7.9 Surface Water

This chapter describes the physical environment within the project area in relation to surface water, including details of the existing catchments, watercourses, sensitive receiving environments, aquatic biodiversity, drainage, flooding and regulation. It identifies and assesses the potential surface water impacts related to the construction and operation of the project, including impacts to water supply and balance, hydrology and water quality. This section also details the impacts associated with the discharge of treated groundwater. An assessment of the existing groundwater environment and the impacts associated with groundwater inflow and drawdown is provided in **Section 7.8** (Hydrogeology and soils).

The key objectives of the surface water assessment were to:

- Identify potential impacts on surface water flows and water quality associated with construction and operation of the project.
- Identify environmental management measures that would be required to manage the identified impacts.
- Inform the future detailed design of the project with respect to surface water flows and quality.

Table 7-172 sets out the Director-General's Requirements as they relate to surface water and where in the environmental impact statement these have been addressed.

Table 7-172 Director-General's Requirements – surface water

Director-General's Requirement	Where addressed
An assessment of construction and operational erosion and sediment and water quality impacts, taking into account impacts from both accidents and runoff (i.e. acute and chronic impacts), having consideration to impacts to surface water runoff, soil erosion and sediment transport, mass movement, and urban and regional salinity. The assessment of water quality impacts is to have reference to relevant public health and environmental water quality criteria, including those specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000), and any applicable regional, local or site-specific guidelines.	Potential surface water impacts are described in **Section 7.9.3** and mitigation measures identified in **Section 7.9.4.** Salinity is discussed in **Section 7.8** (Hydrogeology and soils)
Groundwater impacts as a result of the project (including ancillary facilities such as the tunnel control centre and any deluge systems), considering local impacts along the length of the tunnels and impacts on local and regional hydrology. The assessment must consider: extent of drawdown; impacts to groundwater quality; discharge requirements; location and details of groundwater management and implications for groundwater-dependent surface flows, groundwater dependent ecological communities, and groundwater users. The assessment should be prepared having consideration to the requirements of the NSW Aquifer Interference Policy.	Groundwater impacts are described in **Section 7.8** (Hydrogeology and soils)

7.9.1 Assessment methodology

The assessment methodology for the surface water assessment involved:

- Compilation and review of background information (previous studies, survey and mapping data) relevant to the project, including data on watercourse conditions and water quality to define the existing environment within the potentially affected catchments and watercourses.
- Consultation with relevant government agencies and stakeholders.
- Identification and assessment of construction and operational activities that may impact on the water quality of receiving environments.
- Identification of mitigation measures, including type of controls and design criteria required to manage potential impacts.

The surface water assessment also considered the following current policies and guidelines applicable to water quality management:

- Managing Urban Stormwater – Soils and Construction, Volume 1, 4th Edition (Landcom, 2004) (Blue Book 1).
- Managing Urban Stormwater – Soils and Construction, Volume 2D, Main Road Construction (DECC, 2008) (Blue Book 2).
- NSW Water Quality and River Flow Objectives (EPA, 2006) available at http://www.epa.nsw.gov.au/ieo/index.htm.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000).
- Using the ANZECC Guidelines and Water Quality Objectives in NSW (DEC, 2006b).
- Practical Consideration of Climate Change (DECC, 2007b).
- Water Quality Report Card 2012 (Hornsby Shire Council, 2012c).
- Water Quality Companion Technical Report: Water Quality Report Card (Hornsby Shire Council, 2012d).

7.9.2 Existing environment

Catchment description

The main alignment tunnels would be constructed generally under Pennant Hills Road, which marks the boundary between two major catchments:

- Areas to the north of the Pacific Highway in Wahroonga and to the west of Pennant Hills Road drain into the Hawkesbury-Nepean River Catchment.
- Areas to the east of and south of Pennant Hills Road and areas around the Hills M2 Motorway west of Pennant Hills Road, drain into the Sydney Metropolitan Catchment.

Figure 7-78 shows the location of the project relative to water catchments, including subcatchments.

The project corridor runs adjacent to, and in some cases crosses, a number of tributaries within these catchments. Generally, the project intercepts these tributaries at the top of the catchment due to its location following a ridge line. These tributaries have been impacted by development to varying degrees and are largely urbanised, ie the surface water in these tributaries is collected in developed stormwater networks by a combination of stormwater infrastructure elements, including lined and unlined drainage channels, kerb and gutter networks on roads and dish drains. These tributaries eventually discharge into several subcatchments of the principal Hawkesbury-Nepean and Sydney Metropolitan Catchment areas as follows:

- Parts of the northern interchange and other works to the east of the M1 Pacific Motorway and to the north-east of the Pacific Highway would be located within the Cowan Creek / Pittwater Subcatchment of the Hawkesbury-Nepean River Catchment.
- Parts of the northern interchange and other works to the west of the M1 Pacific Motorway and west of Pennant Hills Road (south to around Castle Hill Road) would be located within the Berowra Creek Subcatchment of the Hawkesbury-Nepean River Catchment.
- All works to the east of Pennant Hills Road between the northern and southern interchange locations would be located within the Lane Cove River Subcatchment of the Sydney Metropolitan Catchment.
- Parts of the southern interchange to the west of Pennant Hills Road and the Hills M2 Motorway integration works would be located in the Parramatta River Subcatchment of the Sydney Metropolitan Catchment.

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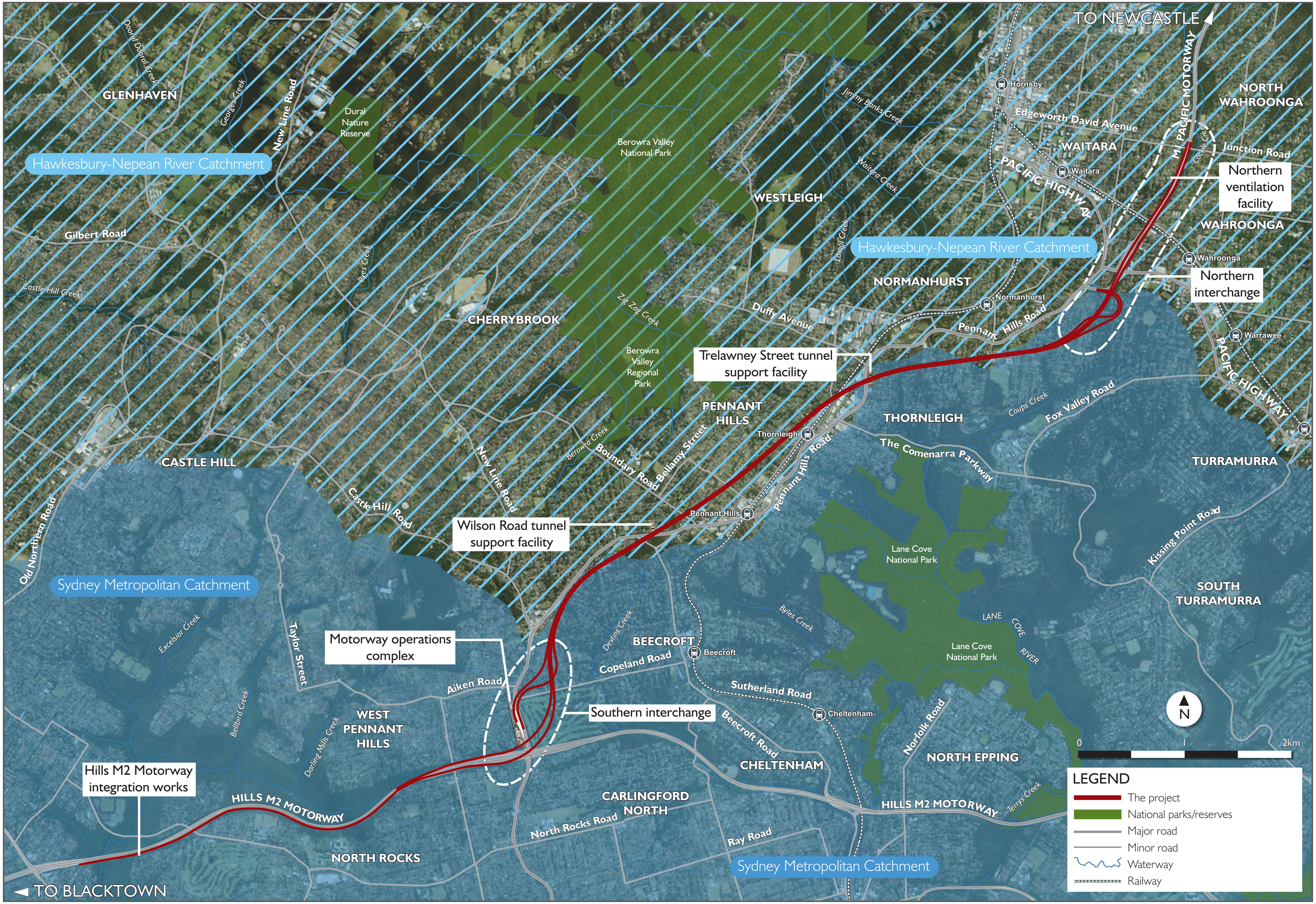

Figure 7-78 Water Catchments

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Hawkesbury-Nepean River Catchment

The Hawkesbury-Nepean River catchment measures around 22,000 square kilometres (2.2 million hectares). The river flows 470 kilometres, from south of Goulburn near Lake Bathurst to Broken Bay, making it the longest coastal catchment in NSW.

