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New M5

Environmental Impact Statement

Technical working paper: Surface water

Appendix N

November 2015

WestConnex

WestConnex The New M5

Technical Working Paper - Surface Water

Client: Roads and Maritime Services

ABN: 76 236 371 088

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Glossary of terms and acronyms

Term	Meaning
Acid Sulfate Soils (ASS)	Naturally acid clays, mud and other sediments usually found in swamps and estuaries. They may become acidic when drained and exposed to oxygen and may produce acidic leachate run-off that can pollute waters and liberate toxins.
AEP	Annual exceedance probability. The probability of a rainfall or flood event exceeding a nominated level in a year. For example, a one per cent AEP is the probability of an event exceeding a nominated level in 100 years.
Afflux	An increase in water level resulting from obstacles in the flow path.
AHD	Australian Height Datum. The standard reference level used to express the relative height of various features. A height given in metres AHD is the height above sea level. Mean sea level is set as zero metres elevation.
Alluvial	Relating to, consisting of, or formed by sediment deposited by flowing water.
Alluvial material (alluvium)	Relatively recent deposits of sedimentary material within river / creek beds, floodplains, lakes or at the base of mountain slopes.
ANZECC	Australian and New Zealand Environment and Conservation Council.
Aquatic ecology	Flora and fauna that live in or on water for all or a substantial part of the life span (generally restricted to fresh / inland waters).
Aquifer	Underground layer of water-bearing permeable rock or unconsolidated material (such as gravel, sand, or silt) from which groundwater can be usefully extracted.
AR&R	Australian Rainfall & Runoff.
ARI	Average Recurrence Interval. Used to describe the frequency or probability of flood occurring. (eg a 100 year ARI flood is a flood that occurs or is exceeded on average once every 100 years (100:1)).
As	Arsenic
Batter	The constructed side slope of road embankments and cuttings usually expressed as a ratio of horizontal distance to a vertical height value of one e.g. 2H: 1V. A fill batter is where the road is above the existing surface on a filled embankment and refers to the sloping sides of the embankment. A cut batter is where the road is below the existing surface.
BBWQIP	Botany Bay Water Quality Improvement Program.
Bedrock	Rock of a substantial thickness and extent underlying a relatively soft and variable surface.
Biota	All organisms in a given area (including flora and fauna), considered as a unit.
BOD	Biological Oxygen Demand.
BoM	Bureau of Meteorology.
Box culvert	A culvert of rectangular cross section.
Bund	A small embankment designed to retain water.
Cd	Cadmium.
CEMP	Construction environmental management plan.
Chl-a	Chlorophyll-a.
CMA	Catchment Management Authority.
Confluence	A point at which streams combine.
Construction footprint	The area required to construct the project, including underground components, above ground components and temporary ancillary construction facilities.
Cr	Chromium.

Term	Meaning
CRSMP	Cooks River Stormwater Management Plan.
Cu	Copper.
Culvert	An enclosed channel for conveying water below a road.
Cumulative impacts	Impacts that, when considered together, have different and / or more substantial impacts than a single impact considered alone.
D&C	Design and Construction
DAF	Dissolved Air Floatation.
DEC	(NSW) Department of Environment and Conservation (now OEH and the EPA).
DECC	(NSW) Department of Environment and Climate Change (now OEH and EPA).
DECCW	(NSW) Department of Environment, Climate Change and Water (now OEH and the EPA).
Detailed design	The phase of the project following concept design where the design is refined, and plans, specifications and estimates are produced. These typically include two dimensional and three dimensional models.
Dewatering	The removal of water from solid material or soil by wet classification, centrifugation, filtration or similar solid-liquid separation processes.
Discharge	The volumetric rate of water flow.
DLWC	(NSW) Department of Land and Water Conservation (now part of DPI).
DO	Dissolved Oxygen.
DoP	(NSW) Department of Planning (now Department of Planning and Environment).
DP&E	(NSW) Department of Planning and Environment.
DP&I	(NSW) Department of Planning and Infrastructure (now Department of Planning and Environment).
DPI	(NSW) Department of Primary Industries.
DPI (Water)	(NSW) Department of Primary Industries (Water), formerly the NSW Office of Water
DPWS	(NSW) Department of Public Works and Services
Drainage	Natural or artificial means for the interception and removal of surface or subsurface water.
DRAINS	A stormwater drainage system design and analysis program for estimating water flows. It is a successor to the ILSAX program which has been widely used for urban stormwater system design and analysis.
Earthworks	All operations involved in loosening, excavating, placing, shaping and compacting soil or rock.
Eastern Portal	Land around the eastern end of the project, where the main alignment tunnels and on and off ramps connect with the surface, generally bounded by the Princes Highway, Campbell Road, Burrows Road and Canal Road with the actual location also to be determined during the design phase.
EC	Electrical Conductivity.
Ecosystem	A functional unit of energy transfer and nutrient cycling in a given place. It includes all relationships within the biotic community and between the biotic components of the system.
EIS	Environmental Impact Statement.
Embankment	An earthen structure where the road (or other infrastructure) subgrade level is above the natural surface.
Environmental assessment (process)	A specialised part of the decision-making process, where the environmental impact of a development or proposal or activity is considered in detail, together with other aspects of the development.

Term	Meaning
EP&A Act	Environmental Planning and Assessment Act 1979 (NSW).
EP&A Regulation	Environmental Planning and Assessment Regulation 2000 (NSW).
EPA	(NSW) Environment Protection Authority.
EPBC Act	(Commonwealth) Environment Protection and Biodiversity Conservation Act 1999.
Ephemeral creek	A creek that only exists for a short duration of time following rainfall.
EPL	Environment Protection Licence under the (NSW) Protection of the Environment Operations Act 1997.
Erosion	A natural process where wind or water detaches a soil particle and provides energy to move the particle.
ESCP	Erosion and Sedimentation Control Plan.
Fill	The material placed in an embankment.
Flood Immunity	Relates to the level at which a particular structure would be clear of a certain flood event.
FM Act	(NSW) Fisheries Management Act 1994.
Footprint	The extent of direct impact that a development makes on the land.
FRP	Filterable Reactive Phosphorus.
Geomorphology	The study of shaping of the landscape by water, wind and other processes. Commonly used to describe the condition of streams as they are shaped by erosion and / or accretion of sediments.
GIS	Geographical Information System.
GPT	Gross pollutant trap.
Grade	Rate of longitudinal rise (or fall) with respect to the horizontal expressed as a percentage or ratio.
Groundwater	Water that is held in the rocks and soil beneath the earth's surface.
GWTP	Groundwater treatment plant.
ha	Hectare(s).
Habitat	The place where a species, population or ecological community lives (whether permanently, periodically or occasionally). Habitats are measurable and can be described by their flora and physical components.
HEC-RAS	A computer program that models the hydraulics of water flow through natural rivers and other channels. The program is one-dimensional, meaning that there is no direct modelling of the hydraulic effect of cross section shape changes, bends, and other two- and three-dimensional aspects of flow.
Hydrology	The study of rainfall and surface water runoff processes.
ID	Insufficient Data.
IFD	Intensity-Frequency-Duration.
IPCC	Intergovernmental Panel on Climate Change.
LGA	Local Government Area.
LiDAR	Light Detection and Ranging.
LLS	Local Land Services.
MHL	Manly Hydraulics Laboratory.
MUSIC	Model for Urban Stormwater Improvement Conceptualisation – predicts the performance of stormwater quality management systems. It is intended to help organisations plan and

Term	Meaning
	design (at a conceptual level) appropriate urban stormwater management systems for their catchment.
Ni	Nickel.
NOW	NSW Office of Water, now DPI (Water).
NOx	Oxides of nitrogen.
NSW	New South Wales.
OEH	(NSW) Office of Environment and Heritage.
Operation footprint	The area required to accommodate the permanent features of the project, including underground components, above ground components and ancillary facilities associated with motorway operations.
Pavement	The portion of a carriageway placed above the subgrade for the support of, and to form a running surface for vehicular traffic.
Pb	Lead.
pH	A measure of acidity or alkalinity of a solution, numerically equal to 7 for neutral solution, increasing with increasing alkalinity and decreasing with increasing acidity.
PMF	Probable Maximum Flood.
Pollutant	Any measured concentration of solid or liquid matter that is not naturally present in the environment.
Portal	Where a tunnel emerges to the surface, being the entrance or exit of the main alignment tunnels, off-ramps or on-ramps.
PPK	PPK Environment and Infrastructure Services.
(The) project	The WestConnex New M5 project.
Project corridor	Forms the basis for the assessment within this document.
Proprietary stormwater treatment device	Pre-fabricated device designed for removal of pollutants from stormwater. These are usually installed underground and connected to the pipe drainage network.
RCBC	Reinforced concrete box culvert.
RCC	Rockdale City Council.
Remnant native vegetation	Small patches of native vegetation that remain after land use changes to the surrounding area.
RESA	Runway End Safety Area.
Revegetation	To revegetate an area by direct seeding with non-native species or cover crops and / or native species using manual or mechanical means such as hydromulching, straw mulching and tractor seeding.
Riffle	A rocky or shallow part of a waterway where the water flows brokenly.
Riparian	The part of the landscape adjoining rivers and streams that has a direct influence on the water and aquatic ecosystems within them.
Runoff	The part of the rainfall on a catchment which flows as surface discharge past a specified point.
Scour	The erosion of material by the action of flowing water.
SEARs	Secretary's Environmental Assessment Requirements. Requirements and specifications for an environmental assessment prepared by the Secretary for the Department of Planning and Environment under section 75F of the *Environmental Planning and Assessment Act 1979*.

Term	Meaning
Sediment	Material, both mineral and organic, that is being or has been moved from its site of origin by the action of wind, water or gravity and comes to rest either above or below water level.
Sedimentation	Deposition of sediment usually by water.
Sedimentation basins	A stormwater detention system that promotes the settling of sediments trough the reduction of flow velocities and temporary detention. Key elements include purpose designed inlet and outlet structures, settling pond and high flow, overflow structures.
Shotcrete	Concrete applied to a surface through a pressure hose.
SMCMA	Sydney Metropolitan Catchment Management Authority.
SMP	Spoil Management Plan
St Peters interchange	Would initially provide road connections from the new tunnels to Campbell Road and Euston Road, St Peters and Gardeners Road, Mascot
Stockpile	Temporarily stored materials such as soil, sand, gravel and spoil / waste.
Strahler stream ordering process	A stream classification system where waterways are given an ‘order’ according to the number of additional tributaries associated with each waterway. This is used as a measure of system complexity and therefore the potential for fish habitat to be present. Flow paths at the top of a catchment are assigned the number one.
Stratum	A layer of rock in the ground.
Surface road widening works	Located between the M5 East Motorway, east of King Georges Road and the new tunnel portals.
Surface water	Water flowing or held in streams, rivers and other wetlands in the Landscape.
Swale	A shallow, grass-lined drainage channel.
SWMP	Stormwater Management Plan.
SWSOOS	South Western Suburbs Ocean Outfall System.
Terrestrial	Living or growing on land (i.e. terrestrial flora or fauna).
Thalweg	The lowest point along the length of a stream bed.
Threatened	As defined under the *Threatened Species Conservation Act 1994*, a species, population or ecological community that is likely to become extinct or is in immediate danger of extinction.
TKN	Total Kjeldahl Nitrogen.
TN	Total Nitrogen.
Training walls	Artificial embankments or walls used to direct the course of a waterway.
TP	Total Phosphorus.
Transverse Drainage	Existing drainage lines (typically) that cross linear infrastructure such as roads. Synonym: cross drainage
Tributary	A river or stream flowing into a larger river or lake.
TSS	Total Suspended Solids.
TUFLOW	A 1D / 2D finite difference numerical model that simulates hydrodynamic behaviour in rivers, floodplain and urban drainage environments.
TURB	Turbidity.
Turbidity	A measure of light penetration through a water column containing particles of matter in suspension.
UoQ	University of Queensland.
Urban design	The process and product of designing human settlements, and their supporting infrastructure, in urban and rural environments.

Term	Meaning
Waterway	Any flowing stream of water, whether natural or artificially regulated (not necessarily permanent).
WBNM	A flood hydrograph model that calculates flood runoff from rainfall hyetographs.
WDA	WestConnex Delivery Authority. On 1 October 2015, the transfer of the project delivery functions of WDA to Sydney Motorway Corporation (SMC) was finalised, forming a single decision-making entity to finance and deliver the WestConnex program of works.
Western Portal	Land around the western end of the project, where the main alignment tunnels and on and off ramps connect with the surface. Located east of King Georges Road and west of Bexley Road.
Wetland	Wetlands are areas of land that are wet by surface water or groundwater, or both, for long enough periods that the plants and animals in them are adapted to, and depend on, moist conditions for at least part of their lifecycle. They include areas that are inundated cyclically, intermittently or permanently with fresh, brackish or saline water, which is generally still or slow moving except in distributary channels such as tidal creeks which may have higher peak flows. Wetlands may be constructed for the purposes of removing pollutants from runoff.
WQIP	Water Quality Improvement Plan.
WSUD	Water sensitive urban design.
WTP	Water treatment plant.
XP-RAFTS	A runoff routing model that is used for hydrologic and hydraulic analysis of stormwater drainage and conveyance systems.
Zn	Zinc.
μS/cm	Microsiemens per centimetre (a measure of electrical conductivity).

Executive summary

NSW Roads and Maritime Services (Roads and Maritime) is seeking approval to construct and operate the New M5 (the project), which would comprise a new, tolled multi-lane road link between the existing M5 East Motorway, east of King Georges Road, and St Peters. The project would also include an interchange at St Peters and connections to the existing road network.

This technical working paper presents the assessment of the potential impacts of the project during construction and operation on surface water, including localised flooding and drainage, water quality and geomorphology. This technical working paper also assesses mainstream flooding impacts during construction. An assessment of mainstream flooding impacts during operation is presented in Technical Working Paper: Flooding (Lyall and Associates, 2015).

The project is located within the Cooks River catchment and the sub-catchments of Alexandra Canal, Wolli Creek, Eastern Channel, all of which are located within the greater Botany Bay catchment. The catchments are highly urbanised and extensively altered. The water quality in the three main watercourses (Wolli Creek, Cooks River and Alexandra Canal) has been found to representative of the water quality expected in highly urbanised catchments.

Construction

During construction, the potential impacts on surface water would be associated with:

- Erosion of soils, sedimentation of waterways and exposure of contaminated soils and Acid sulfate soils (ASS)
- Accidental leaks or spills of chemicals, fuels and oils from construction plant
- Direct disturbance of waterway beds and riparian areas, or increase scour due to increased discharge flows and volumes
- Discharge of treated water to waterways during construction, which could have an impact on water quality and/or geomorphology of receiving waterways.

The potential impacts on surface water quality during construction of the project are considered minor and manageable with the application of standard mitigation measures. The Construction Environmental Management Plan (CEMP) would control potential surface water quality impacts during construction. Construction water treatment plants would be established during the construction phase to treat water to a quality that would comply with ANZECC Water Quality Guidelines (ANZECC, 2000) – trigger values derived from a local reference data set.

Discharges of treated construction water would not have an impact the geomorphology of those waterways for due to the location of discharge and the relatively low level of discharges compared to existing flows. Specific localised mitigation measures are proposed where outlet scour protection and energy dissipation is required prior to releasing water into local creeks / waterways.

A qualitative construction phase flooding impact assessment was made based on proposed locations of surface works and activities. Potential mainstream flooding impacts are generally minor in nature and readily mitigated by adjusting specific aspects of the compound designs and site planning to better suit identified flooding conditions and avoid the potential for off-site flooding impacts.

All construction works would also have the potential to impact local overland flows and existing minor drainage paths. These would require consideration during future detailed design and construction planning, along with mitigation measures.

Operation

Operation of the project has the potential to impact surface water quality due to increased runoff and associated pollutant loads from roads. This could be caused by increases in impervious surfaces, spills or leaks of fuels and / or oils from vehicle accidents, or from operational plant and equipment, discharges of treated groundwater and other waste waters (such as tunnel wash or deluge system water).

Operational water treatment would be designed with consideration to the pollutant reduction targets of the Botany Bay and Catchment Water Quality Improvement Plan (SMCMA, 2011). The pollutant loads associated with increases in imperviousness would be managed through a range of stormwater treatment measures such as gross pollutant traps, constructed wetlands, bioretention systems, water quality basins and proprietary treatment devices. These would designed with consideration to the pollutant reduction targets of the Botany Bay and Catchment Water Quality Improvement Plan (SMCMA, 2011).

Current provisions are sufficient to meet the treatment targets for most catchments, and stormwater treatment in some catchments exceeds the treatment requirements, such that the project overall would result in less pollutants being delivered to Botany Bay. The final design would be would be confirmed during detailed design.

New stormwater outlets would be built to discharge into Alexandra Canal. These have the potential to scour the in-situ contaminated sediments, leading to poor water quality. Stormwater drainage discharge at the canal would be designed with sufficient energy dissipation or scour protection to minimise the potential for scour and suspension of sediments.

A water treatment plant would be permanently established at the Arncliffe motorway operations complex to treat groundwater inflows into the tunnels as well as discharges collected via the tunnel drainage system and sump. Treated water would be discharged at a rate of up to 20 litres per second into the Cooks River downstream from Marsh Street Bridge. The requirements for quality of the water produced by the treatment plant would be the same as for the construction phase, which would ensure that the project would not have an impact on existing water quality. Discharge volumes would also result in an insignificant increase in baseflows and as such, impacts to geomorphology are unlikely.

Conclusion

Construction and operation of the project has the potential to impact on surface water features (waterways, drainage channels and Botany Bay) as a result of altered hydrology and soil management within the catchment, as well as the discharge of treated groundwater. The implementation of mitigation measures would reduce or address these impacts to a level such that conditions are no worse than the existing situation.

1.0 Introduction

NSW Roads and Maritime Services (Roads and Maritime) is seeking approval to construct and operate the New M5 (the project), which would comprise a new, tolled multi-lane road link between the existing M5 East Motorway, east of King Georges Road, and St Peters. The project would also include an interchange at St Peters and connections to the existing road network. The project is shown in Figure 1.

Approval is being sought under Part 5.1 of the Environmental Planning and Assessment Act 1979 (EP&A Act). The project is declared to be State significant infrastructure (SSI) under section 115U(2) of the EP&A Act by reason of the operation of clause 14 and Schedule 3 of the *State Environmental Planning Policy (State and Regional Development) 2011*. Accordingly, the project is subject to assessment under Part 5.1 of the EP&A Act and requires the approval of the Minister for Planning. An environmental impact statement (EIS) is therefore also required.

Roads and Maritime is seeking the project to be declared by the Minister for Planning as State significant infrastructure and critical State significant infrastructure under sections 115U(4) and 115V of the EP&A Act.

On 11 August 2015, the Commonwealth Minister for the Environment determined that the project has the potential to significantly impact on a matter of national environmental significance and is therefore a 'controlled action'. This means that approval of the project will be required from the Commonwealth Minister for the Environment in addition to environmental and planning approvals required under State legislation.

Under the Bilateral Agreement relating to environmental assessment (February 2015) between the Commonwealth Government and the NSW Government, this EIS has been adopted for the purpose of meeting the assessment requirements of both the Commonwealth EPBC Act and the NSW EP&A Act.

This technical working paper provides a surface water impact assessment of the project, specifically in relation to impacts during construction and operation on localised flooding and drainage, water quality and geomorphology.

This report also assesses mainstream flooding impacts during construction. The assessment of mainstream flooding impacts during operation is presented in the Technical Working Paper: Flooding (Lyall and Associates, 2015).

1.1 Overview of WestConnex

WestConnex is a 33 kilometre motorway that is intended to link Sydney's west with the airport and the Port Botany precinct. The component projects of the WestConnex program of works are:

- M4 Widening – Pitt Street, Parramatta to Homebush Bay Drive, Homebush (planning approval granted on 21 December 2014 and under construction)
- M4 East – Homebush Bay Drive, Homebush to Parramatta Road and City West Link (Wattle Street) at Haberfield (planning application lodged and subject to planning approval)
- New M5 – (the subject of this EIS)
- King Georges Road Interchange Upgrade (planning approval granted on 3 March 2015 and under construction)
- M4-M5 Link – Haberfield to St Peters (undergoing concept development and subject to planning approval)
- Sydney Gateway (is the subject of further investigations by the NSW Government and would be subject to separate planning approval).

Separate planning applications have or will be lodged for each component project. Each project will be assessed separately, but the impact of each project will also be considered in the context of the wider WestConnex program of works.

A proposed Southern extension from Arncliffe to Kogarah is currently being investigated by the NSW Government, and would connect the New M5 to the southern and bayside suburbs of Sydney, and the proposed F6 motorway.

The WestConnex Delivery Authority (WDA) was established by the NSW Government to manage the delivery of the WestConnex series of projects for Roads and Maritime on behalf of the State. The WDA was a public subsidiary corporation of the Roads and Maritime. Following the achievement of early milestones for the

WestConnex program of works, the NSW Government took the opportunity to evolve this early governance model.

On 1 October 2015 the transfer of the project delivery functions of WDA to Sydney Motorway Corporation (SMC) was finalised, forming a single decision-making entity to finance and deliver the WestConnex program of works. SMC is a private corporation, the shareholders of which are the Minister for Roads, Maritime and Freight and the Treasurer, with a majority independent board of nine directors.

Roads and Maritime is the Government client agency for the WestConnex program of works. In that capacity Roads and Maritime will enter into contractual arrangements with SMC subsidiary entities which will design, build, own and operate the motorway on behalf of Roads and Maritime. Roads and Maritime and SMC are working together to manage the planning approval process for the project. However, for the purpose of the planning application for the project, Roads and Maritime is the proponent.

1.2 Overview of the project

Key components of the project would include:

- Twin motorway tunnels between the existing M5 East Motorway (between King Georges Road and Bexley Road) and St Peters. The western portals along the M5 East Motorway would be located east of King Georges Road, and the eastern portals at St Peters would be located in the vicinity of the Princes Highway and Canal Road. Each tunnel would be about nine kilometres in length and would be configured as follows:
  - Between the western portals and Arncliffe, the tunnels would be built to be three lanes but marked for two lanes as part of the project. Any change from two lanes to three lanes would be subject to future environmental assessment and approval
  - Between the Arncliffe and St Peters, the tunnels would be built to be five lanes but marked for two lanes as part of the project. Any change from two lanes to any of three, four or five lanes would be subject to future environmental assessment and approval
- The western portals along the M5 East Motorway would be located east of King Georges Road, and the eastern portals at St Peters would be located in the vicinity of the Princes Highway and Canal Road
- Tunnel stubs to allow for a potential future connection to the future M4-M5 Link and a potential future connection to southern Sydney
- Surface road widening works along the M5 East Motorway between east of King Georges Road and the new tunnel portals
- A new road interchange at St Peters, which would initially provide road connections from the main alignment tunnels to Campbell Road and Euston Road, St Peters
- Two new road bridges across Alexandra Canal which would connect St Peters interchange with Gardeners Road and Bourke Road, Mascot
- Closure and remediation of the Alexandria Landfill site, to enable the construction and operation of the new St Peters interchange
- Works to enhance and upgrade local roads near the St Peters interchange
- Ancillary infrastructure and operational facilities for electronic tolling, signage (including electronic signage), ventilation structures and systems, fire and life safety systems, and emergency evacuation and smoke extraction infrastructure
- A motorway control centre that would include operation and maintenance facilities
- New service utilities and modifications to existing service utilities
- Temporary construction facilities and temporary works to facilitate the construction of the project
- Infrastructure to introduce tolling on the existing M5 East Motorway
- Surface road upgrade works within the corridor of the M5 East Motorway.

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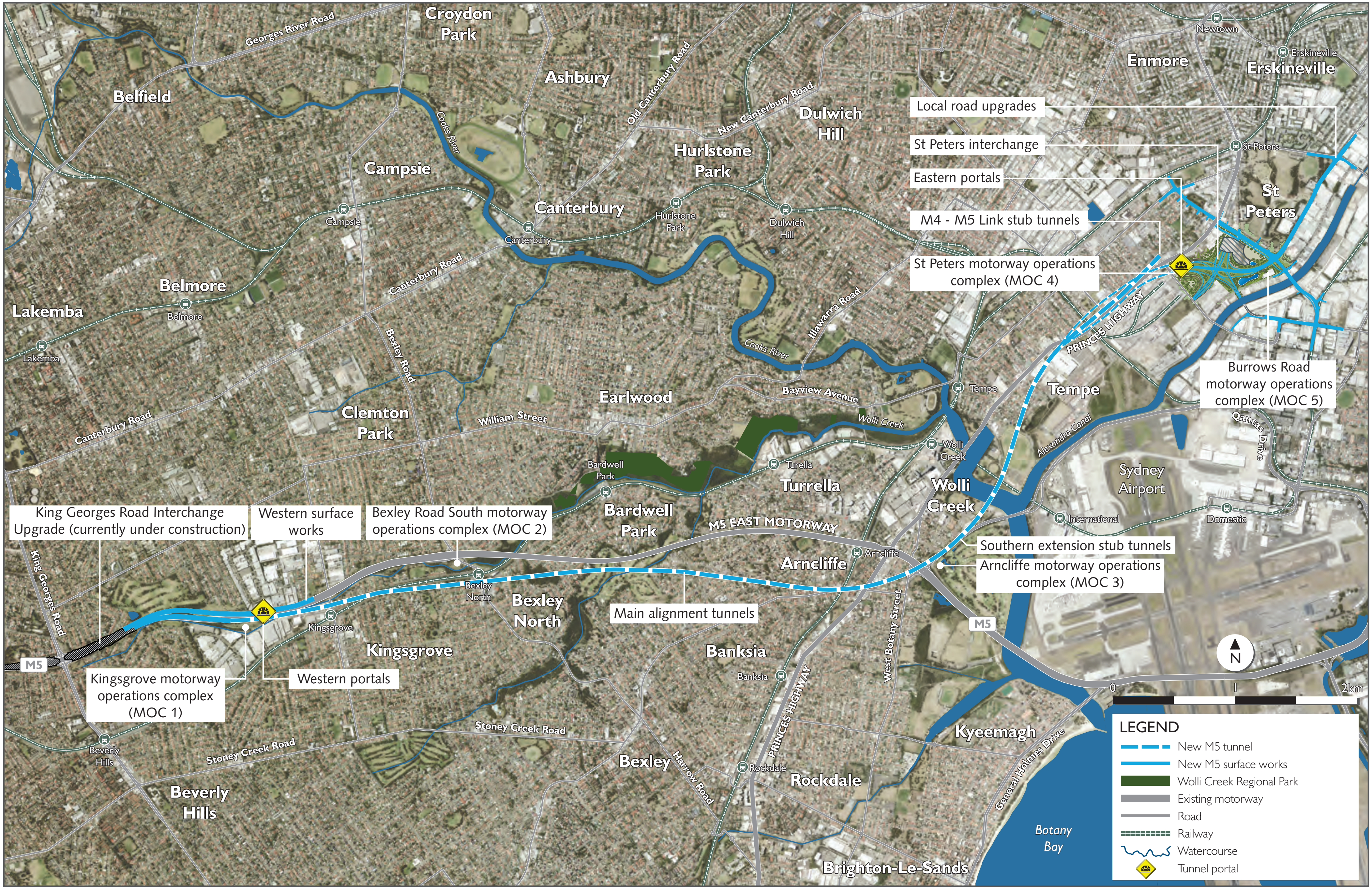

Figure 1 The project

Construction activities associated with the project would generally include:

- Commencement of enabling and temporary works, including construction power, water supply, ancillary site establishment, demolition works, property and utility adjustments and public transport modifications (if required)
- Construction of the road tunnels, interchanges, intersections and roadside infrastructure
- Haulage of spoil generated during tunnelling and excavation activities
- Fitout of the road tunnels and support infrastructure, including ventilation and emergency response systems
- Construction and fitout of the motorway control centre and ancillary operations buildings
- Upgrades to surface roads and construction of bridges
- Implementation of environmental management and pollution control facilities for the project.

Subject to the project obtaining environmental planning approval, construction of the project is anticipated to commence around mid-2016 and is expected to take around three years to complete.

The M5 Motorway corridor (the M5 East Motorway and the M5 South West Motorway) is the main passenger, commercial and freight corridor between Port Botany, Sydney Airport and south-west Sydney. Traffic demands on the M5 East Motorway currently exceed the design capacity of the roadway, and as a result, present a significant bottleneck to the M5 Motorway corridor with motorists experiencing heavy congestion and unreliable journey times. The project is needed to provide additional capacity along the M5 Motorway corridor, and would allow for a more robust and reliable transport network

1.3 Project location

The project would be located within the Canterbury, Hurstville, Rockdale, Marrickville, Sydney and Botany Bay local government areas. The project corridor is located from about five to twenty kilometres to the south and south-west of the central business district of Sydney. The project would traverse the suburbs of Beverly Hills, Kingsgrove, Bexley North, Earlwood, Bardwell Park, Bardwell Valley, Arncliffe, Wolli Creek, Tempe, Sydenham, St Peters, Alexandria and Mascot.

1.4 Secretary’s Environmental Assessment Requirements (SEARs)

In preparing this Technical Working Paper: Surface water, the Secretary’s Environmental Assessment Requirements (SEARs) issued for the New M5 Project on 5 March 2015, and re-issued on 26 August 2015 have been addressed. The key matters raised by the Secretary for consideration in the Technical Working Paper: Surface Water and where this report addresses the SEARs are outlined in Table 1.

Table 1 SEARs applicable to the Technical Report: Surface Water

Secretary's Environmental Assessment Requirements		Section addressed
Direct requirements		
Soil, water and hydrology	An assessment of construction and operational erosion and sediment and water quality discharge impacts, taking into account impacts from treated discharge, accidents and runoff (i.e. acute and chronic impacts), having consideration to impacts to surface water runoff, soil erosion and sediment transport, mass movement, salinity and iron levels. The assessment must include identification and estimation of the quality and quantity of pollutants that may be introduced into any waterways by source and discharge point;	For construction, refer to Section 6.2.2 For operational impacts refer to Section 7.2.2
	An assessment of water quality impacts on receiving waterways likely to be affected by the proposal (including Wolli, Cup and Saucer Creeks, Cooks River and Alexandra Canal). The assessment must include existing water quality, geomorphology, riparian vegetation and rehabilitation of riparian land, and have reference to the NSW Water Quality Objectives and relevant public health and environmental water quality trigger values and criteria, including those specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000), any applicable regional, local or site-specific guidelines and any licensing requirements.	For construction, refer to Section 6.2.2 For operation, refer to Section 7.2.2
	An assessment of groundwater impacts (including ancillary facilities such as the tunnel control centre and any deluge systems), considering local impacts along the length of the tunnels and impacts on local and regional hydrology including consideration of any Water Sharing Plan and impacts on groundwater flow. The assessment must consider: extent of drawdown; impacts to groundwater quality; volume of groundwater that will be taken (including inflows); discharge requirements; location and details of groundwater management and implications for groundwater-dependent surface flows, groundwater-dependent ecological communities, and groundwater users. The assessment must include details of proposed surface and groundwater monitoring and be prepared having consideration to the requirements of the NSW Aquifer Interference Policy;	For construction, refer to Section 6.2.2 and 6.4 For operation, refer to Section 6.4 and Section 7.4 For groundwater impacts, refer to Technical Working Paper: Groundwater (AECOM, 2015)
	Identification of potential impacts of the proposal on existing flood regimes, consistent with the Floodplain Development Manual (NSW Government, 2005), including impacts to existing receivers and infrastructure and the future flood mitigation options for and development potential of affected land, demonstrating consideration of the changes to rainfall frequency and / or intensity as a result of climate change on the proposal. The assessment must demonstrate due consideration of flood risks during construction and in the proposal design.	For construction, refer to Section 6.2 For operation, refer to Technical Working Paper: Flooding (Lyall and Associates, 2015)
	Identifying potential impacts of the development on acid sulfate soils in accordance with the relevant guidelines and a description of the mitigation measures proposed to minimise potential impacts.	Technical Working Paper: Contamination (AECOM, 2015)
Links with requirements directly dealt elsewhere within the EIS		
Biodiversity	An assessment of the potential ecological impacts of the proposal, with specific reference to vegetation and habitat clearing, connectivity, edge effects, weed dispersal, riparian and aquatic habitat impacts, soil and water quality impacts and operational impacts.	Technical Working Paper : Biodiversity (Eco Logical Australia, 2015)

Secretary's Environmental Assessment Requirements		Section addressed
	Where there are potential impacts to the OEH estate reserved under the *National Parks and Wildlife Act 1974* or where the proposal is located upstream of OEH estate, an assessment of the matters to be considered outlined in the *Guidelines for Developments Adjoining Land and Water Managed by DECCW* (DECCW, 2010).	Technical Working Paper : Biodiversity (Eco Logical Australia, 2015) Chapter 13 (Land Use and property) of the EIS
Land use, social and economic	Potential impacts on utilities (including communications, electricity, gas, and water and sewerage) and the relocation of these utilities.	Chapter 13 (Land Use and property) of the EIS
Contaminated sites	An assessment of the potential disturbance of contaminated bed sediments in the Alexandra Canal, and interception of contaminated water from the Botany Sand Beds aquifer.	Technical Working Paper: Contamination (AECOM, 2015) and Technical Working Paper: Groundwater (AECOM, 2015)

This technical working paper describes the physical environment within the study area in relation to surface water, including details of the existing catchments, watercourses, sensitive receiving environments, drainage, and flooding. It identifies and assesses the potential surface water impacts related to the construction and operation of the project, including impacts to hydrology, water quality and geomorphology. This technical working paper also details the extent of impacts on surface water features associated with the discharge of treated groundwater to waterways.

