Chapter 17

Hydrodynamics and water quality

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17 Hydrodynamics and water quality

This chapter provides an assessment of the construction and operational impacts associated with hydrodynamics and (surface) water quality.

A detailed surface water quality and hydrology assessment has been carried out for the project and is included in Appendix O (Technical working paper: Surface water quality and hydrology). Hydrodynamic and dredge plume modelling has also been carried out and is detailed in Appendix P (Technical working paper: Hydrodynamic and dredge plume modelling).

The impacts associated with flooding are detailed in Chapter 18 (Flooding), while assessments of contamination and groundwater impacts are included in Chapter 16 (Soils, geology and groundwater).

The Secretary's environmental assessment requirements as they related to hydrodynamics and water quality, and where in the environmental impact statement these have been addressed, are detailed in Table 17-1.

The proposed environmental management measures relevant to hydrodynamics and water quality are included in Section 17.6.

Table 17-1 Secretary's environmental assessment requirements – hydrodynamics and water quality

Secretary's requirement	Where addressed in EIS
Water – Hydrology	
1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes and groundwater dependent ecosystems) likely to be impacted by the project, including rivers, streams, wetlands and estuaries as described in Appendix 2 of the *Framework for Biodiversity Assessment – NSW Biodiversity Offsets Policy for Major Projects* (Office of Environment and Heritage, 2014).	Details of surface water resources likely to be impacted by the project are presented in **Section 17.3.1**. Biodiversity consideration are outlined in **Chapter 19** (Biodiversity) and the hydrological regime for groundwater is considered in **Chapter 16** (Soils, geology and groundwater).
2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations (including mapping of these locations), volume, frequency and duration for both the construction and operational phases of the project.	A surface water balance for construction and operation is provided in **Section 17.4.5** and **17.5.6** respectively. Refer to **Chapter 16** (Geology, soils and groundwater) for groundwater inflow predictions.

Secretary's requirement	Where addressed in EIS
3. The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including: a. natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity, water-dependent fauna and flora and access to habitat for spawning and refuge;	Surface water hydrological impacts and impacts on natural processes are included in **Section 17.4** and **17.5**. Groundwater hydrological impacts are included in **Chapter 16** (Geology, soils and groundwater). Impacts on flooding are included in **Chapter 18** (Flooding). Surface water and groundwater hydrological impacts on the health of the fluvial, riparian, estuarine or marine system, aquatic connectivity, fauna and flora, and access to habitat for spawning and refuge are included in **Chapter 19** (Biodiversity).
b. impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Groundwater hydrological impacts are included in **Chapter 16** (Geology, soils and groundwater). Implications for groundwater dependent ecosystems and species are included in **Chapter 19** (Biodiversity).
c. changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources including the stormwater harvesting scheme implemented by North Sydney Council at the storage dam at Cammeray Golf Course;	An assessment of the changes to environmental water availability and flows (including the stormwater harvesting scheme implemented by North Sydney Council at the storage dam at Cammeray Golf Course) is included in **Section 17.4.5** and **17.5.6**.
d. direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Potential impacts on surface water with regard to erosion, siltation, and bank stability are assessed in **Section 17.4** and **17.5**. Impacts from scour and erosion on geomorphology are discussed in **Section 17.4.4**. The effects of proposed stormwater and wastewater management on surface water quality are assessed in **Section 17.4.3** and **17.5.3**. Impacts on riparian vegetation are included in **Chapter 19** (Biodiversity).

Secretary's requirement	Where addressed in EIS
e. minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and reuse options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems;	Information on wastewater discharge, including volumes and rates of discharge, is included in **Section 17.4.3** and **17.5.3**.
f. measures to mitigate the impacts of the proposal and manage the disposal of produced and incidental water; and	Environmental management measures relating to surface water are detailed in **Section 17.6**. Water drainage and management infrastructure is detailed in **Chapter 5** (Project description) and **Chapter 6** (Construction work).
4. The assessment must provide details of the final landform of the sites to be excavated or modified (eg portals), including final void management and rehabilitation measures.	Details of the final landforms and rehabilitation for the project are provided in **Chapter 22** (Urban design and visual amenity). Landscape treatments for the project are detailed in **Chapter 5** (Project description).
5. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	A description of surface water monitoring carried out to inform this environmental impact statement, and requirements for operational monitoring are provided in **Section 17.2.2** and **17.6** respectively. Proposed groundwater monitoring is identified in **Chapter 16** (Geology, soils and groundwater).
6. The assessment must include details of proposed surface and groundwater monitoring.	A description of surface water monitoring carried out to inform this environmental impact statement, and requirements for operational monitoring are provided in **Section 17.2.2** and **17.6** respectively. Proposed groundwater monitoring is identified in **Chapter 16** (Geology, soils and groundwater).
7. The Proponent must identify design approaches to minimise or prevent drainage of alluvium in the paleochannels.	Tunnel design in relation to drainage resulting from paleochannels is provided in **Chapter 5** (Project description) and **Chapter 6** (Construction work).
Water – Quality	
1. The Proponent must: a. describe the background conditions for any surface or groundwater resource likely to be affected by the development	A description of the background surface water and groundwater conditions is included in **Section 17.3** and **Chapter 16** (Geology, soils and groundwater) respectively.

Secretary's requirement	Where addressed in EIS
b. state the ambient NSW Water Quality Objectives (NSW WQO) (as endorsed by the NSW Government [see www.environment.nsw.gov.au/ieo/index.htm]) and environmental values for the receiving waters (including groundwater where appropriate) relevant to the project and that represent the community's uses and values for those receiving waters, including the indicators and associated trigger values or criteria for the identified environmental values in accordance with the ANZECC (2000) *Guidelines for Fresh and Marine Water Quality* and/or local objectives, criteria or targets endorsed by the NSW Government;	A list of the ambient NSW Water Quality Objectives (NSW WQO) for receiving waters within the project area is included in **Section 17.1.2**. Environmental values for the receiving waters are discussed in **Section 17.3.8**. The ANZG (2018) and ANZECC/ARMCANZ (2000) default trigger values are provided in **Appendix O** (Technical working paper: Surface water quality and hydrology).
c. identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Potential pollutants of concern are identified in **Section 17.4**, **17.5** and **Appendix O** (Technical working paper: Surface water quality and hydrology). An assessment of the potential for construction to introduce pollutants into receiving waterways is provided in **Section 17.3.5**. Discharge quantities and locations are provided in **Section 17.4.3** and **17.5.3**.
d. identify the rainfall event that the water quality protection measures will be designed to cope with;	**Appendix O** (Technical working paper: Surface water quality and hydrology) outlines water quality protection measures to be adopted during construction and operation, which basins would be designed for.
e. assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes;	The significance of identified impacts on ambient water quality outcomes is assessed in **Section 17.4** and **17.5**.
f. demonstrate how construction and operation of the project (including mitigating effects of proposed stormwater and wastewater management) will, to the extent that the project can influence, ensure that: - where the NSW WQOs for receiving waters are currently being met they will continue to be protected; and - where the NSW WQOs are not currently being met, activities will work toward their achievement over time;	Discussion of whether the NSW WQOs are currently met is included in **Section 17.3.5**. An assessment on how construction and operation of the project would impact on the NSW WQOs is included in **Section 17.1.1**. Management measures relevant to surface water quality impacts are provided in **Section 17.6**. The ability of the project to meet the NSW WQOs is discussed in **Section 17.4** and **17.5**.

Secretary's requirement	Where addressed in EIS
g. justify, if required, why the WQOs cannot be maintained or achieved over time;	
h. demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Practical management measures to be adopted for the project are provided in **Section 17.6**. The project has been designed to avoid or minimise environmental impacts. Relevant environmental controls are detailed in **Chapter 5** (Project description) and **Chapter 6** (Construction work). Management measures to ensure the protection of human health are outlined in **Chapter 13** (Human health).
i. identify sensitive receiving environments (which may include estuarine and marine waters downstream including Quarry Creek and its catchment) and develop a strategy to avoid or minimise impacts on these environments; and	Sensitive receiving environments are identified and described in **Section 17.3.7**. Management measures to avoid (or minimise) impacts are provided in **Section 17.6**. Proposed surface water monitoring locations are discussed in **Section 17.2.2**. Further details, including monitoring frequency and indicators are provided in **Appendix O** (Technical working paper: Surface water quality and hydrology). The project has been designed to avoid or minimise environmental impacts. Relevant environmental controls are detailed in **Chapter 5** (Project description) and **Chapter 6** (Construction work).
j. identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Proposed surface water monitoring locations, frequency and indicators are identified in **Section 17.6**. The proposed monitoring locations, frequency and indicators of groundwater quality are outlined in **Chapter 16** (Geology, soils and groundwater).
2. The assessment should consider the results of any current water quality studies, as available, in the project catchment.	Surface water quality studies considered for this assessment are listed in **Appendix O** (Technical working paper: Surface water quality and hydrology).

17.1 Legislative and policy framework

17.1.1 Relevant legislation

Chapter 2 (Assessment process) describes the environmental impact assessment and approval process for the project, including relevant NSW and Commonwealth legislation applicable to the project. Legislative requirements specific to water quality and hydrodynamics is provided in Table 17-2.

Table 17-2 Legislation relevant to the project

Legislation	Relevance to project
Protection of the Environment Operations Act 1997	Environment protection licences are issued for a broad range of activities listed in Schedule 1 of the *Protection of the Environment Operations Act 1997* and aim to address air, noise, waste, land contamination and water pollution issues created by those activities. An environment protection licence would be required for construction of the project.
Fisheries Management Act 1994	In accordance with section 199 of the *Fisheries Management Act 1994*, notification to the Department of Planning, Industry and Environment (Regions, Industry, Agriculture & Resources) (former Department of Primary Industries (Fisheries)) is required if dredging or reclamation works are required in water land classed as key fish habitat.
Water Management Act 2000, Water Management Amendment Act 2014, and Water Management Regulation (General) 2011	The project is located within an area covered by the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources* (NSW Department of Primary Industries (DPI), 2011). This plan applies to surface water sources and includes rules for protecting the environment, water extraction, managing licence holders' water accounts, and water trading within the plan area. Under Schedule 4, Part 1, clause 2 of the Water Management (General) Regulation 2011, roads authorities are exempt from the requirement to hold a water access licence to take water for road construction and road maintenance.
Coastal Management Act 2016 and the related *State Environmental Planning Policy (Coastal Management) 2018*	The objects of the *Coastal Management Act 2016* are to manage the coastal environment in a manner consistent with the principles of ecologically sustainable development for the social, cultural and economic well-being of the people of the State. *State Environmental Planning Policy (Coastal Management) 2018* promotes an integrated and coordinated approach to land use planning in the coastal zone, consistent with the objects of the *Coastal Management Act 2016*. It provides development controls for four coastal management areas – coastal wetlands and littoral rainforest areas, coastal vulnerability areas, coastal environment areas and coastal use areas. The project footprint is not located within the coastal wetlands and littoral rainforest area or the coastal vulnerability area. The development controls for coastal environment areas and coastal use areas do not apply to the project, as the project footprint is within

Legislation	Relevance to project
	the catchment of the Sydney Harbour Catchment Regional Environmental Plan 2005 (refer below).
Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005	*The Sydney Harbour Catchment Regional Environmental Plan 2005* covers all the waterways of the Harbour, the foreshores and entire catchment. It provides an improved and clearer planning framework and better environmental outcomes for Sydney Harbour and its tributaries.