The catchment's natural landscapes are varied comprising rainforests, open woodlands, heathlands, wetlands and highland freshwater streams. Whilst many of these landscapes have been altered due to residential development and agriculture, around half of the catchment is protected in national parks and water catchment reserves.

The Hawkesbury-Nepean catchment is under pressure from the demands of supplying resources to Sydney and the rest of Australia and is housing much of Sydney's rapidly growing population.

Some of the key issues and challenges for the catchment identified in the Hawkesbury-Nepean Catchment Action Plan 2007-2016 (HNCMA, 2008) include:

- Vegetation clearing for agriculture and urban development in Western Sydney.
- Conservation of remnant vegetation.
- Inadequate drinking water supplies.
- Loss of water flow.
- High levels of groundwater extraction.
- Aquatic weed outbreaks and algal blooms.
- Poor water quality in creeks and drainage lines.

The two subcatchments of this principal catchment that would be affected by the project are the Cowan Creek / Pittwater Subcatchment and the Berowra Creek Subcatchment.

Cowan Creek / Pittwater Subcatchment

Cowan Creek Subcatchment is a tidal subcatchment of the Hawkesbury River and a typical drowned river valley. The majority of this catchment is in the Ku-ring-gai Chase National Park. The headwaters of waterways within the Cowan Creek Subcatchment are heavily urbanised, while the lower reaches are primarily bushland and are popular for recreational uses.

The Pittwater Subcatchment is dominated by tidal influences and estuarine waters and the majority of the western side of the subcatchment is within Ku-ring-gai Chase National Park. The major landscape characteristics are well-vegetated sandstone valleys interspersed with small local foreshore settlements. The eastern and southern areas of the Pittwater Subcatchment contain significant urban development. Recreation, such as boating, has been identified as a threat to water quality.

Berowra Creek Subcatchment

The Berowra Creek Subcatchment, which lies to the west of the Cowan Creek / Pittwater Subcatchment, is a tidal river subcatchment with 40 per cent of the total stream length having tidal influences. Most of the lower reaches of the subcatchment are located within the Marramarra National Park and the Muogamarra Nature Reserve, while some of the upper reaches are located in the Berowra Valley National Park.

The headwaters of this subcatchment drain both residential and rural areas. Two sewage treatment plants discharge into waterways of this subcatchment, one in Waitara Creek and the other in Calna Creek.

The water quality within this subcatchment is generally poor (Hawkesbury-Nepean Catchment Management Authority, 2007).

Sydney Metropolitan Catchment

The Sydney Metropolitan Catchment is a catchment of around 1,860 square kilometres (0.186 million hectares), which comprises the core of urban Sydney and its coastline. The catchment extends from Narrabeen to the north, Campbelltown to the west, Helensburgh to the south and to the three nautical mile limit off the NSW eastern coastline.

The Sydney Metropolitan Catchment supports a wide variety of land uses including:

- Urban development.
- Industrial development.
- Infrastructure, including international and domestic shipping facilities, airports and motorways.
- Tourism and recreation.
- Sand extraction.
- Natural and modified open space.
- Water harvesting for domestic and industrial use.
- Commonwealth military reserve.
- Agriculture.

The Sydney Metropolitan Catchment supports the most populated city (Sydney) in Australia and urban development is the predominant land use. Around 37 per cent of the catchment area is comprised of native vegetation, 42 per cent of which is in conservation reserves. Agricultural activities are limited to the urban rural fringe areas in the western and south-western portions of the catchment.

The Sydney Metropolitan Catchment is under increased pressure to supply high density housing in Sydney for the rapidly growing population.

Some of the key issues and challenges for the catchment identified in the Sydney Metropolitan Catchment Action Plan (SMCMA, 2009) include:

- Intensive and growing urban, industrial, transport and recreational land uses.
- The natural resource values, ecological footprint and management capacity of more than three million residents and millions of visitors annually.
- Risk management in the coastal zones.
- Fragmentation, modification and degradation of natural processes, such as through vegetation clearing, weed and feral animal infestation, and soil and ground water contamination.
- Ongoing and escalating impacts from a growing population, resulting in demands for drinking water, healthy recreational waterways, sewage management and stormwater management.

The two subcatchments of this principal catchment that would be affected by the project are the Lane Cove River Subcatchment and the Parramatta River Subcatchment.

Lane Cove River Subcatchment

The Lane Cove River Subcatchment is a catchment of around 92 square kilometres (9,200 hectares). The Lane Cover River flows roughly in a south-east direction before discharging to Port Jackson and is around 15 kilometres long. A number of tributaries located within and adjacent to the project corridor, as well as the Lane Cove River, flow through the Lane Cove National Park located south-east of the project. The land uses within this subcatchment are mainly residential, with some bushland, commercial and recreational uses.

Parramatta River Subcatchment

The Parramatta River Subcatchment is a catchment of around 298 square kilometres (29,800 hectares). It has three major subcatchments including the Darling Mills Creek, Toongabbie Creek and the upper Parramatta River catchments. Parramatta River is one of Sydney's major river systems discharging into Middle Harbour. It is around 13.7 kilometres long. A number of tributaries located within and adjacent to the project corridor flow through sensitive areas before discharging into Parramatta River, including the Cumberland State Forest and the Bidjigal Reserve.

Watercourses

Parramatta River, Lane Cove River, Cowan Creek / Pittwater and the Berowra Creek subcatchments form receiving environments for a number of tributaries identified within or adjacent to the project corridor. **Figure 7-79** and **Table 7-173** detail each of these identified watercourses and their location in relation to each project area.

Table 7-173 Identified watercourses crossed or adjacent to the project

Catchment	Watercourse	Project area	Suburb
Parramatta River	Stevenson Creek	Hills M2 Motorway integration works	Baulkham Hills
	Darling Mills Creek	Hills M2 Motorway integration works	Baulkham Hills / North Rocks
	Blue Gum Creek	Hills M2 Motorway integration works	West Pennant Hills
	Bellamys Creek	Southern interchange	West Pennant Hills
	Unnamed creek (Darling Mills Creek tributary)	Main alignment tunnels	West Pennant Hills
Lane Cove River	Unnamed creek (Devlins Creek tributary)	Main alignment tunnels	Beecroft
	Devlins Creek	Main alignment tunnels	Beecroft
	Unnamed creek (Byles Creek tributary)	Main alignment tunnels	Pennant Hills
	Terra Ulong Creek	Main alignment tunnels	Pennant Hills
	Camp Creek	Main alignment tunnels	Pennant Hills
	Scout Creek	Main alignment tunnels	Thornleigh / Pennant Hills
	Unnamed creek (Lane Cove River tributary)	Main alignment tunnels	Thornleigh
	Unnamed creek (Lane Cove River tributary)	Main alignment tunnels	Normanhurst
	Coups Creek	Main alignment tunnels	Wahroonga
Berowra Creek	Unnamed creek (Berowra Creek tributary)	Main alignment tunnels	West Pennant Hills
	Tedbury Creek	Main alignment tunnels	Pennant Hills
	Unnamed creek (Waitara Creek tributary)	Main alignment tunnels	Normanhurst
	Unnamed creek (Waitara Creek tributary)	Main alignment tunnels	Normanhurst
Cowan Creek / Pittwater	Cockle Creek (also known as Spring Gully Creek)	Northern interchange	Wahroonga

The surface water quality within the project area is generally poor, typical of a heavily urbanised environment. Hornsby Shire Council and The Hills Shire Council currently undertake comprehensive water quality monitoring programs. These two local government areas cover the majority of the project area and the receiving watercourses downstream of the project. The results of these monitoring programs have been used as part of this assessment.

Water quality monitoring with the Hornsby local government area between 2011 and 2012 has identified the surface water quality within the project areas as having a ‘fail’ grade, with poor physical and chemical condition. Surface water also has a fail grade for both bacterial contamination, and water bugs and microscopic plant life. This implies that the water quality within this area is consistently poor and that the ecosystems are severely impaired (Hornsby Shire Council, 2012d).

