Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 17

Hydrodynamics and water quality

17 Hydrodynamics and water quality

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

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). A marine water quality assessment is provided in Appendix Q (Technical working paper: Marine water quality). 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.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to 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* (OEH, 2014).	The existing hydrological regime for surface water resources is described in **Section 17.3**. Details of water resources likely to be impacted by the project is presented in **Section 17.3.1**. Biodiversity considerations 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 **Section 17.5.6** respectively. Further details, including wastewater treatment plants and associated discharge locations, are provided in **Section 17.4.3**. Refer to **Chapter 5** (Project description) for locations of permanent water quality basins proposed for the project.

Secretary's requirement	Where addressed in EIS
	Refer to **Chapter 16** (Geology, soils and groundwater) for groundwater inflow predictions.
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 **Section 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 **Section 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 **Section 17.5**. Impacts from scour and erosion on geomorphology are discussed in **Section 17.4.4** and **Section 17.5.4**. Impacts on riparian vegetation are included in **Chapter 19** (Biodiversity).
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 re-use options) and on the conveyance capacity of existing stormwater	The effects of proposed stormwater and wastewater management on surface water quality are assessed in **Section 17.4.3** and **Section 17.5.3**. Information on wastewater discharge, including volumes and rates of discharge, are included in **Section 17.4.3** and **Section 17.5.3**.

Secretary's requirement	Where addressed in EIS
systems where discharges are proposed through such systems;	
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 17.2.3** and **Section 17.6** respectively. Proposed surface water monitoring locations are presented in **Section 17.2.2**.
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 17.2.3** and **Section 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.	Palaeochannels near the project are described in **Chapter 16** (Geology, soils and groundwater). Details of tunnel design are 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.
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	A list of the ambient NSW water quality objectives for receiving waters within the project area is included in **Section 17.1.2**. Environmental values for the receiving waters are discussed in **Section 17.3.9**. The ANZG (2018) and ANZECC/ARMCANZ (2000) default trigger values are provided in **Appendix O** (Technical working paper: Surface water quality and hydrology).

Secretary's requirement	Where addressed in EIS
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;	
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**, **Section 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 **Section 17.5.3**.
d. identify the rainfall event that the water quality protection measures will be designed to cope with;	**Section 17.1.3** identifies design standards, targets and considerations to be adopted during construction and operation, including criteria to which water quality protection measures 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 **Section 17.5**.
f. demonstrate how construction and operation of the project (including mitigating effects of proposed stormwater and wastewater management) would, to the extent that the project can influence, ensure that: - where the NSW WQOs for receiving waters are currently being met they would continue to be protected; and - where the NSW WQOs are not currently being met, activities would work toward their achievement over time;	Discussion of whether the NSW water quality objectives 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 water quality objectives is included in **Section 17.1.2**. Management measures relevant to surface water quality impacts are provided in **Section 17.6**. The ability of the project to meet the NSW water quality objectives is discussed in **Section 17.4.3** and **Section 17.5.3**.
g. justify, if required, why the WQOs cannot be maintained or achieved over time;	Treatment of wastewater to meet ANZG (2018) and ANZECC/ARMCANZ (2000) would maintain or improve existing water quality. The ability of the project to meet the NSW WQOs is discussed in **Section 17.4.3** and **Section 17.5.3**.
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

Secretary's requirement	Where addressed in EIS
	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 17.3.8**. Management measures to avoid (or minimise) impacts 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).
j. identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Surface water monitoring locations are discussed in **Section 17.2.3**. Proposed surface water monitoring is included in **Section 17.6**. **Appendix O** (Technical working paper: Surface water quality and hydrology) provides further detail on the proposed surface water quality monitoring for the project. It is anticipated that the same monitoring sites detailed in **Section 17.2.3** and indicators detailed in Section 3.2, Annexure A and Annexure B of the **Appendix O** (Technical working paper: Surface water quality and hydrology) would be monitored in the future. Details relating to the proposed groundwater monitoring are provided in **Chapter 16** (Geology, soils and groundwater).
k. identify how the development meets the objectives of the *Coastal Management Act 2016* and management objectives of relevant Coastal Management Areas defined under the *Coastal Management Act 2016.*	Consistency with the objectives of the *Coastal Management Act 2016* is outlined in **Section 17.1.1** and discussed further in **Appendix O** (Technical working paper: Surface water quality and hydrology).
l. demonstrate consistency with any relevant certified Coastal Management Program (or Coastal Zone Management Plan).	Consistency with the vision and objectives presented in the Greater Sydney Harbour Estuary Coastal Management Program Scoping Study which are consistent with the *Coastal Management Act 2016* is outlined in **Section 17.1.1** and discussed further in **Appendix O** (Technical working paper: Surface water quality and hydrology).
2. The assessment should consider the results of any current water quality studies, as available, in the project catchment.	Water quality studies considered for this assessment are listed in **Section 17.2.2**.

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 are 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 for road construction and road tunnel emissions under Chapter 3 of the Act 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 and Resources) 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 (General) Regulation 2011	The project is located within an area covered by the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources* (NSW DPI, 2011b). 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.

Legislation	Relevance to project
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 rainforests areas, coastal vulnerability areas, coastal environment areas and coastal use areas. Management objectives are listed in the *Coastal Management Act 2016* for each of the four coastal management areas. The construction footprint is located on land mapped as “proximity area for coastal wetlands” and “proximity area for littoral rainforest”, “coastal environment area” and “coastal use area”. As described in Chapter 2 (Assessment process), environmental planning instruments do not apply to State significant infrastructure; however, consideration has been given to the management objectives of the coastal management areas through which the project passes. The applicable management objectives are established in the *Greater Sydney Harbour Estuary Coastal Management Program Scoping Study* (BMT WBM, 2018), which was prepared in 2018 to facilitate the development of the Coastal Management Program coastal management program for Greater Sydney Harbour. This program will soon supersede the *Clontarf/Bantry Bay Estuary Management Plan* (Manly Council, 2008) and provide more coverage over the study area. The objectives presented in the scoping study are consistent with the *Coastal Management Act 2016* and are proposed for inclusion in the development of the Greater Sydney Harbour Coastal Management Program. The vision and objectives of the program and relevance to marine water quality are presented in Section 17.1.2 and Appendix O (Technical working paper: Surface water quality and hydrology) and Appendix Q (Technical working paper: Marine water quality).
Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005	The Sydney Regional Environmental Plan (Sydney Harbour Catchment) 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 18 years (ANZG, 2018).

The study area would typically fall under the ANZG (2018) and ANZECC/ARMCANZ (2000) water quality guidelines for 'South-east Australia slightly disturbed lowland rivers and estuaries'. Wastewater treatment plants during construction and operation would be designed such that discharges comply with these guidelines.

NSW Water Quality and River Flow Objectives

Water quality objectives have been developed for the Sydney Harbour and Parramatta River and Northern Beaches Lagoons catchments (DECCW, 2006a; DECCW, 2006b). The water quality objectives are 'primarily aimed at maintaining and improving water quality, for the purposes of supporting aquatic ecosystems, recreation and where applicable, water supply'. Waterways relevant to this assessment (Willoughby Creek, Quarry Creek, Flat Rock Creek, Burnt Bridge Creek, Manly Creek and Trefoil 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)
- Aquatic foods (cooked), which refers to protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.

Environmental values, as identified by the Department of Planning, Industry and Environment (Environment, Energy and Science), for the Sydney Harbour and Parramatta River and Northern Beaches Lagoon catchments are discussed further in Section 17.3.9.

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 the 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 construction 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.

Greater Sydney Harbour Estuary Coastal Management Program Scoping Study

As described above, the *Greater Sydney Harbour Estuary Coastal Management Program Scoping Study* (BMT WBM, 2018) was prepared in 2018 to facilitate the development of the coastal management program for Greater Sydney Harbour. A vision and objectives were presented in the scoping study that are consistent with the *Coastal Management Act 2016* for inclusion in the Greater Sydney Harbour Coastal Management Program. The objectives of the program relevant to marine water quality and references to applicable parts of this environmental impact statement are outlined in Table 17-3. Other coastal management objectives are deemed not applicable to the project.

Table 17-3 Relevant Greater Sydney Harbour coastal management objectives

Relevant coastal management objectives	Consideration
To protect and enhance natural processes and environmental values of the Greater Sydney Harbour coastal zone.	Section 17.3 with respect to the protection of environmental values of the estuary.
To support the social and cultural values of the Greater Sydney Harbour and maintain public access, amenity, use and safety.	Section 17.3 with respect to the maintenance of the estuary as a public amenity and for public use and safety.
To acknowledge Aboriginal peoples' spiritual, social, customary and economic connection with and use of the Greater Sydney Harbour coastal zone.	Chapter 15 (Aboriginal heritage) discusses the potential impacts of the project on Aboriginal heritage including potential submerged Aboriginal sites.
To recognise the Greater Sydney Harbour coastal environment is a vital economic zone, the maritime gateway to Australia's largest city.	Chapter 21 (Socio-economics) outlines the potential economic impacts of the project.
To facilitate ecologically sustainable development in the Greater Sydney Harbour coastal zone and promote strategic, coordinated and sustainable land use planning decision-making.	Chapter 25 (Sustainability) outlines how the project would meet the principles of ecologically sustainable development.
To mitigate current and future risks from coastal hazards, taking into account the effects of climate change, including impacts from extreme storm events.	Chapter 26 (Climate change and greenhouse gas) outlines how the project would mitigate current and future climate risks.

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: Soils and Construction,* Volume 2D Main Road Construction (DECC, 2008) (known as the Blue Book Volume 2)
- Guideline for Construction Water Quality Monitoring (RTA, 2003a)
- Road Design Guideline, Section 8 Erosion and Sediment (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 4 (Transport for NSW, 2020f).

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

New or modified drainage would be provided along the Gore Hill Freeway, and along modified or new surface roads at Balgowlah, North Balgowlah, Killarney Heights, Seaforth and Frenchs Forest. Also, new water quality basins would be provided at Balgowlah Golf Course and along Wakehurst Parkway.

The project would provide water quality treatment that meets the design targets listed in Table 17-4 where feasible and reasonable. These targets are as based on typical requirements for pollutant reduction described in the *Draft Managing Urban Stormwater – Council Handbook* (NSW EPA, 1997). 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 design targets listed in Table 17-4 require annual average pollutant reduction as opposed to pollutant reduction levels for a specific rainfall event. Long term impacts are best described by the use of long term rainfall data which has been expressed as average annual pollutant loads.

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

Table 17-4 Operational water quality design targets

Issue	Design target
Total nitrogen	45 per cent annual average pollutant load reduction
Total phosphorus	65 per cent annual average pollutant load reduction
Total suspended solids	85 per cent annual average 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

It is noted that these targets largely align to the stormwater quality targets established in Sydney Water's *Stormwater quality targets (Version 2)* (Sydney Water, 2020), with the exception of phosphorus, for which the project exceeds the Sydney Water stormwater quality target of a 60 per cent average annual pollutant load reduction. If stormwater discharge from the project is required to connect to Sydney Water's stormwater assets, the project would install and operate water treatment devices during operation to achieve the Sydney Water pollutant load reduction targets where feasible and reasonable.

Wastewater treatment plant discharges

The Gore Hill Freeway wastewater treatment plant would be designed to achieve the following discharge criteria:

- The relevant physical and chemical stressors set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000)
- The ANZG (2018) 95 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 99 per cent species protection levels
- The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water) of which public comments are under consideration as of November 2020.

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 Middle Harbour during project construction and operation
- Dredge plume modelling to assess potential water quality impacts as a result of dredging activities during construction of the immersed tube tunnels
- 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
- MUSIC (Model for Urban Stormwater Improvement Conceptualisation) modelling to assess the operational impacts against the water quality design targets and standards
- Assessment of changes to the North Sydney Council and Balgowlah Golf Course stormwater harvesting schemes
- Identification of appropriate management measures to mitigate potential hydrology and water quality impacts.

17.2.2 Desktop review

The desktop review involved a review of existing information that was available for the surface water environment upstream and downstream of the construction footprint and marine water quality information for Middle Harbour and Sydney Harbour. The review was carried out to develop an understanding of the existing environment and the potential impacts of the project. The review of information included data collected by Willoughby City Council, North Sydney Council and Northern Beaches Council, as well as the following sources:

- *Sydney Harbour Catchment Coastal Zone Management Plan Scoping Study*. Literature and Data Review – Management and Use of Sydney Harbour (Sydney Coastal Council Group, 2015)

- *Sydney Harbour: A systematic review of the science*, Sydney Institute of Marine Science (Hedge et al., 2013)
- *Flat Rock Creek Catchment Flood Study and Overland Flow Mapping Volume 1. Draft Report for Public Exhibition* (Lyall and Associates, 2017)
- *Water Quality Monitoring Program for Willoughby City Council. Spring 2015-Autumn 2016* (Sydney Water, 2016)
- The National Atlas of Groundwater Dependent Ecosystems to identify the location and groundwater dependence of surface water systems and vegetation (Bureau of Meteorology, 2018)
- *Water Sharing Plan for the Greater Metropolitan Region groundwater sources 2011* (NSW DPI, 2011a)
- Water quality data collected between 2014 and 2016 as part of Transport for NSW's Northern Beaches Hospital road upgrade project (SMEC, 2017)
- *The chemistry of suspended particulate material in a highly contaminated embayment of Port Jackson (Australia) under quiescent, high-wind and heavy-rainfall conditions*. Environmental Geology (Birch & O'Hea, 2007)
- *Parramatta River Estuary Data Compilation and Review Study* (Cardno Lawson Treloar, 2008)
- *Trace metal and total suspended solids concentrations in freshwater: the importance of small-scale temporal variation*. Journal of Environmental Monitoring (Hatje et al., 2001)
- *Dissolved trace metal distributions in Port Jackson estuary (Sydney Harbour), Australia.* Marine Pollution Bulletin (Hatje et al., 2003)
- *Water Quality of the Upper Parramatta River. Analysis of data collected between 1990 and 1996* (Laxton, 1997)
- *Mid Parramatta (North) River Stormwater Management Plan* (Robinson GRC Consulting, 1999)
- *Water Quality Sampling of Parramatta River - Methods & Sampling Protocol*. Sydney Institute of Marine Science (Harrison, 2012)
- *Contaminant dynamics in offchannel embayments of Port Jackson, New South Wales*. AGSO Journal of Australian Geology and Geophysics (Taylor & Birch, 1999)
- The Barangaroo project's monthly water quality reports 2012 to 2017 (Lend Lease, 2017).

17.2.3 Monitoring

Hydrodynamic monitoring of Middle Harbour

Hydrodynamic monitoring was carried out between August and November 2017 to measure variability in hydrodynamic conditions within Middle 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-based monitoring using a mounted acoustic doppler current profiler was carried out along two transects across Middle Harbour near the proposed location of the immersed tube tunnel 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 Middle Harbour

Water quality monitoring was carried out as part of the marine water quality assessment in two discrete sampling periods:

- Sampling period 1 – an eight week period from 5 December 2017 to 31 January 2018
- Sampling period 2 – a five week period from 17 April 2020 to 1 June 2020.

