WestConnex

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New M5

Environmental Impact Statement

Technical working paper: Flooding

Appendix P

November 2015

WestConnex

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APPENDICES

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NOTE ON FLOOD FREQUENCY

The frequency of floods is generally referred to in terms of their Annual Exceedance Probability (AEP) or Average Recurrence Interval (ARI). For example, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year. As another example, for a flood having a five year ARI, there would be floods of equal or greater magnitude once in five years on average. The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) per cent	Average Recurrence Interval (ARI) years
0.5	200
1	100
5	20
20	5

In this technical working paper the frequency of floods generated by runoff from the study catchments is referred to in terms of their ARI, for example the 100 year ARI flood.

The frequencies of peak levels derived from ocean storm tides are referred to in terms of their return periods; for example, 1 in 100 years for the 100 year storm tide.

The technical working paper also refers to the Probable Maximum Flood (PMF). This flood occurs as a result of the probable maximum precipitation (PMP) on the study catchments. The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a catchment hydrologic model which simulates the conversion of rainfall to runoff. The PMF is defined as the upper limiting value of floods that could reasonably be expected to occur.

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GLOSSARY OF TERMS AND ABBREVIATIONS

Term	Meaning
Afflux	Increase in water level resulting from a change in conditions. The change may relate to the watercourse, floodplain, flow rate, tailwater level etc.
AEP	Annual Exceedance Probability. The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 cubic metres per second has an AEP of five per cent, it means that there is a five per cent chance (that is one-in-20 chance) of a 500 cubic metres per second or larger events occurring in any one year (see also average recurrence interval).
ALS	Airborne Laser Scanning. A type of aerial survey used to measure the elevation of the ground surface.
AHD	Australian Height Datum. A common national surface level datum approximately corresponding to mean sea level.
ARI	Average Recurrence Interval. The average period in years between the occurrence of a flood of a particular magnitude or greater. In a long period of say 1,000 years, a flood equivalent to or greater than a 100 year ARI event would occur 10 times. The 100 year ARI flood has a one per cent chance (i.e. a one-in-100 chance) of occurrence in any one year (see annual exceedance probability). The frequency of floods is generally referred to in terms of their AEP or ARI. In this report the frequency of floods generated by runoff from the study catchments is referred to in terms of their ARI, for example the 100 year ARI flood.
ARR	Australian Rainfall and Runoff (Institute of Engineers Australia, 1998).
BoM	Bureau of Meteorology
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
DECC	Department of Environment and Climate Change (now OEH).
DECCW	Department of Environment, Climate Change and Water (now OEH).
DoP	Department of Planning (now DP&E)
DPE	Department of Planning and Environment (formerly DoP)
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving (e.g. metres per second [m/s]).

Term	Meaning
Emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
Flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood fringe area	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
Flood prone land	Land susceptible to flooding by the Probable Maximum Flood. Note that the flood prone land is synonymous with flood liable land.
Flood storage area	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event (i.e. flood prone land).
Floodplain Risk Management Plan	A management plan developed in accordance with the principles and guidelines in the NSW Floodplain Development Manual (FDM), (DIPNR, 2005). Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
Floodway area	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
FPA	Flood Planning Area. The area of land inundated at the Flood Planning Level.
FPL	Flood Planning Level. A combination of flood level and freeboard selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans. Typically equal to the 100 year ARI flood level plus a freeboard of 0.5 metres.

Term	Meaning
Freeboard	A factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted Flood Planning Level and the peak height of the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as "greenhouse" and climate change. Freeboard is included in the Flood Planning Level.
GPT	Gross pollutant trap. A device designed to capture pollutants in stormwater runoff prior to discharge into the receiving system. GPT's are typically designed to capture litter and debris but may also capture hydrocarbons, suspended sediments and particle bound pollutants such as nitrogen, phosphorus and heavy metals.
GSDM	Generalised Short Duration Method. A method for estimating the Probable Maximum Precipitation for catchments up to 1,000 square kilometres in area.
HHWSS	Highest High Water Solstice Spring. The tide level reached on average once or twice per year.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to the NSW Floodplain Development Manual (FDM), (DIPNR, 2005) the hazard is flooding which has the potential to cause damage to the community.
Headwater	The upper reaches of a drainage system.
Hydraulics	The term given to the study of water flow in waterways, in particular the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
Hydrology	The term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Merits based approach	The merits based approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well-being of the State's rivers and floodplains.
OEH	Office of Environment and Heritage (formerly DECCW)
Overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
Peak discharge	The maximum discharge occurring during a flood event.

Term	Meaning
Peak flood level	The maximum water level occurring during a flood event.
PMF	Probable Maximum Flood The flood that occurs as a result of the Probable Maximum Precipitation (PMP) on a study catchment. The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land (i.e. the floodplain).
PMP	Probable Maximum Precipitation. The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a catchment hydrologic model which simulates the conversion of rainfall to runoff.
PRM	Probabilistic Rational Method
Probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RL	Reduced Level. The reduced level is the vertical distance between an elevation and an adopted datum plane such as the Australian Height Datum (AHD).
Roads and Maritime	NSW Roads and Maritime Services
Runoff	The amount of rainfall which actually ends up as stream flow, also known as rainfall excess.
Stage	Equivalent to water level (both measured with reference to a specified datum)
SW	Sydney Water
Flow Velocity	A measure of how fast water is moving (e.g. metres per second [m/s]).
Water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
WDA	WestConnex Delivery Authority

EXECUTIVE SUMMARY

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

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.

This technical working paper forms part of the EIS for the project and deals with the potential flood risks associated with its as-built form. The flood risk assessment was based on design floods with average recurrence intervals (ARI's) of 20, 100 and 200 years, as well as the Probable Maximum Flood (PMF). This technical working paper also sets out the findings of an assessment of the potential impact both future climate change and a partial blockage of major hydraulic structures would have on flooding behaviour in the vicinity of the project. An assessment of the potential flood risks associated with the construction of the project is set out in a separate technical working paper entitled Technical Working Paper: Surface Water (AECOM, 2015).

The assessment found that the reference design for the project would result in a minor impact on flooding behaviour outside the motorway corridor for events up to and including the 100 year ARI. The locations where the project would lead to a minor increase in peak flood levels in existing development should further design development not be undertaken during detailed design are as follows:

- In a portion of two commercial/industrial properties that are located on the southern side of the motorway corridor on The Crescent, Kingsgrove. Peak 100 year ARI flood levels in a portion of the two properties would be increased by a maximum of about 20 millimetres. The impact on flooding behaviour in these two properties is attributed to the loss of floodplain storage which would be lost as a result of the widening of the M5 East Motorway along its northern side, in combination with the realignment several motorway transverse drainage structures. **Figure 5.2**, sheet 1 shows the impact the project would have on peak 100 year ARI flood levels in the vicinity of these two properties.
- In seven residential properties that are located on the northern side of Marsh Street in Arncliffe. Peak 100 year ARI flood levels in the properties would be increased by a maximum of about 10 millimetres. The impact on flooding behaviour in these properties is attributed to the loss of about 12,000 cubic metres of floodplain storage which would result from the construction of the Arncliffe motorways operation complex. **Figure 5.6**, sheet 2 shows the impact the project would have on peak 100 year ARI flood levels in the vicinity of the motorway complex.

- In a portion of two commercial/industrial properties that are located on the western overbank of Alexandra Canal on Burrows Road, St Peters, immediately upstream of Campbell Road bridge. Peak 100 year ARI flood levels in a portion of the two properties would be increased by a maximum of about 30 millimetres. The impact on flooding behaviour in these two properties is attributed to the redistribution of flow which would be caused by the raising of the Campbell Road / Burrows Road intersection. The inset in **Figure 5.6**, sheet 1 shows the impact the project would have on peak 100 year ARI flood levels in the vicinity of these two properties.
- In a portion of the recently upgraded section of TransGrid's Beaconsfield West Substation which is located on the western overbank of Alexandra Canal on Burrows Road, St Peters, a short distance upstream of Campbell Road bridge. Peak 100 year ARI flood levels in the south west corner of the substation would be increased by a maximum of about 30 millimetres. The impact on flooding behaviour in the substation is attributed to the redistribution of flow which would be caused by the raising of the Campbell Road / Burrows Road intersection. The inset in **Figure 5.6**, sheet 1 shows the impact the project would have on peak 100 year ARI flood levels in the vicinity of this property.

The key findings of the assessment in regards to the impact the project would have on flooding behaviour for a PMF event were as follows:

- The proposed widening of the existing M5 East Motorway along its northern side would result in an increase of up to 1.6 metres in peak PMF levels in the vicinity of the Canterbury Golf Course (refer **Figure 5.4**, sheet 1).
- The effects of the road widening on peak PMF levels would extend into seven residential properties that are located to the west of the Canterbury Golf Course in Elouera Street and Kirrang Street, Beverly Hills. Increases in the depth of inundation attributable to the project range from around 0.45 metres to around 0.95 metres (refer inset in **Figure 5.3**, sheet 1, which shows the maximum increase in peak PMF levels in the individual properties). Flooding in the seven properties would generally be of a ponding nature, with flow velocities shown to be less than about 0.1 metres per second during a PMF event.