Guided by the SEARs, the key objectives of the surface water assessment were to:

- Identify potential impacts on flooding (during construction), surface water flows, water quality, geomorphology, riparian vegetation and rehabilitation of riparian land associated with construction and operation of the project, with reference to relevant guidelines *NSW Water Quality and River Flow Objectives* (DECCW, 2006).
- Identify environmental management measures that would be required to manage the identified impacts.
- Inform the future detailed design of the project with respect to surface water flows and quality.

1.5 Study area

The interaction of the project with the surface water environment would include use, treatment and discharge of water (including increased runoff from road surfaces and the discharge of groundwater inflows) and activities within various catchments and subcatchments.

All project activities, including surface water discharges, would lie within the Cooks River catchment. Tributary catchments (known as sub-catchments) of the Cooks River within the surface water study area include Wolli Creek, Alexandra Canal and Eastern Channel catchments as shown on Figure 3 and Figure 4.

The study area was determined based on the location of the surface construction and operational footprints for the project as well as areas where potential impacts could occur as a result of construction or operation of the project. The following catchments and subcatchments are identified across the project area:

- Wolli Creek – from upstream of the project boundary, near King Georges Road, to its confluence with the Cooks River. The parts of the project within this catchment is the western portals, widened and connecting roads between the portals and King Georges Road Interchange, and supporting ventilation facilities
- Cooks River – from the Bayview Avenue Bridge, Tempe to Botany Bay. This bridge is around 1.5 kilometres upstream of the Arncliffe surface works (within Kogarah Golf Course) and there would be no impact on the water quality, geomorphology or hydrology upstream of this point. The entire project lies within this catchment
- Alexandra Canal – The parts of the project within this catchment include a portion of the Local Road Upgrades and the St Peters interchange
- Eastern Channel – The parts of the project within this catchment include a portion of the Local Road Upgrade.

The SEARs included a requirement to assess the potential impacts on Cup and Saucer Creek, which is within the Cooks River catchment. The study area excludes Cup and Saucer Creek as the project would not discharge to Cup and Saucer Creek and would not have any impacts on its hydrology, water quality or geomorphology.

1.6 Report structure

This technical working paper is structured as follows:

- **Chapter 1** – Introduction. This chapter outlines the project and presents the purpose of this report.
- **Chapter 2** – Statutory and policy context. This chapter lists the various governing publication that guide surface water impact for the project.
- **Chapter 3** – Methodology. This chapter describes the methodology employed for the Technical Working Paper – Surface water impact assessment.
- **Chapter 4** – Existing environment. This chapter describes the surface water study area and its existing surface water conditions.
- **Chapter 5** – The project. This chapter provides a summary of potential impacts the project could have on the surface water environment.
- **Chapter 6** – Impact assessment (construction). This chapter describes the potential impacts to surface water resulting from the project.
- **Chapter 7** – Impact assessment (operation). This chapter describes the potential impacts to surface water resulting from the project.
- **Chapter 8** – Mitigation and management. This chapter provides a summary of environmental mitigation, management and monitoring responsibilities in relation surface water management for the project.
- **Chapter 9** – Conclusion.
- **Chapter 10** – References.
- **Appendix A** – Water quality reference criteria.
- **Appendix B** – Water quality monitoring program.

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2.0 Statutory and policy context

This chapter details the key policies and guidelines applicable to surface water management in NSW which have been considered in this assessment.

2.1 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARNCANZ, 2000)

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARNCANZ, 2000), (commonly referred to as the 'ANZECC Water Quality Guidelines') form part of the National Water Quality Management Strategy and list a range of environmental values for water bodies. Different water quality criteria are set for the water bodies based on environmental values assigned to that water body. These values include consideration as to whether the water is to be used for drinking, recreation or according to ecological values. The ANZECC Water Quality Guidelines provide water quality criteria (scientifically-based benchmark values) for a wide range of parameters for each of these values. The ANZECC Water Quality Guidelines state that "*The Guidelines are not intended to be used as mandatory standards because there is significant uncertainty associated with the derivation and application of water quality guidelines*" (Chapter 1: Introduction). However the guidelines provide a useful measure of risks to aquatic ecosystem health.

The ANZECC Water Quality Guidelines are ambient water quality guidelines, appropriate for the assessment of the existing water quality of watercourses in proximity to the project as discussed in Section 7.2.3. The ANZECC Water Quality Guidelines criteria would also be used in future monitoring of ambient conditions (baseflow) of the downstream waterways to identify appropriate criteria for the ongoing compliance.

2.2 NSW Water Quality and River Flow Objectives

The *NSW Water Quality and River Flow Objectives* (DECCW, 2006) are consistent with the agreed national framework of the ANZECC Water Quality Guidelines and are "*primarily aimed at maintaining and improving water quality, for the purposes of supporting aquatic ecosystems, recreation and where applicable water supply and the production of aquatic foods suitable for consumption and aquaculture activities*" (DECCW, 2006).

The *NSW Water Quality and River Flow Objectives* have been developed for the Cooks River catchment. The water quality and river flow objectives that were determined are shown in Table 2.

Table 2 NSW water quality and river flow objectives

Objective	Where covered in this paper
Water quality objectives	
Protect aquatic ecosystems	Technical Working Paper : Biodiversity (Ecological Australia, 2015)
Protect visual amenity	Section 7.3
Protect irrigation water supply	n/a – no agriculture in surface water study area
River flow objectives	
Maintain natural flow variability	Section 7.2
Maintain natural rates of change in water levels	Section 7.2
Minimise effects of weirs and other structures	Section 7.2

2.3 Managing Urban Stormwater – Soils and Construction

The Managing Urban Stormwater (MUS) – Soils and Construction series of handbooks are an element of the NSW Government's urban stormwater program specifically applicable to the construction phase of developments. These are aimed at providing guidance for managing soils in a manner that protects the health, ecology and amenity of urban streams, rivers estuaries and beaches through better management of stormwater quality.

The MUS handbooks were produced to provide guidelines, principles, and recommended minimum design standards for good management practice in erosion and sediment control during the construction of roads. Of particular relevance to the project are Volume 1, 4th Edition (Landcom, 2004) (commonly known as The Blue Book 1) and Volume 2D, Main Road Construction (DECC, 2008) (commonly known as The Blue Book 2).

2.4 Managing Urban Stormwater – Environmental Targets

Stormwater pollution control targets have been set by the NSW Government in the draft document *Managing Urban Stormwater: Environmental Targets* (Consultation Draft, 2007). These targets are applicable to the operational phase of the project. They were developed to support the protection of waterways through the NSW Water Quality and River Flow Objectives, and are recommended to be adopted by consent authorities such as councils for medium-large scale developments.

This document acknowledges that "*cost-effective stormwater treatment*" is usually insufficient to prevent impacts to the environment, but recommends that the following targets are the minimum requirements for developments to minimise impacts on the environmental values of water. These targets require pollutant reductions for Total Suspended Solids – 85 per cent, Total Phosphorus – 65 per cent, and Total Nitrogen – 45 per cent (Managing Urban Stormwater: Environmental Targets (DECC, 2007)).

2.5 Botany Bay and Catchment Water Quality Improvement Plan

Sydney Metropolitan Catchment Management Authority's (SMCMA) *Botany Bay and Catchment Water Quality Improvement Plan* (SMCMA, 2011) is a contemporary plan designed specifically for the catchment of Botany Bay. The Cooks River catchment is a sub catchment- of the larger Botany Bay catchment hence this plan applies to the study area.

The main objective of the Botany Bay and Catchment Water Quality Improvement Plan was to set targets for pollutant load reductions (in terms of total nitrogen, total phosphorus and suspended sediment) required to protect the condition of Botany Bay, its estuaries and waterways. The plan is an agreed water quality improvement plan that builds on research and engagement undertaken as part of the Botany Bay Water Quality Improvement Program (BBWQIP) to provide direction for future land use and water quality management decisions in the Botany Bay catchment.

The plan was aimed at Local, State and Federal Government agencies. A primary objective of the *Botany Bay and Catchment Water Quality Improvement Plan* (SMCMA, 2011) is to establish stormwater pollution reduction targets for all new development and re-development within the Botany Bay catchment to protect the condition of the bay, its estuaries and waterways. These pollutant reduction targets are shown in Table 3. The targets for large redevelopments have been applied to the project.

Table 3 Stormwater reduction targets recommended for urban development in the Botany Bay catchments

Stormwater pollutant	Reduction target	
	Greenfield developments large re-developments	Multi-unit dwellings, commercial developments, industrial developments and small re-developments
Gross pollutants	90%	90%
Total suspended solids (TSS)	85%	80%
Total phosphorus (TP)	60%	55%
Total Nitrogen (TN)	45%	40%

2.6 Floodplain Development Manual

The Floodplain Development Manual (NSW Government, 2005) incorporates the NSW Government's Flood Prone Land Policy, the primary objectives of which are to reduce the impact of flooding and flood liability on owners and occupiers of flood prone property and to reduce public and private losses resulting from floods, whilst also recognising the benefits of use, occupation and development of flood prone land.

The Floodplain Development Manual forms the NSW Government's primary technical guidance for the development of sustainable strategies to support human occupation and use of the floodplain, and promotes strategic consideration of key issues including safety to people, management of potential damage to property and infrastructure, and management of cumulative impacts of development. Importantly, the Floodplain Development Manual promotes the concept that proposed developments be treated on their merit rather than through the imposition of rigid and prescriptive criteria.

2.7 Floodplain Risk Management Guideline – Practical Considerations of Climate Change

Climate change is expected to impact sea levels and rainfall intensities, both of which may have significant influence on flood behaviour at specific locations. IPCC 2007 trends indicate that average global sea level rise (not including ice flow melt) may be between 0.18 to 0.59 metres by between 2090 and 2100. Adding to this the ice flow melt uncertainty of up to 0.2 metres gives an adjusted global range of 0.18 to 0.79 metres. IPCC 2007 and recent CSIRO modelling (see for example McInnes et al 2007) indicate that mean sea levels along the NSW coast are expected to rise by more than the global mean.

Combining the relevant global and local information indicates that sea level rise on the NSW coast is expected to be in the range of 0.18 to 0.91 metres by between 2090 and 2100. In addition, climate change impacts on flood producing rainfall events show a trend towards more intense storms, at least for larger scale events (DECC, 2007).

The Cooks River, Alexandra Canal, the Eastern Channel and Wolli Creek are all tidal. Therefore, for these areas climate change in terms of potential sea level rise is a relevant consideration. DECC (2007) recommended sensitivity analyses be undertaken to assess the potential impact of sea level rise in the range 0.18 to 0.91 metres, dependent on the relevant project time horizon. These recommendations are still widely applied in NSW for urban and infrastructure planning purposes in the absence of any formal state-wide sea level rise planning benchmarks. They have been considered as part of technical investigations that have informed development of the project.

2.8 Other policies and guidelines

Other polices and guidelines that apply to the project include:

- *Water Act 1912*
- *NSW Water Management Act 2000*
- *Fisheries Management Act 1994*
- *NSW Protection of the Environment Operations Act 1997*
- *NSW State Rivers and Estuaries Policy* (NSW Water Resources Council,1993)
- *National Water Quality Management Strategy* (ANZECC, 2000)
- *Guidelines for Design of Fish and Fauna Friendly Waterway Crossings* (Fairfull and Witheridge, 2003)
- *Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge, 2003)
- *Controlled Activities – Guidelines for Riparian Corridors* (NSW Office of Water, 2011)
- *Controlled Activities – Guidelines for Watercourse Crossings* (NSW Office of Water, 2010)
- *Controlled Activities – Guidelines for In-stream Works* (NSW Office of Water, 2010)

- *Controlled Activities – Guidelines for Laying Pipes and Cables in Watercourses* (NSW Office of Water, 2011)
- *Controlled Activities – Guidelines for Outlet Structures* (NSW Office of Water, 2010)
- *Managing Urban Stormwater: Council Handbook, Draft* (EPA, 1981)
- *Australian Rainfall and Runoff* (Institute of Engineers Australia, 1987; AR&R).

Relevant policies and guidelines of Roads and Maritime that also apply to the project include:

- *Water Policy* (RTA, 1997)
- *Code of Practice for Water Management - Road Development and Management* (RTA, 1999)
- *Stockpile Site Management Procedures* (RTA, 2001)
- *Erosion and Sediment Management Procedure* (RMS, 2008)
- *Technical Guideline: Temporary Stormwater Drainage for Road Construction* (RMS, 2011)
- *Procedures for Selecting Treatment Strategies to Control Road Runoff* (RTA, 2003).

Relevant Austroads guidelines that apply to the project include:

- *AP-R180 Road Runoff and Drainage: Environmental Impacts and Management Options* (Austroads, 2011)
- *AP-R232 Guidelines for Treatment of Stormwater Runoff from the Road Infrastructure* (Austroads, 2003)
- *Guide to Road Design, Part 5: Drainage Design* (Austroads, 2013).

3.0 Methodology

This chapter details the methodology applied in this assessment, which involved:

- Characterisation of the existing environment and potential surface water issues through review and analysis of existing information (desktop analysis)
- A field inspection to confirm the outcomes of the desktop analysis, and further refine the scope or relevant issues to be considered in the surface water impact assessment
- Assessment of specific surface water issues, including flooding (construction only), surface water quality and geomorphology impacts during construction and operation, having regard to applicable policies and guidelines.

3.1 Desktop analysis

The existing surface water environment across the study area has been characterised, and potential impacts have been identified through an initial desktop analysis of available information. The desktop analysis has included consideration of:

- Review of information and previous studies conducted within the surface water study area, including those for the existing M5 East Motorway and other developments along Alexandra Canal (refer Section 3.1.2). This included flooding, geomorphological and water quality studies, used to inform the EIS for this project
- Other Technical Working Papers included in the EIS, including those relating to groundwater, contamination, biodiversity and flooding.

3.1.1 Compilation of relevant information

Information concerning the existing environmental conditions within the study area has been obtained from the following sources:

- The local councils of Marrickville, Sydney, Botany, Canterbury, Rockdale and Hurstville
- The Cooks River Alliance – a partnership of eight Councils
- NSW government agencies: Roads and Maritime, WDA, Local Land Services (LLS), the Office of Environment and Heritage (OEH), NSW Public Works and Sydney Water Corporation
- Local community groups, including Streamwatch.

3.1.2 Review of previous studies

A number of previous studies have been made into various aspects of surface water in the study area. These have been in relation to similar works, including the M5 East Motorway and for environmental management purposes, as presented in Table 4.

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Table 4 Previous studies relating to surface water in the study area

Catchment	Report title	Author(s)	Year	Summary
Flooding				
Wolli Creek	King Georges Road Interchange Upgrade – Flooding and Drainage Investigation. Prepared for Roads and Maritime.	Lyall and Associates	2014	Assessment of flooding and drainage upgrades for King Georges Road Interchange Upgrade
	M5 East Upgrade – King Georges Road to Bexley Road – Review of pavement drainage issues. Prepared for Roads and Maritime.	Lyall and Associates	2011	Assessment of pavement drainage upgrades for the M5 East Motorway
	Cooks River Flood Study. Prepared for Sydney Water.	PB MWH	2009	Regional flood study
	Update of Wolli Creek Pipe Drainage & Overland Flow Study	WMA Water	2008	Localised flooding and drainage study
	M5 East Project – Report on Flood Risk Management	Hyder	2000	Assessment of flood risk attributed to previous M5 East works.
Cooks River	Technical Note No.1. Impacts of Proposed Airport Drive Option on Flooding Patterns M5 East Upgrade – March Street To Sydney Park Road. Prepared for Roads and Maritime.	Lyall and Associates	2012	Assessment of flooding and drainage upgrades for early motorway options
	Technical Note No. 2. M5 East Upgrade – March Street to Sydney Park Road Potential Impacts of Airport Orbital North-west over Alexandra Canal Solution on Flooding Behaviour. Prepared for Roads and Maritime.	Lyall and Associates	2012	Assessment of flooding and drainage upgrades for early motorway options
	Cooks River Flood Study. Prepared for Sydney Water.	PB MWH	2009	Regional flood study
Alexandra Canal	Proposed Bridge over Alexandra Canal – Preliminary Flood Impact Assessment. Prepared for WDA.	Lyall and Associates	2015	Preliminary assessment to inform design of the project
	Alexandra Canal Flood Study. Prepared for City of Sydney.	Cardno	2014	Municipal / catchment flood study
	Technical Note No.1. Impacts of Proposed Airport Drive Option on Flooding Patterns M5 East Upgrade – March Street To Sydney Park Road. Prepared for Roads and Maritime.	Lyall and Associates	2012	Assessment of flooding and drainage upgrades for early motorway options

Catchment	Report title	Author(s)	Year	Summary
	Technical Note No. 2. M5 East Upgrade – March Street to Sydney Park Road Potential Impacts of Airport Orbital North-west over Alexandra Canal Solution on Flooding Behaviour. Prepared for Roads and Maritime.	Lyall and Associates	2012	Assessment of flooding and drainage upgrades for early motorway options
	Cooks River Flood Study. Prepared for Sydney Water.	PB MWH	2009	Regional flood study
Eastern Channel	Marrickville Valley Flood Study – Draft Report. Prepared for Marrickville Council and Sydney Water.	WMA Water	2011	Municipal flood study
	EC East Sub-catchment Management Plan Volume 2- Flood Study. Prepared for Marrickville Council.	Golder Associates	2010	Municipal flooding and drainage study
	Cooks River Flood Study. Prepared for Sydney Water.	PB MWH	2009	Regional flood study
Water Quality				
	Botany Bay & Catchment Water Quality Improvement Plan. Sydney: Botany Bay Water Quality Improvement Program	SMCMA	2011	Catchment management strategy for water quality management
	Cooks River Stormwater Management Plan (CRSMP). Prepared for the Cooks River Catchment Association of Councils.	PPK-WMA	2009	Catchment management strategy for water quality management
	Alexandra Canal, 61 Huntley Street, Stormwater Asset Renewal Program. Review of Environmental Factors. Prepared for Sydney Water.	GHD	2014	Environmental impact assessment
	Sediment Water Quality Interactions. Prepared for Sydney Water Corporation.	UoQ	2002	Environmental study
Geomorphology				
	Sydney Metropolitan CMA Waterways Health Strategy. Prepared for Sydney Metropolitan Catchment Management Authority (CMA).	EarthTech	2007	Catchment management strategy for stream management
	Alexandra Canal Conservation Management Plan (NSW DPW, 2004).	DPWS	2004	Management plan

3.1.3 Review of baseline data

A number of sources provided data for the purpose of the study. These include:

- Details of pit and pipe drainage provided by City of Sydney, Botany Bay, Rockdale, Marrickville, Canterbury and Hurstville. Data included locations of pits and pipes
- Details of trunk drainage assets operated by Sydney Water
- Light Detection and Ranging (LIDAR) topographic surveys
- Water quality monitoring data provided by Rockdale City Council, Streamwatch and Sydney Water.

3.2 Field assessment

The objective of field inspections was to assess the current state of surface water features within the surface water study area. A judgement of their resilience was made so as to determine if the surface water environment is likely to be impacted by the project. Field assessment included inspection of features that could be impacted by changes to surface water flooding, hydrology or water quality.

Field inspections were made on three separate occasions, as shown in Table 5.

Table 5 Field inspections

Date	Watercourses Visited	Antecedent Conditions	Outcomes
16 April 2015	Alexandra Canal, Eastern Channel, Lower Cooks River.	Dry conditions in days leading up to inspections.	Inspection of geomorphology and waterways
17 April 2015	Wolli Creek and wetlands around Cooks River	Dry conditions in days leading up to inspections.	Inspection of geomorphology and waterways as well as existing water quality improvement devices
23 April 2015	Alexandra Canal, Sheas Creek, Botany Road / Doody Street stormwater channel, Eastern Channel, Sydenham storage pit, and Upper Wolli Creek	Heavy rainfall prior to inspection (over 200 millimetres in previous 48 hours), which resulted in localised flooding.	Inspection of drainage infrastructure. Assessment of waterway capacity following heavy rainfall.

3.3 Assessment of potential flooding and drainage impacts

3.3.1 Overview

A Technical Working Paper: Flooding (Lyall and Associates, 2015) was prepared for the project to define mainstream flooding behaviour across the study area under present day conditions, as well as to assess the potential impacts on mainstream flooding that are associated with the operational phase of the project. This investigation involved two dimensional hydraulic modelling of the major study watercourses, including Wolli Creek, Alexandra Canal and the lower Cooks River. Refer to the Technical Working Paper: Flooding (Lyall and Associates, 2015) for a detailed description of the methodology that was adopted for this study.

3.3.2 Flooding during construction

A qualitative construction phase flooding impact assessment was made based on indicative areas and activities as provided in the concept design. Locations of surface works, construction compounds and other structures such as temporary noise barriers were mapped against the existing 20 year ARI, 100 year ARI and Probable Maximum Flood (PMF) indicative flood extents as outlined in the Technical Working Paper: Flooding (Lyall and Associates, 2015). This provided an understanding of the likelihood that flooding would occur in the vicinity of construction activities.

An assessment was made on the potential for mainstream flooding to affect the construction process and the potential for construction activities to impact flooding behaviour and any nearby properties. Treatment was also given to the potential for localised overland flooding occurring at construction locations.

3.3.3 Flooding during operation

The Technical Working Paper: Flooding (Lyall and Associates, 2015) was prepared to assess the potential impacts on mainstream flooding associated with operation of the project in upper Wolli Creek, lower Cooks River and Alexandra Canal. Flooding of the Eastern Channel has been assessed within this report. The project would include measures (for example the upgrade of Camdenville Park Basin) to ensure that flooding downstream of the works would not be exacerbated.

The impacts of the project on localised flooding and drainage during operation of the project are addressed in this paper. The assessment was made with reference to the proposed connection of new and upgraded drainage systems to existing local drainage networks. Details of the existing networks were sought from the various authorities that own and maintain these networks, typically local Councils and Sydney Water. Historical information about existing localised flooding issues was also gathered.

3.4 Assessment of potential water quality impacts

3.4.1 Water quality during construction

The quality of surface water runoff during the construction phase is largely determined by sediment and erosion control measures, this requires:

- Assessment of the erosion hazard of the site soils
- Bunding in place for spills.

These controls are guided by 'The Blue Book' (Landcom, 2004) and CEMP requirements.

The assessment of surface water quality impacts during proposed works has involved:

- Assessment of potential construction activities that could mobilise sediments into the surface water environment, in particular contaminated sediments
- Review of existing policies and guidelines applicable to the management of water quality during construction
- Assessment of the quality of proposed discharges of treated construction water with reference to water quality reference criteria (Appendix A).

The water quality reference criteria were developed in accordance with guidelines from the Australian and New Zealand Environment Conservation Council (ANZECC, 2000). For highly disturbed receiving environments such as those that could be impacted by the project, ANZECC (2000) recommends that suitable guidelines for water quality trigger values can be trigger values derived from a local reference data set for nutrients, dissolved oxygen and pH where the quality of discharge should not exceed the 80th and/or 20th percentile values. The water quality reference criteria were developed from available water quality data from the receiving environments in the vicinity of the project. For toxicants (such as heavy metals or organic chemical compounds) the water quality requirements should be consistent with the 80 percent protection level for freshwater ecosystems (see Table 3.4.1 in ANZECC 2000).

3.4.2 Water quality during operation

The assessment of surface water quality impacts from proposed works has involved:

- Collation and review of available data on stream condition, water quality and soils to define the existing environment within the catchments and watercourses
- Review of existing policies and guidelines applicable to the management of water quality
- Assessment of proposed activities for impacts on the water quality of receiving environments. The assessment of the project impacts on surface water runoff incorporates an assessment of the mitigation measures provided in the design
- Identification of required mitigation measures, including type of controls and design criteria required to manage potential impacts.

Pollutant loads generated by the project were assessed to determine if mitigation would be sufficient to meet the stormwater pollution reduction targets from the *Botany Bay and Catchment Water Quality Improvement Plan*. This plan establishes stormwater pollution reduction targets (in terms of gross pollutants, total suspended solids, total phosphorus and total nitrogen) for all new development and re-development within the Botany Bay catchment. These pollutant reduction targets are presented in Table 6. The targets recommended by SMCMA for large redevelopment are applicable to the project.

Table 6 Pollution reduction targets applicable to the project

Stormwater pollutant	Pollution reduction target
Gross Pollutants	90%
Total Suspended Solids	85%
Total Phosphorus	60%
Total Nitrogen	45%

Note: Gross Pollutant removal is not reported since if the treatment target for Total Suspended Solids is met, the target for Gross Pollutants is typically also met.

Designs are assessed against the SMCMA targets for the upgrade of the roads i.e. the increase in pollutant loads above the existing condition that are attributable to the project. A treatment train approach was adopted to improve water quality of runoff from new impervious areas of the project. The aim is to achieve the stormwater targets where practical.

In order to assess the pollutant loads of the pavement runoff, assessments incorporating MUSIC modelling were undertaken. The MUSIC model was developed by the Cooperative Research Centre for Catchment Hydrology (now eWater CRC) as a decision support system for the design of stormwater treatment devices, and is now considered the standard method for determining compliance with water quality targets within the stormwater industry. The MUSIC model used was based on the NSW MUSIC modelling guidelines for the meteorological template and pollutant generation parameters. The pollutant load reduction targets that would be required to achieve the treatment targets were calculated as follows:

1) An estimate was made of the extent of the proposed impervious area associated with the project catchment after development. The imperviousness of the existing catchment was then calculated by subtracting the increase in impervious area that would result from the project.
2) Pollutant loads were modelled for each project catchment area before development (the existing condition).
3) Pollutant loads were modelled for each project catchment area after development.
4) The increase in pollutants in stormwater runoff resulting from the project was calculated from the above [(3) – (2) = increase in pollutants].
5) The targeted pollutant reduction loads were calculated based on pollution reduction targets, for example Total Suspended Solids 85 per cent removal, Total Phosphorus 60 per cent removal, Total Nitrogen 45 per cent removal. The required pollutant load reduction was calculated by multiplying the increase in pollutants for each catchment (i.e. (4) above)) by the pollutant load reduction required (i.e. Total Suspended Solids 85 per cent removal etc.).

The performance of the treatment devices proposed for stormwater quality treatment has been modelled and the results are presented in Section 7.3.The type and design of specific stormwater treatment measures across the project would be further refined as part of detailed design. Due to the conceptual nature of design to date, the modelling undertaken for this assessment has required assumptions to be made regarding the size of catchments and the size and design of stormwater quality improvement devices. Therefore the results of the modelling should be considered estimates of the likely treatment performance that can be expected. Modelling will need to be revised during detailed design, and this would be accompanied by a description of the treatment devices and any accompanying calculations, including the assumptions.

Discharge from the groundwater treatment plant was assessed for potential impacts from the quality of water discharged. Discharged water quality would meet water quality reference criteria developed for the project in accordance with guidelines from the Australian and New Zealand Environment Conservation Council (ANZECC, 2000) (refer to Appendix A).

3.5 Assessment of potential geomorphology impacts

The surface water impacts on geomorphology of relevant watercourses were assessed for the construction and operation phases of the project has involved:

- Collation and review of available data on stream condition to define the existing environment within the catchments and watercourses.
- Visual inspection of the receiving watercourses at a number of locations to verify the current condition.
- Review of historical stabilisation works along the watercourses.
- Review of existing policies and guidelines applicable to the management of erosion and sedimentation.
- Review of the proposed groundwater discharge rates and comparison with estimates of watercourse flow rates derived from the Cooks River Flood Study (WMA, 2009). The most frequent return interval flows from the flood study (the 2-year ARI) were used to derive an extrapolated approximation for the 1 year ARI flow and used for comparison to predicted discharge of treated groundwater. This comparison allows a relative assessment of whether the groundwater discharges are likely to create flow conditions that are rare or common for the streams being assessed. Coupled with the flow comparison, the channel type and condition in the vicinity of the discharge location, and cumulative impacts, was considered to understand potential impacts from the proposed groundwater discharge rates.
- Assessment of proposed activities for impacts on the water quality of receiving environments.
- Identification of required mitigation measures, including type of controls and design criteria required to manage potential impacts.
- Review of the dominant soil landscapes found in the study area.

As a basis of understanding the types of watercourses that exist in the project corridor, a geomorphic categorisation framework called River Styles (Brierley and Fryirs, 2005) was used to classify watercourses based on morphology and behaviour (character). This is the method adopted by DPI (Water) to define the physical form of rivers to measure and report on progress towards the Governments 'river health' targets. The River Styles classification for morphology and behaviour provides the basis for determining the vulnerability of each watercourse to geomorphic impacts. Fieldwork was undertaken on 16 and 17 April 2015 to inform this assessment, confirming that the mapping is accurate for the reaches of watercourses that have the potential to be affected by the project.

Desktop assessment of the current morphology and behaviour of the receiving watercourses was completed using a modified River Styles® geomorphic assessment technique, employed for the Sydney Metropolitan Waterways Health Strategy (EarthTech, 2007), to understand the potential for geomorphic impacts (Table 7). All of the watercourses within the surface water study area are likely to have been anthropogenically modified to some degree within the last 100 years.

Table 7 Categories of RiverStyles® used in categorising the existing physical form of rivers for this assessment

GIS label	Map descriptors	Channel continuity	Channel controls
Confined 2	Occasional pockets	Continuous channel	Bedrock controlled, channel abuts valley margin >90per cent of reach length. Alternating discontinuous floodplain pockets and opportunistic deposits at areas of localised valley widening.
Partly Confined 1	Bedrock controlled, discontinuous floodplain	Continuous channel	Channel abuts valley margin 50-90 per cent of stream length. Plan form aligned with valley alignment. Common vertical bedrock controls. Alternating, discontinuous pockets of floodplain deposits.
Partly Confined 3	Meandering, planform controlled, alternating discontinuous floodplain	Continuous channel	Channel abuts valley margin 10-50 per cent of stream length. Meanders independently of valley alignment. Common vertical bedrock controls.
Anthropogenic 1	Shaped channel	Continuous channel	Channels that have a modified morphology but may not have been entirely stabilised. May be partially concreted or rock-lined but there is limited potential for lateral adjustment.
Anthropogenic 2	Piped channel	Continuous channel	No potential for lateral or vertical adjustment. No open channel.
Anthropogenic 3	Concrete channel	Continuous channel	No potential for lateral or vertical adjustment.
Anthropogenic 4	Rock-lined channel	Continuous channel	Open channel. The potential for lateral and vertical adjustment limited by the stability of channel bed and walls.
Anthropogenic 5	Underground concrete channel	Continuous channel	No potential for lateral or vertical adjustment. No open channel.

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4.0 Existing environment

The project extends from Beverly Hills to St Peters and Mascot, covering a distance of around nine kilometres, following roughly the alignment of the existing M5 East Motorway. The project crosses a number of waterways draining to the Cooks River. These waterways include the Cooks River, Wolli Creek and Alexandra Canal. At the eastern end of the project, in St Peters, the project also drains to the Eastern Channel, a trunk drainage line with a relatively large catchment.

The existing environment across the surface water study area consists of highly altered land, impacted by land clearing and subsequent urbanisation. The topography ranges from relatively flat to steep banks through parts of Lower Wolli Creek. The climate is temperate with average annual rainfall of roughly 1080 millimetres spread relatively evenly throughout the year.

The existing surface water environment is described in the following sections in relation to:

- Soil landscapes
- Catchments and watercourses
- Catchment land use
- Geomorphology
- Hydrology and flooding
- Water quality
- Sensitive receiving environments.

4.1 Soil landscapes

The *Soil Landscapes of the Sydney 1:100,000 Sheet 9130* (1989) indicates that the study area in underlain by seven soil landscape groupings. The Gymea soil landscape covers the majority of the project corridor in the west, along with smaller areas of the Hawkesbury, Blacktown, Birrong, Warriewood and Oxford Falls soil landscapes. The eastern extent of the project corridor is largely covered by land identified as being disturbed terrains, associated with Alexandra Canal and industrial land uses. Soil landscapes within the study area are shown in Figure 2, and the key characteristics of relevant soil landscapes are summarised in Table 8.

