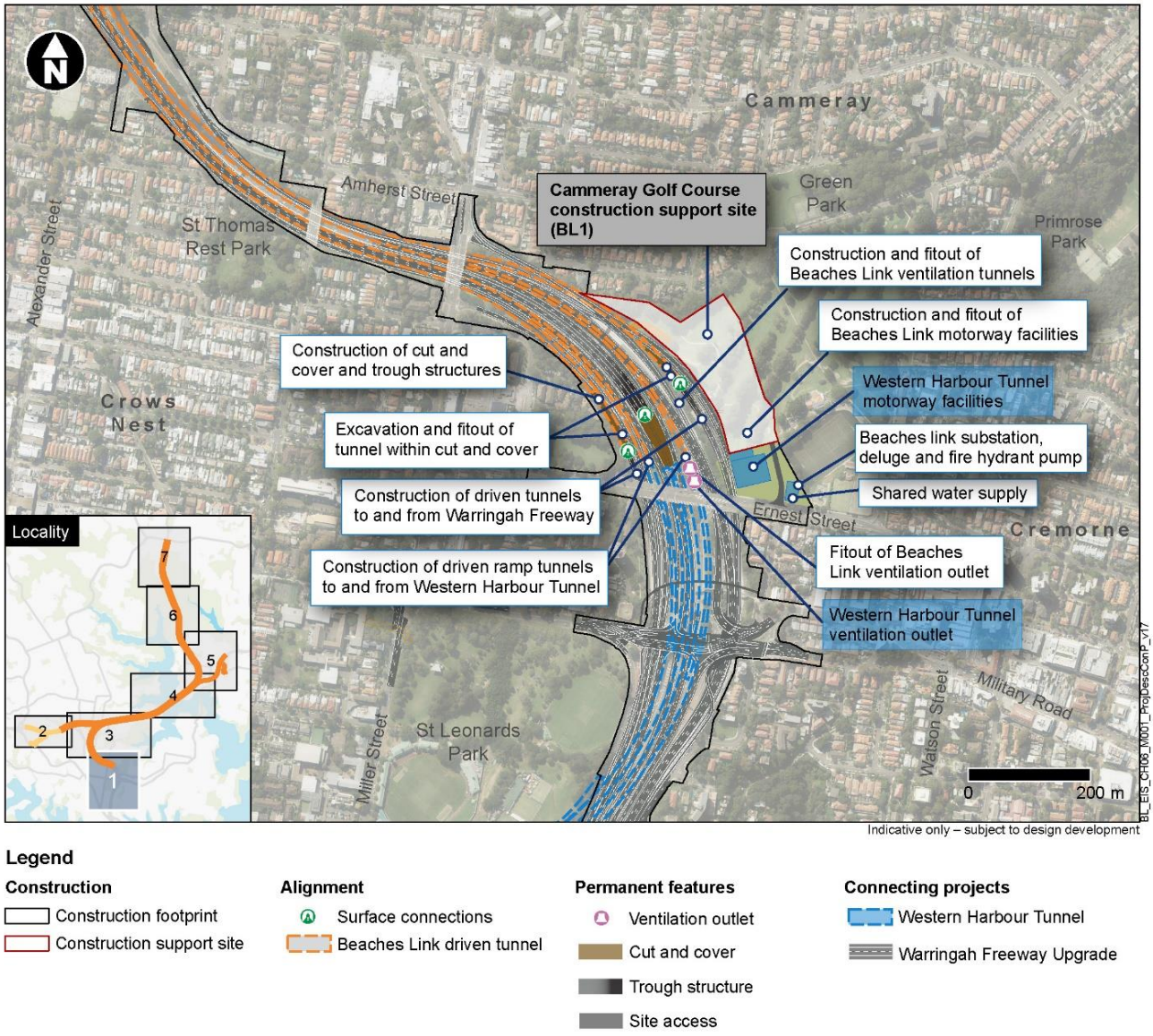
6.8.1 Construction footprint

The total area required for construction of the project is referred to as the construction footprint. The construction footprint consists of the anticipated area needed for the project and includes temporary construction support sites and additional areas where work would be required to construct the project. Temporary construction support sites required for the project are discussed in Section 6.8.2.

While a substantial amount of the work for the project would occur underground, temporary construction support sites on the surface would be required to support underground construction activities and to support and construct the surface connections, tunnel portals, surface road works including the realignment and upgrade of the Wakehurst Parkway, active transport facilities (pedestrian and cyclist facilities) and operational facilities.

Apart from the motorway facilities, cut and cover structures, trough structures and tunnelling works in Cammeray, the construction footprint shown on the Warringah Freeway would consist of low impact activities such as traffic control and management, line marking and staged surface roadworks tie in works, and utility and cable works required to connect to the Western Harbour Tunnel and Warringah Freeway Upgrade project and other local roads.

An overview of construction activities and the construction footprint is shown in Figure 6-23 to Figure 6-29.



Note: The Beaches Link construction footprint shown on Warringah Freeway within this area extends to include construction activities that would be associated with traffic control and management, line marking, tie-in works and utility and cable works.

Figure 6-23 Overview of construction activities and construction footprint (map 1)

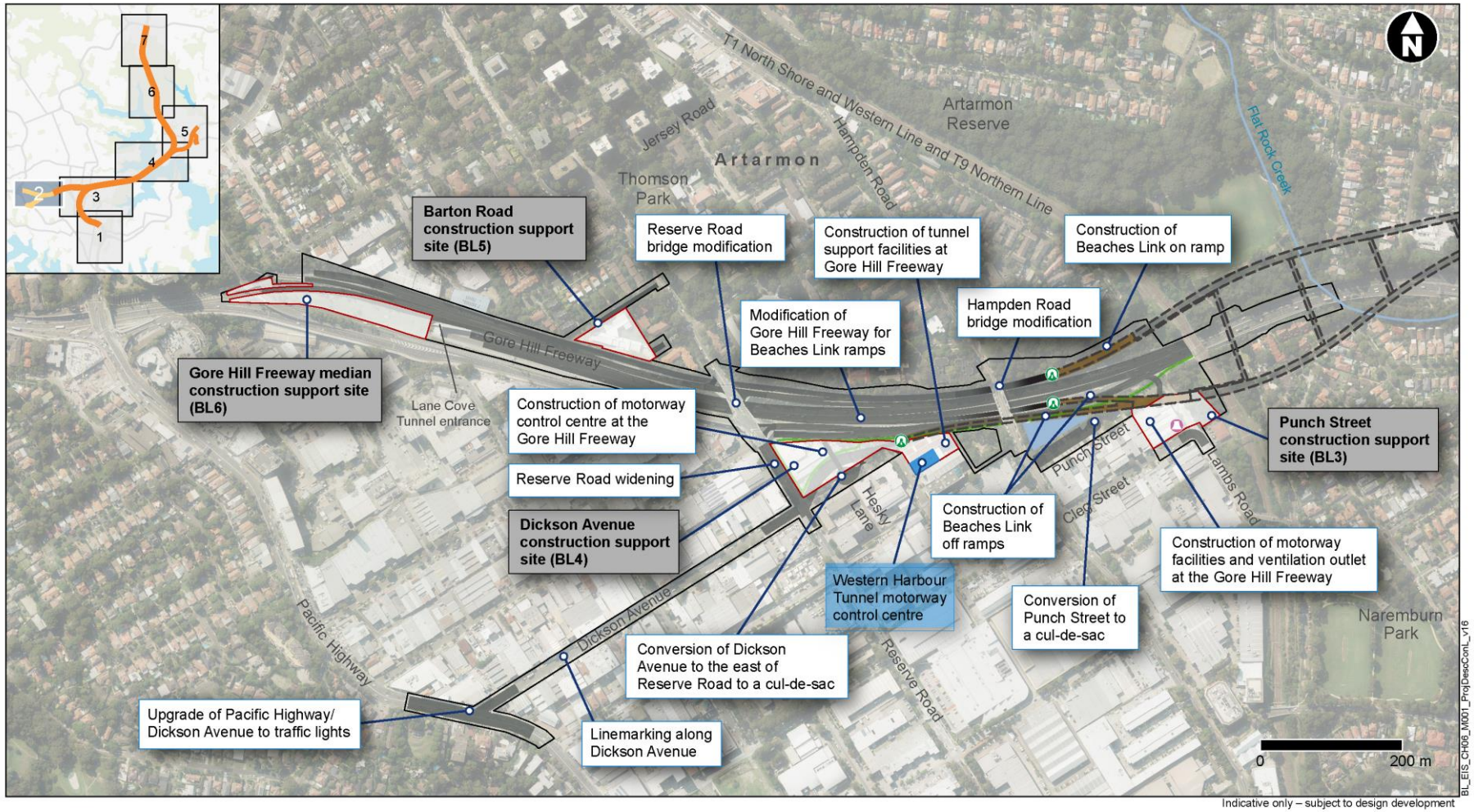
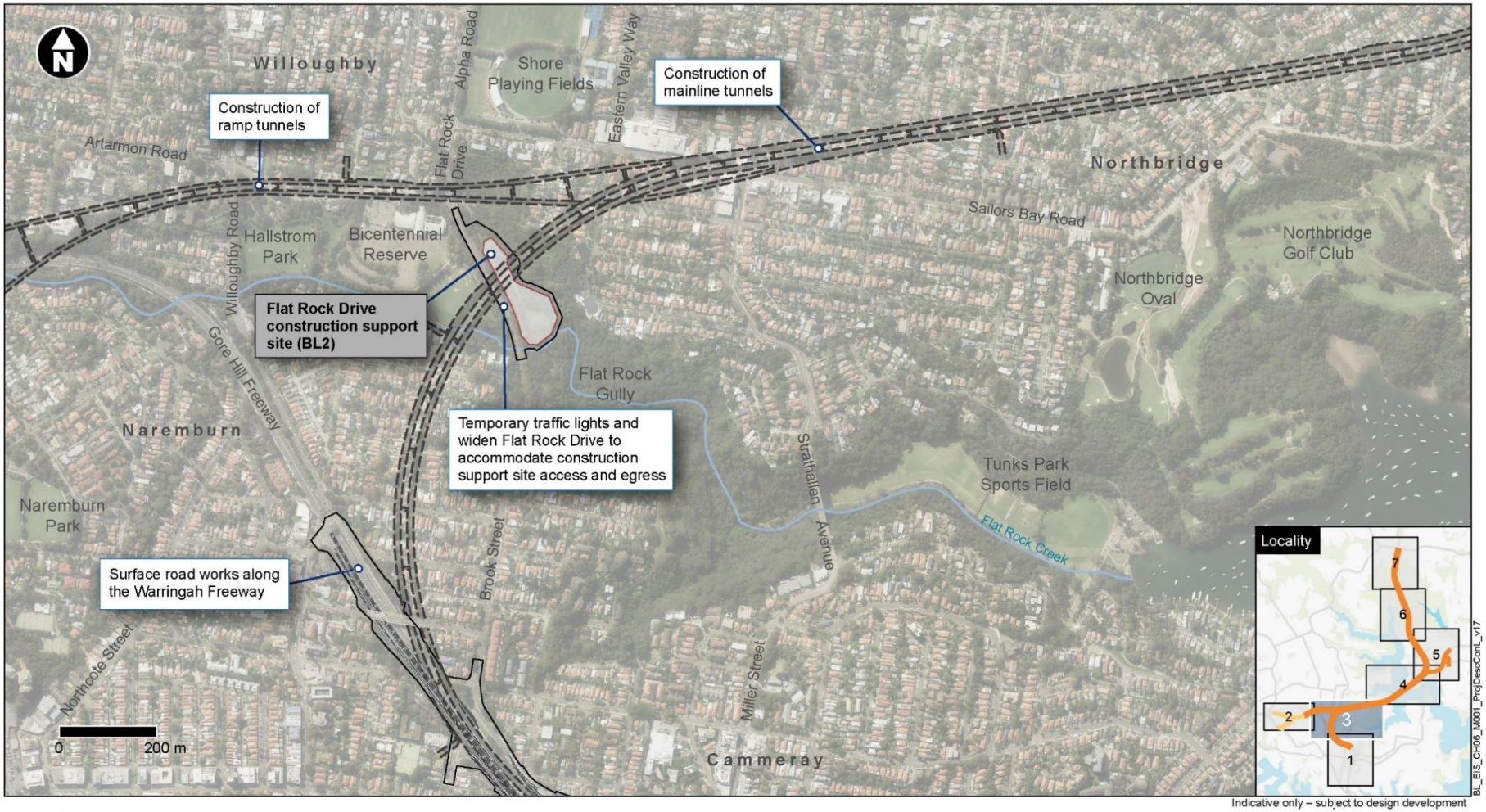


Figure 6-24 Overview of construction activities and construction footprint (map 2)



Note: The Beaches Link construction footprint shown on Warringah Freeway within this area extends to include construction activities that would be associated with traffic control and management, line marking, tie-in works and utility and cable works.

Figure 6-25 Overview of construction activities and construction footprint (map 3)