Water quality monitoring within the Hills local government area between 2006 and 2013 has identified that surface water within the project area is generally poor (Hills Shire Council, 2014). The results regularly exceed the ANZECC guidelines for secondary contact, especially for bacterial contamination. A review of this data also indicates that there are no clear patterns of water quality throughout the year. That is, seasonality does not appear to be a factor in determining water quality. Water quality is more likely to be impacted by individual events such as deterioration in response to rainfall.

Based on the availability and extent of existing water quality data for receiving waters, the collection of additional baseline data was not considered necessary.

Sensitive receiving environments

The project would drain to a number of tributaries that eventually discharge to the Cowan Creek / Pittwater, Berowra Creek, Parramatta River or Lane Cove River subcatchments. These watercourses comprise the receiving waters for the project, or the waters that have the potential to be impacted by construction and operation of the project.

Many of the tributaries, and therefore downstream receiving waters for the project, drain to or support sensitive aquatic and riparian environments, including aquatic ecosystems and fish habitat. These sensitive aquatic and riparian environments are referred to throughout this section as sensitive receiving environments.

A sensitive receiving environment is defined as one that has a high conservation or community value or supports ecosystems or human uses of water that are particularly sensitive to pollution or degradation of water quality. Sensitive receiving environments include:

- Nationally Important Wetlands and *State Environmental Planning Policy No 14* (SEPP 14) wetlands (actual or potential groundwater dependent ecosystems).
- National parks, marine parks, nature reserves and State conservation areas.
- Threatened ecological communities associated with aquatic ecosystems.
- Known and potential habitats for threatened fish.
- Key fish habitats as identified by the NSW Department of Primary Industries (DPI).
- Recreational swimming areas.
- Areas that contribute to drinking water catchments.
- Areas that are available or used for aquaculture and commercial fishing.

Sensitive receiving environments that would be crossed, or located adjacent to the project, are identified in **Figure 7-80** and **Table 7-174.**

Table 7-174 Sensitive receiving environments crossed and adjacent to the project

Project area	Receiving watercourse	Description	Sensitive receiving environment
Hills M2 Motorway integration works	Stevenson Creek (tributary of Darling Mills Creek) Darling Mills Creek Blue Gum Creek	Watercourses are freshwater systems	Bidjigal Reserve
Southern interchange	Blue Gum Creek	Watercourse is a small freshwater system	Bidjigal Reserve
Main alignment tunnels	Blue Gum Creek	Watercourses are small freshwater systems	Bidjigal Reserve
	Coups Creek		Lane Cove National Park
Northern interchange	Cockle Creek	Watercourses are small freshwater systems	Ku-ring-gai Chase National Park

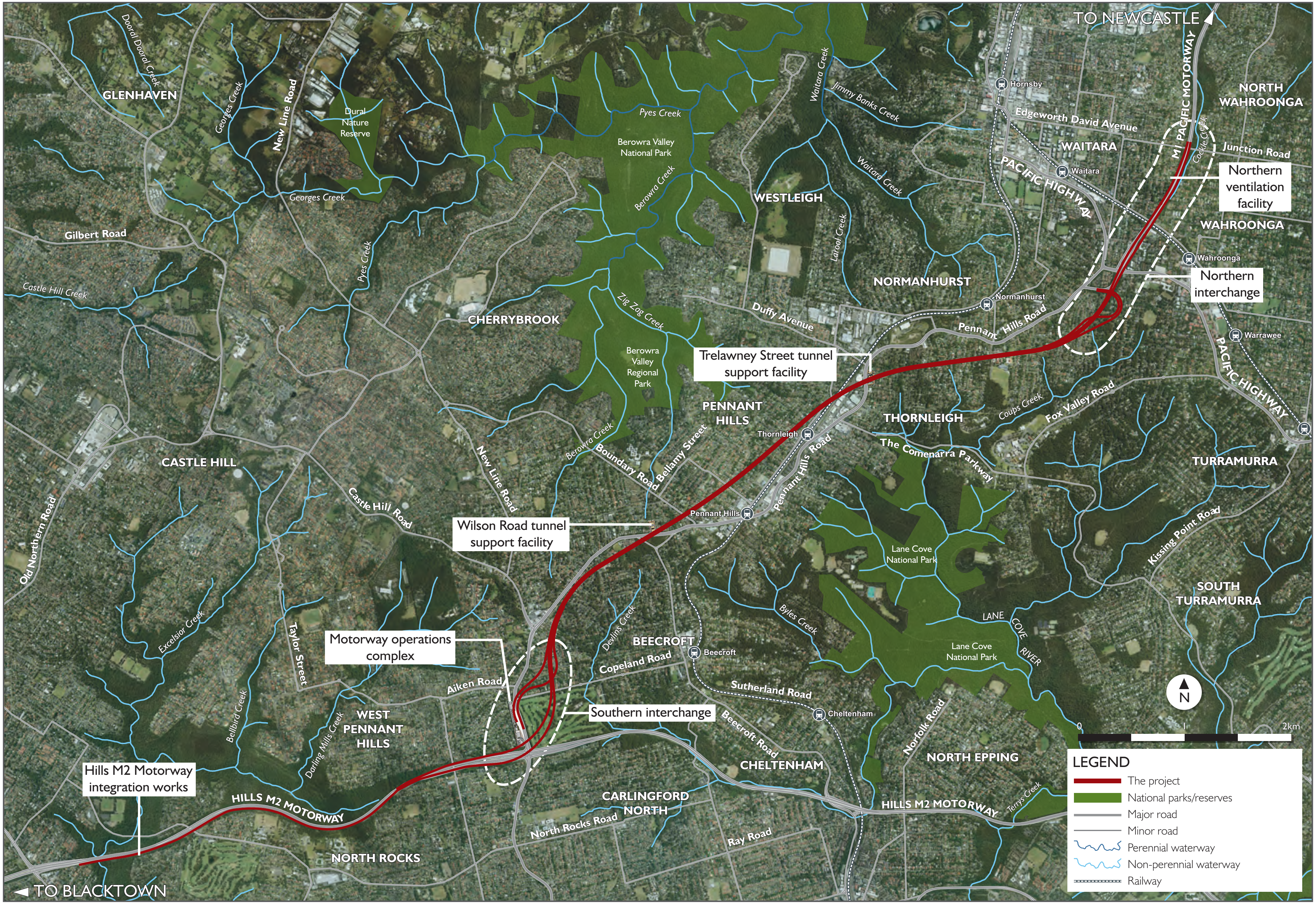

Figure 7-79 Watercourses

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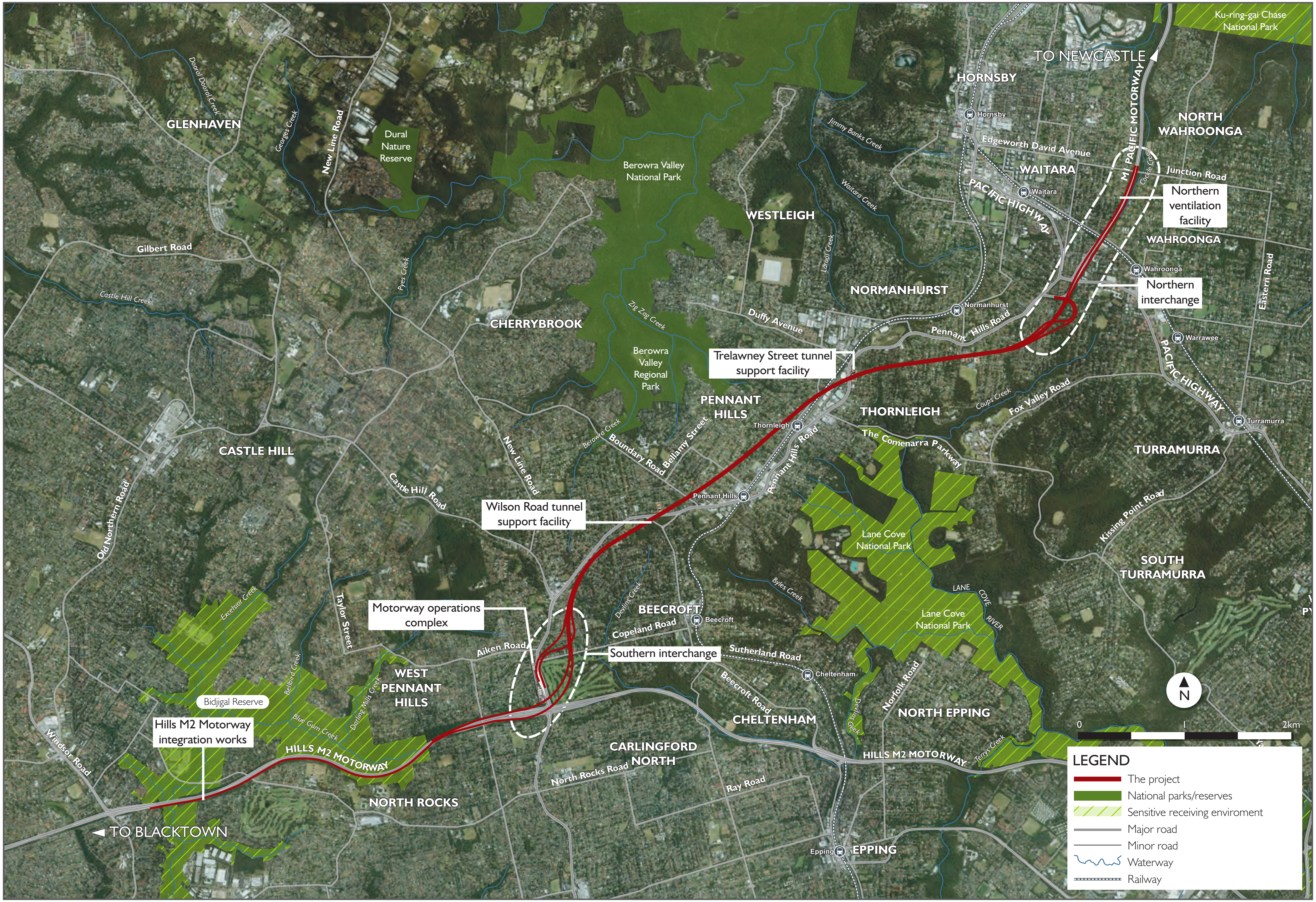