17.1.2 Relevant policies and guidelines

The water quality assessment has been prepared in accordance with a number of policies and guidelines as described below.

Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ, 2000) provide guidelines for water quality, taking into account their environmental values. The guidelines were updated in 2018 to incorporate new science and knowledge developed over the past 20 years (ANZG, 2018).

The study area would typically fall under the ANZG (2018) and ANZECC/ARMCANZ (2000) water quality guidelines for 'South-east Australian slightly disturbed lowland rivers and estuaries'. Wastewater treatment plants used during construction and operation would be designed such that discharges would comply with these guidelines. Site-specific trigger values would be used when setting the wastewater treatment plant discharge criteria to ensure wastewater is treated to a level that is representative of background concentrations at the receiving environment.

NSW Water Quality and River Flow Objectives

Water quality objectives have been developed for the Sydney Harbour and Parramatta River catchment (DECCW, 2006). The marine waterbodies relevant to this assessment, have been identified as 'upper estuary' (Iron Cove) and 'lower estuary' (Rozelle Bay, Snails Bay and Berrys Bay). Waterways relevant to this assessment (Whites Creek, Quarry Creek, Flat Rock Creek and Willoughby Creek) have been classified as 'waterways affected by urban development'. Based on this classification, the Water Quality Objectives and nominated environmental values relevant to the project include:

- Protection of aquatic ecosystems – ecological condition of waterways and the riparian zone (lower and upper estuary)
- Protection of visual amenity – aesthetic qualities of waters (lower and upper estuary)
- Protection of primary contact recreation – water quality for activities, such as swimming (lower and upper estuary)
- Protection of secondary contact recreation – water quality suitable for activities, such as boating and wading (lower and upper estuary).

Environmental values, as identified by the Department of Planning, Industry and Environment (Environment, Energy and Science) (formerly NSW Office of Environment and Heritage), for the Sydney Harbour and Parramatta River catchment are discussed further in Section 17.3.8.

Guidelines for Managing Risks in Recreational Water

The *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2008b) aim to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters. The guidelines have been applied in this background research for the project to understand the current recreational water quality and threat to public health of waterways relevant to the project.

Sydney Harbour Water Quality Improvement Plan

The *Sydney Harbour Water Quality Improvement Plan* (Greater Sydney Local Land Services, 2015) provides a coordinated management framework to improve the future health of Sydney Harbour and its catchments. This plan applies to the majority of the project footprint which ultimately drains to Sydney Harbour. While the plan itself does not include pollutant reduction targets for individual developments, catchment load and estuary condition targets have been developed for some sub-catchments and local government areas using feasible scenario options for both the management of stormwater and improvements in sewer outflow performance.

17.1.3 Design standards, targets and considerations

Construction

Construction erosion and sediment controls would be designed in accordance with:

- *Managing Urban Stormwater: Soils and Construction*, Volume 1 4th Edition (Landcom, 2004) (known as the Blue Book Volume 1)
- *Managing Urban Stormwater: Volume 2D Main Road Construction* (Department of Environment and Climate Change, 2008) (known as the Blue Book Volume 2)
- *Road Design Guideline, Section 8 Erosion and Sediment* (RTA, 2003a)
- *Guideline for Construction Water Quality Monitoring* (RTA, 2003b)
- *Erosion and Sediment Management Procedure* (RTA, 2009)
- *Code of Practice for Water Management – Road Development and Management* (RTA, 1999)
- *QA Specification G38 – Soil and Water Management, Edition 2/Revision 2* (Roads and Maritime Services, 2015g).

The ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines would be used for designing temporary construction wastewater treatment plants and setting their discharge criteria.

Operation

Impervious surfaces and stormwater discharges

At Rozelle, the project would include a surface connection to the City West Link. Surface water collected from the Western Harbour Tunnel portals and the road connecting the Western Harbour Tunnel with City West Link would be collected by the tunnel drainage system.

Along the Warringah Freeway, the project would provide drainage infrastructure to convey runoff from the upgraded section of the Warringah Freeway and to maintain drainage performance that is generally consistent with the existing arrangements. Impervious catchment area sizes upstream of the freeway would change marginally (between minus six and 2.3 per cent) and are not expected to change the pollutant load because of the project. For this reason, no formal water quality treatment infrastructure is proposed except for the motorway facilities at the Warringah Freeway, within the existing Cammeray Golf Course, which would have water quality infrastructure to treat runoff before discharge to the existing local stormwater network.

Should further design development identify the need for additional water quality controls, the project would provide water quality treatment that meets the design targets listed in Table 17-3. These targets are described in the *Draft Managing Urban Stormwater – Council Handbook* (NSW EPA, 2007). Where the design targets cannot be met due to site constraints, the project would provide water quality treatment to meet or improve existing conditions to ensure that there is no impact on surface water quality as a result of the project.

The type and design of specific stormwater treatment measures would be further refined, including confirmation of performance with modelling, if required.

Table 17-3 Operational water quality design targets

Issue	Design target
Total nitrogen	45 per cent mean annual pollutant load reduction
Total phosphorus	65 per cent mean annual pollutant load reduction
Total suspended solids	85 per cent mean annual pollutant load reduction
Grease	No visible grease
Water quality	Neutral or beneficial impacts where percentage design targets cannot be practicably met
Spills	Spill containment of up to 40 cubic metres where possible for environmentally sensitive areas
Existing infrastructure	Minimise impacts to existing water quality infrastructure and performance as a result of the design

Wastewater treatment plant discharges

The Rozelle Interchange wastewater treatment plant discharge criteria would comply with ANZG (2018) 95 per cent species protection level and a 99 per cent protection level for contaminants that bioaccumulate (or as otherwise agreed with relevant stakeholders including the EPA, DPI Water and Sydney Water). Discharge criteria for iron would comply with the NHMRC (2008b) recreational guidelines water quality criteria.

17.2 Assessment methodology

17.2.1 Overview

The methodology for the assessment included:

- A review of the existing environment including water quality data and reporting from previous monitoring activities
- Water quality monitoring and visual condition assessment at selected locations in the study area
- Site classification as sensitive receiving environments, identification of environmental values and assessment of existing geomorphic characteristics
- Hydrodynamic modelling to assess the potential hydrodynamic impacts on Sydney Harbour during project construction and operation
- Dredge plume modelling to assess potential water quality impacts as a result of increased dredging activities during construction of the immersed tube tunnel

- Assessment of potential impacts during construction and operation to water quality with reference to the ANZG (2018) and ANZECC/ARMCANZ (2000) water quality guidelines and with regard to the relevant environmental values
- Assessment of changes on the North Sydney Council stormwater harvesting scheme
- Identification of appropriate management measures to mitigate potential hydrology and water quality impacts.

17.2.2 Monitoring

Hydrodynamic monitoring of Sydney Harbour

Hydrodynamic monitoring was carried out between August and November 2017 to measure variability in hydrodynamic conditions within Sydney Harbour due to tidal and non-tidal influences. Specifically:

- An acoustic doppler current profiler type instrument was used at two locations to take continuous measurements of water level, current speed, current direction and acoustic backscatter. The monitoring sites also measured water quality parameters (primarily turbidity)
- Vessel mounted monitoring using an acoustic doppler current profiler was carried out along three transects across Sydney Harbour near the project crossing during spring tidal conditions to determine the spatial variability in currents and discharge throughout a tidal cycle
- Opportunistic surface sediment samples were collected from the bed of the harbour and analysed for particle size distribution.

Water quality monitoring of Sydney Harbour

Water quality monitoring was carried out as part of the marine water quality assessment at eight locations in Sydney Harbour that could be potentially affected by dredging and construction activities. Monitoring activities involved:

- Four fixed water quality monitoring moorings with a number of sensors to monitor turbidity, photosynthetically available radiation, chlorophyll-a, salinity, pressure and temperature (from 5 December 2017 to 31 January 2018)
- Water sampling and profiling carried out at eight sites over two days (18 and 31 January 2018) to monitor water quality parameters (turbidity, photosynthetically available radiation, conductivity, temperature, depth, fluorometric chlorophyll-a, pH and dissolved oxygen) through the water column from the water surface to the harbour bed. Water samples were also collected at a depth of 1.5 metres below the water surface at each site for laboratory testing of total suspended solids (turbidity) and chlorophyll-a concentrations.

Table 17-4 details the water quality monitoring locations for the project, including the two sites monitored as part of the hydrodynamic assessment. The monitoring locations are shown in Figure 17-1.

Table 17-4 Sydney Harbour hydrodynamic and water quality monitoring sites

Site	Location	Monitoring activity
SH1	Wrights Point, Drummoyne	Fixed water quality monitoring mooring and profiling site
SH2	Pulpit Point, Hunters Hill	Water quality profiling site
SH3	Onions Point, Woolwich	Water quality profiling site

Site	Location	Monitoring activity
SH4	Manns Point, Greenwich	Hydrodynamic monitoring location
SH5	Berry Island Reserve	Hydrodynamic monitoring location
SH6	Manns Point, Greenwich	Water quality profiling site
SH7	Longnose Point, Birchgrove	Fixed water quality monitoring mooring and profiling site
SH8	Berrys Bay, Waverton	Fixed water quality monitoring mooring and profiling site
SH9	Goat Island	Water quality profiling site
SH10	Cremorne Point, Cremorne	Fixed water quality monitoring mooring and profiling site