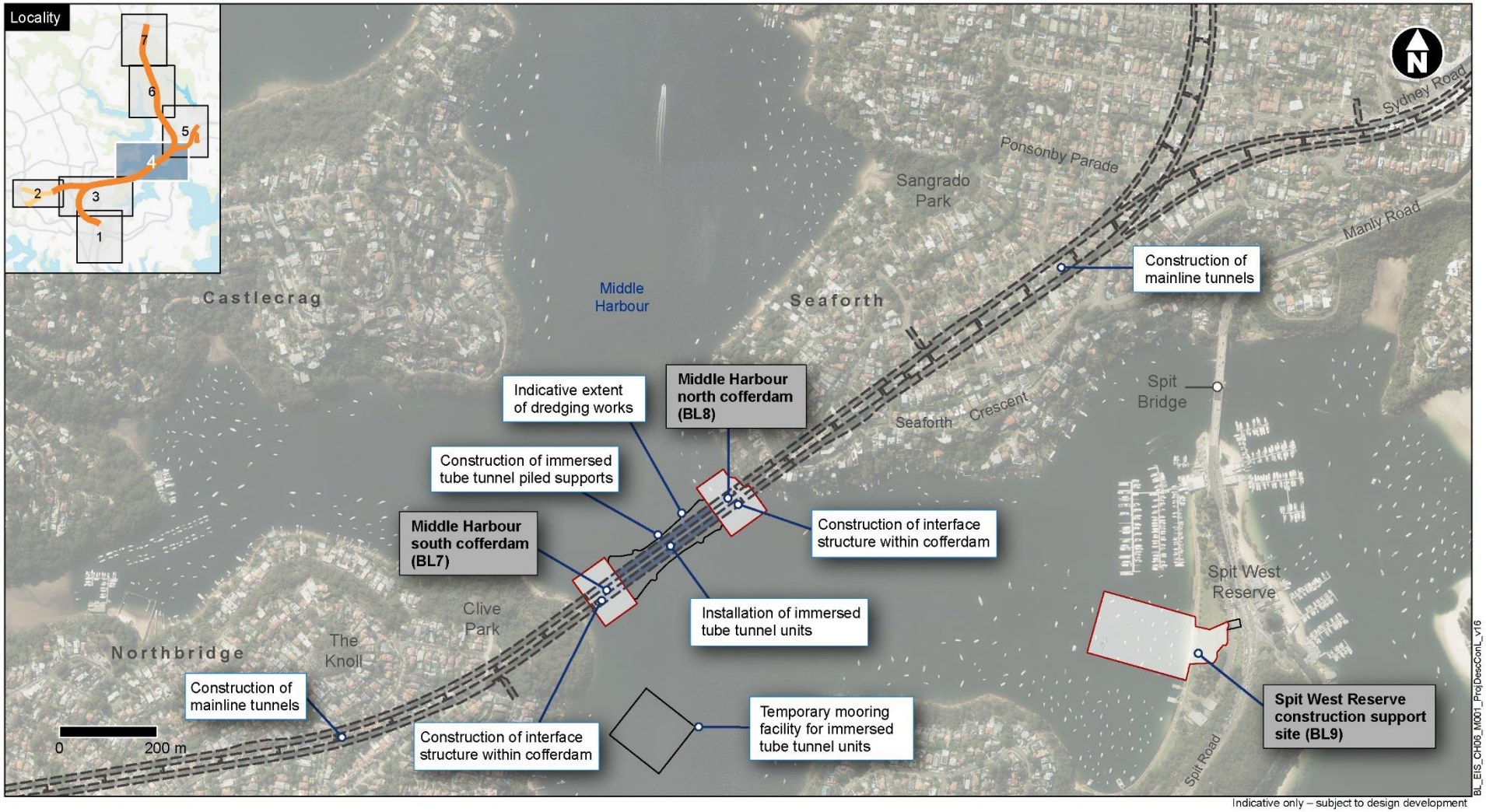
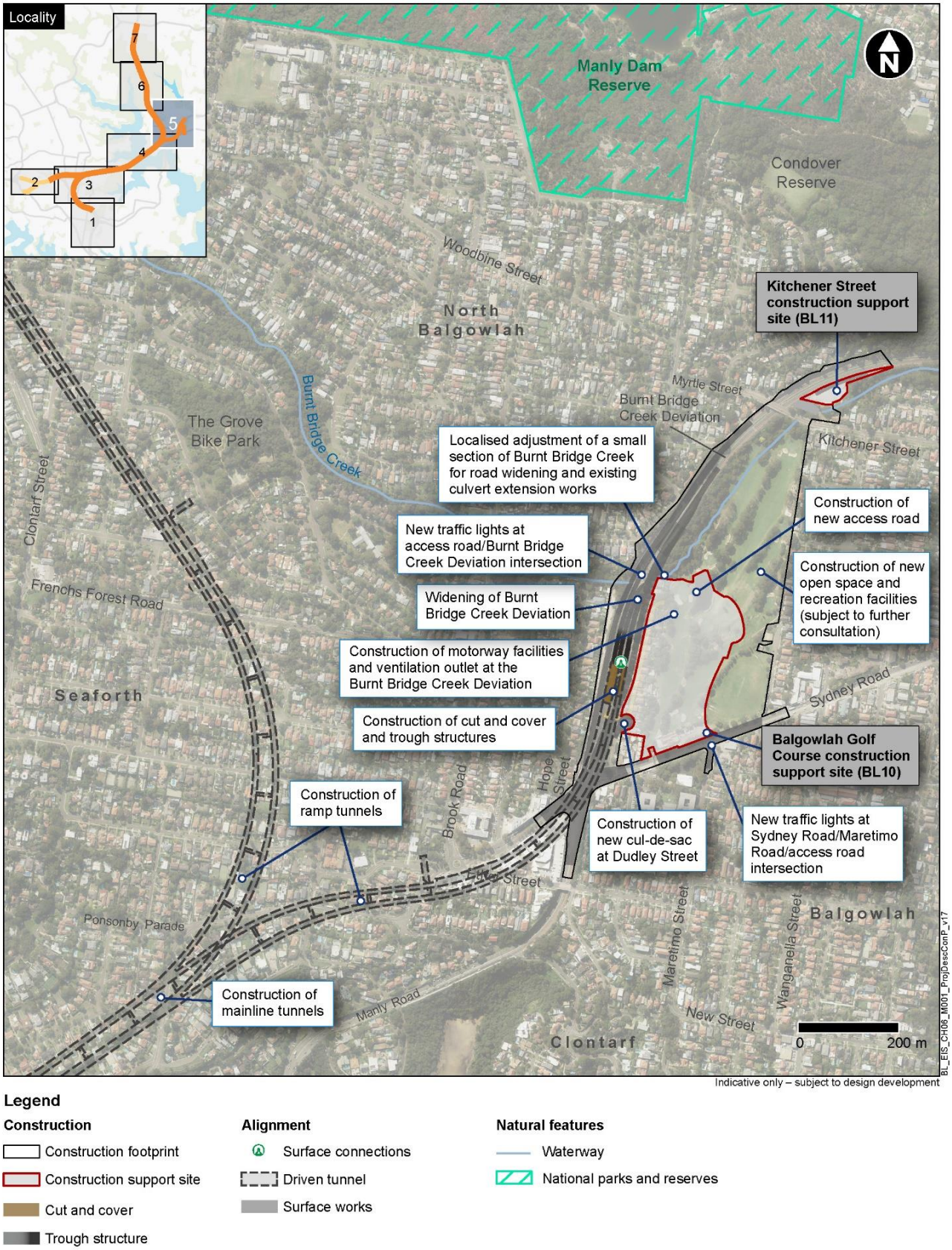


Figure 6-26 Overview of construction activities and construction footprint (map 4)



Legend

Construction

- Construction footprint
- Construction support site
- Cut and cover
- Trough structure

Alignment

- Surface connections
- Driven tunnel
- Surface works

Natural features

- Waterway
- National parks and reserves

Figure 6-27 Overview of construction activities and construction footprint (map 5)

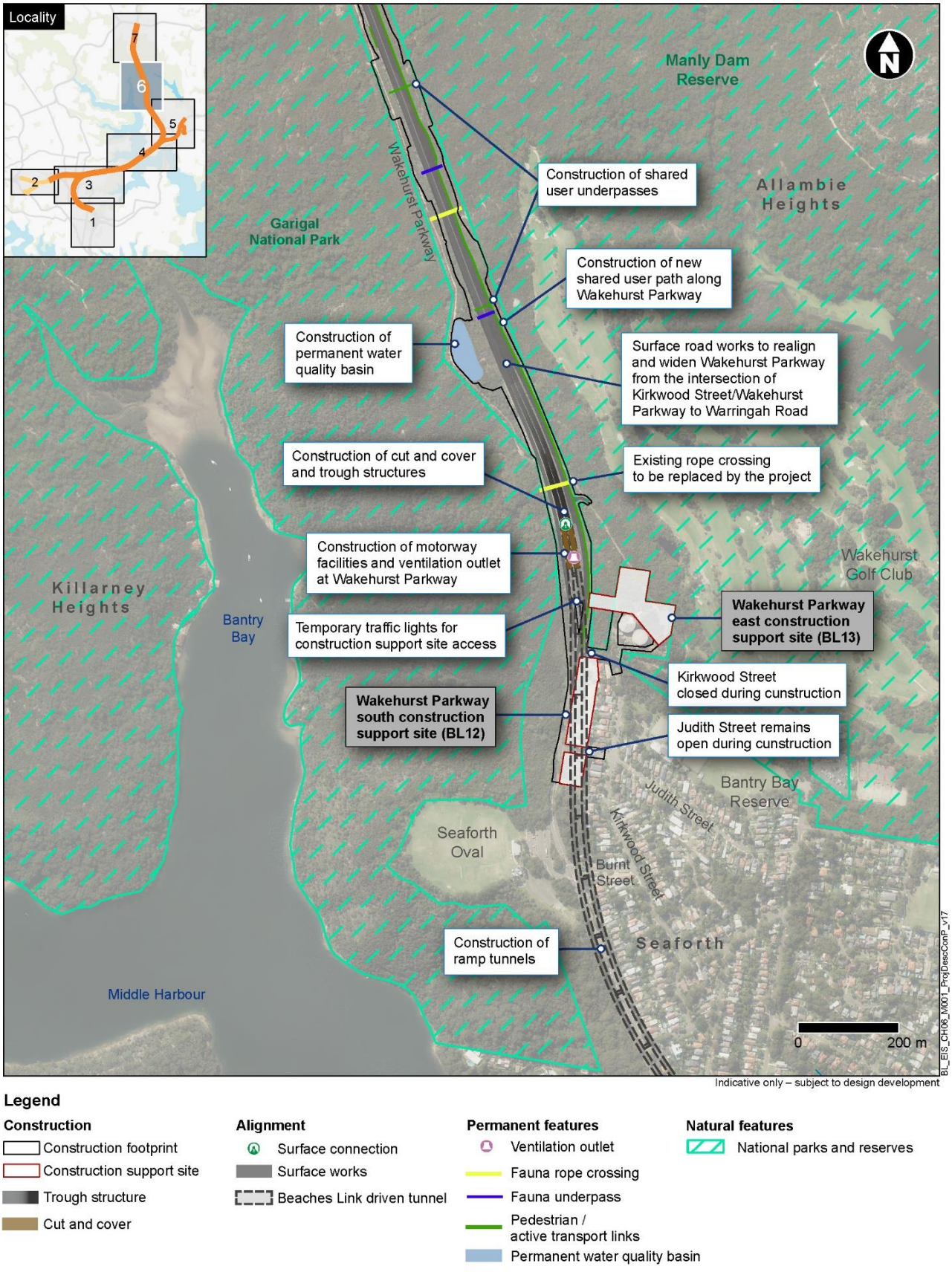


Figure 6-28 Overview of construction activities and construction footprint (map 6)

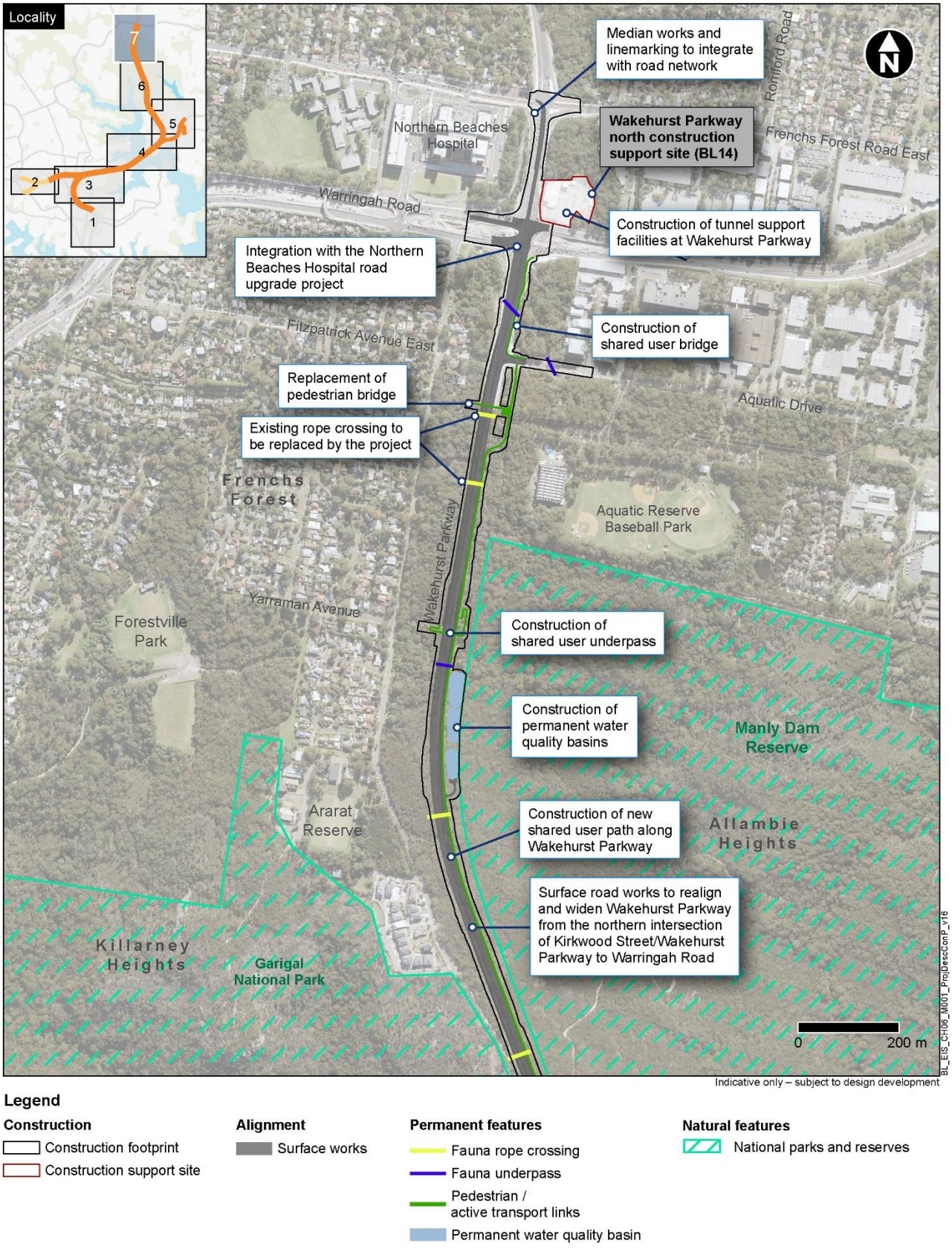


Figure 6-29 Overview of construction activities and construction footprint (map 7)

6.8.2 Beaches Link and Gore Hill Freeway Connection temporary construction support sites

Temporary construction support sites for the project would include tunnelling and tunnelling support sites, surface civil sites, cofferdams, mooring sites, wharf and berthing facilities, construction storage (laydown) areas, parking and workforce amenities.

All temporary construction support sites would have appropriate boundary fencing. This would be typical construction hoarding or security fencing. Where required, temporary noise barriers would be installed on the site boundary. Indicative locations are shown on the temporary construction support site figures (Figure 6-30 to Figure 6-42).

To support operation of the sites, power, potable water supply and suitable connection for stormwater and sewerage discharge would be required (discussed in Section 6.9.4).

Construction hours at temporary construction support sites would vary depending on the type of construction activity being carried out. Proposed hours for each temporary construction support site are outlined in the following sections and construction work hours associated with specific activities are detailed in Section 6.9.1.

The following sections describe the proposed temporary construction support sites and their anticipated functions/uses during construction.

Cammeray Golf Course (BL1)

A summary of the key features of the Cammeray Golf Course construction support site (BL1) is included in Table 6-9. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-30. An indicative program for construction activities is provided in Table 6-10.

Table 6-9 Key features of the Cammeray Golf Course construction support site (BL1)

Key feature	Summary
Site area	27,600 m^2
Site description	Located within the north-west portion of the Cammeray Golf Course. The site is bound by the Cammeray Golf Course to the north, Cammeray Golf Course and Cammeray Park to the east, Warringah Freeway to the west and Ernest Street to the south. Residential properties are located to the north on Warringa Road and Morden Street and to the south across Ernest Street.
Key activities	This site would be used for the construction and fitout of motorway facilities at the Warringah Freeway and would provide tunnel and construction support for the Beaches Link component of the project. The site would initially be established as a temporary construction support site for the Western Harbour Tunnel and Warringah Freeway Upgrade project and was assessed as part of the environmental impact statement for Western Harbour Tunnel and Warringah Freeway Upgrade (Transport for NSW, 2020b). The site has been designed and developed to minimise impacts to the golf course, and allow for a reconfigured nine-hole golf course to operate throughout construction and operation. Key activities that would occur on, or be supported by this site would include: • Site reconfigured for Beaches Link project works including construction and operation of temporary site facilities, including

Key feature	Summary
	an acoustic shed, workshop, wastewater treatment facility, air intake, staff offices and amenities, pavements and car parking • Excavation of a tunnelling access decline connecting to a modified ventilation tunnel • Excavation of driven mainline tunnels from Cammeray towards Naremburn • Excavation of shafts and ventilation tunnels for the ventilation outlet and motorway facilities at the Warringah Freeway • Construction and fitout of the Beaches Link motorway facilities and fitout of the ventilation outlet structure at the Warringah Freeway (the ventilation outlet civil works would be constructed as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project) • Construction support for the Beaches Link cut and cover and trough structures and their connection to the Warringah Freeway • Construction of the substation and operational support facilities • Treatment of wastewater from tunnelling activities • Excavation, handling and stockpiling of tunnel spoil • Utility works associated with surface works • Tunnel civil and mechanical and electrical fitout • Backfill access decline • Testing, commissioning and site rehabilitation.
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Tunnel construction and fitout would be carried out up to 24 hours per day, seven days per week either within an acoustic shed or underground. Night time deliveries would be required to support the tunnelling activities.
Access arrangements	Access in and out of the site would be primarily via Warringah Freeway around the location of the existing bus layover area at Cammeray. A secondary access would be provided at Ernest Street.