Figure 7-80 Sensitive receiving environments

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Aquatic biodiversity

The biodiversity values of the waterways within the project area are discussed in detail in **Section 7.6**. (Biodiversity).

Existing drainage and surface water management infrastructure

The aboveground components of the project are located within residential areas within the suburbs of West Pennant Hills, Carlingford, Beecroft, Pennant Hills, Thornleigh, Normanhurst and Wahroonga. Within these areas surface water is conveyed as overland flow and is collected in developed stormwater networks by a combination of stormwater infrastructure elements. This includes lined and unlined drainage channels, kerb and gutter networks on roads and dish drains, all feeding into a well-developed subsurface pit and pipe network.

The discharge locations of these developed stormwater networks include surrounding vegetated areas, such as reserves and national parks, where surface water follows natural contour flow paths forming watercourses in natural depressions.

Within the vicinity of the Hills M2 Motorway integration works, a number of stormwater detention basins manage surface water runoff along the Hills M2 Motorway alignment. These collect surface water drained via overland flow to pit and pipe networks conveying stormwater away from the road surface.

Flooding

The project does not fall within flood prone areas as mapped by Hornsby, Ku-ring-gai or The Hills Shire Councils. The nearest identified flood prone areas are along the northern boundaries of the Hornsby and Hills Shire local government areas, which are both over 20 kilometres north of the project corridor.

Due to the location of the project area along a ridgeline, flooding has not been identified as a major design constraint. However, localised flooding may occur within the area during high intensity rainfall events. It is anticipated that these localised flooding events would be of short duration and would have limited impacts to surrounding receptors and infrastructure. The potential for localised flooding is currently managed through the existing drainage and surface water management infrastructure as described above.

Existing drainage systems in and around areas to be developed as part of the project are summarised in **Table 7-175**.

Table 7-175 Existing drainage systems in project areas

Project area	Existing drainage systems
Hills M2 Motorway integration works	• Runoff from this area currently flows into the road drainage system and is conveyed to a water quality basin. A bifurcation pit directs the one year ARI flows to the water quality basin and flows above this to the adjacent stormwater channel.
Southern interchange	• Runoff from this area currently drains into a detention basin on the corner of Pennant Hills Road and the Hills M2 Motorway, which then discharges to the Hornsby Shire Council drainage system in Gum Grove Place. • The ridgeline along Pennant Hills Road around the location of the southern tunnel portals drains away from the ridgeline indicating that flooding from external catchments and during Probable Maximum Flood is unlikely to lead to inundation issues in this location. • Runoff from areas within the Hills M2 Motorway corridor, including around the location of the ramp tunnel portals in this area, drains to the existing motorway drainage system.
Wilson Road site	• Runoff from the Wilson Road site is conveyed as overland flow and is collected in developed stormwater networks by a combination of stormwater infrastructure elements, including lined and unlined drainage channels, kerb and gutter networks on roads and dish drains, which all feed into a well-developed subsurface pit and pipe network. • Drainage from the Wilson Road site flows to an ephemeral tributary of Berowra Creek, which ultimately drains into the Hawkesbury-Nepean Catchment.
Trelawney Street site	• Runoff from the Trelawney Street site is conveyed as overland flow and is collected in developed stormwater networks by a combination of stormwater infrastructure elements, including lined and unlined drainage channels, kerb and gutter networks on roads and dish drains, which all feed into a well-developed subsurface pit and pipe network. • Drainage from the Trelawney Street site flows to an ephemeral tributary of the Lane Cove River, which ultimately drains into the Sydney Metropolitan Catchment.
Northern interchange	• Runoff from this area drains to the Hornsby Shire Council drainage system located within Hewitt Avenue. • There is currently no on-site detention or water quality treatment measures in place in this area.
M1 Pacific Motorway tie-in works	• Runoff from this area drains into Cockle Creek, to the east of the M1 Pacific Motorway. • There is currently no on-site detention or water quality treatment measures in place in this area.

Surface water regulation

The project falls within the Hawkesbury and Lower Nepean Rivers region as defined in the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources* (NOW, 2011b). The plan details the sharing of water resources with the goal of protecting water sources and its dependent ecosystems, whilst also protecting basic landholder rights. Water sharing plans provide a legal basis for sharing water between the environment and consumptive purposes.

The trading rules within the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources* (NOW, 2011b) that are relevant to the project are as follows:

- Berowra Creek and Cowan Creek Management Zone:
  - Trading into this zone is not permitted if the trade will increase the total licensed entitlement for the management zone.
  - Trading within this zone is permitted, subject to assessment.
  - The conversion to a high flow access licence is not permitted.
- Lane Cove River Management Zone:
  - Trading into this zone is not permitted.
  - Trading within this zone is permitted, subject to assessment.
  - The conversion to a high flow access licence is not permitted.
- Upper Parramatta River Management Zone:
  - Trading into this zone is not permitted if the trade will increase the total licensed entitlement for the zone.
  - Trading within this zone is permitted, subject to assessment.
  - The conversion to a high flow access licence is not permitted.
- Lower Parramatta River Management Zone:
  - Trading into this zone is not permitted if the trade will increase the total licensed entitlement for the zone.
  - Trading within this zone is permitted, subject to assessment.
  - The conversion to a high flow access licence is not permitted.

7.9.3 Assessment of potential impacts

Construction

Water supply and water balance

During construction, water would be required for dust suppression, earthwork compaction and planted vegetation maintenance. The anticipated source and volume of construction water required is detailed in **Table 7-176.**

Table 7-176 Indicative source and volume of construction water supply

Source		Southern interchange compound (C5)	Wilson Road compound (C6)	Trelawney Street compound (C7)	Northern interchange compound (C9)	Road works	Total
Total potable water supply (ML)	Sydney Water mains	635	485	450	600	80	2,250
Total non-potable water supply (ML)	Collected rainwater	35	10	10	15	-	70
	Treated groundwater	190	160	150	235	-	735
Total		860	655	610	850	80	3,055

Preference would be given to the use of non-potable water sources during construction over potable sources where appropriate.

The volume of water required would depend on a number of factors including rainfall, wind direction and intensity, soil type and area of ground disturbance at any one time.

Section 8.3 (Resource management and waste minimisation) provides further description relating to construction water resources.

Dewatering programmes during construction would involve the collection of tunnel groundwater (through gravity systems) and pumping to construction water treatment plants located at the four surface tunnel support sites, being:

- The southern interchange compound (C5).
- Wilson Road compound (C6).
- Trelawney Street compound (C7).
- The northern interchange compound (C9).

Groundwater inflows into the tunnels and transport of the water to the water treatment plants are described in **Section 7.8** (Hydrogeology and soils). The inflow rate is anticipated to be in the order of one litre per second per kilometre of tunnel, which equates to around 0.09 mega litres per day per kilometre of excavated tunnel.

The water treatment plants would treat construction water, surface water runoff that drains into the tunnels, and groundwater inflows.

The volume of water generated from the combination of groundwater and construction water would vary depending on the:

- Activities taking place within the tunnels.
- Amount of groundwater infiltrating the works.
- Length of the tunnels that have been excavated.