  While the inundation of previously flood free land would generally be confined to the landscaped portion of five of the seven properties, floodwater would inundate land bordering the dwellings in Nos. 50 and 52 Elouera Street, Beverley Hills. While floor level survey would be required to determine whether the project would result in the above-floor inundation of these two dwellings, inspection of the LiDAR survey data shows that ground levels in the majority of No. 50 Elouera Street and in the south-west corner of No. 52 Elouera Street lie above the PMF level, indicating that evacuation would still be possible from the two properties by foot during an event of this magnitude.
- Peak flood levels would generally be increased in the range of 10 to 50 millimetres on the lower Cooks River floodplain, with greater increases shown to occur immediately upstream of the new Campbell Road bridge (generally in the range of 50 to 200 millimetres) and on the northern side of Marsh Street opposite the Arncliffe motorway operations complex (in the range of 50 to 100 millimetres).
- While the impact of the project on peak PMF flood levels on the lower Cooks River floodplain is widespread, the extent of flood prone land would not be greatly increased.
- The flood risk in Sydney Airport would not be increased given the minor impact the project would have on flooding behaviour.

- The project would not impact existing evacuation routes.
- While the main carriageways of the project lie above peak 100 year ARI flood levels, it is recommended that more detailed flood modelling be undertaken during detailed design to confirm finished road levels and the heights of any flood walls which are required to prevent the ingress of floodwater to the road tunnels for events up to the PMF.

The investigation found that the project would not increase the duration of flooding for all events up to the PMF.

The impact of a partial blockage of major hydraulic structures on flooding behaviour on the project would be limited to the Arncliffe motorway operations complex during a 100 year ARI event (refer **Figure 5.11**, sheet 2), while increases in peak flood levels would occur in the vicinity of the Arncliffe, St Peters and Burrows Road motorway operations complexes, as well as the St Peters interchange during a PMF event (refer **Figure 5.12**). It is recommended that consideration be given during detailed design to the effects a partial blockage of major hydraulic structures would have on flooding behaviour when setting finished road level and flood wall heights.

The effects of future climate change on flooding behaviour have the potential to impact the project where it crosses the lower Cooks River floodplain. For example, an increase in rainfall intensity would increase the frequency and depth of inundation in the vicinity of the Arncliffe motorway operations complex (refer **Figure 5.14**, sheet 2), while a rise in sea level would impact flooding behaviour in the vicinity of the Arncliffe, St Peters and Burrows Road motorway operations complexes, as well as the St Peters interchange (refer **Figures 5.15** to **5.18**). A more detailed assessment would need to be undertaken during detailed design to determine the climate change related flood risks to the project and to scope requirements for any management measures. The assessment should be undertaken in accordance with the NSW Government's *Practical Considerations of Climate Change – Floodplain Risk Management Guideline* (Department of Environment and Climate Change (DECC), 2007).

A flood management strategy (FMS) would be prepared prior to construction to minimise the potential project impacts on existing flooding characteristics within its vicinity. The FMS would identify appropriate design standards for managing the flood risk during the construction and operational phases of the project. It would also include procedures aimed at reducing the flooding threat to human safety and infrastructure, as well as controls that are aimed at mitigating the impact of the project (during construction and operation) on flooding behaviour.

To mitigate the increase in flood risk to residential properties north of Marsh Street at Arncliffe during a 100 year ARI flood, further investigations would be undertaken during detailed design to confirm the floor levels of impacted properties and determine the final mitigation strategy. An option considered in this assessment is to lower ground levels in the northern part of the Kogarah Golf Course adjacent to the Arncliffe motorway operations complex. An initial assessment found that it would be necessary to lower ground levels by an average of about 200 millimetres across the construction footprint in order to recapture sufficient floodplain storage (estimated to be about 8,000 cubic metres) so as not to impact peak flood levels in existing residential development. However, the final design solution and requirement (and extent) for compensatory flood storage would be determined during detailed design.

No measures are proposed which would be aimed at mitigating the impact of the project on flooding behaviour in the vicinity of the Canterbury Golf Course, where seven residential properties are affected by increases in peak PMF flood levels of up to around 0.95 metres. This is because the project would not affect the development potential of these properties for residential purposes (i.e. because they lie above the residential Flood Planning Level (FPL), which in the Canterbury local government area is equal to the 100 year ARI flood level plus an allowance of 0.5 metres for freeboard) and self-evacuation would still be possible for all floods up to the PMF. The project would constrain the development potential for at least one residential property in Elouera Street for vulnerable uses such as child or aged care.

Further investigations would be undertaken during detailed design to confirm the floor levels for the four commercial/industrial properties and TransGrid's Beaconsfield West Substation which would be impacted by the project, and to identify any additional measures that would need to be incorporated into the project design to mitigate the impact of the project on flooding conditions in these properties.

1 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 1.1**.

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 forms part of the EIS for the project and deals with the potential flood risks associated with its as-built form.

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.

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.

Figure 1.1 provides an overview of the location and catchment plan for the project. **Figure 1.2** and **Figure 1.3** depict the key features of the project within the Upper Wolli Creek and Lower Cooks River floodplains. **Figure 1.4** provides an overview of the project that is the subject of this application.

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

The Secretary's Environmental Assessment Requirements (SEARS) for the project were issued on 5 March 2015, and re-issued on 26 August 2015, by the Department of Planning and Environment (DPE). The requirements relevant to flooding are as follows:

> *"identification of potential impacts of the proposal on existing flood regimes, consistent with the Floodplain Development Manual (Department of Natural Resources, 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 that due consideration of flood risks during construction and in the proposal design;"*

This technical working paper forms part of the EIS for the project and deals with the potential flood risks associated with its as-built form. The findings of a similar assessment which was undertaken into the potential flood risks associated with the construction phase of the project are set out in a separate technical working paper entitled Technical Working Paper: Surface Water (AECOM, 2015).

The key objectives of the flood risk assessment were to:

- Identify the flood risk to the project in its as-built form over the full range of potential flood events.
- Identify the potential impacts of the project on flooding behaviour in areas outside the project corridor.
- Identify measures aimed at reducing the flood risk to the project.
- Identify measures aimed at mitigating the impacts of the project on flooding behaviour in areas outside the project corridor.

1.5 Study area

The project is located in the Cooks River catchment, as shown on **Figure 1.1**. Works located in the vicinity of the tunnel portals have the potential to impact flooding behaviour on the main arm of the river near its outlet to Botany Bay, as well as two of its major tributaries, Wolli Creek and Sheas Creek / Alexandra Canal. **Figures 1.2** and **1.3** show the key features of the project on the upper Wolli Creek and lower Cooks River floodplains, respectively.

1.6 Report structure

Chapter 2 sets out the flood related statutory and policy context for the project, as well as several industry guidelines that are relevant to the flooding investigation. This chapter also sets out how the relevant government policies and industry guidelines have been taken into account as part of the assessment.

Chapter 3 sets out the methodology that has been adopted in the definition of flooding behaviour in the vicinity of the project and also the impact the project would have on flooding behaviour. Also presented in this chapter of the technical working paper is the methodology which has been adopted for assessing the impact a partial blockage of major hydraulic structures and also future climate change (both sea level rise and increases in rainfall intensity) would have on flooding behaviour under post-construction conditions. The methodology adopted for assessing measures aimed at mitigating the impact of the project on flooding and also the impact flooding has on the project is also presented in this chapter of the technical working paper.

Chapter 4 contains a brief description of the Cooks River catchment within which the project is located. This chapter of the technical working paper also provides a description of flooding behaviour in the vicinity of the project under present day (i.e. pre-project) conditions.

Chapter 5 presents the findings of an assessment which was undertaken into the impact the project would have on flooding behaviour. Also presented in this chapter of the report is an assessment of the impact flooding would have on the project and also the key findings of an analysis which was undertaken to test the sensitivity of flooding behaviour to a partial blockage of major hydraulic structures, as well as potential changes in rainfall intensity and a rise in sea level associated with future climate change.

Chapter 6 deals with the findings of a preliminary assessment of measures which are aimed at mitigating the impacts of the project on flooding conditions in adjacent development.

Chapter 7 contains a list of references cited in this technical working paper.

Appendices A and **B** of this technical working paper contain background to the development and testing of the flood models that were used to define flooding behaviour on the upper Wolli Creek and lower Cooks River floodplains, respectively.

Appendix C contains a summary of peak flows in the drainage systems of both the upper Wolli Creek and lower Cooks River floodplains.

The scales on figures referred to in this technical working paper are applicable when printed at A3 size. The figures referred to in the main body of this technical working paper are located after Chapter 7 of this report.

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2 STATUTORY AND POLICY CONTEXT

2.1 Relevant Government policies and industry guidelines

Government policies and guidelines that have been considered as part of the current assessment (arranged in date order) include:

- *Flood Prone Land Policy* (NSW Government).
- Section 117(2) Local Planning Direction 4.3 Flood Prone Land (NSW Government).
- Planning circular PS 07-003 *New guideline and changes to section 117 direction and (Environmental Planning and Assessment Regulation on flood prone land* (NSW Government).
- *Guideline on Development Controls on Low Flood Risk Areas* (NSW Government).
- *Sydney Regional Environmental Plan No.33 - Cooks Cove*.
- *Australian Rainfall and Runoff* (AR&R) (Institution of Engineers Australia (IEAust), 1998).
- *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method* (Bureau of Meteorology (BoM), 2003).
- *Floodplain Development Manual* (Department of Infrastructure, Planning and Natural Resources (DIPNR), 2005).
- *Floodplain Risk Management Guideline – Practical Considerations of Climate Change* (Department of Environment and Climate Change (DECC), 2007).
- *Derivation of the NSW Government's Sea Level Rise Planning Benchmarks*. Technical Note (Department of Environment, Climate Change and Water (DECCW), 2009).
- *Coastal Planning Guideline – Adapting to Sea Level Rise* (Department of Planning (DoP), 2010).
- *Coastal Risk Management Guideline – Incorporating Sea Level Rise Benchmarks in Coastal Risk Assessments* (DoP, 2010).
- *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2010).
- *Canterbury Local Environmental Plan 2012*.
- *Canterbury Development Control Plan 2012* (Canterbury City Council, 2012).
- *Hurstville Local Environmental Plan 2012*.
- *Hurstville Development Control Plan 1- LGA Wide DCP* (Hurstville City Council, 2012).
- *Requirements for Overland Flow Studies – Fact Sheet* (Hurstville City Council).
- *Rockdale Local Environmental Plan 2011*.
- *Rockdale Development Control Plan 2011* (Rockdale City Council, 2011).
- *Marrickville Local Environmental Plan 2011*.
- *Marrickville Development Control Plan 2011* (Marrickville City Council, 2011).
- *Sydney Local Environmental Plan*.
- *Sydney Development Control Plan* (City of Sydney Council, 2012).
- *Botany Bay Local Environmental Plan 2013*.
- *Botany Bay City Council Development Control Plan 2013* (Botany Bay City Council, 2013).