Note: Leasing and acquisition at this site would be carried out as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

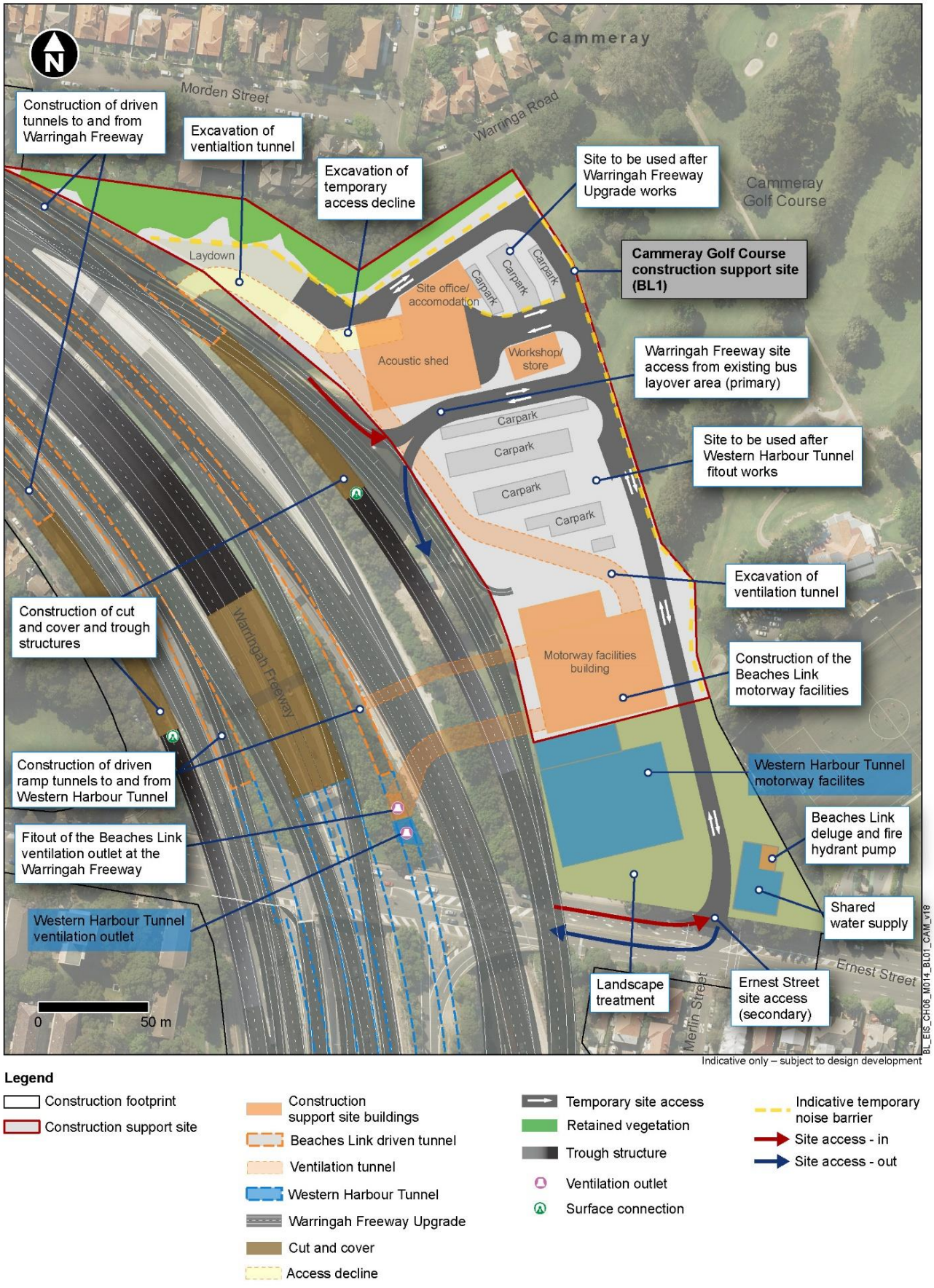


Figure 6-30 Indicative layout - Cammeray Golf Course construction support site (BL1)

Table 6-10 Cammeray Golf Course construction support site (BL1) indicative construction program

Construction activity	Indicative construction program															
	2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment																
Construction of tunnel access decline																
Tunnel construction																
Construction of cut and cover and trough structures																
Fitout of cut and cover and trough structures																
Tunnel fitout and finishing																
Construction of motorway facilities and fitout of ventilation outlet (civil works constructed by Western Harbour Tunnel and Warringah Freeway Upgrade project)																
Testing, commissioning and site rehabilitation																

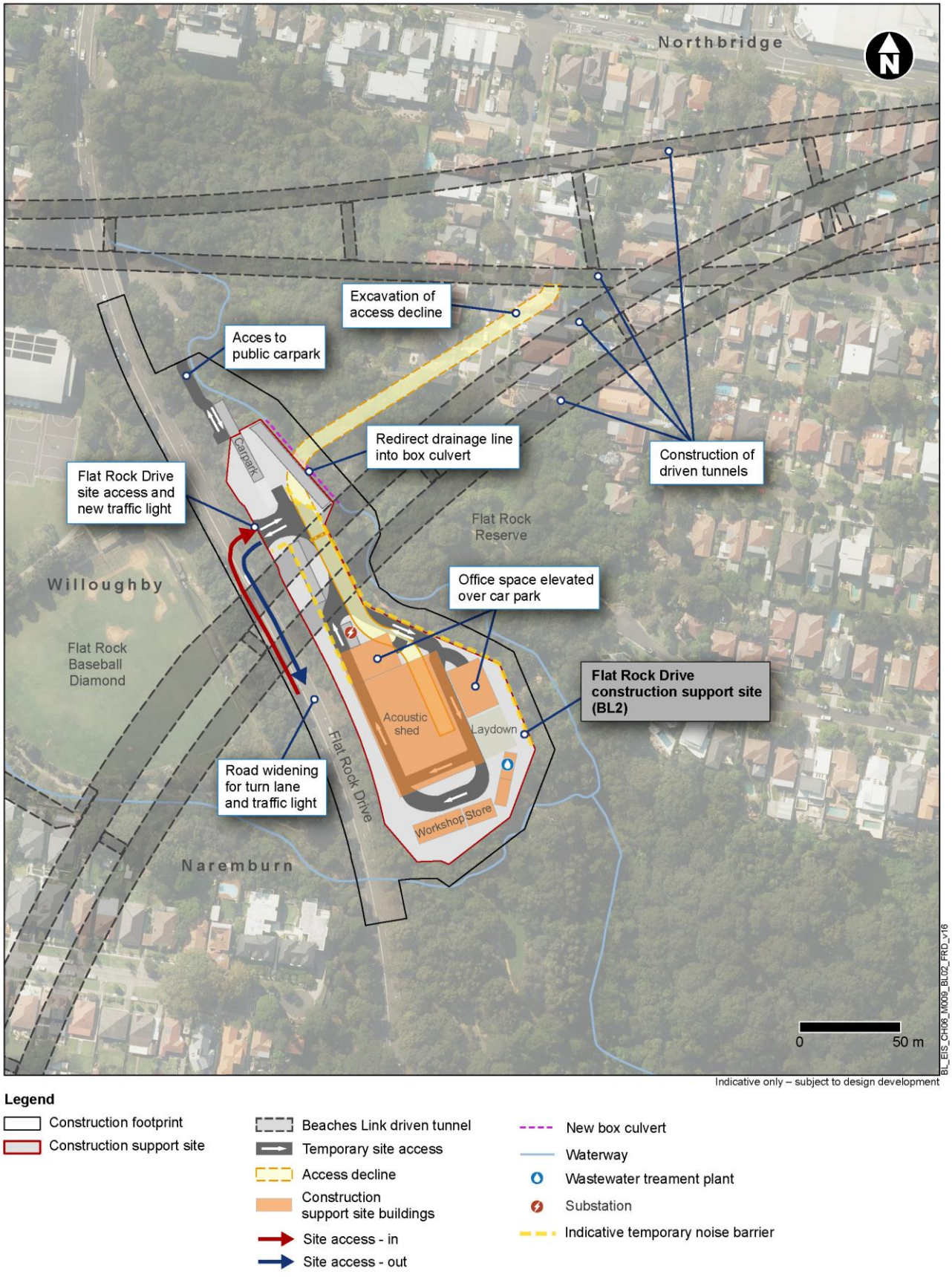
Flat Rock Drive (BL2)

A summary of the key features of the Flat Rock Drive construction support site (BL2) is included in Table 6-11. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-31. An indicative program for construction activities is provided in Table 6-12.

Table 6-11 Key features of the Flat Rock Drive construction support site (BL2)

Key feature	Summary
Site area	11,760 m^2
Site description	Located in Flat Rock Reserve, on the eastern side of Flat Rock Drive, opposite to the Flat Rock Baseball Diamond in Northbridge. This site was chosen to avoid direct impact on nearby residential or commercial properties, the Flat Rock Baseball Diamond, or the Willoughby Leisure Centre indoor facilities, netball courts or car park. It also provides direct access to and from the site via a main road, avoiding the need to use local roads for site access. The temporary construction support site is located on a revegetated former landfill site. Potentially contaminated materials disturbed during site establishment and access decline construction would be subject to further investigation, remediation and/or management. All identified contaminated materials would be managed during construction with the implementation of environmental management measures detailed Chapter 16 (Geology, soils and groundwater) and in accordance with the

Key feature	Summary
	Guideline for the Management of Contamination (Roads and Maritime Services, 2013a).
Key activities	This would be a tunnel support site. Key activities that would occur on, or be supported by, this site would include: • Support site works including the temporary diversion of existing shared user paths and walking tracks, clearing and grubbing, topsoil stripping, bulk earthworks, management of potentially contaminated waste, retaining structures to reshape and regrade existing reserve • Construction and operation of temporary site facilities, including an acoustic shed, temporary noise barriers, workshop, wastewater treatment facility, air intake, staff offices and amenities, pavements and car parking • Installation of a culvert in an existing aboveground watercourse within the northern extent of Flat Rock Reserve along the north eastern boundary of the site • Excavation of an access decline to the main tunnel alignment (via the westbound ramp tunnel connection at the Gore Hill Freeway) • Excavation of the main tunnel alignment towards both Cammeray and Middle Harbour and excavation of ramp tunnels toward Artarmon • Treatment of wastewater from tunnelling activities • Support for tunnel excavation works • Support for tunnel fitout and finishing works • Utility works associated with surface works • Excavation, handling and stockpiling of tunnel spoil • Backfill of access decline • Testing, commissioning and site rehabilitation.
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Tunnel construction and fitout would be carried out up to 24 hours per day, seven days per week either within an acoustic shed or underground. Night time deliveries would be required to support the tunnelling activities.
Access arrangements	Access in and out of the site would be via a temporary signalised intersection at Flat Rock Drive. Local surface works for road widening, shared user path and utility adjustments would be required on Flat Rock Drive to establish a traffic light intersection and turning lane. Road widening works would be carried out on the eastern side of Flat Rock Drive.



Note: The waterway includes a constructed surface creek, above ground concrete lined stormwater channels, a naturalised bedrock channel and an underground box culvert. Flat Rock Creek is within a box culvert from Willoughby Road to a point 150m east of Flat Rock Drive. Further detail on Flat Rock Creek characteristics is provided in Chapter 17 (Hydrodynamics and water quality) (refer to Figure 17-2).

Figure 6-31 Indicative layout - Flat Rock Drive construction support site (BL2)

Table 6-12 Flat Rock Drive construction support site (BL2) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment																				
Construction of tunnel access decline																				
Tunnel construction																				
Tunnel fitout																				
Testing, commissioning and site rehabilitation																				

Punch Street (BL3)

A summary of the key features of the Punch Street construction support site (BL3) is included in Table 6-13. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-32. An indicative program for construction activities is provided in Table 6-14.

Table 6-13 Key features of the Punch Street construction support site (BL3)

Key feature	Summary
Site area	4800 m^2
Site description	Located within the Artarmon industrial area, next to the T1 North Shore and Western Line and T9 Northern Line rail corridor, on the southern side of the Gore Hill Freeway. The western portion of the site is currently occupied by industrial buildings and the eastern portion is vegetated.
Key activities	This would be a tunnel support and project management site for Beaches Link. Key activities that would occur on, or be supported by this site would include: • Demolition of existing structures • Construction and operation of temporary site facilities, including an acoustic shed, temporary noise barrier, workshop, wastewater treatment facility, air intake, staff offices and amenities • Excavation of an access decline • Excavation of ramp tunnels and cross passages from the Gore Hill Freeway Artarmon to the mainline tunnels under Northbridge • Treatment of wastewater from tunnelling activities • Support for tunnel fitout and finishing works • Utility works associated with surface works including existing 132kV utility support works over cut and cover. Access for the service provider would be maintained throughout construction • Excavation, handling and stockpiling of tunnel spoil

Key feature	Summary
	• Construction of permanent operational facilities, including motorway facilities • Backfill access decline • Testing, commissioning and site rehabilitation.
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Tunnel construction and fitout would be carried out up to 24 hours per day, seven days per week either within an acoustic shed or underground. Night time deliveries would be required to support the tunnelling activities.
Access arrangements	Access into the site would be via Reserve Road and Cleg Street, and out of the site via Punch Street. An alternative heavy goods vehicle exit would be constructed and staged with the cut and cover works to connect directly to the Gore Hill Freeway westbound.

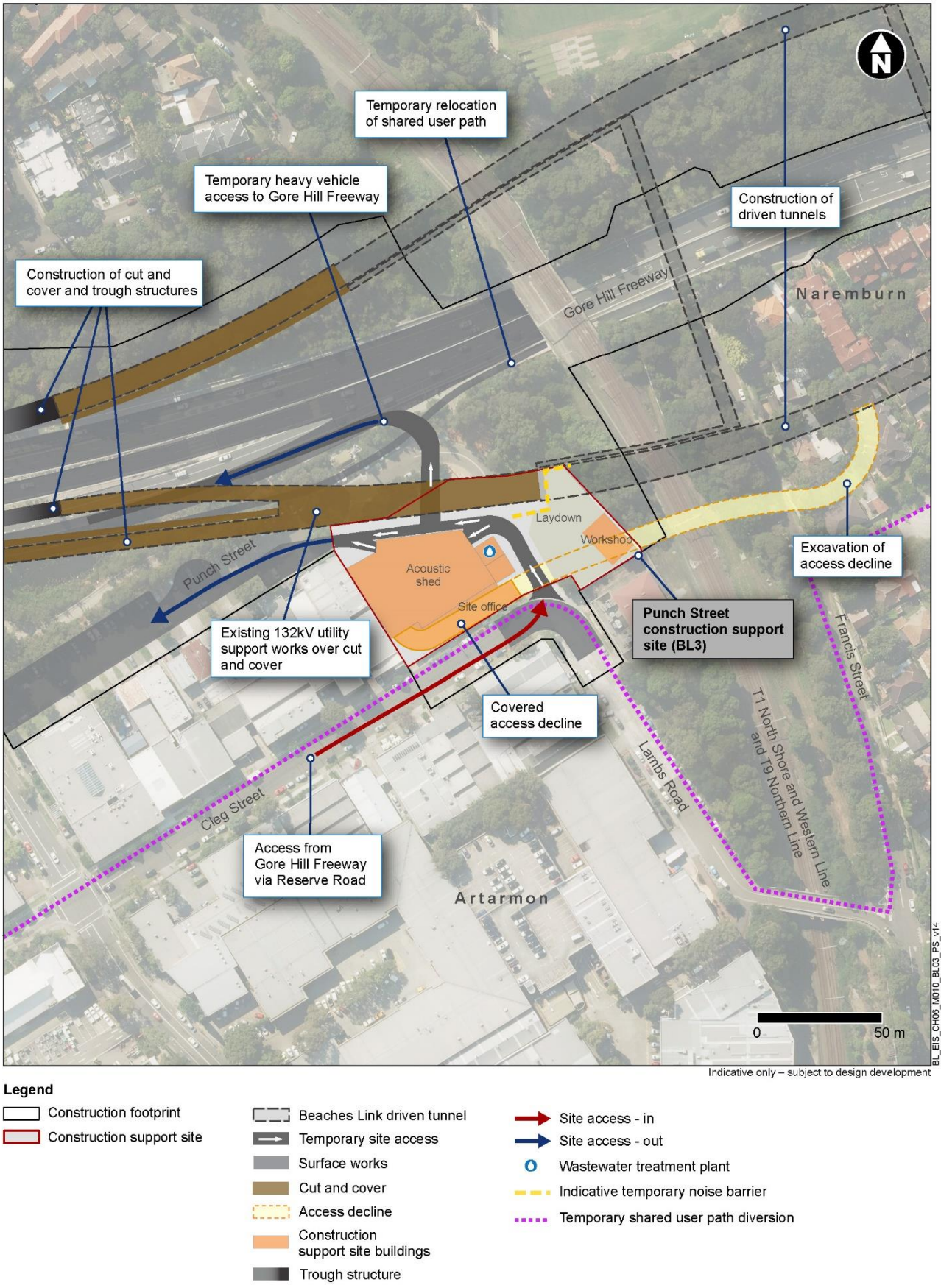


Figure 6-32 Indicative layout - Punch Street construction support site (BL3)

Table 6-14 Punch Street construction support site (BL3) indicative construction program

Construction activity	Indicative construction program															
	2023				2024				2025				2026			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment																
Excavation of tunnel access decline																
Tunnel construction																
Tunnel fitout																
Construction of operational facilities																
Testing, commissioning and site rehabilitation																

Dickson Avenue (BL4)

A summary of the key features of the Dickson Avenue construction support site (BL4) is included in Table 6-15. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-33. An indicative program for construction activities is provided in Table 6-16.