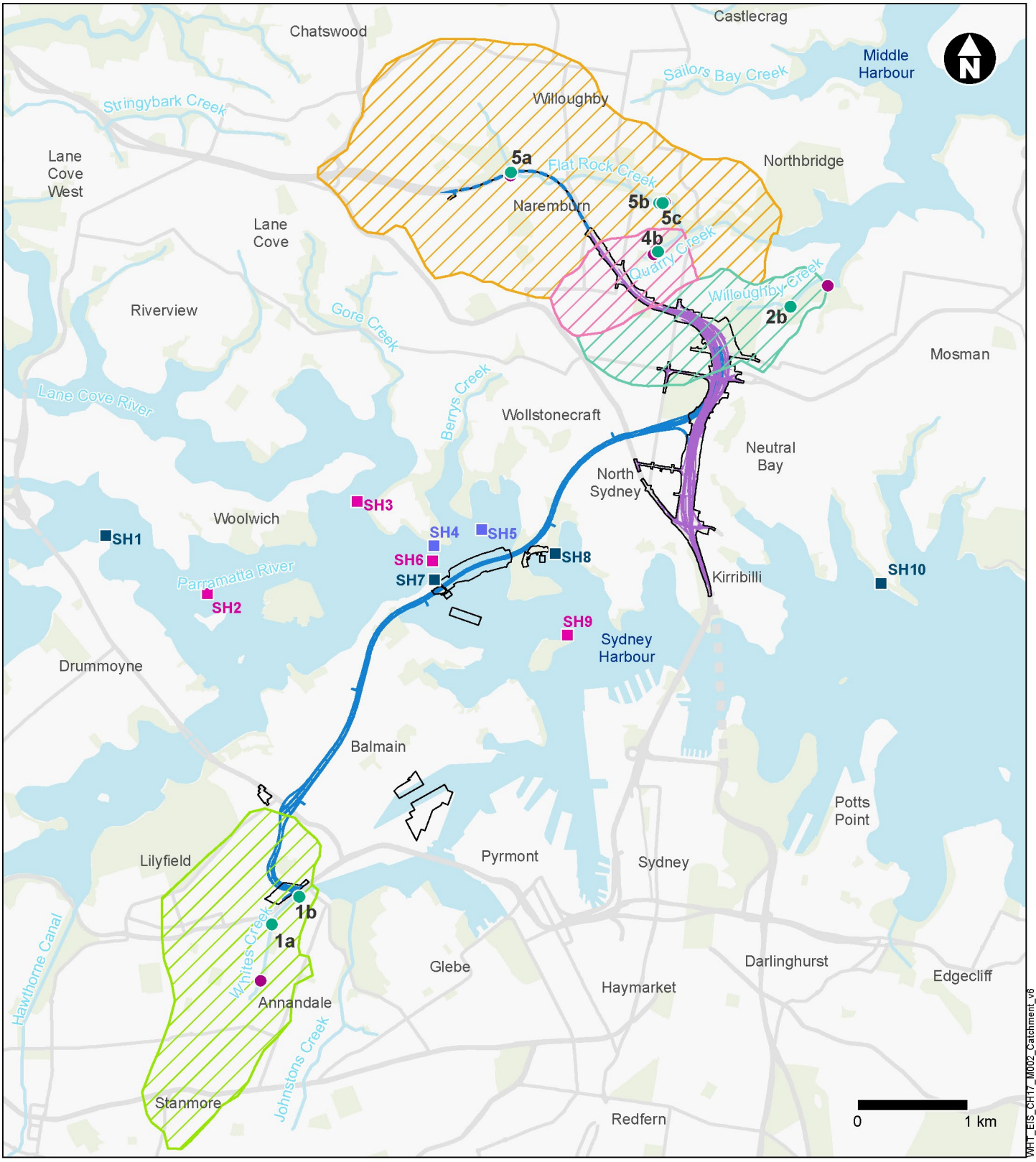
Surface water quality monitoring

Site visits were carried out between October 2017 and January 2018 to monitor surface water quality and to visually assess the conditions of relevant waterways.

Seven monitoring locations were selected immediately upstream and downstream of the proposed waterway crossing. It is noted that only one wet weather event was captured, with the results representing mainly dry weather events. Dry weather is classified as less than 15 millimetres of rainfall recorded at the same Bureau of Meteorology rainfall gauge in the 24 hours prior to sampling, with wet weather classified as 15 millimetres or more of rainfall recorded. Monitoring locations are provided in Table 17-5 and shown in Figure 17-1.

Table 17-5 Water quality monitoring sites in waterways

Site	Waterway	Location
1a	Whites Creek upstream	Brennan Street, Annandale
1b	Whites Creek downstream	Railway Parade, Annandale
2b	Willoughby Creek downstream	Primrose Park, Cremorne
4b	Quarry Creek	Quarry Street, Naremburn
5a	Flat Rock Creek upstream	Grandview Street, Naremburn
5b	Flat Rock Creek downstream (upstream of Quarry Creek inflow)	Flat Rock Gully, Northbridge
5c	Flat Rock Creek downstream (downstream of Quarry Creek inflow)	Tunks Park, Northbridge Suspension bridge



Legend

Operational features

- Western Harbour Tunnel
- Warringah Freeway Upgrade
- Communications cable for motorway control centre
- M4-M5 Link project (indicative)

Construction features

- Construction footprint

Catchments and waterways

- Flat Rock Creek
- Quarry Creek
- Whites Creek
- Willoughby Creek
- Waterways

Marine water quality monitoring sites

- Fixed and profiling site
- Hydrodynamic site
- Profiling site

Surface water quality monitoring sites

- Project monitoring site
- Existing monitoring site

Figure 17-1 Catchments, waterways and water quality monitoring locations

17.2.3 Model development

Hydrodynamic model development

A three-dimensional hydrodynamic model of Sydney Harbour was developed using MIKE 3 software which simulated currents, water levels and flow characteristics to:

- Provide a realistic representation of the existing marine environment within Sydney Harbour near the project, as it relates to hydrodynamic characteristics
- Understand what impacts the construction of an immersed tube tunnel would have on the hydrodynamic characteristics within Sydney Harbour.

Plume model development

Construction of the project would involve dredging of the bed of Sydney Harbour to create the trench within which the immersed tube tunnel units would be placed (Refer to Chapter 6 (Construction work) for more information relating to dredging).

Numerical modelling was used to determine the likely movement of sediments released into the water column (known as a plume) from dredging. Plume modelling simulates the dispersal of suspended sediment by ambient currents in Sydney Harbour, as well as the subsequent deposition of these sediments. The modelling was carried out using the hydrodynamic model of Port Jackson.

The plume modelling was applied to fine sediments only, as these would be the most mobile within the water column. The modelling was based on the sequence of dredging activities (both the dredge plant and sediment types) and the location of sediment types within the dredging footprint, for four sizes of fine sediment (clay, fine silt, medium silt and coarse silt).

Sydney Harbour Ecological Response Model

The Sydney Harbour Ecological Response Model simulates numerous physical, nutrient, algal and biological processes in response to tidal forcing, river inflows, wind, waves and atmospheric heat fluxes.

The model was not run specifically for this project, however adopted simulation results that were available for a 12 month simulation period from April 2012 to March 2013 have been used to inform the assessment on marine water quality.

Surface water quality modelling

No water quality model was run for the surface water collected at the Western Harbour Tunnel portals and the road connecting the Western Harbour Tunnel with the City West Link because this surface water would be collected by the tunnel drainage system and treated at the Rozelle wastewater treatment plant.

A water quality model for the Warringah Freeway Upgrade was not warranted because this section of the project would result in negligible change to pavement catchment areas immediately upstream of the project and is therefore not expected to increase pollutant loads.

17.3 Existing environment

17.3.1 Catchments and waterways

The project would be located within the Sydney Harbour and Parramatta River regional catchment, located within Port Jackson. Port Jackson is comprised of three harbours: North Harbour, Middle Harbour and Sydney Harbour (the main branch of the estuary). Sydney Harbour is a drowned river valley, characterised by steep sided banks which have been eroded by up to 85 metres into the Hawkesbury Sandstone and overlying Ashfield Shale. The catchment comprises both natural and urban landscapes rich in cultural, geological and biological diversity and heritage. The regional catchment covers Sydney Harbour, Parramatta River, Lane Cove River and Middle Harbour.

The Sydney Harbour catchment is a highly-urbanised catchment (86 per cent) which results in rapid runoff during high rainfall events.

This catchment is highly urbanised and is influenced by human factors which have altered the frequency, volume and seasonality of streamflows through intermittently flowing watercourses. The waterways in the study area are highly modified, predominantly concrete-lined trenches, and although containing little ecosystem value, they provide good stability during stormwater overflows. Flat Rock Creek differs where it becomes a naturalised creek and forms a ravine at Flat Rock Gully. Willoughby Creek also has entrenched bedrock (constructed) with soil banks for a small section behind Primrose Park at Cremorne.

The main bodies of water surrounding the study area are Middle Harbour and Sydney Harbour, which are estuaries. The main waterways in proximity to the project are Flat Rock Creek, Quarry Creek, Willoughby Creek and Whites Creek. All are first order streams that discharge directly to the harbours.

The waterways and associated catchments within the study area are shown in Figure 17-1. Table 17-6 outlines the catchments that form part of the larger Sydney Harbour and Parramatta River regional catchment as relevant to the project and provides a description of the key waterways relevant to the project.

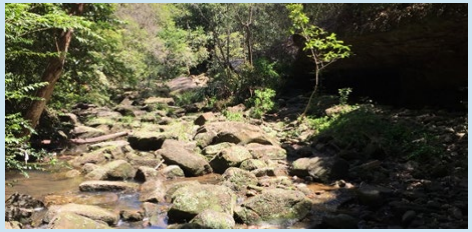
Some areas of the project would be located on catchments dominated by drainage lines that drain towards Sydney Harbour, rather than watercourses, and would include:

- Victoria Road construction support site (WHT2) – drainage lines from this construction support site drain towards Iron Cove
- Yurulbin Point construction support site (WHT4) – drainage lines from this construction support site drain towards Snails Bay
- Berrys Bay construction support site (WHT7) – drainage lines from this construction support site drain towards Berrys Bay
- Warringah Freeway Upgrade – drainage lines from the southern end of the upgrade drain towards Neutral Bay
- Waltham Street construction support site (WHT11) – drainage lines from this construction support site, drain towards Flat Rock Creek.

Table 17-6 Description of key waterways and catchments relevant to the project

Waterway/catchment	Description	Relevant project features
Sydney Harbour (Sydney Harbour and Parramatta River regional catchment)	• Sydney Harbour in the context of the project comprises two main tributaries: Lane Cove River and Parramatta River • The bathymetry near the immersed tube tunnel crossing of Sydney Harbour is complex and irregular with defined channels, shallow bays including Balls Head, Snails Bay and Berrys Bay, and deep holes up to 32 metres deep • The hydrodynamic conditions at the proposed immersed tube tunnel crossing of Sydney Harbour are primarily influenced by astronomical tides with other influences from barometric effects (environmental air pressure), wind and freshwater flows from local creeks and rivers being comparatively small.	• Victoria Road construction support site (WHT2) drains towards Iron Cove • White Bay construction support site (WHT3) drains into White Bay • Yurulbin Point construction support site (WHT4) drains towards Snails Bay • Sydney Harbour south cofferdam (WHT5) • Crossing of Sydney Harbour • Sydney Harbour north cofferdam (WHT6) • Berrys Bay construction support site (WHT7) drains towards Berrys Bay • Southern portion of the Warringah Freeway Upgrade drains towards Neutral Bay.

Waterway/catchment	Description	Relevant project features
Whites Creek (Whites Creek catchment) 	• Small creek (about two kilometres long) in the densely developed inner western suburbs of Sydney. It drains a catchment dominated by residential areas and roads • Headwaters are in the suburbs of Stanmore and Leichhardt, and flows in a northerly direction discharging to Rozelle Bay, Sydney Harbour • The complete length of the creek is a stormwater drain with buried pipes in the upper reaches and open concrete channel for the lower one kilometre • Sydney Water has begun works on naturalising Whites Creek due to its deteriorated condition. It is likely to incorporate features such as sandstone blocks and vegetated benches to provide ecological benefits to the channel.	• Rozelle Rail Yards construction support site (WHT1).
Willoughby Creek (Willoughby Creek catchment) 	• Willoughby Creek is a small modified concrete and rock channel which drains the suburbs of Neutral Bay and Cammeray directly into Willoughby Bay at Cremorne • The development of impervious surfaces within the catchment has increased the volume and rate of runoff, which has in turn necessitated flood mitigation measures • Willoughby Bay and Long Bay are popular boating and swimming areas for local residents.	• Mid portion of Warringah Freeway Upgrade • Cammeray Golf Course (WHT10 and WFU8) and Rosalind Street east (WFU9) construction support sites.