Sampling period 1 focused on collecting information about the effects of turbidity on underwater light that would assist interpretation of the potential effects of dredging. Data were collected at a high temporal resolution using the following methods:

- Two water quality monitoring moored loggers deployed from 5 December 2017 to 31 January 2018 to monitor turbidity, photosynthetically available radiation, chlorophyll-*a*, salinity, pressure and temperature in shallow waters near areas of known benthic primary producers, namely seagrass and rocky reef habitats
- Water sampling and water column vertical 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 bed of the harbour to the surface. 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
- The collation of meteorological and oceanographic data to provide information on the weather and ocean conditions that are key drivers of the estuary water quality response.

Sampling period 2 was designed to better understand dissolved oxygen concentration variability within the deep water to assist with understanding the potential impacts of the Middle Harbour crossing, and included the following methods:

- Two water quality moored loggers deployed from 27 April 2020 to 1 June 2020
- Water column profiling carried out on six days in 2020 (17 April, 4, 14, 23 and 27 May and 1 June)
- The collation of meteorological and oceanographic data to provide information on the weather and ocean conditions that are key drivers of tidal flushing and the water quality response.

The locations of monitoring sites for sampling period 1 were informed by preliminary predictions of the dredge plume footprint in Middle Harbour (Royal HaskoningDHV, 2020). Sites for sampling period 2 were spread further apart to better understand upstream and downstream potential variability in tidal flushing.

Table 17-5 details the Middle Harbour water quality monitoring locations for the project, including the two sites monitored as part of the hydrodynamic assessment. These monitoring locations are shown in Figure 17-1.

Table 17-5 Middle Harbour hydrodynamic and water quality monitoring sites

Site Name	Location	Monitoring activity
Sampling period 1		
BL1	Pickering Point, Seaforth	Fixed water quality monitoring mooring and profiling site
BL2	Clive Park, Northbridge	Fixed water quality monitoring mooring and profiling site
BLP1	Yeoland Point, Castle Cove	Water quality profiling site

Site Name	Location	Monitoring activity
BLP2	Peach Tree Bay, Seaforth	Water quality profiling site
BLP3	Seaforth Bluff, Seaforth	Water quality profiling site
BLP4	Hallstrom Point, Northbridge	Water quality profiling site
BLP5	Beauty Point, Mosman	Water quality profiling site
BLP6	The Spit, Mosman	Water quality profiling site
MH1	Seaforth Bluff, Seaforth	Hydrodynamic monitoring location
MH2	Southwest of Spit Bridge	Hydrodynamic monitoring location
Sampling period 2		
BM1/B1	Clontarf Point, Clontarf	Fixed water quality monitoring mooring and profiling site
BM2/B5	Seaforth Bluff, Seaforth	Fixed water quality monitoring mooring and profiling site
B2	The Spit, Mosman	Water quality profiling site
B3	Shell Cove, Clontarf	Water quality profiling site
B4	Seaforth Bluff, Seaforth	Water quality profiling site
B6	Quakers Hat, Mosman	Water quality profiling site
B7	Fig Tree Point, Northbridge	Water quality profiling site
B8	Sailors Bay, Northbridge	Water quality profiling site
B9	Seaforth Bluff, Seaforth	Water quality profiling site
B10	Peach Tree Bay, Seaforth	Water quality profiling site
B11	Pickering Point, Seaforth	Water quality profiling site
B12	Yeoland Point, Castle Cove	Water quality profiling site
B13	Bantry Bluff, Seaforth	Water quality profiling site

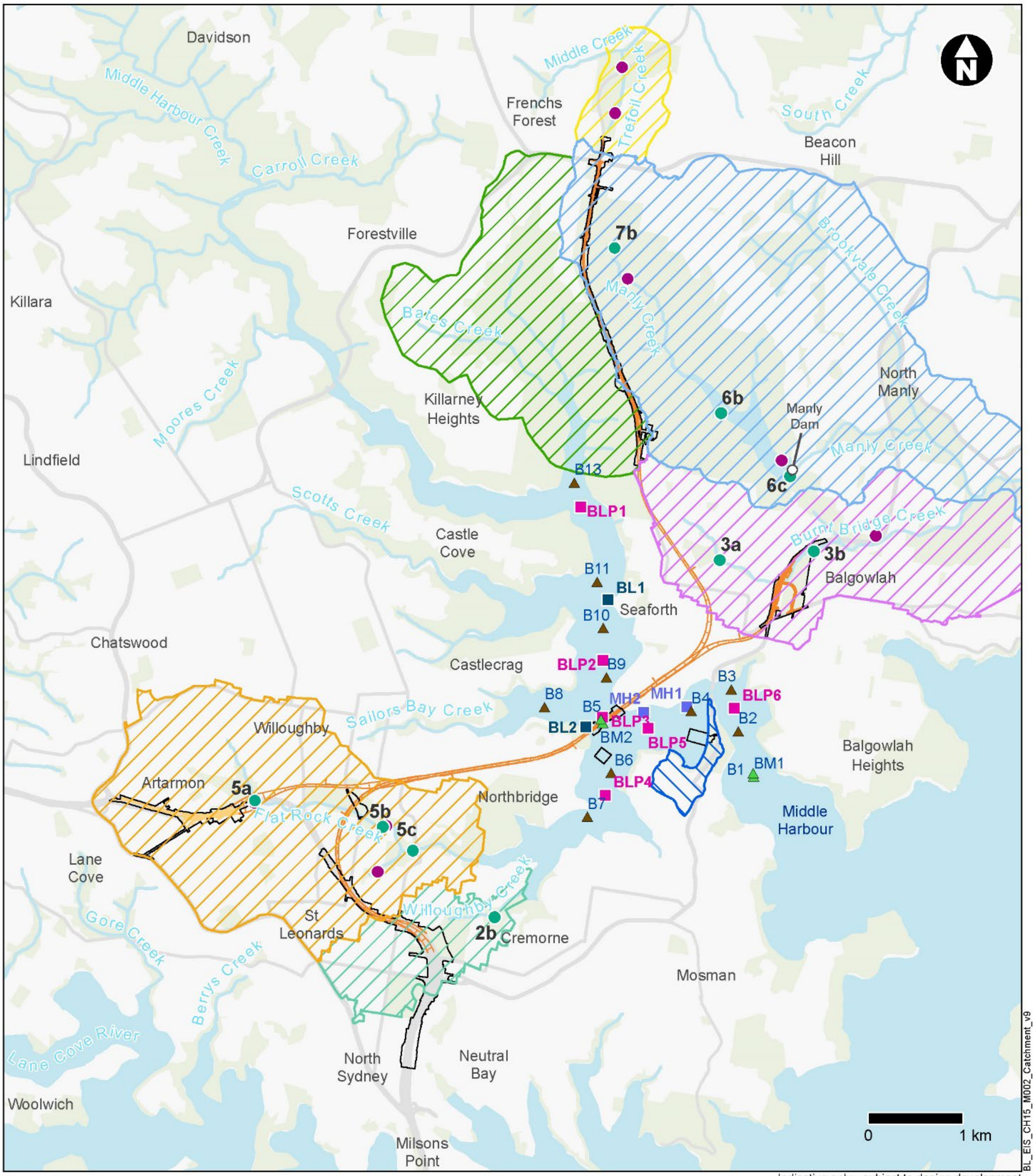
Surface water quality monitoring

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

Nine monitoring locations were selected immediately upstream and downstream of the project alignment, except for sites where access was prevented. It is noted 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 Bureau of Meteorology rainfall gauge (Gauge #066011) in the 24 hours prior to sampling, with wet weather classified as 15 millimetres or more of rainfall recorded. Monitoring locations are provided in and Table 17-6 and shown in Figure 17-1.

Table 17-6 Water quality monitoring sites in waterways

Site	Waterway	Location
2b	Willoughby Creek downstream	Primrose Park, Cremorne
3a	Burnt Bridge Creek upstream	Footbridge near Worrobil Street, North Balgowlah
3b	Burnt Bridge Creek downstream	Kitchener Street, Balgowlah
5a	Flat Rock Creek upstream	Grandview Street, Naremburn
5b	Flat Rock Creek downstream (upstream of Quarry Creek inflow)	Flat Rock Reserve, Northbridge
5c	Flat Rock Creek downstream (downstream of Quarry Creek inflow)	Tunks Park, Long Gully bridge, Northbridge
6b	Manly Dam mid (downstream)	Mid dam – Section 4 picnic area, Allambie Heights
6c	Manly Dam downstream	Dam wall, Allambie Heights
7b	Manly Creek downstream	Allambie Heights



Indicative only - subject to design development

Legend

Operational features
- Beaches Link
- Gore Hill Freeway Connection

Construction features
- Construction footprint

Catchments and waterways
- Bantry Bay
- Burnt Bridge Creek
- Flat Rock Creek
- Manly Creek
- Pearl Bay
- Trefoil Creek
- Willoughby Creek
- Waterways

Marine water quality monitoring sites
- Fixed and profiling site (2017)
- Hydrodynamic site (2017)
- Profiling site (2017)
- Fixed and profiling site (2020)
- Profiling site (2020)

Surface water quality monitoring sites
- Project monitoring site
- Existing monitoring site

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

17.2.4 Model development

Hydrodynamic model development

A three-dimensional hydrodynamic model of Middle 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 Middle Harbour near the project, as it relates to hydrodynamic characteristics
- Understand the potential impacts of the construction and operation of an immersed tube tunnel on the hydrodynamic characteristics within Middle Harbour.

Plume model development

Construction of the project would involve dredging of the bed of Middle 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 Middle 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). Plume modelling incorporated the use of the two proposed 12 metre deep draft silt curtains, however, did not consider the proposed floating silt curtain enclosures (sometimes referred to as a ‘moon pool’) that would be attached to the dredge or the additional shallow draft silt curtains that would be installed along the shorelines at the crossing location to provide protection to nearby ecologically sensitive areas (eg seagrass and rocky reef habitat).

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

A Model for Urban Stormwater Improvement Conceptualisation (MUSIC) was carried out to assess the operational impact of the project and performance of the proposed water quality management strategy against the water quality design targets and standards. The MUSIC modelling results are presented in Appendix O (Technical working paper: Surface water quality and hydrology) for the main locations where stormwater would be discharged (Gore Hill Freeway Connection, surface connections at the Burnt Bridge Creek Deviation, Balgowlah as well as the surface connection and integration works along the Wakehurst Parkway and the realigned and upgraded Wakehurst Parkway).

17.3 Existing environment

17.3.1 Catchments and waterways

The project is within the broader Sydney Harbour and Parramatta River catchment and the Northern Beaches Lagoons catchment.

The Sydney Harbour and Parramatta River catchment is comprised of three harbours: North Harbour, Middle Harbour and Sydney Harbour (the main branch of the estuary). The Middle Harbour region of Sydney Harbour is the north western branch of the estuary, and is one of the three main tributaries; the other two being Parramatta River (Western Harbour) and Lane Cove River.

The Sydney Harbour and Parramatta River catchment is a highly urbanised catchment (86 per cent) which results in rapid runoff during high rainfall events. The catchment is heavily influenced by human factors which have altered the frequency, volume and seasonality of stream flows.

The Northern Beaches Lagoons catchment consists of Narrabeen Lagoon and catchment, Dee Why Lagoon and catchment, Curl Curl and Manly lagoons and their catchments and Manly Dam (within the Manly Lagoon catchment). Relevant sub-catchments to the project include Narrabeen Lagoon, Manly Lagoon and Manly Dam. Narrabeen Lagoon is the largest of the coastal lagoons within the Northern Beaches local government area and an important environmental and recreational area (SMEC, 2011). Manly Lagoon is a small shallow coastal lagoon in the Northern Beaches local government area and is considered of poor water quality due to local pollution sources including urban stormwater runoff, sewage overflows, former landfill leachate and illegal discharge and dumping of industrial and trade waste (Cardno, 2010).

The project and surroundings are dominated by residential areas (ranging from low to high density), with some industrial and commercial developments in Artarmon, St Leonards and Willoughby. At the northern end of the project, the Garigal National Park and Manly Dam War Memorial Park are located to the west and east of Wakehurst Parkway respectively. The main bodies of water surrounding the project area are Middle Harbour and Manly Dam. The main waterways in proximity to the project include Willoughby Creek, Flat Rock Creek, Burnt Bridge Creek, Manly Creek and Trefoil Creek. Burnt Bridge Creek is a first order stream that discharges to Manly Lagoon via Manly Creek. Trefoil Creek is also a first order stream that feeds into Middle Creek which discharges to Narrabeen Lagoon. Manly Creek feeds into Manly Dam. Willoughby Creek and Flat Rock Creek are first order streams that discharge directly into Middle Harbour.

The waterways and associated catchments within the study area are shown in Figure 17-1. Table 17-7 outlines the catchments that form part of the Sydney Harbour and Parramatta River and Northern Beaches Lagoons catchments 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, rather than watercourses and would include:

- Spit West Reserve construction support site (BL9) has drainage lines which drain towards Middle Harbour
- Wakehurst Parkway south (BL12) and Wakehurst Parkway east (BL13) construction support sites drain towards Burnt Bridge Creek and Manly Dam, respectively
- The eastern edge of the connections to and from the Wakehurst Parkway has drainage lines which drain towards Burnt Bridge Creek and Manly Dam
- The western edge of the connections to and from the Wakehurst Parkway has drainage lines which traverse Garigal National Park and drain into Bantry Bay.

Table 17-7 Description of key waterways and catchments relevant to the project

Waterway/catchment	Description	Relevant project features
Middle Harbour (Sydney Harbour and Parramatta River catchment)	• The Middle Harbour region of Sydney Harbour is the north western branch of the estuary, and is one of the three main tributaries; the other two being Parramatta River and Lane Cove River • It drains a large catchment of about 7700 hectares of a wide variety of land-uses • The main channel of Middle Harbour features a relatively shallow, constricted, sharp bend between The Spit and Seaforth, which controls the volume of tidal waters that propagate upstream beyond The Spit • The channel is surrounded by a number of bays (including Quakers Hat Bay to the south, Sailors Bay to the west and Fig Tree Cove to the north) which act as reservoirs for the tidal waters • The immersed tube tunnel crossing of Middle Harbour would be located in a low energy hydrodynamic environment with relatively low current speeds and little to no expected transport of sediment from the bed of the harbour • The surface currents in the vicinity of the Spit West Reserve construction support site (BL9) are relatively slow, with the exception of the shoreline area associated with a return eddy that forms in Pearl Bay during the flood tide. During both the flood and the ebb current speeds reduce slightly with depth • The immersed tube tunnel crossing of Middle Harbour would be located in a low energy or mild wave environment. Waves are mainly derived from local winds and vessels (generally recreation craft) • Fresh and saline waters are typically well mixed due to low fresh water discharges and turbulent tidal mixing.	• Gore Hill Freeway Connection western edge drains into Bantry Bay • Crossing of Middle Harbour • Middle Harbour south cofferdam (BL7) • Middle Harbour north cofferdam (BL8) • Spit West Reserve construction support site (BL9) • Upgrade and integration works along the Wakehurst Parkway western edge drains into Bantry Bay.