Table 6-15 Key features of the Dickson Avenue construction support site (BL4)

Key feature	Summary
Site area	9900 m^2
Site description	Located within the Artarmon industrial area, between Reserve Road, Dickson Avenue and Waltham Street, on the southern side of the Gore Hill Freeway. The site is currently occupied by industrial buildings and the Freeway Hotel. It is noted that an area in the eastern part of this site (off Waltham Street) would be occupied by the Western Harbour Tunnel motorway control centre (delivered as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project). The area allocated for the Western Harbour Tunnel motorway control centre is not currently proposed for use by the project for construction activities.
Key activities	The site would support construction activities for both the Beaches Link and Gore Hill Freeway Connection components of the project. The site would initially involve support site works including: • Demolition of existing structures • Construction and operation of temporary site facilities, including laydown areas, staff offices and amenities, pavements and car parking. For the Beaches Link construction works, the site would be used for supplementary support for tunnelling activities that occur from the Punch Street construction support site (BL3) and construction of operational facilities. For the Gore Hill Freeway Connection construction works the site would be used as a project management site and used for equipment laydown, car parking for construction workers and temporary site office buildings. Once most of the surface and tunnelling works have been completed, the temporary construction

Key feature	Summary
	support site would be rearranged to allow for construction of permanent infrastructure (ie the off ramp trough structures and surface works to Reserve Road, the motorway control centre and the tunnel support facility).
Hours of construction	General site activities, including construction of the motorway control centre and tunnel support facilities and most surface works, would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday and no construction works on Sundays or public holidays). Some construction activities (eg some more complex and constrained surface works and utility adjustments) supported by this site would require out of hours work due to site access restrictions and constraints presented by existing traffic staging requirements. This would require periods throughout the construction program where works at this site would occur outside of standard construction hours.
Access arrangements	Access in and out of the site would be via Dickson Avenue/Reserve Road.

Figure 6-33 Indicative layout - Dickson Avenue construction support site (BL4)

Table 6-16 Dickson Avenue construction support site (BL4) indicative construction program

Construction activity	Indicative construction program															
	2023				2024				2025				2026			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Beaches Link construction works																
Early works and site establishment																
Additional tunnel support at Punch Street																
Construction of operational facilities																
Testing and commissioning																
Gore Hill Freeway Connection construction works																
Early works and site establishment																
Construction of Gore Hill Freeway surface works and bridge modifications																
Construction of the off ramp trough and surface works to Reserve Road																
Site rehabilitation																

Barton Road (BL5)

A summary of the key features of the Barton Road construction support site (BL5) is included in Table 6-17. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-34. An indicative program for construction activities is provided in Table 6-18.

Table 6-17 Key features of the Barton Road construction support site (BL5)

Key feature	Summary
Site area	3830 m^2
Site description	Located on the northern side of Gore Hill Freeway, between Butchers Lane and Barton Road.
Key activities	Used for equipment laydown facilities, car parking for construction workers and temporary site office buildings associated with the Gore Hill Freeway Connection works.
Hours of construction	General site activities, including most surface works, would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday and no construction works on Sundays or public holidays). Some construction activities (eg some more complex and constrained surface works and utility adjustments) supported by this site would require out of hours work due to site access restrictions and constraints presented by existing traffic staging requirements. This would require periods throughout the construction program where works at this site would occur outside of standard construction hours.

Key feature	Summary
Access arrangements	Access in and out of the site would be via Barton Road and Butchers Lane, via Reserve Road.

Figure 6-34 Indicative layout - Barton Road construction support site (BL5)

Table 6-18 Barton Road construction support site (BL5) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment			▬	▬																
Construction support for surface works					▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬				
Site restoration and demobilisation																	▬	▬		

Gore Hill Freeway median (BL6)

A summary of the key features of the Gore Hill Freeway median construction support site (BL6) is included in Table 6-19. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-35. An indicative program for construction activities is provided in Table 6-20.

Table 6-19 Key features of the Gore Hill Freeway median construction support site (BL6)

Key feature	Summary
Site area	7700 m^2
Site description	Located within the Gore Hill Freeway road corridor on top of the Lane Cove Tunnel portal. The site is currently a grassed area with scattered juvenile and mature trees.
Key activities	Used for equipment laydown facilities associated with the Gore Hill Freeway Connection works.
Hours of construction	General site activities, including most surface works, would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday and no construction works on Sundays or public holidays). Some construction activities (eg some more complex and constrained surface works and utility adjustments) supported by this site would require out of hours work due to site access restrictions and constraints presented by existing traffic staging requirements. This would require periods throughout the construction program where works at this site would occur outside of standard construction hours.
Access arrangements	Access into the site would be primarily via Gore Hill Freeway, a secondary access would be provided via Epping Road. Access out of the site would be via Gore Hill Freeway (eastbound).

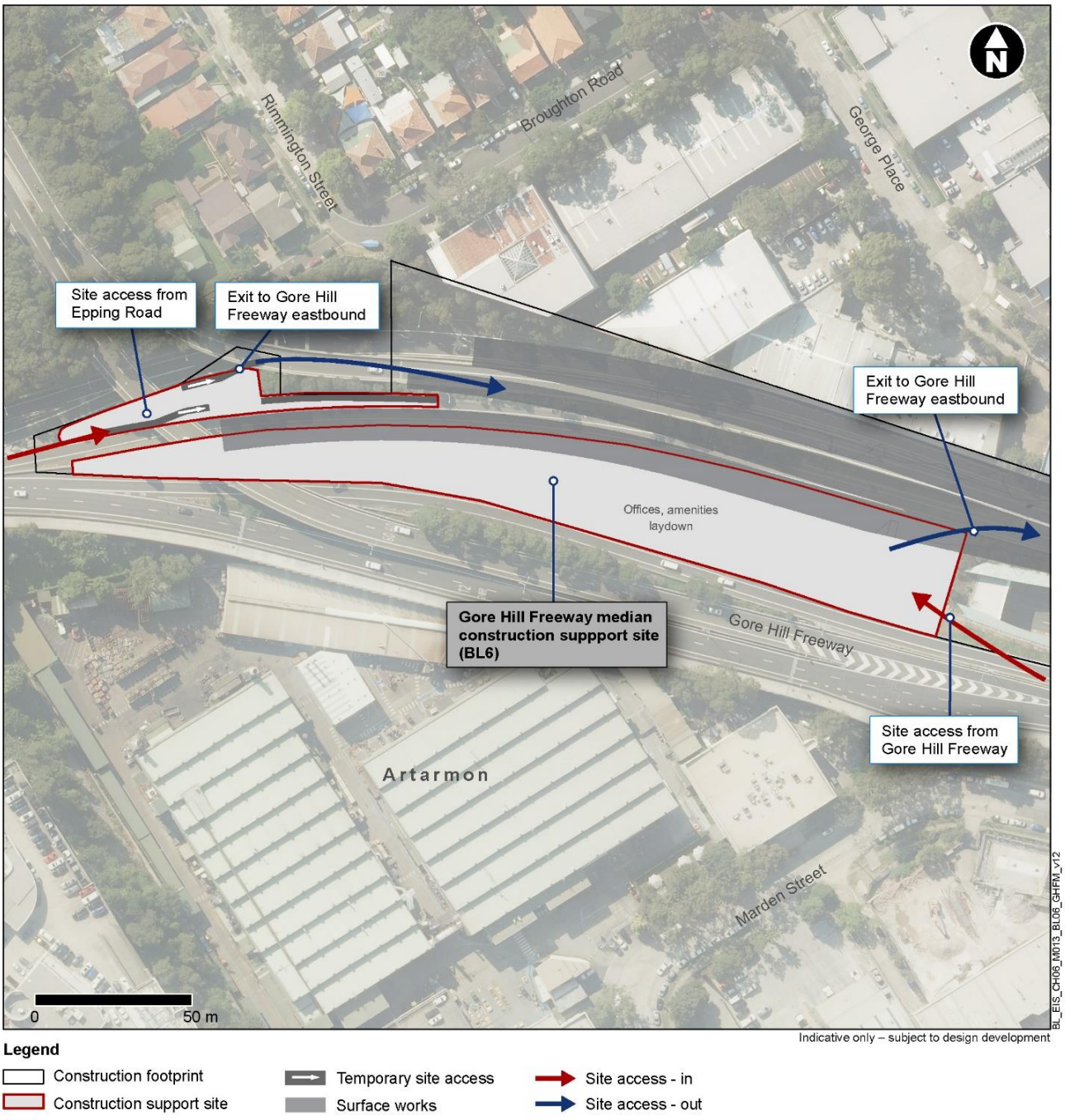


Figure 6-35 Indicative layout - Gore Hill Freeway median construction support site (BL6)

Table 6-20 Gore Hill Freeway median construction support site (BL6) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment			▬	▬																
Construction support for surface works					▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬				
Site restoration and demobilisation																	▬	▬		

Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8)

A summary of the key features of the Middle Harbour cofferdams (BL7 and BL8) is included in Table 6-21. An indicative layout for the cofferdams is shown in Figure 6-36. An indicative program for construction activities is provided in Table 6-22. Marine transport routes are shown in Figure 6-36.

Table 6-21 Key features of the Middle Harbour cofferdam construction support sites (BL7 and BL8)

Key feature	Summary
Site area	9200 m^2 (BL7) and 9900 m^2 (BL8)
Site description	Temporary cofferdams would be constructed at each end of the Middle Harbour crossing and within the harbour off the shore at Northbridge to the south and Seaforth to the north. Access would be from Spit West Reserve construction support site (BL9).
Key activities	The cofferdams would facilitate construction of the interface structures which connect the driven mainline tunnels and the immersed tube tunnel units. Key activities that would occur on, or be supported by, these sites would include: • Temporary relocation of about 10 moorings below Seaforth Bluff • Construction of temporary cofferdam structure, including ground treatment, piling, dewatering, installation of structural steel supports and excavation • Construction of interface structure (connection between the driven tunnels and the immersed tube tunnels, refer to Section 6.5.4) within the cofferdams • Construction support from the water, including the use of a work barge (such as a flat top barge as shown in Figure 6-12, and barge movements for transfer of dredged material, deliveries and staff transport • Construction of immersed tube tunnel piled supports • Removal of cofferdam structure and site rehabilitation. Alternative facilities (swing mooring or marina berth) would be provided nearby for the users of the three fixed jetties below Seaforth Bluff that would have access restricted during construction.

Key feature	Summary
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Rock hammering, piling and dredging would be carried out during standard construction hours only. However, certain activities may be carried out up to 24 hours per day, seven days per week. This would include dewatering of cofferdams. Some transport by barge to the designated offshore disposal site may take place outside standard construction hours. It is noted that weekends are typically the busiest period for recreation including recreational boating, and this would be considered during detailed construction planning stages to minimise impacts to recreational activities and residents.

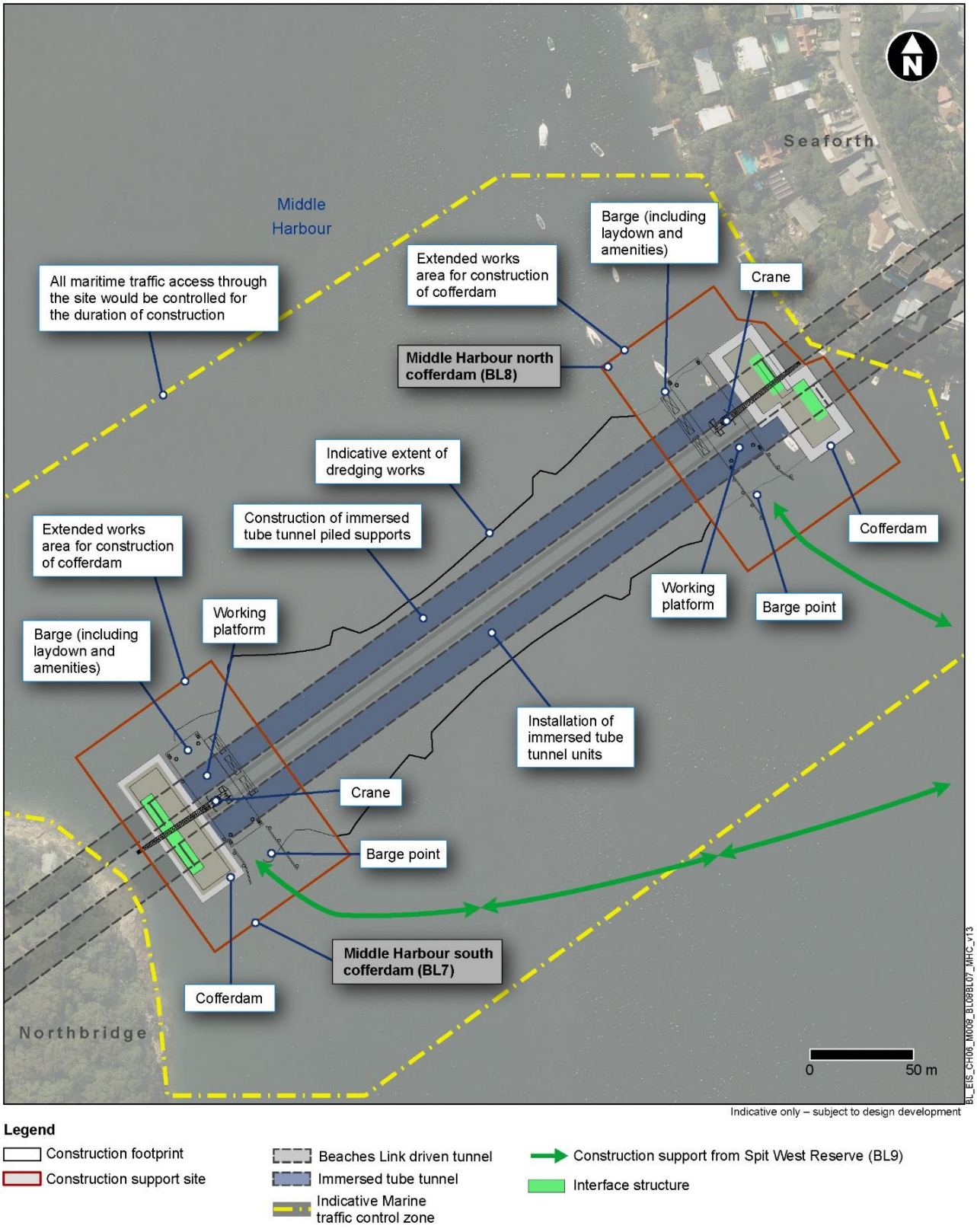
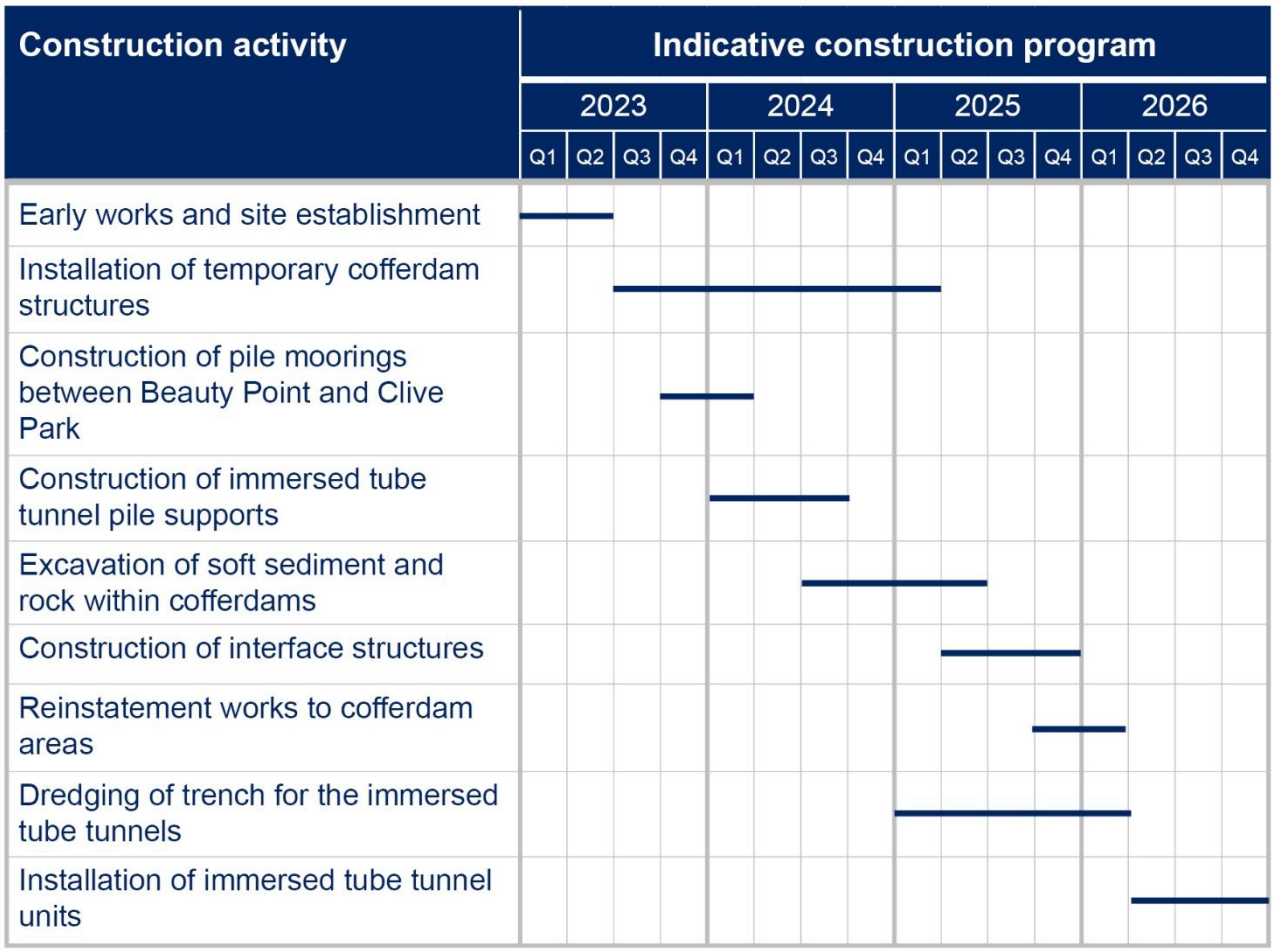


Figure 6-36 Indicative layout – Middle Harbour cofferdams (BL7 and BL8)

Table 6-22 Middle Harbour cofferdams (BL7 and BL8) and other activities indicative construction program



Spit West Reserve (BL9)

A summary of the key features of the Spit West Reserve construction support site (BL9) is included in Table 6-23. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-37. An indicative program for construction activities is provided in Table 6-24. Marine transport routes are shown in Figure 6-43.