- *Stormwater Management Technical Guidelines – December 2013* (Botany Bay City Council, 2013).
- *AR&R Revision Projects – Project 11 – Blockage of Hydraulic Structures* (Engineers Australia (EA), 2013).

2.2 Floodplain Development Manual

The Floodplain Development Manual (FDM) 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 FDM 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 FDM promotes the concept that proposed developments be treated on their merit rather than through the imposition of rigid and prescriptive criteria.

Flood and floodplain risk management studies undertaken by local councils as part of the NSW Government's Floodplain Management Program are carried out in accordance with the merits based approach promoted by the FDM. A similar merits based approach has been adopted in the assessment of the impacts the project would have on existing flood behaviour and also in the development of a range of potential measures which would be aimed at mitigating the impact of the project on the existing environment.

2.3 State Government planning directions and guidelines

In January 2007 the NSW Department of Planning (DOP) issued Planning circular PS 07-003 "*New guideline and changes to section 117 direction and (Environmental Planning and Assessment Regulation on flood prone land*" which provided an overview of its new guideline to the FDM titled Guideline on Development Controls on Low Flood Risk Areas and changes to the Environmental Planning and Assessment Regulation 2000 and section 117 Direction on flood prone land. More specifically, the circular provided advice on a package of changes concerning flood-related development controls on residential development on land above the 100 year ARI flood and up to the PMF. These areas are sometimes known as low flood risk areas.

Guideline on Development Controls on Low Flood Risk Areas confirmed that unless there are exceptional circumstances, councils should adopt the 100 year ARI flood as the basis for deriving the Flood Planning Level (FPL) for residential development. In proposing a case for exceptional circumstances, a council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. The guideline also notes that, unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land above the residential FPL (low flood risk areas). However, the guideline does acknowledge that controls may need to apply to critical infrastructure (such as hospitals) and consideration given to evacuation routes and vulnerable developments (like nursing homes) in areas above the 100 year ARI flood.

In July 2007 the NSW Government's Minister for Planning issued a list of directions to local councils under section 117(2) of the Environmental Planning and Assessment Act 1979. Direction 4.3 - Flood Prone Land applies to all councils that contain flood prone land within their LGA and requires that:

- A draft Local Environmental Plan (LEP) shall include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the FDM (including the *Guideline on Development Controls on Low Flood Risk Areas*).
- A draft LEP shall not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.
- A draft LEP shall not contain provisions that apply to the flood planning areas which:
  - permit development in floodway areas,
  - permit development that will result in significant flood impacts to other properties,
  - permit a significant increase in the development of that land,
  - are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or
  - permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.
- A draft LEP must not impose flood related development controls above the residential flood planning level for residential development on land, unless a council provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).
- For the purposes of a draft LEP, a council must not determine a flood planning level that is inconsistent with the FDM (including the Guideline on Development Controls on Low Flood Risk Areas) unless a council provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

Based on the above requirements, the assessment of the impacts the project would have on existing flood behaviour and also the future development potential of flood affected land outside the project corridor relates to all storms with ARI's up to 100 years in the case of residential type development (and by default commercial and industrial type development) and for storms with ARI's greater than 100 years in the case of critical infrastructure (such as hospitals) and vulnerable developments (such as aged care facilities). The key findings of the assessment in this regard are set out in **Section 5.2**.

2.4 State Government floodplain risk management guidelines

Scientific evidence shows that climate change would lead to sea level rise and potentially increase flood producing rainfall intensities. The significance of these effects on flood behaviour would vary depending on geographic location and local topographic conditions. Climate change impacts on flood producing rainfall events show a trend for larger scale storms and resulting depths of rainfall to increase. Future impacts on sea levels are likely to result in a continuation of the rise which has been observed over the last 20 years.

The NSW Government's *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC, 2007) recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent. Under present day climatic conditions, increasing the 100 year ARI design rainfall intensities by 10 per cent would produce about a 200 year ARI flood; and increasing those rainfalls by 30 per cent would produce about a 500 year ARI flood. On current projections the increase in rainfalls within the design life of the project is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit. Given that finished road levels for the project generally lie well above the upper envelope of 100 year ARI flooding, only the impact a 10 per cent increase on 100 year ARI design rainfall intensities would have on flooding behaviour was assessed as part of this investigation.

Climate Change 2007: The Physical Science Basis. Summary for Policymakers (Intergovernmental Panel on Climate Change (IPCC, 2007)) includes trends that 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 *Projected Changes in Climatological Forcing Conditions for Coastal Erosion in NSW* (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 its *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC, 2007), the NSW Government 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.

In 2009 the NSW Government released its *Sea Level Rise Policy Statement* (NSW Government, 2009) which supported adaptation to projected sea level rise impacts. The policy statement included sea level rise planning benchmarks for use in assessing potential impacts of projected sea level rise in coastal areas, including flood risk and coastal hazard assessment. These benchmarks were a projected rise in sea level (relative to 1990 mean sea level) of 0.4 metres by 2050 and 0.9 metres by 2100, based on work carried out by the Intergovernmental Panel on Climate Change and CSIRO. In its *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2010), the NSW Government recommended that these benchmark rises should be used to assess the sensitivity of flood behaviour to future sea level rise.

In 2012 the NSW Government announced its *Stage 1 Coastal Management Reforms* (NSW Government, 2012). As part of these reforms, the NSW Government no longer recommends state-wide sea level rise benchmarks, with local councils now having the flexibility to consider local conditions when determining local future hazards.

In the absence of a formal State Government policy on sea level rise benchmarks, the previously recommended rises in sea level of 0.4 metres by 2050 and 0.9 metres by 2100 have been adopted for assessing the impact future climate change could have on flooding conditions in the vicinity of the project. The key findings of the assessment in this regard are set out in **Section 5.5**.

The *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC, 2007) also contains guidance on strategies which are aimed at managing the impact of future climate change on both existing and proposed development. The guideline includes several examples on how to deal with the ramifications of future climate change which are dependent on location and the potential to effectively and practically manage its impact.

2.5 Flood related planning controls

The western end of the project is located in the local government areas (LGA's) of Canterbury, Hurstville and Rockdale, while the eastern end of the project is located in the LGA's of Botany Bay, Marrickville and Sydney. While the level of documentation differs between the various councils, the Flood Planning Level (FPL) for residential development is in all cases equal to the peak 100 year ARI flood level plus 0.5 metres for properties subject to main stream flooding. Botany Bay, Hurstville and Marrickville councils also incorporate a reduced freeboard allowance of 0.3 metres in areas subject to overland flow.

The above approach is consistent with the NSW Government's *Guideline on Development Controls on Low Flood Risk Areas* which confirms that unless there are exceptional circumstances, councils should adopt the 100 year ARI flood as basis for deriving the FPL for residential development. **Table 2.1** over the page lists the LEP for each council and notes which of these contains Flood Planning Maps showing the presence of flood affected land at the western and eastern ends of the project. Note that the Flood Planning Area (FPA) is defined as land which lies below the FPL.

While all councils require that site specific flood studies be undertaken in accordance with the FDM, City of Sydney Council includes the requirement that studies be undertaken in accordance with the *NSW Coastal Planning* Guideline: *Adapting to Sea Level Rise* (DoP, 2010), the *Coastal Risk Management Guideline: Incorporating Sea Level Rise Benchmarks in Coastal Risk Assessments* (DoP, 2010) and the *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2010).

It is noted that Kogarah Golf Course lies within the area covered by the *Sydney Regional Environmental Plan No 33 – Cooks Cove*, a deemed State Environmental Planning Policy. Rockdale City Council is the consent authority for the purpose of this plan, except as provided otherwise by the EP&A Act. The following clauses set out in the plan relate to flooding:

Clause 18 titled *"Environmental management – special requirements"*

> *"(e) the proposed development will be carried out in a manner that minimises flood risk to both people and property, but has due regard to environmental considerations, and*
>
> *(f) changes in local flow regimes due to development will be minimised, …"*

Clause 19 titled "*Development of flood prone land*"

> *"(1) This clause applies to land in the vicinity of the Cooks River and Muddy Creek defined as flood prone land in the latest appropriate study adopted by the consent authority for the purposes of this clause.*
>
> *(2) Before granting consent for development of land to which this clause applies, the consent authority must consider:*
>
> > *(a) the impact of the proposed development on flood flows and whether any compensatory works should be provided, and*
> >
> > *(b) if land filling is involved, whether any compensatory flood storage or other flood mitigation works should be provided, and*
> >
> > *(c) the impact of the development on the ecological significance of the Cooks River and Muddy Creek and their wetlands and measures that can minimise any adverse impact, such as the provision of compensatory wetland habitats."*

It is noted that flood prone land is defined in the Dictionary of the plan as:

> *"**flood prone land** means land that is susceptible to flooding by a 1% Annual Exceedance Probability flood event."*

This definition is not consistent with the FDM, which defines flood prone land as land susceptible to flooding by the PMF event.