Table 8 Soil landscapes found in the surface water study area

Soil Landscape Grouping	Soil Landscape	Characteristics	Erosional nature
Residual	Blacktown	- Occurs on gently undulating rises on Wianamatta Group Shales - Poorly drained, moderately reactive soil	No appreciable erosion occurs on this unit as most of the surface is covered by tiles, concrete, bitumen or turf.
Alluvial	Birrong	- Occurs on level to gently undulating alluvial flood plan draining the Wianamatta Group Shales - High soil erosion hazard, saline soils, seasonal waterlogging and localised flooding	Most drainage lines have been artificially lined with concrete preventing most erosion. Minor streambank erosion has occurred along remaining natural drainage lines.
Erosional	Gymea	- Occurs on undulating to rolling rises and low hills on Hawkesbury Sandstone - Localised steep slopes - High soil erosion hazard	Severe sheet erosion occurs following bushfires which destroy or damage stabilising vegetative cover. Minor gully erosion occurs along unpaved roads and fire trails especially those frequented by four wheel drive vehicles and trail bikes

Soil Landscape Grouping	Soil Landscape	Characteristics	Erosional nature
Colluvial	Hawkesbury	- Occurs on rugged, rolling to very steep hills on Hawkesbury Sandstone - Extreme soil erosion and mass movement hazard.	Severe sheet erosions often occur during storms and after ground cover has been destroyed by bushfires. Minor gully erosion occurs along unpaved tracks and fire trails, especially those used regularly by four wheel drive vehicles, motorcycles and horses.
Swamp	Warriewood	- Occurs on level to gently undulating swales, depressions and infilled lagoons in Quaternary sands - High water tables and localised flooding, highly permeable soils, compressible soils.	No appreciable erosion occurs where slopes are low and a vigorous ground cover is maintained. Isolated blowouts caused by wind erosion occur in exposed area where cover has been removed.
Disturbed Terrain	Disturbed Terrain	- Terrain extensively disturbed by human activity, including complete disturbance, removal or burial of soil. Variable relief and slopes	Erosion varies markedly according to site characteristics including slope, aspect and exposure. In general, severe sheet and rill erosion often occur at quarries, gravel pits and places where unconsolidated or disturbed material remains without a protective cover of vegetation, asphalt or concrete

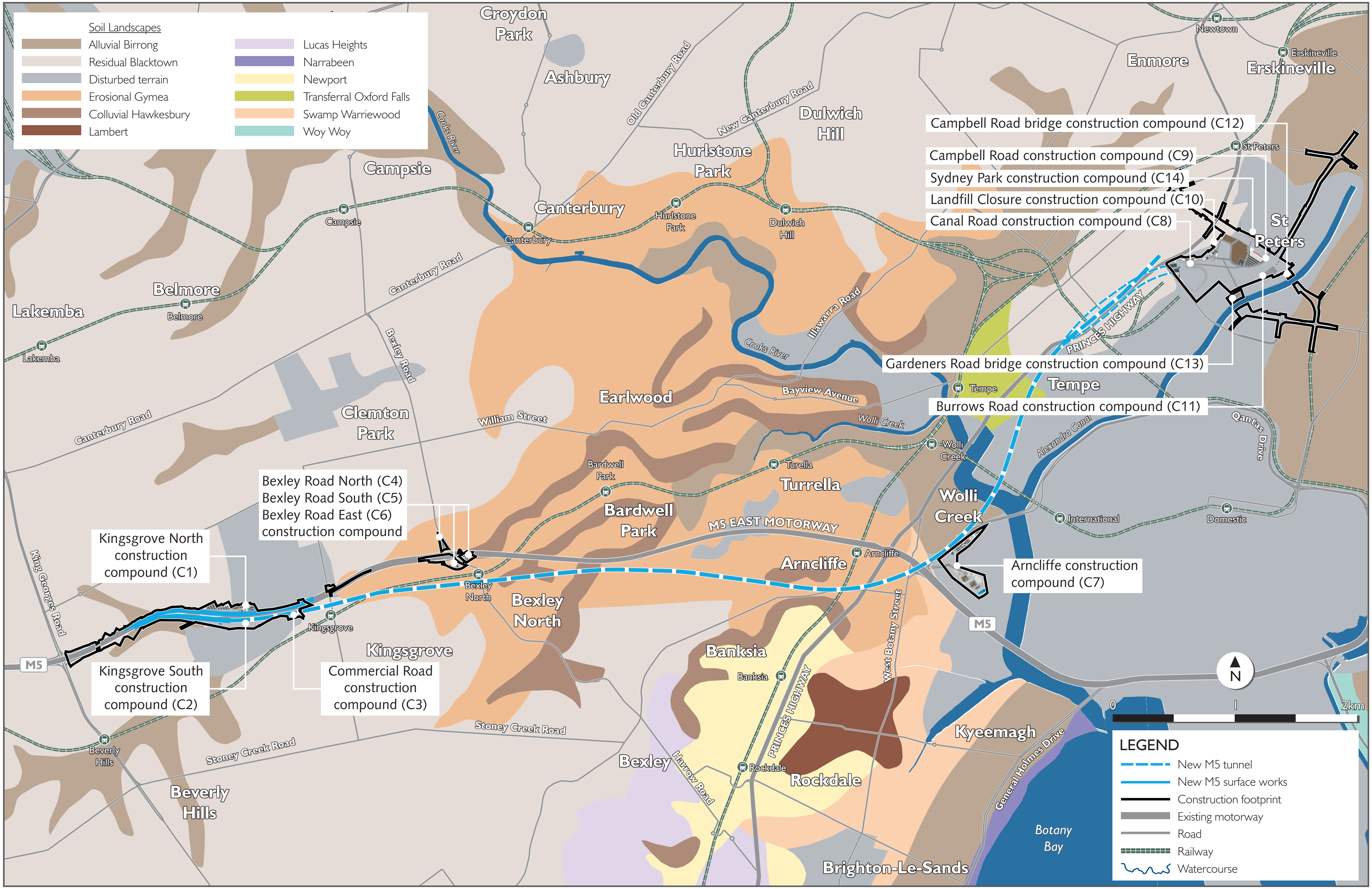

Figure 2 Soil landscapes

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4.2 Catchments and watercourses

The project corridor is located within the Cooks River catchment. The Cooks River catchment extends from Botany Bay in the south east to Randwick in the north east, Strathfield in the north west and Hurstville in the south west forming part of the greater 116,500 hectare Botany Bay catchment (SMCMA, 2011). The Cooks River catchment is fed by nine tributaries:

- Greenacre Creek
- Cox’s Creek
- Cup and Saucer Creek
- Fresh Water Creek
- Bardwell Creek
- Wolli Creek
- Muddy Creek
- Alexandra Canal, which includes Sheas Creek
- Eastern Channel.

Of these nine tributaries, the Wolli Creek, Alexandra Canal and Eastern Channel are located within the study area. There are several channels that drain Kogarah Golf Course that discharge into the Cooks River. For the purposes of this assessment, these drainage channels are considered as part of the overall Cooks River catchment.

The catchment boundaries and watercourses in the study area are shown on Figure 3 and Figure 4.

4.2.1 Cooks River catchment

The Cooks River catchment covers an area of around 10,000 hectares in south western Sydney, discharging to Botany Bay at Mascot. The catchment was stripped of its natural vegetation during early European settlement and has been subject to long term anthropogenic degradation. The Cooks River catchment is highly urbanised and has a history of intensive land use ranging from residential to heavy industry. The catchment has very little remaining bushland, and a small amount of parkland (SMCMA, 2011).

Residential land use is the predominant zoning within the catchment. The major portion of industrially zoned land is concentrated in the Port Botany area, along Alexandra Canal within Tempe and the southern portion of the Strathfield local government area. Thin corridors of open space line the Cooks River and many of its tributaries. (RCC, 2011)

The landscape and natural function of the catchment and waterways has been impacted by urbanisation within the catchment and the density of the built environment. As a result, the majority of watercourses within the Cooks River catchment are anthropogenically modified channels. Generally the artificial modifications have included dredging, widening, re-alignment and various forms of armouring such as concrete linings and rock revetments. The development of impervious surfaces within the catchment has increased the volume and rate of runoff, which has in turn necessitated flood mitigation measures primarily in the mid and upper catchment, and bank stabilisation works in the lower catchment (Earth Tech, 2007). Semi-natural channel morphology exists as small laterally discontinuous reaches where bedrock controls on confinement have negated the need for channel stabilisation initiatives or the watercourse abuts natural floodplain or parkland.

Partly confined and alluvial unconfined reaches exist in the lower catchment only in relatively low energy environments (Earth Tech, 2007). In most instances channel modification has masked or removed in-channel geomorphic units and the built environment masks the floodplain thereby making it problematic to determine historic channel morphology (Earth Tech, 2007).

Within the catchment it is estimated that roughly 89 per cent of stormwater travels through a combination of pit and pipe networks, open concrete channels, metal sheet piled channels and rock armoured channels. Around 71 per cent of the stream reaches in the Cooks River catchment have no vegetation or are used for flood control (SMCMA, 2011).

The Cooks River flows for roughly 23 kilometres from Graf Park in Bankstown into Botany Bay at Kyeemagh (CRA, 2013). The Cooks River is so highly modified that it functions more like a stormwater drainage system than a river system. The river in the study area is largely lined with steel sheet pilings, concrete walls or stone/block revetments, though with some rehabilitated, naturalised sections. The Cooks River is almost uniformly 50 metres wide upstream of Cahill Park, Tempe where it widens to roughly 150 metres until its discharge through training walls into Botany Bay.

The tidal limit of the Cooks River is estimated to be adjacent to Sando Reserve, Croydon Park (Manly Hydraulics Laboratory (MHL), 2005). This is roughly 7.5 kilometres upstream of the Bayview Avenue Bridge and the upstream extent of any impacts related to the project.

Most of the river bank was built between the late 1940s to the early 1950s as part of the river diversion and land reclamation works associated with the construction of the Sydney Airport. The mouth of the Cooks River was relocated 1.6 kilometres west to its current position during these works (PPK, 1999).

A number of authorities are responsible for the management of the Cooks River and its catchment, including the local councils located within the Cooks River catchment, the Local Land Services Board, the Environment Protection Agency and Sydney Water.

4.2.2 Wolli Creek catchment

The Wolli Creek catchment has an area of about 2,100 hectares and includes the suburbs of Narwee, Beverly Hills, Kingsgrove, Canterbury, Bexley, Bardwell Park, Earlwood, Turrella, Arncliffe and Tempe. The area consists primarily of residential development with some industrial and remnant bushland areas.

This catchment has been significantly altered by urbanisation, as well as the existing M5 East Motorway and the East Hills Railway line. Open areas include the Canterbury Golf Course, the M5 Linear Park (established as part of the M5 East Motorway, incorporating open spaces such as Beverly Grove Park), and around fifty hectares of natural bushland within the suburbs of Earlwood and Bardwell Valley. Part of the natural bushland has been declared as a regional park (the Wolli Creek Regional Park), managed by the National Parks and Wildlife Service. Remaining sections of bushland are managed by local councils.

Wolli Creek is the largest tributary of the Cooks River. The creek begins in the suburb of Beverly Hills and runs through the Wolli Creek Valley in a north-easterly direction from Kingsgrove in the west, flowing towards the east until joining the Cooks River near Tempe.

The upper section of Wolli Creek, from Bevery Hills to Bexley Road, is generally anthropogenically modified with hard engineered lining with the majority consisting of a concrete-lined trapezoidal channel (refer to photographic example in Figure 5). This upper section is owned and managed by Sydney Water as part of its trunk drainage system. Sydney Water owns and manages the creek from its beginning until Bexley Road where it enters Crown Land.

The upper section consists of a mix of open concrete-lined trapezoidal channels, reconstructed semi-natural watercourse channel, underground concrete channels, piped channels and rock-lined channels. Given the channel protection material, the channels here are devoid of geomorphic features, apart from the occasional sediment deposition slug that forms around / behind a channel intrusion, such as a bridge pier, or debris blockage. The susceptibility for in-channel erosion is minimal.

The reconstructed semi-natural watercourse channel extends for around 400 metres near The Crescent, Kingsgrove. The 400 metre reach of formed, but unlined, earthen channel is constructed of grouted rock rip-rap and vegetation (refer to Figure 6). Although naturalised, this reach is heavily degraded with sedimentation and infested with weeds. However, the grouted rock-rip rap means that the channel at this point is generally stable, with the bed and banks likely to be resistant to erosion. Downstream of The Crescent, the channel then returns to a constructed concrete-lined trapezoidal channel. Through the M5 Linear Park a number of water treatment measures are present; notably a Gross Pollutant Trap (GPT) operated by Sydney Water near Beaumont Street, Kingsgrove. The GPT filters low flows, resulting in some hydraulic head loss, particularly when partially blocked, though is bypassed in high flows.

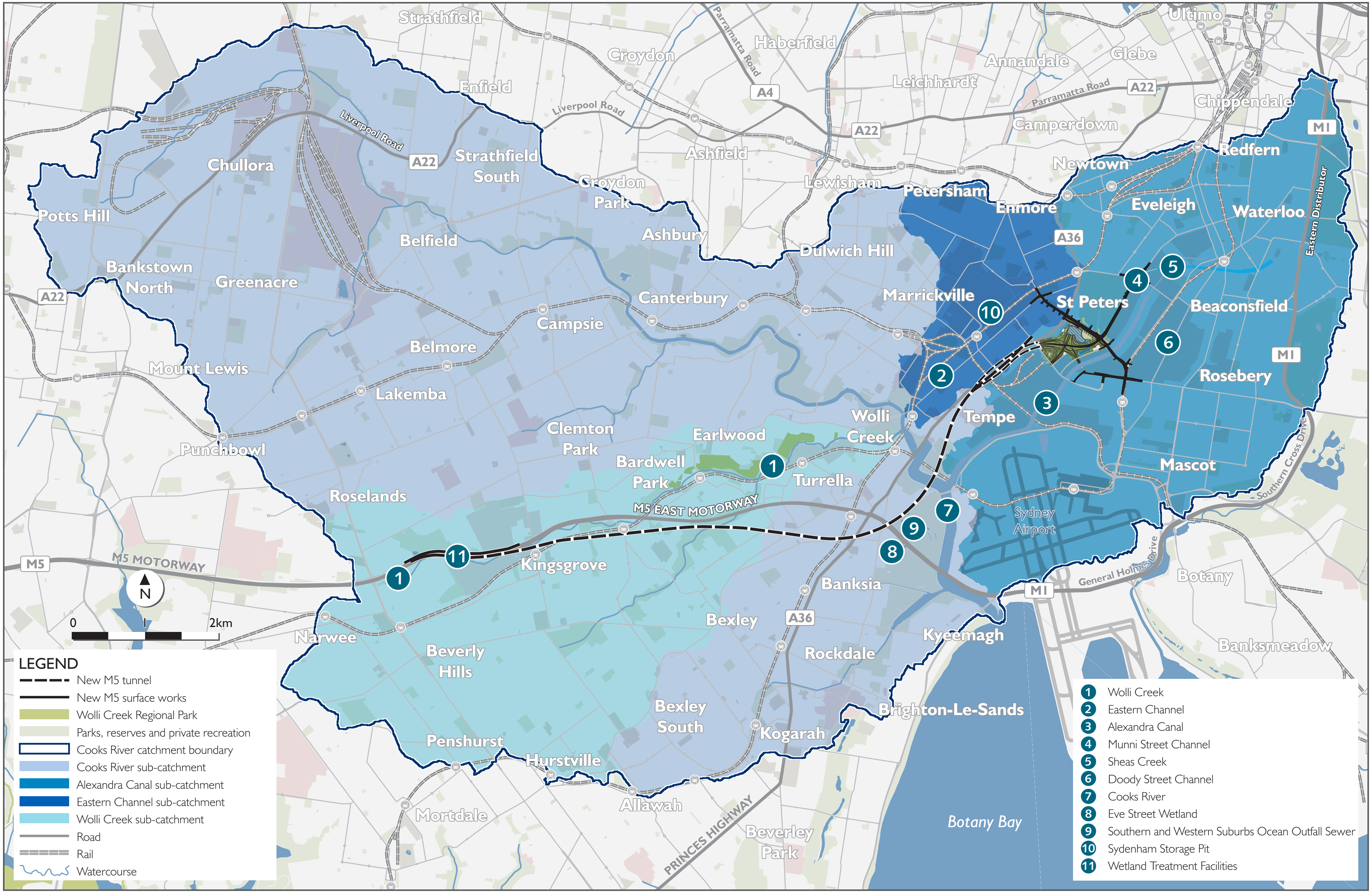

Figure 3 Catchments within the study area

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Figure 4 Watercourses within the study area

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At Bexley Road the creek passes through a box culvert before flowing into a modified (shaped), but more natural, channel (the lower section) (refer to Figure 7). Downstream of Bexley Road, the creek features alluvial banks within a confined valley setting containing a number of modifications to accommodate the railway line, urban development, bridge crossings or recreational sports fields. This section of the creek is densely vegetated, predominately with weed species. The channel traverses through a short, confined valley setting with floodplain pockets before transitioning into a partly confined meandering, platform controlled setting.

This section includes the following categorisations: the 'Confined Channel with Alternating Discontinuous Floodplain Pockets'; 'Partly Confined – Meandering', 'Platform Controlled', 'Discontinuous Floodplain'; and 'Anthropogenic Shaped Channel'.

The watercourse travels through the Wolli Creek Regional Park and is joined by Bardwell Creek on the northern side of the passenger rail line at Bardwell Park. Treated groundwater from the existing M5 East Motorway tunnel is discharged into the creek near Turrella Station (refer to Figure 8). A weir and associated fishway (refer to Figure 9) at Turrella Park, near Henderson Street regulates flow before reaching its confluence with the Cooks River adjacent to Wentworth Park, Wolli Creek.

Based on the vegetation present it is expected that the majority of the tidal limit is roughly at the Turrella (Henderson Street) weir, with the upper extent (i.e. king tide) in the vicinity of the confluence of Bardwell Creek (MHL, 2005).

The in-stream, lower bank and riparian zone of the lower section of Wolli Creek is dominated by weeds that have historically, and continue to cause sedimentation and minor bank erosion where the banks are exposed. Much of the geomorphic units within this semi-natural system are smothered by weed growth and difficult to define. The channel geometry generally consisted of a flattened U-shaped channel with a steep 1(vertical):1(horizontal) to sub-vertical low-flow bank, of an approximate height range between one to three (3) metres. The creek banks in many places illustrated signs of minor scour, slumping and fretting erosion, likely to be caused by a combination of tidal fluctuations, coupled with weed infestations providing no deep-rooted stability and intense storm flow events. At the downstream extent this erosion was less evident where mangroves were present (refer to Figure 9), which provide additional protection against the storm flows, tidal fluctuations and encourage sediment accumulation.

Generally there appeared to be minimal in-stream geomorphic or large wood habitat features, however the water turbidity at the time of the site investigation did impair visibility.

The locations of photographs shown in Figure 5 to Figure 10 are shown in Figure 11.

4.2.3 Alexandra Canal catchment

The Alexandra Canal catchment (including Sheas Creek) has an area of about 2,300 hectares and includes the suburbs of Alexandria, Rosebery, Erskineville, Beaconsfield, Zetland, Waterloo, Redfern, Newtown, Eveleigh, Surry Hills and Moore Park. The catchment is heavily altered, predominantly covered by commercial, industrial and residential development with a small amount of parkland such as Sydney Park and Moore Park.

Alexandra Canal is a constructed canal, originally a natural watercourse named Sheas Creek. It flows into the Cooks River near the north-western corner of Sydney Airport. Dredging and canalisation of Sheas Creek started in the 1880s to make the creek navigable in order to attract industries to the area. By 1896 the creek was excavated by about three metres and spoil was used to fill banks by up to 1.8 metres to reclaim the low lying swampy areas surrounding the creek.

The canal was substantially complete by 1900. As it was originally built for navigation by boat for transportation purposes it is much larger than technically required to convey stormwater from the catchment area draining to it (roughly 16 square kilometres). Due to its size in relation to its inflows as well as tidal action, the canal accumulates sediment. Dredging was regularly undertaken up to the 1950's to remove sediment build up. By that time, road and rail had made boat navigation in the canal superfluous for goods transportation. The last major works on the canal, including backfilling and dredging, were carried out in the 1970's when the north-south runway for Sydney Airport was built (DPWS, 2004).

Figure 5 Wolli Creek concrete-lined trapezoidal channel upstream of Kingsgrove Road

Figure 6 Constructed 400 m reach of grouted rock rip-rap and vegetation near The Crescent

Figure 7 Wolli Creek downstream of Bexley Road, near Illoura Park (looking upstream)

Figure 8 The existing M5 East Motorway ventilation outlet and groundwater treatment plant discharge location near Turrella Station

Figure 9 Wolli Creek Turrella Weir fishway at Henderson Street

Figure 10 Downstream extent of Wolli Creek, looking from Waterworth Park to the mangroves on the southern bank

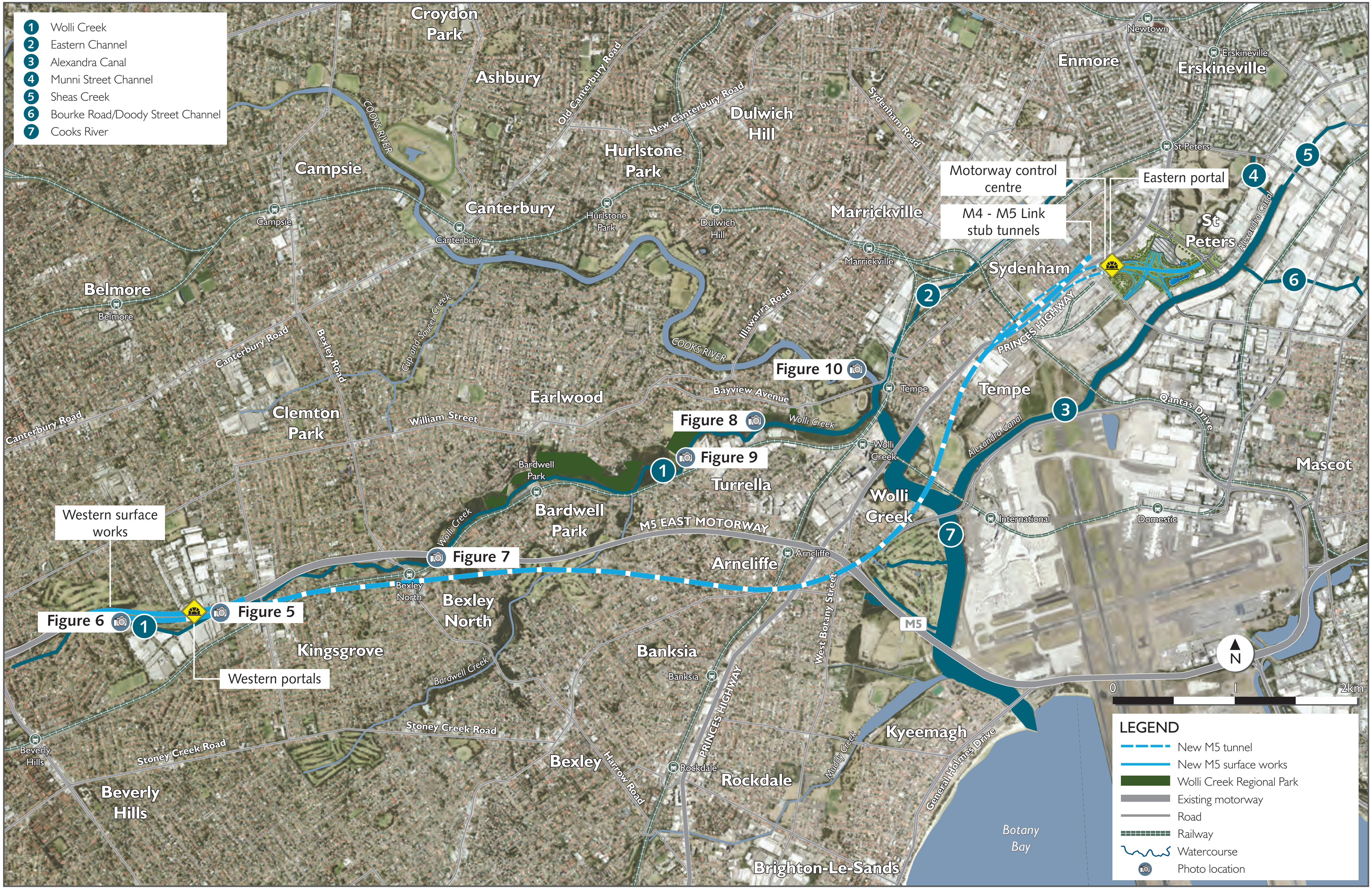

Figure 11 Location of photos shown in Figures 5 - 10

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The canal bank walls were originally constructed from sandstone blocks forming a 1:1 sloping bank from roughly 0.5 metres below low water mark to about 1.5 metres above high water mark on each side with rubble ballast as a footing. The condition of these walls is highly variable, with numerous slumps some having required remediation / restoration. Lower reaches have been rebuilt in a variety of 20th century materials including concrete block, shotcrete over rubble and fabricon and range from good to poor condition (SW, 2014). The bottom of the canal is mainly earth except where Sheas Creek enters the canal near Huntley Street, where a base has been laid in sandstone (DPWS, 2004).

The majority of the canal is devoid of geomorphic units, due to the rock-lined banks and dredged canal base. The canal contains a scour hole at the headwaters of the canal and a number of sediment deposition material (slugs), particularly at the extents of the waning flow energy, channel edges, tidal influence, and in-stream structures. These sediment slugs are remobilised when larger events pass through the system, eventually overtime entering the Cooks River.

Alexandra Canal is tidally dominated through its connection to the Cooks River. It is around 3.9 kilometres long and 60 metres at its' widest. The tidal influence from the Cooks River extends to the head of the canal. A University of Queensland study (UoQ, 2002) indicated that the flows pushing in from the Cooks River can trap the catchment flows in the canal, indicating that "*the residence time of waters conveyed into the canal from the catchment is long*".

Peak flow velocities vary little along the canal, with average velocities generally between 0.5 and 0.8 metres per second with maximum localised velocities of up to 1.2 metres per second. The existing velocities where the Sheas Creek channel enters the canal near Huntley St are fairly high, in the order of 4.8 metres per second under high tide conditions and 6.5 metres per second under low tide conditions. These high velocities dissipate very quickly in the canal, but explain a big scour hole visible at the head of the canal (AAJV, 2014).

The canal is owned and operated by Sydney Water as are the major trunk drainage lines discharging into it. Numerous minor drains in the Alexandra Canal sub-catchment are managed by South Sydney, Marrickville and Botany Councils.

Three channels discharge into Alexandra Canal: Munni Street Stormwater Channel, Sheas Creek and the Botany Road to Doody Street Channel. These are discussed below and shown in Figure 4.

Munni Street Stormwater Channel

The Munni Street Stormwater Channel drains an urban catchment of Enmore and Eveleigh into Alexandra Canal. Sections of the Local Roads Upgrades drain into this channel. The channel is concrete lined U-shape and passes under Sydney Park Road, Sydney Park, Euston Road and Burrows Street until its confluence roughly 150 metres from the head of Alexandra Canal. Stormwater in harvested from the channel by a sump near Euston Road which pumps 500-1,000 litres per second into the Sydney Park Stormwater Harvesting ponds to the south-west (Turf Design 2011).

Sheas Creek

Sheas Creek is now a shortened concrete-lined channel upstream of Alexandra Canal. Sections of the Local Roads Upgrades drain into this creek. The creek services the piped drainage system of the upper Alexandra Canal catchment. As previously mentioned a scour patch exists in the base of Alexandra Canal due to the discharge of Sheas Creek. Sydney Water owns roughly a 360 metre section of the creek / channel with the rest belonging to the City of Sydney Council.

Botany Road to Doody Street Channel

The Botany Road to Doody Street channel is a brick lined channel conveying stormwater from the parts of the Alexandria, Beaconsfield and Rosebery pipe drainage system to Alexandra Canal roughly 900 metres downstream of its head. Sections of the Local Roads Upgrades drain into this channel. The catchment is named SW_031 and Sydney water owns the final 630 metres of channel to its discharge point. A moderate amount of vegetation grows alongside the creek in Alexandria. At its discharge point with the canal, there has been some slumping of the channel / canal walls and a prominent patch of weeds exists.

4.2.4 Eastern Channel Catchment

The Eastern Channel catchment includes the suburbs of Tempe, Sydenham, Enmore and Newtown and is about 500 hectares in area. The catchment is heavily urbanised and altered by a relatively even mix of commercial and residential property. The catchment has a very small proportion of open space in the form of recreational parklands.

The Eastern Channel (SWC 66) runs along the Sydenham to Tempe railway line, discharging into the Cooks River. The channel conveys stormwater as a trapezoidal-shaped concrete-lined open channel with 1 to 4 slopes. The main open section is roughly 2.3 kilometres from near Murray Street, Marrickville to its confluence with the Cooks River adjacent to Tempe Station. Part of the channel is tidal due to its connectivity with the Cooks River.

4.3 Catchment land use

The geomorphology and water quality of the watercourses in the study area are closely linked to the land use in each of the catchments. Details of the four catchments considered in this assessment, including size and current land use, are outlined in Table 9.

Table 9 Catchments relevant to the project categorised by land use (per cent)

Land use	Catchment/Sub-catchment							
	Cooks River catchment		Alexandra Canal sub-catchment		Wolli Creek sub-catchment		Eastern Channel sub-catchment	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Commercial	3,343	31	1,409	63	327	16	218	45
Residential	6,389	58	609	27	1,513	72	242	49
Open space	1,169	11	248	10	255	12	30	6
Total sub-catchment area	**10,901**	**100**	**2,266**	**100**	**2,095**	**100**	**490**	**100**

4.4 Geomorphology

Waterways within each catchment consist of a mix of concrete lined and modified watercourses that convey stormwater to the Cooks River. The network of open and partially open channels within the study area, and their geomorphological characteristics, is shown in and Figure 12.

The characteristics of the watercourses in the study area are explained previously in Section 4.2 and Section 4.4. However, in summary, the geomorphology characteristics of the watercourses are primarily categorised as having no potential for lateral or vertical adjustment (concrete channel, piped channel, rock-lined channel, shaped channel and underground concrete channel). The geomorphic characteristics of the watercourses reflect their urban and anthropogenic nature.

Conversely, slopes in part of the study area are greater than ten per cent. This combined in an R factor (rainfall erosivity) of 3000 to 3500 for this area of Sydney presents a high erosion hazard.

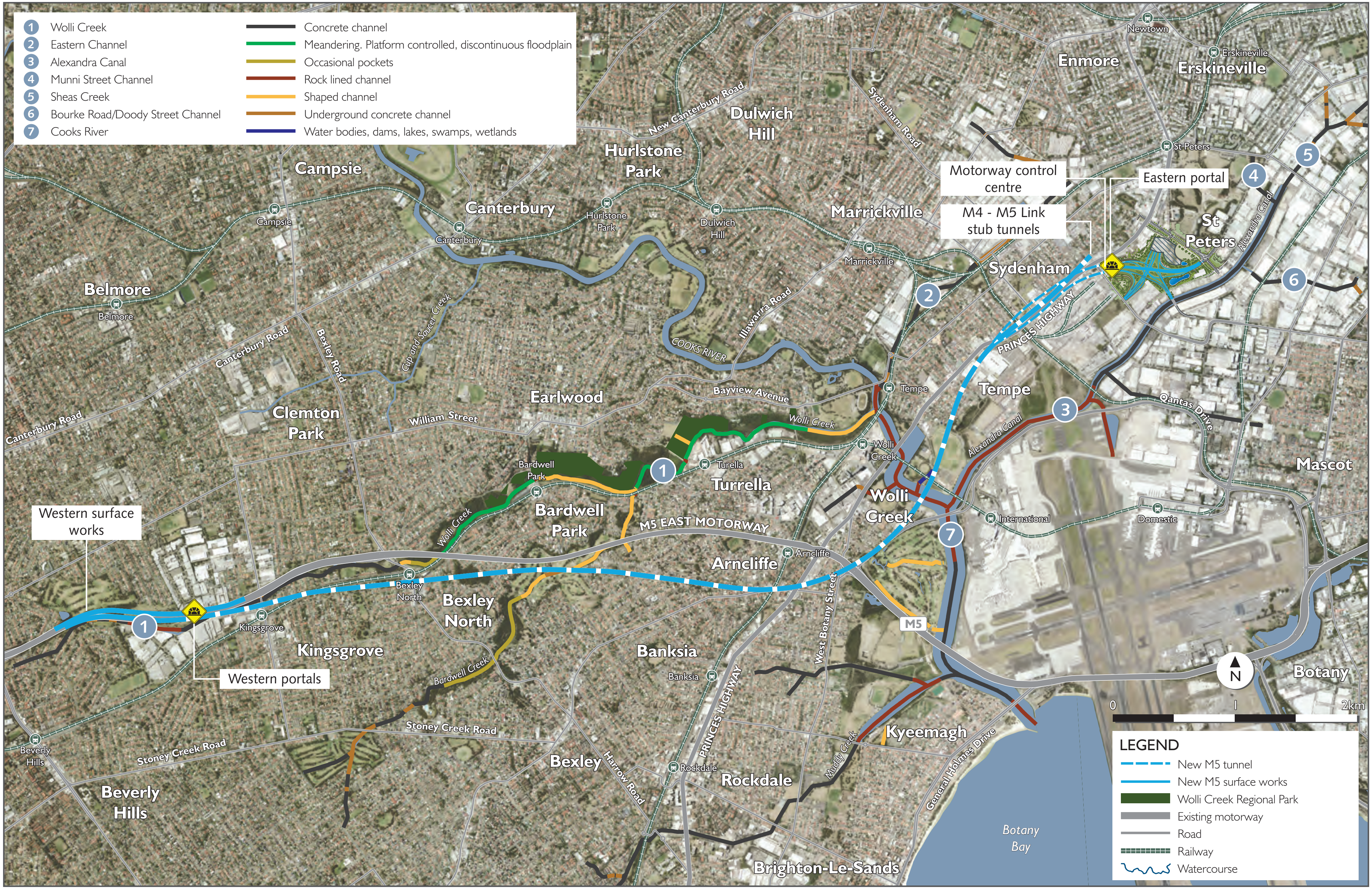

Figure 12 Geomorphology within the surface water study area

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Table 10 Surface water study area Riverstyles® categorisation (Earth Tech, 2007)

River Style Categorisation	Length (metres)	Percentage of study area (%)
Concrete channel	10,230	50
Partly confined channel - Meandering, planform controlled, discontinuous floodplain	2,690	13
Occasional pockets - Confined channel with alternating discontinuous floodplain pockets	270	1
Piped channel	220	1
Rock-lined channel	3,700	18
Shaped channel	1,540	8
Underground concrete channel	1,880	9

4.5 Hydrology and flooding

As discussed in Section 4.2, the study area is located within the Cooks River, Wolli Creek, Alexandra Canal and Eastern Channel catchments. The Wolli Creek catchment is underlain by clay soils and sandstone contributing to low soil permeability. In contrast, the Alexandra Canal and the Eastern Channel catchments are underlain by sandy soils, allowing greater soil permeability and reduced run-off from unsurfaced areas.