Table 6-23 Key features of the Spit West Reserve construction support site (BL9)

Key feature	Summary
Site area	26,000 m^2 (water area) and 4500 m^2 (land area)
Site description	Located primarily in the water west of Spit West Reserve, with a small adjoining land-based site. The land-based site is currently a public recreational space. However, a section of the land-based site has been recently used to support construction of the Northern Beaches B-Line infrastructure.
Key activities	The temporary construction support site will include a land-based support site facility in Spit West Reserve including car park, access road, laydown area and shed. The proposed support site works would include construction of a temporary floating immersed tube tunnel casting facility that would be connected to Spit West Reserve by two temporary fixed jetties.

Key feature	Summary
	The floating facility and fixed jetties will require the installation of temporary piling and associated marine structures. The casting facility would provide space for two immersed tube tunnel units to be cast concurrently. The site would also provide support for: • Middle Harbour cofferdams • Interface structures • Immersed tube tunnel unit support piles • Dredging works • Immersed tube tunnel immersion • Immersed tube tunnel granular backfill placement • Site rehabilitation. A mooring location would be provided in Middle Harbour to the west of the Spit West Reserve site to temporarily moor the immersed tube tunnel units prior to immersion. The mooring location would provide space for four immersed tube tunnel units. The proposed mooring location is shown in Figure 6-43. The Spit West Reserve construction support site (BL9) would require the relocation of about 45 moorings in Middle Harbour for about two years. In an effort to minimise impacts to traffic during peak periods and consideration of the limited construction footprint, the construction workforce would be transported to the site by a bus from the Balgowlah Golf Course construction support site (BL10), where required. Following the completion of construction works, both the marine and land-based sites would be rehabilitated and landscaped.
Hours of construction	General site activities would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). Where possible concrete pours would be scheduled to take place within standard construction hours; however, the process of casting the tunnel elements may require some works outside of standard construction hours. Support works (immersion and installation) for the immersed tube tunnel installation would be required on six occasions for continuous periods lasting between 24 to 48 hours for each unit.
Access arrangements	Access in and out of the site would be via Spit Road. Barge access would also service this site.

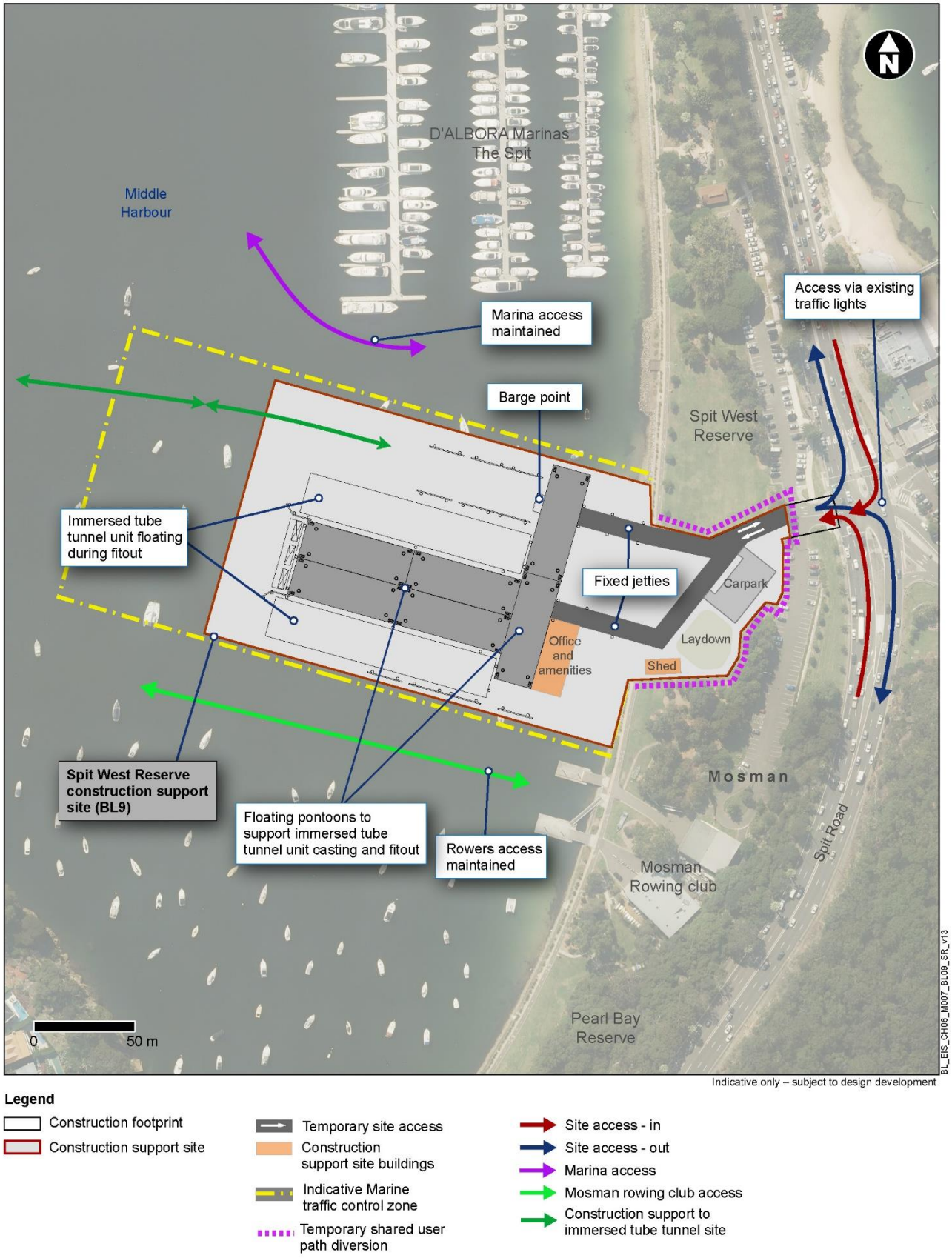


Figure 6-37 Indicative layout – Spit West Reserve construction support site (BL9)

Table 6-24 Spit West Reserve construction support site (BL9) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment																				
Cofferdam support works																				
Immersed tube tunnel unit pile support works																				
Immersed tube tunnel unit casting and fitout																				
Dredging support works																				
Support for the installation of immersed tube tunnel units																				
Site rehabilitation																				

Balgowlah Golf Course (BL10)

A summary of the key features of the Balgowlah Golf Course construction support site (BL10) is included in Table 6-25. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-38. An indicative program for construction activities is provided in Table 6-26.

Table 6-25 Key features of the Balgowlah Golf Course construction support site (BL10)

Key feature	Summary
Site area	74,250 m^2
Site description	Located partially within Balgowlah Golf Course and on privately owned lots on Dudley Street.
Key activities	This would be a tunnel support site, surface works support site and project management site. Key activities that would occur on, or be supported by this site would include: • Demolition of existing structures • Construction and operation of temporary construction facilities, including an acoustic shed, temporary noise barriers, workshops, wastewater treatment facility, air intake, staff offices and amenities, pavements and car parking and concrete batch plant • Localised adjustment of a small section of Burnt Bridge Creek for road widening and existing culvert extension works • Construction of new and improved open space and recreation facilities (refer to Section 6.6 and Chapter 5 (Project description) for further detail). Construction would be staged and the final layout would subject to a dedicated consultation process with the community and jointly led by Transport for NSW and Northern Beaches Council

Key feature	Summary
	• Excavation of an access decline to the ramp tunnel alignment • Excavation of the tunnels and cross passages under Seaforth between Balgowlah and Middle Harbour • Treatment of wastewater from tunnelling activities • Excavation, handling and stockpiling of tunnel spoil • Support for tunnel fitout (driven and immersed tube tunnels) and finishing works • Utility works associated with surface works, the temporary construction site, and permanent operational infrastructure • Support for cut and cover works, trough works, surface works and road widening works at Burnt Bridge Creek Deviation and Sydney Road • Construction of a new access road between Burnt Bridge Creek Deviation and Sydney Road to provide connectivity between the project and Sydney Road and service future users of the new and improved open space and recreation facilities. This would include construction of new traffic lights at both the new Sydney Road and Burnt Bridge Creek Deviation intersections. A car park would also be constructed for users of the open space and recreation facilities • Construction of permanent operational facilities, including a ventilation outlet and motorway facilities • Additional support for construction of the immersed tube tunnels at the Spit West Reserve construction support site (BL9) • Construction of new active transport links through the new and improved open space and recreation facilities and along the widened section of Burnt Bridge Creek Deviation • Backfill of access decline • Testing, commissioning and site rehabilitation.
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Limited out of hours work would be required to stage traffic lanes during surface works construction, to minimise disruption to the road network and to ensure safety of road users, construction personnel and the public, and for delivery of oversized equipment. Tunnel construction and fitout would be carried out up to 24 hours per day, seven days per week either within an acoustic shed or underground. Night time deliveries would be required to support the tunnelling activities.
Access arrangements	Access in and out of the site would be via Burnt Bridge Creek Deviation and Sydney Road.

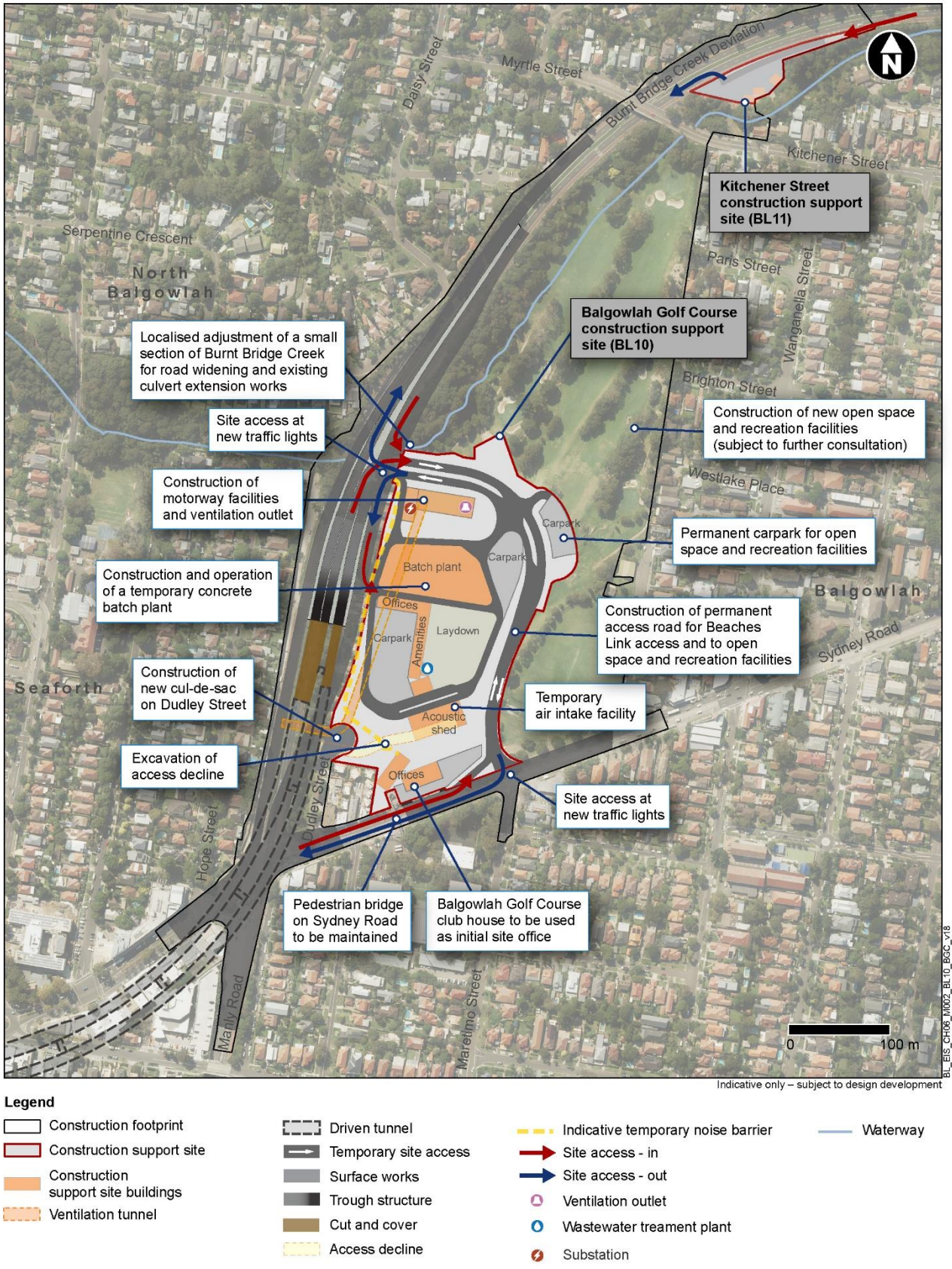


Figure 6-38 Indicative layout – Balgowlah Golf Course construction support site (BL10)

Table 6-26 Balgowlah Golf Course construction support site (BL10) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027				2028			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment																								
Construction of tunnel access decline and ventilation tunnel																								
Tunnel construction																								
Surface works (including cut and cover and trough structures)																								
Construction of operational facilities																								
Tunnel fitout and finishing (driven and immersed tube tunnels)																								
Testing, commissioning and site rehabilitation																								
New and improved open space and recreation facilities at Balgowlah (subject to further consultation)																								

Kitchener Street (BL11)

A summary of the key features of the Kitchener Street construction support site (BL11) is included in Table 6-27. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-39. An indicative program for construction activities is provided in Table 6-28.

Table 6-27 Key features of the Kitchener Street construction support site (BL11)

Key feature	Summary
Site area	5400 m^2
Site description	Located next to Burnt Bridge Creek Deviation directly north of Kitchener Street bridge. The site is currently unoccupied and largely comprises cleared gravel space bordered by mature trees and shrubs. An adjacent property at 36 Kitchener Street is owned by Transport for NSW and is intended to be used by the project as a site office and amenities. The property is included within the construction footprint and should it be used as a site office, an access road would be provided to connect to the construction support site shown in Figure 6-38. This would be confirmed during further design development.
Key activities	The site would support the surface road works and utility relocation works along Burnt Bridge Creek Deviation.

Key feature	Summary
Hours of construction	General site activities would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays.
Access arrangements	Access in and out of the site would be via the existing southbound lanes of Burnt Bridge Creek Deviation. Limited access for light vehicles would be via Kitchener Street.