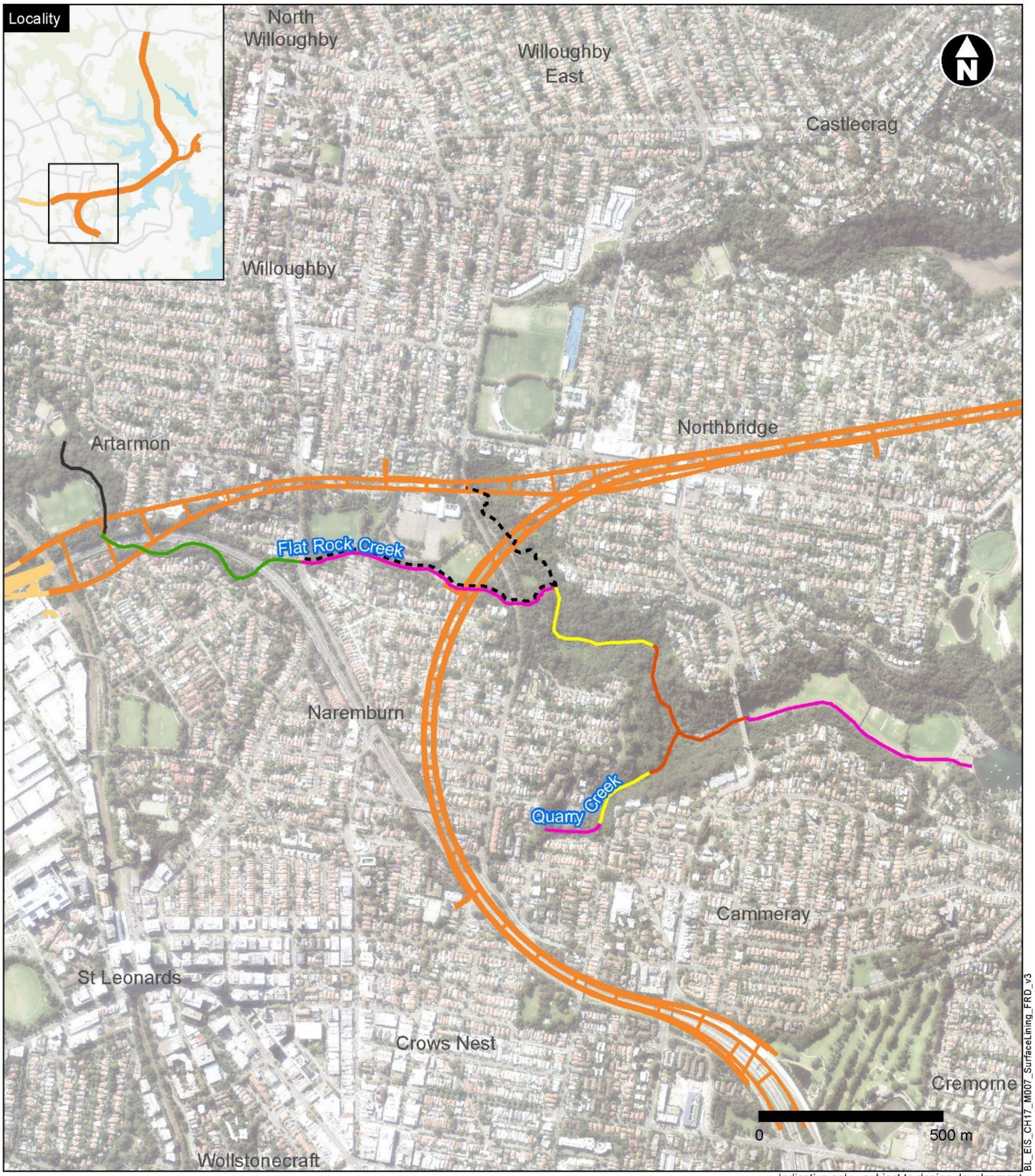
Waterway/catchment	Description	Relevant project features
Willoughby Creek (Willoughby Creek catchment) 	• Willoughby Creek is a small modified concrete and rock channel which drains a catchment of around 150 hectares that includes the suburbs of Neutral Bay and Cammeray directly into Willoughby Bay at 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.	• Southern portion of Beaches Link. • Cammeray Golf Course construction support site (BL1).
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.	• Southern portion of Beaches Link.

Waterway/catchment	Description	Relevant project features
Flat Rock Creek (Flat Rock Creek catchment)  	• Flat Rock Creek is predominantly a concrete lined (open drain and closed box culvert) stormwater channel which drains a catchment of around 390 hectares that include Artarmon, Willoughby and Naremburn. • The upper reaches of Flat Rock Creek in Artarmon consist of a covered concrete lined drain and vegetated floodway associated with the Artarmon Reserve detention basin. The creek is a concrete lined channel as it crosses the Gore Hill Freeway for the first time and continues in an open lined channel as it meanders east and crosses back under the Gore Hill Freeway. • As the creek continues east, it enters a concrete box culvert near Willoughby Road and flows underground until it reaches a point in Flat Rock Reserve around 150 metres east of Flat Rock Drive where the box culvert outlets into a human made (naturalised) excavated bedrock channel followed by a natural bedrock stream until it enters Tunks Park, where it again flows through an underground box culvert. The various surface water linings of Flat Rock Creek are shown in Figure 17-2 • 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 relatively steep catchment characterised by rocky riffle and runs. The downstream reaches are surrounded by native Coachwood forests with popular walking tracks and give 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.	• Beaches Link and Gore Hill Freeway Connection • Flat Rock Drive construction support site (BL2) • Punch Street construction support site (BL3) • Dickson Avenue construction support site (BL4) • Barton Road construction support site (BL5) • Gore Hill Freeway median construction support site (BL6).

Waterway/catchment	Description	Relevant project features
Burnt Bridge Creek (Burnt Bridge Creek catchment  	• Burnt Bridge Creek is an urban intermittent waterway which flows through Seaforth, North Balgowlah, Balgowlah and Manly Vale into Manly Lagoon. It is a freshwater first order stream receiving multiple inflows of stormwater. The various surface water linings of Burnt Bridge Creek are shown in Figure 17-3 • It drains a catchment of about 380 hectares of a wide variety of land-uses including residential areas, the Balgowlah Industrial Estate, golf courses and roads • The creek is naturalised upstream with rock, sand and mud substrate with narrow vegetated buffer zones. Downstream it is a combination of concrete and rock fill construction, which is present at the Kitchener Road crossing in Balgowlah • The creek has been heavily modified due to urban pressure (ie sewage and sewer outfalls) resulting in poor water quality, extensive weed infestation, erosion of creek banks, build-up of sediment and reduced biodiversity • The Balgowlah Golf Course Stormwater Harvesting Dam was installed in 2013 and has allowed the golf course to extract water from the dam rather than Burnt Bridge Creek allowing creek water to remain as environmental flows which has improved the ecological conditions in the creek (Manly Council, 2014) • Surface runoff discharging into Burnt Bridge Creek between Sydney Road and north of Kitchener Street currently does not receive any water quality treatment • The section of creek through the Balgowlah Golf Course has been modified and realigned in the past and is known to experience hazardous flooding.	• Northern portion of Beaches Link (Balgowlah) • Balgowlah Golf Course construction support site (BL10) • Kitchener Street construction support site (BL11).

Waterway/catchment	Description	Relevant project features
Manly Dam (Manly Creek catchment) 	• Manly Dam drains a catchment of 510 hectares of predominantly open space (bushland), and some commercial, industrial and residential areas • The catchment is characterised by sandstone slopes, rock platforms and gullies, as well as some shale areas. Over half of the catchment has gradients steeper than 10 degrees and soils have very high to severe erosion potential • The steep terrain and urban interface pose challenges to water quality, including occurrence of blue-green algal blooms due to external nutrient loading • One of the largest freshwater lakes in Sydney which provides a valued facility for swimming, fishing, water-skiing, canoe/kayaking and boating • The dam is no longer used as a source of drinking water by Sydney Water • Immediately downstream of the dam, the creek is polluted and heavily infested with weeds.	• Northern portion of Beaches Link (upgrade and integration works along the Wakehurst Parkway) • Wakehurst Parkway south construction support site (BL12) • Wakehurst Parkway east construction support site (BL13).

Waterway/catchment	Description	Relevant project features
Manly Creek (Manly Creek catchment) 	• Manly Creek drains a catchment in the urban areas of French Forest and flows into Manly Dam via War Memorial Park • The creek channel is formed of bedrock shelves, boulder and cobble runs and riffles, and pools that hold some sediment. Its banks are generally low and stable • During storm events, the creek is likely to experience high velocity flows. Riparian vegetation creates greater bank stability; however, natural scouring is likely to occur during high rainfall events.	• Northern portion of Beaches Link (upgrade and integration works along the Wakehurst Parkway).
Trefoil Creek (Trefoil Creek catchment) 	• Narrow natural waterway, engorged through a gully located near the corner of Frenchs Forest Road and Wakehurst Parkway • Drains through the suburbs of Frenchs Forest and Oxford Falls and underneath Wakehurst Parkway into Middle Creek (which flows to Narrabeen Lagoon) • The area consists of low density housing and substantial bushland, which is susceptible to flooding and road closures • The creek line is characterised by dense native and exotic vegetation, sediment substrate and rocky outcrops.	• Northern portion of Beaches Link (Frenchs Forest) • Wakehurst Parkway north construction support site (BL14).



Indicative only - subject to design development

Legend

Beaches Link

Gore Hill Freeway Connection

Surface water lining

Above and below ground concrete lined storm water channel

Alluvium

Constructed surface creek

Naturalised bedrock

Underground box culvert

Covered concrete lined drain and vegetated floodway associated with Artarmon Reserve detention basin

Figure 17-2 Surface water lining of Flat Rock Creek

Figure 17-3 Surface water lining of Burnt Bridge Creek

17.3.2 Hydrodynamic features

Bathymetry

The bed of Middle Harbour is made up of many deep holes, basins, shoals and reefs. At the proposed location of the immersed tube tunnel crossing of Middle Harbour, there is a deep 'U' shaped channel reaching a depth of 32 metres. Other key bathymetry features near the crossing of Middle Harbour include:

- The main channel of Middle Harbour, between The Spit and Seaforth is relatively shallow in comparison to the main reaches of Middle Harbour directly downstream. The Spit along with Spit Bridge and its associated piers act as a constriction to tidal flows
- There is a near 180 degree bend in the main channel as it passes between The Spit and Seaforth. This acts to control the volume of tidal waters that propagate upstream beyond The Spit
- Bays near the proposed immersed tube tunnels act as large reservoirs for tidal waters including Quakers Hat Bay, Sailors Bay and Fig Tree Cove.

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 Middle Harbour are influenced by the complex shape of the harbour, the relatively deep U-shaped channel, and the constriction at The Spit. Tidal current speeds at the proposed Middle Harbour crossing location are substantially lower than those at Spit Bridge due to increased depth. The Spit experiences faster peak flood currents than ebb currents. Spatial measurements and monitoring show little change in current speed with changes in depth.
A summary of the current speeds observed as part of the hydrodynamic monitoring is shown in Table 17-8.

Table 17-8 Current speeds near the Middle Harbour crossing

Monitoring location	Parameter	Maximum	95th percentile	Average
Southwest of Spit Bridge (MH9)	Flood current speed (m/s)	0.72	0.42	0.17
	Ebb current speed (m/s)	0.37	0.21	0.09
Seaforth Bluff, Seaforth (MH8)	Flood current speed (m/s)	0.15	0.07	0.03
	Ebb current speed (m/s)	0.21	0.08	0.04

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 Middle 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 during the year range from 4.2 to 4.7 metres per second (50th percentile) to 6.7 to 8.3 metres per second (90th percentile)
- Wind speeds are slightly higher during spring/summer compared to autumn/winter.

Waves

Ocean swells that enter Middle Harbour are deflected by the complex bathymetry and shoreline formation such that most of Middle Harbour is affected only by locally derived wind and vessel generated waves. Most vessels in Middle Harbour are relatively small recreational craft, resulting in limited vessel wakes. The wave climate near the proposed immersed tube tunnel crossing of Middle Harbour is a low energy wave climate with wave heights typically less than 0.3 metres and wave periods of less than four seconds.

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

Rainfall and freshwater runoff into Middle 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.

Middle Harbour has a catchment area of around 7700 hectares. While there are no major rivers flowing into Middle Harbour there are many small creeks including Middle Harbour Creek, Rocky Creek, Carroll Creek, Gordon Creek, Moores Creek, Bates Creek, Scotts Creek, Willoughby Creek and Flat Rock Creek.

Suspended sediments

Turbidity is typically used as an indicator of suspended sediment concentrations. A review of historical data for turbidity of the waters in Port Jackson identifies 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.

As there is limited existing turbidity data for Middle Harbour, a summary of measured turbidity for the waters around Balls Head (about six kilometres south west of the Middle Harbour crossing) is provided in Table 17-9 to provide a reference for expected turbidity levels in Middle Harbour during dry and wet weather events.

Table 17-9 Ambient measured turbidity near Balls Head

Weather	Ambient turbidity (Nephelometric Turbidity Units (NTU))
Dry weather	less than 1 to 4 NTU
Wet weather	4 to 20 NTU – short-lived events, less than two days with higher values on ebb tide

Project specific turbidity data recorded during monitoring for the project near the Middle Harbour crossing identified similar low ambient turbidity levels (less than 5 NTU) (Table 17-10).

Table 17-10 Instantaneous turbidity statistics (in NTU) at Middle Harbour site BL2

Statistical parameter	Ambient total suspended solids (NTU)
95th percentile	1.0
90th percentile	0.9
50th percentile (median)	0.5
10th percentile	0.3
5th percentile	0.3

An example of the high turbidity which occurs within Middle Harbour following heavy rainfall is shown in Figure 17-4 (near Clive Park, near the Middle Harbour crossing in Northbridge) for an event in February 2020.

17.3.3 Marine water quality

A review of historical marine water quality data and project specific monitoring of Middle 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 influence the mixing of the Middle Harbour deep waters
- Total suspended solids concentrations are generally low (below one milligram per litre) during extended dry periods with peaks up to 30 milligrams per litre after heavy rainfall events (refer to Figure 17-4). During the wetter months, total suspended solids concentrations are elevated at around three to five milligrams per litre
- Low dissolved oxygen levels can occur at the bed of the harbour, however vertical mixing maintains high dissolved oxygen content of the overall water column
- Good light penetration occurs through the water column. The euphotic depth, where light decreases to one per cent of its surface value, is typically greater than 15 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:

- Drainage from the existing Warringah Freeway road surface and nearby road networks in North Sydney and Willoughby local government areas discharges to local stormwater drainage systems, and ultimately to Sydney Harbour or Middle Harbour. The Warringah Freeway does not have any specific spill risk management devices
- Drainage from the Gore Hill Freeway discharges to existing water quality basins located at Punch Street and Artarmon Oval. Basin discharges then travel in local drainage systems into Flat Rock Creek which ultimately discharges into Middle Harbour
- Water quality treatment is not provided at Burnt Bridge Creek Deviation between Sydney Road and north of Kitchener Street however the weir located within the golf course provides some water quality treatment by default, capturing some coarse sediment. Stormwater runoff is collected through a pit and pipe network that discharges into Burnt Bridge Creek via several cross drainage pipes without treatment
- Water quality treatment is not provided along Wakehurst Parkway aside from the operational water quality infrastructure that was recently constructed as part of the Northern Beaches Hospital road upgrade project. Road runoff is collected through natural drainage lines before reaching the receiving waterways. Flows travelling to the west reach Middle Harbour while flows travelling to the east reach Manly Dam.