A water treatment plant capable of treating up to ten litres per second would be provided at each of the four surface tunnel support sites listed above. Preliminary designs indicate that this treatment capacity would be sufficient to accommodate the expected maximum water treatment requirements at each surface tunnel support site during construction.

Each treatment plant would comprise a series of modular water-tight tanks with automated probes and dosing units designed to test and treat the water to the required standard. Based on the existing groundwater quality (as described in **Section 7.8** Hydrogeology and soils) water treatment would typically involve:

- Flocculation to remove total suspended solids.
- Reverse osmosis to reduce salinity and dissolved solids.
- Correction of pH level through the addition of lime or acid.

Construction water, as summarised in **Section 7.8** (Hydrogeology and soils), would either be reused on-site wherever feasible, or discharged into the local stormwater system in accordance with the requirements of an environment protection licence issued for the project. Preference would be given to reusing as much water as is practicable before discharging, however the discharge of treated water is considered to be a standard construction practice. In addition, as the increase in impervious surface areas would be limited, the majority of water requiring discharge would be treated groundwater.

The estimated water discharge volumes are identified in **Table 7-177.**

Table 7-177 Estimated water discharge volumes during construction

	Southern interchange compound (C5)	Wilson Road compound (C6)	Trelawney Street compound (C7)	Northern interchange compound (C9)
Anticipated total discharge volume to stormwater (ML)	575	485	455	705
Anticipated average discharge rate (L/s)	6.5	7.0	7.5	8.5

It is anticipated that the discharge water quality requirements would be consistent with the 80 per cent protection level for freshwater ecosystems (Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000). This protection level would ensure that discharged water would result in minimal impacts to the surrounding environment. This discharge water quality is significantly higher than the current water quality of the receiving watercourses. Additionally, a lower protection level (compared to the operational phase) is considered appropriate for the construction phase as it would be temporary in nature.

The receiving waters for this discharge are in heavily urbanised, highly disturbed ecosystems with sections piped underground or concrete lined. Due to the topography of the area, the initial discharge locations would be ephemeral and at the top of the catchments. This discharge would ultimately drain into the Parramatta River, Lane Cove River, and Berowra Creek Subcatchments, within the Hawkesbury-Nepean and Sydney Metropolitan Catchments.

The discharge of treated water, at the estimated rates shown in **Table 7-177**, would result in a consistent base flow in currently ephemeral streams. It would also result in an increase in the instantaneous peak flow rates in downstream watercourses. Existing flow rates in downstream watercourses would be expected to be significantly higher than the discharge rate from the project during large rainfall events.

Hydrology and flooding

During construction, changes to surface water flow regimes may result from:

- An increase in impervious surface areas.
- Alterations to existing drainage infrastructure and construction of new drainage structures.
- Direct disturbance of watercourses for the upgrades of drainage channels and culverts which may lead to an increase in surface water flow rates and volumes, including the temporary crossing of Cockle Creek within the Junction Road compound (C11).
- A temporary crossing of Darling Mills Creek for the viaduct works.
- Discharge of treated water from construction water treatment plants into the local stormwater system, as detailed above.

Potential impacts to surface water flow regimes during construction may include:

- Increased flow rates and volumes in watercourses due to an increase in impervious surface areas upstream or groundwater seepage from the tunnel section (ie discharge of treated water from the water treatment plants and increased flows in Cockle Creek at the northern interchange).
- Modification, either by mechanical or natural disturbance, of stream beds and banks through increased erosion.
- Sedimentation of downstream waterways resulting from the erosion of upstream waterways.
- Localised flooding during high rainfall events.

These potential changes to existing surface water flow regimes would be effectively managed through the design of stormwater infrastructure to accommodate expected changes to flow rates and volumes, and the application of the mitigation and management measures in **Section 7.9.4**. Primarily this would entail the control of discharge flow rates, as well as other standard construction management measures.

Existing drainage and surface water management infrastructure, as described in **Section 7.9.2**, would continue to manage surface drainage and potential flooding during construction. Erosion and sediment controls would be used to manage drainage on construction sites prior to discharge into the existing drainage infrastructure. Due to the location of the project away from flood prone land and the maintenance of existing drainage infrastructure, the construction of the project is not anticipated to result in changes to localised flooding.

Erosion and sediment controls would also direct water away from the tunnel construction access points. Despite this, there remains a low potential for water to flow into the tunnel during high rainfall events. During construction planning, an emergency response plan would be developed including the evacuation of the tunnel of construction personnel based on certain heavy rainfall events.

With the implementation of the mitigation and management measures during construction, adverse impacts as a result of changes to surface water flow regimes and flooding would be unlikely.

Water Quality

During construction the following activities would have the potential to impact upon surface water quality:

- Exposure of soils during surface earthworks (including vegetation clearing, stripping of topsoil, excavation, stockpiling and materials transport), which has the potential to result in soil erosion and off-site movement of eroded sediments by wind and / or stormwater to receiving watercourses, resulting in increased nutrients, metals and other pollutants. The potential for sediment transport and sedimentation issues would be influenced by factors such as severity of storm events, the slope and footprint of disturbed areas and the management controls that are implemented on-site.
- Accidental leaks or spills of chemicals, fuels, oils and / or greases from construction plant and machinery, which have the potential to pollute receiving watercourses and mobilisation of heavy metals in the environment. This potential impact is described and assessed in **Section 8.2** (Hazards and risk).
- Disturbance of contaminated land potentially causing contamination of downstream watercourses, impacting on aquatic and riparian habitats. This potential impact is described and assessed in **Section 7.8** (Hydrogeology and soils).
- Direct disturbance of watercourses, including banks and natural drainage channels, for example during culvert construction and modification, the temporary crossing of Cockle Creek, and the temporary crossing of Darling Mills Creek during the viaduct works, which has the potential to lead to sediments entering and polluting waterways.
- Infiltration of surface water into groundwater sources, potentially transferring pollutants including sediments and particles and soluble compounds (such as acids, salts, nitrates, phosphates and soluble hydrocarbons).
- Leaching of tannins from stockpiles of cleared vegetation, with the potential to affect receiving waters, including:
  - Increased biological demand, with consequent decreases in dissolved oxygen.
  - Reduced water clarity and light penetration.
  - Decreased pH.

Water quality impacts during construction would vary between the different project areas, depending on the nature of construction activities and the proximity to sensitive receiving environments. For example, the tunnelling works would result in groundwater inflows into the tunnel, which would require treatment and discharge from the construction water treatment plants. In comparison, the surface construction works and earthworks at the interchanges, tie-in, integration and ancillary construction sites would result in the exposure of soils and an increase in impervious surfaces, potentially resulting in increased flow rates and volumes, and a risk of sedimentation.

The specific risk level associated with each construction site would be subject to site specific factors including:

- Extent of soil disturbance and susceptibility of the soil to erosion.
- Proximity to local watercourses.
- Stockpiling activities and locations.
- Potential for dust generation.
- Land rehabilitation on completion of construction.

If not appropriately managed, these potential impacts may adversely affect the health of aquatic environments, particularly within sensitive receiving environments. Impacts may include:

- Loss of terrestrial and aquatic species.
- Damage to aquatic, riparian and terrestrial environments.
- Effects on the suitability of downstream waterways for recreational uses, particularly watercourses identified as being of high recreation value (ie Lane Cove River, Hawkesbury River and Parramatta River).

Potential sensitive receiving environments that may be impacted by the project are identified in **Table 7-174.**

These surface water quality impacts are considered to be unlikely, as they would be effectively managed through the application of best practice measures and the proposed mitigation and management measures, including erosion, sediment and leachate controls and other construction management measures as detailed in **Section 7.9.4**.

Additional measures to reduce the risks to surface water quality include:

- Erosion and sediment controls (refer **Section 7.8** Hydrogeology and soils).
- The management of dust (refer **Section 7.3** Air quality).
- The management of dangerous goods and hazardous substances (refer **Section 8.2** Hazards and risk).
- Waste management (**Section 8.3** Resource management and waste minimisation).

Operation

Water supply and water balance

As described in **Section 7.8** (Hydrogeology and soils), the project would include drained tunnels and would require the ongoing capture and management of groundwater inflows into the tunnels.

The tunnel drainage system would flow by gravity to one sump, with a capacity of 420 cubic metres, located at the tunnel low point where water would then be pumped to a water treatment plant located within the motorway operations complex for treatment and either reuse or discharge to the local stormwater system. The sump would contain capacity of 50,000 litres to capture accidental operational hydrocarbon or other spillage within the tunnel.