Development within the study area is typically well established with a high proportion of residential and commercial land use. Land within the surface water study area is also predominantly of urbanised nature with small pockets of open space, notably along some of the watercourses. Flood risk in the study area has increased since the onset of urbanisation, leading to catchments with a high percentage of impermeable land resulting in increased runoff during rainfall events. In addition, concrete drainage lines, relatively low infiltration and reduced flood storage capacity within the catchments also result in a quick response to rainfall events. This is particularly significant in small, frequent storm events and results in high peak flows which can cause flooding in parts of the study area.

4.5.1 Mainstream flooding

For this assessment, the 20 year, 100 year ARI and PMF flooding conditions within each catchment was considered. Flood extents for these events under present day conditions in the context of surface disturbances areas are shown on Figure 14 to Figure 16.

A detailed description of mainstream flooding of Upper Wolli Creek, Alexandra Canal and the Lower Cooks River under present day conditions is contained in Technical Working Paper: Flooding (Lyall and Associates, 2015). The Eastern Channel has been shown to have sufficient capacity to convey flows up to and including the 100 year ARI flood though not the PMF (WMA, 2011).

4.5.2 Localised flooding and drainage

Localised flooding could occur anywhere in the study area. Localised flooding issues could be further exacerbated by:

- The geological nature of the contributing catchment for example the Wolli Creek catchment is underlain by clay soils and sandstone contributing to low soil permeability
- The topographical nature of the contributing catchments, for example parts of the Local Road Upgrades which are situated in low, flat terrain
- High proportion of impermeable surfaces caused by roofs and hardstand such as roads, car parks and pavements which causes runoff to concentrate rapidly
- Limited capacity in existing piped drainage systems
- Lack of maintenance which could lead to blocked culverts and gully pits, sedimentation build-up within drainage systems and /or collapsed drainage infrastructure
- Backing-up effects into the local drainage system when main watercourses are flooded.

Details and/or observations for each catchment are discussed further below.

Cooks River Catchment

The Cooks River catchment is highly urbanised, with extensive subsurface pit and pipe networks. All of these networks within the study area are located within one of the subcatchments described in this section of the report.

Wolli Creek Catchment

The upper Wolli Creek catchment is completely urbanised with a drainage system comprising extensive pit and pipe networks.

Hyder Consulting prepared the design of the M5 East Motorway and its drainage system, including the transverse drainage lines which convey runoff into Wolli Creek from areas north of the road. The transverse drainage system was designed to convey flows up to the 100 year ARI magnitude. There are no records of major flood events along the existing M5 East Motorway between King Georges Road and Bexley Road (Roads and Maritime, 2015).

Alexandra Canal Catchment

The section of the project within the Alexandra Canal catchment lies on flat terrain of low elevation. The drainage systems are hence placed under pressure during relatively small events. A number of areas within the catchment are known to experience localised flooding including the following within the study area:

- The low points of Euston Road and Burrows Road
- Industrial development bordering Munni Street Channel downstream of Euston Road (Cardno, 2014)
- The intersection of Campbell Road with Euston Road and Burrows Road currently subject to localised flooding (Preliminary stormwater advice for WestConnex St Peters and Alexandra Canal, Sydney Water, 2015).

Eastern Channel Catchment

Stormwater runoff is presently generated by a significant catchment along Campbell Road. From beyond the Princes Highway in the east, the catchment drains towards the intersection of Campbell Street and May Street. The existing piped drainage system at the intersection directs runoff into a 1200 millimetre diameter pipe running to the north-west under Bedwin Road, which in turn discharges into a 1550 by 870 millimetre box culvert that crosses under the adjacent rail line. This box culvert connects into the Eastern Channel on the northern side of the rail line. In larger storm events, stormwater ponds in the intersection before surcharging into an existing detention basin located at the western end of Camdenville Park. The existing basin cannot drain via gravity, and is dewatered by two pumps that direct stormwater into the above-mentioned box culvert.

The intersection of Campbell Street and May Street is frequently flooded as a result of lack of street drainage in areas, limited local inlet capacity in existing piped drainage network and a limited hydraulic capacity in the downstream trunk drainage system (Golder, 2010).

A flooding investigation entitled *EC East Sub-catchment Management Plan Volume 2 – Flood Study* undertaken by Golder Associates (2010) for Marrickville Council provided some further, limited details of existing drainage arrangements, capacity constraints and local flooding behaviour in this area.

4.6 Surface water quality

Results from 2012-13 River Health monitoring for the Cooks River have been presented as the River Health Report Card. The report card rates river health (A^+ = excellent, A-B^+ = Good, B-C^- = Fair, D^+ - F^- = Poor). The River Health Report Card from 2013 that the Cooks River freshwater sites have an ecological condition rated as 'Poor' (D). Estuary conditions the Cooks River were 'Fair" (B) (CRA, 2013). This is consistent with previous studies (PPK, 1999), which showed that the Cooks River catchment is regarded as one of the most polluted urban river catchments in Australia. Water quality in the catchment has been affected historically by stormwater pollution, industrial and domestic wastewater discharge, rubbish dumping and modifications of the waterway. Present levels of pollutants, including nutrients, sediments, toxicants and faecal coliforms make the Cooks River unsafe for swimming, unsuitable for many aquatic species and a health risk for commercial fishing.

A number of past studies were used in generating an understanding of the base case water quality condition in the watercourses that would be subject to impact from the project. Previously collected water quality data was available at a number of locations as outlined in Figure 12. A Water Quality Monitoring Program specific for the project commenced in June 2015 and is ongoing (refer to Appendix B). Where historical data was not available from existing sources, results from the Water Quality Monitoring Program were also used to supplement the data set. Locations of these sites are shown in Appendix B.

The existing water quality data has been provided in tables in the following section, including default ANZECC trigger values for each parameter. The values provided for physical and chemical stressors are those for south-east Australia for slightly to moderately disturbed ecosystems. For toxicants – the trigger for 80 per cent protection of species was chosen for comparison, due to the disturbed water quality of the waterways. As ANZECC guidelines do not set trigger values for highly disturbed ecosystems, a comparison to these trigger values has been made to determine if the waterways within the study area do or do not meet the definition of a slightly to moderately disturbed ecosystem.

Comparison of both historical and recent samples with the ANZECC triggers for slightly to moderately ecosystems shows that the water quality generally does not meet these values. Samples from both historical and recent sampling failed to meet these trigger values for a number of parameters.

The ANZECC Water Quality Guidelines (ANZECC, 2000) guidelines define waterways classified as highly disturbed systems as "*measurably degraded ecosystems of lower ecological value. Examples of highly disturbed systems would be … urban streams receiving road and stormwater runoff….*" (ANZECC, 2000). This supports this assessment that the watercourses are highly disturbed ecosystems. As such, project specific trigger values have been generated by forming a reference data set. This reference data set has been developed to provide guidance on the quality of water that must be produced by water treatment plants to make that water suitable for discharge into the receiving environment. The reference data set has been prepared with the objective to improve water quality of the receiving environment, which is consistent with the objectives of the Botany Bay and Catchment Water Quality Improvement Plan. The method is explained in more detail in Appendix A.

A general comparison of water quality in Wolli Creek, Alexandra and the Cooks River was provided in the Sydney Water Environmental Indicators Compliance Report Volume 3 and measured in 2000/2001 is shown in Table 11. The table provides a summary of measurements taken at a range of locations throughout each watercourse.

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Table 11 Summary of water quality data for 2000/2001 (Woodlots, 2004)

Site	Condition	Wolli Creek		Alexandra Canal		Cooks River		ANZECC (2000) default trigger values*
		Mean	SD	Mean	SD	Mean	SD	
Dissolved Oxygen (per cent Saturation)	**Dry**	62	16	108	47	119	36	80-110
	Wet	73	28	86	34	95	17	
pH	**Dry**	7.5	0.2	7.8	0.4	8.1	0.4	7.0-8.5
	Wet	7.2	0.3	7.3	0.2	7.8	0.7	
Faecal coliforms (CFU/100 mL)	**Dry**	60	1000	46	506	2,058	6,499	<1,000 for secondary contact
	Wet	190,788	193,907	10,954	31464	55,857	60,000	
Faecal enterococci (CFU/100 mL)	**Dry**	66	754	28	509	296	33,985	< 230
	Wet	65,269	77,460	21,909	25,923	53,066	62,929	
Total Phosphorus (mg/L)	**Dry**	0.068	0.029	0.139	0.153	0.281	0.175	0.03
	Wet	0.34	0.19	0.13	0.01	0.315	0.183	
Total Nitrogen (mg/L)	**Dry**	0.86	0.57	1.38	0.99	1.81	1.26	0.3
	Wet	3.46	2.63	1.11	0.44	2.48	1.43	
Chlorophyll ‘a’ (mg/L)	**Dry**	0.012	0.018	0.096	0.213	0.134	0.131	0.004
	Wet	0	0	0	0	0	0	

Shading indicates that recorded data is outside of the respective guidelines

**ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly to moderately disturbed ecosystems in estuaries*

4.6.1 Wolli Creek

In 2014, The City of Rockdale Water Quality Monitoring Study (Equatica, 2014) was released and this included four monitoring sites within the study area (refer Figure 13). Three locations along Wolli Creek, namely:

- Bonalbo Street, Kingsgrove (WC1)
- Roughly 150 metres downstream of Bexley Road, near Slade Road, Bardwell Valley (WC2)
- Henderson Street, Turrella (WC3)
- At a small mangrove wetland between Marsh Street and Levey Street, Wolli Creek, roughly 200 metres from the Cooks River at Marsh Street Bridge (LS 1).

A summary of the parameters analysed during the study is shown Table 12 . The report concluded that Wolli Creek showed:

- Dissolved oxygen (DO) levels higher than guidelines range at the upstream location (Bonalbo Street) and low dissolved oxygen the other locations
- pH levels were generally acceptable, though above the guidelines on one instance at Bonalbo Street and below the threshold on four instances at Henderson Street
- Median turbidity generally falling within the guidelines but exceedance occurs at most sites
- Elevated levels of nutrients (Total Nitrogen (TN), Nitrates (nitrogen oxides, NO_x) and Total Phosphorous (TP) at all sites on the majority of samples. Nitrogen at its highest after the confluence of Bardwell Creek
- High levels of copper at all sites, decreasing downstream where the majority of samples showed acceptable levels
- High levels of zinc at all sites, increasing downstream
- Faecal coliforms (Enterococci) exceeded the guidelines for secondary recreational contact at times at all sites.

The mangrove site near Marsh Street is poorly flushed and was observed to have suspected iron bacteria covering the surface and lower branches of mangroves. Samples showed:

- Dissolved oxygen below the guideline range
- Low pH during some tests
- Turbidity above the guidelines
- Nutrients (TN, NO_x and TP) above the guidelines
- Zinc levels above the threshold
- Faecal coliforms (enterococci) were found above the guidelines for secondary recreational contact.

Sydney Water monitors the intertidal communities at Wolli Creek. In 2007-08 the estuarine health at the Wolli Creek site continued to improve from ‘Mild impact or disturbed’ in 2004-2005, approaching ‘Clean or not disturbed’ in 2005-2006. This improved situation was maintained into 2007. In 2008-09 the community structure of intertidal organisms in 2008-09 at Wolli Creek was comparable to that at control locations having a biological community dominated by oysters and gastropods and can both be regarded as ‘Healthy’ (Marrickville Council, 2009).

4.6.2 Cooks River

The 2011 Annual Water Quality Study by the Cooks River Valley Association (2010/2011) reported on a range of water quality parameters measured by Streamwatch at locations in the Cooks River catchment. Sampling at Younger Road, Earlwood (CR1), Wardell Road, Marrickville (CR2), Bruce Street, Marrickville (CR3) and Richardson Crescent, Tempe (CR4) gave an indication of water quality in the Cooks River, upstream of the project (refer Figure 13). The results of their reporting are summarised in Table 13.

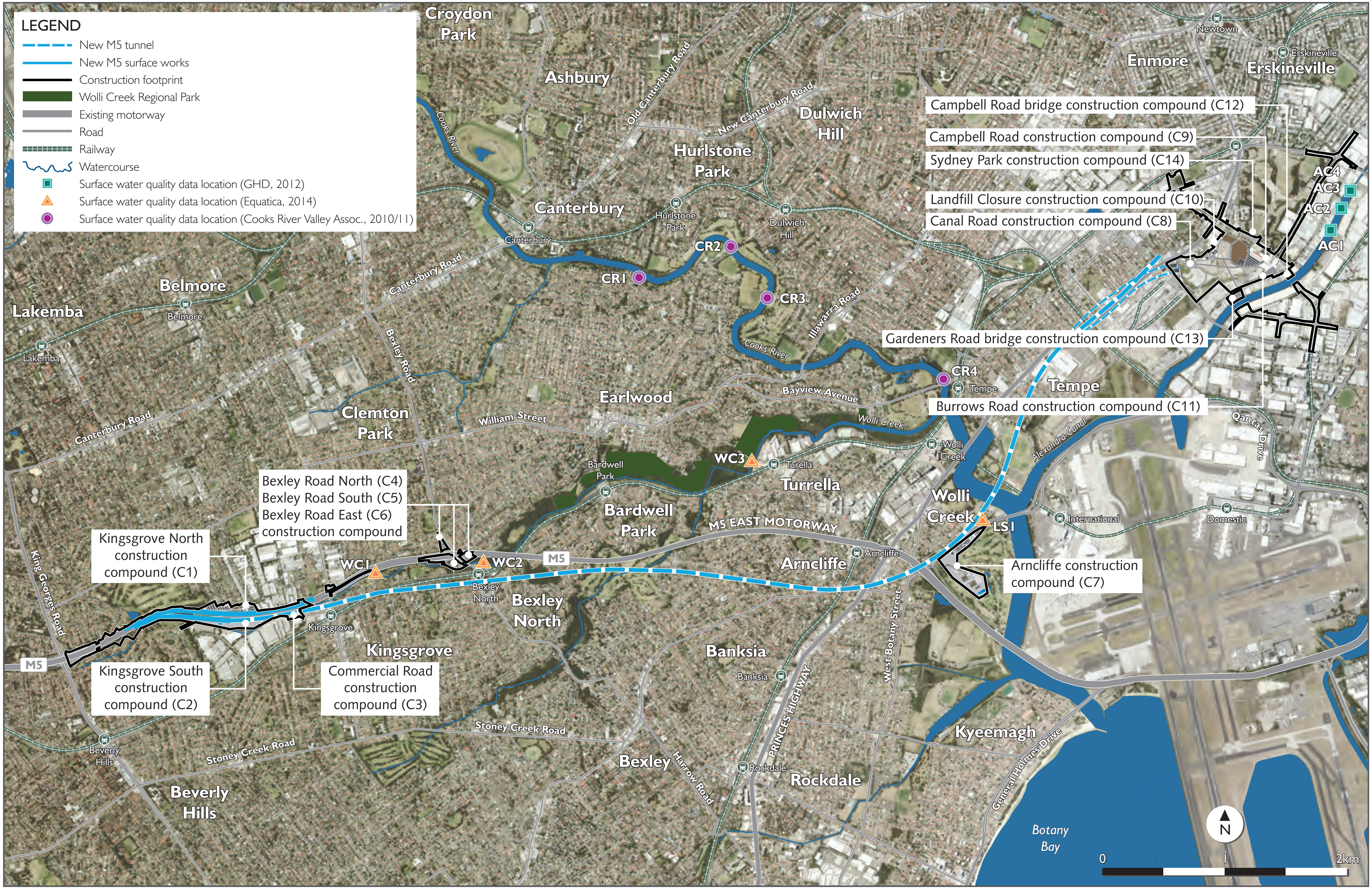

Figure 13 Water quality data locations

The study concluded that water quality at a number of locations in the Cooks River is generally poor with frequent occurrences of test results outside the ANZECC Water Quality Guidelines (ANZECC, 2000). The following were noted at through the four sites

- DO was below the suggested lower threshold at all sites
- Turbidity was above the threshold during all tests at all four sites
- Filterable Reactive Phosphorus was found well above the guidelines at all sites
- E.coli was predominantly above the guideline at all sites
- Faecal coliforms (E.coli) were found at levels above the trigger for secondary contact at Younger Avenue and Wardell Avenue. Test sites further downstream contained fewer coliforms, particularly at Richardsons Crescent where the median of tests were acceptable for primary contact
- pH fell within the guideline range for a majority of samples.

To inform an understanding of metal concentrations in the river, recent samples taken have also been included in Table 14. These show high levels of nutrients as well as copper and zinc. Details of the sample sites are provided in Appendix B.

Prior studies of water quality in the Cooks River catchment have provided the following remarks about various contaminants (CRSMP, 2011):

- Nutrients – Phosphorus and Nitrogen – Found in high levels in the Cooks River. Sources include pets and birds, fertilisers, detergents, sewage discharges and golf courses
- Chlorophyll-a – High levels, at or approaching bloom status
- Faecal Coliforms – High levels found in the Cooks River, exceeding those of recreational guidelines
- Dissolved Oxygen – Depleted levels found in the lower reaches of Cooks River
- Toxicants – Elevated levels of toxicants such as organics and heavy metals have been found in high concentrations in the Cooks River. Fish kills have also been attributed to pesticide use
- Suspended Solids or Turbidity – Results for all Cooks River catchments in the past have indicated results well above the ANZECC Water Quality Guidelines (ANZECC, 2000)
- pH – Results of testing the Cooks River have tended to indicate compliance with pH guidelines.

Rockdale, Canterbury and Marrickville councils along with The University of New South Wales completed sediment sampling between 2008 and 2011 and showed highly contaminated river sediments were present. It was noted that surface sediments were less contaminated than at depth and unlikely to be mobilised, implying that improvements in waste or discharge management in recent years had reduced the transport of contaminated materials to the river. They cited the greater risk of heavy metal mobilisation would be associated with remediation activities (RCC, 2011).

Table 12 Water quality in Rockdale LGA (City of Rockdale Water Quality Monitoring Study (Equatica, 2014))

Parameter	Wolli Creek: Bonalbo St, Kingsgrove (WC1) (Lowland Freshwater River)		Wolli Creek: Slade Rd, Bardwell Valley (WC2) (Lowland Freshwater River)		Levey St Wetland: Henderson St, Turrella (WC3) (Estuary/Marine)		Levey St Wetland: Levey St, Wolli Creek (LS1) (Estuary/Marine)		ANZECC (2000) default trigger values*	
	Range	Median	Range	Median	Range	Median	Range	Median	Lowland rivers	Estuaries
Dissolved oxygen (% Sat)	91-182	135.5	9-109	75.5	15-151	53	13-50	17.5	85-110	80-110
Temp (°C)	12.1-27.5	21.4	9.4-22.8	18.8	10.8-23.6	19.45	15.5-26	21.5	-	-
pH	6.63-8.52	7.205	6.52-7.93	6.865	6.02-7.86	6.65	6.2-7.5	6.965	6.5-8.0	7.0-8.5
Turbidity (NTU)	1.5-290	8.05	2-64	6.7	2.5-23	5.55	15-370	110	6-50	0.5-10
Total suspended solids (TSS) mg/L	5-200	13	5.5-52	16.5	6-13	11	8.5-110	51		
EC (µS/cm)	70-3030	1340	220-4600	725	*	*	*	*	125-2200	n/a
NOx (µg/L)	20-2200	190	20-940	420	170-1900	785	120-210	165	40	15
TKN (µg/L)	300-1800	700	200-3800	750	400-9000	1000	300-2200	1200		
TP (µg/L)	20-130	60	20-320	70	30-230	55	20-320	125	50	30
BOD (mg/L)	2-7.1	2.8	2.3-9.3	4.3	2.4-5.2	2.95	3.4-11	6.9		
Chl - a (ug/L)	< 0.2-< 0.2	< 0.2	< 0.2-< 0.2	< 0.2	< 0.2-< 0.2	< 0.2	< 0.2-< 0.2	< 0.2	5	4
Parameter	**ANZECC (2000) trigger value for protection of 80% of marine species**								**Freshwater**	**Marine Water**
As (µg/L)	<1-2	2	1	1	1-2	1.5	2	2	360 (III) 140 (V)	ID
Cd (µg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.8	36
Cr (µg/L)	<1	<1	<1	<1	<1	<1	<1	<1	40 (VI)	90.6 (III) 85 (VI)

Parameter	Wolli Creek: Bonalbo St, Kingsgrove (WC1) (Lowland Freshwater River)		Wolli Creek: Slade Rd, Bardwell Valley (WC2) (Lowland Freshwater River)		Levey St Wetland: Henderson St, Turrella (WC3) (Estuary/Marine)		Levey St Wetland: Levey St, Wolli Creek (LS1) (Estuary/Marine)		ANZECC (2000) default trigger values*	
	Range	Median	Range	Median	Range	Median	Range	Median	Lowland rivers	Estuaries
Cu (µg/L)	4-8	5.5	3-7	3.5	1-7	2	<1-3	2.5	2.5	8
Pb (µg/L)	<1-2	1.5	<1-1	1	<1-2	2	<1	<1	9.4	12
Ni (µg/L)	<1-1	1	1-3	1	<2-2	1	<3-2	2	17	560[3]
Zn (µg/L)	<5-46	15	9-60	23.5	6-52	33	14-82	51	31	43
Water quality guidelines for recreational waters										
Enterococci (MPN/100 mL)	20-16000	170	74-20000	470	10-9200	114	20-9200	390	35[1]	230[2]

** ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly to moderately disturbed ecosystems. Trigger values for toxicants are for 80 per cent protection of marine species.*
1 = Maximum for any one sample for primary contact associated with recreational purposes.
2 = Maximum for any one sample for secondary contact associated with recreational purposes.
3 = Figure may not protect key test species from acute toxicity (and chronic).
ID = Insufficient data. DO = dissolved oxygen, TSS = Total Suspended Solids, EC = Electrical conductivity, NOx = Nitrate + Nitrite, TKN = Total Kjeldahl Nitrogen, TP = Total Phosphorus, FRP = Filterable Reactive Phosphorus, BOD = Biological Oxygen Demand, Chl-a = Chlorophyll a, As = Arsenic, Cd = Cadmium, Cr = Chromium, Cu = Copper, Pb = Lead, Ni = Nickel, Zn = Zinc.
Shading indicates that recorded data is outside of the respective guidelines.

Table 13 Water quality in the Cooks River (CRVA, 2011)

Parameter	Cooks River								ANZECC (2000) Default Trigger Values*
	Younger Ave, Earlwood (CR1)		Wardell Rd, Marrickville (CR2)		Bruce St, Marrickville (CR3)		Richardsons Cr Marrickville (CR4)		
	Range	Median	Range	Median	Range	Median	Range	Median	
DO %	11-98	40	16-67	32	30-82	55	38-68	56	80-110
Temp (ºC)	12-24	19	14-19	19	14-25	20	12-29	21	-
pH	7.5-9.0	8.5	8	8	8.0-9.0	8.5	8.0-9.0	8	7.0-8.5
TURB (NTU)	15-30	18	<10-20	10	10-15	15	10-20	15	0.5-10
FRP (µg P^{-1})	0-390	180	80-270	160	40-540	130	90-280	140	30
E.coli	100-70,000	2,500	200-6,800	2,000	100-7,300	400	<100-900	<100	1,000*

**ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightlyto moderately disturbed ecosystems (estuaries)*
DO = dissolved oxygen, TURB = Turbidity, FRP = Filterable Reactive Phosphorus, EC = Electrical conductivity
Shading indicates that recorded data is outside of the respective guidelines

Table 14 Water quality in the Cooks River (AECOM, 2015)

Parameter	Site 3 - Cooks River- Levey Street, Wolli Creek &		Site 4 – Cooks River - Riverine Park, Arncliffe		ANZECC (2000) default trigger values*
	Range	Median	Range	Median	Estuaries
NOx (µg/L)	130-290	155	90-870	125	15
TN (µg/L)	500-1300	800	300-1400	700	300
TP (µg/L)	60-90	75	40-140	70	30
Parameter	**ANZECC (2000) trigger value for protection of 80% of marine species for marine water**				
As (µg/L)	10-28	10	1-10	10	ID
Cd (µg/L)	1-5.5	1	0.1-1	1	36
Cr (µg/L)	10-22	10	1-10	10	90.6 (III) 85 (VI)
Cu (µg/L)	10-107	10	7-10	10	8
Pb (µg/L)	10-36	10	4-10	10	12
Ni (µg/L)	10-16	10	1-10	10	560[3]
Zn (µg/L)	50-120	50	21-52	50	43
Mn (µg/L)	10-49	19.5	10-49	11.5	N/A
Fe (µg/L)	440-470	500	240-640	500	N/A

** ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly to moderately disturbed ecosystems. Trigger values for toxicants are for 80 per cent protection of marine species.*

3 = Figure may not protect key test species from acute toxicity (and chronic).

ID = Insufficient data. NOx = Nitrate + Nitrite, TN = Total Nitrogen, TP = Total Phosphorus, As = Arsenic, Cd = Cadmium, Cr = Chromium, Cu = Copper, Pb = Lead, Ni = Nickel, Zn = Zinc, Mn=Manganese

Shading indicates that recorded data is outside of the respective guidelines.

4.6.3 Alexandra Canal

Alexandra Canal is a heavily polluted waterway, impacted by a past and present discharges and runoff. A range of studies conducted within the catchment indicated the following main sources of pollution:

- Stormwater pollution including runoff from roads, industrial, commercial and residential premises
- Seeps and overflows form the sewer system.
- Discharges from industry.
- Contaminated land within the catchment combined with porous soils allowing leachate to migrate via stormwater or groundwater into the canal.
- Release of chemicals from contaminated sediments in the canal into the water column.
- Contaminated groundwater input (DPWS, 2004).

Older sediments are known to be highly contaminated, and these are overlain by more recent less contaminated sediments (UoQ, 2002).

In 2012 Sydney Water engaged GHD to undertake a Review of Environmental factors for the Alexandra Canal (6a Huntley Street, Stormwater Renewal Program). The study included water quality testing at four locations in the upper 350 metres of Alexandra Canal. Sampling locations are shown in Figure 13.

A summary of the parameters analysed during the study in relation to the ANZECC Water Quality Guidelines (ANZECC, 2000) for 80 per cent protection of marine water quality is shown in Table 15.

Table 15 Water sampling results in upper Alexandra Canal (GHD, 2012)

Parameter	Site AC1	Site AC2	Site AC3	Site AC4	ANZECC (2000) trigger value for protection of 80% of marine species
As ($\mu g\ L^{-1}$)	3	3	2	2	ID
Cd ($\mu g\ L^{-1}$)	0.2	0.1	<0.1	<0.1	36
Cr ($\mu g\ L^{-1}$)	<1	<1	<1	<1	85
Cu ($\mu g\ L^{-1}$)	1	3	3	<1	8
Pb ($\mu g\ L^{-1}$)	<1	<1	<1	<1	12
Ni ($\mu g\ L^{-1}$)	28	<1	<1	1	560
Zn ($\mu g\ L^{-1}$)	36	43	50	68	43
Hg ($\mu g\ L^{-1}$)	<0.1	<0.1	<0.1	0.2	1.4
Ammonia as N (μg/L)	540	470	410	-	1,700

Shading indicates that recorded data is outside of the respective guidelines.

The GHD study concluded that metal concentrations in the upper reaches of Alexandra Canal were below the ANZECC Water Quality Guidelines (ANZECC, 2000) for cadmium, chromium, Lead, nickel and mercury and Ammonia. Copper concentrations were greater than the 95 per cent though below the 80 per cent protection level at two sites. Zinc concentrations were greater than the 95 per cent trigger value at all test locations, and the 80 per cent value at other two test sites.

To supplement the data from the GHD study, results from four samples collected in 2015 are shown in Table 16. Details of the site are provided in Appendix B

Table 16 Water quality in Alexandra Canal (AECOM, 2105)

Parameter	Site 1- Alexandra Canal- Via Alexandra Cycleway, near Coward St		ANZECC (2000) default trigger values*
	Range	Median	Estuaries
Dissolved oxygen (% Sat)	34-53	45.5	80-110
Temp (°C)	9.5-19.8	14.6	-
pH	7.27-7.92	7.41	7.0-8.5
Turbidity (NTU)	2.3-256	9.6	0.5-10
EC (µS/cm)	11483-39060	24714	n/a
NOx (µg/L)	270-4710	1285	15
TN (µg/L).	900-5400	2600	300
TP (µg/L)	10-110	55	30

** ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly to moderately disturbed ecosystems. Trigger values for toxicants are for 80% protection of marine species.*

DO = dissolved oxygen, EC = Electrical conductivity, NOx = Nitrate + Nitrite, TN = Total Nitrogen, TP = Total Phosphorus

Shading indicates that recorded data is outside of the respective guidelines.

This data shows elevated levels of nutrients in the canal, almost always above the trigger values for slightly to moderately disturbed ecosystems.

Sydney Water monitors the intertidal communities at the confluence of Alexandra Canal with the Cooks River. From 2007 to 2009 the intertidal communities in Alexandra Canal were considered disturbed, and the canal was found to be poorly flushed with consistently elevated concentrations of chlorophyll-a (Marrickville Council, 2009).

4.6.4 Eastern Channel

Water quality within the Eastern Channel has recently been sampled near Murray Street Marrickville. The results are provided in Table 17 (AECOM, 2015). Details of the site are provided in Appendix B.

Table 17 Water Quality in the Eastern Channel (AECOM, 2015)

Parameter	Site 10- Eastern Channel- Murray St, Marrickville		ANZECC (2000) default trigger values*
	Range	Median	Estuaries
Dissolved oxygen (% Sat)	63-133	75	80-110
Temp (°C)	13.5-19	16.7	-
pH	8-8.8	8.3	7.0-8.5
Turbidity (NTU)	20-249	93.5	0.5-10
EC (µS/cm)	291-765	529	n/a
NOx (µg/L)	150-1580	1070	15
TN (µg/L)	1200-3200	2100	300
TP (µg/L)	30-140	80	30
	ANZECC (2000) trigger value for protection of 80% of marine species in marine water		
As (µg/L)	1-5	3	ID
Cd (µg/L)	0.1-1	<0.1	36
Cr (µg/L)	0.001-0.002	0.0015	90.6 (III) 85 (VI)
Cu (µg/L)	5-20	14	8

Parameter	Site 10- Eastern Channel- Murray St, Marrickville		ANZECC (2000) default trigger values*
	Range	Median	Estuaries
Dissolved oxygen (% Sat)	63-133	75	80-110
Temp (°C)	13.5-19	16.7	-
pH	8-8.8	8.3	7.0-8.5
Turbidity (NTU)	20-249	93.5	0.5-10
EC (µS/cm)	291-765	529	n/a
NOx (µg/L)	150-1580	1070	15
TN (µg/L)	1200-3200	2100	300
TP (µg/L)	30-140	80	30
	ANZECC (2000) trigger value for protection of 80% of marine species in marine water		
Pb (µg/L)	2-13	7.5	12
Ni (µg/L)	2-4	2.5	560[3]
Zn (µg/L)	30-61	42.5	43
Mn (µg/L)	53-64	56	N/A
Fe (µg/L)	600-1950	630	N/A

** ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly to moderately disturbed ecosystems. Trigger values for toxicants are for 80% protection of marine species.*

3 = Figure may not protect key test species from acute toxicity (and chronic).

ID = Insufficient data. DO = dissolved oxygen, EC = Electrical conductivity, NOx = Nitrate + Nitrite, TN = Total Nitrogen, TP = Total Phosphorus, As = Arsenic, Cd = Cadmium, Cr = Chromium, Cu = Copper, Pb = Lead, Ni = Nickel, Zn = Zinc, Mn=Manganese

Shading indicates that recorded data is outside of the respective guidelines.