Figure 17-4 Evidence of increased turbidity at Clive Park (looking north) after heavy rain in February 2020

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 in the study area are in very poor condition and are representative of a heavily urbanised system. The water quality at each assessed waterway is summarised in Table 17-11.

Table 17-11 Existing water quality conditions in the project area

Waterway	Commentary on ANZG (2018) and ANZECC/ARMCANZ (2000) indicators	Monitoring sites/source data
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.	• 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 • Willoughby City Council
Burnt Bridge Creek	• High levels of heavy metals • High nutrient concentrations • Low dissolved oxygen levels • Low chlorophyll-*a* levels.	• Sites 3a, 3b • Northern Beaches Council
Manly Dam	• Dissolved oxygen levels just below the recommended limit • High concentrations of total nitrogen and oxidised nitrogen • Total phosphorus levels were compliant	• Sites 6b, 6c • Northern Beaches Council

Waterway	Commentary on ANZG (2018) and ANZECC/ARMCANZ (2000) indicators	Monitoring sites/source data
	• Low concentrations of heavy metals.	
Manly Creek	• Low dissolved oxygen levels • High levels of heavy metals • Varied nutrient levels • Low chlorophyll-a levels.	• Site 7b • Northern Beaches Council
Trefoil Creek	• High concentrations of heavy metals • High nutrient concentrations (total nitrogen).	• Northern Beaches Hospital road upgrade project • Northern Beaches 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 of about 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, which is 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 has become habitat for wildlife such as ducks and saves about 30 million litres of clean water each year. The dam would be directly impacted by the proposed Western Harbour Tunnel and Warringah Freeway Upgrade project prior to the Beaches Link project using the Cammeray Golf Course construction support site (BL1).

17.3.7 Balgowlah Golf Course stormwater harvesting dam

The construction of the Balgowlah Golf Course stormwater harvesting project was completed in 2013. The stormwater harvesting project involved construction of a four megalitre pond/dam with a maximum nominal water depth of 2.5 metres and installation of a gross pollutant trap in Balgowlah Oval upstream of Balgowlah Golf Course. Dam storage of four megalitres allows for around 60 million litres per year of captured stormwater to be used for irrigation. The dam and the underground gross pollution trap treat 100 per cent of the stormwater flowing through the golf course. A key outcome of the Balgowlah Golf Course stormwater harvesting project is the golf course no longer extracts water from Burnt Bridge Creek for irrigation. As such, creek water remains as environmental flows, which re-creates the natural creek conditions.

17.3.8 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 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 17-12.

Table 17-12 Sensitive receiving environments

Waterway	Sensitive receiving environment	Reason for classification
Middle 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 Rockcod which is listed under the *Fisheries Management Act 1994* and *Environment Protection and Biodiversity Conservation Act 1999* • Includes endangered populations of the seagrass *Posidonia Australis* which is listed under the *Fisheries Management Act 1994* • Is a primary contact recreation area.
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.
Burnt Bridge Creek	No	• Considered a Type 2 moderately sensitive Key Fish Habitat (NSW DPI, 2013) due to limited aquatic habitat and urbanisation of the channel.
Manly Dam	Yes	• Considered a Type 1 highly sensitive Key Fish Habitat (NSW DPI, 2013) due to potential fish refuge • Located within 100 metres of the Coastal Sandstone Gully Forest groundwater dependent ecosystem • Located near patches of endangered ecological community Coastal Upland Swamp in the Sydney Basin Bioregion, as listed under the Biodiversity Conservation Act 2016 • Is a primary contact recreation area.
Manly Creek	Yes	• Considered a Type 1 highly sensitive Key Fish Habitat (NSW DPI, 2013) due to potential fish refuge • Located within 100 metres of the Coastal Sandstone Gully Forest groundwater dependent ecosystem • Located near patches of endangered ecological community Coastal Upland Swamp in the Sydney Basin Bioregion, as listed under the *Biodiversity Conservation Act 2016* • Is a secondary Contact Recreation area.
Trefoil Creek	Yes	• Potential habitat for the Red-Crowned Toadlet which is listed as Vulnerable under the *Biodiversity Conservation Act 2016* • Is a secondary contact recreation area.

17.3.9 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 catchment (which includes Middle Harbour) and Northern Beaches Lagoons 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 nutrient levels, 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
- Aquatic foods (cooked) – which refers to protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities. This objective applies to all waters where aquatic foods are taken for non-commercial and commercial harvesting. For this assessment this includes turbidity, metals and organochlorines.

These environmental values have been assigned to each waterway within the study area as shown in Table 17-13. Aquatic ecosystems and visual amenity apply to all waterways within the study area.

Table 17-13 Assigned environmental values

Waterway	Environmental value				
	Aquatic ecosystems	Visual amenity	Primary contact recreation	Secondary contact recreation	Aquatic foods (cooked)
Middle Harbour	✓	✓	✓	✓	
Willoughby Creek	✓	✓		✓	
Burnt Bridge Creek	✓	✓			
Flat Rock Creek	✓	✓		✓	
Manly Dam	✓	✓	✓	✓	✓
Manly Creek	✓	✓		✓	✓
Trefoil Creek	✓	✓		✓	✓

17.4 Assessment of potential construction impacts

17.4.1 Hydrodynamic features of Middle Harbour

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

- The establishment of Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8)
- The establishment of deep draft silt curtains at either side of the proposed immersed tube tunnel crossing location where most of the dredging works would occur
- The establishment of the Spit West Reserve construction support site (BL9).

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 Middle Harbour north cofferdam (BL8) would cause a reduction in current speeds around Seaforth Bluff at all water depths. There would be an increase in current speeds in the middle of the channel and at the bed of the harbour (ie beneath the silt curtain). Current speeds would also increase at the upper layers of the water column between the bank near Clive Park and the Middle Harbour south cofferdam (BL7).

During the flood tide (recharging of the estuary), there would be a decrease in current speed at both cofferdams as well as within and surrounding the silt curtains. There would also be a decrease in current speed along Seaforth Bluff upstream of the Middle Harbour north cofferdam (BL8). An increase in current speed along the bank upstream of the Middle Harbour south cofferdam (BL7) would occur.

A general reduction in current speeds adjacent to the shoreline is predicted near the Spit West Reserve construction support site (BL9), in particular during the flood tide. The reduced current speeds result from the temporary structures impeding the eddy that forms in this area. The eddy would be redirected, particularly in the surface layers, towards the west resulting in a small area of current speed increase to the west of the immersed tube tunnel unit casting facility.

Due to the existing low energy hydrodynamic environment, the changes in current speeds observed during ebb and flood tides are not expected to have a substantial impact on the surrounding environment.

During both ebb and flood tide, the current reductions would be more pronounced in the surface layer due to the effect of the silt curtains on the upper water column. As these changes are more pronounced in the surface layer it is not expected that any major erosion or accretion of the bed of the harbour would occur in this area. The localised increases in current speeds near the bed of the harbour are not expected to result in a substantial change to the sediment dynamics in this area.

17.4.2 Marine water quality

Construction of the immersed tube tunnels would require dredging of the bed of Middle 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, excavating and piling activities associated with the establishment of the Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and immersed tube tunnel support piles, as well as adjacent land based activities at the Spit West Reserve construction support site (BL9) have the potential to reduce water quality and disturb contaminated sediments

- Construction vessel movements have the potential to generate localised plumes of suspended sediments associated with vessel wash in shallower waters, generally less than five to ten metres water depth
- Maintenance or refuelling of construction plant and equipment resulting in spills or leaks of fuels and chemicals that could be discharged directly or indirectly to the marine environment
- Transport of dredged and excavated material that is unsuitable for offshore disposal to a suitable shore-based load out facility prior to disposal at a licensed land-based facility. This would be at a shore-based location outside Middle Harbour
- Land based activities involving the exposure or handling of soils may result in possible soil erosion and off-site transport of sediment via air or runoff to receiving marine waterways.

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
- Increases in turbidity resulting in lowered dissolved oxygen levels and increased nutrients
- 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 was assessed using dredge plume modelling, which identified the following:

- The extent of the dredge plume (two milligrams per litre suspended sediment concentration) would be relatively small. It would spread further at the bed of the harbour than at the surface
- Deep draft silt curtains would effectively contain the surface layer suspended sediments and to a lesser degree the deeper suspended sediments. Additional shallow draft silt curtains are proposed and would further reduce potential impacts and protect near shore ecologically sensitive areas
- Suspended sediment concentrations would be generally low (less than five milligram per litre) for areas outside of the silt curtains. Concentrations would be highest in the bottom layer
- Suspended sediment in the lower layers would be transported via relatively slow upstream and to a greater extent downstream currents within a tidal stream adjacent to the Seaforth shoreline
- Suspended sediment concentrations in the waters next to Seaforth would peak (up to eight milligrams per litre) during the first four weeks of dredging due to the removal of soft surface sediments. For the majority (95 per cent) of the dredge time the concentrations are predicted to be less than 2.5 milligrams per litre
- Brief periods of increased suspended sediment concentrations (up to 3.5 milligrams per litre) are predicted at the surface layer immediately outside the silt curtain surrounding the Middle Harbour south cofferdam (BL7) near Clive Park. For the majority (99 per cent) of the dredge time, surface layer concentrations are predicted to be less than 1.7 milligrams per litre.

Figure 17-5 shows the results of the dredge plume modelling for the 95th percentile (ie the value that is predicted to be exceeded for only five per cent of the time, or 8.4 hours in a week) for the 37 week dredging program for the bottom, middle and surface layers of Middle Harbour.

The results indicate that the dredging program would not have a substantial impact on marine water quality. The dredging and construction activities for the project are likely to cause short term increases in suspended sediment concentrations but due to the rapid dispersion of suspended sediments in Middle Harbour, impacts on water quality would be temporary and minimal in nature. Monitoring during the dredging activities would provide data to assess the compliance of the activities with this assessment.

Although there is limited existing data for turbidity during high rainfall events in Middle Harbour, the expected dredge plumes are likely to result in less impact than turbidity that occurs due to ongoing high rainfall events. One such high rainfall event occurred in February 2020 (refer to Figure 17-4) resulting in an increase in turbidity in Middle Harbour.

Along with the use of several shallow and deep draft silt curtains around cofferdams and dredging activities, shallow draft silt curtains would be installed along the shorelines where appropriate to mitigate potential impacts to nearby ecologically sensitive areas (eg seagrass and rocky reef habitat).

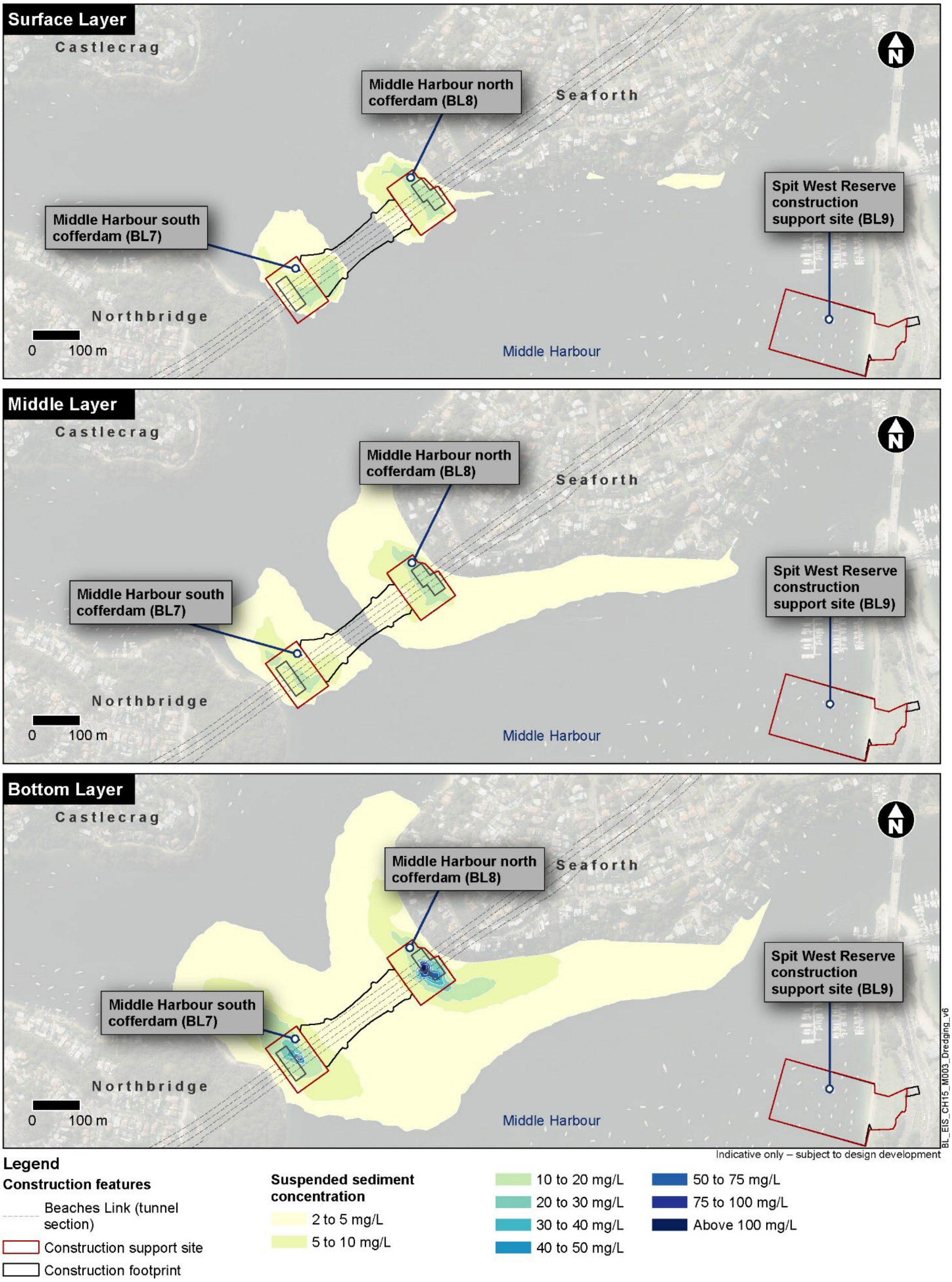


Figure 17-5 Dredge plume impacts within Middle Harbour during dredging activities

Deposition of mobilised sediment

Deposition of dredged material would be contained within the silt curtains proposed to be used during dredging activities and limited to a thickness of less than five millimetres.

Modelling of sediment deposition on the bed of the harbour two weeks after the completion of dredging activities indicated the following (refer to Figure 17-6):

- The majority of deposition would occur within and adjacent to the dredging footprint due to the low current speeds throughout the area and the use of deep draft silt curtains. Deposits would be concentrated in front of each cofferdam where most of the rock dredging and rehandling would occur
- Low levels of sedimentation (one to five millimetres) would mostly occur downstream of the dredge footprint due to stronger currents during the ebb tide, with some deposition reaching beyond Spit Bridge near Clontarf. Low level sedimentation would occur upstream about 600 metres from the immersed tube tunnel crossing of Middle Harbour
- Deposition is not predicted to accumulate in the area around Spit Bridge where tidal currents and bed shear stresses are high
- Deposition rates at the Middle Harbour south cofferdam (BL7) would remain low throughout the dredge period, despite its location close to the dredge footprint, due to the effectiveness of the deep and shallow draft silt curtains.