The operational water treatment plant would be designed to treat up to 40 litres per second (around 1,050 ML/year). Based on the anticipated groundwater quality, the water treatment methods would typically involve:

- pH adjustment.
- Removal of suspended solids.
- Removal of dissolved solids.
- Brackish water reverse osmosis.
- Dissolved iron removal by oxidising the Ferric ion ($Fe3+$) to Ferrous ($Fe2+$) which enables precipitation and physical removal.
- Biocide dosing of iron reducing bacteria.

The tunnel drainage system and operational water treatment plant would also capture and treat:

- Deluge water produced in the unlikely event of an emergency within the tunnels or from regular testing of the system.
- Tunnel wall washing water as part of regular tunnel maintenance.

In the event of significant rainfall event above the design capacity of the water treatment plant of 40 litres per second, the high flow bypass would be activated. Under this scenario, the first flush would be captured by the treatment plant with subsequent flows bypassing treatment. This is likely to occur in rare events only.

Treated water would be either reused or discharged to the local stormwater system on Gum Grove Place, which in turn discharges into Blue Gum Creek (a tributary of Darling Mills Creek and part of the Upper Parramatta River catchment under the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources* (the Water Sharing Plan)). The project has been designed to achieve a maximum water discharge quality equivalent to the 95 per cent protection level specified for freshwater eco-systems in accordance with ANZECC guidelines (ANZECC & ARMCANZ, 2000). The discharge water quality level would be determined in consultation with the NSW Environment Protection Authority during the detailed design phase taking into consideration the current water quality of the receiving watercourses. A higher discharge water quality (compared to the construction phase) is likely to be adopted for the operational phase due to the ongoing nature of the impact.

The discharge of treated groundwater would change the flow in downstream watercourses, including Blue Gum Creek and Darling Mills Creek, from ephemeral to perennial flow regimes. However, the introduction of flows from the water treatment plant would be negligible compared to the existing peak flows in Blue Gum Creek. This introduction of a continuous variable flow condition may result in:

- A weakened soil structure within the wetted zone resulting in increased bed and bank erosion.
- Channel bed incision and lateral expansion.
- Increased mobilisation of sediments into receiving waters.
- Increased localised flooding at narrow points in the channel.
- Increased damage to existing public and private infrastructure / assets.

The upper first order reaches of Blue Gum Creek from its start at Gum Grove Place to around 1.2 kilometres to the west, is considered to be at high to medium risk of erosion if subjected to substantial increases in baseflows. The high to medium risk rating is due to the relatively small size of the channel, the erosive nature of the channel material, and the impacts of an urbanised hydrology that has weakened and extensively eroded the channel. These reaches also have a number of locations where the increased flow could potentially cause damage, via creek erosion, to private and public infrastructure. The downstream section of Blue Gum Creek up to the confluence with Darling Mills Creek, has a medium to low risk of erosion as the bed is mostly stable but banks are unstable. Darling Mills Creek is considered to be at low risk as the stream is much wider and able to accommodate increased flows without a substantial increase in depth or velocity.

The exact location of discharge to Blue Gum Creek or Darling Mills Creek would be further investigated during the detailed design phase. Additional mitigation measures such as stream bed and bank stabilisation, or re-sizing of existing drainage infrastructure would be determined at this stage based on the location of discharge. Detailed design of the discharge and identification of an appropriate location for the discharge would take into account potential geomorphic, property and ecological impacts.

The increased flow may also allow the NSW Office of Water to increase the surface water extraction limits in the Upper Parramatta River catchment under the Water Sharing Plan. The potential impacts on aquatic and riparian ecology associated with the increased flow in receiving watercourses are described in **Section 7.6** (Biodiversity).

The tunnel water management strategy for the project, incorporating both groundwater inflows and surface water inflows into the tunnels, is depicted in **Figure 7-81.**

In addition to the tunnel drainage system, drainage structures and water treatment methods would be implemented for surface infrastructure. The drainage structures incorporated into the project would include existing drainage infrastructure around the interchanges, tie-in and integration works, and operational ancillary facilities which would be augmented to meet additional capacity requirements associated with increased impervious areas. Appropriate protection would be provided downstream of relevant drainage infrastructure to prevent adverse impacts on bed and bank stability, and to protect the existing water quality of downstream watercourses.

These drainage systems would be designed and implemented to minimise potential impacts on receiving watercourses.

Surface works at the portals, the tie-in to the M1 Pacific Motorway and the integration with the Hills M2 Motorway are located in areas managed by existing drainage infrastructure. The project would increase the area of impervious surfaces and the catchment areas of this drainage infrastructure. This would necessitate the following alterations and / or augmentations:

- Demolition and reconstruction of pits and pipes.
- Modification to four existing operational detention basins adjacent to the Hills M2 Motorway, to minimise the risk of any spills entering sensitive receiving environments downstream, including Darling Mills Creek.
- Extension of five transverse drainage culverts on the Hills M2 Motorway.
- Alterations to the Pennant Hills Road drainage system to provide capacity for a 20 year ARI storm event, including increasing the size of the existing Pennant Hills Road detention basin and collection of the first flush for the one year ARI storm event.
- Alterations to the northern interchange drainage system to provide capacity for a 20 year ARI storm event. Provision for water quality treatment of a one year ARI storm event around the northern interchange using gross pollutant traps and oil / water separators.
- Provision of spillage containment tanks around the northern interchange, with a capacity of 50,000 litres.
- A new transverse drainage culvert under the M1 Pacific Motorway / Pennant Hills Road connector to act as a relief culvert for a probable maximum flood event.

The modifications to existing drainage infrastructure have been designed to replicate the current design standard and operational functionality. For example, the detention basins along the Hills M2 Motorway are currently designed and function to capture the first flush from a one year ARI event. Where the project would increase the road surface area draining to a particular basin, the basin would be modified to continue to capture the first flush from a one year ARI event. Despite this, opportunities to design to a higher standard and provide improved environmental outcomes have been incorporated into the design where feasible and reasonable.

Additionally, surface operational ancillary facilities would require connections to third party stormwater systems.

Hydrology and flooding

During operation, changes to surface water flow regimes may result from:

- The increased impervious surface area.
- New and altered drainage infrastructure.
- Discharge of treated water from the operational water treatment plant into the local stormwater system on Gum Grove Place which in turn discharges into Blue Gum Creek (a tributary of Darling Mills Creek and part of the Upper Parramatta River catchment as detailed above).

During operation, effective mitigation and management measures would be implemented to avoid or minimise potential impacts on surface water quality associated with:

- Increased surface water runoff due to an increase in impervious surfaces and a concentration of road runoff through drainage infrastructure. Associated with this risk is the increased potential for the following pollutants to enter nearby watercourses via road runoff:
  - Sediments from paved surfaces.
  - Nutrients (phosphorus and nitrogen) deposited onto paved surfaces due to atmospheric deposition.
  - Heavy metals attached to particles washed off paved surfaces.
  - Oil, grease and other hydrocarbon products, generated by general vehicular use of the motorway.
  - Gross pollutants (roadside litter).
  - Fuels and chemicals from spills caused by traffic accidents.
  - Contaminants from runoff from the roadway or road shoulders.
- Increased flow rates and volumes in watercourses due to an increase in impervious surface areas upstream.
- Modification, through natural disturbance, of stream beds and banks through increased erosion.
- Sedimentation of downstream waterways resulting from the erosion of upstream waterways.
- Localised flooding during high rainfall events.

In addition, the discharge from the operational water treatment plant would result in a consistent base flow in the currently ephemeral Blue Gum Creek. This in turn would increase the frequency, volume and velocity of flows in the downstream Darling Mills Creek, potentially leading to or exacerbating erosion and impacting on the water quality within the potential receiving environments.

These potential changes to existing surface water flow regimes would be effectively managed through the design and construction of stormwater infrastructure that accommodates changes to flow rates and volumes, as detailed in the water supply and water balance section above, and the application of the mitigation and management measures in **Section 7.9.4**. Primarily this would entail stormwater detention to control discharge flow rates as well as other operational management measures. In addition, water discharge from the operational water treatment plant would be controlled to ensure that discharge does not exceed the capacity of the downstream system.

With the implementation of the proposed measures during operation, adverse impacts as a result of changes to surface water flow regimes and flooding would be unlikely.

In addition, the project would result in a negligible overall change in overland flows within the project area. A summary of the existing and proposed contributing catchment areas for each road drainage outfall within the project area and how these catchments would be managed is described below.