TABLE 2.1
RELEVANT LOCAL ENVIRONMENTAL PLANS
AND FLOOD PLANNING MAPS

Local Environmental Plan	Component of Project (excluding road tunnels)	Flood Planning Maps
Canterbury Local Environmental Plan 2012	Western surface works, Kingsgrove motorway operations complex and Bexley Road South motorway operations complex	Flood Planning Map FLD_005 which covers the area north of the M5 East Motorway corridor in the vicinity of Canterbury Golf Course is not attached to the LEP. Flood Planning Map FLD_008 does not identify land immediately to the north of the M5 East Motorway corridor between Canterbury Golf Course and Bexley Road as FPA.
Hurstville Local Environmental Plan 2012	Western Surface Works	No Flood Planning Maps are attached to the LEP.
Rockdale Local Environmental Plan 2011	Arncliffe motorway operations complex[1]	Flood Planning Maps FLD_003 shows land to the north of Marsh Street on the western overbank of the Cooks River as FPA. Flood Planning Maps FLD_003 does not show Kogarah Golf Course as FPA as the LEP does not apply to this land. Flood Planning Maps FLD_007 shows a portion of Sydney Airport on the eastern overbank of the Cooks River as FPA.
Marrickville Local Environmental Plan 2011	St Peters interchange, local road upgrades and St Peters motorway operations complex	Flood Planning Maps FLD_004 and FLD_005 identify land along the eastern overbank of the Cooks River and the northern overbank of Alexandra Canal as FPA.
Sydney Local Environmental Plan 2012	St Peters interchange, local road upgrades and Burrows Road motorway operations complex	No Flood Planning Maps are attached to the LEP.
Botany Bay Local Environmental Plan 2013	Local road upgrades	No Flood Planning Maps are attached to the LEP.

1. The land impacted by the project at the Kogarah Golf Course is subject to the requirements of the *Sydney Regional Environmental Plan No.33 - Cooks Cove*. Refer **Section 2.5** for further details.

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3 ASSESSMENT METHODOLOGY

3.1 Key tasks

The key tasks comprising the flooding investigation are broadly described below:

- Review and update several existing flood models that had previously been developed during concept design development for the WestConnex project.
- Develop new flood models in areas not covered by the existing flood models referred to above.
- Run the flood models and prepare exhibits showing flooding behaviour under present day (pre-project) conditions for the 20 year, 100 year and 200 year ARI events, as well as the Probable Maximum Flood (PMF).
- Assess the impact the project would have on flooding behaviour for the aforementioned design flood events.
- Assess the impact a partial blockage of major hydraulic structures would have on flooding behaviour under post-construction conditions.
- Assess the impact future climate change would have on flooding behaviour under post-construction conditions.

The followings sections of this technical working paper set out the methodology which was adopted in the assessment of flooding behaviour under present day and post-conditions. Further discussion on the assessment of measures which would be required to mitigate the impact of the project on flooding behaviour is contained in **Chapter 6** of this technical working paper.

The assessment has considered a worst case disturbance footprint at the Arncliffe motorway operation complex.

3.2 Definition of present day flooding behaviour

In order to define the nature of flooding in the vicinity of the project it was necessary to review and update, as well as develop a new set of computer based flood models. Both the RAFTS and DRAINS rainfall-runoff modelling software packages were used to generate design discharge hydrographs for input to the hydraulic models, while flooding patterns in the vicinity of the project were defined using the TUFLOW two-dimensional (in plan) hydraulic modelling software. The HEC-RAS hydraulic modelling software was also used to define the upper envelope of flooding in the vicinity of Bexley Road on the Upper Wolli Creek floodplain.

In regards the definition of flooding behaviour on the lower Cooks River floodplain, it was necessary to decide upon coincident catchment and ocean flooding conditions from which design flood envelopes could be derived.[1] Site specific ocean level data were used to define peak storm tide levels for ocean floods ranging between one in five and one in 100 years (as opposed to the adoption of the default storm tide hydrographs recommended in OEH's guideline *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2010)). An estimate of the peak storm tide level which would be reached for an

[1] For each assessed ARI flood event, the highest peak flood level generated by an adopted set of coincident catchment and ocean floods was used to derive a single design flood envelope. The design flood envelope therefore represents the highest peak flood level which could be reached by a flood of a given ARI, whether as a result of a catchment or ocean flood event. **Appendix B** provides background to the derivation of the design flood envelopes presented in this technical working paper.

extreme ocean flood event was also derived by extrapolation of the site specific data. **Section B4.4** in **Appendix B** of this technical working paper contains further background to the derivation of storm tide hydrographs which were used for defining design flood levels on the lower Cooks River floodplain.

Flooding behaviour in the vicinity of the project was defined for events with ARI's of 20, 100 and 200 years, as well as the PMF. A brief description of flooding behaviour in the vicinity of the project under present day (pre-project) conditions is presented in **Chapter 4** of this technical working paper.

3.3 Sensitivity analyses

The sensitivity of the hydraulic model was tested to variations in model parameters such as hydraulic roughness, and in the case of the lower Cooks River, to varying tailwater conditions. The main purpose of these studies was to give some guidance on the freeboard which might be adopted in the design of the project.

Runs of both of the hydraulic models were undertaken assuming a 20 per cent increase in hydraulic roughness (compared to the best estimate values given in **Table B4.3** in **Appendix B** of this technical working paper). The findings of the sensitivity analysis in relation to the resulting changes in flooding behaviour are presented in **Section A3.4** in **Appendix A** (Upper Wolli Creek floodplain) and **Section B4.5.1** in **Appendix B** (Lower Cooks River floodplain) of this technical working paper.

Runs of the hydraulic model developed to define flooding behaviour on the lower Cooks River floodplain were also undertaken to assess the sensitivity of flooding behaviour to variations in the adopted tailwater condition in Botany Bay. This included the testing of the hydraulic model using both normal tide and High High Water Solstice Spring (HHWSS) conditions, as well as the default storm tide hydrographs recommended in *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2010). Background to the derivation of coincident catchment and ocean flooding conditions which were adopted for model testing purposes is contained in **Section B4.4** of **Appendix B**, while a brief discussion on the findings of the sensitivity analysis are contained in **Section B4.5.2** in **Appendix B** of this technical working paper.

3.4 Comparison with findings of previous studies

While no detailed investigations have been undertaken to define flooding behaviour in the upper reaches of Wolli Creek, several flood studies have been undertaken which deal with flooding on the lower Cooks River floodplain in the vicinity of the project. **Section B5.5** in **Appendix B** of this technical working paper provides a comparison of peak flow and flood level data which are presented in these studies with those of this investigation.

3.5 Provisional flood hazard

Flood hazard categories may be assigned to flood affected areas in accordance with the procedures outlined in the FDM. Flood prone areas may be provisionally categorised into *Low Hazard* and *High Hazard* areas depending on the depth of inundation and flow velocity. Flood depths as high as one metre, in the absence of any significant flow velocity, could be considered to represent Low Hazard conditions. Similarly, areas of flow velocities up to two metres per second, but with small flood depths could also represent Low Hazard conditions.

Provisional Flood Hazard diagrams for the 100 year ARI event based on Diagram L2 in the FDM have been prepared as part of the current investigation (refer **Section 4.2** for further details).

The Flood Hazard assessment presented herein is based on considerations of depth and velocity of flow and is *provisional* only. As noted in the FDM, other considerations such as the rate of rise of floodwaters and access to high ground for evacuation from the floodplain should also be taken into consideration before a final determination of Flood Hazard can be made. These factors are generally taken into account during the preparation of a Floodplain Risk Management Study and Plan for an area.

3.6 Impact of the project on flooding behaviour

The structure of the Upper Wolli Creek and Lower Cooks River TUFLOW models was adjusted to incorporate details of the project. Background to the changes that were made to the structure of the hydraulic models that were used to assess the impact of the project on flooding behaviour on the upper Wolli Creek and lower Cooks River floodplains is contained in **Section A3.5** in **Appendix A** and **Section B4.7** in **Appendix B** of this technical working paper, respectively,

The results of modelling the 20, 100 and 200 year ARI events, together with the PMF event were used to prepare a series of afflux diagrams showing the impact the project would have on flooding behaviour.[1] A discussion on the impact the project would have on flooding behaviour is contained in **Section 5.2** of this technical working paper.

3.7 Impact of flooding on the project

The results of the modelling described in **Section 5.3** of this technical working paper were used to assess the impact flooding would have on the project. This included a review of the freeboard which would be available to the tunnel portals and motorway ventilation infrastructure during a PMF event.

3.8 Impact of a partial blockage of major hydraulic structures on flooding behaviour

Engineers Australia's guideline *AR&R Revision projects – project 11 – Blockage of Hydraulic Structures* (EA, 2013) includes guidance on modes of blockage which are likely to be experienced for different hydraulic structures. In regards bridge structures, those with clear opening heights less than three metres are said to be susceptible to blockage in streams where large floating debris is conveyed by floodwater. The guideline also states that debris is likely to wrap around the bridge piers, irrespective of the height of the clear opening

The impact an accumulation of debris on both existing and proposed bridge structures was assessed given the potential for the New M5 tunnel portal to be flooded due to a rise in flood levels in Alexandra Canal. The impact a one metre thick raft of debris lodged beneath the underside of both existing and proposed bridge decks in combination with a four metre wide raft of debris lodged on the upstream side of each bridge pier over the full height of the clear opening was assessed as part of the investigation.