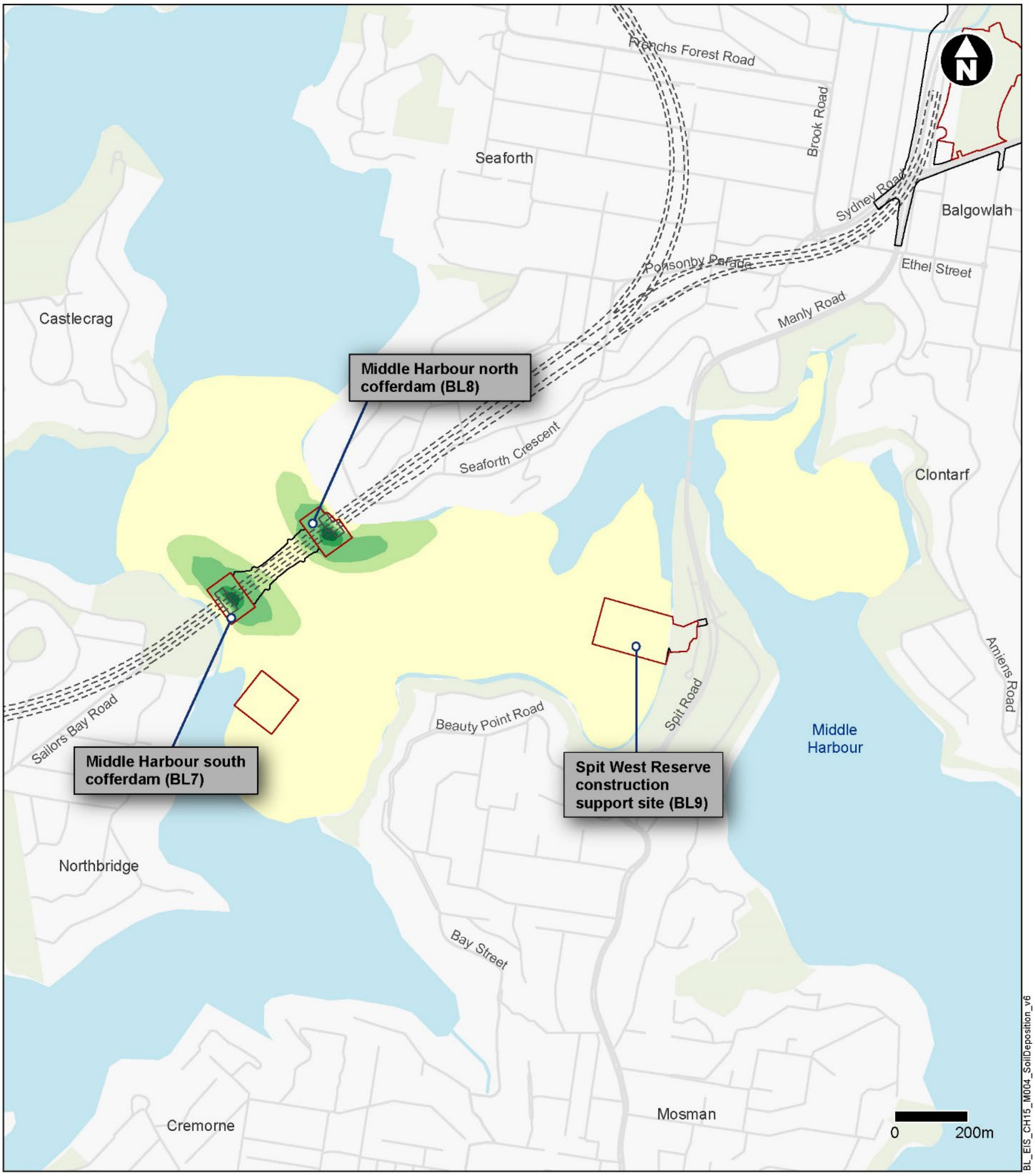
In summary, the effects of sedimentation as a result of dredging are expected to be minor. Short term effects of turbidity and deposition would likely be less than the effects from significant rainfall events.

Mobilisation of contaminants

Sediment sampling carried out for the project within Middle Harbour identified levels of selected contaminants within the top 0.5 metres to one metre of sediments from the bed of the harbour, which would, if mobilised, exceed guideline criteria. Dredging and other construction activities within Middle 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 bucket would be used to remove the top layer of sediment. This would reduce the potential for release of contaminated sediments into the water (refer to Chapter 6 (Construction work)). On the basis of this proposed methodology, plume modelling has shown it is therefore unlikely that marine water quality would be substantially affected.



Legend

Construction features

- Beaches Link (tunnel section)
- Construction footprint
- Construction support site

Soil deposition depth

- 1 to 5 (mm)
- 5 to 10 (mm)
- 10 to 50 (mm)
- 50 to 100 (mm)
- Above 100 (mm)

Figure 17-6 Sediment deposition two weeks after completion of dredging activities

Discharges, runoff, spills and leaks

Land based construction activities occurring immediately adjacent to Middle Harbour could result in of the release of sediment via runoff to the harbour. There is also potential for spills or leaks of fuels and/or oils from maintenance or re-fuelling of construction plant or equipment or vehicle incidents, which could result in discharges to surrounding waterways and Middle Harbour. The discharge of treated water from onshore construction areas may also affect water quality in Middle Harbour.

These potential impacts would be effectively managed through the implementation of environmental management measures and procedures such that impacts on marine water quality would be minimised.

17.4.3 Surface water quality

Surface activities

A summary of potential impacts to surface water quality as a result of surface construction works is provided in Table 17-14. Identified surface water quality impacts would be managed via standard erosion and sediment control management and mitigation measures for all work sites including surface works areas.

Table 17-14 Summary of potential surface construction impacts on surface water quality

Construction activities/ incidents	Potential impacts
Temporary construction support sites	Establishment of temporary construction support sites may result in erosion and mobilisation of exposed soils by stormwater runoff and wind leading to sedimentation of waterways. Temporary construction support sites may include activities that have a high 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 not appropriately managed, direct impacts would 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: • Willoughby Creek • Flat Rock Creek • Burnt Bridge Creek

Construction activities/ incidents	Potential impacts
	• Manly Creek and Manly Dam.
Stockpiling	Storage of earthworks materials, crushed rock, mulch and vegetation in stockpiles on construction sites and within temporary construction support sites have the potential to impact water quality and impact the aquatic environment if not appropriately managed. Stockpiles within 500 metres of a waterway that could potentially present a risk to water quality would be located at: • Flat Rock Drive (BL2) and Punch Street (BL3) construction support sites (Flat Rock Creek) • Balgowlah Golf Course (BL10) and Kitchener Street (BL11) construction support sites (Burnt Bridge Creek) • Wakehurst Parkway south and east construction support sites (BL12 and BL13) (Manly Creek and Manly Dam) • Wakehurst Parkway north (BL14) construction support site (Trefoil Creek) • Surface connection at Balgowlah (Burnt Bridge Creek) • Realignment and upgrade of Wakehurst Parkway (Manly Creek and Trefoil Creek).
Demolition	Demolition works have the potential to disturb and/or spread sources of pollutants including asbestos and other building materials, pollutant-laden soils, or heavy metals and chemicals 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 to downstream receiving waterways via the drainage network.
Contamination and acid sulfate soils	If not appropriately managed, disturbance of contaminated land or groundwater, or acid sulfate soils during construction could result in the mobilisation of contaminants 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 (refer to Appendix M (Technical Working Paper: Contamination)). There is the possibility of acid sulfate soils being present within sediments within Middle Harbour and/or The Spit.
Spills and leaks	If not appropriately managed, accidental spills or leaks could occur from spillage of diesel during refuelling, and leakage of hydraulic and lubricating oil from plant and equipment. Washdown water from plant washing and concrete slurries also have the potential to enter waterways if not appropriately managed.
Relocation of utilities	The relocation of utilities would involve soil disturbance as a result of trench excavation and underboring and construction of new utility routes. The disturbance of soil by machinery would increase the potential for soil erosion which has the potential to impact on downstream water quality if not appropriately managed.

Construction activities/ incidents	Potential impacts
Removal of vegetation	The removal of vegetation has the potential to increase the risk of erosion and sedimentation within the surrounding waterways if not appropriately managed. The majority of vegetation that would be removed for the project is located along the Wakehurst Parkway. Additionally, a small area of riparian vegetation and instream habitat would be removed for the localised adjustment and drainage works at Burnt Bridge Creek and the existing aboveground watercourse within the northern extent of Flat Rock Reserve. The removal of riparian vegetation and instream habitat at both creeks has the potential to impact bank stability and surface water quality if environmental management measures are not implemented. Vegetation removal for the localised adjustment of a small section of Burnt Bridge Creek would be mitigated by constructing a naturalised channel comprising of new plantings and retaining walls.

Tunnelling activities

Sources of wastewater

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

- Groundwater infiltration into tunnelling works
- Rainfall runoff into tunnel portals and ventilation outlet tunnels
- Wash down runoff
- Heat and dust suppression water.

Most of this wastewater would be collected from groundwater infiltration into the tunnelling works. 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. Groundwater infiltration into tunnelling works has been estimated as a worst case without consideration of the progressive installation of tunnel linings designed to reduce infiltration to an average of one litre per second per kilometre of tunnel.

The reuse of wastewater would be maximised during construction works (eg dust suppression and compaction of earthworks and pavements). Despite this reuse, there is expected to be a surplus of wastewater, which would need to be treated appropriately 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. Discharges from construction wastewater treatment plants would be required to meet the following discharge criteria:

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

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 approximate duration of operation of the treatment plants are presented in Table 17-15. Discharge quantities are presented as a worst case, excluding progressive installation of tunnel linings to reduce infiltration to below one litre per second per kilometre. Therefore, the predicted tunnel infiltration, and discharge volumes, would be less than predicted by the modelling. Wastewater treatment plants and discharge locations are shown in Figure 17-7.

Table 17-15 Construction wastewater treatment plants

Plant location	Approximate duration of operation	Discharge quantity (kL/d)	Discharge location	Ultimate receiving waters
Cammeray Golf Course construction support site (BL1)	Three years and three months	296	Local stormwater system	Willoughby Creek
Cammeray Golf Course construction support site (BL1) and Western Harbour Tunnel and Warringah Freeway Upgrade project Cammeray Golf Course construction support site (WHT10) (cumulative discharge)[1]	Six months	321	Local stormwater system	Willoughby Creek
Flat Rock Drive construction support site (BL2)	Four years	711	Local stormwater system	Flat Rock Creek
Punch Street construction support site (BL3)	Three years and nine months	308	Local stormwater system	Flat Rock Creek
Balgowlah Golf Course construction support site (BL10)	Four years	428	Local stormwater system	Burnt Bridge Creek
Wakehurst Parkway east construction support site (BL13)	Three years and six months	10	Drainage channel to be formed at the eastern section of the temporary construction support site	Wakehurst Golf Course dam for reuse by the golf course (via overland flow)

Note 1: Cumulative impact during the time the two wastewater treatment plants would be discharging concurrently into the local stormwater system.

The wastewater treatment plants at Cammeray Golf Course (BL1), Flat Rock Drive (BL2), Punch Street (BL3), Balgowlah Golf Course (BL10) and Wakehurst Parkway east (BL13) construction support sites would treat wastewater generated from tunnelling activities to a standard suitable for discharge based on ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines. Construction wastewater treatment plants would be designed to maintain the water quality outcomes of the receiving ambient environment so that water quality objectives are achieved and impacts on water quality of affected catchments would be low compared to the existing pollutant loads.

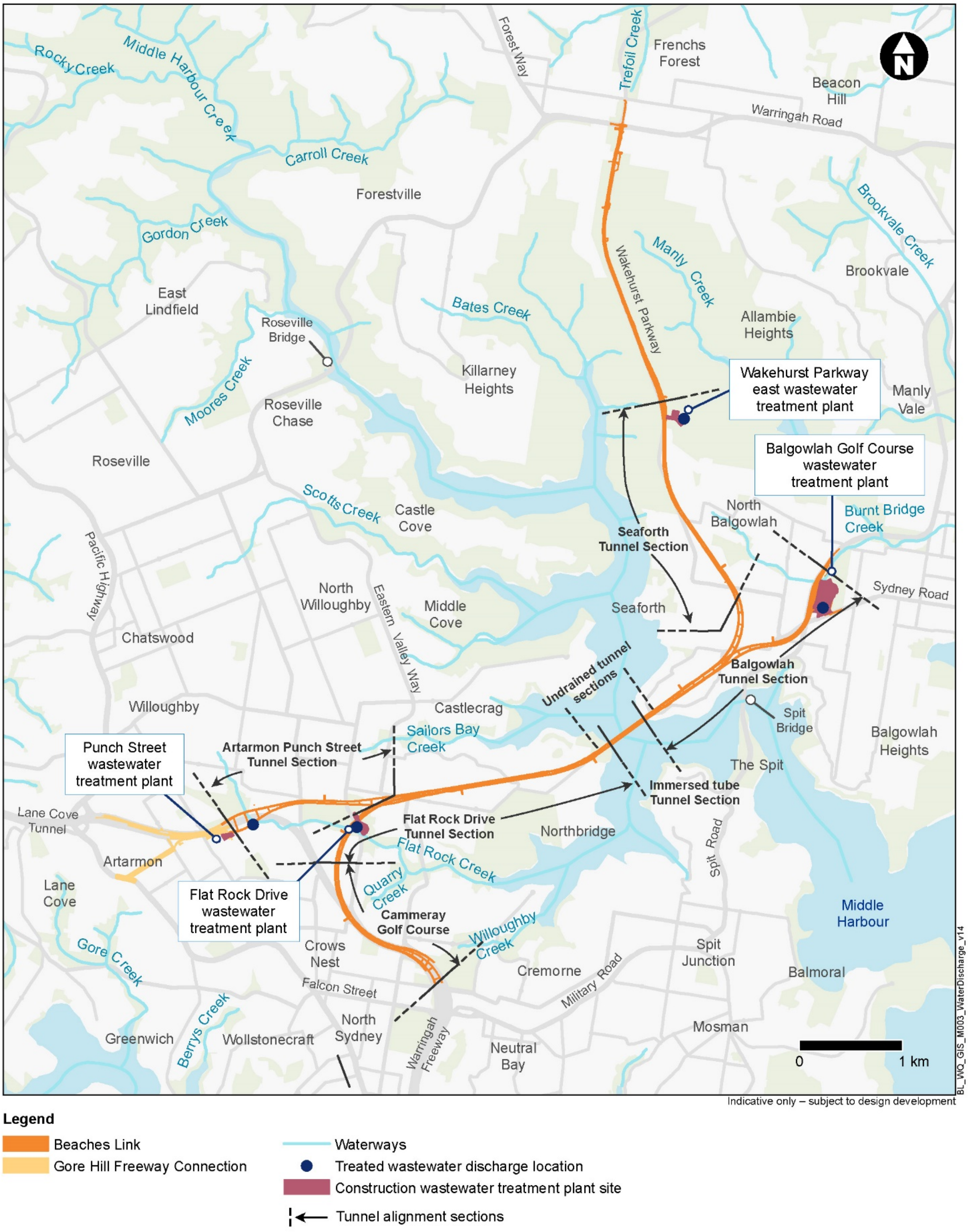


Figure 17-7 Construction wastewater treatment plants and discharge locations

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 standard, environmental management measures, potential pollutant loading to the receiving waterways is considered to be low compared to the existing pollutant loading from Willoughby Creek, Flat Rock Creek, Burnt Bridge Creek, Manly Creek and Trefoil Creek catchments.