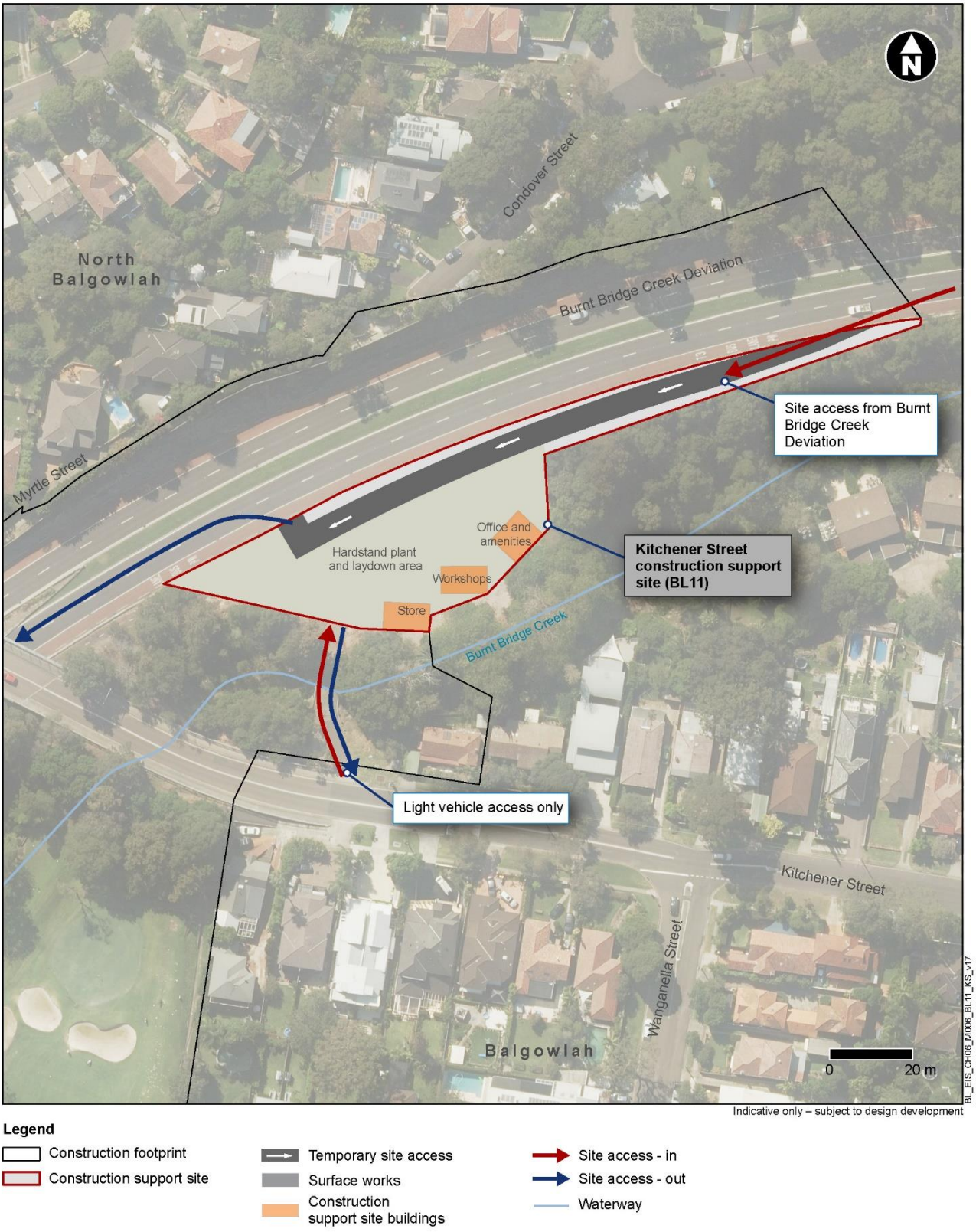


Figure 6-39 Indicative layout – Kitchener Street construction support site (BL11)

Table 6-28 Kitchener Street construction support site (BL11) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment																				
Support surface road works at Burnt Bridge Creek Deviation																				
Support utility relocation works																				

Wakehurst Parkway south (BL12)

A summary of the key features of the Wakehurst Parkway south construction support site (BL12) is included in Table 6-29. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-40. An indicative program for construction activities is provided in Table 6-30.

Table 6-29 Key features of the Wakehurst Parkway south construction support site (BL12)

Key feature	Summary
Site area	10,200 m^2
Site description	Located on the eastern side of Wakehurst Parkway just south of Judith Street and Kirkwood Street at Seaforth.
Key activities	Key activities that would occur on, or be supported by, this site would include: • Support site works including clearing and grubbing, topsoil stripping, bulk earthworks, minor retaining structures to reshape and regrade existing site • Construction and operation of temporary site facilities, including a workshops, staff offices and amenities, pavements and car parking • Support the upgrade of Wakehurst Parkway and also the construction of the cut and cover tunnel and trough and motorway facilities at Wakehurst Parkway • Supplementary office support for tunnelling works at Wakehurst Parkway east construction support site (BL13).
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Occasional works outside of standard hours to support traffic staging and switches on the Wakehurst Parkway and intersection modifications during site establishment may be required.
Access arrangements	Access in and out of the site would be via Judith Street and Kirkwood Street directly to the Wakehurst Parkway.

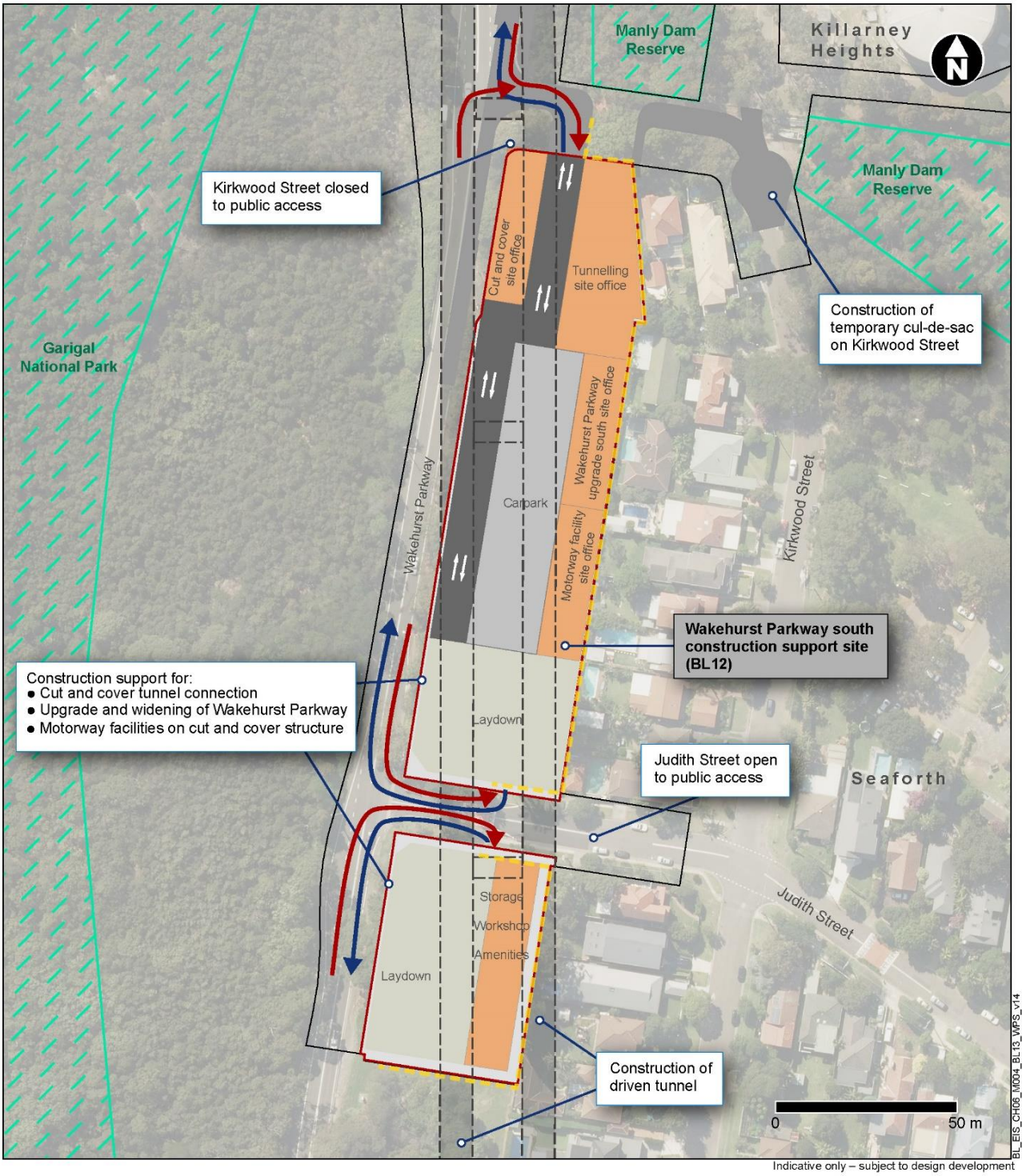


Figure 6-40 Indicative layout – Wakehurst Parkway south construction support site (BL12)

Table 6-30 Wakehurst Parkway south construction support site (BL12) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment																				
Surface road works support																				
Cut and cover and trough support																				
Motorway facilities support																				
Testing, commissioning and site rehabilitation																				

Wakehurst Parkway east (BL13)

A summary of the key features of the Wakehurst Parkway east construction support site (BL13) is included in Table 6-31. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-41. An indicative program for construction activities is provided in Table 6-32.

Table 6-31 Key features of the Wakehurst Parkway east construction support site (BL13)

Key feature	Summary
Site area	11,000 m^2
Site description	Located on the eastern side of Wakehurst Parkway, on land within Sydney Water's Bantry Bay Reservoir site, next to the Wakehurst Parkway Golf Course. The site is mostly level and includes vegetated areas that would be cleared as part of the site establishment works. Sydney Water facility operations and the on-site Telstra tower would remain operational for the duration of the construction activities on the site. Existing driveways and services crossings would be upgraded as required to suit access for heavy vehicles.
Key activities	The Wakehurst Parkway east construction support site (BL13) would be a tunnel support site and project management site. The site would be used for the construction of Beaches Link tunnelled ramps between the Wakehurst Parkway and the mainline tunnels beneath Seaforth. Key activities that would occur on, or be supported by this site would include: • Support site works including clearing and grubbing, topsoil stripping, bulk earthworks, minor retaining structures to reshape and regrade existing site • Construction and operation of temporary construction facilities, including an acoustic shed, temporary noise barrier, workshop, wastewater treatment facility, air intake and staff offices and amenities, pavements and car parking • Excavation of an access decline • Construction of the Wakehurst Parkway tunnel ramps to mainline tunnels at Seaforth

Key feature	Summary
	• Treatment of wastewater from tunnelling activities • Support for tunnel fitout and finishing works • Utility works associated with surface works, the temporary construction site, and permanent operational infrastructure • Excavation, handling and stockpiling of tunnel spoil • Backfill of access decline • Testing, commissioning and site rehabilitation.
Hours of construction	General site activities and spoil haulage would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday). No spoil haulage or surface civil works would occur on Sundays or public holidays. Tunnel construction and fitout would be carried out up to 24 hours per day, seven days per week either within an acoustic shed or underground. Night time deliveries would be required to support the tunnelling activities.
Access arrangements	Access in and out of the site would be via a new temporary connection to the Wakehurst Parkway.

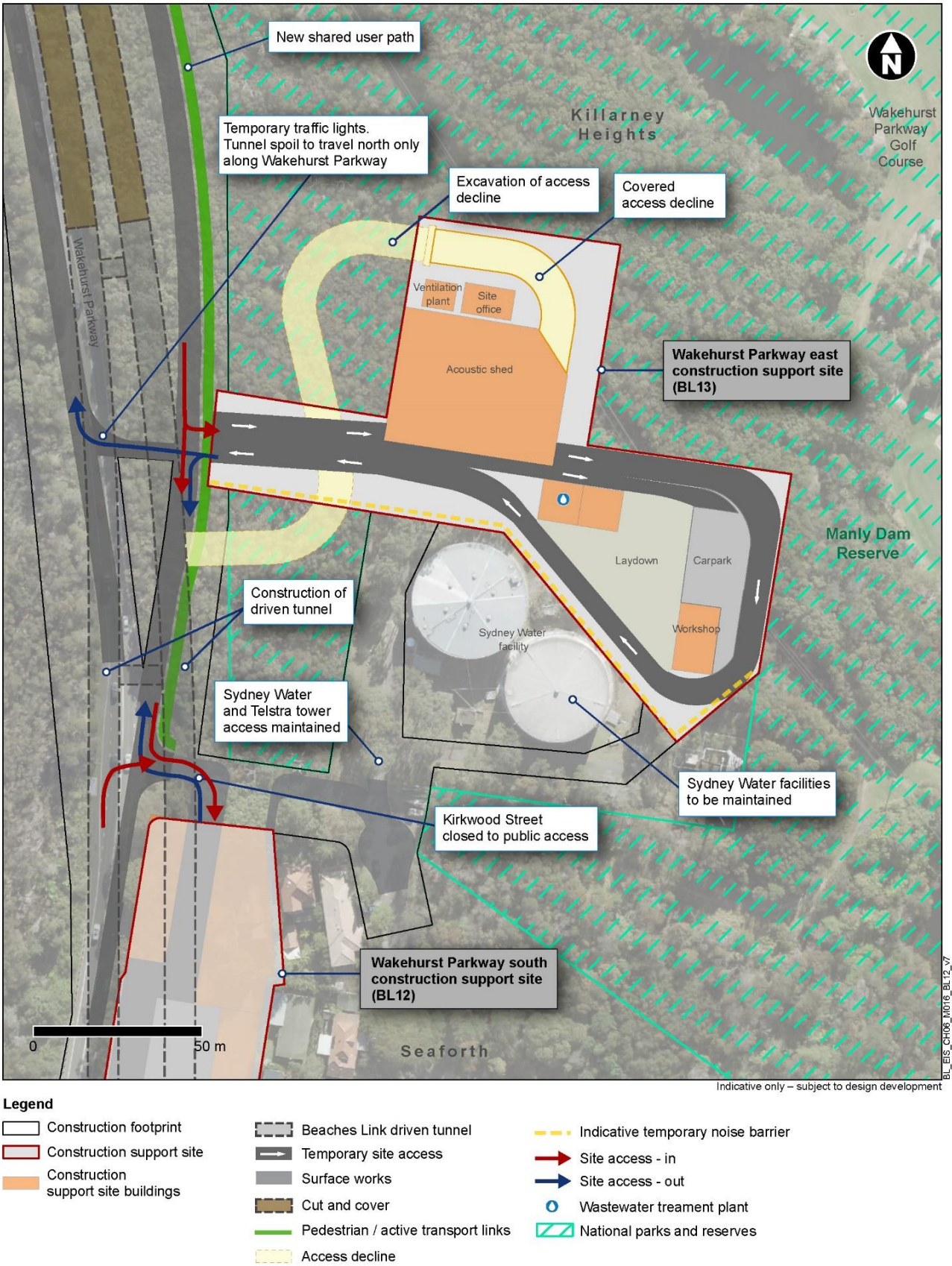


Figure 6-41 Indicative layout – Wakehurst Parkway east construction support site (BL13)

Table 6-32 Wakehurst Parkway east construction support site (BL13) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment																				
Construction of tunnel access decline																				
Tunnel construction																				
Tunnel fitout																				
Testing, commissioning and site rehabilitation																				