In regards pipe and culvert structures, the guideline recommends the adoption of a 20 per cent blockage factor where the height of a hydraulic structure is less than three metres or its width is less than five metres. The structure of the hydraulic model which was used to define flooding

[1] In the context of this report, afflux is the difference in peak flood levels caused by changes to the floodplain. For example, due to a change in hydraulic roughness or the construction of the project.

behaviour on the Upper Wolli Creek floodplain was adjusted to include a 20 per cent blockage factor which was applied to all major hydraulic structures.

The findings of the blockage related impact assessment are contained in **Section 5.4** of this technical working paper.

3.9 Impact of future climate change on flooding behaviour

Section 2.4 of this technical working paper provides background to the derivation of the adopted sea level rise benchmarks and percentage increase in 100 year ARI design rainfall intensities which were used to assess the potential impact of future climate change on flooding behaviour in the vicinity of the project. Further details on the peak storm tide levels that have been adopted for assessing the impact of future sea level rise on flooding behaviour in the vicinity of the project are contained in **Section B4.4** of **Appendix B** of this technical working paper, while the findings of the climate change impact assessment are contained in **Section 5.5** of this technical working paper.

4 EXISTING ENVIRONMENT

4.1 Catchment description

4.1.1 Cooks River

The Cooks River drains a catchment of about 100 square kilometres in the southern suburbs of Sydney and discharges to Botany Bay at Tempe, adjacent to Sydney Airport. The catchment has been extensively developed and the river channel highly modified. Almost the entire length of the river is lined and the channel has been straightened and re-aligned in several locations.

The Cooks River has two major tributaries: Wolli Creek and Sheas Creek. Smaller tributaries include Muddy Creek and Cup and Saucer Creek. **Figure 1.1** shows the extent of the Cooks River catchment.

4.1.2 Upper Wolli Creek

The M5 East Motorway runs in a west to east direction through the upper portion of the Wolli Creek catchment. The catchment is completely urbanised with a drainage system comprising piped and open channel reaches. **Figure A2.1** in **Appendix A** of this technical working paper shows the location of the M5 East Motorway and the division of the overall catchment into sub-areas which was used in catchment modelling (RAFTS) to determine discharge hydrographs. On the southern side of the M5 East Motorway, the main arm of the creek is channelised to the east of Beverly Hills Park, where a concrete lined stormwater channel continues to Bexley Road. Immediately downstream of Bexley Road the creek enters a densely vegetated steep walled valley which significantly restricts creek flows (ref. **Figure 1.2**, sheet 2). The catchment area at Bexley Road is about 11.5 square kilometres.

The original design for the M5 East Motorway project and its drainage system included modifications to the open channel section of Wolli Creek between Kingsgrove Road and Bexley Road, as well as the cross drainage lines which convey runoff into the creek from areas north of the road (ref. **Figure 1.2**, sheet 1). The motorway drainage system was designed to convey flows up to the 100 year ARI magnitude. Several underpasses were also provided between King Georges Road and Bexley Road (including Kingsgrove Road itself) which provide additional capacity to convey flows greater than 100 year ARI magnitude.

4.1.3 Sheas Creek / Alexandra Canal

Sheas Creek is a major tributary of the Cooks River. The creek was widened in the late 1800's over about a four kilometres length to form the Alexandra Canal. The size of the catchment draining to the canal increases from about 6.6 square kilometres at its northern (upstream) end near Sydney Park Road, to about 17.7 square kilometres at its confluence with the Cooks River. **Figure B3.1** in **Appendix B** of this technical working paper shows the extent of the catchment which drains to Alexandra Canal upstream of its confluence with the Cooks River.

4.2 Description of existing flood behaviour

4.2.1 Upper Wolli Creek floodplain

Figures 4.1, **4.2**, **4.3** and **4.4** (2 sheets each) respectively show present day flooding patterns along Wolli Creek in the vicinity of the project for design floods of 20, 100 and 200 year ARI, as well as the PMF. **Figure 4.5** shows design water surface profiles along the main arm of Wolli Creek and one of its tributaries extending from Kooemba Road to a location downstream of

Bexley Road. Peak flows at key locations in the drainage system are summarised in **Table C1** in **Appendix C**.

Minor surcharge of transverse drainage structure XD1 would occur in a 100 year ARI event, when a peak flow of 1.7 cubic metres per second would discharge in an easterly direction toward the Kindilan Street underpass. Floodwater which surcharges the inlet of transverse drainage structure XD1 would pond along the northern side of the motorway before discharging to inlet pits located on cross drainage structures XD1A and XD2.

The concrete lined channel which runs to the south of the water quality pond located on the southern side of the motorway adjacent to Kirrang Street is surcharged by storms as frequent as 20 year ARI event east (downstream) of Kooemba Road (refer **Figure 4.2**, sheet 1). As a result, two existing residential properties that are located on the southern side of the motorway corridor on Tallawalla Street are subject to flooding during a flood of this recurrence interval. The presence of colorbond fencing that extends from Tallawalla Street to the motorway boundary would result in increased depths of inundation on the western (upstream) side of the two affected properties and divert flood flows into Tallawalla Street. Floodwater which surcharges the channel at this location flows in an easterly direction, where it does not fully re-enter the channel system until it reaches a location opposite the Kindilan Street underpass.

Flooding would be experienced in commercial and industrial development which is located between Beverly Hills Park and Kingsgrove Road as a result of floodwater which surcharges the main arm of Wolli Creek for events as frequent as a 20 year ARI event. Depths of inundation in several properties would exceed one metre.

The transverse drainage structures which lie immediately to the east of the Kindilan Street underpass generally have sufficient capacity to convey peak 100 year ARI flows generated by the local catchments which drain from the north. However, it is noted that floodwater which surcharges the main arm of Wolli Creek at the Karingal Street and Kingsgrove Road underpasses discharges in a northerly direction where it partially inundates a number of properties located along the northern side of the elevated motorway.

Major ponding of floodwater would occur along the northern side of the motorway corridor in the vicinity of Canterbury Golf Course during a PMF event (refer **Figure 4.3**, sheet 1). Peak flood levels along the northern side of the motorway fall from about RL 26.0 metres AHD adjacent to the inlet of transverse drainage structure XD1 to about RL 25.2 metres AHD adjacent to the northern end of the Kindilan Street underpass.

It is noted that the elevation of the eastbound carriageway between the inlets of transverse drainage structures XD1 and XD1A lies below the level of the PMF and that it is only the presence of a solid F-type barrier arrangement which presents floodwater from discharging onto the surface of the motorway at this location. Included on **Figure 4.5** is the energy grade line for the PMF event which was generated by the Wolli Creek HEC-RAS model (refer **Section A4** in **Appendix A** of this technical working paper for background to the development of the Wolli Creek HEC-RAS Model). The additional modelling was undertaken due to the Wolli Creek TUFLOW Model generating very high flow velocities (greater than eight metres per second) in the concrete lined section of channel downstream of Kingsgrove Road and the concern that any obstruction in the flow could cause a rapid rise in water surface levels adjacent to the motorway. The elevation of the energy grade line is considered to represent the upper limit of potential flooding along the reach of Wolli Creek downstream of Kingsgrove Road and should be used for setting critical levels such as ingress points to the Bexley Road South motorway operations complex.

Figure 4.6 shows that high hazard flooding conditions are generally confined to the inbank area of Wolli Creek and its tributaries at the 100 year ARI level of flooding. The major exception is in the commercial and industrial development which lies to the south of the motorway corridor, where high hazard flooding conditions are present in a large number of properties.

4.2.2 Lower Cooks River floodplain

Figures 4.7, **4.8**, **4.9** and **4.10** (2 sheets each) respectively show present day flooding patterns along the lower reaches of the Cooks River and Alexandra Canal for design floods of 20, 100 and 200 year ARI, together with the PMF, while **Figures 4.11** and **4.12** respectively show the design water surface profiles which were used to derive the flood envelopes along the lower Cooks River and Alexandra Canal for design floods of 20, 100 and 200 year ARI, together with the PMF. Peak flows at key locations in the drainage system are summarised in **Table C2** in **Appendix C**.

In the lower reaches of the Cooks River downstream of the Southern and Western Suburbs Ocean Outfall Sewer (SWSOOS) crossing, ocean flooding controls flood levels. Upstream of that location there is a crossover in the water surface profiles and levels associated with catchment flooding control. Catchment flooding controls the design flood levels along the length of Alexandra Canal.

Kogarah Golf Course is inundated by floodwater for events as frequent as 20 year ARI (refer **Figure 4.7**, sheet 2). Floodwater discharges to the golf course via Marsh Street and also due to surcharge of the river bank immediately north of the SWSOOS.

The golf course principally acts as a temporary flood storage area for events up to 100 year ARI. For example, a ponding area forms in the northern portion of the golf course which is partially filled by floodwater which discharges in a southerly direction across Marsh Street and in a northerly direction from the backwater which extends north from near the SWSOOS. The magnitude of the inflows to the ponding area during a 100 year ARI event is insufficient for it to fill during a flood of this return period. As a result, the peak flood level in the ponding area is below that in the river. For example, the peak 100 year ARI flood level in the river is about RL 2.1 metres AHD, while in the ponding area it is about 0.5 metre lower at about RL 1.6 metres AHD.[1] Depths of ponding in the northern portion of the Kogarah Golf Course are sufficient to result in hazardous flooding conditions arising during a flood of this recurrence internal (refer **Figure 4.13**, sheet 2).

In the case of the PMF event, the golf course would be inundated to depths exceeding two metres, with the peak flood level along its common boundary with Marsh Street reaching about RL 4.4 metres AHD.