As a consequence, the project construction is 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:

- Treated water discharges from construction wastewater treatment plants have the potential to impact creek channel bed and bank conditions due to changes in baseline volumes and velocities
- Temporary changes in downstream creek flows and velocities as a result of increased surface runoff
- Mobilised sediment build up in the streams if not appropriately managed
- Impervious surfaces created by the project increasing the volume and rate of runoff, causing erosion within the instream channel
- Potential subsidence below watercourses, potentially impacting on channel bed and bank conditions.

Groundwater infiltration to the tunnels would be collected, treated and reused as required or discharged to local waterways including Willoughby Creek, Flat Rock Creek and Burnt Bridge Creek. This is expected to largely offset baseflow reduction to these waters, as the additional creek flows could partially feed the surrounding groundwater system.

Treated wastewater discharges into Willoughby Creek are not anticipated to change the creek geomorphology as the modified concrete and rock channel would be able to handle greater flows during frequent flood events. The susceptibility of Willoughby Creek 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 project discharges when compared to existing flows.

Cumulative average daily treated wastewater discharges into Flat Rock Creek would be 0.012 kilolitres per second for about four years. This cumulative flow is considered minor when compared to creek flows experienced during a two-year average recurrence interval (ARI) event (0.02 kilolitres per second). Construction wastewater treatment plant discharges into Flat Rock Creek are not anticipated to change the form of the creek channel and banks as Flat Rock Creek is able to handle greater flows during frequent flood events. The overall predicted maximum total flow reduction in Flat Rock Creek at the end of construction is 20 per cent, increasing to 39 per cent after 100 years of operation, however given the circular nature of water flows (treatment of groundwater infiltration and discharge back into local waterways), discharges may partially offset this impact. There is also little potential for further incision of the concrete-lined sections and rocky riffle/runs at Flat Rock Creek. Baseflow impacts are modelled conservatively without tunnel linings designed and installed to reduce groundwater inflows into the tunnels. Baseflow impacts are therefore likely to be lower than that predicted. Refer to Section 17.4.5 for further discussion on water availability and flows.

Average daily treated wastewater discharges into Burnt Bridge Creek would be about 0.005 kilolitres per second for about four years. This flow is considered negligible when compared to creek flows experienced during a two-year ARI event (29.7 kilolitres per second) and is not expected to change the stability or form of Burnt Bridge Creek channel or banks.

Most of the treated wastewater generated at the Wakehurst Parkway east construction support site (BL13) wastewater treatment plant would be reused. The small amount discharged would be into the drainage channel to be formed at the eastern section of the site which would naturally drain towards Wakehurst Golf Course and the golf course dam. Therefore, geomorphology impacts from treated wastewater discharges at the Wakehurst Parkway east construction support site are not expected.

If not appropriately managed, 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 includes Willoughby Creek, Flat Rock Creek, Burnt Bridge Creek, Manly Creek and along drainage lines that pass under Wakehurst Parkway. Impacts to Flat Rock Creek are considered to have low potential of occurring given the concrete-lined or piped nature of the creek.

Drainage works associated with an existing aboveground watercourse within Flat Rock Reserve at the Flat Rock Drive construction support site (BL2) and localised adjustment of Burnt Bridge Creek as part of surface connections at Balgowlah would be staged to ensure creek flows and velocities are not substantially changed and to avoid downstream erosion and bed and bank stability impacts. The potential for watercourse geomorphology impacts would be mitigated through environmental management measures outlined in Section 17.6.

Works along the Wakehurst Parkway, the Wakehurst Parkway south construction support site (BL12), Wakehurst Parkway east construction support site (BL13) and Wakehurst Parkway north construction support site (BL14) are unlikely to change the bed and bank conditions of the existing drainage lines within the Garigal National Park and Manly Dam Reserve provided environmental management measures outlined in Section 17.6 are implemented. Refer to Chapter 6 (Construction work) for further details regarding the scope and extent of stormwater drainage works.

17.4.5 Water balance, environmental water availability and flows

Water balance

The expected construction water balance, based on average groundwater infiltration, and the estimated treated discharge quantities are shown in Table 17-16. The actual water usage during construction is expected to show considerable variation during this period depending on the nature and extent of construction activities taking place. Non-potable water uses would include earthworks and pavement compaction, landscape watering, roadheader supply, dust suppression, plant wash-down and rock bolting, amongst other activities. Some activities are consumptive such as concrete batching and the water used in the offices, with some consumptive demand assumed to be discharged directly into 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 17-15.

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 17-16 Construction water balance

Activity[1]	Total water demand (kL/d)	Consumptive use (kL/d)	Groundwater infiltration (kL/d)	Harvested rainwater (kL/d)	Treated wastewater reused (kL/d)	Sydney water supply (kL/d)	Discharge quantity (kL/d)
Surface works[2]	368	368	0	0	185	183	0
Tunnelling							
Cammeray Golf Course (BL1)	159	15	278	1	127	32	296
Flat Rock Drive (BL 2)	635	61	440	1	305	331	711
Punch Street (BL 3)	125	40	347	1	130	0	308
Balgowlah Golf Course (BL 10)	810	457	521	1	263	547	428
Wakehurst Parkway east (BL 13)	548	370	30	1	199	349	10
Total	**2645**	**1311**	**1616**	**5**	**1209**	**1442**	**1753**

Note 1. Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and Spit West Reserve (BL9) construction support sites are not included in the water demand estimates
Note 2. Surface works estimates include works along the existing Gore Hill Freeway, surface works between the mainline tunnels at Balgowlah and Killarney Heights, and surface works at Wakehurst Parkway.

Water availability and flows

Water extraction from surface water is not proposed during construction. However, surface environmental water availability and flows have the potential to be reduced as a result of groundwater drawdown during construction of the project. Baseflow impacts are modelled conservatively without tunnel linings designed and installed to reduce groundwater infiltration into the tunnels. Baseflow impacts are likely to be lower than that predicted in Appendix N (Technical working paper: Groundwater) due to conservative modelling assumptions.

The assessment of groundwater impacts for the project indicate that the maximum predicted groundwater drawdown at Willoughby Creek during construction is up to three metres in the upper reaches. Baseflow impacts are not expected as the creek is lined in this area. There is the potential for baseflow reductions of more than five per cent to occur at Flat Rock Creek and Quarry Creek at the end of construction. The drawdown beneath Burnt Bridge Creek is estimated to be up to five metres. There would be maximum of 79 per cent reduction in baseflow at the end of construction. Due to the very low existing baseflows along Burnt Bridge Creek and Quarry Creek and the existing geomorphologies, the predicted baseflow reductions are unlikely to have any substantial hydrodynamic or water quality impacts. An estimated drawdown of less than one metre is expected at Manly Dam, resulting in maximum baseflow reduction of two per cent. Other creeks would be unaffected by changes to baseflow conditions. As discussed below, it is expected that the additional creek flows from treated water from the construction wastewater treatment plants could partially feed the surrounding groundwater system. Further details regarding the potential impacts of baseflow reductions and measures to minimise potential impacts on ecological conditions are provided in Chapter, 16 (Geology, soils and groundwater), Chapter 19 (Biodiversity) and Appendix S (Technical working paper: Biodiversity development assessment report).

Stormwater harvesting schemes

The project would not impact the stormwater harvesting scheme implemented by North Sydney Council at the storage dam at the Cammeray Golf Course. However, the existing storage dam at the Cammeray Golf Course would be impacted by the Western Harbour Tunnel and Warringah Freeway Upgrade project.

As part of the Western Harbour Tunnel and Warringah Freeway Upgrade project and subject to a timely agreement with Cammeray Golf Club and North Sydney Council regarding a suitable alternative location, Transport for NSW would install a new permanent replacement storage dam (and associated infrastructure) within the golf course prior to decommissioning of the existing dam.

The reinstatement and management of impacts to North Sydney Council prior to the reinstatement of the permanent solution form part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

The project would impact the Balgowlah Golf Course stormwater harvesting dam as part of constructing the new access road between Sydney Road and Burnt Bridge Creek Deviation. The Balgowlah Golf Course Stormwater Harvesting dam will initially be retained and maintained as construction water and irrigation of Balgowlah Oval by Northern Beaches Council. As construction progresses the stormwater harvesting dam would be removed. The ongoing need for a stormwater harvesting water quality basin at Balgowlah would be assessed and determined during further design development. If the stormwater harvesting water quality basin is considered to be required, a suitable alternate location and future use would be determined as part of the dedicated consultation process regarding the final layout of the new and improved public open space and recreation facilities at Balgowlah.

17.4.6 Residual impacts 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 17.3.8 and Section 17.3.9 is expected be low provided the proposed management measures are implemented, maintained and monitored.

Construction activities are not expected to result in a substantial change to the sediment dynamics in the vicinity the Middle Harbour crossing. The use of floating silt curtain enclosures immediately around dredging plant and associated deep draft silt curtains is expected to effectively contain any mobilised sediments.

17.5 Assessment of potential operational impacts

17.5.1 Hydrodynamic environment of Middle Harbour

The immersed tube tunnels would be installed as a series of pre-cast units. Due to the profile of the harbour bed, the units would sit both partially within a trench closer to the shore and above the bed of the harbour towards the centre of the harbour crossing. The middle sections would be placed with the tops of the tunnel units being about 9.2 metres above the existing level of the bed of the harbour, creating a sill-like feature over a length of around 250 metres and around 40 metres wide. The water depth above the immersed tube tunnels would vary between 16 metres and 22 metres, depending on the distance from the shore.

Hydrodynamic modelling of the potential impacts on tidal currents and tidal flushing indicates:

- The changes to currents for both flood and ebb tides as a result of the project would be small and less than those seen through natural variations such as wind driven circulation
- Water levels upstream of the Middle Harbour crossing would not be affected
- The tidal prism of Middle Harbour (ie the volume of water between mean high tide and mean low tide) would be marginally reduced (0.4 per cent decrease)
- Tidal flushing (replacement of water via tidal fluctuations) would take slightly longer for water located upstream and below the level of the sill; however, flushing would remain relatively rapid.

Due to the existing low energy hydrodynamic environment at the proposed Middle Harbour crossing, little to no bedload transport or resuspension of existing sediment is expected to occur where the immersed tube tunnels would be located above the bed of the harbour. Localised increases in current speed are not expected to result in a change to the sediment dynamics near the proposed Middle Harbour crossing. Figure 17-8 to Figure 17-11 show the changes to tidal flows as a result of the project during peak flood and peak ebb tides at the top of the sill and at the surface.

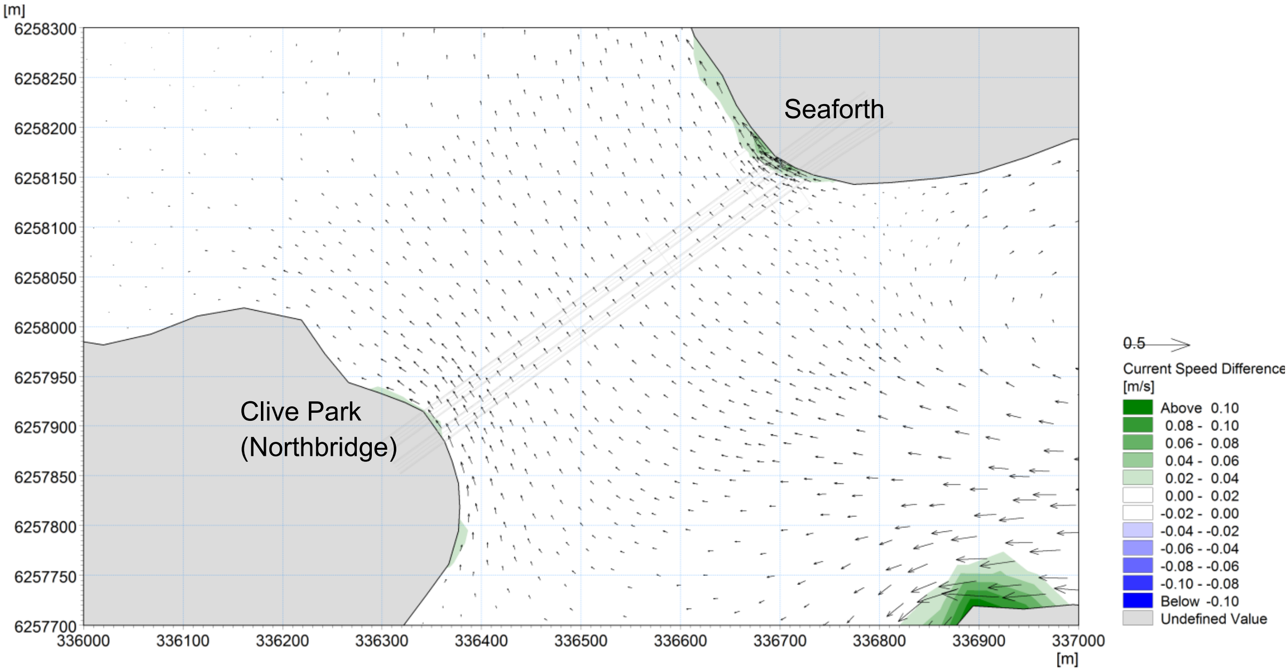


Figure 17-8 Current speed difference: project design less existing conditions (Peak flood tide: surface layer)