The data shows that the Eastern Channel is of generally poor water quality – characteristic of a suburban drainage channel. The samples show particularly high levels of nutrients, well above the trigger values for the receiving water, the Cooks River estuary.

4.7 Sensitive receiving environments

The project has the potential to interact with a number of sensitive receiving environments, namely:

- The Cooks River
- Botany Bay
- Towra Point Wetlands
- Saltmarsh and other wetlands around the airport
- Green and Golden Bell Frog ponds at Arncliffe. These were constructed in conjunction with the M5 East Motorway. Water quality data from the two (east and west) ponds is shown in Table 18
- Seagrass in Botany Bay.

Potential impacts on groundwater dependent ecosystems and other sites of ecological significance are provided in Chapter 19 (Groundwater) and Chapter 21 (Biodiversity) of the EIS.

Table 18 Water quality in the Green and Golden Bell Frog ponds (White, 2015)

Parameter	Green and Golden Bell Frog pond – East		Green and Golden Bell Frog pond – West		ANZECC (2000) default trigger values*
	Range	Median	Range	Median	Lowland River
Dissolved oxygen (% Sat)	10.4-21.4	17.9	10.3-20.5	17.7	85-110
Temp (ºC)	16.5-23	17.5	16.5-23	17.5	-
pH	7.2-7.6	7.5	7.3-7.6	7.4	6.5-8.0
Turbidity (NTU)	1.4-5	2.6	1.3-4.8	3.1	6-50
EC (µS/cm)	235-440	337	260-442	341	125-2200

DO = dissolved oxygen, EC = Electrical conductivity.
Shading indicates that recorded data is outside of the respective guidelines.
** ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly to moderately disturbed ecosystems.*

The data shows the ponds have consistently low dissolved oxygen and turbidity, though maintain an acceptable temperature, pH and conductivity / salinity.

5.0 The project

This chapter provides a summary of the potential impacts of the project during construction and operation. A full description of the project is provided in Chapter 5 and Chapter 6 of the EIS.

5.1 Construction

Construction of the project would involve a variety of activities with potential to impact on various aspects of surface water, they include:

- Construction flooding and drainage impacts that could potentially arise from:
  - Construction sites may increase runoff volumes, peak flows and / or time of concentration following rainfall events due to an increase in impermeable surfaces
  - Bunding or spoil stored within construction compounds has the potential to interrupt or divert existing flood routes and also reduce flood storage, increasing flood risk in adjacent areas
  - Drainage infrastructure may become blocked or temporarily diverted due to construction activities. Disruption to local drainage lines may result in localised flooding upstream of the construction compounds
  - Removal of existing pavement could divert flow away from designed drainage structures and into new receiving areas. Diverting drainage lines may also create localised areas of flooding and scour.
- Water quality impacts could potentially arise from:
- Earthworks and exposed soil, followed by wind or rain has the potential to mobilise sediments that could be discharged to local watercourses
- Spills of chemicals or construction materials during construction
- Construction activities adjacent to or within waterways could introduce foreign contaminants such as oil or greases, and disturb contaminated sediments, potentially having an adverse impact on water quality
- The project would increase the impervious surfaces in the road corridor. Consequently, pollutant loads building up on the road surfaces would increase, and greater loads of pollutants may be washed off and discharged to receiving environments
- Contaminated sediments mobilised by works in and around Alexandra Canal
- Discharge of groundwater and construction water extracted during construction.
- Leachate - contaminated runoff during works in the landfill.
- Geomorphology impacts could potentially arise from:
  - Construction activities adjacent to or within watercourses could impact channel bed and bank conditions
  - Water discharged from the construction groundwater water treatment plants may lead to localised erosion within the receiving waters
  - Water discharged from the groundwater water treatment plants may increase the baseflows experienced in receiving waterways, reducing the capacity for the watercourses to convey storm flows
  - Mobilised sediment could build up in the streams
  - Impermeable surfaces created by the project would lead to increases in the volume and rate of runoff, which could cause erosion.

The Construction Environmental Management Plan(s) (CEMP) for the project would include controls and design features to minimise impacts to surface water that could arise from these activities including:

- Construction compounds located within the 20 year Average Recurrence Interval (ARI) flood extent
- Water treatment facilities
- Temporary bunding, drainage and diversion
- Appropriate treatment of contaminated soils and Acid Sulfate Soils (ASS).

5.2 Operation

Operation of the project could impact on various aspects of surface water, these include:

- Localised flooding and drainage impacts could potentially arise from:
  - Increased runoff volumes, peak flows and / or time of concentration following rainfall events due to an increase in impermeable surfaces
  - New built development in flood risk areas would have the potential to interrupt or divert existing overland flow routes.
  - Drainage infrastructure may not have sufficient capacity to accommodate increased inflow rates
- Water quality impacts could potentially arise from:
  - Increased stormwater discharge due to larger and new pavement surface areas
  - Accidental spills and general motor vehicle discretions
  - Discharge of operational wastewater sources, including for maintenance, cleaning and fire deluge systems
  - Discharge of groundwater
  - Discharge of inadequately treated water from the water treatment plants. This includes treated groundwater and leachate captured at the St Peters interchange
  - Contaminated sediments mobilised by scour caused by new infrastructure installed in and around Alexandra Canal.
- Geomorphology impacts could potentially arise from:
  - Impermeable surfaces created by the project would lead to increases in the volume and rate of runoff, which could cause scour
  - Water discharged from treatment plants could change the bed profile and sediment processes.

The project would include controls and design features to minimise impacts that could arise from operational activities including:

- Drainage designs targeted at high levels of flood immunity
- Treatment of pavement drainage and intercepted groundwater before discharge into the receiving waterways
- Upgrades to existing transverse drainage structures
- Armouring in watercourses where the potential for scour is identified.

6.0 Impact assessment – construction

Construction of the project would involve a range of activities at sites of both permanent and temporary occupancy. Activities with the potential to impact surface water include:

- Clearing of vegetation, removal of existing pavement, excavation and stockpiling of spoil prior to reuse or removal from site. These activities could expose underlying soils that could cause erosion, landform instability, sedimentation and reduction in water quality.
- Upgrades to transverse drainage would involve removal of some existing drainage services, during which time the exposed soils may be highly susceptible to erosion and flow paths may be interrupted or diverted.
- Potential spills or leaks of fuels and / or oils can come from maintenance or re-fuelling of construction plant and equipment or vehicle / truck incidents.
- Rinse water from plant washing and concrete slurries may contain polluting contaminants.
- Discharge of treated groundwater from tunnel construction work. The volumes of groundwater and treatment requirements differ depending on the depth of the tunnel to be constructed, and the geological units through which it passes. Groundwater encountered by tunnelling activities would be discharged to either, an existing local drainage network, or, a local watercourse as surface water. The discharge of groundwater has the potential to impact the receiving environment by:
    - Increasing volume and velocity of flows.
    - Causing erosion and potentially modifying channel geometry at the outlet location and downstream.
    - Reducing water quality.
    - Introducing increased sediments, altering channel geometry and potential habitat loss and channel geometry alterations.
    - May result in algal blooms, increase risk to human health and reduction in visual amenity.
- Temporary construction facilities located within flood risk areas, potentially resulting in altered flood storage or conveyance.
- Water used in construction of the project, for activities such as dewatering and dust suppression, has the potential to generate polluted runoff.

A list of construction compound sites and their respective areas facilities and activities is shown in Table 20. There are a number of receiving environments where surface water could be impacted: Wolli Creek, the Cooks River, Alexandra Canal and the Eastern Channel. Each is described in turn.

6.1 Water extraction / use

Water would be used in construction of the project for the following purposes:

- Tunnelling activities such as cooling water and dust suppression
- Surface works such as compaction of pavement materials and dust suppression
- Concrete batching
- Site office and ablutions
- Commissioning of the fire and life safety deluge systems within the tunnels.

Details of water sources and use at each of the construction compounds are outlined in Table 19. Most of the water used would be sourced from the Sydney Water potable supply network. Rainwater would be collected from compound roofs where practical. Treated groundwater would be used on those sites where it is produced, to the extent practical.

Table 19 Total water use during construction period

Compound	Potable water supply from Sydney Water mains (megalitres)	Non-potable water supply (megalitres)		Total (ML)
		Collected rainwater	Treated groundwater	
Kingsgrove North construction compound (C1)	440	1.6	55	497
Kingsgrove South construction compound (C2)	20	-	55	75
Bexley Road construction compounds (C4, C5 and C6)	301	6.8	60	368
Arncliffe construction compound (C7)	480	5.7	100	586
Canal Road construction compound (C8)	340	3.0	70	413
Campbell Road construction compound (C9)	420	0.7	-	421
Euston Road construction compound (C10)	35	0.4	-	35
Burrows Road construction compound (C11)	30	0.1	-	30
Gardeners Road bridge construction compound (C12)	30	-	-	30
Total	**2,096**	**18.3**	**340**	**2,455**

**subject to confirmation during detailed design*

6.2 Flooding and drainage

Flooding during construction of the project could impact areas within and near construction sites. The construction phase footprint is shown in Figure 14 to Figure 16. Flood related impacts during construction phase could include:

- Damage to construction plant or machinery caused by inundation from floodwaters.
- Risk to personal safety of construction workers.
- Increased flooding of adjacent areas due to temporary loss of floodplain storage or conveyance of floodwaters.
- Reduced flood residence times caused by altered hydrologic / hydraulic conditions.

6.2.1 Mainstream flooding

The construction footprint and construction compounds are shown against the 20 year ARI and 100 year ARI flooding extents in Figure 14 to Figure 16. The flooding extents are based on Technical Working Paper: Flooding (Lyall and Associates, 2015).

The construction compounds and associated construction activities, the likelihood for flooding and a summary of the potential impacts is provided in Table 20. These are based on preliminary construction plans and indicative layouts that would be refined in future as the detailed design and site construction planning is further developed.

Tunnelling would occur through temporary shafts at a number of construction compounds (C1, C3, C4, C5, C7 and C8). In addition to this, the western and eastern portals for the project would be formed using cut and cover. Ingress of floodwater into the shafts or portals would pose significant risk to personal safety to those working in the tunnel. Where these facilities occur within the floodplain, protection such as bunding would be provided to ensure floodwaters do not enter shafts or portals. A detailed risk assessment would be undertaken to inform the flood protection measures put in place, prior to construction. The flood immunity that would be adopted would need to take into consideration the duration of construction, magnitude of inflows, including local overland flows, and potential risks. The flood mitigation measures adopted to protect shafts and portals would be designed in a way that would not worsen flooding to adjacent property.

Other mainstream flooding impacts during construction are generally minor in nature. These are readily mitigated by adjusting specific aspects of the compound designs and site planning in a way that recognises the identified flooding conditions in order to minimise the potential for off-site flooding impacts. Typical mitigation measures that would be employed are outlined in Section 8.1.1.

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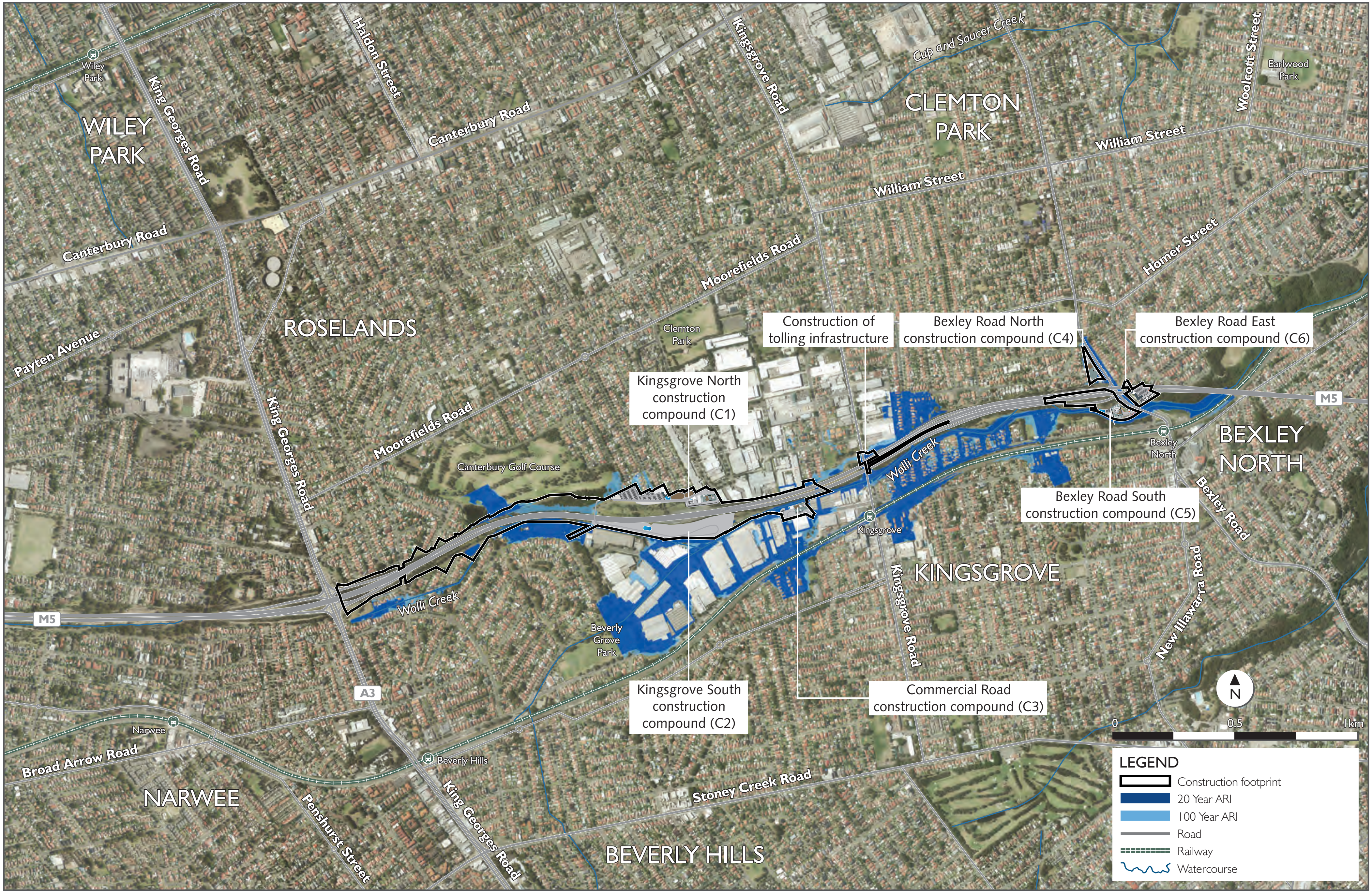

Figure 14 Modelled flood extents - Western surface works

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Figure 15 Modelled flood extents - Arncliffe construction compound

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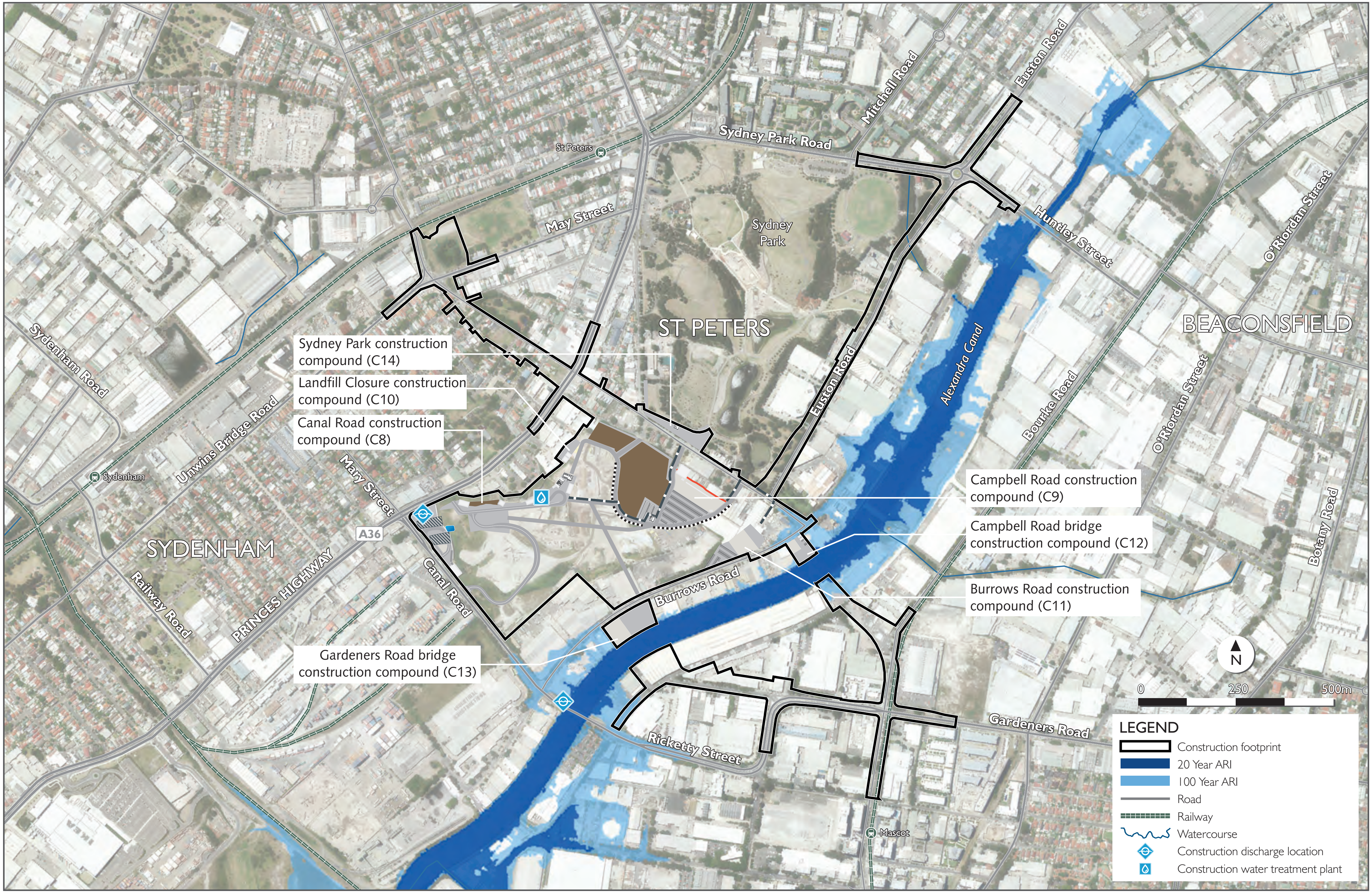

Figure 16 Modelled flood extents - St Peters interchange and local road upgrades

Table 20 Construction compounds and flooding

Compound	Size (ha)	Facilities	Activities	Existing Flooding Conditions	Potential Impacts of activities for 20 year ARI Flooding
Kingsgrove North construction compound C1	2.43	- Site offices - Staff amenities - Parking - Laydown area - Spoil management - Workshop and maintenance - Tunnelling launch and support - Construction water treatment plant	- Demolition of existing structures, including buildings and noise barriers - Establishment of site offices, amenities and temporary infrastructure including noise barriers - Stockpiling of fill and pavement materials as well as materials generated from excavation activities prior to off-site removal - Construction of the cut and cover structure at the eastbound main alignment tunnel entry portal, including piling, concrete works, excavation of structures and installation of a precast concrete roof - Construction and sinking of a shaft for tunnelling works and assembly of an acoustic shed - Excavation of the eastbound main alignment tunnel using a roadheader and associated construction activities, including stockpiling of material and spoil haulage - Installation of mechanical and electrical services within the eastbound main alignment tunnel and fit-out of the tunnel with additional infrastructure (eg signage) - Laydown and storage of materials, including precast concrete - Delivery of materials, plant and equipment.	- Outside of the 20 year ARI flood extent. - Partially within the 100 year ARI flood extent. 100 year flooding predominantly confined to carpark and laydown area. - Tunnel dive shaft outside of PMF.	None anticipated

Compound	Size (ha)	Facilities	Activities	Existing Flooding Conditions	Potential Impacts of activities for 20 year ARI Flooding
Kingsgrove South construction compound C2	3.31	- Site offices - Staff amenities - Parking - Laydown area - Spoil management - Workshop and maintenance	- Demolition of structures, including buildings and noise barriers - Stockpiling of materials, including spoil generated during tunnelling and surface works - Stockpiling of fill and pavement materials as well as materials generated from excavation activities prior to off-site removal - Laydown and storage of materials to be incorporated into permanent works - Construction of the Kingsgrove South motorway operations complex (MOC1) - Demobilisation - Rehabilitation and landscaping.	- Marginally within 20 year and 100 year ARI flood extents along boundaries bordering Wolli Creek. - Due to the local topography the 20 and 100 year ARI flood extents within the compound boundaries are very similar.	None anticipated
Commercial Road construction compound C3	0.59	- Tunnelling launch and support - Construction water treatment plant	- Demolition of existing structures, including buildings and noise barriers - Site establishment, including site offices, amenities, water treatment plant and acoustic shed installation - Construction and sinking of a shaft for tunnelling works - Excavation of the westbound main alignment tunnel using a roadheader and associated construction activities, including stockpiling of material and spoil haulage - Installation of mechanical and electrical services within the westbound tunnel and fit-out of the tunnel with additional infrastructure (eg signage).	Completely within 20 year and 100 year ARI flood extents.	All activities would be impacted by 20 year ARI flood. The acoustic shed and flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. Temporary compensatory drainage works would be implemented to minimise impacts adjacent to existing development as far as practicable.

Compound	Size (ha)	Facilities	Activities	Existing Flooding Conditions	Potential Impacts of activities for 20 year ARI Flooding
Bexley Road North construction compound C4	0.43	- Staff amenities - Laydown area - Spoil management - Workshop and maintenance - Tunnelling launch and support	- Site establishment - Construction of an acoustic shed - Construction and sinking of a shaft for tunnelling works - Decline and tunnel excavation of the eastbound and westbound main alignment tunnels using roadheaders, as well as stockpiling of excavated material and spoil haulage - Installation of mechanical and electrical services within the westbound main alignment tunnel and fit-out of the tunnel with additional infrastructure (eg signage) - Finishing works including landscaping asphalting, line marking and signage installation - Demobilisation.	Completely within 20 year and 100 year ARI flood extents.	All activities would be impacted by 20 year ARI flood. The acoustic shed and flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. However these impacts are unlikely to impact existing development.
Bexley Road South construction compound C5	0.52	- Staff amenities - Parking - Laydown area - Spoil management - Workshop and maintenance - Tunnelling launch and support - Construction water treatment plant	- Site establishment - Construction of an acoustic shed - Construction and sinking of a shaft for tunnelling works - Decline and tunnel excavation of the eastbound and westbound main alignment tunnels using roadheaders, as well as stockpiling of material and spoil haulage - Construction of the Bexley Road South motorway operations complex (MOC2), including a permanent emergency smoke extraction facility and operational ancillary infrastructure - Installation of mechanical and electrical services within the westbound tunnel and fit-out of the tunnel with additional infrastructure (eg signage) - Commissioning of operational ancillary infrastructure (the Bexley motorway operations complex (MOC2)) - Finishing works, including landscaping, asphalting, line marking and signage installation - Demobilisation.	Partially within 20 year and 100 year ARI flood extents, which are similar in outline at this location.	The acoustic shed and flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. However these impacts are unlikely to impact existing development.

Compound	Size (ha)	Facilities	Activities	Existing Flooding Conditions	Potential Impacts of activities for 20 year ARI Flooding
Bexley Road East Construction Compound C6	0.58	- Noise barriers / hoarding - Parking - Site offices - Crib rooms - Ablutions block	- Site establishment, including car parking and site offices - M&E installation - Commissioning - Finishing works including landscaping asphalting, line marking and signage installation - Demobilisation	Completely outside of 100 year ARI flood extent.	None anticipated
Arncliffe Construction Compound C7	4.92	- Site offices - Staff amenities - Parking - Laydown area - Spoil management - Workshop and maintenance - Tunnelling launch and support - Construction water treatment plant	- Site establishment, including clearing, levelling and earthworks - Construction of site offices, amenities, laydown, material storage, water treatment plant and acoustic shed - Construction and excavation of two shafts; one for temporary tunnel access and one for the permanent smoke extraction facility - Decline and tunnel excavation with roadheaders and associated construction activities, including stockpiling of material and spoil haulage - Installation of mechanical and electrical services within the tunnels and fit-out - Construction and commissioning of the Arncliffe motorway operations complex (MOC3), including the emergency smoke extraction facility and operational water treatment plant - Finishing works, including landscaping, asphalting, line marking and signage installation - Demobilisation.	Predominantly within 20 year and 100 year ARI flood extent. Tunnel dive shaft outside of PMF.	The majority of activities would be impacted by flooding although the stockpile and acoustic shed are outside of 20 year ARI. Flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. Design of these measures would give consideration to minimising adverse flooding impacts adjacent to existing development north of Marsh Street as far as practicable.

Compound	Size (ha)	Facilities	Activities	Existing Flooding Conditions	Potential Impacts of activities for 20 year ARI Flooding
Canal Road construction compound C8	2.30	- Site offices - Staff amenities - Parking - Laydown area - Spoil management - Workshop and maintenance - Tunnelling launch and support - Construction water treatment plant	- Site establishment for construction activities associated with eastern portals - Demolition of buildings - Construction of the cut and cover structure at the eastern portals - Installation of piles for the on and off ramps connecting the main alignment tunnels to the St Peters interchange - Construction and commissioning of the St Peters motorway operations complex (MOC4) - Dive excavation for tunnelling activities - Tunnelling support including spoil removal - Civil tunnel back end works (which would include pavement and drainage works) and mechanical and electrical installation - Finishing works including asphalting, line marking, signage installation and landscaping - Demobilisation.	Completely outside of 100 year ARI flood extent	None anticipated
Campbell Road construction compound C9	2.53	- Site offices - Staff amenities - Parking - Laydown area - Spoil management	- Site establishment for construction activities associated with St Peters interchange - Demolition of existing buildings - Construction of the on and off ramps and bridge structures at the St Peters, local road upgrades and shared paths - Construction of carriageways - Tie in with existing roads onto Campbell Road - Finishing works, including asphalting, linemarking, signage installation and landscaping - Demobilisation.	Completely outside of 100 year ARI flood extent	None anticipated

Compound	Size (ha)	Facilities	Activities	Existing Flooding Conditions	Potential Impacts of activities for 20 year ARI Flooding
Landfill Closure construction compound C10	0.15	- Site offices - Staff amenities - Parking - Laydown area - Spoil management	- Site establishment for construction activities associated with the landfill closure works - Installation of access roads, site fencing and barriers - Demolition of buildings - Relocation of utilities - Enabling works - Landfill closure works, including earthworks, foundation treatments and capping - Demobilisation and landscaping.	Completely outside of PMF flood extent	None anticipated
Burrows Road construction compound C11	0.71	- Site offices - Parking - Laydown area - Spoil management	- Site establishment to support construction activities associated with the St Peters interchange and local road upgrades - Demolition of buildings - Construction of hardstand for overflow car parking - Creation of a laydown area and storage of materials for local road upgrades - Construction of the motorway control centre.	Completely outside of 100 year ARI flood extent	None anticipated
Campbell Road bridge construction compound C12	0.32	- Staff amenities - Parking - Laydown area - Spoil management	- Site establishment for the construction activities associated with the new bridge across the Alexandra Canal - Demolition of buildings - Stockpiling of materials for construction works - Utilities relocation - Support for construction of a new bridge across Alexandra Canal - Works to enable tie in with Campbell Road upgrade works - Laydown and storage area for plant and equipment, and permanent materials for bridge works, including precast concrete - Finishing works including landscaping asphalting, line marking and signage installation - Demobilisation.	Partially within the 20 year ARI flood extent. Completely within 100 year ARI flood extent	Potential minor impacts to activities on the immediate banks of canal. No measureable impact on flood storage or conveyance anticipated during a flood event.

Compound	Size (ha)	Facilities	Activities	Existing Flooding Conditions	Potential Impacts of activities for 20 year ARI Flooding
Gardeners Road Bridge construction compound C13	0.82	- Site offices - Staff amenities - Parking - Laydown area - Spoil management	- Site establishment for construction activities associated with the Gardeners Road bridge - Demolition and reinstatement of buildings - Relocation of utilities - Tie-in of the Gardeners Road bridge with the local road upgrades - Storage of bridge construction plant and equipment - Stockpiling of construction materials - Laydown and storage of bridge materials, such as precast concrete - Storage of temporary access platforms for bridge works (western side of the Alexandra Canal) - Pre-assembly of segments, heavy lifts and associated bridge and local road upgrade construction works - Finishing works, including landscaping, asphalting, line marking and signage - Demobilisation.	Only marginally affected by the 20 year ARI flood extent. Partially within 100 year ARI flood extent.	None anticipated
Sydney Park construction compound C14	0.65	- Site offices - Staff amenities - Parking - Laydown area	- Site establishment activities - Construction activities associated with the pedestrian and cycle bridge over Campbell Road - Construction of the bridge over Campbell Road - Construction of a shared pedestrian and cycle path in Sydney Park - Plant and equipment laydown and storage area - Demobilisation.	Completely outside of PMF flood extent	None anticipated

**subject to confirmation during detailed design*

6.2.2 Localised flooding and drainage

All construction works would have the potential to impact local overland flows and existing minor drainage paths. Disruption of existing flow mechanisms, both of constructed drainage systems or those of overland flow paths, could be worsened by the various construction activities and facilities. Specific causes of these impacts could include:

- Disruption of existing drainage networks during decommissioning, upgrade or replacement of drainage pits and pipes.
- Interruption of overland flow paths by installation of temporary construction ancillary facilities.
- Blocking of drainage assets by increased solid loading of surface water.

These would require consideration during future detailed design and construction planning, along with the typical mitigation measures described in Section 8.1.1.

6.2.3 Maintenance of natural flow variability

The discharge of treated ground / construction water would have a minor increase in flow rates of receiving water courses. Alexandra Canal and the Cooks River flow variability is dominated by tides within the study are, hence the project discharges would not impact natural flow variability. Discharge to Wolli Creek would be to the concrete lined section upstream of Bexley Road. Between Bexley Road and the fish weir at Turrella – the discharge would contribute up to 13.1 litres per second to a highly altered reach of creek, affected by both upstream lining and downstream hydraulic controls. This small amount of discharge would not have the potential to impact what was the natural flow variability in the creek.

6.3 Water quality

Potential impacts on surface water quality during construction of the project are considered manageable with the application of standard mitigation measures.

Exposed soils may be eroded by wind or rain, and the eroded soils may lead to water quality issues such as sedimentation in the receiving waters downstream. Soils transported into local waterways can impact water quality through increased turbidity, lowered dissolved oxygen levels, and increased nutrients (nitrogen, phosphorus). The sedimentation may smother aquatic ecosystems and increases in nutrients may contribute to eutrophication.

Drainage works also have the potential to concentrate flows, which may exacerbate erosion. These construction activities pose the greatest risk where they occur near waterways; on steep slopes or on land subject to flow or flooding.

Erosion and sediment loads would gradually diminish with completion of construction activities as the disturbed areas are stabilised and the vegetation of batters start to establish and hold the soils in place.

The key objective during construction would be to minimise erosion of disturbed earthworks areas and to contain any sediments on-site. A preliminary erosion and sedimentation assessment was undertaken for the project in accordance with the *Erosion and Sedimentation Risk Assessment Procedure* (RTA, 2004) – *Appendix 1a &1b for Concept Designs*. This identified the project works to be high risk, with reference to:

- Slopes in parts of the surface water study area with greater than ten per cent grade.
- An R factor (rainfall erosivity) of 3000-3500 for this area of Sydney.

As this presents a high erosion hazard, an Erosion and Sedimentation Management Plan would need to be prepared as outlined in Erosion and Sedimentation Risk Assessment Procedure (RTA, 2004).

Disturbance of contaminated soils or Acid Sulfate Soils (ASS) could affect water quality by liberating acids. There is a high potential for ASS at the Arncliffe construction compound and local road upgrades as well as in sediments in Alexandra Canal. Further contamination investigation would be conducted in areas with medium or high ASS potential. Recommended mitigation and management measures for ASS are provided in Chapter 8.

The following section discusses the potential impacts to water quality by the following key activities and locations:

- Construction water treatment plant discharges
- The western surface works located in proximity to Wolli Creek
- The Arncliffe surface works within the Cooks River catchment
- St Peters interchange and local road works within the Alexandra Canal sub-catchment
- Local road works within the Eastern Channel sub-catchment.

6.3.1 Construction water treatment plants

During construction, tunnelling works would result in significant volumes of wastewater from groundwater ingress and construction activities which would require treatment and disposal. Other sources of wastewater during construction include:

- Water used in dust suppression
- Wash down runoff
- Sewage / grey water from construction compound sites.

Water (including wastewater) volumes generated during the construction of the project would vary based on construction activities that are taking place, the level of groundwater inflow into the tunnel and the length of tunnel that has been excavated.