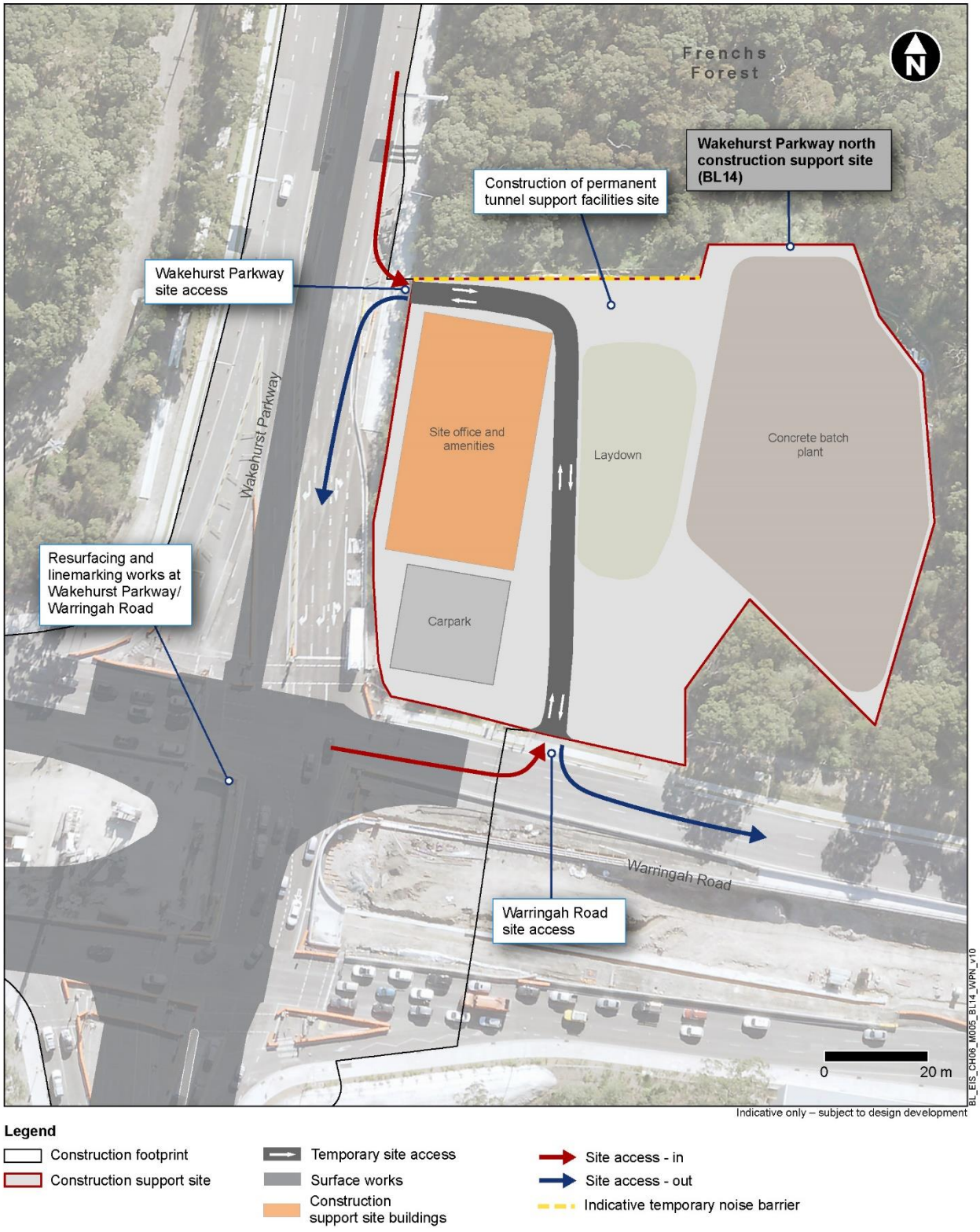
Wakehurst Parkway north (BL14)

A summary of the key features of the Wakehurst Parkway north construction support site (BL14) is included in Table 6-33. An indicative layout for the temporary construction support site, and construction site access routes, is shown in Figure 6-42. An indicative program for construction activities is provided in Table 6-34.

Table 6-33 Key features of the Wakehurst Parkway north construction support site (BL14)

Key feature	Summary
Site area	8400 m^2
Site description	The Wakehurst Parkway north construction support site (BL14) would be located on the north-east corner of the intersection between Wakehurst Parkway and Warringah Road at Frenchs Forest. The same site was used as the main construction support site for the Northern Beaches Hospital road upgrade project, which was completed in August 2020. Revegetation works were carried out within the Northern Beaches Hospital road upgrade project's main construction support site as part of decommissioning. This included planting with species consistent with the Duffys Forest endangered ecological community within the eastern section of the decommissioned construction support site. During site establishment of the Wakehurst Parkway north construction support site (BL14), this revegetated area would remain fenced off and protected from disturbance. Due to the timing of these recent revegetation works, the current site layout of Wakehurst Parkway north construction support site (BL14) does not show the revegetation area. During further design development and construction planning, the temporary construction support site layout would be refined to show the revegetation area, and ensure it is avoided and protected during construction.

Key feature	Summary
Key activities	Key activities that would occur on, or be supported by this site would include: • Construction and operation of temporary construction facilities, including a temporary noise barrier, workshop, staff offices and amenities, pavements and car parking and concrete batch plant • Construction works for Wakehurst Parkway surface road works, minor intersection works at Wakehurst Parkway/Warringah Road and Wakehurst Parkway/Frenchs Forest Road East and construction of the permanent tunnel support facilities.
Hours of construction	General site activities would be carried out during standard construction hours (7am to 6pm Monday to Friday, 8am to 1pm Saturday and no construction works on Sundays or public holidays). Occasional night time deliveries to the site may be required. This site would support occasional night staging works that are necessary for upgrading Wakehurst Parkway between Seaforth and Warringah Road at Frenchs Forest.
Access arrangements	Access in and out of the site would be via Warringah Road. Access from the site would also be provided onto Wakehurst Parkway.



Note: The indicative layout does not show the revegetation area associated with the recent demobilisation of the Northern Beaches Hospital road upgrade project. During further design development and construction planning, the temporary construction support site layout would be refined to ensure the revegetated area is avoided and protected.

Figure 6-42 Indicative layout – Wakehurst Parkway north construction support site (BL14)

Table 6-34 Wakehurst Parkway north construction support site (BL14) indicative construction program

Construction activity	Indicative construction program																			
	2023				2024				2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Early works and site establishment																				
Surface road works																				
Construction of operational facilities																				
Testing, commissioning and site rehabilitation																				

6.9 Construction management and resources

6.9.1 Construction workforce and hours

Construction workforce

The project would be expected to support up to 7500 full time equivalent jobs (direct employment) during the five to six years of construction. About 2350 full time equivalent jobs (2000 for Beaches Link and 350 for the Gore Hill Freeway Connection) would be expected to be supported during peak construction.

Construction work hours

Construction work hours required for the project would generally fall within the following categories:

- Early works and site establishment
- Tunnelling, tunnelling support and underground activities
- Construction traffic for material supply and spoil movement
- Surface construction activities (not covered by the other categories)
- Blasting and rock breaking
- Other activities.

The proposed construction hours for various construction activities are provided in Table 6-35. Standard construction hours from the *NSW Interim Construction Noise Guideline* (DECC, 2009a) are:

- 7am to 6pm Monday to Friday
- 8am to 1pm Saturday
- No construction works on Sundays or public holidays.

Recent planning approval conditions for State significant infrastructure projects have included an extension to standard construction hours on Saturdays, allowing certain activities to be carried out until 6pm. This approval condition has been provided on other major infrastructure projects such as Sydney Gateway, M6 Motorway (Stage 1) and WestConnex M4-M5 Link. Should the project construction contractor elect to use this additional allowance on Saturdays to shorten the construction program and reduce the overall duration of impacts to amenity, site specific construction noise and vibration impact statements prepared for the project will assess any associated noise impacts and adopt appropriate noise mitigation measures accordingly.

Out of hours works would be carried out in specific circumstances at any time, subject to individual requirements for safety and public infrastructure operational reasons (ie to minimise traffic disruptions). Specific management measures would be developed for each relevant activity or

group of activities to manage potential impacts on sensitive receivers (refer to Chapter 10 (Construction noise and vibration) for further details on management of out of hours work). This would include use of respite periods.

Table 6-36 to Table 6-38 provides the proposed out of hours work, locations and an indicative duration of the work outside standard construction hours required. The indicative duration may change as the further construction planning.

Indicative timeframes for construction activities are provided in Table 6-35. The proposed construction hours at each of the temporary construction support sites are summarised in Section 6.8.

Table 6-35 Proposed construction hours

Activity	Construction hours	Comments or exceptions
Early works and site establishment	Standard construction hours and works outside of standard construction hours	Works that require lane occupancy or are immediately adjacent to live traffic would be required outside of standard construction hours to minimise impacts to road users and for the safety of both construction personnel and the public.
Tunnelling, tunnelling support and underground activities		
Underground tunnel excavation and tunnel fitout	Up to 24 hours per day, seven days per week	Tunnelling using roadheaders would occur 24 hours per day, seven days a week, due to each excavation cycle taking around eight to 10 hours (dependent on geological conditions). Once complete, newly excavated sections need to be supported immediately to ensure the tunnel is stable and minimise any potential ground movement. This work cannot be completed entirely during a work shift in standard construction hours. Some other tunnel excavation activities using rock hammers might also need to occur outside standard construction hours for the above reasons.
Surface-based support of underground tunnelling, activities and tunnel fitout	Up to 24 hours per day, seven days per week	Surface-based activities at temporary construction support sites are typically required to support underground tunnelling and tunnel fitout. The support activities would need to occur 24 hours per day, seven days per week when tunnelling and tunnel fitout are occurring. Spoil handling outside of standard construction hours at the surface would be carried out within acoustic sheds at tunnel temporary construction support sites.
Dewatering of cofferdams during construction and filling	Standard construction hours and outside	Dewatering required to create a relatively dry and safe environment to allow the construction of the interface structures.

Activity	Construction hours	Comments or exceptions
of cofferdams during removal	standard construction hours	Pump operation is not expected to generate noise in excess of the applicable noise management level at any sensitive receiver.
Dredging and excavation of the bed of the harbour, and barge movements for associated marine spoil transportation	Standard construction hours	Dredging works would be carried out during daytime hours. Some transport by barge to the designated offshore disposal site may take place outside standard construction hours.
Piling works in Middle Harbour	Standard construction hours	Required for construction of the cofferdams and at the temporary mooring facility east of Clive Park in Middle Harbour. Impact piling in Middle Harbour would only take place one to two hours per day or five to six hours on a single day per week.
Barge movements for transport of immersed tube tunnel units	Standard construction hours and works outside of standard construction hours, for discrete periods	Barges to transport immersed tube tunnel units from the casting facility at the Spit West Reserve construction support site (BL9) to a temporary mooring east of Clive Park in Middle Harbour.
Immersed tube tunnel installation	Standard construction hours and works outside of standard construction hours, for discrete periods	Carried out during closures of Middle Harbour at the crossing location. Likely four partial closures (for outer units) and two full closures (for middle units), each for a continuous period for around 24 to 48 hours.
Fabrication of tunnel tube units	Standard construction hours and works outside standard construction hours for discrete periods	Fabrication of concrete tunnel units would typically occur during standard construction hours. However, some concrete pours might need to continue into the evening period where required to ensure appropriate concrete curing and the structural integrity of the fabricated concrete unit.
Construction traffic for material supply and spoil removal		
Construction traffic for material deliveries and spoil removal	Standard construction hours	Spoil haulage would be carried out during standard construction hours. Some deliveries to and from the temporary construction support sites would be required outside of standard construction hours.

Activity	Construction hours	Comments or exceptions
Surface construction activities		
Cut and cover, trough structures and bridgeworks	Standard construction hours and works outside of standard construction hours	These works would generally be scheduled during standard construction hours wherever feasible and reasonable. Works that require lane occupancy or are immediately adjacent to or above live traffic areas (eg bridge demolition and girder lifts) would be required outside standard construction hours to minimise potential disruption to the road network and to minimise potential safety risks to road users, construction personnel and the public
Demolition and surface construction activities including major surface road upgrades (including major traffic switches), infrastructure construction and utility relocations.	Standard construction hours and works outside of standard construction hours	Non-disruptive (low noise intensive) preparatory work, repairs or maintenance that does not generate noise in excess of the applicable noise management level at any sensitive receiver would be carried out outside standard construction hours. Works that require lane occupancy, are immediately adjacent to live traffic or involve substantial changes to lane configurations and traffic management arrangements would be carried out outside of standard construction hours to minimise impacts to road users as well as to ensure the safety of both construction personnel and the public. Key locations include: • Warringah Freeway • Gore Hill Freeway • Pacific Highway (near Dickson Avenue at Artarmon) • Flat Rock Drive • Burnt Bridge Creek Deviation and Sydney Road.

Activity	Construction hours	Comments or exceptions
Blasting and rock breaking		
Controlled blasting (underground and surface based along Wakehurst Parkway)	9am to 5pm Monday to Friday 9am to 1pm Saturdays No blasting on Sundays or public holidays	Controlled blasting may be used for cross passage excavation and bench removal in mainline and ramp tunnels, and excavation and surface works along Wakehurst Parkway (refer to Section 10.6.15). Controlled blasting might also be adopted along Wakehurst Parkway to minimise the duration over which traditional excavation methods for rock (eg rock hammers) would be required.
Rock breaking and other high impact noise activities	Standard construction hours, and outside of standard construction hours	Respite periods described in *Construction Noise and Vibration Guideline* (Roads and Maritime Services, 2016) would be provided and scheduled. Rock breaking and other high impact noise activities that require lane occupancy or are immediately adjacent to live traffic would be required outside of standard construction hours to minimise impacts to road users as well as to ensure the safety of both construction personnel and the public
Other activities		
Minor activities	At any time	Includes activities that do not generate noise in excess of the applicable noise management level at any noise sensitive receiver.
Works that require road occupancy licences	At any time (typically outside standard construction hours)	Works on busy roads typically must occur under a road occupancy licence issued by the Transport Management Centre. Road occupancy licences specify the allowable working hours and typically require the road works to occur outside standard construction hours when traffic volumes are low. Road occupancy licences can also require works to occur over multiple consecutive nights.
Activities authorised by an environment protection licence	As specified in the environment protection licence (can include works outside standard construction hours)	Construction activities would be managed as required by an environment protection licence issued by the NSW Environment Protection Authority.
Emergency or directed activities	At any time	Activities carried out if required to prevent an imminent injury, loss of life or environmental damage.

Table 6-36 Surface road works – works outside standard construction hours

Work area	Indicative duration	Indicative percentage of work days on which work outside standard construction hours required
Warringah Freeway surface road works and associated use of Cammeray Golf Course construction support site (BL1)	1 year 6 months	10%
Gore Hill Freeway Connection surface road works and associated use of Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6) construction support sites	4 years	10%
Upgrade of Pacific Highway/Dickson Avenue intersection and surface road works and associated use of Dickson Avenue construction support site (BL4)	3 months	30%
Balgowlah surface road works and associated use of Balgowlah Golf Course construction support site (BL10)	3 years	10%
Wakehurst Parkway surface road works and associated use of Wakehurst Parkway south (BL12) and Wakehurst Parkway north (BL14) construction support sites	3 years 3 months	10%
Widening of Flat Rock Drive and associated use of Flat Rock Drive construction support site (BL2)	6 months	30%
Create site access for Wakehurst Parkway east construction support (BL13) and road/intersection modification during site establishment	6 months	10%

Table 6-37 Middle Harbour crossing – works outside standard construction hours

Activity	Indicative duration	Indicative works outside standard construction hours
Dewater cofferdams	1 year 9 months	Continuous pump operation is required during initial dewatering of each cofferdam and then as required once dewatered.
Cast and fitout of immersed tube tunnel units at Spit West Reserve construction support site (BL9)	1 year 6 months	Occasional concrete pours would extend into evening period depending on technical and quality requirements.
Installation of immersed tube tunnel units and associated use Spit West Reserve construction support site (BL9)	9 months	One continual work period of around 48 hours is required for the immersion of each of the six tunnel units. Use of Spit West Reserve construction support site (BL9) outside standard construction hours would be required to provide support each time.
Decommissioning and refill of cofferdams	6 months	Continuous pump operation during to refill of each cofferdam is required prior to commencement of cofferdam removal.

Table 6-38 Surface-based support of underground tunnelling and tunnel fitout activities outside standard construction hours

Temporary construction support site	Indicative duration	Indicative works outside standard construction hours
Cammeray golf course construction support site (BL1)	2 years	Low noise impact activities 24 hours per day, seven days a week while underground tunnel activities are occurring.
Flat Rock Drive construction support site (BL2)	3 years 9 months	Low noise impact activities 24 hours per day, seven days a week during underground tunnel activities are occurring.
Punch Street construction support site (BL3)	2. years 6 months	Low noise impact activities 24 hours per day, seven days a week during underground tunnel activities are occurring.
Balgowlah Golf Course construction support site (BL10)	3 years 9 months	Low noise impact activities 24 hours per day, seven days a week during underground tunnel activities are occurring.
Wakehurst Parkway east (BL13) construction support site	3 years 3 months	Low noise impact activities 24 hours per day, seven days a week during underground tunnel activities are occurring.

6.9.2 Traffic management and access

Road transport

The construction of the project would be subject to comprehensive traffic management measures to ensure the ongoing functionality of surrounding roads, and the safety of members of the public, motorists and construction personnel.

A number of stages of traffic management and traffic switches would be required around the tunnel connections and for Wakehurst Parkway surface road works to facilitate the construction of the on and off ramps and tie-ins to arterial and local roads. Traffic staging at the Gore Hill Freeway Connection would be fundamental to enable access for surface works to be carried out and is likely to require works outside of standard construction hours. Signage would be installed for road closures or detours, where required, to facilitate traffic movement.

