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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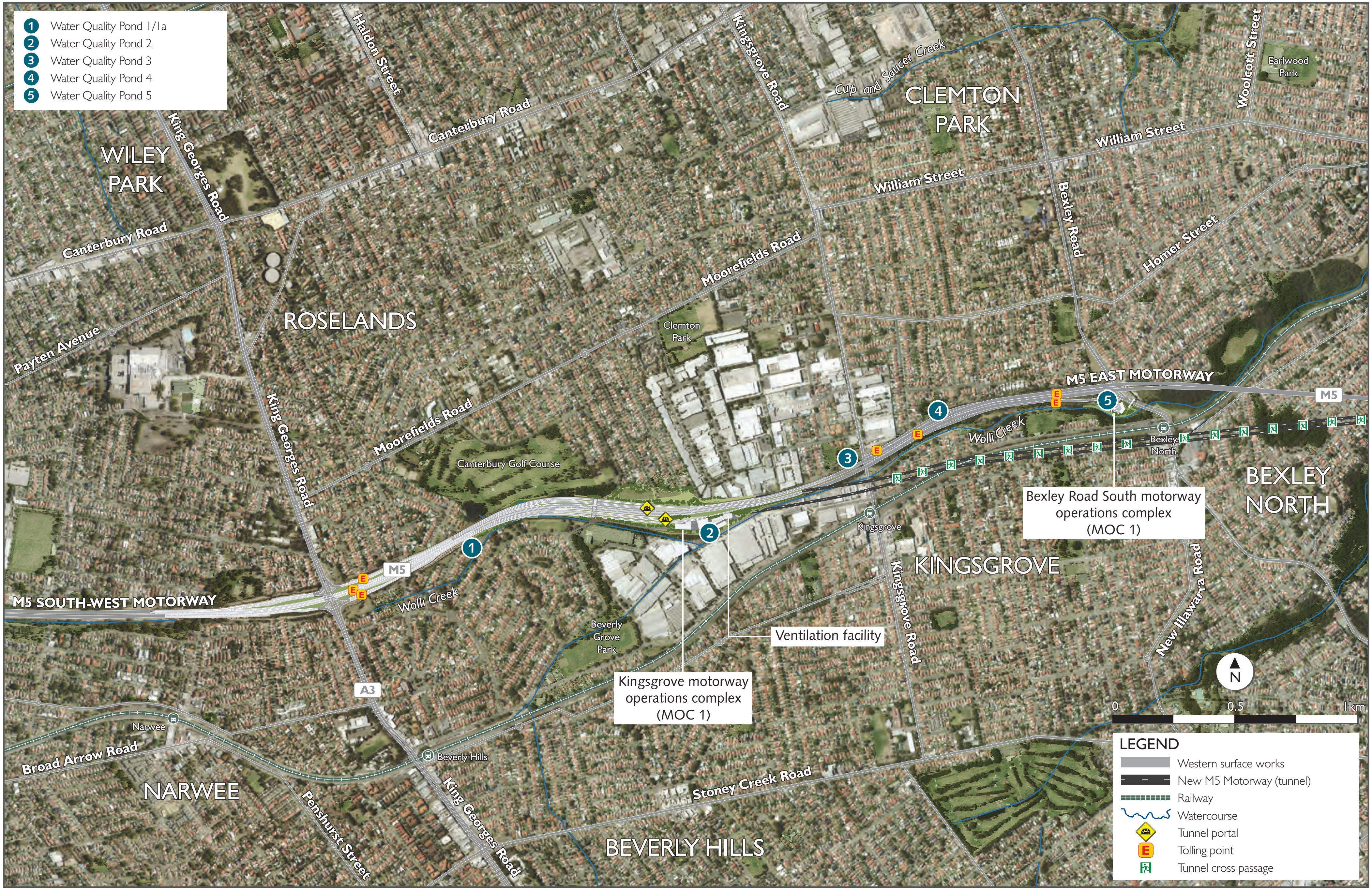

Figure 19 Existing M5 East Motorway water quality ponds

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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.