Groundwater and process water captured during construction would be contaminated with total suspended solids and increased pH levels due to tunnelling and concreting activities. An estimated quality of groundwater influent based on that of the existing M5 East Motorway water treatment plant is shown in Table 21. Estimated quality of existing M5 East Motorway groundwater influent, categorised for contaminated or uncontaminated groundwater is provided in Table 22. These were obtained from *Geotechnical, Hydrological and Contamination Interpretive Report*, (Golder Associates) and the current influent operation data from the M5 East Motorway water treatment plant (M5 East Water Quality Records).

Groundwater collected during construction would also have varying levels of salinity. In some parts, particularly under the estuarine reaches of Wolli Creek, the Cooks River and Alexandra Canal, salinity levels would potentially be high.

Table 21 Groundwater influent water quality measured from M5 East Motorway water treatment plant at Turrella.

	Iron (mg/L)	TSS (mg/L)	Turbidity (NTU)	O&G (mg/L)	pH
Median	16.5	38.5	32.2	0	5.8 (min)
Maximum	91.0	440	211	14	8.1

Table 22 Expected groundwater influent concentrations

Parameter	Contaminated groundwater		Groundwater	
	Average	Peak	Average	Peak
Flow (kL/day)		700		1,037
Flow (L/s)		8.1		12
Ammonia load (kg/d)	19.8	76	0	0
TDs load (kg/d)	472	1,228	145	415
Cyanide load (kg/d)	0.009		0	0
Iron Load (kg/d)	11.5	63.7	17	94
TPH (kg/d)	0.06	0.9	0	0
Phenols (kg/d)	0.0003	0.014	0	0

During construction, water captured from both surface flows and groundwater would be collected in sumps and pumped to holding tanks, which would be pumped to the construction water treatment plants located at each of the four main construction compounds as shown in Figure 17 and Figure 18, and as listed in Table 23.

Table 23 Expected treatment plant discharge volumes

Location	Receiving watercourse	Discharge daily flow L/s (ML/d)
Kingsgrove North construction compound (C1)	Wolli Creek	2.8 (0.09)
Kingsgrove South construction compound (C2)	Wolli Creek	2.8 (0.24)
Bexley Road construction compounds (C4-C6)	Wolli Creek	7.6 (0.66)
Arncliffe construction compound (C7)	Cooks River	11.6 (1.00)
St Peters interchange	Alexandra Canal	7.2 (0.62)

**subject to confirmation during detailed design*

Each water treatment plant would comprise a series of modular water-tight tanks with automated probes and dosing units designed to test and treat the water to the required standard. Water treatment would typically need to involve:

- Flocculation to remove total suspended solids
- Reverse osmosis to reduce salinity and dissolved solids
- Correction of pH level through the addition of lime or acid
- Treatment of elevated levels of iron and manganese
- Treatment of salinity and other contaminants such as ammonia, where necessary.

The treatment train adopted for each plant would vary depending on the origin of water being treated at each plant. However, the construction water treatment plants would be designed to a minimum standard that would meet the water quality reference criteria (AECOM, 2015) (refer to Appendix A).

Treated wastewater would be reused where possible, such as dust suppression. However it is anticipated that there would be an excess of wastewater from the water treatment plants. The water treatment plants would discharge treated water to the existing stormwater drainage systems, which would eventually discharge into the Cooks River via its tributaries including Wolli Creek.

The waterways that would receive discharges during construction are highly disturbed ecosystems, as described in Section 4.6. The water quality reference criteria have been developed to improve water quality of these receiving environments. As such, provided the criteria are met, there would be a low risk of adverse impacts of treated water discharges on the water quality of the receiving environment.

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Figure 17 Location of construction water treatment plants and discharge locations - Kingsgrove and Bexley Road construction compounds

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Figure 18 Location of construction water treatment plants and discharge locations - Arncliffe and St Peters interchange

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6.3.2 Wolli Creek

Construction of the project would involve extensive works within the Wolli Creek catchment. The extent of works includes the western surface works, the Kingsgrove surface works and Bexley Road surface works, and includes construction compounds. These activities have the potential to impact surface water within the study area and an assessment of these impacts has led to the following:

- Stockpiling of spoil and construction materials could present a risk to water quality. However, this would predominantly occur within the acoustic sheds. The sheds would minimise the potential for transport of spoil sediments by both wind and rain.
- Runoff from these construction compounds would drain to the concrete lined tributary of Wolli Creek and the main arm of Wolli Creek. Runoff could impact these environments by delivering sediments and pollutants to Wolli Creek. Wolli Creek is a highly disturbed environment, where the water quality is known to be highly turbid, with elevated nutrient and heavy metal concentrations (refer to Section 4.6). Unmitigated runoff from the project during the construction phase would place increasing pressure on this already stressed environment. Mitigation measures would be required to reduce the potential for environmental impacts arising during construction. Provided that appropriate controls are implemented during construction, short term impacts are expected to be manageable and expected to have no material impact on receiving water quality.
- During construction, an existing water quality wetland would be removed with a replacement wet basin constructed. The basin currently treats pavement runoff from a catchment of 2.21 hectares of the existing M5 East Motorway. The decommissioning of the wetland would not occur until replacement water quality devices are in operation.

6.3.3 Cooks River

The Arncliffe surface works would include the establishment and use of the Arncliffe construction compound (C7) as outlined in Table 20.

Runoff from these construction compounds would drain to the Cooks River, which is a heavily polluted waterway with poor water quality and contaminated sediments (refer to Section 4.6). The location of this compound is very close to the mouth of the Cooks River and Botany Bay. Botany Bay and its estuaries are associated with significant biodiversity and other environmental values as well as significant community, environmental and social values.

Runoff from construction areas could impact this environment by delivering sediments and pollutants to the river. Spoil and other construction materials would also be stockpiled at the site. As discussed earlier, there is also a high risk of ASS. Unmitigated runoff from the project during the construction phase would place increasing pressure on the already-stressed Cooks River, and could endanger the ecological health of Botany Bay. Mitigation measures would be required to reduce the potential for environmental impacts arising during construction.

One sensitive environment in particularly close proximity to construction is the RTA ponds that provide breeding habitat for Green and Golden Bell Frog near Marsh Street, Arncliffe. The species also utilise most of the Kogarah Golf Course for foraging, sheltering and occasionally breeding. Certain golf course ponds located within the construction footprint would be decommissioned. The golf course ponds are expected to have poor water quality due to nutrient runoff associated with golf course management activities.

Dust generated by construction activity, if not properly managed, has the potential to impact the water quality of the RTA ponds and frog habitat on the golf course. The use of sheds for spoil handling, and dust suppression measures would mitigate and manage the potential for indirect impacts. Additional measures specific to the species and project are also detailed in the plan of management (Eco Logical Australia, 2015). As such, the construction activity is not expected to impact the water quality of the RTA ponds or surrounding habitat. It is a commitment in the plan of management to undertake water quality monitoring of the RTA ponds. More detail on the water quality monitoring regime including frequency, sampling locations and parameters would be provided in the Habitat Creation and Captive Breeding Plan due for completion by March 2016.

Provided that appropriate controls are implemented during construction, short term impacts are expected to be manageable and expected to have no material impact on receiving water quality.

6.3.4 Alexandra Canal

Construction of the project would involve extensive works within the Alexandra Canal catchment. The areas of construction compounds are shown previously in Table 20. These activities have the potential to impact surface water in the surface water study area. An assessment of these impacts has led to the following:

- Stockpiling of spoil and construction materials could present a risk to water quality. In some instances, stockpiling would be within sheds. Mitigation and management measures would be implemented to manage risks to water quality.
- Runoff from some construction compounds would drain to Alexandra Canal. Runoff from construction areas could impact these environments by delivering sediments and pollutants to the canal. Alexandra Canal is a heavily polluted waterway with poor water quality and contaminated sediments (refer Section 4.6). Unmitigated runoff from the project during the construction phase would place increasing pressure on this already stressed environment.
- Construction of the bridges over Alexandra Canal would not involve installation of any piers within the canal. However, works would occur in close proximity to the canal. Runoff from these activities would be managed to minimise potential impacts to water quality within the canal.
- Construction of new stormwater outlets along the canal (as outlined in 7.3.2) is likely to cause localised mobilisation of sediment, however, it is considered unlikely that sediments mobilised as a result of the impact of the new outlets would extend a significant distance from the stormwater discharge point given that the canal has a very low sediment transport capacity. More information is provided on contaminated sediments in Technical Working Paper: Contamination (AECOM, 2015).

Mitigation measures (as described in Section 8.1.2) would be required to reduce the potential for environmental impacts arising during construction. Provided that appropriate controls are implemented during construction, short term impacts are expected to be manageable and expected to have no material impact on receiving water quality.

Landfill runoff

The Alexandria landfill site would be closed in preliminary works for the St Peters interchange. This closure would involve landscaping and subsequent disruption drainage and overland paths. Leachate would continue to be captured and treated in the existing leachate treatment plant up until commissioning of the new leachate treatment plant. The plant would continue to discharge to the local sewer.

Surface runoff could potentially become contaminated at the site. Non contaminated runoff would be capture by existing drainage lines which discharge to Alexandra Canal. The quality of this runoff, including control of sediment levels would be managed by methods outlined in Managing Urban Stormwater-Soils and Construction, Volume 1 (Landcom, 2004). Where runoff has the potential to be contaminated, it would be captured and directed to the leachate treatment plant for treatment before discharge to sewer under a trade waste agreement.

6.3.5 Eastern Channel

Construction activities in the Eastern Channel catchment would occur as a result of upgrades to road and drainage structures and works at the existing water quality basin in Camdenville Park as outlined in Table 20.

Runoff from construction areas could impact the receiving environment by delivering sediments and pollutants to the channel. Water quality within the Eastern Channel is not yet known, but due to its direct connection to the Cooks River, and proximity with similar in land use to Alexandra Canal, it is expected that the water quality would be similar to these other watercourses, characterised by high turbidity, high nutrients, pathogens and toxicants (refer Section 4.6). The Eastern Channel, being concrete-lined has little habitat value per se, but is an efficient conveyance for water that would impact upon the ecosystem health of the Cooks River. Therefore, unmitigated runoff from the project during the construction phase would place increasing pressure on the already stressed environment of the Cooks River, and would undermine attempts by the surrounding community and stakeholders to improve the ecosystem health of the Cooks River.

6.4 Geomorphology

The potential impacts on the geomorphic condition (refer Figure 12) of watercourses during construction of the project are considered minor and manageable with the application of current best practice construction mitigation measures.

Direct construction activities within or adjacent to the watercourse and / or riparian zone are likely to involve the clearing of vegetation and excavation of channel bed and bank areas, including installation of bridge abutments. These direct activities are likely to disturb the existing floodplain and / or in-channel geomorphic units, exposing them to scour erosion, altering the trajectory of the channel planform.

Discharge from the outlets of the groundwater treatment system and upgrade of existing drainage infrastructure have the potential to concentrate flows, which may exacerbate erosion. Erosion can lead to channel deepening (bed incision) and channel widening (channel bank lateral expansion and / or migration), altering the trajectory of the channel planform. Locations of discharges from construction water treatment plants are shown in Figure 17.

Construction areas where soil has been exposed and / or weakened by construction activities can be eroded / mobilised by wind or runoff, have the potential to deposit sediments in receiving waterways. Sediments can fill and smoother in-stream geomorphic units and habitat features such as pools and riffles. Furthermore, sediments can accumulation at in-stream barriers and constrictions, which may result in localised flooding and / or channel avulsion (a new altered flow path around an in-stream barrier).

Erosion and sediment loads would gradually diminish after construction as the disturbed areas are stabilised and the vegetation of batters start to establish and hold the soils in place. The key objective is to minimise erosion of disturbed earthworks areas and to contain any sediments on-site before they enter the riparian zone and watercourse / drainage system.

Other potential construction impacts on the geomorphology include: increased impermeable area and / or altered flow paths that may result in increased over bank flows entering the waterway causing erosion; tunnelling activities causing bedrock fracturing and / or subsidence with the watercourse bed.

6.4.1 Wolli Creek

The western surface works have the potential to expose and weaken the terrestrial surface soils. Wind or rainfall may lead to the mobilisation and deposition of these sediments into the channel. Whilst discharges would be into the concrete lined reach of the creek, sediments could be transported to the natural reaches downstream of Bexley Road. With the implementation of best practice sediment and erosion control measures, these impacts can be mitigated.

Kingsgrove surface works would primarily occur within paved areas, with limited disturbance to soils and changes to drainage.

The construction works at the Bexley Road surface works would include clearing of a small portion of grassed / vegetated parkland. Some of this land lies on steep grades and hence have the potential for scour and bank failure in flood events. This is particularly relevant within the Bexley Road South construction compound which is immediately adjacent to Wolli Creek.

Construction and upgrades to the existing drainage and new outlets attributed to the western surface works including a treated groundwater discharge outlet would have the potential to cause localised impacts, such as weaken bed and bank soil structure, localised erosion and mobilisation of sediments.

At western surface works, treated water would be discharged at two locations, each with a discharge rate of up to 2.8 litres per second of treated water. An additional 7.6 litres per second of treated water would be discharged at Bexley Road. The total discharge volume of equating to 13.2 litres per second would enter Wolli Creek during construction.

When compared to the one year ARI flow of 58.9 cubic metres per second at Bexley Road (PB-MWH, 2009), this discharge would contribute an increase of 0.02 per cent. This is a relatively insignificant increase in flow that would likely have minimal impact on stream levels and velocities in the creek hence it is not expected to impact the geomorphology of the creek.

Tunnelling would occur beneath Wolli Creek and its tributaries. The construction methodology would minimise potential impacts to surface geology, such as fracturing and subsidence. As a result no impact on the geomorphology of the watercourses is expected.

6.4.2 Cooks River

A number of construction activities would occur at the Arncliffe surface works, including stockpiling of spoil and construction materials, wastewater treatment and associated discharge infrastructure and outlet at the Cooks River. Construction of the project would result in discharging up to 20 litres per second of treated water into the Cooks River adjacent to Kogarah Golf Course via the existing stormwater system.

When compared to the one year ARI flow of 357.3 cubic metres per second (PB-MWH, 2009), the estimated rate of discharge to Botany Bay from the treatment plant is a very small (less than 0.01 per cent increase). At this location the river is almost fully tidal due to its close proximity to Botany Bay. This small inflow would not impact the geomorphology of the river.

At the outlet location, scour resulting from the discharges related to construction activities has the potential to locally impact the floodplain, bank and bed morphology at the outlet location.

Tunnelling would occur beneath the Cooks River. The construction methodology would minimise potential impacts to surface geology, such as fracturing and subsidence. As a result no impact on the geomorphology of the watercourses is expected.

6.4.3 Alexandra Canal

Bridge construction works would occur at Campbell Road and Gardeners Road, although no piers would be installed within the canal.

Construction and upgrades to the existing drainage and new outlets adjacent to Campbell Road and Gardeners Road bridges have the potential to cause localised impacts, such as weaken bed soil structure, localised erosion and mobilisation of sediments.

Construction of the project would result in up to 7.2 litres per second of treated water discharged at the Ricketty Street Bridge via the existing stormwater system. Contaminated leachate and runoff would be discharged into sewer under a trade waste agreement.

When compared to the one year ARI flow of 83.9 cubic metres per second at its confluence with the Cooks River (PB-MWH, 2009), this discharge would contribute an increase of 0.02 per cent. This is a relatively insignificant increase in flow that would likely have minimal impact on levels and velocities in the canal hence it is not expected to impact the geomorphology of the canal.

6.4.4 Eastern Channel

No discharges would be made to the Eastern Channel during construction of the project. A small extent of land clearing would create the potential for materials to be transported into the existing stormwater detention basin in Camdenville Park thought not the channel itself.

6.5 Cumulative impacts

The project area is within a continually altering urban environment. Further developments are likely to occur in or around the project area during and after construction of the project. These include other works on the WestConnex program, as well as mixed used, residential, rail, commercial and precinct developments.

For water quality and geomorphology, the key potential construction related impacts are erosion of exposed soil resulting in sedimentation and water pollution associated with sediment-laden runoff. Although this might be considered a temporary impact, ongoing re-development within the catchment has the potential to persistently expose the receiving environment to these impacts. These cumulative impacts would be managed through proper implementation of the respective Construction Environmental Management Plans (CEMPs).

Significant works are currently underway directly to the west of the project as part of the King Georges Road Interchange Upgrade. The project has produced a Construction Soil and Water Quality Management Plan that has sufficient mitigation measures to significantly minimise the potential for cumulative impacts with the project (Fulton Hogan, 2015).

In regards to flooding, if other construction activities are not in close proximity to the project, cumulative temporary flood impacts are not considered likely. The King Georges Road Interchange Upgrade are not expected to exacerbate flooding in the study are as the only works in the same catchment are upstream of the project (Jacobs, 2014).

7.0 Impact assessment – operation

Operation of the project has the potential to result in impacts to surface water from the following activities:

- Increased impervious surfaces and changes to the total catchment area of existing drainage infrastructure due to surface work at tunnel portals and tie-ins to existing roads. This could lead to potential localised flooding. Considerable increases to runoff at these locations require upgrades to existing drainage infrastructure, and may require additional mitigation measures (such as stormwater drainage basins and the like).
- Potential obstruction to flood flows as a result of new infrastructure and reductions in flood plain, which could have an impact on downstream flooding behaviour or on nearby existing developments.
- Impact to water quality of receiving watercourses due to the discharge of treated groundwater and other waste waters (such as tunnel wash or deluge system water). The discharge would be into Cooks River. This could have an impact on the water quality of the receiving waterway, depending on the discharge volumes and prior level of treatment.
- Impact to water quality of receiving watercourses due to increased runoff from roads. This would typically contain oils and greases, petrochemicals and heavy metals as a result of vehicle leaks, operational wear, road wear and atmospheric deposition. Increased flows could also lead to increased potential for scouring of soils and watercourses.
- Spills or leaks of fuels and / or oils from vehicle accidents, or from operational plant and equipment.
- Impact to the geomorphology of receiving watercourses due to the discharge of treated groundwater and other waste waters (such as tunnel wash or deluge system water). The discharge would be into the Cooks River near Marsh Street Bridge.

A list of operational facilities and their respective areas is show in Table 24.

Table 24 Operational infrastructure following completion of the project

Catchment	Facilities	Combined footprint (ha)
Wolli Creek	- Kingsgrove motorway operations complex (Op1) - Bexley Road South motorway operations complex (Op2) - Noise barriers - Substations - Western surface works - Western portals	22.7
Cooks River	- Arncliffe motorway operations complex (Op3), including substation, operational water treatment plant and emergency smoke extraction facility	1.7
Alexandra Canal	- St Peters interchange - Local Road Upgrades and connections - Motorway operations complexes	44.7
Eastern Channel	- Road upgrades - Water quality / detention upgrades	3.6
Total		**72.7**

**subject to confirmation during detailed design*

7.1 Water extraction / use

Water used for various operational activities such as building use, emergency deluge and cleaning would be sourced from Sydney Water mains. Alternative sources to potable water (such as rainwater and treated wastewater) would be investigated during detailed design.

Opportunities for reuse of treated water generated by the Arncliffe motorway operations complex would be considered in preference to discharge to the stormwater system, including irrigation of landscaped areas within the project, and / or local parks.

7.2 Flooding and drainage

The project crosses a number of creeks and watercourses and their associated floodplains. A range of works would occur within these floodplains, constructing new embankments, noise barriers, bridge abutments, surface road works, treatment and operational facility structures. Any works within the floodplain have the potential to change flood behaviour and adversely impact on the surrounding environment.

In accordance with the Floodplain Development Manual, the design of the project would manage the extent of impacts on the surrounding environment. Mainstream flooding of these waterways has been assessed in the Technical Working Paper: Flooding (Lyall and Associates, 2015).

The pavement drainage system would convey runoff collected form the 10 year ARI rainfall event. Drainage infrastructure would minimise stormwater flow widths to shoulders, or one metre into the adjacent traffic lane if they are not provided.

The following sections provide an outline of the potential localised flooding and drainage impacts attributed to the project assessed within each catchment.

7.2.1 Tunnel drainage

Twin underground motorway tunnels would extend from Beverly Hills to St Peters. Flooding of the tunnels has the potential to pose a risk to life of motorists. Consequently entries to the tunnels have been protected from the PMF through use of:

- Elevated portal levels
- Bunding
- Catch drains.

This was done in order to minimise the potential for floodwaters entering the tunnel. The tunnel drainage systems would be designed to cater for the flows produced by a range of sources including stormwater, spills, deluge and firefighting water and groundwater inflow.

The worst case credible combination of flows – for design of tunnel sumps and pumps, would be taken as the sum of:

- Fire deluge from 60 metres of tunnel
- Three hydrants
- A tanker spill
- Runoff from cleaning up a tanker spill
- Groundwater seepage.

7.2.2 Localised flooding and drainage

Wolli Creek

The western surface works are located adjacent to Wolli Creek. New pipe connections would be installed where the existing transverse drainage has been impacted by the upgrade and / or require relocation. Indicative details of new and upgraded trunk and transverse drainage infrastructure upgrades that would be required in the Wolli Creek catchment are outlined in Table 25. These would be confirmed during detailed design.

Pavement drainage would be designed for the 10 year ARI event – with pits spaced to limit flow width to shoulders where provided or one metre into the adjoining traffic lane where no shoulder is provided. An indicative list of new discharge locations in the catchment is shown in Table 26.

Table 25 Proposed trunk and transverse drainage upgrades in Wolli Creek catchment

Location	Details*
North of alignment. Kirrang Street to Kooemba Road	New 3000 x 2400 RCBC beneath shared path
North of alignment Kooemba Road toward east	Replacement concrete lined open channel. Minimum 4850 base width x 1800 minimum height
Transverse drainage at Ch. 1200	Extension of 2 x 2400 x1800 by around 30 metres
Transverse drainage from Canterbury Golf Course	Extension 1200 and 1350 RCP extended by around 25 metres each
Transverse drainage from Canterbury Golf Course	Upgrade existing 1050 RCP to 1350 and divert for around 40 metres
Transverse drainage from parkland near south-east corner of Canterbury Golf Course	Divert existing transverse-drainage by construction of new 2 x1500 RCP's
Transverse drainage from parkland near south-east corner of Canterbury Golf Course	New 750 to divert drainage away from road to allow for tunnel portal cut and cover. Slotted F type barrier.
North of alignment near south-east corner of Canterbury Golf Course	New 750 surface stormwater pipe beneath shallow batter
North of alignment	New rock mattress channel
Near western ventilation station	New concrete lined drainage channel
Transverse drainage at Ch. 2180	New 1800 transverse drainage pipe

**subject to confirmation during detailed design*

Table 26 Proposed new discharge locations in the Wolli Creek catchment

Location Ch.	Discharging structure*	Drainage input	Discharges to
1350	600 millimetre pipe	Pavement drainage	Into existing concrete channel
1580	450 millimetre pipe	Pavement drainage	Connect to existing stormwater system
1815	2x1500 RCBC	Transverse drainage	Wolli Creek concrete lined channel
1825	450 millimetre pipe	Pavement drainage	Existing drainage system
2190	1800 millimetre pipe	Transverse drainage	Into existing concrete channel
2210	525 millimetre pipe	Pavement drainage	Into existing concrete channel

**subject to confirmation during detailed design*

In the western part of the corridor the project would connect to the pavement drainage system of the existing M5 East Motorway. The design would incorporate the existing M5 East Motorway drainage network where necessary. The potential for the works to result in localised flooding issues along the existing M5 East Motorway are considered minimal as any alterations to the existing system would be in the form of upgrades leading to an increase in conveyance capacity.

Alexandra Canal

The project is located in the Alexandra Canal catchment. New pipe connections would be installed where the existing transverse drainage has been impacted by the upgrade and / or require relocation. Indicative details of new and upgraded trunk and transverse drainage infrastructure upgrades that would be required in the Alexandra Canal catchment are outlined in Table 27.

An indicative list of new discharge locations in the catchment is shown in Table 28. These would be confirmed during detailed design

Table 27 Proposed trunk and transverse drainage upgrades in the Alexandra Canal catchment

Location	Details*
Euston Road north of Campbell Road	New 600 millimetre RCP transverse drainage toward water quality basin
Euston Road north of Campbell Road	New 1350 millimetre RCP transverse drainage toward culvert
Euston Road over Munni Street Channel	Stormwater drainage channel to be altered to allow for road widening above.
Campbell Road near Harber Street	New 1350 millimetre RCP transverse drainage
Campbell Street near Sydney Park Road	Connect existing piped drainage system to new 900 millimetre stormwater pipe

**subject to confirmation during detailed design*

Table 28 Proposed new discharge locations in the Alexandra Canal catchment

Location Ch.	Discharging structure*	Drainage input	Discharges to
Western bank of Alexandra Canal, south of Campbell Road	3300 x 2400 open channel	Pavement and transverse drainage from St Peters interchange	Alexandra Canal
Eastern bank of Alexandra Canal, south of Campbell Road	525 millimetre pipe	Pavement drainage	Alexandra Canal
Canal Road	2 x 450 millimetre pipe	Grass lined drainage channels from St Peters interchange landscaping	Existing piped drainage system
Canal Road	450 and 675 millimetre pipe	Pavement drainage	Existing piped drainage system
Burrows Road	450 millimetre pipe	Pavement drainage	Existing piped drainage system
Bourke Road 100m north of Campbell Road extension	450 millimetre pipe	Pavement drainage	Existing piped drainage system
Princes Highway north of Campbell Street.	750 millimetre RCP	Pavement drainage	Existing piped drainage system
Corner of Burrows Road and Campbell Road	450 and 375 millimetre pipe	Pavement drainage	Existing piped drainage system
Corner of Burrows Road and Campbell Road	450 millimetre pipe	Treated water from water quality basin	Existing piped drainage system
Burrows Road near Motorway Control Centre	450 millimetre pipe	Pavement drainage	Existing piped drainage system
Bourke Street near Church Avenue	375 millimetre pipe	Pavement drainage	Existing piped drainage system
Corner of Kent and Gardeners Road	750 and 2 x 375 millimetre pipes	Pavement drainage	Existing piped drainage system
New road between Gardeners Road and Ricketty Street	375 millimetre and 450 millimetre pipe	Pavement drainage	Existing piped drainage system

Location Ch.	Discharging structure*	Drainage input	Discharges to
Western end of Gardeners Road	1050 millimetre pipe	Pavement drainage	Existing piped drainage system
Southern side of Euston	450 and 525 millimetre pipes	Pavement drainage	Existing piped drainage system
Southern side of Euston Road between Maddox Street and Huntley Street	450 millimetre pipe	Pavement drainage	Existing piped drainage system
Corner of Euston Road and Maddox Street	2x450 millimetre pipes	Pavement drainage	Existing piped drainage system
Munni Street Channel downstream of Euston Road	750 and 450 millimetre pipe	Pavement drainage	Munni Street Stormwater Channel
Eastern side of Huntley Street, east of Burrows Road	525 millimetre pipe	Pavement drainage	Existing piped drainage system
Southern side of Sydney Park Road	2x450 millimetre pipes	Pavement drainage	Munni Street Stormwater Channel

**subject to confirmation during detailed design*

The upgrades and replacements of drainage infrastructure are in response to altered and increased catchment attributed to newly paved areas. Due to the urbanised nature and relatively flat topography in the area, the majority of new pipes connect into existing networks prior to discharging as surface water. Detailed design would require additional survey information and assessment of existing drainage networks. This would be used to ensure that any pits or pipes receiving flow would have sufficient capacity and be of adequate condition to receive design flows.

The raising of the intersection of Campbell Road and Burrows Road to incorporate bridge ramps has been identified as having the potential to cause localised flooding due to disruption of overland flow paths. A 3300 by 1500 millimetre culvert would be constructed under Burrows Road to the south of Campbell Road, conveying flows to Alexandra Canal. Detailed design would aim at minimising the potential for localised flooding at this location.

The Munni Street Channel would be crossed by a widened bridge structure to allow for the widening of Euston Road. These works would have the potential to impact flooding in the area. The detailed design of the bridge and roadworks would give consideration to minimising flooding impacts on adjacent property whilst achieving the geometric design requirements for the road. This would be informed by flood analysis with the benefit of detailed survey information relating to existing stormwater infrastructure, ground levels and existing development.

A number of overland flow paths would be impacted by the local road upgrades around the St Peters interchange. The relatively flat topography and limited capacity in existing drainage systems mean that the roadworks have the potential to redirect flows toward existing development in certain areas, for example in the vicinity of Church Avenue to the west of Bourke Road. The extent of potential impacts would be confirmed during detailed design with the benefit of detailed survey information relating to existing stormwater infrastructure, ground levels and existing development. Detailed design of the roadworks would minimise impacts as far as possible, potential mitigation measures are outlined in section 8.2.1.

Eastern Channel

Parts of project (local road upgrades) are located in the Eastern Channel catchment. New pipe connections would be installed where the existing transverse drainage has been impacted by the upgrade and / or require relocation. Indicative details of new and upgraded trunk and transverse drainage infrastructure that would be required in the Eastern Channel catchment are outlined in Table 29. An indicative list of new discharge locations in the catchment is shown in Table 30.

Table 29 Proposed trunk and transverse drainage upgrades in the Eastern Channel catchment

Location	Details*
May Street, north of Campbell Street	New 3 x 900 millimetre transverse drainage
Campbell Street, North of St Peters Street	Connect grated drain to existing network
Campbell Street Ch. 750	Connect existing piped drainage system to new 900 millimetre stormwater pipe.

**subject to confirmation during detailed design*

Table 30 Proposed new discharge locations in Eastern Channel catchment

Location Ch.	Discharging structure*	Drainage input	Discharges to
May Street, north of Campbell Street	4 x 900 millimetre RCP	Pavement drainage	Upgraded detention basin in Camdenville Park
Bedwin Road east of Unwins Bridge Road	1200 millimetre pipe	Pavement drainage	Upgraded detention basin in Camdenville Park
Eastern Channel next to Bedwin Road	Existing stormwater outlet pipe (new input pump)	Treated drainage from Camdenville Park Basin	Eastern Channel (Cooks River trunk drainage)

**subject to confirmation during detailed design*

The local road upgrade works would result in additional pavement areas attributed to widening of Campbell Street and adjoining streets. This would cause a relatively large increase in runoff within the catchment draining to Camdenville Park. The works would include improvements to the hydraulic standard of the drainage system servicing the roads that would be upgraded. It is proposed to offset the increase in runoff potential through provision of additional detention storage within and adjacent to Camdenville Park. This would limit increases in peak flow rates discharged to the downstream trunk drainage system. The proposed drainage strategy would be determined during detailed design and would be based on not increasing flows into the Eastern Channel for all events up to and including the 100 year ARI flood. An option to achieve this would involve the following key elements:

- Enlargement of the existing detention basin through excavation to lower existing ground levels and use of retaining walls adjacent to upgraded sections of Bedwin Road and May Street. Note this is a contaminated site and excavation would be planned accordingly. Based on preliminary analysis the existing storage volume of about 6000 cubic metres would need to be increased to about 17,000 cubic metres to limit peak flow rates downstream of the basin to no greater than occurs under present day conditions for events up to and including the 100 year ARI. The required increase in capacity would be confirmed during detailed design.
- Upgrade of the existing discharge system (and associated infrastructure including rising mains) to suit the enlarged basin, to renew these assets whilst maintaining the current pumping capacity.
- Construction of supplementary underground detention storage along the south-western side of Bedwin Road, within the space created by realignment of this road. This would be hydraulically connected to the upgraded basin, with discharge via an outlet control structure to the existing box culvert beneath the rail line. The need for this supplementary storage would be confirmed during detailed design.

Matters relating to the disturbance of Camdenville Park have been considered in Technical Working Paper: Contamination (AECOM, 2015).

7.2.3 Maintenance of natural flow variability

The discharge of treated groundwater would be to the Cooks River. Flow variability in the river is dominated by tides, hence the proposed discharges would not impact natural flow variability.

7.3 Water quality

Operation of the project has the potential to result in impacts to surface water from the increased areas of impervious surfaces and changes to the total catchment area. Surface runoff washes off pollutants that build up on these surfaces. Runoff would typically contain pollutants such nutrients, oils and greases, petrochemicals and heavy metals, which result from atmospheric deposition, vehicle leaks, operational wear, road wear or spills of materials on the road.

Pollutants from impervious surfaces are generated at a rate of about:

- Total Suspended Solids (TSS): 3,130 kilograms per year per hectare
- Total Phosphorus (TP): 5.83 kilograms per year per hectare
- Total Nitrogen (TN): 25.5 kilograms per year per hectare

The above were estimated from MUSIC stormwater quality modelling for a 100 per cent impervious catchment. These additional pollutant loads would be mitigated in accordance with the stormwater pollution reduction targets from the *Botany Bay and Catchment Water Quality Improvement Plan* (SMCMA, 2011).

For surface runoff, the stormwater treatment devices proposed for the project have been modelled to determine if the provisions made would be sufficient to meet the stormwater pollution reduction targets. These results are presented on a catchment by catchment basis in Sections 7.3.1 to 7.3.3.

The increased discharge of treated groundwater and other tunnel-associated waste waters (such as tunnel wash or deluge system water) during the operation of the project has the potential to result in impacts to surface water. This has been discussed in detail in Section 7.4.3. The discharge would be into the Cooks River near Marsh Street Bridge as shown on Figure 18.