Waterway/catchment	Description	Relevant project features
Quarry Creek (part of Flat Rock Creek catchment) 	• Quarry Creek is a small natural estuarine tributary of Flat Rock Creek which drains Cammeray • The creek has steep embankments on both sides now densely vegetated by weeds and has limited accessibility.	Northern portion of Warringah Freeway Upgrade.
Flat Rock Creek (Flat Rock Creek catchment)  	• Flat Rock Creek is predominantly a concrete lined (open and closed) stormwater channel which drains the suburbs of Artarmon, Willoughby and Naremburn. It travels underground between Naremburn and Willoughby. The natural drainage characteristics of Flat Rock Creek have been altered by residential, commercial and industrial development • At its downstream reach the creek drains a steep catchment characterised by rocky riffle and runs. The downstream reaches are surrounded by native Coachwood forests with walking tracks which provide access to large sporting fields at Tunks Park, Cammeray • The end point of the creek is a tidally influenced naturalised estuary at the base of Flat Rock Gully discharging into Long Bay.	• Northern portion of the Warringah Freeway Upgrade • Waltham Street construction support site (WHT11). Drainage lines from this construction support site drain towards Flat Rock Creek.

17.3.2 Hydrodynamic features

Bathymetry

The bed of Sydney Harbour is made up of many deep holes, shoals, basins, rocky islands and reefs. At the proposed immersed tube tunnel crossing of Sydney Harbour, there is a defined channel with relatively steep banks, with an average depth of around 15 metres. Other key bathymetry features near the crossing of Sydney Harbour include:

- A hole about 17 metres deep near Birchgrove
- A deep hole to the south of the Sydney Harbour proposed immersed tube tunnel crossing about 32 metres deep
- Shallow bays which act as large reservoirs for tidal waters, including Balls Head Bay, Snails Bay and Berrys Bay.

Tides and currents

Port Jackson is a semi-diurnal estuary meaning that it has two high tides and two low tides per day. It has a small tidal range (less than two metres) and the ebb (outgoing) and flood (incoming) tidal discharges are the dominant cause of water movement.

Current patterns in Sydney Harbour are influenced by the complex shape of the harbour with stronger tidal streams in the main channels, weaker currents outside the main channels along with circulating eddies in some of the bays (eg Balls Head Bay). Spatial measurements and monitoring showed little change in current speed with changes in depth. A summary of the current speeds observed as part of hydrodynamic monitoring is shown in Table 17-7.

Table 17-7 Current speeds near the Sydney Harbour crossing

Monitoring location	Parameter	Maximum	95th percentile	Average
Manns Point, Greenwich (SH4)	Flood current speed (m/s)	0.43	0.27	0.12
	Ebb current speed (m/s)	0.41	0.26	0.13
Berry Island Reserve (SH5)	Flood current speed (m/s)	0.18	0.08	0.04
	Ebb current speed (m/s)	0.29	0.12	0.05

Wind

The wind statistics from the Bureau of Meteorology's weather station at Fort Denison (1990 to 2017) were considered to be the most representative of overwater wind conditions at the proposed immersed tube tunnel crossing of Sydney Harbour and indicate that:

- Easterly winds are the prominent wind direction in the spring/summer months, with westerly winds dominating during autumn/winter months
- Wind speeds range from 4.2 to 4.7 metres per second (50th percentile) and 6.7 to 8.3 metres per second (90th percentile) throughout the year
- Wind speeds are slightly higher during spring/summer compared to autumn/winter.

Waves

Ocean swells that enter Sydney Harbour are deflected by the complex bathymetry and shoreline formation such that most of Sydney Harbour is affected only by locally derived wind- and ship-generated waves. The wave climate near the proposed immersed tube tunnel crossing of Sydney Harbour is a low energy wave climate with wave heights typically less than 0.3 metres and wave periods of less than four seconds. Wave periods associated with Rivercat and Harbourcat ferries can exceed four seconds depending on vessel speed.

The bathymetry near the proposed immersed tube tunnel crossing of Sydney Harbour is relatively deep, meaning that the potential effect of waves (either wind waves or boat wakes) on hydrodynamic or sediment plumes at the bed of the harbour is minimal.

Rainfall and freshwater runoff into Sydney Harbour

Rainfall in Sydney varies substantially both year-to-year and month-to-month. Much of the variability in precipitation is due to large-scale climate variations, with El Niño Southern Oscillation being the most important. Weather data recorded at Observatory Hill, Sydney indicates that average annual rainfall is 1215 millimetres. Average monthly rainfall between the years 1859 and 2017 ranged from a minimum of 67.9 millimetres in September to a maximum of 133.2 millimetres in June.

The amount of freshwater runoff into Sydney Harbour depends on the amount of rainfall in the local catchment. There are no permanent rivers or streams which discharge into Sydney Harbour. The Parramatta and Lane Cove Rivers are merely arms of the estuary and provide limited to no freshwater flux into the system, except during major rainfall events.

During dry weather conditions (rainfall less than one millimetre per day) freshwater discharge from the Parramatta and Lane Cove catchment is minimal and is estimated to be less than 0.1 cubic metres per second from both catchments (Rochford, 2008; Birch and Rochford, 2010).

Suspended sediments

Turbidity is typically used as an indicator of suspended sediment concentrations. A review of historical data for turbidity of the waters within Port Jackson displays a noticeable gradient from high turbidity in the shallower upper reaches of the Parramatta River and longer bays, to low turbidity in the lower reaches of the harbour where tidally driven ocean exchange influences water quality.

A summary of measured turbidity for the waters around Balls Head is provided in Table 17-8.

Table 17-8 Ambient measured turbidity near Balls Head

Weather	Ambient turbidity
Dry weather	<1 to 4 NTU
Wet weather	4 to 20 NTU – short-lived events ~<2 days with higher values on ebbing tide

17.3.3 Marine water quality

A review of historical marine water quality data and project specific monitoring of Sydney Harbour indicates that:

- The complex interactions between rainfall/runoff, mixing within the broader Sydney Harbour and Parramatta River regional catchment and exchange with ocean waters leads to seasonal

variations in temperature and salinity that in turn influences the mixing of the Sydney Harbour deep waters

- Total suspended solids concentrations are generally low (below one milligram per litre) during extended dry periods with peaks up to 40 milligram per litre after heavy rainfall events. During the wetter months, total suspended solids concentrations are elevated at around three to eight milligram per litre
- Good vertical mixing maintains high dissolved oxygen content of the overall water column
- Good light penetration occurs through water column. The euphotic depth, where light decreases to one per cent of its surface value, was typically between seven and 10 metres depth.

17.3.4 Existing road surface water quality infrastructure

Existing infrastructure related to road surface water quality control relevant to the project includes:

- Pavement drainage from Rozelle road network discharges to existing council drainage systems and ultimately to Whites Creek and Rozelle Bay. The M4-M5 Link project would provide road surface water quality infrastructure in this area
- Drainage from the existing Warringah Freeway road surface and nearby road networks in North Sydney and Willoughby local government areas currently discharge to existing local stormwater drainage systems, before discharging to Sydney Harbour or Middle Harbour
- Drainage from Waltham Street construction support site (WHT11) would discharge into the local stormwater system then travel into Flat Rock Creek before discharging into Middle Harbour.

17.3.5 Surface water quality

The water quality of waterways relevant to the project is influenced by several factors including:

- Current and former polluting land uses within the catchments
- Stormwater and sewage overflows and leachate from contaminated and/or reclaimed land
- Urbanisation of the catchments and subsequent reduction in permeable area, increasing run-off and pollutant loads entering waterways.

A review of the existing water quality data and site specific water quality monitoring indicates that the waterways are in very poor condition and are representative of a heavily urbanised system. The water quality of each assessed waterway is summarised in Table 17-9.

Table 17-9 Existing water quality conditions in the study area

Waterway	Commentary on ANZG (2018) and ANZECC/ARMCANZ (2000) indicators	Monitoring sites/data source
Whites Creek	• Median faecal coliforms and ammonia concentrations above the recommended limit for protection of aquatic ecosystems • High levels of heavy metals • High nutrient concentrations • Low dissolved oxygen levels • High pH (ie alkaline conditions) • High turbidity.	• Sites1a, 1b • Sydney Water • M4-M5 Link project and Bays Precinct project.

Waterway	Commentary on ANZG (2018) and ANZECC/ARMCANZ (2000) indicators	Monitoring sites/data source
Willoughby Creek	• High levels of heavy metals • High nutrient concentrations • Low dissolved oxygen levels.	• Site 2b.
Quarry Creek	• High levels of heavy metals • High nutrient concentrations • High pH (ie alkaline conditions) • High dissolved oxygen levels • Very high faecal coliform counts indicating microbial contamination.	• Site 4b • North Sydney Council.
Flat Rock Creek	• High concentrations of heavy metals • Very high nutrient concentrations, indicating eutrophic conditions • Microbiological contamination • High pH (ie alkaline conditions) in some areas • Varied dissolved oxygen levels.	• Sites 5a, 5b, 5c • North Sydney Council.

17.3.6 North Sydney Council stormwater harvesting scheme

North Sydney Council has established an extensive stormwater harvesting scheme, which includes a storage dam at Cammeray Golf Course, measuring 45 metres by 35 metres in size. The dam receives stormwater harvested from the surrounding catchments that is then used to irrigate a number of community parks and the golf course itself. Harvested water is also piped through the existing stormwater system back to St Leonards Park, and used to irrigate the public parklands and North Sydney Oval. The dam also serves as a sediment settlement pond which improves the quality of water re-entering the catchment and harbour. The dam provides habitat for wildlife such as ducks and saves about 90 million litres of clean water each year.

17.3.7 Sensitive receiving environments

A sensitive receiving environment is an environment that has high conservation or community value, or that supports ecosystem or human uses of water and that is particularly sensitive to pollution or degradation of water quality.

The classification of the waterways within the study area regarding their status as sensitive receiving environments is shown in Table 17-10.

Table 17-10 Sensitive receiving environments

Waterway	Sensitive receiving environment	Reason for classification
Sydney Harbour	Yes	• Considered a Type 1 Key Fish Habitat (due to known presence of several species of seagrass) • Potential habitat for vulnerable species such as the Black Rock Cod which is listed under the *Fisheries Management Act 1994* and *Environment Protection and Biodiversity Conservation Act 1999* • Is a primary contact recreation area.