Peak PMF levels in the vicinity of the Alexandria Landfill site (ie the location of the planned St Peters interchange) are controlled by flows generated by a storm centred over the Sheas Creek catchment, rather than from backwater flooding caused by a storm centred over the larger Cooks River catchment (refer **Figure 4.12**).

[1] Note that this finding is linked to a design storm of two hours duration which was found to be critical for maximising peak flows in the river. During a longer duration storm event, the volume of floodwater discharging to the golf course may be sufficient to fill the ponding area such that water levels equalise with those in the river.

As shown on **Figure 4.10**, sheet 1, floodwater would partially inundate the Alexandria Landfill site to an elevation of about RL 4.5 metres AHD during a PMF event. It is noted that an existing spoil mound (known as Bradshaw Mountain) which is located near Campbell Road prevents floodwater from discharging to the landfill site during a PMF event. The peak flood level on the canal side of the spoil mound is about RL 4.7 metres AHD.

5 FLOOD RISK ASSESSMENT

5.1 Overview

This chapter of the technical working paper deals with the key findings of the flooding investigation in terms of the impact the project would have on flooding behaviour on both the upper Wolli Creek and lower Cooks River floodplains. Also set out in this chapter is an assessment of the impact flooding would have on key components of the project, such as the road tunnels and motorway operations complexes. The findings of an assessment into the impact a partial blockage of major hydraulic structures and future climate change would have on flooding behaviour under post-construction conditions are also presented.

The figures referred to in this chapter show the impact the project would have on flooding behaviour in terms of changes in peak flood levels (commonly referred to as “afflux”). A positive afflux represents an increase and conversely a negative afflux represents a decrease in peak flood levels when compared to present day conditions. Differences in peak flood levels of ±0.01 metres (equal to one centimetre or 10 millimetres) are considered to be within the accuracy of the hydraulic model. The project is therefore considered to have a negligible or nil effect on flooding behaviour in areas where an afflux of ±0.01 metres is shown to be present. The figures also show the extent of additional land which would be inundated by floodwater, and conversely the extent of land which would be rendered flood free, as a result of the project.

5.2 Impact of the Project on flood behaviour

5.2.1 Upper Wolli Creek floodplain

Figures 5.1, **5.2**, **5.3** and **5.4** (2 sheets each) respectively show the impact the project would have on existing flooding behaviour on the upper Wolli Creek floodplain for design floods of 20, 100 and 200 year ARI, as well as the PMF. **Table 5.1** at the end of this chapter gives the change that would occur in peak flood levels at four locations outside the motorway corridor, while **Table C1** in **Appendix C** gives the change that would occur in the distribution of flow in the drainage system as a result of the project.

The key findings of the assessment were as follows:

- The project would not increase peak flood levels in existing residential development for all floods up to 100 year ARI.
- The project would not increase the duration of flooding for all events up to the PMF.
- The widening of the M5 East Motorway would result in an increase in peak flood levels along the northern side of the motorway corridor for floods up to 100 year ARI. However, the resulting impacts would be confined to the motorway corridor and the Canterbury Golf Club.
- The minor change in the distribution of flow in the drainage system would result in a minor increase in peak 100 year ARI flood levels in two industrial/commercial properties that are located on the southern side of the motorway corridor opposite the outlet of transverse drainage structures XD2 and XD3. The maximum increase in peak 100 year ARI levels in both properties would be about 20 millimetres.
- The constriction imposed on flow by the widening of the M5 East Motorway would lead to an increase in peak PMF levels of up to about 1.6 metres in the vicinity of the Canterbury Golf Course. Peak PMF flood levels would also be increased by around 0.45 metres to around 0.95 metres in seven residential properties that are located immediately to the

west of the golf course in Elouera Street and Kirrang Street, Beverly Hills (refer maximum increase in peak PMF levels shown in the inset on **Figure 5.4**, sheet 1). Flooding in the seven properties would generally be of a ponding nature, with flow velocities shown to be less than about 0.1 metre per second during a PMF event.

While the inundation of previously flood free land would generally be confined to the landscaped portion of five of the seven properties, floodwater would inundate land bordering the dwellings in Nos. 50 and 52 Elouera Street, Beverley Hills. While floor level survey would be required to determine whether the project would result in the above-floor inundation of these two dwellings, inspection of the LiDAR survey data shows that ground levels in the majority of No. 50 Elouera Street and in the south-west corner of No. 52 Elouera Street lie above the PMF level, indicating that evacuation would still be possible from the properties by foot during an event of this magnitude.

- The constriction imposed by the widening of the M5 East Motorway would lead to a reduction in peak PMF flood levels on the northern side of the motorway corridor in the vicinity of Beverly Grove Park and on the southern side of the motorway corridor in the vicinity of Tallawalla Street.
- The realignment of the existing motorway transverse drainage structure XD4 would not result in a major redistribution of flow in the drainage system for all floods up to the PMF. The project would not result in the more frequent inundation of property or the local road network over the full range of flood events.

Based on the above findings, it is concluded that the project would not impact the development potential of existing properties for residential, commercial and industrial purposes. However, the increase in peak PMF levels which would occur along the northern side of the motorway corridor in the vicinity of Canterbury Golf Course would constrain development in at least one residential property which is located in Elouera Street, Beverly Hills, if for example the property owner(s) decided to augment the existing dwelling to incorporate a child or aged-care facility.

5.2.2 Lower Cooks River floodplain

Figures 5.5, **5.6**, **5.7** and **5.8** (2 sheets each) respectively show the impact the project would have on existing flooding behaviour on the lower Cooks River floodplain for design floods of 20, 100 and 200 year ARI, as well as the PMF. **Table 5.2** at the end of this chapter gives the change that would occur in peak flood levels at four locations outside the motorway corridor, while **Table C2** in **Appendix C** gives the change that would occur in the distribution of flow in the drainage system as a result of the project.

The key findings of the assessment were as follows:

- The loss of about 12,000 cubic metres of floodplain storage associated with the construction of the Arncliffe motorway operations complex in Kogarah Golf Course would result in an increase in peak 100 year ARI flood levels in seven residential properties that are located on the northern (upstream) side of Marsh Street. The maximum increase in peak flood levels in these properties would be about 10 millimetres. The potential impacts would be confirmed based on the detailed design of the Arncliffe motorway operations complex. Floor level survey would be required to determine whether the project would result in the above-floor inundation of these properties.

- The construction of the two new road bridges across Alexandra Canal would generally not impact peak flood levels for events up to 100 year ARI. However, the raising of the Campbell Road / Burrows Road intersection would impact local flooding patterns, leading to an increase in peak 100 year ARI flood levels of about 30 millimetres in two commercial/industrial properties, as well as in a recently upgraded section of TransGrid's Beaconsfield West Substation.
- The loss of floodplain storage resulting from the construction of both the Arncliffe motorway operations complex in Kogarah Golf Course and the St Peters interchange in the Alexandria Landfill site in combination with the constrictive effects imposed by the two new road bridges across Alexandra Canal would result in an increase in peak PMF flood levels across a large portion of the lower Cooks River floodplain. While increases in peak PMF levels are generally in the range 10 to 50 millimetres, increases of greater than 100 millimetres would occur in a number of commercial/industrial properties that are located on the western overbank of Alexandra Canal immediately upstream of the new Campbell Road bridge.
- The resulting increase in peak PMF flood levels would not translate into a significant increase in the extent of flood prone land.
- The project would not alter the distribution of flows on the lower Cooks River floodplain.
- The project would not result in the more frequent inundation of property or the local road network over the full range of flood events.
- The project would not increase the duration of flooding for all events up to the PMF.

Based on the above findings, it is concluded that the project could potentially increase the frequency and depth of above-floor inundation in a number of residential properties that are located along the northern (upstream) side of Marsh Street opposite the Arncliffe motorway operations complex. As detailed in **Chapter 6**, a floor level survey would be completed for these properties and further investigations would be undertaken during detailed design to minimise the potential for increased flood risk at these properties during the 100 year ARI. Any such mitigation could also reduce the impact during a PMF.

TransGrid advised that while a conservative approach was adopted in the recent upgrade of its Beaconsfield West Substation, whereby critical infrastructure was positioned above about RL six metres AHD, all transformer switch bays and reactive plant were set at ground level (about RL two metres AHD) as per the existing design philosophy for the site. Further liaison would be carried out with TransGrid to determine whether the predicted increases in peak flood levels attributable to the project would adversely affect its infrastructure.

5.3 Impact of flooding on the project

5.3.1 Upper Wolli Creek floodplain

The Kingsgrove motorway operations complex would be located on land that lies above the PMF event.

While the Bexley Road South motorway operations complex is located on land that is currently subject to flooding during events as frequent as 20 year ARI, the extent of land affected by flooding is restricted to areas directly adjacent to Wolli Creek for events up to 100 year ARI. The emergency smoke extraction facility at the complex has been designed to be above the peak PMF level.

Consideration would also need to be given to setting appropriate road/flood wall heights which are aimed at preventing floodwater from discharging onto the surface of the widened motorway in the vicinity of the tunnel portals during a PMF event. The findings of the assessment into the impact a partial blockage of major hydraulic structures could have on flooding behaviour should also be taken into considering when setting road/flood wall heights (refer **Section 5.4** for details).

5.3.2 Lower Cooks River floodplain

The ventilation facilities at the Arncliffe and St Peters motorway operations complexes have been designed to be above the PMF event. The Burrows Road motorway operations complex, which contains the Motorway Control Centre lies on land which is located above peak 100 year ARI flood levels. However, it would be impacted during a PMF event. Components critical to tunnel operations would be located on the first floor of the centre, which would lie above the peak PMF level.