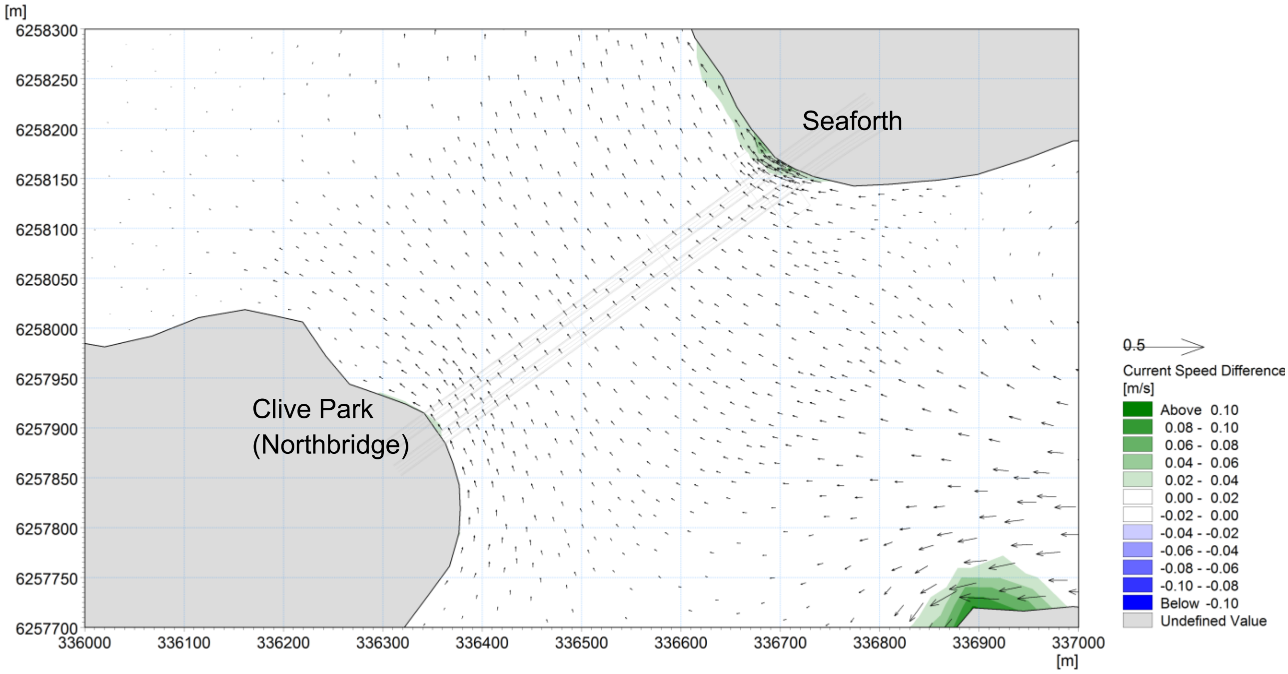


Figure 17-9 Current speed difference: project design less existing conditions (Peak flood tide: layer just above the crown of the tunnel)

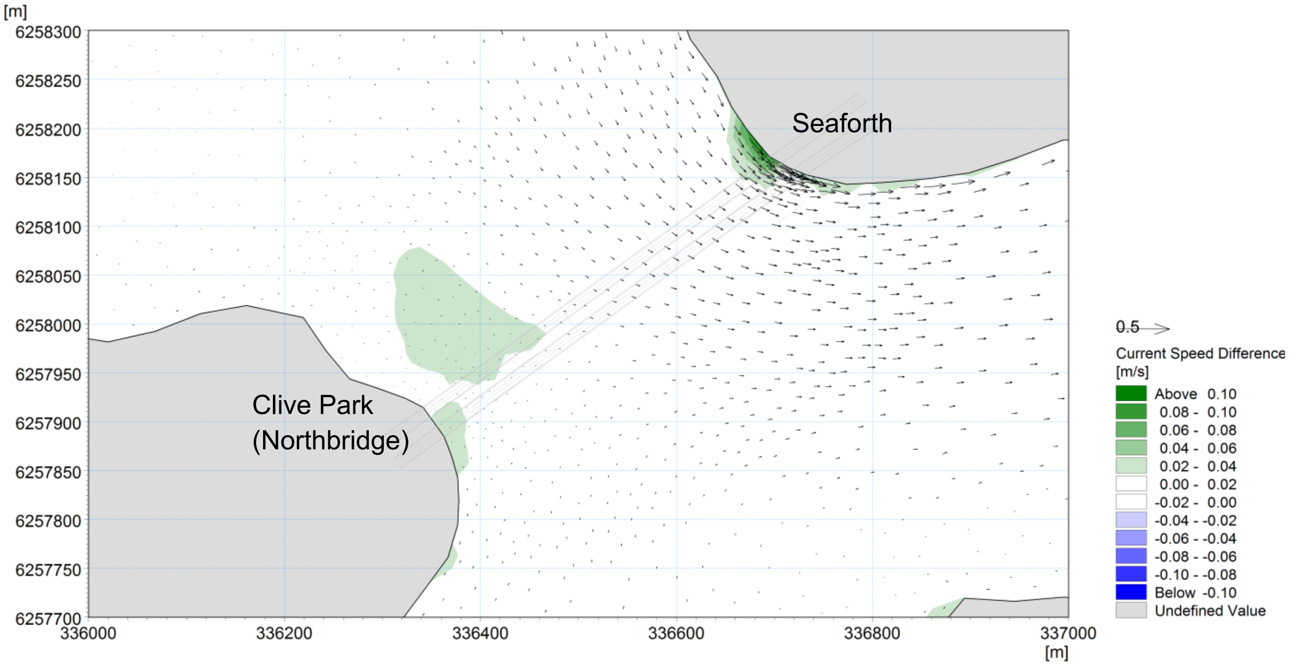


Figure 17-10 Current speed difference: project design less existing conditions (Peak ebb tide: surface layer)

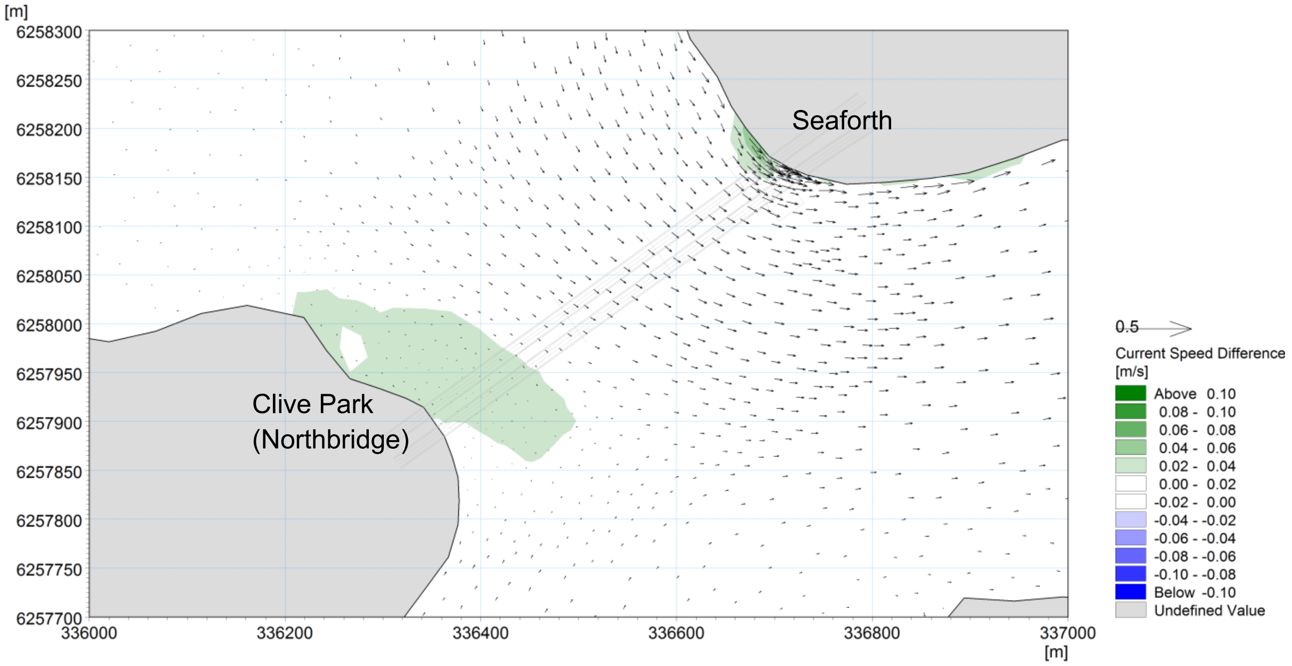


Figure 17-11 Current speed difference: project design less existing conditions (Peak ebb tide: layer just above the crown of the tunnel)

17.5.2 Marine water quality

Tidal flushing upstream of the Middle Harbour crossing has the potential to be affected by the permanent sill-like feature that would be created by the project. The longer term effects of the sill have the potential to reduce water exchange and therefore increase residence times in the near-bed waters for about one kilometre upstream of the sill from 1.6 days to 2.4 days. Increased residence time of the deep water upstream may lead to longer periods of low dissolved oxygen concentrations in the near-bed waters below the sill level and/or increased siltation behind the sill. Lower dissolved oxygen concentrations may lead to a nutrient release from the sediments and its subsequent vertical mixing, potentially stimulating algal growth near the surface.

When dissolved oxygen concentrations are reduced there may be mortality to some benthic infauna and epifauna in soft sediment habitat in the deepest parts of the harbour, but fish and sharks would generally be able to avoid these bottom layers. It would be expected that recolonisation of affected deep water soft sediment habitat would occur through natural processes of recruitment of planktonic larvae and from movement of fauna from shallower unaffected areas of soft sediment.

Based on average annual rainfall patterns, the conditions leading to dissolved oxygen depletion to about 50 per cent saturation concentrations are likely to naturally occur a few times per year, particularly during the warmer late summer and autumn period. While the project would potentially result in low dissolved oxygen events lasting slightly longer at a slightly lower dissolved oxygen concentration than currently occurs, any depletion of dissolved oxygen in deeper waters would be rapidly mixed vertically resulting in the project having a negligible effect on dissolved oxygen in surface waters in which Type 1 and Type 2 Key Fish Habitats are located. The potential impacts of the likely slightly longer periods of low dissolved oxygen concentrations in the deep waters to the marine ecology of Middle Harbour are discussed further in Chapter 19 (Biodiversity).

17.5.3 Surface water quality

Surface water runoff

During 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 Flat Rock Creek and Burnt Bridge 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.

Runoff from upgraded road pavement would typically contain pollutants such as sediments, litter, nutrients, oils and greases, petrochemicals and heavy metals, which could potentially impact on water quality when discharged into receiving waterways and sensitive receiving environments (Trefoil Creek, Manly Creek, Manly Dam, Burnt Bridge Creek and Flat Rock Creek). Potential impacts on the water quality of nearby watercourses and drainage lines would include increased sedimentation, erosion, and mobilisation of contaminated sediments resulting in potential impacts to aquatic flora and fauna if not appropriately managed.

Where possible, surface water quality controls for the project would be provided so that water is treated to a standard that would meet the design targets for the project. Where the design targets are not able to be met due to site constraints, water quality treatment to meet existing conditions would be provided such that impacts on surface water quality would be minimal.

MUSIC modelling was carried out to assess the performance of the proposed surface water quality treatment measures against the pollutant reduction targets outlined in Section 17.1.3.

The modelling results for the main locations where stormwater would be discharged (ie Gore Hill Freeway Connection, surface connections at Balgowlah and the realigned and upgraded Wakehurst Parkway) indicate that while the project would not meet the design targets in all locations, it would still meet or improve the existing water quality. On this basis impacts on surface water quality are expected to be minimal.

Chapter 5 (Project description) and Appendix O (Technical working paper: Surface water quality and hydrology) provide further details of the stormwater drainage infrastructure and proposed stormwater quality treatment systems.

Tunnel drainage and wastewater treatment

The tunnels, when operational, would include drainage infrastructure to capture groundwater and stormwater ingress, spills, maintenance wastewater, fire suppressant deluge and other potential water sources.

Water intercepted by the tunnel drainage systems would be collected and pumped to the Gore Hill Freeway wastewater treatment plant for treatment. Following treatment, the water would then be discharged into Flat Rock Creek via a new drainage pipe connecting with Flat Rock Creek at a flow rate of about 16 litres per second (refer to Figure 17-12).

The wastewater treatment plant would be designed to meet the following discharge criteria:

- The relevant physical and chemical stressors set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000), and
- The ANZG (2018) 95 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which will be treated to meet the ANZG (2018) 99 per cent species protection levels, and
- The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water) of which public comments are under consideration as of November 2020.

Impacts on NSW water quality objectives during operation

During operation, the project would treat tunnel infiltration and road tunnel runoff at the Gore Hill Freeway operational wastewater treatment plant. The plant would be designed to treat key indicators of concern to a level that is consistent with the ANZG (2018) water quality guidelines and the NHMRC (2008b) recreational water quality guidelines.

Runoff from the Gore Hill Freeway Connection, surface connections at Balgowlah and the realigned and upgraded Wakehurst Parkway is predicted to meet or improve the existing water quality of receiving waters (Flat Rock Creek, Burn Bridge Creek, Manly Dam, Manly Creek or Bantry Bay).

The overall impacts to ambient water quality are likely to be negligible. The project is considered to have a negligible influence on goals to achieve the NSW water quality objectives.

17.5.4 Impacts to the local stormwater system

Treated wastewater from the Gore Hill Freeway operational wastewater treatment plant would discharge into Flat Rock Creek via a new drainage pipe at a flow rate of about 0.016 kilolitres per second (16 litres per second) (refer to Figure 17-12). This discharge rate is unlikely to have a material impact on the operation of the local stormwater system.

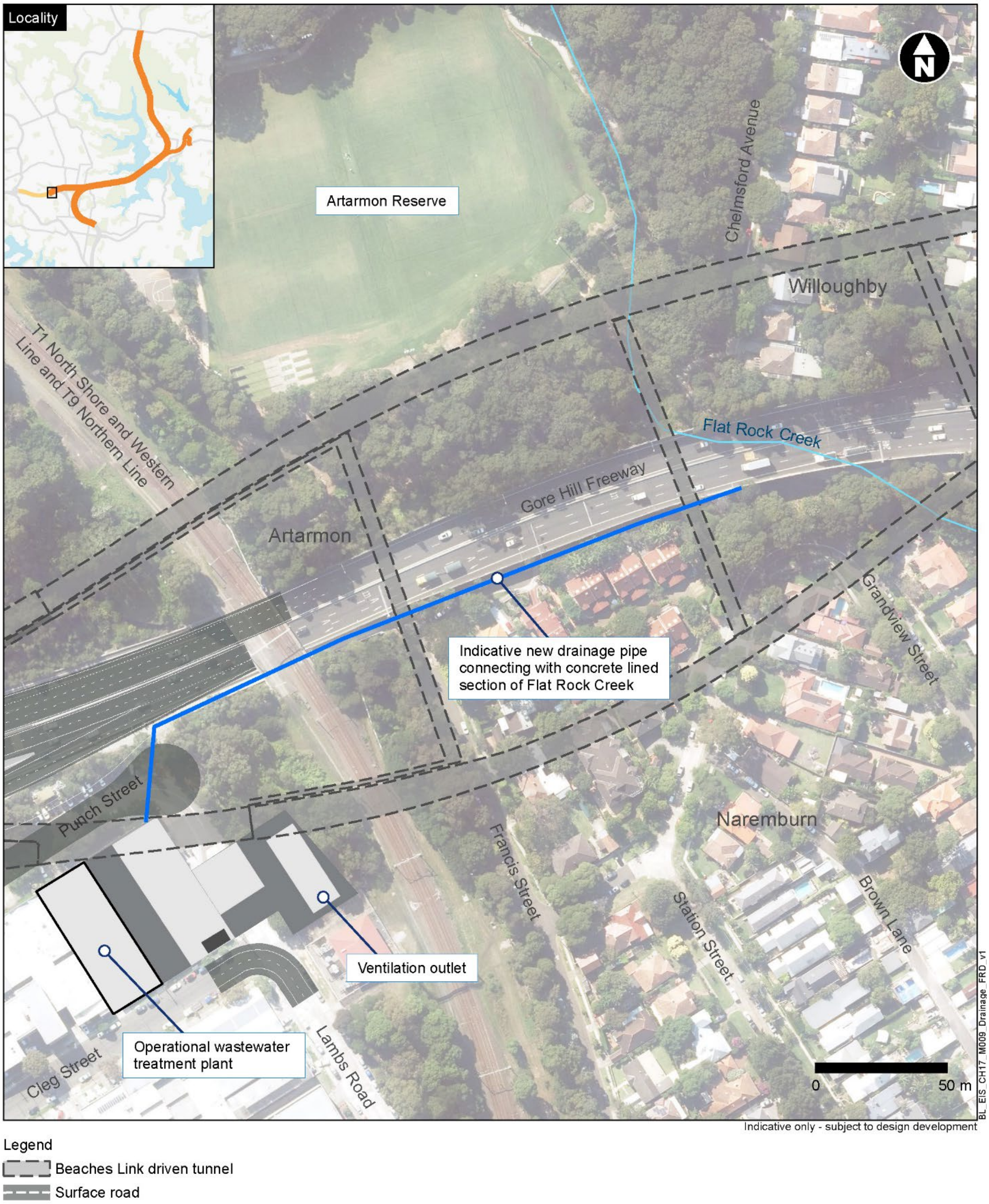


Figure 17-12 Operational wastewater treatment discharge location

17.5.5 Impacts on geomorphology

The potential impact to the geomorphology of watercourses from surface water runoff is considered negligible given that project stormwater discharges would be via the stormwater network. Drainage works would be designed to include velocity flow dissipation structures so as to prevent scouring of creeks and drainage lines.