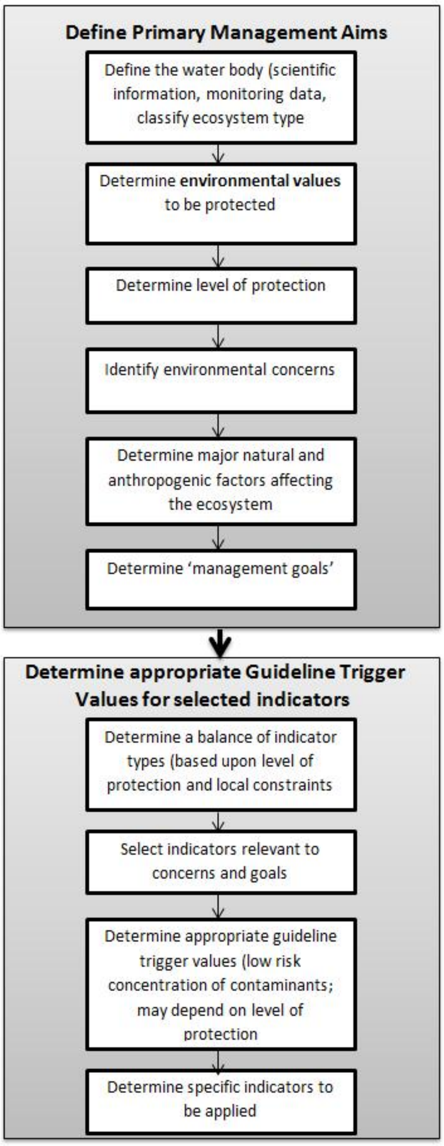

Figure A1 Framework for 'Determining appropriate guideline trigger values' (ANZECC Guidelines, 2000)

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).

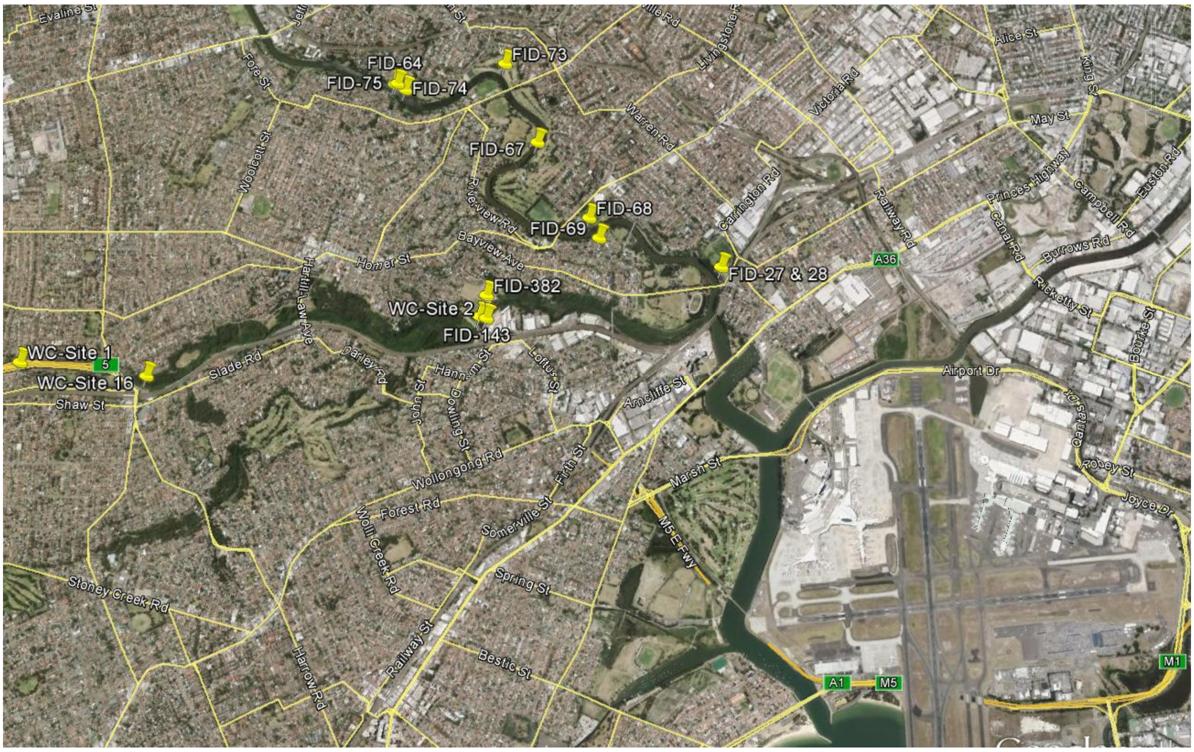

Figure A2 **Cooks River & Wolli Creek Test Sites obtained from the Streamwatch Website and RCC (2014) report**

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 (°C)	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

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Rockdale City Council (RCC), 2014; Rockdale Water Quality Monitoring Report-Part A & B

Streamwatch, 2015; Water quality data, http://streamwatch.org.au/streamwatch/flow/anon/k/_cF7C46929-5C3F-0714-26EA-640FA3633A32_k59DDCA9D-FD6B-EE25-BF42-CDD4C00A8E4F. [Accessed 22 June 2015]

Sydney Metropolitan Catchment Management Authority (SMCMA), 2011, Botany Bay & Catchment Water Quality Improvement Plan

Woodlots & Wetlands, 2004; Alexandra Canal Catchment Stage One Assessment. Unpublished report prepared for South Sydney Development Corporation

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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WestConnex