Consideration would also need to be given to setting appropriate road/flood wall heights in order to prevent floodwater from discharging to the tunnel portals via the St Peters interchange.

5.4 Impact of a partial blockage of major hydraulic structures on flood behaviour

Figures 5.9 and **5.10** show the impact a partial blockage of all major hydraulic structures located on the upper Wolli Creek floodplain in the vicinity of the project would have on flooding behaviour for the 100 year ARI and PMF events, respectively, while **Table 5.3** at the end of this chapter gives the increases which would occur in peak 100 year ARI and PMF levels at key locations bordering the project. The assessment showed that a partial blockage of major hydraulic structures located on the upper Wolli Creek floodplain would only have a minor impact on peak flood levels.

Figures 5.11 and **5.12** show the impact a partial blockage of all major hydraulic structures located on the lower Cooks River floodplain in the vicinity of the project would have on flooding behaviour for the 100 year ARI and PMF events, respectively, while **Table 5.3** at the end of this chapter gives the increases which would occur in peak 100 year ARI and PMF levels at key locations bordering the project. A partial blockage of the SWSOOS where it crosses the Cooks River would increase peak 100 year ARI flood levels adjacent to the Arncliffe motorway operations complex. A partial blockage of major hydraulic structures located downstream of Campbell Road bridge would also increase peak PMF levels adjacent to the St Peters interchange.

5.5 Impact of future climate change on flood behaviour

5.5.1 Potential increase in rainfall intensities

Figures 5.13 and **5.14** show the impact a potential increase of 10 per cent in 100 year ARI design rainfall intensities would have on flooding behaviour on the upper Wolli Creek and lower Cooks River floodplains, respectively, **Table 5.4** at the end of this chapter gives the increases that would occur in peak 100 year ARI flood levels at key locations bordering the project.

A 10 per cent increase in 100 year ARI design rainfall intensities would generally not have an impact on the project except at the Arncliffe motorway operations complex. At this location, there is the potential for peak flood levels to be increased by up to 190 millimetres in areas adjacent to the complex. Increases in rainfall intensity associated with future climate change would also increase the frequency of floodwater surcharging the banks of the Cooks River, which could also impact the complex.

5.5.2 Sea level rise

Figures 5.15 and **5.16** show the impact a projected rise in sea levels of 0.4 metre by the year 2050 would have on flooding behaviour on the lower Cooks River floodplain for the 100 year ARI and PMF events, respectively, while **Figures 5.17** and **5.18** show the impact a projected rise in sea levels of 0.9 metre by the year 2100 would have on flooding behaviour on the lower Cooks River floodplain for the 100 year ARI and PMF events, respectively. **Table 5.5** at the end of this chapter gives the increases that would occur in peak 100 year ARI and PMF flood levels at key locations bordering the project under both 2050 and 2100 sea level rise conditions.

While climate change induced sea level rise would not impact the St Peters interchange for events up to 100 year ARI, it would result in the more frequent inundation of Kogarah Golf Course in the vicinity of the Arncliffe motorway operations complex. Peak 100 year ARI flood levels would also be increased in the vicinity of the motorway operations complex by about 0.49 metres and 0.84 metres in the case of a 0.4 metre and 0.9 metre rise in sea level, respectively.[1]

A rise in sea level of 0.4 metres would result in an increase in peak PMF levels of about 0.13 metres in the vicinity of the St Peters interchange (including the Burrows Road and St Peters motorway operation complexes) and about 0.14 metres in the vicinity of the Arncliffe motorway operations complex. A rise in sea level of 0.9 metres would result in an increase in peak PMF levels of about 0.29 metres in the vicinity of the Burrows Road and St Peters motorway operation complexes, as well as the St Peters interchange and about 0.32 metres in the vicinity of the Arncliffe motorway operations complex.

[1] Note that the greater relative increase in peak 100 year ARI flood levels adjacent to the motorway operations complex under 2050 sea level rise conditions is a function of the filling of the temporary flood storage within the northern portion of the golf course.

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TABLE 5.1
IMPACT OF PROJECT ON PEAK FLOOD LEVELS
POST-CONTRUCTION VERSUS PRESENT DAY CONDITIONS
UPPER WOLLI CREEK FLOODPLAIN

Location identifier(1)	Location of peak flood level comparison	Peak flood level (metres AHD)(2)								Impact of project on peak flood levels (metres)(3)			
		Present day conditions				Post- construction conditions							
		20 year ARI	100 year ARI	200 year ARI	PMF	20 year ARI	100 year ARI	200 year ARI	PMF	20 year ARI	100 year ARI	200 year ARI	PMF
LOC 1	Northern side of motorway corridor adjacent to transverse drainage structure XD1.	24.62	24.71	25.01	26.08	24.12	25.09	25.43	27.68	-0.50	0.38	0.42	1.60
LOC 2	Within commercial / industrial development located on southern side of motorway corridor opposite the outlet of transverse drainage structure XD2.	22.57	22.85	22.97	24.44	22.56	22.87	23.02	24.31	-0.01	0.02	0.05	-0.13
LOC 3	Within commercial / industrial development located on southern side of motorway corridor opposite the outlet of transverse drainage structure XD3.	20.31	20.45	20.55	21.67	20.31	20.47	20.59	21.63	0.00	0.02	0.04	-0.04
LOC 4	Within commercial / industrial development located on northern side of motorway corridor opposite the inlet of transverse drainage structure XD5.	N/A	N/A	N/A	23.38	N/A	N/A	N/A	23.50	N/A	N/A	N/A	0.12

1. Refer **Figures 5.1**, **5.2**, **5.3**and **5.4** (sheets 1 and 2) for location of peak flood level identifiers.
2. Peak flood levels are typically quoted to one decimal place to reflect the accuracy of the flood modelling. However, they have been quoted to two decimal places in the above table to highlight minor differences in levels.
3. A positive value represents an increase in peak flood levels resulting from the project. Conversely, a negative value represents a decrease in peak flood levels resulting from the project.

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TABLE 5.2
IMPACT OF PROJECT ON PEAK FLOOD LEVELS
POST-CONTRUCTION VERSUS PRESENT DAY CONDITIONS
LOWER COOKS RIVER FLOODPLAIN

Location Identifier(1)	Location of peak flood level comparison	Peak flood level (metres AHD)(2)								Impact of project on peak flood levels (metres)(			
		Present day conditions				Post- construction conditions							
		20 year ARI	100 year ARI	200 year ARI	PMF	20 year ARI	100 year ARI	200 year ARI	PMF	20 year ARI	100 year ARI	200 year ARI	PMF
LOC 1	Western overbank of Alexandra Canal immediately upstream of new Campbell Road bridge.	N/A	2.77	2.92	4.72	N/A	2.80	2.97	4.90	N/A	0.03	0.05	0.18
LOC 2	Western overbank of Alexandra Canal beneath new Gardeners Road bridge.	N/A	2.60	2.80	4.53	N/A	2.60	2.80	4.55	N/A	0.00	0.00	0.02
LOC 3	Western overbank of Alexandra Canal on Burrows Road immediately north (upstream) of Canal Road intersection.	N/A	2.67	2.77	4.53	N/A	2.67	2.77	4.55	N/A	0.00	0.00	0.02
LOC 4	Within residential properties located along the northern (upstream) side of Kogarah Golf Course.	N/A	1.95	2.12	4.35	N/A	1.96	2.15	4.39	N/A	0.01	0.03	0.04

1. Refer **Figures 5.5**, **5.6**, **5.7** and **5.8** (sheets 1 and 2) for location of peak flood level identifiers.
2. Peak flood levels are typically quoted to one decimal place to reflect the accuracy of the flood modelling. However, they have been quoted to two decimal places in the above table to highlight minor differences in levels.
3. A positive value represents an increase in peak flood levels resulting from the project. Conversely, a negative value represents a decrease in peak flood levels resulting from the project.

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TABLE 5.3
IMPACT OF A PARTIAL BLOCKAGE OF MAJOR HYDRAULIC STRUCTURES ON PEAK FLOOD LEVELS
POST-CONSTRUCTION CONDITIONS

Floodplain	Location identifier(1)	Location of peak flood level comparison	Peak flood level (metres AHD)(2)				Increase in peak flood levels due to blockage (metres)(3)	
			Without blockage		With blockage			
			100 year ARI	PMF	100 year ARI	PMF	100 year ARI	PMF
Upper Wolli Creek	LOC 1	Northern side of motorway corridor adjacent to transverse drainage structure XD1.	25.09	27.68	25.47	27.85	0.38	0.17
	LOC 2	Within commercial / industrial development located on southern side of motorway corridor opposite the outlet of transverse drainage structure XD2.	22.87	24.31	22.84	24.36	-0.03	0.05
	LOC 3	Within commercial / industrial development located on southern side of motorway corridor opposite the outlet of transverse drainage structure XD3.	20.47	21.63	20.41	21.63	-0.06	0.00
	LOC 4	Within commercial / industrial development located on northern side of motorway corridor opposite the inlet of transverse drainage structure XD5.	N/A	23.50	N/A	24.06	N/A	0.56
Lower Cooks River	LOC 1	Western overbank of Alexandra Canal immediately upstream of new Campbell Road bridge.	2.80	4.90	2.98	5.10	0.18	0.20
	LOC 2	Western overbank of Alexandra Canal beneath new Gardeners Road bridge.	2.60	4.55	2.66	4.67	0.06	0.12
	LOC 3	Western overbank of Alexandra Canal on Burrows Road immediately north (upstream) of Canal Road intersection.	2.67	4.55	2.70	4.67	0.03	0.12
	LOC 4	Within residential properties located along the northern (upstream) side of Kogarah Golf Course.	1.96	4.39	2.00	4.53	0.04	0.14

1. Refer **Figures 5.7** and **5.8** (sheets 1 and 2) for location of peak flood level identifiers on upper Wolli Creek floodplain and **Figures 5.9** and **5.10** (sheets 1 and 2) for location of peak flood level identifiers on lower Cooks River floodplain.
2. Peak flood levels are typically quoted to one decimal place to reflect the accuracy of the flood modelling. However, they have been quoted to two decimal places in the above table to highlight minor differences in levels.
3. A positive value represents an increase in peak flood levels resulting from a partial blockage. Conversely, a negative value represents a decrease in peak flood levels resulting from a partial blockage.