The Gore Hill Freeway wastewater treatment plant discharge volumes would be ultimately received into Flat Rock Creek via the local stormwater system at a flow rate of about 0.016 kilolitres per second. This rate is lower than the creek flow rate under a two-year ARI flood event (0.02 kilolitres per second). It is therefore considered that Flat Rock Creek bed and banks would be able to handle expected wastewater treatment plant flow rates without impacting the creek form and geomorphic processes.

The upgrade of the concrete lined drainage line between Punch Street and Flat Rock Creek via Chelmsford Avenue would be located on existing flow paths and sized to not restrict the free flow of water. It would be designed with low gradient and scour protection to minimise impacts to geomorphology. Additionally, installation of culverts would be in accordance with the *Temporary Stormwater Drainage for Road Construction technical guideline* (Roads and Maritime Services, 2011b).

The proposed localised adjustment of Burnt Bridge Creek would be designed considering the susceptibility of the creek to scour from increased flow and runoff. The extension to the existing culvert would be designed with low gradient and scour protection to minimise impacts to geomorphology. The extent of scour protection would be minimised during further design development as far as practicable. The gradient, sinuosity and channel capacity would remain consistent with upstream and downstream sections of the creek. Where required, grade controls and bank stabilisation works would be implemented to manage anticipated high velocity conditions.

Cumulative long-term surface settlement from tunnelling works and groundwater drawdown have been assessed for the project (Arup and WSP, 2020). Cumulative long-term surface settlement is expected to be nil or very minor at creeks intersected or in proximity to the tunnels. 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. The exception to this is the cumulative long-term surface settlement predicted at Flat Rock Creek within poorly consolidated fill beneath Flat Rock Baseball Diamond. At this location, settlement is predicted to be up to 85 millimetres under a worst case (conservative) modelling scenario. With the inclusion of proposed tunnel lining for around 300 metres beneath Flat Rock Reserve, modelling indicates that predicted settlement at Flat Rock Reserve reduces from 85 millimetres without the lined tunnel to 35 millimetres with the lined tunnel.

Contours of calculated surface angular distortion have been developed based on the calculated surface settlement data (Arup and WSP, 2020). The calculated maximum settlement is at the north east section of the link at Balgowlah Connection, Burnt Bridge Creek, Wakehurst Parkway Connection and north of the Warringah Freeway portal with the maximum settlement being 35 to 40 millimetres in these areas.

Settlement is not expected to have noticeable impact on Flat Rock Creek or Burnt Bridge Creek form and geomorphology as the existing creek drainage infrastructure along both these creeks would be designed as culverts and would mitigate some of the predicted settlement impacts.

17.5.6 Water balance, environmental water availability and flows

Water balance

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

Table 17-17 Operational water balance

Wastewater treatment plant location	Water demand		Average groundwater infiltration (kL/d)	Treated groundwater re-used (kL/d)	Discharge quantity (kL/d)
	Washdown (kL/d)	Deluge testing (kL/d)			
Gore Hill Freeway	2	8	1435	10	1425

Water availability and flows

Water extraction from waterways is not proposed during operation of the project. However, surface environmental water availability and flows have the potential to be reduced as a result of groundwater drawdown during operation of the project. This has the potential to result in impacts to groundwater dependant ecosystems and other surrounding riparian ecosystems reliant on surface water (refer to Appendix N (Technical working paper: Groundwater)).

The assessment of groundwater impacts for the project identified that the project has the potential to result in a worst case groundwater drawdown of up to 29 metres beneath Flat Rock Creek after 100 years of operation. The modelling indicates that there would be a maximum total flow reduction of about 39 per cent in Flat Rock Creek after 100 years of operation, noting operational wastewater treatment plant discharges to Flat Rock Creek may offset this impact. Potential impacts would also be experienced at Quarry Creek and Burnt Bridge Creek, where maximum total flows would be reduced by 69 and 96 per cent respectively after 100 years of operation.

While these reductions could be considered significant, in particular for Burnt Bridge Creek and Quarry Creek, they are unlikely to result in a complete loss of aquatic habitat. Pools would be retained and there would still be high flows within the waterways immediately after rainfall events. Between rainfall events there would still be some (low) flow along the waterways. Further consideration to the potential impacts of baseflow reduction on aquatic ecosystems is provided in Appendix S (Technical working paper: Biodiversity development assessment report).

It is noted that groundwater modelling provides a conservative assessment which excludes the designed tunnel linings. Additional modelling was carried out for a scenario in which the section of tunnel beneath Flat Rock Creek is lined. With the linings assumed, the predicted water table drawdown after 100 years of operation was predicted to be up to eight metres less than the drawdown predicted without the lining, demonstrating that implementation of tunnel lining would help mitigate potential groundwater drawdown impacts and that potential baseflow impacts would be lower than predicted (refer to Chapter 16 and Appendix N (Technical working paper: Groundwater)).

A minor flow reduction of two per cent would be experienced at Manly Creek/Manly Dam, however other watercourses including Willoughby Creek would be unaffected by changes to baseflow and would experience a negligible total flow reduction after 100 years of operation.

Environmental management measures to minimise potential impacts due to reduced groundwater baseflow to creeks are provided in Chapter 16 (Geology, soils and groundwater). Monitoring of surface water flows and groundwater levels would occur in the vicinity of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, both prior to and during construction to confirm potential baseflow loss to these surface water features.

Stormwater harvesting schemes

The stormwater harvesting scheme implemented by North Sydney Council at the storage dam at Cammeray Golf Course would not be impacted by the project as the storage dam would be reinstated as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

The ongoing need for a stormwater harvesting water quality basin at Balgowlah would be assessed and determined during further design development. If a basin is considered to be required, a suitable alternate location and future use will be determined as part of the dedicated consultation process regarding the final layout of the new and improved public open space and recreation facilities at Balgowlah.

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) and ANZG (2018) guidelines (refer to Section 17.1.3). MUSIC model results for several areas, including the Gore Hill Freeway Connection stormwater catchment, combined stormwater sub-catchments at Balgowlah and stormwater catchments at Wakehurst Parkway, show that the proposed water quality strategy would achieve general reductions on annual pollutant exports when compared to existing conditions. However, the water quality strategy at Balgowlah would not achieve the operational water quality design targets for total suspended solids and total phosphorus, while the water quality strategy for the Wakehurst Parkway would not achieve the operational water quality design target for nitrogen. Spill controls and water quality monitoring would be implemented to identify and manage operational impacts on ambient water quality within the receiving waterways.

For locations where stormwater would be discharged (ie Gore Hill Freeway, Balgowlah and Wakehurst Parkway), water quality treatment to meet existing conditions would be provided, at a minimum, such that impacts on surface water quality would be minimal.

Impacts to the baseflow of Quarry Creek and Flat Rock Creek would occur because of groundwater drawdown that occurs due to the project. Provided controls are implemented, maintained and monitored, impacts on downstream receivers would be minimal.

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 17.3.8 and Section 17.3.9 respectively is expected to 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 17-18. No specific measures are required for hydrodynamics during construction given the methodology to be implemented during construction; activities in Middle Harbour (refer to Chapter 6 (Construction work)) and the minimal hydrodynamic impacts expected as a result of the project.

Table 17-18 Environmental management measures – hydrodynamics and water quality

Ref	Phase	Impact	Environmental management measure	Location
WQ1	Design	Stormwater harvesting	The need for a stormwater harvesting water quality basin at Balgowlah will be assessed and determined during further design development. If the stormwater harvesting water quality basin is considered to be required, a suitable alternate location and future use will be determined as part of the dedicated consultation process regarding the final layout of the new and improved public open space and recreation facilities at Balgowlah.	BL (Balgowlah)

Ref	Phase	Impact	Environmental management measure	Location
WQ2	Design	Spill containment	Spill containment controls along surface roads will be confirmed during further design development and determined with consideration of: • The environmental sensitivity of the receiving waterways • The likelihood of vehicle accidents, informed by the annual average daily traffic (AADT) loading along the surface road • Where implementation of controls measures may have a negative impact on other areas of environmental importance, such as biodiversity and heritage.	BL/GHF
WQ3	Design and operation	Local stormwater system capacity	The capacity for the local stormwater system to receive operational wastewater treatment plant discharge will be confirmed during further design development. If 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 motorway facility site.	GHF
WQ4	Design and operation	Burnt Bridge Creek geomorphology	The localised adjustment of Burnt Bridge Creek will be designed with consideration of existing channel conditions and an understanding of existing hydrology to minimise alterations to, and erosion of, the bed and banks. The gradient, sinuosity and channel capacity will be consistent with upstream and downstream sections. The extension to the existing culvert will be designed with a low gradient and scour protection to minimise impacts to geomorphology. Where required, the adjustment will include grade controls and bank stabilisation works to manage anticipated high velocity conditions.	BL

Ref	Phase	Impact	Environmental management measure	Location
WQ5	Design and operation	Water sensitive urban design	Opportunities for water sensitive urban design will be considered during the development of the design for the stormwater management system for the new and upgraded road infrastructure and during development of the urban design and landscape plans. Identified water sensitive urban design features will be implemented where practical and with consideration to best management practice guidelines including Transport for NSW's *Water sensitive urban design guideline* (Roads and Maritime Services, 2017d).	BL/GHF
WQ6	Design and operation	Surface water discharge	Water quality treatment controls for stormwater will meet the design targets, where possible. Where the design targets cannot be met due to site constraints, water quality treatment controls will be provided to meet or improve existing surface water quality.	BL/GHF
WQ7	Design and operation	Connection to Sydney Water stormwater assets	The need for direct connection to Sydney Water stormwater assets will be reviewed during further design development and in consultation with Sydney Water. Where direct connection to a Sydney Water stormwater asset is required, the project will install and operate water treatment devices during operation to achieve the Sydney Water pollutant load reduction targets where feasible and reasonable.	BL/GHF
WQ8	Design and construction	Watercourse geomorphology	The potential for scour and erosion of watercourse bed and banks will be considered during the design of new discharge outlets. Construction work activities within or next to the watercourses and drainage lines will be minimised as much as reasonably practical to minimise disturbance of sediments in or near the waterway.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
WQ9	Design and construction	Local stormwater system capacity	Further design development will confirm the local stormwater system capacity to receive construction wastewater treatment plant inflows. If 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 considered and implemented within the construction support site where feasible and reasonable.	BL/GHF
WQ10	Pre-construction and 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 Western Harbour Tunnel and Warringah Freeway Upgrade project and the completed Northern Beaches Hospital road upgrade project. The program will be developed in consultation with the Environment Protection Authority, Department of Planning, Industry and Environment (Natural Resources Access Regulator), Department of Planning, Industry and Environment (Water), and relevant councils. Sampling locations and monitoring methodology including frequency and indicators will be in accordance with the *Guideline for Construction Water Quality Monitoring* (RTA, 2003a) and ANZG (2018). If exceedances of the criteria established under the freshwater monitoring program are detected, a management response will be triggered and appropriate mitigation measures to address the exceedance will be identified and implemented.	BL

Ref	Phase	Impact	Environmental management measure	Location
WQ11	Construction	Wastewater discharge	Discharges from wastewater treatment plants during the construction phase will be required to meet the following discharge criteria: • The relevant physical and chemical stressors set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000), and • The ANZG (2018) 90 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which will be treated to meet the ANZG (2018) 95 per cent species protection levels, and • The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water).	BL/GHF
WQ12	Construction	Dredge plumes	Monitoring of dredge plumes will be carried out during dredging activities 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 will be implemented, such as adjustments to the dredging process.	BL
WQ13	Construction	Watercourse geomorphology	During construction, the drainage and adjustment works associated with Burnt Bridge Creek and an existing aboveground constructed drainage line within Flat Rock Reserve will be staged to ensure creek flows and velocities are not substantially changed and to avoid downstream erosion and bed and bank stability impacts.	BL/GHF
WQ14	Construction	Sediment basin discharge	Sediment basin discharge impact assessments, commensurate with the potential risk and consistent with the *National Water Quality Guidelines* (ANZG (2018)) and *Managing Urban Stormwater – Soils and Construction, Volume 1* (Landcom, 2004) will be prepared to inform the criteria for discharge from sediment basins.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
WQ15	Construction	Erosion and sedimentation	Disturbed floodplain environments next to the watercourses and/or along overland drainage lines should be stabilised as soon as practical following disturbance.	BL/GHF
WQ16	Construction	Marine water quality	Management measures that will be implemented during dredging activities to minimise impacts on marine water quality, vegetation and habitats will include: • Use of a backhoe dredge with a closed environmental clamshell bucket operated within a localised floating silt curtain enclosure to a depth of two to three metres to dredge the top layer of marine sediments • Implementation of 10 to 12 metre deep-draft silt curtains around the dredge works • Implementation of silt curtains in accordance with environmental management measures B31 to B33.	BL
WQ17	Operation	Wastewater discharge	The Gore Hill Freeway wastewater treatment plant will be designed to treat wastewater generated from tunnel groundwater ingress and rainfall runoff in tunnel portals and the following discharge criteria: • The relevant physical and chemical stressors set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000), and • The ANZG (2018) 95 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 99 per cent species protection levels, and • The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water).	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
WQ18	Operation	Operational monitoring	Operational phase monitoring of surface water quality of sensitive receiving environments will be described in the operational surface water quality monitoring program and carried out in line with the post construction phase requirements of the *Roads and Maritime Guideline for Construction Water Quality Monitoring* (RTA, 2003a). As a minimum, monthly monitoring will be carried out for the first year of operation or until a suitably qualified and experienced independent expert determines that a site has adequately stabilised and stormwater basin discharge criteria are achieved. Should discharge criteria from operational stormwater basins be exceeded, a management response will be triggered and appropriate mitigation measures to address the exceedance will be identified and implemented.	BL/GHF

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