Waterway	Sensitive receiving environment	Reason for classification
Whites Creek	No	• Not identified as Key Fish Habitat based on NSW DPI (2007) mapping.
Willoughby Creek	No	• Considered a Type 3 minimally sensitive Key Fish Habitat • Is a highly-urbanised stormwater channel containing limited natural features.
Quarry Creek	Yes	• Downstream Flat Rock Creek characterised as Type 1 highly sensitive Key Fish Habitat (NSW DPI, 2013) due to potential fish refuge.
Flat Rock Creek	Yes	• Downstream Flat Rock Creek characterised as Type 1 highly sensitive Key Fish Habitat (NSW DPI, 2013) due to potential fish refuge • Is a secondary contact recreation area.

17.3.8 Environmental values

The Department of Planning, Industry and Environment (Environment, Energy and Science) identifies a number of environmental values for the Sydney Harbour and Parramatta River regional catchment including relevant indicators and guideline levels. Environmental values relevant to the regional catchment are:

- Aquatic ecosystems – which signal physical and chemical water quality stressors that cause degradation of aquatic ecosystems. For the purpose of this assessment, indicators include nutrients, dissolved oxygen, pH, metals, salinity and turbidity
- Visual amenity – the aesthetic appearance of a waterbody. For the purpose of this assessment, indicators include transparency, odour and colour
- Primary and secondary contact recreation – where primary contact recreation implies direct contact with the water via bodily immersion or submersion with a high potential for ingestion (eg swimming, diving and water skiing), and secondary contact recreation implies some direct contact with the water would be made but ingestion is unlikely (eg boating, fishing and wading. Bacteriological indicators are used to assess the suitability of water for recreation.

These environmental values have been assigned to each waterway within the study area as shown on Table 17-11. Aquatic ecosystems and visual amenity would apply to all waterways within the study area.

Table 17-11 Assigned environmental values

Waterway	Environmental value			
	Aquatic ecosystems	Visual amenity	Primary contact recreation	Secondary contact recreation
Sydney Harbour	✓	✓	✓	✓
Whites Creek	✓	✓		
Willoughby Creek	✓	✓		✓
Quarry Creek	✓	✓		✓
Flat Rock Creek	✓	✓		✓

17.4 Assessment of potential construction impacts

17.4.1 Hydrodynamic features of Sydney Harbour

Construction of the immersed tube tunnel has the potential to affect tidal and current flows within Sydney Harbour due to:

- The establishment of Sydney Harbour south cofferdam (WHT5) and Sydney Harbour north cofferdam (WHT6) and associated shallow draft silt curtains. The use of deep draft silt curtains during dredging activities is not proposed due to tidal currents and maritime traffic within Sydney Harbour
- The establishment of the Yurulbin Point (WHT4) and Berrys Bay (WHT7) construction support sites.

Each cofferdam would be constructed using steel tubular piles which would act as a temporary but complete barrier to the flow of water.

The modelling of hydrodynamic impacts has identified that during the ebb (outgoing) tide, the Sydney Harbour south cofferdam (WHT5) would cause a reduction in the current speed downstream of the structure. This would be offset by a small increase in speeds in the middle of the channel and around Balls Head. During the flood tide, a similar pattern is observed with currents largely reduced downstream of the structure and a corresponding increase in the middle of the channel and along the northern bank (near Birchgrove Wharf). Increased current speeds are expected to occur near Greenwich Baths, however it is not expected to have any notable impact on recreational amenity.

The Sydney Harbour north cofferdam (WHT6) would have a very minor impact on current speeds during the ebb tide. This is because near the Coal Loader Wharf ebb current speeds are relatively low in both existing and with cofferdam scenarios resulting in the structure not significantly impacting on flow conditions. Larger reductions in current speeds are expected near the cofferdam and the Coal Loader Wharf during the flood tide due to the interaction with the eddy in the entrance to Balls Bay.

During both ebb and flood tide the differences would be more pronounced in the surface layer when compared to bottom layers. The bed of the harbour potentially affected is composed of cobbles, boulders, sand and clay, is not expected to be eroded by the higher current speeds. The foreshore area potentially affected is also protected from erosion by seawalls or rocky

shorelines. Overall the changes in tidal currents are unlikely to lead to erosion of the bed of the harbour or adjacent foreshores.

17.4.2 Marine water quality

Construction of the immersed tube tunnel would require dredging of the bed of Sydney Harbour which would result in sediments being released into the water column. Other construction activities within and adjacent to the harbour would also have the potential to impact marine water quality including:

- Dredging and piling activities associated with the establishment of the Sydney Harbour south cofferdam (WHT5) and Sydney Harbour north cofferdam (WHT6), as well as adjacent land based activities at White Bay construction support site (WHT3), Yurulbin Point construction support site (WHT4) and Berrys Bay construction support site (WHT7) have the potential to reduce water quality and disturb contaminated sediments
- Vessel movements have the potential to generate localised plumes of excess suspended sediments associated with vessel wash in shallower waters, generally less than five to ten metres water depth
- Potential spills or leaks of fuels and chemicals from maintenance or re-fuelling of construction plant and equipment that could potentially be discharged directly or indirectly to the marine environment
- Potential impacts on marine water quality could be the transport, treatment and temporary storage of dredged material that is unsuitable for offshore disposal while temporarily stored on barges or at the White Bay construction support site (WHT3) (an application for offshore disposal of suitable dredged material has been submitted to the Commonwealth Department of the Environment and Energy)
- Land based activities involving the exposure or handling of soils (eg removal of pavement, vegetation clearance, stripping of topsoil, excavation, disturbance of contaminated soil, stockpiling and materials transport) resulting in potential soil erosion and off-site transport of sediment via air or runoff to receiving marine waterways. This could impact water quality, such as increased turbidity, lowered dissolved oxygen levels and increased nutrients.

Potential marine water quality impacts from these activities would include:

- Increases in turbidity resulting in a visible plume and reducing light penetration into the water column
- Transfer of sediment deposits onto the bed of the harbour
- Mobilisation of contaminants associated with the transportation and dispersion of disturbed sediments
- Direct impacts from discharges, runoff, spills and leaks.

These are discussed in more detail below.

Increases in turbidity

Water quality impacts as a result of the dispersion of sediments released during dredging were assessed using dredge plume modelling (refer to Figure 17-2) which identified the following:

- The extent of the dredge plume (two milligrams per litre suspended sediment concentration) throughout the water column would be limited to a relatively small area, concentrated at the north eastern end of the dredging footprint near Balls Bay and around Balls Head
- The extent of the visible plume (suspended sediment content >20 milligram per litre) is expected to be very small, and would be contained in the dredging footprint next to the Sydney Harbour north cofferdam (WHT6)

- Suspended sediment released would be transported both in an upstream and to a greater extent downstream direction. Suspended sediment would also be transported into Balls Bay during dredging of the eastern part of the dredge footprint
- For half the duration (ie 50 per cent) of proposed dredging activities, the increases in suspended sediment concentrations are expected to be low (ie less than one milligram per litre), even within the dredging footprint
- The dredge plume extents are expected to be greater in the bottom layer than at the surface of the water, as shown in the example of the 95th percentile
- For a short duration (ie less than one per cent of the time), increases in suspended sediment concentrations above five milligram per litre are expected to occur in the area adjacent to the Coal Loader Wharf
- The sensitivity of dredging impacts to wind is likely to be limited to brief periods at selected locations in the off-channel bays (eg Balls Bay), due to weaker tidal currents and shallower bathymetry.

The results indicate that the dredging program would not have a significant impact on marine water quality. The dredging and construction activities for the project are likely to cause localised increases in suspended sediment concentrations but due to the rapid dispersion in Sydney Harbour is not likely to result in significant water quality impacts. Monitoring during the dredging activities would provide data to assess the compliance of the activities with this assessment.

Along with the use of shallow silt curtains around dredging activities, additional shallow silt curtains would be installed where appropriate to mitigate the potential impact to adjacent ecologically sensitive areas (eg seagrass beds).The use of deep draft silt curtains during dredging activities would not be possible, due to tidal currents and maritime traffic within Sydney Harbour.

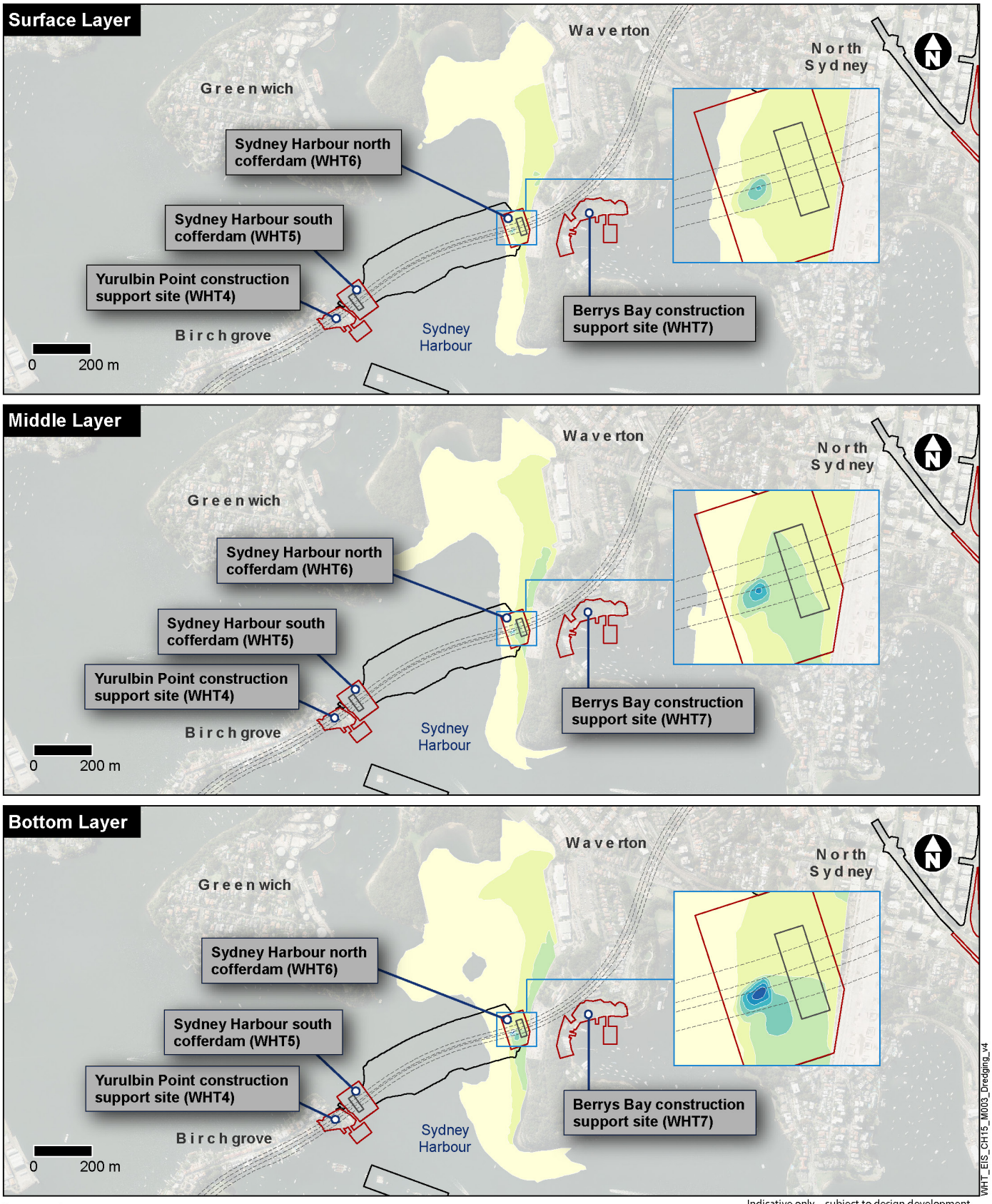


Figure 17-2 Dredge plume impacts within Sydney Harbour during dredging activities

Deposition of mobilised sediment

Modelling of sediment deposition on the bed of the harbour two weeks after the completion of dredging activities identified the following (refer to Figure 17-3):

- The majority of deposition would occur within and adjacent to the dredging footprint, concentrated at the north eastern end of the dredging footprint and along the shoreline adjacent to the Coal Loader Wharf, with sedimentation rates of just over one millimetre/day expected
- Lower levels of sedimentation are expected to occur within Balls Bay and the bays that line Sydney Harbour due to the lower tidal current speeds in these bays
- The highest rate of deposition is expected to occur during dredging activities in the sandy silty clay deposit adjacent to Balls Head
- Overall, the maximum and daily average deposition rates for the dredging within Balls Bay were less than the lowest thresholds noted in the literature.