7.3.1 Wolli Creek

The project would result in extensive new permanent infrastructure within the Wolli Creek catchment. The new facilities are outlined in Table 24.

Pavement drainage

The project would include the construction of new pavements within the Wolli Creek catchment. Additional pavement resulting from the western surface works and western portals would increase the imperviousness within the project footprint in this area (22.74 hectares in total) from an existing imperviousness of about 68 per cent, to an imperviousness of 100 per cent. This represents an increase of about seven hectares of impervious surfaces to the pavement drainage catchment. This increase in imperviousness creates the potential for higher pollutant loads to be washed into the receiving Wolli Creek environment. MUSIC modelling was undertaken to estimate the increase in pollutant loads and the pollutant load reduction that would be required to comply with the treatment targets (listed in Table 31).

Table 31 Wolli Creek – Western surface works: increases in pollutant loads in surface water runoff, and required pollutant load reduction targets*.

	TSS	TP	TN
Increase in pollutant loads resulting from the project within the Wolli Creek catchment (kg/y)	33,000	37.00	147.00
Target pollutant load reduction (%) (SMCMA,2011)	85 %	60 %	45 %
Target pollutant load reduction (kg/y)	28,050	22.20	66.15

** Note that these load reductions are indicative and would need to be updated based on the catchment areas used in detailed design*

Runoff from the existing pavement surfaces is currently treated by a series of five water quality ponds that were constructed for treatment of the M5 East Motorway pavement drainage. Three of the ponds are situated to the south and two to the north of the existing alignment. Their details are shown in Table 32 and locations shown on Figure 19.

As indicated in Table 32, WQP – 1 would be upgraded to include a bioretention system as part of the King Georges Road Interchange Upgrade (Lyall and Associates, 2014).

WQP – 2 would be removed during construction of the project to make way for ancillary facilities. The stormwater treatment lost in the removal of WQP – 2 would be offset by the installation of new stormwater treatment devices as described in Section 8.2.2. This would be determined during the detailed design stage with a target of meeting the pollutant load reductions outlined in Table 6.

Table 32 Existing M5 East Motorway water quality pond details

Water Quality Pond	Pond surface area (m^2)	Current catchment area (ha)	Catchment area following KGRIU (ha)
WQP – 1 (existing)	1,200	6.43 (65% impervious)	
WQP – 1a (upgraded)	1,400		6.6 (80% impervious)
WQP – 2 (to be removed during construction)	700	2.21	no change
WQP – 3	600	1.87	no change
WQP – 4	600	2.02	no change
WQP - 5	500	2.62	no change

Sydney Water own and operate a Gross Pollutant Trap (GPT) constructed in 1994 in the concrete lined section of Wolli Creek at Kingsgrove. The trap would receive both treated and untreated drainage from the project stormwater treatment systems as outlined previously.

Stormwater runoff from new impervious surfaces created by the project would be treated by new stormwater treatment systems. These are listed in Table 33 and would be confirmed during detailed design. The expected pollutant reductions that would be achieved by each device, and the combined treatment performance, are provided in Table 33.

For the Wolli Creek catchment, the TSS removal was substantial but the target not met. The TP and TN targets were met. The deficit in treatment for TSS is somewhat compensated for by the high pollutant removals from the Alexandra Canal and Eastern Channel catchments further downstream.

However, it is acknowledged that:

- Sydney Water own and operate a Gross Pollutant Trap (GPT) in the concrete lined section of Wolli Creek at Kingsgrove. The trap would receive both treated and a relatively small amount of untreated drainage from the project drainage network, and would contribute further to TSS reductions in the catchment
- The catchment of the project (around 7.1 hectares) compared to the total Wolli Creek catchment (2100 hectares) is relatively minor and is unlikely to generate significant impacts to downstream water quality.

The designs would be refined during detailed design in consultation with the future owners and or operators, and should be designed in accordance with the recommendations made in Section 8.2.2.

Table 33 Wolli Creek catchment modelled stormwater treatment performance

Treatment device	Catchment area (ha)	Future basin catchment imperviousness	Proposed treatment device	Treatment area (ha)
Basin	1.78	100%	Bioretention	0.0535
GTP 1	1.39	100%	GPT	NA
GPT 2	0.16	100%	GPT	NA
GPT 3	0.63	100%	GPT	NA
GPT 4	1.13	100%	GPT	NA
GPT 5	1.79	100%	GPT	NA
Achieved pollutant reduction through the proposed treatment devices (kg/y)				
	TSS	**TP**	**TN**	
Basin 1	6,416	11.28	33.50	
GTP 1	3,460	0.82	4.70	
GPT 2	351	0.01	0.54	
GPT 3	1,340	0.36	2.10	
GPT 4	2,750	0.7	3.9	
GPT 5	3,640	0.9	5.1	
Total	**17,957**	**14**	**50**	
Treatment performance				
	TSS	**TP**	**TN**	
Target pollutant load reduction (kg/y)	28,050	22.20	66.20	
Total Pollutant reduction through proposed treatment devices (kg/y)	17,957	14.00	50.00	
Percent of pollutant reduction target achieved	64%	64%	75.3%	
Pollutant reduction target met	No (85% required)	Yes (60% required)	Yes (45% required)	

** Note that these treatment performances are indicative and would need to be updated based on the detailed design of treatment devices*

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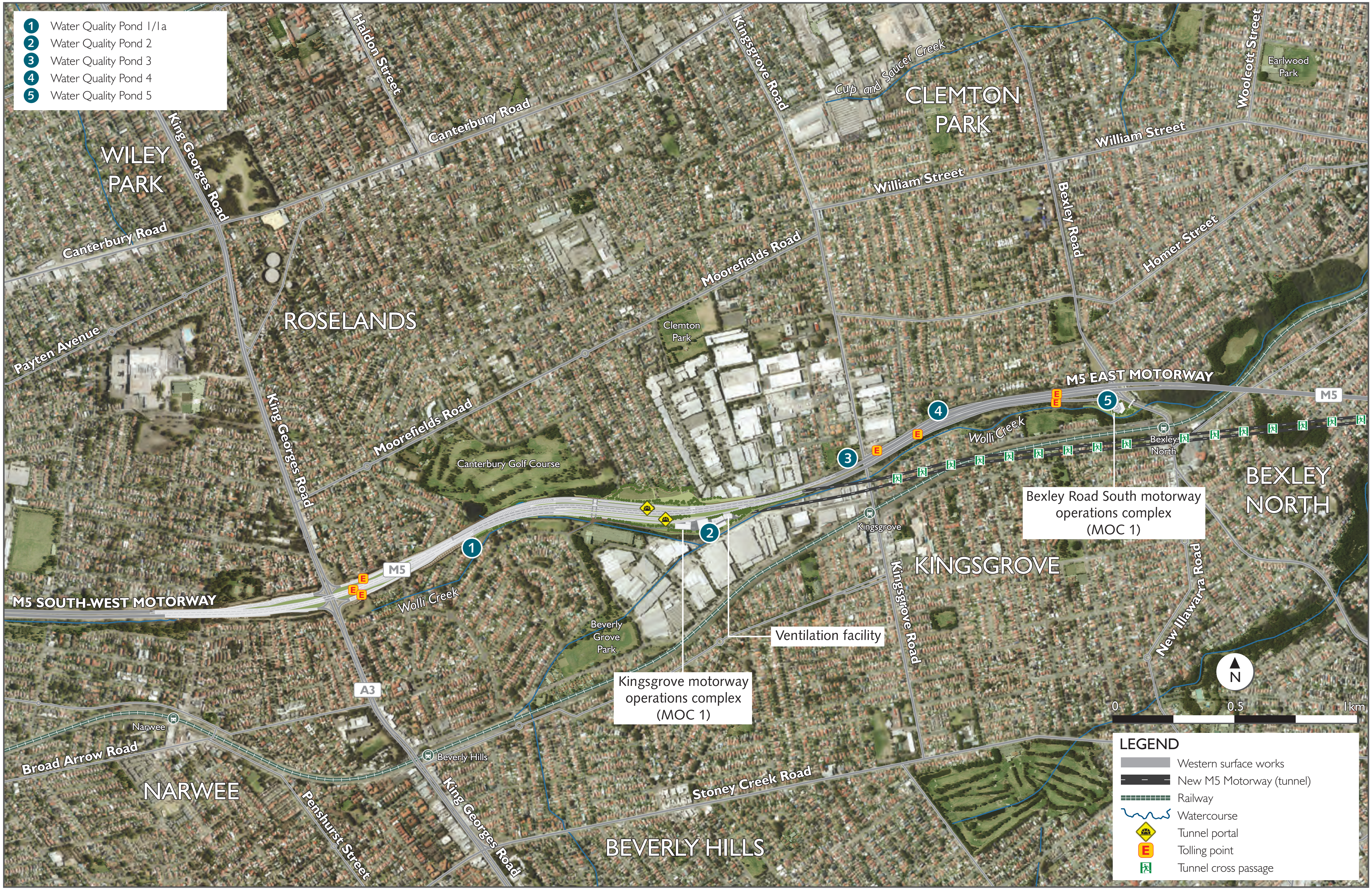

Figure 19 Existing M5 East Motorway water quality ponds

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7.3.2 Alexandra Canal

Construction of the project would result in extensive new permanent infrastructure within the Alexandra Canal catchment. The new facilities are outlined in Table 24.

New discharge outlets

The project would include two new discharge outlets into Alexandra Canal (subject to detailed design):

- A 3300 by 2400 millimetre open channel discharging immediately to the south west of Gardeners Road Bridge.
- A 525 millimetre RCP discharging immediately to the south east of Gardeners Road Bridge.

The new stormwater discharge outlets would be constructed upstream of Ricketty Street bridge. The Ricketty Street bridge is located over two kilometres from the junction of the canal with the Cooks River.

Alexandra Canal is tidal in this location, with two tidal cycles daily, producing relatively small velocities. High energy flows as a result of rainfall events have the potential to create high velocities in the canal. Peak velocities and the size of sediments likely to be mobilised by various flow scenarios are shown in Table 34.

Table 34 Sediment mobilisation estimates (AAJV, 2014)

Flow scenario	Peak velocity in middle reaches of canal (m/s)	Mobilisation of sediments up to (mm)
100 year ARI tidal current	0.15	0.4
2 year ARI flood	0.5	5
20 year ARI flood	0.8	10
100 year ARI flood	0.9	20

New discharges have the potential to cause both a change in direction and velocity of flows in the canal. Based on grain size distribution, the majority of sediment would likely experience minor mobilisation even under tidal conditions and various flood events would have the potential to uncover a greater volume of sediment. The canal floor is said to be in a state of dynamic equilibrium meaning mobilised sediments would not travel far and the system would tend to return to its preceding state (AAJV, 2014).

There is some potential for impacts associated with sediment disturbance, due to:

- Uncertainty regarding the sediment distribution in the canal – including contamination therein.
- Minimal understanding of three dimensional flow mechanisms within the canal.
- Point velocities would be increased in the ‘scour apron’.

These are considered to be manageable given they are provided suitable sediment controls for the following reasons:

- Sediment disturbance which is likely to occur during operation of the new stormwater outlets would be localised and limited in extent and therefore unlikely to have an additional impact on downstream water bodies (eg. Cooks River or Botany Bay).
- The canal’s tendency (based on previous numerical modelling and anecdotal evidence) to return to equilibrium, and accrete sediment in its middle reaches (AAJV, 2014).
- Modelling of the stormwater network would be undertaken prior to design of the outlets to determine velocities prior to discharge. Scour protection measures would be installed at the discharge outlets to further minimise the potential for sediment disturbance caused by the construction and operation of new outlets. The design of the outlets, including discharge velocities and scour protection measures, would be confirmed during detailed design.
- A large number of stormwater discharge points/outlets and in channel anthropogenic features with the potential to disrupt sediment movement are already present within and along the banks of the canal.

Further details on the likelihood of sediments being contaminated are included in Technical Working Paper: Contamination (AECOM, 2015). The potential impacts relating to scour would need to be mitigated as per mitigation measures in Section 8.2.2.

Pavement drainage

The project would include the construction of new roads and bridges within the Alexandra Canal catchment. Additional pavement proposed for the design of the project would increase the imperviousness of the project footprint in this area (45.74 hectares in total) from an existing imperviousness of about 82 per cent, to an imperviousness of 100 per cent, This represents an increase of about 8.2 hectares of impervious surfaces to the pavement drainage catchment. This creates the potential for higher pollutant loads to be discharged to the receiving environment of Alexandra Canal. MUSIC modelling was undertaken to estimate the increase in pollutant loads and the pollutant load reduction that would be required to comply with the treatment targets.

The required pollutant loads reductions are listed in Table 35

Table 35 Alexandra Canal increases in imperviousness and resultant pollutant loads in surface water runoff, and required pollutant load reduction targets*

	TSS	TP	TN
Increase in pollutant loads resulting from the project within the Alexandra Canal catchment (kg/y)	3,000	5.00	20.00
Target pollutant load reduction (%) (SMCMA,2011)	85%	60%	45%
Target pollutant load reduction (kg/y)	2,550	3.00	9.00

** Note that these load reductions are indicative and would need to be updated based on the catchment areas used in detailed design*

There is minimal or no available space in the road reserve for stormwater treatment devices such as bioretention systems or constructed wetlands in some drainage catchments in the Alexandra Canal catchment. Further, as the project connects directly into the existing stormwater drainage network, there are no treatment opportunities further downstream. Although some catchments cannot accommodate full stormwater treatment, the catchments that can accommodate stormwater treatment are the largest. By increasing the pollutant load reduction in these catchments there is the opportunity to offset the treatment deficit from the untreated catchments and provide a net overall environmental benefit.

The untreatable catchments discharge to Alexandra Canal, which has very little habitat value. Therefore the environmental benefit of treating stormwater that is discharged to this canal is only realised as water is discharged into the Cooks River and the downstream natural environment at Botany Bay. Consequently, untreated stormwater runoff from small urban catchments is unlikely to impact the habitat value of Alexandra Canal, but if total pollutant loads to Botany Bay can be reduced, this would be of direct benefit to that receiving environment. Therefore, to determine the likely impact and adequacy of mitigation measures, the pollutant loads from all catchments that discharge to Alexandra Canal would need to be considered together.

The stormwater treatment devices proposed for the Alexandra Canal catchment are listed in Table 36, which would be confirmed during detailed design. Table 36 also provides the pollutant reductions expected to be achieved for each device and the combined treatment performance of the treatment devices. For the Alexandra Canal catchment, the treatment targets for TSS, TP and TN would be easily met with the current provisions. The pollutant removal exceeded 100 per cent because these removals include pollutants from the existing catchment that are over and above the requirements of the project.

The designs would be refined during detailed design in consultation with the future owners and or operators, and designed in accordance with the recommendations made in Section 8.2.2.

Table 36 Alexandra Canal catchment modelled stormwater treatment performance

Treatment device	Catchment area (ha)	Future basin catchment imperviousness	Proposed treatment device	Treatment area (ha)
Burrows Road basin (St Peter interchange)	8.53	30%	Wetland	0.60
Campbell Road basin (St Peters interchange)	2.18	30%	Wetland	0.11
Burrows Road / Campbell Road basin	1.49	85%	Wetland	0.01
Achieved pollutant reduction through the proposed treatment devices (kg/y)				
	TSS	**TP**	**TN**	
Burrows Road basin (St Peter interchange)	11,740	20.64	55.50	
Campbell Road basin (St Peters interchange)	2,750	4.64	11.90	
Burrows Road / Campbell Road basin	1,280	1.73	2.90	
Total	**15,770**	**27.01**	**70.30**	
Treatment performance				
	TSS	**TP**	**TN**	
Target pollutant load reduction (kg/y)	2,550	3.00	9.00	
Total Pollutant reduction through proposed treatment devices (kg/y)	15,770	27.01	70.30	
Percent of pollutant reduction target achieved	618%	900%	781%	
Pollutant reduction target met	Yes (85% required)	Yes (60% required)	Yes (45% required)	

**Note that these treatment performances are indicative and would need to be updated based on the detailed design of treatment devices*

7.3.3 Eastern Channel

Construction of the project would result in extensive new permanent infrastructure within the Eastern Channel catchment. The new facilities are outlined in Table 24.

New discharge outlets

The project would include an upgraded discharge outlet into the Eastern Channel. This water would have been captured by the pavement drainage system, held and treated in Camdenville Park, and then pumped into the concrete lined Eastern Channel at the location and discharge rate of the existing facility. The discharge would be into a concrete lined trapezoidal channel and so would not have the potential to mobilise sediments at point of discharge.

Pavement drainage

The project would include increased road surfaces within the Eastern Channel catchment. The additional pavement proposed for the design of the project would increase the imperviousness of the project footprint in this area (3.62 hectares in total) from an existing imperviousness of about 88 per cent to 100 per cent. This represents an increase of about 0.4 hectares of impervious surfaces to the pavement drainage catchment. This creates the potential for higher pollutant loads on the receiving Cooks River. MUSIC modelling was undertaken to estimate the increase in pollutant loads and the pollutant load reduction that would be required to comply with the treatment targets. The required pollutant load reductions are listed in Table 37.

Table 37 Eastern Channel: increases in imperviousness and resultant pollutant loads in surface water runoff, and required pollutant load reduction targets*

	TSS	TP	TN
Increase in pollutant loads resulting from the project within the Eastern Channel catchment (kg/y)	800	2.00	7.00
Target pollutant load reduction (%) (SMCMA,2011)	85%	60%	45%
Target pollutant load reduction (kg/y)	680	1.26	3.20

** Note that these load reductions are indicative and would need to be updated based on the catchment areas used in detailed design*

Pavement drainage from the Eastern Channel catchment discharges to the Cooks River catchment via the Eastern Channel trunk drainage system. Downstream of the catchment, a constructed stormwater treatment wetland is proposed to be provided within the existing retarding basin in Camdenville Park. This aligns with the Marrickville Council landscape master plan for Camdenville Park (Marrickville Council 2014), which identifies the need to establish a constructed wetland within the existing flood retarding basin for the purposes of treating stormwater and to provide a supply of water for the irrigation of the adjacent oval.

The wetland proposed for stormwater treatment in the Eastern Channel catchment is listed in Table 38, along with the pollutant reductions expected to be achieved. Finally, the combined treatment performance of the treatment devices is evaluated by comparing the total pollutant load reduction required, with the reduction achieved. For the Eastern Channel catchment, the treatment targets for TSS, TP and TN would be easily met with the current provisions. The pollutant removal exceeded 100 per cent because these removals include pollutants from the existing catchment that are over and above the requirements of the project. The designs would be refined during detailed design in consultation with Marrickville Council, and designed in accordance with the recommendations made in Section 8.2.2.

Table 38 Eastern Channel catchment modelled stormwater treatment performance

Proposed Treatment devices	Basin catchment area (ha)	Future basin catchment imperviousness	Proposed treatment Device	Treatment area (ha)
Camdenville Park Basin	25.3	85%	Wetland	0.35
Achieved pollutant reduction through the proposed treatment devices (kg/y)				
	TSS	**TP**	**TN**	
Camdenville Park Basin	34,700	50.00	94.00	
Comparison of the achieved pollutant loads reduction with the required reductions				
	TSS	**TP**	**TN**	
Target pollutant load reduction (kg/y)	680	1.26	3.20	
Total Pollutant reduction through proposed treatment devices	34,700	50.00	94.00	
Pollutant loads reduction (% of target pollutant reduction)	5,103%	3,968%	2,492%	
Pollutant reduction target met	Yes (85% required)	Yes (60% required)	Yes (45% required)	

** Note that these treatment performance are indicative and would need to be updated based on the detailed design of treatment devices*

7.3.4 Cooks River

The project would result in a small amount of new permanent infrastructure within the Cooks River catchment. The new facilities are outlined in Table 24. The final footprint of the facilities would be roughly 1.7 hectares.

The Kogarah Golf Course currently has a very low impervious fraction (assumed to be zero). The project would result in the creation of new impervious surfaces of roughly 1.7 hectares, with an accompanying increase in pollutant loads that would be discharged to the Cooks River. MUSIC modelling was undertaken to estimate the increase in pollutant loads and the pollutant load reduction that would be required to comply with the treatment targets (listed in Table 39).

Table 39 Kogarah Golf Course: increase in pollutant loads in surface water runoff, and required pollutant load reduction targets*.

	TSS	TP	TN
Increase in pollutant loads resulting from the project at Kogarah Golf Course within the Cooks River catchment (kg/y)	4,100	7.0	27.0
Target pollutant load reduction (%) (SMCMA,2011)	85 %	60 %	45 %
Target pollutant load reduction (kg/y)	3,485	4.2	12.2

** Note that these load reductions are indicative and would need to be updated based on the catchment areas used in detailed design*

Although no provision has been made for the treatment of stormwater runoff from the permanent infrastructure located at the Arncliffe motorway operations complex, the increase in pollutants from this site has been offset by the pollutant removal achieved in the Eastern Channel and Alexandra Canal catchments. In those catchments, the pollutant reductions are excess of the required load reductions, and these more than account for the additional pollutants created by the project at the Arncliffe motorway operations complex (refer Table 39). Therefore the project's net environmental impact immediately downstream of the golf course is a substantial reduction in pollutant loads (refer Table 40).

Table 40 Arncliffe motorway operations complex: Net environmental benefit as measured by pollutant reductions downstream of the Kogarah Golf Course*

	TSS (kg/y)	TP (kg/y)	TN (kg/y)
Pollutants generated throughout the project (kg/y)	40,900	51.00	201.00
Target pollutant load reduction for the project (kg/y)	34,765	30.66	90.55
Pollutant load reduction achieved throughout the project (kg/y)	68,427	91.00	214.00
Percentage of targets achieved project wide	197%	297%	236%

**Note that these treatment performances are indicative and would need to be updated based on the detailed design of treatment devices*

Operational water treatment

An operational water treatment plant and would be built within the Arncliffe motorway operations complex. This plant would treat groundwater inflows into the tunnels. Surface water flows collected within the tunnels would also be collected and pumped to the operational water treatment plant. The water treatment plant would be designed to receive and treat two separate streams:

- Contaminated groundwater from the eastern section of the project
- Non-contaminated groundwater from the western section of the project, stormwater, wash down, fire testing, hydrant and deluge water.

The drainage and water treatment system within the tunnel would comprise of:

- A main sump at the tunnel low point, which would have the capacity to store 50,000 litres in case of a spill within the tunnel, with a separate sump to capture potentially contaminated groundwater from the eastern portion of the project.
- A holding tank at Arncliffe motorway operations complex which would receive water from the tunnel sumps. Water would then be directed to the water treatment plant or removed for alternative disposal, eg in case of a spill (see below).
- The water treatment, which would comprise of a water treatment plant and wetland system.
- In the case of higher flows (eg from washdown or deluge), overflow from the holding tank would be directed to the deluge holding tank. These flows would be discharged to the Cooks River via the existing stormwater drainage network.

Expected influent concentrations from groundwater flows are shown in Table 21 and Table 22. Groundwater from the eastern (contaminated) side of the project would be treated through sedimentation / floatation to remove iron, suspended solids, hydrocarbons and other settle-able compounds, and through a wetland to remove ammonia and other contaminants. The water treatment plant would utilise the following processes:

- Polyaluminium chloride (PAC) dosing for coagulation and flocculation
- Sodium hydroxide pH correction dosing system to adjust the pH as required
- Polymer dosing system for liquid stream treatment
- Polymer dosing system for solids dewatering
- Process unit utilising dissolved air floatation to remove suspended solids and iron
- Treatment of salinity.

Following the water treatment plant, the contaminated stream from the eastern section of the project would be transferred to a wetland system that would be designed remove nitrogen (organic nitrogen, ammonia, nitrate and nitrite). The wetland system would sit adjacent to the treatment plant and have a surface area of about 1000 square metres, with floating treatment media to allow plant growth. Treated water would be monitored to ensure pollutant concentrations are below of discharge criteria. When this is not achieved – the water would be passed through a polishing tertiary treatment system consisting of ozone and biologically activated carbon or membrane filtration and reverse osmosis) to remove additional heavy metals. The monitoring would also be used to inform maintenance of the wetland.

Groundwater from the western section (non-contaminated) of the project, which is not expected to have elevated levels of ammonia, would be treated to remove suspended solids and iron using the same water treatment process as outline above, without the need to be transferred to a wetland system.

Once the two streams of water have been treated they would be blended downstream of the wetland to form a combined effluent which would be discharged into the Cooks River. The outfall would consist of a submerged diffuser system such that the effluent stream is dispersed into the Cooks River.

The treated groundwater would be discharged at a predicted maximum rate 20.1 litres per second into the Cooks River at the Marsh Street Bridge.

The waterways that are receiving environments for treated water discharges are ‘highly disturbed’ ecosystems, which cannot feasibly be returned to a ‘slightly to moderately disturbed’ condition (ANZECC Water Quality Guidelines – Section 2.2, 2000). In such cases, ANZECC (2000) recommends suitable guidelines for water quality trigger values.

To avoid adverse impacts on water quality of the Cooks River as a result of the project, the water quality reference criteria have been developed to improve water quality of these receiving environments. As such, provided the criteria are met, there would be a low risk of adverse impacts of treated water discharges on the water quality of the receiving environment.

7.4 Geomorphology

During operation the project has the potential to impact the geomorphology of receiving watercourses in the surface water study area. Impacts on watercourses could result from:

- Discharge of groundwater.
- Discharge of drainage at new locations.
- Increased discharges at existing locations due to drainage upgrades.
- New overland flow paths constructed in the floodplain.

7.4.1 Wolli Creek

A greater proportion of impervious surface in the Wolli Creek catchment would have the potential to increase flow levels and velocities in Wolli Creek during operation of The New M5. The increase in impervious surface would be roughly seven hectares representing and less than one per cent of the 1,100 hectares catchment draining to Bexley Road.

Upstream of Bexley Road, new drainage discharges into Wolli Creek would not have any impact on the creeks’ geomorphology due to its concrete lined construction. Downstream of Bexley Road however, the creek is natural and more susceptible. The relatively minor reduction in time of concentration of the peak flow attributed to the project works is unlikely to impact the geomorphology of the creek.

7.4.2 Alexandra Canal

Drainage discharges from new and upgraded pipes would potentially increase peak flow into Alexandra Canal during operation of the project. These discharges are generally the result of very minor changes in impervious surface in the catchment. The increase of roughly 1.5 hectares (0.1 per cent) would not alter flow velocities significantly and as a result would not lead to any geomorphological impacts.

New discharges into the canal would increase the potential for bank failure as material at the toe of the canal walls could be lost. Scour protection would alleviate this issue.

7.4.3 Cooks River

During operation of the project, the water treatment plant at the Arncliffe motorway operations complex would discharge up to 20.1 litres per second of treated water in the Cooks River immediately downstream of the Marsh Street bridge via the existing stormwater system

This additional discharge would not represent a notable increase (0.01 per cent) of the estimated one year ARI Cooks River discharge of 357 cubic metres per second into Botany Bay. This is a relatively insignificant increase in flow that would have minimal impact on stream levels and velocities in the river. As such, the project discharges would not impact geomorphology of the river, particularly considering its constructed bank formation.

7.5 Cumulative impacts

The project area is within a continually altering urban environment. Further developments are likely to occur in or around the project area during and after construction of the project. These include other works on the WestConnex program, as well as mixed used, residential, rail, commercial and precinct developments.

Surface water quality is maintained through the routine application of stormwater treatment devices to new infrastructure and development projects to ensure that water discharged to Botany Bay complies with legislative requirements. Potential flooding and geomorphological impacts associated with new developments would be mitigated through detailed design to ensure no unacceptable increases in velocities, discharges, flood levels or flood extents, in line with legislative requirements.

The project would connect directly to the King Georges Road Interchange Upgrade (KGRIU). Consideration of the KGRIU EIS has shown that the project would not exacerbate surface water impacts when combined with those of New M5 (Jacobs, 2014).

The project would involve the construction of the St Peters interchange, which would include drainage and pavements associated with future connections for the future Sydney Gateway and the future M4-M5 Link. As such, the cumulative impacts of all infrastructure at this location for WestConnex have been accounted for in this assessment. Due to insufficient information available regarding the impacts, design and management of surface water flows and infrastructure associated with other development proposals, cumulative surface water impacts cannot all be fully understood at this stage. However, if mitigation requirements are applied consistently to all projects, no adverse cumulative surface water impacts are anticipated, and residual risk to the environment would be low. Where legislative requirements are applied consistently across the catchment, there is the potential for overall improvement in water quality and / or reduction in flood risk.

8.0 Mitigation and management measures

The following measures are suggested to mitigate the residual impacts as outlined and discussed in Chapter 6 and Chapter 7.

8.1 Construction

8.1.1 Hydrology and flooding

During the construction, works would occur at a number of locations throughout the project. Some of these are within the extent of various flood event magnitudes as outlined in Section 6.2.1. Flood management plans would be developed as part of the Construction Environmental Management Plan (CEMP) prior to construction to guide the design of compounds so as to minimise impacts of flooding. This would be in line with minimising risk to the safety of both the community and construction personnel.

Inherent flood risks would be managed through the following methods:

- Further detailed assessment of the construction compounds and measures to manage flooding onsite and mitigate flood impacts during construction would be undertaken during detailed design
- Where transverse drainage structures are to be upgraded or replaced during the project, any existing transverse drainage structures would be left in place for operation during the process. If this is not achievable, temporary drainage would be adopted
- Detailed flood modelling to understand the effects of likely rainfall events. Construction layouts would be finalised accordingly
- Stockpile locations would be located outside the 20 year ARI flood extent where possible. Where construction compounds are located in the 20 year ARI flood extent (refer Table 20), a contingency plan to manage flooding would be prepared and implemented
- Temporary bunding around parts of the site that would be adversely affected by floodwaters
- Temporary drains / detention areas within the site
- Use of carparks to provide detention
- Elevation of site buildings on stilts where necessary to get floor levels above expected flood levels
- Use of noise barriers to provide bunding to some parts of the sites while directing overland flows through less sensitive parts of sites, particularly at Kingsgrove and Arncliffe
- Contingency plans would be formulated for high risk temporary facilities proposed including fuel storages, water treatment plants and substations
- Development of suitable procedures for flood warning, emergency management, site evacuation and planning.

Tunnelling locations

Tunnel dive shafts, portals and cut and cover sections of tunnel located within the floodplain would need to be protected against flooding through either locating openings outside of the floodplain or constructing temporary bunding and / or appropriate compensatory drainage works, where this is not possible. The flood level adopted for design of temporary protection would need to be informed by consideration of both mainstream and local overland flows, the potential risk to safety and the potential disruption and damage to project works. All mitigation works would be designed to ensure no exacerbation of impacts to surrounding property.

8.1.2 Water quality

The control and mitigation of potential surface water quality impacts during construction would be defined in a Soil and Water Management Plan (SWMP) prepared as part of the overall Construction Environmental Management Plan (CEMP). The SWMP would be developed to incorporate controls and measures in accordance with Managing Urban Stormwater – Soils and Construction, Volume 2D (Landcom, 2004) and the plan would be continually updated to suit the changing needs as the project works progress. The plan would be developed in consultation with the EPA and DPI (Water) and document the types of measures that would be put in place to minimise the risk of soil erosion or polluted discharges reaching the receiving environments. Features of this would include:

- Construction traffic would be restricted to access tracks, fenced before the start of construction and maintained until construction is complete
- Erosion and sediment controls would be implemented prior to soil disturbance
- Lateral flow (i.e. stormwater) would be managed to avoid flow over exposed soils which may result in erosion and impacts to water quality
- Stockpile sites would be located outside the 20 year ARI flood extent where possible. Where construction compounds are located in the 20 year ARI flood extent (refer Table 20) appropriate management control measures such as bunding would be in place
- Staging of surface works to minimise exposed surfaces, with re-vegetation and / or stabilisation of disturbed areas to occur as soon as feasible
- Site compounds sealed or hard stand to minimise erosion where possible
- Wheel wash or rumble grid systems would be installed at exit points to minimise dirt on roads
- A soil conservation specialist would be contracted to supervise construction in 'high risk' areas in accordance with the Roads and Maritime Erosion & Sedimentation Management Procedure
- All water generated during construction would be captured tested (and treated if required) prior to reuse or discharge under a site specific arrangement, depending on the quality of water generated. This would target compliance with the water quality reference criteria (Appendix A). At the St Peters interchange site this would include transfer of some water to the leachate treatment plant as outlined below. Varying levels of groundwater quality would also require a variation to treatment approaches
- Contaminated sediments and potential acid sulfate soil would be segregated and disposed of at a licensed facility or treated onsite.
- Measures to minimise the disturbance of sediments in Alexandra Canal during construction of new discharge stormwater outlets. These would satisfy the requirements of the existing Remediation Order for the canal.
- Disturbed floodplain environments adjacent to watercourses (including waterfront land) and/or along overland drainage lines would be stabilised and vegetation managed in accordance with the *Guidelines for Controlled Activities on Waterfront Land* (DPI, 2012).

Water Quality Monitoring

Water quality monitoring has commenced in June 2015. Monitoring would continue to collect to at least 12 months of data or to the commencement of construction (whichever is sooner) to represent pre-construction conditions for the project. Monitoring would continue during construction of the project.