- Hills M2 Motorway integration catchments:
  - The introduction of the project tunnel dive structures would result in a negligible change to the contributing catchment area as flows from the dive structures would be taken into the tunnel drainage system, collected in the tunnel sump, and ultimately discharged through the operational water treatment plant, as detailed in **Section 7.9.3**.
  - The total volume of runoff to the Hills M2 Motorway drainage system would be slightly increased as a result of the project due to the additional westbound carriageway. However, minor modifications, including increases in existing basin volume where necessary, would ensure that the Hills M2 Motorway drainage system continues to operate at the same design capacity as the current situation.
- Southern interchange and motorway operations complex catchments:
  - The project would result in a negligible change to the overall contributing catchment areas for the southern interchange and motorway operations complex.
  - The contributing surface catchment areas would be directed through an on-site detention tank within the motorway operations complex of around 2,000 cubic metres.
- Northern interchange and M1 Pacific Motorway tie-in works catchments
  - The contributing catchment area for the Northern interchange and M1 Pacific Motorway tie-in works would remain primarily unchanged.
  - An on-site detention tank, which incorporates spillage control measures, would be installed to ensure flows resulting from the project do not exceed existing flows. In addition, any flows in the vicinity of the dive structures would be taken into the tunnel drainage system and collected in the tunnel sump, as detailed in **Section 7.9.3**.
- Operational ancillary facilities
  - The operational ancillary facilities would be located within residential areas within the suburbs of West Pennant Hills, Pennant Hills, Thornleigh, and Wahroonga. Within these areas surface water would be conveyed as overland flow and would be managed by existing stormwater networks as described in **Section 7.9.2**.
  - The project would result in no net change to the overall contributing catchments in these areas.
  - This existing drainage and surface water management infrastructure would be maintained and augmented as detailed in the water supply and water balance section above to manage the surface water flows during operation.

The operational tunnel drainage system would also be designed to manage any potential flooding within the tunnel during operation through the following measures:

- Stormwater runoff would be collected and directed safely from all pavements associated with the project.
- On-site detention would be incorporated into the design to ensure there is no increase in discharge from the site in a 100 year ARI event.
- The tunnel portals, and surrounding roads, would be designed to minimise the amount of water flows into the portals and to prevent the ingress of floodwaters up to the probable maximum flood. This may include:
  - Relief culverts under the roadways to prevent probable maximum flood flows from entering the portals.
  - Retaining walls, channel diversions and culverts to convey the probable maximum flood flow away from the tunnel portals.
- The tunnel drainage system, including the operational water treatment plant, would have sufficient capacity to accommodate water from surface runoff at the portals and approaches, groundwater inflows into the tunnel, operation of the fire and life safety systems, and from operation and maintenance activities.
- The tunnel sump, located at the tunnel low point would be sized to take the greater of peak operational flows (including operation of the deluge system) and 100 year ARI inflows from the tunnel portals.
- Flows collected in the tunnel sump would be pumped to the water treatment plant holding tank. In large storm events first flush stormwater flows would pass through the water treatment plant.

The potential impacts from flooding would be effectively managed through the design and construction of stormwater and drainage infrastructure that would accommodate the changed surface water flow rates and volumes.

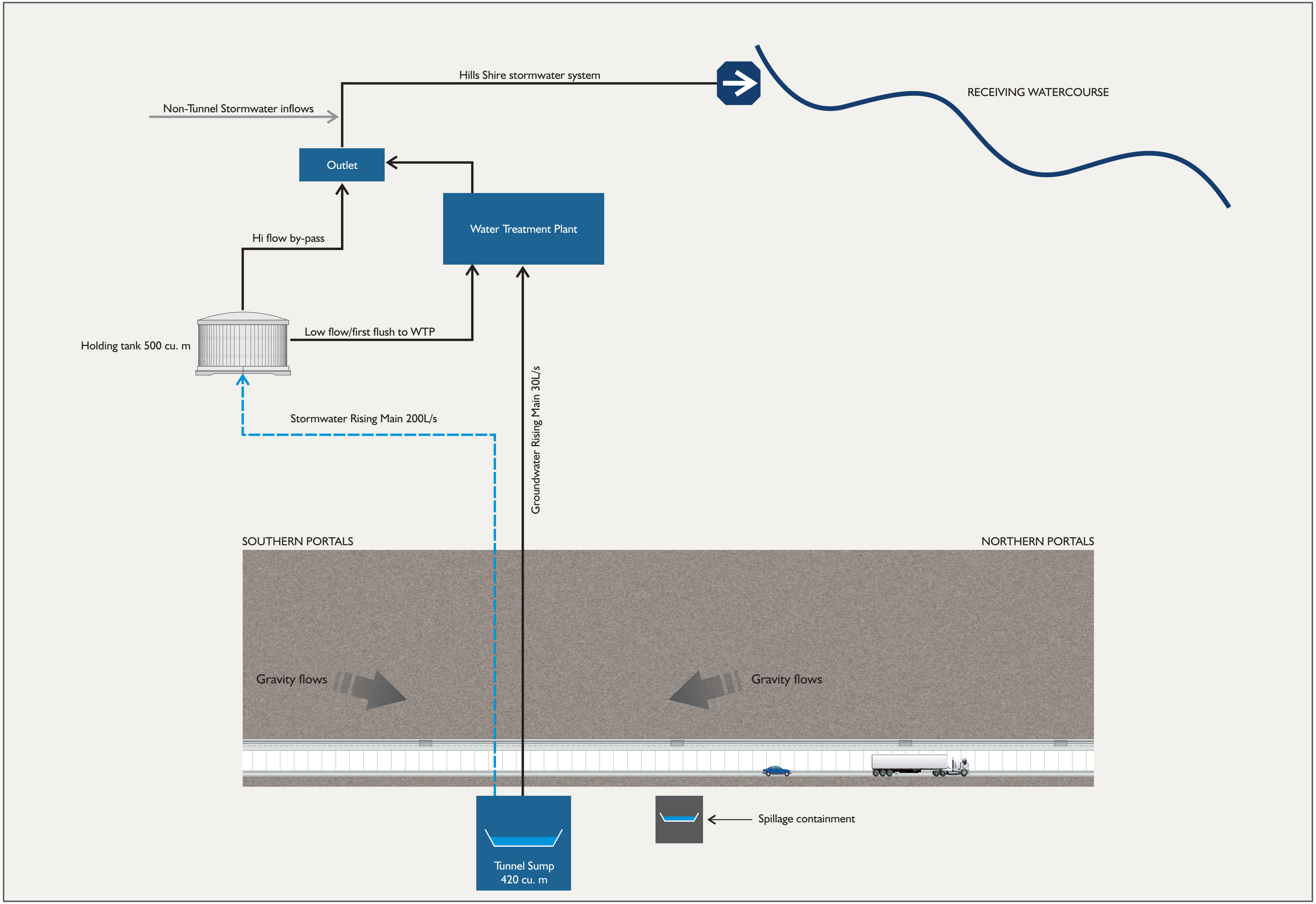

Figure 7-81 Tunnel water management strategy

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Water quality

The impacts of the project may include potential changes in the hydrological regime leading to increased erosion and sedimentation and pollutant generation. Water quality measures would be incorporated into the design of stormwater drainage systems in accordance with ANZECC (2000) and relevant Council standards.

The increased impervious surfaces associated with the works (such as paved areas and building roofs) would have the potential to affect the hydrological regime in terms of increased runoff volumes and peak flows. This could lead to a range of impacts associated with increased erosion and sedimentation. Where feasible and reasonable, water sensitive urban design principles would be incorporated into the design to minimise the impacts of the works on the existing hydrologic regime. Such measures would include:

- Managing total runoff volumes through the use of rainwater tanks at project surface buildings and measures that would promote stormwater infiltration (such as pervious paving and rain gardens).
- Minimising increases in peak flows through the use of detention and retention measures (such as water detention basins).
- Treating stormwater through a range of at source and end point measures that are integrated with the urban landscape. Such measures would include water detention basins.

The project would incorporate a system of drainage structures and water treatment measures, including an operational water treatment plant and surface water quality detention basins, to manage surface runoff generated from the increase in impervious surfaces in the project area. The design of the drainage system would minimise potential impacts on receiving watercourses, including scour and erosion.

The project drainage system has been designed to prevent adverse effects on private properties for the 100 year ARI storm event and to accommodate water from surface runoff at the portals and approaches, water from groundwater inflows into the tunnel, deluge system water (as part of the fire and life safety system), and water from operation and maintenance activities.

A summary of potential pollutants and proposed measures for each drainage element is provided in **Table 7-178** with further details provided in the following sections.