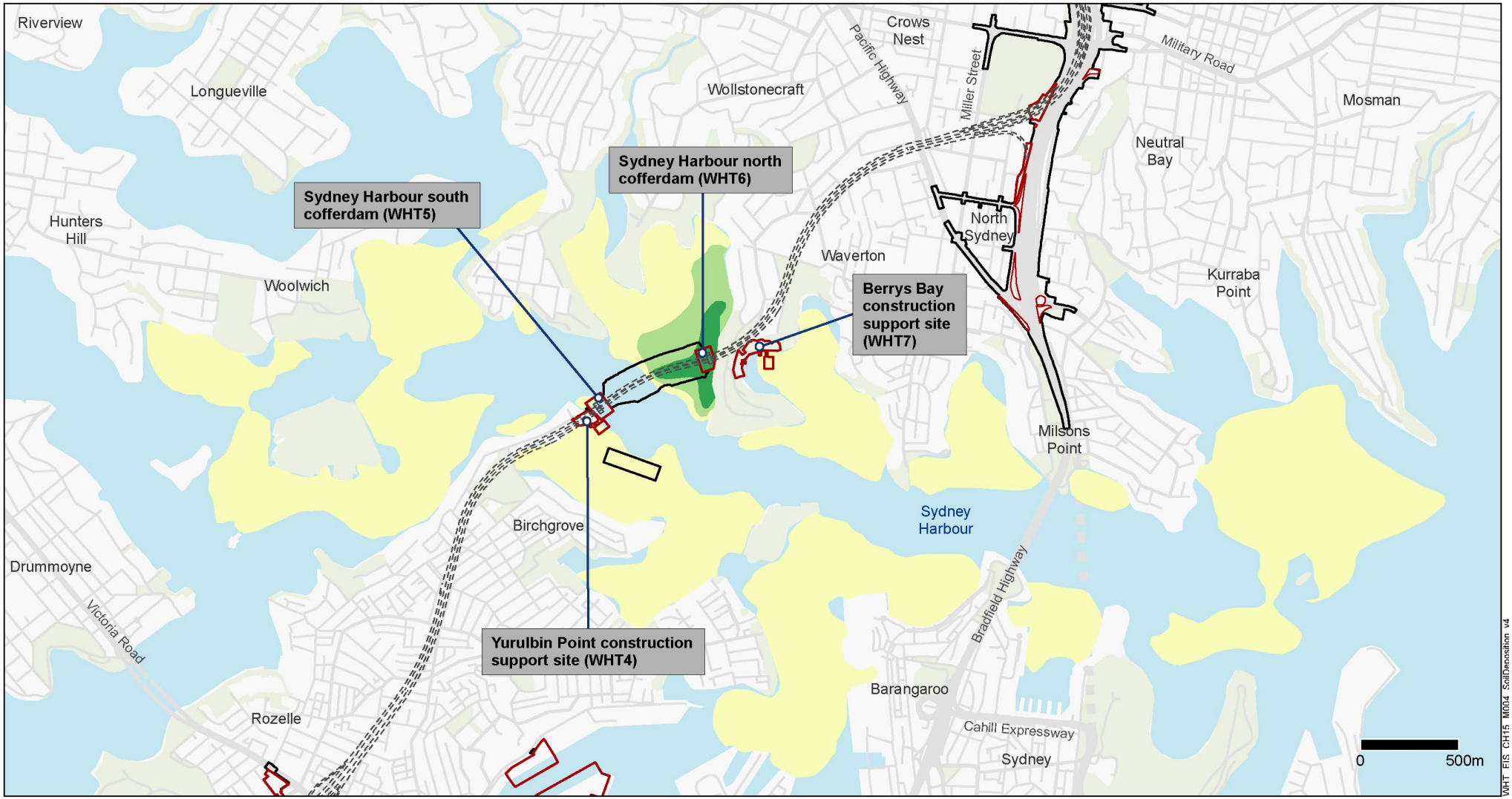
In summary, the effects of sedimentation as a result of dredging are expected to be minor. Short-term effects of turbidity and deposition would be similar to the effects following heavy rainfall events.

Mobilisation of contaminants

Sediment sampling carried out for the project within Sydney Harbour, White Bay and Berrys Bay identified levels of contaminants within the top 1.5 metre of sediments which would, if mobilised, exceed guideline criteria. Dredging and other construction activities within the harbour have the potential to mobilise these contaminants.

The behaviour of sediment-bound contaminants when resuspended into the water column has been previously assessed (Geotechnical Assessments, 2015) for other construction projects (Sydney Metro City & Southwest) which determined that contaminants are likely to remain bound to sediment particles and not be released into the water column.

A backhoe dredge with a closed environmental clamshell would be used to remove the top 1.5 metres of sediment. This would reduce the potential for release of contaminated sediments into the water (refer to Chapter 6 (Construction)). On this basis, it is unlikely that marine water quality would be substantially impacted.



Legend

Construction features

- Western Harbour Tunnel (tunnel section)
- Construction footprint
- Construction support site

Soil deposition depth

- 1 to 5 (mm)
- 5 to 10 (mm)
- 10 to 50 (mm)

Figure 17-3 Sediment deposition two weeks after completion of dredging activities

Discharges, runoff, spills and leaks

Land based construction activities occurring immediately adjacent to marine waterbodies could potentially result in the release of sediment via air or runoff to receiving waterways. There is also potential for spills or leaks of fuels and/or oils from maintenance or re-fuelling of construction plant or equipment or vehicles incidents which could result in discharges to waterways. The discharge of treated water from onshore construction areas may also affect water quality in the marine waters.

These potential impacts would be effectively managed through the implementation of management controls and procedures such that there would be no major impacts on marine water quality.

17.4.3 Surface water quality

Surface activities

A summary of potential impacts to surface water quality as a result of surface works is provided in Table 17-12. Identified surface water quality impacts would be managed via standard erosion and sediment control management and mitigation measures for all work sites and surface works areas.

Table 17-12 Summary of potential construction impacts on surface water quality

Construction activities/ incidents	Potential impacts
Construction support sites	Establishment of construction support sites may result in erosion and mobilisation of exposed soils and open cuts by stormwater runoff and wind leading to sedimentation of waterways. Construction support sites may include activities that have the potential to impact downstream water quality, if unmitigated, through spills of pollutants flowing to downstream watercourses. Typical activities that pose a risk include: • Storage of chemicals • Vehicle wash down areas • Vehicle refuelling areas. Further, the movement of construction vehicles may transfer soil and pollutants to adjacent roads, which may then be conveyed via stormwater runoff into waterways.
Earthworks	Exposure of soils during earthworks, (including stripping of topsoil, excavation, removal of existing paved areas, stockpiling and transport of materials), can result in soil erosion and off-site movement of eroded sediments by wind and/or stormwater into receiving waterways. Once sediments enter waterways, they can directly and indirectly impact on the aquatic environment. If unmitigated, direct impacts could include reducing light penetration (limiting the growth of macrophytes), clogging fish gills, altering stream geomorphology, smothering benthic organisms and reducing visibility for fish. Indirect impacts of increased sediments occur over the longer term and include accumulation and the release of attached pollutants such as nutrients and heavy metals. The waterways at most risk of being impacted by earthworks would be: • Whites Creek

Construction activities/ incidents	Potential impacts
	• Willoughby Creek • Quarry Creek • Flat Rock Creek.
Stockpiling	Storage of earthwork materials, crushed rock, mulch and vegetation in stockpiles on construction support sites has the potential to impact water quality and impact the aquatic environment if not appropriately managed. Stockpiles within 500 metres of a waterway which could potentially present a risk to water quality, if unmitigated, would be located at: • Rozelle Rail Yards construction support site (WHT1) • Cammeray Golf Course construction support site (WHT10) and Warringah Freeway Upgrade and its construction support sites • Waltham Street construction support site (WHT11).
Demolition	Demolition works have the potential to disturb and/or spread sources of pollutants that could affect water quality if not appropriately managed. Demolition can also generate dust and airborne pollutants. These pollutants once mobilised can be picked up by stormwater runoff and distributed downstream receiving waterways via the drainage network.
Contamination and acid sulfate soils	If unmitigated, disturbance of contaminated land or groundwater, or acid sulfate soils during construction could result in the mobilisation of contamination or acid sulfate soils by stormwater runoff and subsequent transportation to downstream waterways, potentially increasing contaminant concentrations in the receiving environment (refer to Chapter 16 (Geology, soils and groundwater)). The project is located within areas of low or extremely low probability of acid sulfate soils for the areas of Lilyfield to Snails Bay and Balls Head to Crows Nest (refer to Appendix M (Technical Working Paper: Contamination)). There are isolated areas of high risk of potential acid sulfate soils being present at Rozelle Rail Yards and Birchgrove Park which could potentially affect Whites Creek if not managed appropriately.
Spills and leaks	If unmitigated, accidental spills or leaks could occur from spillage of diesel during refuelling, and leakage of hydraulic and lubricating oil from plant and equipment. Rinse water from plant washing and concrete slurries also have the potential to enter waterways if unmitigated.
Relocation of utilities	The relocation of utilities would involve soil disturbance as a result of trench excavation and under-boring. The disturbance of soil by machinery would increase the potential for soil erosion which has the potential to impact downstream water quality if not appropriately managed.
Installation of the communication cable	The trenching and underboring for the communication connection link between the Western Harbour Tunnel at Cammeray and the motorway control centre at Waltham Street, Artarmon would involve soil disturbance. If unmitigated, the disturbance of soil by machinery has the potential to increase soil erosion which has the potential to impact downstream water quality.