The parameters and the locations of monitoring sites is detailed in Appendix B. The monitoring program would include upstream (control) and downstream measurement locations. Samples would be taken twice a month, once in dry and once in wet conditions where possible.

This would be detailed in a water quality monitoring plan as part of the SWMP.

Contaminated runoff and spills

The following measures would be in place to manage spills of contaminated fluids:

- Areas would be allocated for the storage of fuels, chemicals and other hazardous materials
- Facilities would be secured and bunded to levels dictated by the Environmental Protection Agency (EPA) guidelines
- Spills or contaminated runoff would be captured and disposed of at a licensed facility
- Activities such as re-fuelling, wash down and preparation of construction materials would be undertaken in bunded areas to mitigate risks in relation to spills or leaks of fuels / oils or other hazardous onsite construction material
- The application of good practice in the storage and handling of dangerous and hazardous goods would provide appropriate practical responses to manage impacts on occupational health and safety and minimise the risk of a spill occurring
- Potential discharges from construction sites such as accidental construction spills or leaks would be managed through the installation of basins (primarily designed for sediment capture but with capacity to contain the nominated spill volume) constructed in accordance with Managing Urban Stormwater – Soils and Construction, Volume 2D (Landcom, 2004). Captured contaminants resulting from spills or leaks would be treated and disposed of at a licensed facility
- Any soil which has been contaminated with fuel, oils or other chemicals would be disposed as contaminated soil through the project's waster subcontractor.

Landfill closure works

Specific surface water management measures for the landfill closure works would include provisions for the capture of potentially contaminated water. This could include leachate or runoff created by altered catchments during the landfill closure works. Contaminated water would be transferred to the leachate treatment plant rather than the other construction water treatment plant situated at the St Peters interchange site. This process would include measures outlined in *Managing Urban Stormwater – Soils and Construction, Volume 2D* (Landcom, 2004) such as the provision of temporary catch drains and diversion bunding.

8.1.3 Geomorphology

To manage potential geomorphic impacts during construction the following measures would be implemented:

- Construction work activities within and / or adjacent to the watercourses would be minimised as much as feasibly possible to minimise disturbance of sediments in or near the waterway
- Alignment of drainage and discharge outlet infrastructure would direct flows downstream to minimise thalweg alterations and erosion of the bed and banks
- Drainage and discharge outlet infrastructure would include energy dissipation and erosion scour protection as appropriate
- Stabilisation of disturbed floodplain environments adjacent to the watercourses and / or along overland drainage lines.

8.2 Operation

8.2.1 Hydrology and flooding

Bridges

Bridges over Alexandra Canal would be designed to span the entire width of canal. Their soffit levels would be designed to allow sufficient freeboard to the 100 year ARI flood level. The bridge over Munni Street Channel and associated Euston Road roadworks would be designed with the objective of minimising flooding impacts on existing development.

Drainage and localised flooding

The control and mitigation of potential localised flooding and drainage impacts during the operational phase are as follows:

- Drainage systems that are of insufficient capacity would be modified or upgraded to cater for increased flows.
- Where new drains connect with existing drainage networks a detailed survey and condition assessment would need to be undertaken to inform detailed design.
- Transverse drainage upgrades would be investigated further during detailed design to maximise efficiency.
- An assessment of blockage and maintenance would be included in the detailed design process.
- Overland flow paths impacted by roadworks would be investigated during detailed design to confirm the extent of property related impacts. Where undesirable impacts are identified – potential mitigation measures include:
    - Road design refinements
    - Additional drainage infrastructure, for example catch drains and piped drainage
    - Upgrades to existing piped drainage systems.

8.2.2 Water quality

Surface runoff

Suitable treatment devices would be provided to treat surface water runoff from additional impervious surfaces that result from the project. Treatment of surface water runoff would target the stormwater management objectives outlined in the *Botany Bay and Catchment Water Quality Improvement Plan* (SMCMA, 2011). Where space is available, stormwater treatment systems would be installed. In the case where space is unavailable, the treatment suite would include proprietary stormwater treatment devices. The final design of treatment trains would be informed by an assessment of the sensitivity of the receiving environments and supported by further MUSIC modelling. This would be undertaken during detailed design.

Water quality monitoring

Operational water quality monitoring would be conducted for 12 months post-construction or as otherwise required by the conditions of approval. This would include upstream (control) and downstream measurement locations. Samples would be taken twice a month, once in dry and once in wet conditions where possible. This would include upstream (control) and downstream measurement locations. Parameters to be tested for and locations of monitoring sites are shown in Appendix B.

New discharge outlets

New discharge outlets into Alexandra Canal would be designed with scour protection measures to further minimise the potential for sediment disturbance caused by the operation of new outlets. The design of the outlets, including discharge velocities and scour protection measures, would be confirmed during detailed design, informed by appropriate drainage modelling.

Existing drainage outlets

Where existing drainage lines are to be subject to increased inflow, an assessment of their discharge characteristics would be made. If necessary, energy dissipation or scour protection would be added to prevent contaminated sediments from being subject to scour or resuspended. This would be undertaken during detailed design.

Mitigation for spills

The assessment of risk of spills on the motorway would be undertaken, with emphasis placed on the receiving environment. If warranted, in areas such as those upstream of the natural reaches of Wolli Creek, spill containment would be provided. This would be determined during detailed design.

8.2.3 Water treatment plant discharges

The water treatment plant would be designed to ensure that discharge water quality would meet the Water Quality Reference Criteria (AECOM, 2015) (provided in Appendix A). Monitoring of the Cooks River would be undertaken in accordance with the water quality program as provided in Appendix B for 12 months post-construction or as otherwise required by the conditions of approval to ensure discharge is meeting these criteria.

8.2.4 Geomorphology

The control and mitigation of potential geomorphology impacts during operation are as follows:

- Suitably designed scour and erosion control measures would be included in the detailed design.
- Drainage and discharge infrastructure shall incorporate measures to trap and remove sediments in line with the outcomes of the pollutant reduction targets.

These protection measures would be included as part of the detailed design.

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9.0 Conclusion

This report assesses the impacts of the project on surface water during construction and operation; including localised flooding and drainage, water quality and geomorphology. This report also assesses mainstream flooding impacts during construction. Assessment of mainstream flooding impacts during operation is presented in Technical Working Paper: Flooding (Lyall and Associates, 2015).

Where impacts have been identified, a range of mitigation measures and requirement have been proposed to minimise such impacts. Generally speaking, it is expected that impacts would be managed with mitigation measures that are standard for this type of development.

9.1 Flooding

Assessment of the flood risks to the project and surrounding environment, along with development of appropriate flood standards and mitigation measures has been carried out in accordance with the Floodplain Development Manual, the requirements of the environmental approvals process and industry guidelines.

The application of standard mitigation measures and refinements during detailed design are expected to be sufficient to mitigate potential mainstream flooding impacts during construction.

Similarly, for operation phase impacts on drainage in the project corridor, it is expected that impacts would be generally manageable through design that would be further refined in detailed design.

9.2 Water quality

Potential impacts on surface water quality during construction of the project are considered minor and manageable with the application of standard mitigation measures.

The Construction Environmental Management Plan (CEMP) would control potential surface water quality impacts during construction. Construction water treatment plants would be established during the construction phase to treat water to a quality that would comply with ANZECC Water Quality Guidelines (ANZECC, 2000) – trigger values derived from a local reference data set. The operational water treatment plant t would also be designed to meet the recommended discharge criteria.

During operation, there is potential for the project to impact surface water quality through increases in imperviousness that would lead to increases in pollutant loads associated with surface runoff. This would be managed through a range of treatment devices including gross pollutant traps, wetlands, bioretention systems, and proprietary treatment devices. Current provisions are sufficient to meet the treatment targets for most catchments, and stormwater treatment in some catchments exceeds the treatment requirements, such that the project overall would result in less pollutants being delivered to Botany Bay.

9.3 Geomorphology

The potential impacts on the geomorphic condition of watercourses during construction of the project are considered minor and manageable with the application of current practice construction mitigation measures.

During construction and operation, the project would discharge treated groundwater and construction water to Wolli Creek, which is either concrete or rock-lined in the upper reaches, and sufficiently wide in the lower reaches to accommodate the extra flow. Discharges to Alexandra Canal and the Cooks River are of a similar magnitude and not expected to impact the geomorphology of those waterways for the same reasons. Specific localised mitigation measures are proposed where outlet scour protection and energy dissipation is required prior to releasing water into local creeks / waterways. These protection measures would be included as part of the detailed design.

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Appendix A

Water Quality Reference Criteria

Appendix A Water Quality Reference Criteria

1 Introduction

The project corridor is located in the Cooks River Catchment (refer Figure 3). The Cooks River Catchment is a highly urbanised area located in the south western area of Sydney. The catchment has a high proportion of impervious surfaces and the river is contaminated with litter, petroleum, and nutrients after storms (Cooks River Alliance (CRA), 2014). The river is joined by a number of tributaries along its course. Three main watercourses within the project study area are the Cooks River, Wolli Creek and Sheas Creek/Alexandra Canal. Reference water quality criteria for each watercourse were developed to identify the quality of water for discharges from the project to the receiving environment. These criteria were defined based on available data and in accordance with the relevant guidelines (The Australian and New Zealand Environment Conservation Council (ANZECC) 2000).

1.1 Water quality guidelines

The Australian and New Zealand Environment Conservation Council (ANZECC) provide guidelines for the protection of ambient water quality of the rivers. The ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) provide a framework for determining guideline trigger values for an aquatic system (refer to Figure A1). The NSW Water Quality and River Flow Objectives are consistent with the agreed national framework of ANZECC (2000). These are applicable to discharges from water treatment plants for the construction and operation phases of the project.

Indicators values can be derived from default values presented in guidelines, or where appropriate, a reference condition can be defined using pre-impact data.

1.2 Water treatment requirements

The waterways that are receiving environments for treated groundwater discharge from the project are highly disturbed ecosystems, which cannot feasibly be returned to a ‘slightly to moderately disturbed’ condition (ANZECC, 2000). In such cases, the ANZECC (2000) recommends that suitable guidelines for water quality trigger values can be either:

- Compliant with the ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems. Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types (ANZECC 2000, Table 3.3.2 on p96).
- Trigger values derived from a local reference data set for nutrients, dissolved oxygen and pH where the quality of discharge should not exceed the 80th and/or 20th percentile values.

Note: For stressors that cause problems at high concentrations (e.g. nutrients, suspended particulate matter, salinity), the 80th percentile of the reference distribution is the low-risk trigger value. For stressors that cause problems at low levels (e.g. low temperature water releases from reservoirs, low dissolved oxygen in waterbodies), the 20th percentile of the reference distribution is a low-risk trigger value. For stressors that cause problems at both high and low values (e.g. temperature, salinity, pH), the desired range for the median concentration is defined by the 20th percentile and 80th percentile of the reference distribution (from ANZECC 2000, Section 3.3.2.4).

The selection of 80th and/or 20th percentile values from the reference dataset is recommended since the objective for the receiving environment is to improve water quality. The improvement of water quality is consistent with the objectives of the Botany Bay and Catchment Water Quality Improvement Plan (Sydney Metropolitan Catchment Management Authority (SMCMA), 2011).

For toxicants (such as heavy metals or organic chemical compounds), a reference data set is not needed (see Table 3.4.1. in ANZECC 2000) The water quality requirements should be consistent with the 80 percent protection level for freshwater ecosystems, i.e. the percentage of species that are expected to be protected if water quality meets or exceeds this criterion (ANZECC, 2000). This protection level would ensure that discharged water would result in minimal impacts to the surrounding environment. If these guidelines are followed, the discharge water quality is expected to be typically better than the current water quality of the receiving watercourses.

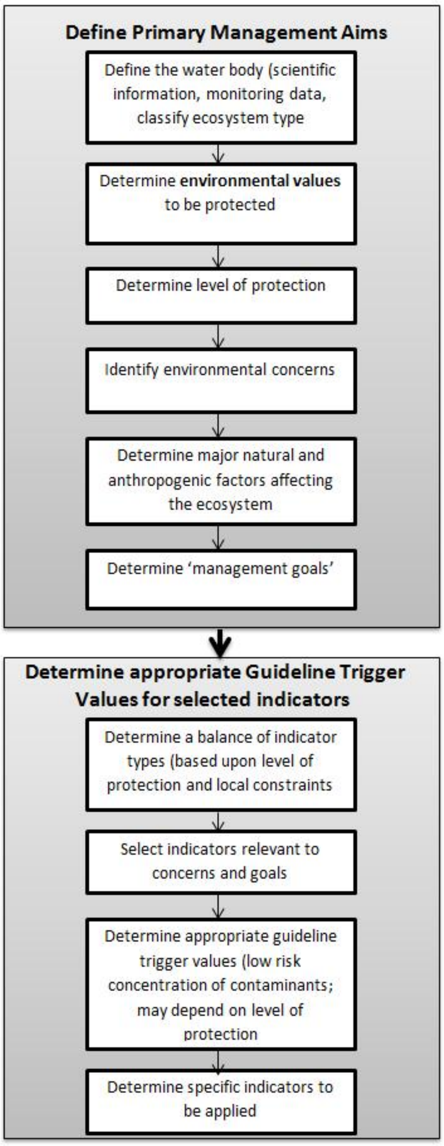

Figure A1 Framework for 'Determining appropriate guideline trigger values' (ANZECC Guidelines, 2000)

2 Methodology

Using the framework presented in Figure A1, the following steps were followed to define a reference condition for each watercourse:

- Available water quality data was gathered to determine the existing health condition of each watercourse.
- Environmental values were determined based on the NSW Water Quality and River Flow Objectives.
- The level of protection was defined based on the existing river health condition and according to ANZECC (2000).
- Management goals were determined based on the level of protection and the NSW Government long-term goals for protection of the Cooks River Catchment.
- Indicators relevant to environmental values and goals were selected.
- Guideline trigger values for selected indicators were defined using available water quality data, level of protection and management goals.
- A reference condition was defined for each watercourse using defined guideline trigger values.

2.1 Assigning Levels of Ecosystem Protection

The Cooks River Catchment is divided into the upper, middle and lower catchments that each has its own characteristics. This study focused on the middle and lower catchments only as this is the area that would be impacted by the project. These reaches of the river are below the tidal limit that lies adjacent to Sando Reserve, Croydon Park (Manly Hydraulics Laboratory (MHL), 2005), hence are considered estuarine.

The Office of Environment and Heritage (OEH, 2006) determined four objectives for improving water quality of the Cooks River estuaries, including aquatic system health, visual amenity primary contact recreation and secondary contact recreation.

Accordingly, these objectives were identified in this study as environmental values that need to be protected. Indicators to assess water quality relevant to these environmental values were selected based on ANZECC (2000), OEH (2006) and possible contamination that may be caused by groundwater discharge as a result of the activities of the project. Selected indictors are: Total Suspended Solid (TSS), Turbidity, Total Nitrogen (TN), Available/Total Phosphorus (TP), Electrical Conductivity (EC), Dissolved Oxygen (DO), pH, and Temperature (T).

Based on the ANZECC guidelines (2000), the existing condition of the Cooks River catchment is identified as a 'Highly Disturbed'. Highly disturbed systems are measurably degraded ecosystem of lower ecological value. Such an ecosystem still retains, or after rehabilitation may have, ecological and conservation values. It may not be feasible to return degraded aquatic ecosystem to a 'slightly-moderately disturbed' condition and so the general objectives can be more flexible and might be to retain a functional ecosystem that would support the assigned management goals. Low-risk guideline trigger values should be defined for 'Highly Disturbed' systems (ANZECC, 2000).

For a 'Highly Disturbed' system with management goals to slightly improve the condition, ANZECC (2000) suggests defining the trigger values using 20^{th} and 80^{th} percentiles of measured values (the "reference condition"). SMCMA (2011) in association with other government and community groups provided a Water Quality Improvement Plan (WQIP) for Botany Bay catchments including Cooks River catchment. The general goal of this plan is to improve the existing condition of the Bay by reducing pollution. To be consistent with general goal of this plan, 20 and 80 percentiles were used in this study that helps to improve the existing condition slightly. For indicators with no available water quality information, the default values for south-east Australia provided in ANZECC (2000) should be used until sufficient local data can be collected to define a reference condition.

Due to limited available water quality data for the Cooks River Catchment, it is not possible to define seasonal variation in pollutant loads. But because treated groundwater would be constantly discharged to the receiving environments, dry and wet flow conditions are not provided in the reference criteria. One trigger value for both dry and wet condition has been defined for each indicator.

3 Reference Condition

Water quality data at 11 locations along the Cooks River and Wolli Creek was obtained from the Streamwatch Website. Figure A2 shows the location of these test sites (labelled as FID). Rockdale City Council (RCC) also provided water quality data of three test sites along Wolli Creek (labelled as WC). At the time of doing this work, minimal data was available from test sites showing historical water quality of Alexandra Canal. The most recent study was undertaken by Woodlots and Wetlands (WW) in 2004 was used to determine TP and TN values. AECOM has started monthly sampling in Alexandra Canal (on behalf of WDA, now SMC) and samples from two sites for one sampling date (29/06/2015) were also used to determine other values (EC, DO, PH, Temperature and Turbidity).

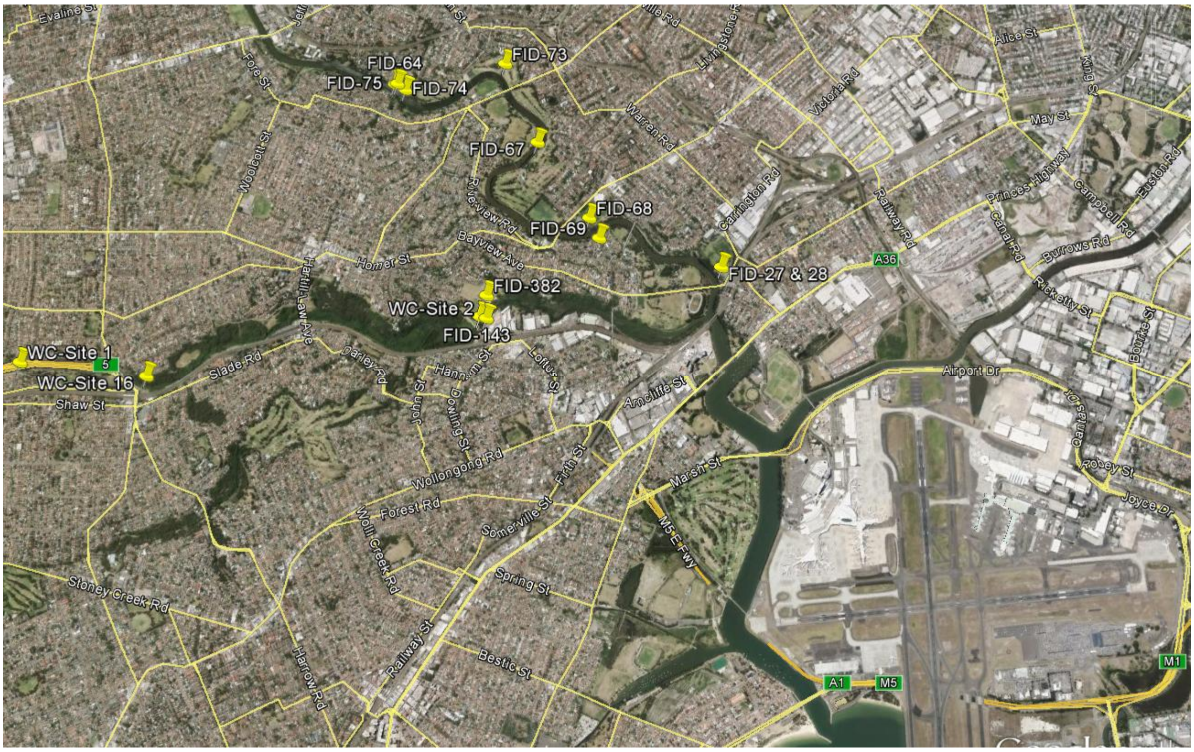

Figure A2 Cooks River & Wolli Creek Test Sites obtained from the Streamwatch Website and RCC (2014) report

The following sections outline how reference conditions were defined for each watercourse.

3.1 Cooks River

Data was obtained from the Streamwatch Website for nine sampling sites (refer to Figure A2; sites FID27, FID28, FID64, FID67, FID68, FID69, FID73, FID74 and FID75)). . These test sites were grouped based on their location. Test sites in an area with a radius of one kilometre were grouped together. Accordingly, sites 64, 73, 74 and 75 were grouped as Area 1; sites 67, 68 and 69 were grouped together as Area 2; and sites 27 and 28 were grouped as Area 3. More information on number of samples and sampling period is presented in Table 41.

Thereafter, 20th and 80th percentiles of measured water quality values for each indicator were calculated in Excel to define the guideline trigger values. Excel's PERCENTILE.EXC uses NIST method for calculating percentiles. The method is based on ranking the P-th percentile and splitting the calculated rank into its integer and decimal component to calculate the value of P-th percentile. Table 41 presents the recommended water quality trigger values for Cooks River based on the assessed reference condition.

Table 41 Cooks River Recommended Water Quality Trigger Values Based on the reference condition

Indicator	Statistic	Middle Catchment Area 1 (4 sites & 90 samples taken from Feb 2005 to Dec 2010)	Middle catchment Area 2 (3 sites & 45 samples taken from Sep 2003 to July 2010)	Lower Catchment Area 3 (2 sites & 40 samples taken from Dec 2007 to Jun 2015)
Type		**Estuary**	**Estuary**	**Estuary**
Available Phosphorus (mg/L)	80%ile	0.21	0.18	0.2
	Min	0	0	0.01
	Max	0.64	0.37	0.3
	Mean	0.13	0.11	0.12
	ANZECC trigger value**	NA	NA	NA
Total Nitrogen (mg/L)	80%ile-obtained from AECOM dataset-refer to Note 1	1.04	1.04	1.04
	Min	0.3	0.3	0.3
	Max	1.1	1.1	1.1
	Mean	0.75	0.75	0.75
	ANZECC trigger value**	0.3	0.3	0.3
Electrical Conductivity (mS/cm)	20%ile	10.5*	14**	17.54**
	80%ile	43*	48**	54.2 **
	Min	0.40*	0.50	3.00
	Max	54*	62.00	73.00
	Mean	25.10*	32.00	40.50
	ANZECC trigger value**	NA	NA	NA
Dissolved Oxygen (% saturation)	20%ile	44.00	41.20	39.80
	Min	16.00	30.00	18.00
	Max	131.00	133.00	92.00
	Mean	61.00	59.00	48.00
	ANZECC trigger-Lower limit**	80	80	80
pH	20%ile	7.00	8.00	8.00
	80%ile	8.50	9.00	8.50
	Min	5.50	7.00	7.00
	Max	9.00	9.00	9.00
	Mean	7.60	8.40	8.00
	ANZECC trigger value - lower limit**	7	7	7
	ANZECC trigger value - upper Limit**	8.5	8.5	8.5

Indicator	Statistic	Middle Catchment Area 1 (4 sites & 90 samples taken from Feb 2005 to Dec 2010)	Middle catchment Area 2 (3 sites & 45 samples taken from Sep 2003 to July 2010)	Lower Catchment Area 3 (2 sites & 40 samples taken from Dec 2007 to Jun 2015)
Type		**Estuary**	**Estuary**	**Estuary**
Temperature (^oC)	20%ile	15.00	15.00	15.00
	80%ile	23.50	23.40	23.00
	Min	11.50	11.00	11.00
	Max	28.00	26.00	28.50
	Mean	19.20	19.00	19.10
	ANZECC trigger value**	NA	NA	NA
Turbidity (NTU)	80%ile	30.00	15.00	15.00
	Min	10.00	10.00	10.00
	Max	400.00	60.00	50.00
	Mean	31.00	14.20	13.60
	ANZECC trigger value**	NA	NA	NA

Note 1: A concentration of Total Nitrogen was not available in the Streamwatch dataset. Consequently, samples taken by AECOM (on behalf of WDA, now SMC) at three locations in Cooks River in late June and early July 2015 were used.

** Data was assessed for plausibility and extreme outliers were removed.*
***Default trigger values for south-east Australia for slightly disturbed ecosystems.*

3.2 Wolli Creek

Water quality data for Wolli Creek was obtained from Rockdale Water Quality Monitoring Report, Rockdale City Council (RCC, 2014) and the Streamwatch Website. Locations of Streamwatch sample sites (labelled as FID) and RCC sample locations (Labelled as WC) are shown in Figure A2. Water quality data for two sites in the upstream area (WC-Site 1 & WC-Site 16) and three sites in the downstream area (sites (WC-Site 2, FID 143 & FID 382) was used to calculate 20th and 80th percentiles of measured values for each indicator.

Table 42 presents the recommended water quality trigger values for Wolli Creek.

Table 42 Wolli Creek Recommended Water Quality Trigger Values Based on the Reference Condition

Indicator	Statistic	Upstream (2 sites & 25 samples)	Downstream (3 sites & 30 samples)
Type		**Upland River**	**Estuary**
Total Phosphorous (mg/L)	80%ile	0.12	0.10
	Min	0.02	0.03
	Max	0.32	0.23
	Mean	0.08	0.07
	ANZECC trigger value**	0.02	0.03
Total Nitrogen (mg/L)	80%ile	1.90	3.80
	Min	0.40	0.80
	Max	3.90	10.00
	Mean	1.30	2.76
	ANZECC trigger value**	0.25	0.3
Total Suspended Solids (mg/L)	80%ile	22.00	8.00
	Min	5.00	5.00
	Max	200.00	13.00
	Mean	19.50	6.25
	ANZECC trigger value**	NA	NA
Electrical Conductivity (mS/cm)	20%ile	0.31	0.30*
	80%ile	1.66	1.13*
	Min	0.07	0.22
	Max	3.03	4.60
	Mean	1.11	0.91
	ANZECC Trigger value**	NA	NA
Dissolved Oxygen (% saturation)	20%ile	60.00	26.40
	Min	9.00	15.00
	Max	182.00	151.00

Indicator	Statistic	Upstream (2 sites & 25 samples)	Downstream (3 sites & 30 samples)
	Mean	101.50	44.00
	ANZECC trigger value**	90	80
pH	20%ile	6.70	6.50
	80%ile	7.70	7.00
	Min	6.50	6.00
	Max	8.50	7.90
	Mean	7.15	6.90
	ANZECC trigger value-lower limit**	6.5	7.5
	ANZECC trigger value-upper limit**	7.5	8.5
Temperature (^{o}C)	20%ile	12.10	13.00
	80%ile	23.20	21.50
	Min	9.40	10.50
	Max	27.50	23.60
	Mean	18.60	17.00
	ANZECC trigger value*	NA	NA
Turbidity (NTU)	80%ile	29.00	11.00
	Min	1.50	2.50
	Max	290.00	23.00
	Mean	25.10	9.65
	ANZECC trigger value*	NA	NA

** Data was assessed for plausibility and extreme outliers were removed.*
***Default trigger values for south-east Australia for slightly disturbed ecosystems.*

3.3 Alexandra Canal

Limited information was available on Alexandra Canal water quality. A number of water quality studies were undertaken in the early 1990s; however, these studies would not be expected to be representative of current conditions.

The most recent study was undertaken by Woodlots and Wetlands (WW) in 2004. AECOM has started monthly sampling in Alexandra Canal (on behalf of WDA, now SMC) and samples from two sites for one sampling date are available. The reference condition for Alexandra was defined using mean values derived from the WW (2004) study and AECOM monitoring data.

Table 43 summarises these recommended water quality trigger values. These trigger values would be reviewed in line with the Water Quality Monitoring Program for the project.

Table 43 Alexandra Canal Recommended Water Quality Trigger Values Based on the Reference Condition

Indicator	Statistic	Trigger value	Source
Type		**Estuary**	
Total Phosphorous (mg/L)	Upper Limit	0.14	Mean value reported by Woodlots and Wetlands (2004)
Total Nitrogen (mg/L)	Upper Limit	1.38	Mean value reported by Woodlots and Wetlands (2004)
Electrical Conductivity (mS/cm)	Lower Limit	0.49	Min value obtained from AECOM dataset
	Upper limit	21.41	Max value obtained from AECOM dataset
Dissolved Oxygen (% saturation)	Lower Limit	39.00	Min value obtained from AECOM dataset
pH	Lower Limit	7.30	Min value obtained from AECOM dataset
	Upper limit	7.90	Max value obtained from AECOM dataset
Temperature (^{o}C)	Lower Limit	14.30	Min value obtained from AECOM dataset
	Upper Limit	23.00	Using 80%ile of data obtained from sites FID-28 and FIS-28
Turbidity (NTU)	Upper Limit	6.30*	Max value obtained from AECOM dataset

**Turbidity – The ANZECC (2000) maximum default trigger value is 10 NTU. 10 NTU should be adopted until a more comprehensive dataset is available*

4 Recommendations

It is recommended that the discharge criteria for physical and chemical stressors in water quality discharged from groundwater treatment plants be based on the recommended water quality trigger values – derived from the data sets, as presented in Table 41, Table 42 and Table 43.

For toxicants (such as heavy metals or organic chemical compounds), a reference data set is not recommended and trigger values should be those consistent with the 80 percent protection level for freshwater ecosystems (see Table 3.4.1. in ANZECC 2000). The available trigger values for metals, metalloids and non-metallic inorganics are shown in Table 44.

Table 44 Trigger values for chemical toxicants in marine water for 80% protection of species (ANZECC 2000)

Chemical	Trigger values for freshwater (µgL^{-1})	Trigger values for marine water (µgL^{-1})
Metals and Metalloids		
Aluminium pH > 6.5	150	ID
Arsenic (As III)	360	ID
Arsenic (AsV)	140	ID
Boron	1300	ID

Chemical	Trigger values for freshwater (μgL^{-1})	Trigger values for marine water (μgL^{-1})
Metals and Metalloids		
Cadmium	0.8	36
Chromium (Cr III)	ID	90.6
Chromium (Cr VI)	40	85
Cobalt	ID	150
Copper	2.5	8
Lead	9.4	12
Manganese	3600	ID
Mercury (inorganic)	5.4	1.4
Nickel	17	560
Selenium (Total)	34	ID
Silver	0.2	2.6
Tributyltin (as µg/L Sn)	ID	0.05
Vanadium	ID	280
Zinc	31	43
Non-metallic Inorganics		
Ammonia	2300	1700
Chlorine	13	ID
Cyanide	18	14
Nitrate	17000	ID
Hydrogen Sulfide	2.6	ID

** ID = Insufficient data*

A water quality monitoring program should be established and data collected for a minimum period of 6 months prior to construction of the project. The data collected would be used to refine the water quality criteria for the treatment of construction and operation phase groundwater discharged as surface water.

5 References

Australian and New Zealand Environment and Conservation Council (ANZECC). 2000; Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Cooks River Alliance, 2014, Management Plan

Cooks River Alliance, 2013; River Health-Georges and Cooks River

Cooks River Valley Association (CRVA), 2011; Annual; Water Quality Report-2010/11

Manly Hydraulics Laboratory. (2006). *Survey of Tidal Limits and Mangrove Limits in NSW Estuaries 1996 to 2005.* Prepared for the Department of Natural Resources.

Office of Environment and Heritage, NSW Government, 2006, *NSW Water Quality and River Flow Objectives-Cooks River* http://www.environment.nsw.gov.au/ieo/CooksRiver/index.htm. [Accessed 03 July 15]

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Appendix B

Water Quality Monitoring Program

Appendix B Water Quality Monitoring Program

Water quality monitoring parameters

In-situ field parameters	Analytical sampling for Contaminants of Potential Concern (CoPC)
- pH - Reduction Oxidation Potential - Dissolved Oxygen - Temperature - Conductivity - Turbidity - Colour - Odour	- Total Recoverable Hydrocarbons (TRH) (C6-C20) - Benzene, Toluene, Ethylbenzene, Xylene and Naphthalene (BTEXN) - Nutrients including: Total Nitrogen, Total Kjeldahl Nitrogen (TKN), Nitrogen Oxide (NOx), Nitrite (NO_2), Nitrate (NO_3), Total Phosphorous and Reactive Phosphorous - Heavy metals (Arsenic, Cadmium, Copper, Chromium, Lead, Mercury, Nickel, Zinc) - Manganese - Ferrous Iron and Total Iron.

Locations of water quality monitoring sites (refer locality plan figure)

Site	Location	Latitude	Longitude
1	Via Alexandra Cycleway, accessed from Coward Street	-33.922475	151.176800
2	Mackey Park, Tempe	-33.923933	151.155384
3	Levey Street, Wolli Creek	-33.933284	151.159560
4	Riverine Park, Arncliffe	-33.943436	151.159990
5	Kirrang Street, Beverly Hills	-33.940764	151.084726
6	Kooreela Street, Kingsgrove	-33.938098	151.102845
7	Bexley Road, Bexley North	-33.936732	151.113154
8	Fish weir at Henderson Street Turrella	-33.929618	151.138163
9	Huntley Street, Alexandria	-33.909258	151.192232
10	Murray Street, Marrickville	-33.913624	151.167402

Appendix B Water quality monitoring sampling locations

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