Controlled blasting may be required along sections of the Wakehurst Parkway. Controlled blasts would not take place during peak hour traffic periods and not on Sundays or public holidays. Traffic near the area would be stopped while the controlled blast is initiated and delays of up to 10 minutes may be experienced. Traffic control measures and advanced signage would be in place to notify vehicles using Wakehurst Parkway of any proposed controlled blasting.

The project would also necessitate the temporary alteration of pedestrian and cyclist facilities, although alternative access arrangements would be implemented around construction sites and access points. Appropriate detour routes would be established, utilising existing cycle routes and paths where feasible.

The proposed access points to and from the temporary construction support sites are described in Section 6.8 and shown in figures for each temporary construction support site. Where possible, site access points have been configured to provide access directly to and from arterial roads.

Over-size and over-mass vehicles would be required for the delivery and removal of large plant and equipment on discrete occasions. There would be a higher proportion of these movements during site establishment and site closure, as large plant and equipment (such as roadheaders) are moved to and from site respectively.

Peak construction daily light vehicle and heavy vehicle numbers associated with spoil and waste removal, material deliveries and arrival and departure of construction works are summarised in Table 6-39.

Potential traffic and transport impacts from the construction of the project, and measures which address these impacts, is provided in Chapter 8 (Construction traffic and transport).

Table 6-39 Peak construction vehicle movement and access

Site	Proposed access route	Daily heavy vehicle movements[1]	Daily light vehicle movements	Construction vehicle movements during AM peak hours (6am to 10am)		Construction vehicle movements during PM peak hours (3pm to 7pm)	
				Heavy vehicles	Light vehicles	Heavy vehicles	Light vehicles
Cammeray Golf Course (BL1)	Warringah Freeway Ernest Street	275	305	72	99	73	142
Flat Rock Drive (BL2)	Flat Rock Drive	545	355	145	165	146	136
Punch Street (BL3)	Cleg Street Punch Street Gore Hill Freeway	370	580	110	222	87	203
Dickson Avenue (BL4)	Dickson Avenue	90	500	40	160	8	132
Barton Road (BL5)	Reserve Road	35	120	5	45	10	45
Gore Hill Freeway median (BL6)	Gore Hill Freeway Epping Road	10	100	2	20	0	21
Spit West Reserve (BL9)	Spit Road	220	200	60	71	60	86
Balgowlah Golf Course (BL10)	Burnt Bridge Creek Deviation Sydney Road	495	1195	149	429	119	460
Kitchener Street (BL11)	Burnt Bridge Creek Deviation	10	65	2	27	2	25
Wakehurst Parkway south (BL12)	Judith Street Kirkwood Street	15	285	6	119	1	102

Site	Proposed access route	Daily heavy vehicle movements[1]	Daily light vehicle movements	Construction vehicle movements during AM peak hours (6am to 10am)		Construction vehicle movements during PM peak hours (3pm to 7pm)	
				Heavy vehicles	Light vehicles	Heavy vehicles	Light vehicles
Wakehurst Parkway east (BL13)	Wakehurst Parkway	275	305	72	99	73	142
Wakehurst Parkway north (BL14)	Warringah Road Wakehurst Parkway	95	180	29	58	26	52

Note 1: Vehicle movements are each way (ie a heavy/light vehicle arriving at a site and leaving a site counts as two movements).

Construction workforce car parking

A portion of the project's labour force would be required to drive and park at temporary construction support sites. The numbers of construction personnel requiring parking would vary over the duration of the construction program.

Due to the generally constrained nature of temporary construction support sites, only limited car parking for construction workers would be available on site. Car parking areas would be provided at the following temporary construction support sites:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Dickson Avenue (BL4)
- Barton Road (BL5)
- Spit West Reserve (BL9)
- Balgowlah Golf Course (BL10)
- Kitchener Street (BL11)
- Wakehurst Parkway south (BL12)
- Wakehurst Parkway east (BL13)
- Wakehurst Parkway north (BL14).

The number of car parking spaces at the above temporary construction support sites would be determined during construction planning. Shuttle bus transfers between temporary construction support sites would also be provided, where required.

The construction workforce would be encouraged to use public transport (except where construction personnel are required to travel to site with construction-related tools and equipment). The public transport provisions available near the project to provide access to temporary construction support sites include:

- Military Road/Spit Road, the Pacific Highway, Epping Road, Eastern Valley Way, Frenchs Forest Road, Warringah Road and Condamine Street/Pittwater Road are key bus corridors near the project with multiple bus routes that would provide access to temporary construction support sites along the project
- Artarmon Station and North Sydney Station on the Sydney Trains suburban train network would provide access to construction sites around Artarmon and Cammeray respectively.

Measures to manage any potential parking impacts during construction are discussed in Chapter 8 (Construction traffic and transport).

Property access

At locations where temporary and/or permanent road closures are required, access to properties would be maintained or alternative arrangements made in agreement with the affected stakeholder(s). For further details on property impacts refer to Chapter 20 (Land use and property).

Marine transport

Marine construction vessels would be required during construction. Figure 6-43 shows the main routes which would be used during construction. Table 6-40 details the indicative type and number of marine transport and construction vessels likely to be used during construction. Refer to Chapter 8 (Construction traffic and transport) for discussion on maritime navigation during construction.

Table 6-40 Marine-based construction vessel movements

Site	Indicative vessel movements per day at peak
Between Spit West Reserve construction support site (BL9) and Middle Harbour south (BL7) and Middle Harbour north (BL8) cofferdams	• Twelve small boats movements for transporting construction workforce • Four barge movements for support of cofferdam dredging, piling and tube tunnel immersion • Three barge movements for disposal of dredged material to sea • 48 barge movements for concrete deliveries.

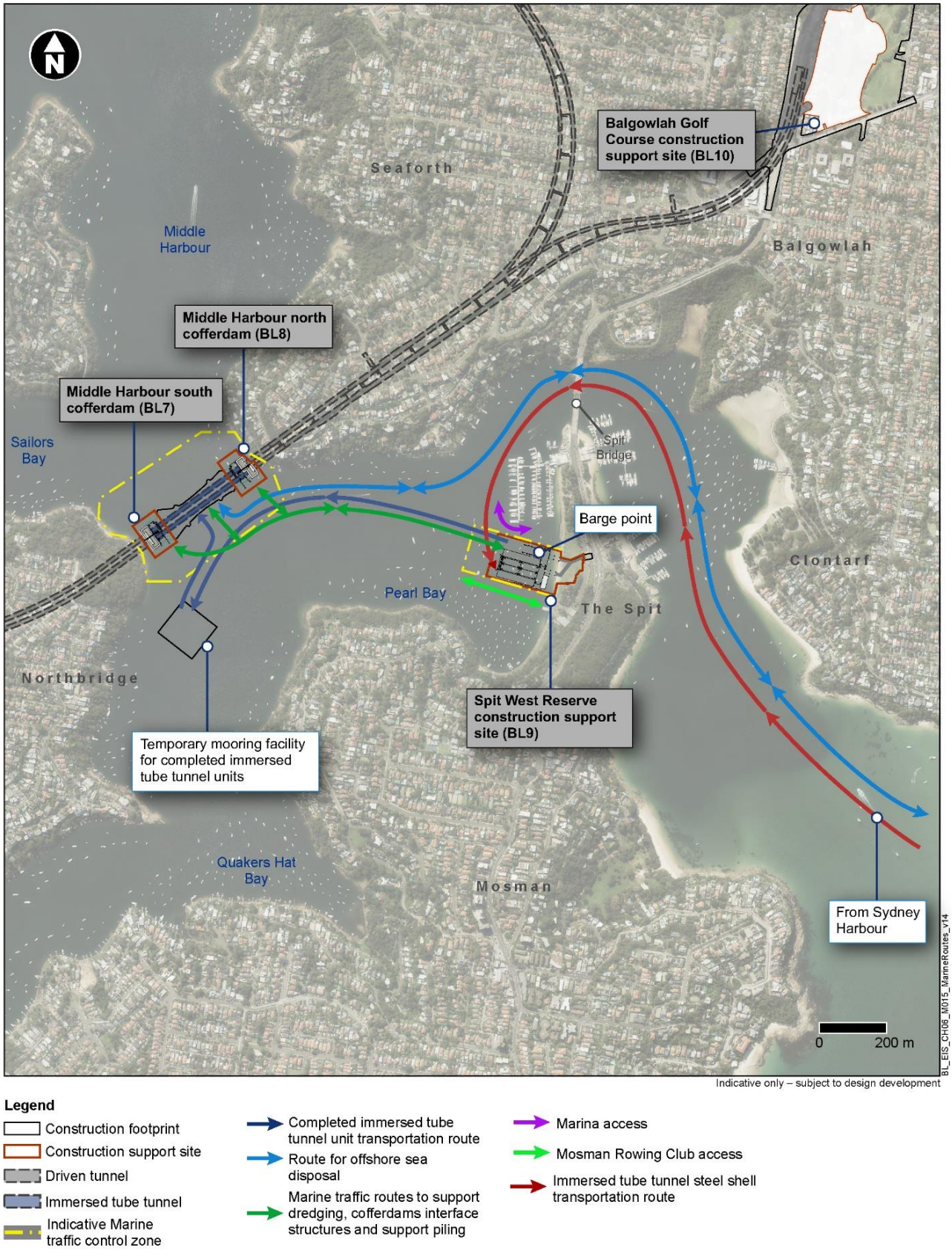


Figure 6-43 Marine transport and construction vessel routes in Middle Harbour

6.9.3 Construction plant and equipment

The plant and equipment listed in Table 6-41 are likely to be used during construction of the project. The final list of plant and equipment required for each construction activity would depend on the final construction methodology developed by the construction contractor.

Table 6-41 Indicative construction plant and equipment

Plant and equipment	Early works	Site establishment	Construction of driven tunnels	Installation of immersed tube tunnels	Construction of operational facilities	Tunnel fitout and finishing works	Surface road works	Testing, commissioning and demobilisation
Vacuum truck	X						X	
Grader, excavator, excavator with rock hammer	X	X	X	X	X		X	
Bulldozer		X					X	
Backhoe, bobcat, front end loader	X	X	X		X	X	X	X
Chainsaw[1]		X					X	
Grinder, mulcher[1]		X					X	X
Forklift		X	X			X		
Elevated work platform, scissor lift		X		X	X	X	X	X
Light tower[2]				X			X	
Mobile crane[2]	X	X	X	X	X	X	X	X
Light vehicle	X	X	X	X	X	X	X	X
Dump truck, cement delivery truck, concrete agitator	X	X	X	X	X	X	X	X
Truck	X	X	X		X	X	X	X
Linemarking truck		X					X	
Pavement laying machine		X				X	X	
Vibratory roller, compactor		X					X	
Power generator				X	X	X	X	X
Compressor		X	X	X	X		X	
Jackhammer[1]				X		X	X	
Rock crusher[1]							X	

Plant and equipment	Early works	Site establishment	Construction of driven tunnels	Installation of immersed tube tunnels	Construction of operational facilities	Tunnel fitout and finishing works	Surface road works	Testing, commissioning and demobilisation
Concrete saw[1]	X					X	X	
Concrete pump, concrete vibrator		X	X	X	X	X	X	
Concrete batch plant			X	X	X	X	X	
Hand tools, welding equipment	X	X	X	X	X	X	X	X
Piling rig (bored)[1]		X	X		X		X	
Piling rig (impact)[1]				X			X	
Drilling machine (diesel)			X					
Pneumatic hammer/vibrator[1]			X			X		
Shotcrete rig			X				X	
Air track drilling rig[1]			X				X	
Roadheader			X					
Dust scrubber			X					
Ventilation fan		X	X					
Water cart		X				X	X	X
Road sweeper			X			X	X	X
Barge, small boat, tugboat			X	X				
Flat top barge				X				
Mooring pontoon				X				
Dredging equipment				X				

Note 1: Refers to high noise generating equipment

Note 2: Refers to plant and equipment likely to generate a visual impact

6.9.4 Construction resources and waste management

Construction resource use

Construction would require various resources and materials. The main construction materials required would include:

- General fill and select fill for earthworks (sourced from within the project cutting and from tunnel spoil where the material is available and of suitable quality)
- Pavement materials, cement, concrete and steel reinforcement

- Materials for lining drainage channels
- Aggregate used for concrete and asphalt
- Water
- Pre-cast concrete including pipes, culvert segments, bridge elements, retaining wall elements and roadside barriers
- Structural steel
- Plastics used for drainage, piping and conduits
- Pre-fabricated steel and road furniture units
- Wood for use in formwork and other temporary structures.

Construction material would generally be sourced from off-site suppliers. Where reasonable and feasible, local sources of construction materials would be preferred to minimise haulage distances.

Indicative quantities of the main sources of materials required for construction are provided in Chapter 24 (Resource use and waste management).

Construction power requirements

Power supply would be required during the construction works at the majority of temporary construction support sites. In particular, high voltage power would be required at the tunnel support sites. Prior to the connection of mains power supply to the tunnel support sites, roadheaders may be powered by diesel generators.

The power supply for each site would be sourced from outside the project area. The power supply requirements for temporary construction support sites is described in Chapter 24 (Resource use and waste management). Potential supply source, supply route and power demand is described in Appendix D (Utilities management strategy).

Construction water requirements

Tunnelling works would require substantial volumes of water for excavation and would generate wastewater requiring treatment and disposal.

Construction water supply would also be required for tunnel connection construction and surface activities, including earthworks, concreting, building construction and dust suppression. Additional information about construction water requirements is provided in Chapter 24 (Resource use and waste management).

Suitable connections for water discharge from wastewater treatment plants at temporary construction support sites would be required at:

- Cammeray Golf Course (BL1) – to Willoughby Creek
- Flat Rock Drive (BL2) – to a drainage pit on Flat Rock Drive then to Flat Rock Creek
- Punch Street (BL3) – to Flat Rock Creek near Station Street at Artarmon
- Balgowlah Golf Course (BL10) – to Burnt Bridge Creek
- Wakehurst Parkway east (BL13) – to a drainage channel to be formed at the eastern section of the site (which would drain towards a Wakehurst Golf course dam for reuse by the golf course).

Further details are provided in Chapter 17 (Hydrodynamics and water quality).

Spoil and waste management

The project is estimated to generate a substantial volume of spoil from tunnelling, surface works, and dredging operations. Spoil generation and dredged material from each temporary construction support site is provided in Chapter 24 (Resource use and waste management).

Excess spoil that cannot be reused within the project would require offsite disposal. The final destination(s) for excess spoil from construction of the project would be planned prior to construction commencing.

The majority of the spoil generated by the project would be virgin excavated natural material (VENM) – typically consisting of crushed sandstone and shale. VENM is generally considered a desirable material for clean and stable fill in development sites and major earthworks projects across Greater Sydney. Recent examples include the use of crushed sandstone from Sydney Metro to construct runway pavements for the new Western Sydney Airport, and reuse of crushed sandstone from the WestConnex tunnels for numerous development projects.

An application for offshore disposal of suitable dredged material will be submitted to the Australian Government Department of the Agriculture, Water and the Environment under the *Environment Protection (Sea Dumping) Act 1981*. It is proposed that suitable dredged material would be transported by barge and disposed of at a designated offshore disposal site (in accordance with legislative requirements). These sites have been carefully selected by the Commonwealth to provide suitable disposal grounds for dredge material and minimise impacts on sensitive marine ecology. The designated offshore disposal site is over 20 square-kilometres in area and is a non-dispersive ground, meaning that material placed within the area generally does not migrate from that area. Any material not suitable for offshore disposal would be barged to a loadout facility for treatment to be made spadable and then loaded onto trucks and disposed of at a suitably licensed land-based facility and classified according to the NSW Environment Protection Authority's *Waste Classification Guidelines* (NSW EPA, 2014a).

Any contaminated material disturbed during construction would be separated from uncontaminated material on site to prevent cross contamination. Contaminated material would be encapsulated on site where appropriate, and in accordance with relevant regulatory requirements. Any material that is not suitable for encapsulation would be loaded into sealed and covered trucks for disposal at a suitably licensed facility. Further site investigations during the further design development and construction planning phases would inform contamination management including determining where encapsulation is appropriate. Other waste streams which would be generated during construction include:

- Demolition waste from existing structures and properties
- General construction waste such as concrete, steel and timber formwork off-cuts
- Vegetation waste from clearing and grubbing
- Plant and vehicle maintenance waste such as oils and lubricants
- General office waste such as paper, cardboard, plastics and food waste
- Sewage waste.

Further details are provided in Chapter 24 (Resource use and waste management) including potential opportunities for reuse.