Construction activities/ incidents	Potential impacts
Vegetation removal	The removal of vegetation has the potential to increase the risk of erosion and sedimentation within the surrounding waterways if not properly managed. The majority of vegetation that would be removed would be located within the Warringah Freeway road reserve and the Cammeray Golf Course site. Additionally, a small area of vegetation would be removed from Yurulbin Park at Birchgrove. None of this vegetation is riparian or would impact bank stability.

Tunnelling activities

Sources of wastewater

During construction, tunnelling works would result in large volumes of wastewater being generated from the following sources:

- Groundwater ingress
- Rainfall runoff into tunnel portals and ventilation outlet tunnels
- Washdown runoff
- Heat and dust suppression water.

Most of this wastewater would be collected from groundwater seepage. Estimated volumes of construction wastewater are included in Section 17.4.5. Water volumes generated during the construction of the project would vary based on construction activities both above and below the ground surface, the amount of groundwater infiltrating into the tunnels and the length of tunnels that have been excavated.

The reuse of wastewater would be maximised during construction works (eg dust suppression). Despite this reuse, there is expected to be a surplus of wastewater, which would need to be treated before discharge to the local stormwater system or directly to a local surface watercourse.

Wastewater treatment

The wastewater collected from tunnelling activities would be tested and treated at construction wastewater treatment plants prior to reuse or discharge. Site-specific trigger values would be developed during construction planning when setting the wastewater treatment plant discharge criteria to ensure that wastewater would be treated to a level that is representative of background concentrations of suitable reference sites or the ANZG (2018).

Temporary construction wastewater treatment plants would generally consist of settling tanks/ponds, flocculation tanks (which bind small particles suspended in the water together to make them easier to remove) and filtration.

Indicative construction wastewater treatment discharges and discharge points are presented in Table 17-13. The approximate duration of operation of construction wastewater treatment plants can be found in (Chapter 6 (Construction works)).

Table 17-13 Construction wastewater treatment plants

Plant location	Discharged quantity (kL/d)	Discharge location	Ultimate receiving waters
Rozelle Rail Yards construction support site (WHT1)	214	Local stormwater	Rozelle Bay

Plant location	Discharged quantity (kL/d)	Discharge location	Ultimate receiving waters
Victoria Road construction support site (WHT2)	413	Local stormwater	Iron Cove
Yurulbin Point construction support site (WHT4)	214	Snails Bay	Snails Bay
Berrys Bay construction support site (WHT7)	249	Berrys Bay	Berrys Bay
Cammeray Golf Course construction support site (WHT10)	196	Local stormwater	Willoughby Creek

The only discharge of treated water to freshwater would be from the Cammeray Golf Course wastewater treatment plant which would treat and discharge tunnel inflows to Willoughby Creek via the local stormwater system. Other wastewater treatment plants would discharge treated water into the harbour. The construction wastewater treatment plant at Cammeray Golf Course would treat wastewater generated from tunnelling activities to a standard suitable for discharge based on site specific trigger values to be developed during construction planning. Construction wastewater treatment trains would be designed to maintain or improve the water quality of the receiving ambient environment. As such, the impacts on the water quality of Willoughby Creek and ultimately Middle Harbour would be negligible.

Impacts on NSW water quality objectives during construction

The project would treat wastewater from tunnelling activities and implement standard erosion and sediment control measures for all work sites and surface works areas. With the implementation of these management measures, pollutant loading to the receiving waterways is considered to be low compared to the existing pollutant loading from Whites Creek, Willoughby Creek, Quarry Creek and Flat Rock Creek catchments.

The project construction is therefore likely to have a negligible influence on whether the NSW water quality objectives of receiving waters are protected (if currently met) or achieved (if currently not met).

17.4.4 Impacts on geomorphology

Construction of the project has the potential to impact on geomorphology due to:

- Mobilised sediment which could build up in the streams if not appropriately managed
- Impervious surfaces created by the project, leading to increases in the volume and rate of runoff, which could cause erosion within the instream channel
- Subsidence below watercourses, potentially impacting on channel bed and bank conditions.

The Cammeray Golf Course wastewater treatment plant would discharge into Willoughby Creek via the local stormwater network at a cumulative and continuous average rate of about 0.002 kilolitres per second for 3.5 years. There would be also a period of about six months when the wastewater treatment plants at the Cammeray Golf Course construction support site (WHT10) and Beaches Link and Gore Hill Freeway Connection project Cammeray Golf Course construction support site (BL1) would discharge concurrently into Willoughby Creek at a continuous average rate of about 0.004 kilolitres per second (that is, four litres per second).

This cumulative flow is considered low when compared to creek flows experienced for the 50 per cent annual exceedance probability (12.8 kilolitres per second). Annual exceedance probability is the likelihood of occurrence of a flood of given size or larger occurring in any one year and is expressed as a percentage.

Cammeray Golf Course wastewater treatment plant discharges into Willoughby Creek are not anticipated to change the creek geomorphology as the creek channel is a modified concrete and rock channel that handles greater flows during frequent flood events. The susceptibility of the waterway to degradation as a result of increased flows is considered to be low based on assessment of its current stability and the relatively low level of discharges anticipated compared to existing flows.

If unmitigated, impacts to geomorphology as a result of increased mobilised sediment or increased surface runoff (volume or velocity) could occur where activities are near watercourses. This could include Willoughby Creek, Quarry Creek, Flat Rock Creek and along drainage lines flowing into the harbour. Potential for watercourse geomorphology impacts would be mitigated through environmental management measures outlined in Section 17.6.

17.4.5 Water balance, environmental water availability and flows

Water balance for the construction of the project

The expected water balance for the project construction, based on average groundwater inflows, and the estimated treated discharge quantities are shown in Table 17-14. Non-potable water uses would include roadheader supply, dust suppression, plant wash-down and rock bolting.
Some demand activities are consumptive such as water used in the offices which would be discharged to the sewerage network. There would also be minor losses in the system due to evaporation. The remainder would be treated and either reused or discharged at the proposed discharge locations listed in Table 17-13.

Non-potable sources (eg treated wastewater and harvested rainwater) may be used to meet construction water demand requirements. The deficit for the non-potable demand and any potable demand would be sought from the Sydney Water supply network. The use of non-potable water over potable would be preferred, however this is dependent on the location and nature of the water use activity as well as the quantity and quality of available water at the time. Water availability would vary as construction progresses as well as seasonally due to climate. It is expected that the potential for treated wastewater reuse would also show variability.

Table 17-14 Construction water balance

Activity[1]	Total water demand (kL/d)	Consumptive use (kL/d)	Groundwater inflows[3] (kL/d)	Harvested rainwater (kL/d)	Treated water reused (kL/d)	Sydney water supply (kL/d)	Discharge quantity (kL/d)
Warringah Freeway Upgrade	109	109	0	0	0	109	0
Tunnelling[2]							
Rozelle Rail Yards (WHT1)	39	39	243	1	30	9	214
Victoria Road (WHT2)	460	39	168	1	177	283	413
White Bay (WHT3)	75	75	0	0	0	75	0
Yurulbin Point (WHT4)	228	17	94	1	92	136	214
Berrys Bay (WHT7)	241	30	144	1	107	134	249
Cammeray Golf Course (WHT10)	159	15	135	1	84	75	196
Waltham Street (WHT11)	16	16	0	0	0	16	0
Total	**1327**	**340**	**783**	**5**	**490**	**837**	**1286**

Note 1: Water demand and use estimates for Sydney Harbour south cofferdam (WHT5) and Sydney Harbour north cofferdam (WHT6) construction support sites are included in White Bay (WHT3) construction support site.

Note 2: Incorporates all nine Warringah Freeway Upgrade construction support sites plus Berry Street North (WHT8) and Ridge Street north (WHT9) construction support sites.

Note 3: Groundwater inflow estimates have been apportioned based on the tunnel drainage design to provide an indicative estimate of likely inflow volumes that would be pumped to each construction wastewater treatment plant.

Water availability and flows

Water extraction from surface water is not proposed during construction of the project. However, surface environmental water availability and flows have the potential to be reduced as a result of groundwater drawdown during construction of the project.

The assessment of groundwater impacts for the project indicate that the maximum groundwater baseflow reductions at Whites Creek and Willoughby Creek would be negligible, with a less than one percent total flow reduction. Quarry Creek and Flat Rock Creek are not within the groundwater drawdown area of influence of the project and would not be impacted.

North Sydney Council stormwater harvesting scheme

The existing storage dam at Cammeray Golf Course would be relocated as part of the project during construction and reinstated indicatively within the north-western end of the golf course. The reinstatement of the storage dam would only occur once the Western Harbour Tunnel and Beaches Link program of works at the Warringah Freeway are completed, due to land availability. During that period of time, North Sydney Council would no longer be able to harvest stormwater runoff to irrigate areas such as the Cammeray Golf Course and other open space areas that form part of the scheme.

Transport for NSW would continue to consult with North Sydney Council to identify opportunities that provide a permanent solution earlier in the program that is reasonable and feasible. During periods in which the storage dam is not operational, Transport for NSW would come to an arrangement with North Sydney Council concerning the increased demand on other water sources.

17.4.6 Residual impacts on water quality and hydrodynamics during construction

With the implementation of the management measures outlined in Section 17.6, and in the context of the overall catchment, any potential short-term impacts are unlikely to have any material impact on ambient water quality within the receiving waterways.

The residual risk to sensitive receiving environments and environmental values identified in Section 17.3.7 and Section 17.3.8 is expected be low provided the proposed management measures are implemented, maintained and monitored.

Construction activities are not expected to result in a significant change to the sediment dynamics in the vicinity of the Sydney Harbour crossing.

17.5 Assessment of potential operational impacts

17.5.1 Hydrodynamic environment of Sydney Harbour

The bed of Sydney Harbour at the proposed immersed tube tunnel would be returned to about the same level as it was prior to works commencing. Therefore, no hydrodynamic impacts to Sydney Harbour are expected during operation of project.

17.5.2 Marine water quality

When operational, the hydrodynamic environment of Sydney Harbour would be restored to existing conditions. No impacts to marine water quality would be expected.

17.5.3 Surface water quality

Surface water runoff

During the operation of the project, all road surfaces would be sealed and embankments landscaped. Suitable stabilisation and management measures would be implemented during periods of vegetation establishment to minimise the potential for erosion and sedimentation impacts at nearby waterways including Whites Creek and Willoughby Creek. Provided appropriate controls are implemented, short-term impacts during the vegetation establishment period would be expected to be manageable with negligible impacts on receiving water quality.

At Rozelle, the surface water from the Western Harbour Tunnel portals and the road connecting the Western Harbour Tunnel with the Rozelle Interchange would be collected by the tunnel drainage system. It would not change the quality of Whites Creek or Rozelle Bay.

At the upgraded Warringah Freeway, stormwater discharge pollutant loads from impervious surfaces would be comparable to existing conditions. No additional surface water quality impacts are predicted.