Table 7-178 Summary of drainage elements, associated water quality impacts and mitigation measures

Drainage element	Impacts and potential pollutant generation	Mitigation and requirements	Examples of typical treatment(s)
Groundwater seepage into the tunnels	Groundwater flows collected from the tunnels would potentially be of poor quality, requiring treatment prior to discharge into the surface water system. Refer to **Section 7.8** (Hydrogeology and soils).	Groundwater flows within the tunnels would be collected and pumped to the water treatment plant near the southern interchange. Refer to **Section 7.8** (Hydrogeology and soils).	Operational water treatment plant near the southern interchange.
Tunnel	Pollutant generation within the tunnels is mainly expected to be due to litter, metals from tyre and vehicle wear, and grease and oils from motor vehicles.	Surface water flows collected within the tunnels would be collected and pumped to the operational water treatment plant near the southern interchange.	• Gross pollutant traps • Oil / water separator • Operational water treatment plant near the southern interchange
Interchanges, tie-in and integration works	Pollutant generation at the interchanges, tie-in and integration is mainly expected to be due to litter, and grease and oils from motor vehicles.	Management of pollutants to be accommodated within the design through the implementation of at source measures such as the use of grassed swales and water quality detention basins.	• Gross pollutant traps • Oil / water separator • Water detention basins

Residual operational impacts of the project

The project would result in minor residual operational impacts to surface water flows and quality. The residual impacts of the project on each receiving watercourse are described below.

Darling Mills Creek:

- Increased detention basin sizes along the Hills M2 Motorway integration works and upstream impacts to Blue Gum Creek, resulting in increased flows in Darling Mills Creek and downstream watercourses.
- Potential for localised flooding during high rainfall events.
- Potential bed and bank instability due to increased flows.

Blue Gum Creek:

- Increased detention basin sizes along the Hills M2 Motorway integration section.
- Increased flows and potential for erosion and sedimentation in Blue Gum Creek due to:
  - Surface water collection and discharge from the southern interchange area.
  - Discharge of deluge water and groundwater inflow into the tunnel following treatment at the water treatment plant.

Coups Creek:

- Outfall point of probable maximum flood relief culverts and on-site detention.
- Discharge of surface water collected for a portion of the northern interchange.

Cockle Creek:

- Increased discharge of surface water as a result of M1 Pacific Motorway tie-in works.

These operational impacts would be effectively managed through the implementation of the mitigation and management measures in **Section 7.9.4**.

7.9.4 Environmental management measures

The project has incorporated appropriate drainage design measures in order to adequately manage potential ongoing operational impacts to surrounding watercourses. This would include the capture, treatment and discharge of groundwater inflow into the tunnels, provision for spillage containment within the tunnels and the augmentation of existing drainage infrastructure along the Hills M2 Motorway and the M1 Pacific Motorway.

During the construction phase, water from the tunnelling process would be captured and treated at four water treatment plant located along the alignment. Erosion and sediment control measures would be implemented to manage surface section of the construction.

Environmental management measures relating to surface water for the construction and operational periods are provided in **Table 7-179.**

Table 7-179 Environmental management measures - surface water

Impact	No.	Environmental management measure	Timing
Construction			
General	SW1	A Construction Soil and Water Quality Management Plan would be prepared to manage surface and groundwater impacts during construction of the project.	Pre-construction and construction
Erosion and sedimentation	SW2	Progressive erosion and sediment control plans (ESCPs) would be prepared and implemented in advance of construction, including earthworks and stockpiling. ESCPs would be updated as required.	Pre-construction and construction
	SW3	Erosion and sediment controls, including sedimentation basins, would be designed, installed and managed in accordance with Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom, 2004) and Managing Urban Stormwater: Soils and Construction Volume 2D, Main Road Construction (DECC, 2008).	Pre-construction and construction
	SW4	A project soil conservationist would be engaged and consulted during construction to provide advice on erosion and sediment control design, installation and maintenance.	Pre-construction and construction
	SW5	Works would be programmed to minimise the extent and duration of disturbance to vegetation.	Pre-construction and construction
	SW6	Cleared native vegetation would be mulched for use in erosion and sediment control where feasible and reasonable, in accordance with the Environmental Direction Management of Tannins from Vegetation Mulch (Roads and Maritime, 2012b).	Pre-construction and construction

Impact	No.	Environmental management measure	Timing
	SW7	Site induction and ongoing toolbox talks would be provided to project personnel, including relevant sub-contractors on soil erosion and sediment control requirements and practices and their responsibilities.	Construction
	SW8	Erosion and sediment control structures would remain installed and maintained until sufficient stabilisation is achieved.	Construction
	SW9	Soil and land rehabilitation would occur as soon as practicable following construction. This would include rehabilitation in stages as the construction process allows.	Construction and post construction
	SW10	Temporary stockpile locations for both site establishment and earthworks would be specified prior to the commencement of construction activities in that area. Diversion drains and erosion and sediment control measures would be in place prior to the commencement of any stockpiling activities. Material would only be stockpiled in designated stockpiling areas.	Pre-construction and construction
Protection of riparian areas	SW11	Scour protection and erosion protection measures would be implemented downstream of the watercourse crossings and surface water discharge points.	Pre-construction
	SW12	Where water is released into local creeks, outlet scour protection and energy dissipation would be implemented. The discharge point would be at the upstream end of a large pool where feasible and reasonable, to allow for slowing of water.	Pre-construction
Water efficiency	SW13	Water efficiency measures would be implemented with a focus on achieving water savings and targeting water recycling and re-use.	Pre-construction and construction
Dewatering	SW14	A specific Work Method Statement for dewatering and discharging from open exposed excavations and sediment controls would be prepared, in accordance with the Technical Guideline Environmental Management of Construction Site Dewatering (Roads and Maritime, 2011d).	Construction
	SW15	Water discharge quality would comply with the requirements of an environmental protection licence issued for the project.	Construction

Impact	No.	Environmental management measure	Timing
Refuelling and storage of chemicals and fuels on-site	SW16	Where refuelling on-site is required, a Work Method Statement would be prepared and the following management practices would be implemented: • Refuelling would be undertaken on level ground and away from drainage lines, waterways and / or environmentally sensitive areas. • Refuelling would be undertaken within the designated refuelling areas with appropriate bunding and / or absorbent material. • Refuelling activities would be attended at all times. • Spill kits would be readily available and personnel trained in their use. A spill kit would be kept on the refuelling truck at all times.	Construction
Localised flooding of receiving watercourses	SW17	The discharge of treated groundwater would be managed to ensure that discharge does not exceed the capacity of the downstream system.	Construction
Blocking of fish passage	SW18	Maintain the flow along the current Cockle Creek and Darling Mills Creek alignment through appropriate design.	Construction
	SW19	Design waterway crossings, structures, bridges and culverts to maintain fish passage with reference to the guidelines contained in Guidelines and Policies for Aquatic Habitat Management and Fish Conservation' (Smith and Pollard 1999), Why do fish need to cross the road? Fish passage requirements for waterway crossings (Fairfull and Witheridge, 2003) and Fish and Fauna Friendly Waterway Crossings (Fairfull & Witheridge, 2003).	Pre-construction and construction
Monitoring	SW20	A surface water quality monitoring program for the construction period would be implemented to monitor water quality upstream and downstream of the construction areas. The monitoring program would commence prior to commencement of any construction works and would build on available water quality data.	Pre-construction and construction
	SW21	Inspection of water quality mitigation controls (eg sediment fences, sediment basins) would be carried out regularly and following significant rainfall to detect any breach in performance.	Construction

Impact	No.	Environmental management measure	Timing
Operation			
Operational Environmental Management Plan	OpSW1	The management of potential surface water impacts during the operation of the project would be detailed as part of an OEMP.	Operation
Contaminant spill	OpSW2	Procedures to quickly address any contaminant spill or accident would be developed prior to operation and implemented during operation project.	Operation
Water treatment and discharge	OpSW3	Treated tunnel water would be discharged to the local stormwater system. The project has been designed to achieve a maximum water discharge quality equivalent to the 95 per cent protection level specified for freshwater eco-systems in accordance with ANZECC guidelines (ANZECC & ARMCANZ, 2000). The discharge water quality level would be determined in consultation with the NSW Environment Protection Authority during the detailed design phase taking into consideration the current water quality of the receiving watercourses.	Detailed design
Water re-use	OpSW4	All feasible and reasonable opportunities for captured surface water reuse would be utilised in the first instance.	Operation
Increased water flow	OpSW5	On-site detention would be provided where required to mitigate impacts associated with increased impervious areas. This would involve the augmentation of existing basins and the construction of new basins.	Operation
	OpSW6	The exact location of discharge to Blue Gum Creek or Darling Mills Creek would be further investigated during the detailed design phase. Additional mitigation measures such as stream bed and bank stabilisation, or re-sizing of existing drainage infrastructure would be determined at this stage based on the location of discharge.	Detailed design
Water quality	OpSW7	Water Sensitive Urban Design principles would be incorporated into the design to minimise impacts on the existing hydrologic regime. Such measures would include: Minimising increases in peak flows through the use of detention and retention measures as appropriate. Treating stormwater through a range of at source and end point measures that are integrated with the urban landscape.	Operatio
Drainage maintenance	OpSW8	Operational drainage infrastructure would be regularly inspected and maintained.	Operation

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