Tunnel drainage and treatment

The tunnels would include drainage infrastructure to capture groundwater and stormwater ingress, spills, maintenance wastewater, fire suppressant deluge and other potential water sources. The water captured would be treated at the Rozelle operational wastewater treatment plant.

Tunnel wastewater treatment

Water intercepted by the tunnel drainage systems would be collected at a sump and pumped to the project wastewater treatment plant at the Rozelle Interchange. Following treatment, the water would then be discharged into drainage infrastructure constructed as part of the M4-M5 Link and ultimately into Rozelle Bay via the local stormwater system at a flow rate of about 0.006 kilolitres per second (that is, six litres per second).

The Rozelle Interchange wastewater treatment plant would be designed to meet specific discharge criteria as per ANZG (2018) 95 per cent species protection levels; ANZG (2018) 99 per cent protection levels for contaminants that bioaccumulate and the NHMRC (2008b) recreational guidelines water quality criteria for iron.

Impacts on NSW water quality objectives during operation

During operation, the project would treat tunnel inflows and road tunnel runoff at the Rozelle wastewater treatment plant. The plant would be designed to treat key indicators of concern to a level that is consistent with the ANZECC/ARMCANZ (2000) water quality guidelines and the NHMRC (2008b) recreational water quality guidelines.

Runoff from the surface connection and portals at Rozelle that is not collected by the tunnel drainage system would use the M4-M5 Link proposed water quality treatment devices. Runoff from the surface connection at Rozelle is unlikely to reduce the water quality of Whites Creek.

Runoff from the upgraded Warringah Freeway would not change exports of annual pollutant loads with no decrease in the water quality of Willoughby Creek or Quarry Creek.

The overall impacts to ambient water quality are likely to be negligible. Therefore, the project is considered to have a negligible influence on goals to achieve the WQOs for NSW waterways.

17.5.4 Impacts to the local stormwater system

Treated water from the Rozelle Rail Yards wastewater treatment plant would discharge into the local stormwater system at a flow rate of about 0.006 kilolitres per second (that is, six litres per second). This discharge rate is unlikely to have a material impact on the local stormwater system.

17.5.5 Impacts on geomorphology

Given that the additional discharge of water from the project would be via the existing stormwater network, the potential impacts to the geomorphology of watercourses are considered negligible. Similarly, Rozelle Rail Yards wastewater treatment plant discharges would be received into Rozelle Bay with negligible impacts to Whites Creek geomorphology.

Cumulative long-term surface settlement from tunnelling works and groundwater drawdown is expected to be nil or very minor at creeks intersected at depth or in proximity to the tunnel including Whites Creek, Willoughby Creek, Quarry Creek and Flat Rock Creek. The risk of rock cracking from such surface settlement is negligible because the ground movement would be insufficient to cause any noticeable change in permeability of the rock cover.

17.5.6 Water balance, environmental water availability and flows

Water balance for the operation of the project

Operation of the project has the potential to alter the water balance of surface and groundwater systems. The permanent wastewater treatment plant at Rozelle would treat all groundwater inflows during operation of the project. Any non-potable water demand during operational of the project would be sourced from this facility. The operational stage water balance is shown in Table 17-15.

Table 17-15 Operational water balance

Wastewater treatment plant location	Water demand		Average groundwater inflows (kL/d)	Treated groundwater reused (kL/d)	Water make-up from other sources (kL/d)	Discharged quantity (kL/d)
	Washdown (kL/d)	Deluge Testing (kL/d)				
Rozelle Rail Yards	1	5	510	6	-	504

Water availability and flows

Water extraction from waterways is not proposed during operation of the project. There are not expected to be any impacts to the flow within Whites Creek as all discharges from the operational wastewater treatment plant would be discharged to Rozelle Bay via the stormwater network.

Groundwater drawdown is expected to be negligible and unlikely to impact creek flows. Similarly, the risk of creek flow losses from bed cracking has been identified as negligible.

North Sydney Council stormwater harvesting scheme

A new dam would be provided at the operational stage of the project indicatively within the north-western end of the golf course. The new dam would have a stormwater harvesting yield comparable to the existing one. The operational stage of the project would not impact the operation and volume of water harvested for the North Sydney Council stormwater harvesting scheme.

17.5.7 Residual impacts on water quality during operation

As discussed in Section 17.3, receiving waterways near the project have existing elevated levels of some heavy metals, nutrients, turbidity and pH, and low dissolved oxygen.

Tunnel water would be treated to comply with ANZECC/ARMCANZ (2000) guidelines (refer to Section 17.1.3), and spill controls and water quality monitoring would be implemented to manage operational impacts on ambient water quality within the receiving waterways.

With the proposed treatment and management measures, residual impacts on ambient water quality are expected to be negligible.

The residual risk to sensitive receiving environments and environmental values identified in Section 17.3.7 and Section 17.3.8 is expected be low provided the proposed management measures are implemented, maintained and monitored.

17.6 Environmental management measures

Environmental management measures relating to water quality impacts are outlined in Table 17-16. No specific measures are required for hydrodynamics given the methodology to be implemented during construction activities in Sydney Harbour (refer to Chapter 6 (Construction work)) and the minimal hydrodynamic impacts expected as a result of the project. Similarly, no hydrodynamic impacts are expected during operation of the project as the tunnels would be located beneath the bed of the harbour.

Table 17-16 Environmental management measures for water quality impacts

Ref	Phase	Impact	Environmental management measure	Location
WQ1	Construction	Erosion and sedimentation	Erosion and sediment measures will be implemented at all work sites and surface road upgrades in accordance with the principles and requirements in *Managing Urban Stormwater – Soils and Construction, Volume 1* (Landcom, 2004), *Managing Urban Stormwater: Volume 2D Main Road Construction* (NSW Department of Environment and Climate Change, 2008) and relevant guidelines, procedures and specifications of Transport for NSW. A soil conservation specialist will be engaged by both Transport for NSW and the Contractor for the duration of construction of the project to provide advice regarding erosion and sediment control including review of Erosion and Sediment Control Plans (ESCPs).	WHT/WFU

Ref	Phase	Impact	Environmental management measure	Location
WQ2	Construction	Spills and leakages	Emergency spill procedures will be developed to avoid and manage accidental spillages of fuels, chemicals or fluids during construction.	WHT/WFU
WQ3	Construction	Wastewater discharge	Construction wastewater treatment plants will be designed to treat wastewater generated from tunnel groundwater ingress, rainfall runoff in tunnel portals, heat and dust suppression water and washdown runoff generated during construction. Site-specific trigger values will be developed during construction planning to set the wastewater treatment plant discharge criteria ensuring wastewater will be treated to a level that is representative of background concentrations of a suitable reference site or the ANZECC/ARMCANZ (2018) guidelines.	WHT/WFU
WQ4	Construction	Freshwater quality monitoring	A freshwater quality monitoring program for the construction of the project will be developed and implemented, with consideration of the freshwater monitoring being carried out for the M4-M5 Link and Beaches Link and Gore Hill Freeway Connection projects. The program will be developed in consultation with the Environment Protection Authority, Department of Planning, Industry and Environment (Regions, Agriculture and Resources), Department of Planning, Industry and Environment (Water), and relevant councils. Sampling locations and monitoring methodology will be in accordance with the *Guideline for Construction Water Quality Monitoring* (RTA 2003b). Each monitoring/discharge point will have a specific concentration of pollutant that cannot be exceeded at the discharge point. Should any of the site-specific trigger values be exceeded, a management response will be triggered. This response will be documented within the construction freshwater quality monitoring program.	WHT/WFU

Ref	Phase	Impact	Environmental management measure	Location
WQ5	Construction	Local stormwater system capacity	Further design development will confirm the local stormwater system capacity to receive construction wastewater treatment plant inflows. In the event that there is a stormwater infrastructure capacity issue with existing infrastructure, mitigation measures such as storage detention to control water outflow during wet weather events will be implemented within the construction support site.	WHT
WQ6	Construction	Dredge plumes	Ongoing monitoring of dredge plumes will be carried out to validate the dredge plume dispersion predictions. Exceedances of the predicted dredge plume extents and intensities will trigger subsequent management responses that will include a range of strategies including, assessing whether secondary impacts are occurring (eg seagrass stress) and if so then further levels of management actions that may ultimately result in the cessation of dredging for a period sufficient to remove the stress.	WHT
WQ7	Construction	Watercourse geomorphology	Construction drainage and discharge outlet infrastructure will direct flows downstream to minimise alterations and erosion of watercourse bed and banks. Energy dissipation and erosion scour protection will be implemented as appropriate. Construction work activities within or next to the watercourses and drainage lines will be minimised as much as feasibly possible to minimise disturbance of sediments in or near the waterway.	WHT/WFU
WQ8	Design and post-construction	North Sydney Council stormwater harvesting scheme	Reasonable and feasible opportunities to provide an interim or permanent solution for the relocation of the existing storage dam at Cammeray Golf Course earlier in program will be identified in consultation with North Sydney Council during detailed construction planning. During periods when the storage dam is no longer operational, Transport for NSW will come to an arrangement with North Sydney Council concerning the period in which the storage dam is no longer operational for the increased demand on other water sources.	WHT

Ref	Phase	Impact	Environmental management measure	Location
WQ9	Design and operation	Wastewater discharge	The permanent wastewater treatment plant at Rozelle will be designed to treat wastewater generated from tunnel groundwater ingress and rainfall runoff in tunnel portals. The level of treatment provided will consider the characteristics of the receiving environment (Rozelle Bay). Discharge from WWTP during the operation of the project will be required to meet specific discharge criteria as per ANZG (2018) 95% species protection levels; ANZG (2018) 99% protection levels for contaminants that bioaccumulate and the NHMRC (2008b) recreational guidelines water quality criteria for iron. These criteria will be defined during the construction planning phase to assist in determining wastewater treatment plant discharge criteria and ensure neutral or beneficial impacts to water quality of Rozelle Bay. Should any of the criteria be exceeded, a management response will be triggered. The management response will be documented within the Water Quality Monitoring Program.	WHT
WQ10	Design and operation	Local stormwater system capacity	The capacity for the local stormwater system to receive operational wastewater treatment plant inflows will be confirmed during further design development. In the event that there is a stormwater infrastructure capacity issue with existing infrastructure, mitigation measures such as storage detention to control water outflow during wet weather events will be implemented at the Rozelle Rail Yards.	WHT
WQ11	Operation	Operational monitoring	Operational monitoring will be carried out in line with the *Guideline for Construction Phase Water Quality Monitoring* (RTA 2003b) to: a) Assess and manage impacts on the receiving waters as the sites stabilise b) Assist in deciding when the site has stabilised c) Identify water quality conditions after development d) Identify appropriate measures to improve water quality performance. As a minimum, monthly monitoring will be	WHT/WFU

Ref	Phase	Impact	Environmental management measure	Location
			carried out for the first year of operation. Should any of the discharge criteria be exceeded, a management response will be triggered. The management response will be documented within the operational water quality monitoring program.	

Western Harbour Tunnel = WHT, Warringah Freeway Upgrade = WFU.

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