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TABLE 5.4
IMPACT OF A 10 PER CENT INCREASE IN 100 YEAR ARI DESIGN RAINFALL INTENSITIES ON PEAK FLOOD LEVELS
POST-CONSTRUCTION CONDITIONS
100 YEAR ARI

Floodplain	Location identifier(1)	Location of peak flood level comparison	Peak flood levels (metres AHD)(2)		Increase in peak flood levels (metres)(3)
			Current climatic conditions	Post-10 per cent increase in design rainfall intensities	
Upper Wolli Creek	LOC 1	Northern side of motorway corridor adjacent to transverse drainage structure XD1.	25.09	25.43	0.34
	LOC 2	Within commercial / industrial development located on southern side of motorway corridor opposite the outlet of transverse drainage structure XD2.	22.87	23.02	0.15
	LOC 3	Within commercial / industrial development located on southern side of motorway corridor opposite the outlet of transverse drainage structure XD3.	20.47	20.59	0.12
	LOC 4	Within commercial / industrial development located on northern side of motorway corridor opposite the inlet of transverse drainage structure XD5.	-	-	-
Lower Cooks River	LOC 1	Western overbank of Alexandra Canal immediately upstream of new Campbell Road bridge.	2.80	2.97	0.17
	LOC 2	Western overbank of Alexandra Canal beneath new Gardeners Road bridge.	2.60	2.77	0.17
	LOC 3	Western overbank of Alexandra Canal on Burrows Road immediately north (upstream) of Canal Road intersection.	2.67	2.80	0.13
	LOC 4	Within residential properties located along the northern (upstream) side of Kogarah Golf Course.	1.96	2.15	0.19

1. Refer **Figures 5.11** and **5.12** (sheets 1 and 2) for location of peak flood level identifiers on upper Wolli Creek and lower Cooks River floodplains, respectively.
2. Peak flood levels are typically quoted to one decimal place to reflect the accuracy of the flood modelling. However, they have been quoted to two decimal places in the above table to highlight minor differences in levels.
3. A positive value represents an increase in peak flood levels resulting from a 10 per cent increase in design rainfall intensities.

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TABLE 5.5
IMPACT OF PROJECTED SEA LEVEL RISE ON PEAK FLOOD LEVELS
POST-CONSTRUCTION CONDITIONS
LOWER COOKS RIVER FLOODPLAIN

Sea level rise scenario	Location identifier[(1)]	Location of peak flood level comparison	Peak flood levels (metres AHD)[(4)]				Increase in peak flood levels due to sea level rise (metres)[(5)]	
			present day conditions		Post-sea level rise			
			100 year ARI	PMF	100 year ARI	PMF	100 year ARI	PMF
2050[(2)]	LOC 1	Western overbank of Alexandra Canal immediately upstream of new Campbell Road bridge.	2.80	4.90	2.90	4.91	0.10	0.01
	LOC 2	Western overbank of Alexandra Canal beneath new Gardeners Road bridge.	2.60	4.55	2.76	4.68	0.16	0.13
	LOC 3	Western overbank of Alexandra Canal on Burrows Road immediately north (upstream) of Canal Road intersection.	2.67	4.55	2.78	4.68	0.11	0.13
	LOC 4	Within residential properties located along the northern (upstream) side of Kogarah Golf Course.	1.96	4.39	2.45	4.53	0.49	0.14
2100[(3)]	LOC 1	Western overbank of Alexandra Canal immediately upstream of new Campbell Road bridge.	2.80	4.90	3.07	4.93	0.27	0.03
	LOC 2	Western overbank of Alexandra Canal beneath new Gardeners Road bridge.	2.60	4.55	2.92	4.84	0.32	0.29
	LOC 3	Western overbank of Alexandra Canal on Burrows Road immediately north (upstream) of Canal Road intersection.	2.67	4.55	2.95	4.84	0.28	0.29
	LOC 4	Within residential properties located along the northern (upstream) side of Kogarah Golf Course.	1.96	4.39	2.80	4.71	0.84	0.32

1. Refer **Figures 5.13**, **5.14**, **5.15** and **5.16** (sheets 1 and 2) for location of peak flood level identifiers on lower Cooks River floodplain.
2. Assumes 0.4 metre rise in sea levels by 2050.
3. Assumes 0.9 metre rise in sea levels by 2100.
4. Peak flood levels are typically quoted to one decimal place to reflect the accuracy of the flood modelling. However, they have been quoted to two decimal places in the above table to highlight minor differences in levels.
5. A positive value represents an increase in peak flood levels resulting from sea level rise.

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6 ASSESSMENT OF POTENTIAL FLOOD MITIGATION MEASURES

6.1 Proposed flood mitigation strategy

A Flood Management Strategy (FMS) would be prepared for flood prone or flood affected land prior to construction, or as otherwise agreed by the Secretary, to ensure that the project does not exacerbate existing flooding characteristics within the vicinity of the project. The Strategy would include but not be limited to:

(a) The identification of flood risks to the project and adjoining areas, including the consideration of local drainage catchment assessments, and climate change implications on rainfall, drainage and tidal characteristics;

(b) Identify design and mitigation measures that would be implemented to protect proposed operations and not worsen existing flooding characteristics during construction and operation, including soil erosion and scouring;

(c) Identifying drainage system upgrades;

(d) The preparation of a flood/emergency management plan; and

(e) The strategy is to be prepared in consultation with the relevant Council's.

The strategy would be prepared by a suitably qualified and experienced person in consultation with directly affected landowners, the NSW Office of Water, OEH, and relevant Councils.

The strategy would be peer reviewed and confirmed as meeting the requirements of this condition by a suitably qualified and experienced independent hydrological engineer. The strategy shall be submitted to the Secretary and the relevant council prior to the commencement of construction in the vicinity of the flood prone land and overland flow paths for the waterways and catchments in the vicinity of the project, or as otherwise agreed by the Secretary.

The following section of this chapter lists measures which should be considered during the preparation of the FMS in regards the project related flood risks and impacts.

6.2 General flood mitigation requirements

The assessment of flood impacts associated with the project has provided an understanding of the scale and nature of the flood risk to the project infrastructure and its operation, as well as the increased flood risks on the surrounding environment. A broad outline of measures which would need to be implemented in order to manage the project related flood risks and impacts are outlined below.

Tunnel portals and ancillary facilities

- Tunnel entries and associated flood protection barriers are to be located above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater).[1]
- The same hydrologic standard would be applied to tunnel ancillary facilities such as tunnel ventilation and water treatment plants where the ingress of floodwaters would also have the potential to flood the tunnels.

[1] The energy grade line computed by the Wolli Creek HEC-RAS model is considered to represent the upper limit of potential flooding along the reach of Wolli Creek downstream of Kingsgrove Road and should be used for setting critical levels such as the ingress points to the Bexley Road South motorway operations complex. Refer **Section A4** in **Appendix A** of this technical working paper for background to the development of the Wolli Creek HEC-RAS Model.

Emergency response facilities

- Emergency response facilities, including the motorway control centre, tunnel fire water tank and pump buildings and associated electrical substations are to be located above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater).

Bridge waterway crossings

- Bridge crossings over Alexandra Canal are to incorporate a suitable freeboard between the underside of the bridge structure and the peak 100 year ARI flood level.

Impacts of flooding on existing development

- A 100 year ARI flood standard is to be adopted in the assessment of measures which are required to mitigate any adverse impacts attributable to the project. Changes in flood behaviour under PMF conditions are also to be assessed in order to identify impacts on critical infrastructure and significant changes in flood hazard as a result of the project.

Potential Blockage of Major Hydraulic Structures

- Consideration should be given during detailed design to the effects a partial blockage of major hydraulic structures would have on flooding behaviour when setting finished road level and flood wall heights.

Potential impacts of future climate change on flooding behaviour

- A more detailed assessment would need to be undertaken during detailed design to determine the climate change related flood risks to the project and to scope requirements for any management measures. The assessment should be undertaken in accordance with the *Practical Considerations of Climate Change – Floodplain Risk Management Guideline* (DECC, 2007).

Management of adverse flood impacts on existing development

- A detailed hydrologic and hydraulic assessment into the impacts the project would have on flooding behaviour and also measures which are required to mitigate those impacts would need to be undertaken during detailed design.
- Works within the floodplain would be designed to minimise adverse impacts on surrounding development for flooding up to the 100 year ARI event. Assessment would also be made of impacts during flooding in excess of the 100 year ARI event up to the PMF in the context of impacts on critical infrastructure and flood hazards.
- A floor level survey would need to be undertaken in affected areas to determine whether the project would increase flood damages in adjacent development (i.e. in properties where there is a potential for increases in peak flood levels for events up to 100 year ARI).
- Measures would need to be incorporated in the design of the project that are aimed at mitigating its impact on flooding behaviour in properties where existing buildings would experience above floor inundation under present day (i.e. pre-project) conditions during storms with ARI's up to 100 years.
- The project and associated drainage arrangements would be designed to limit increases in peak discharges into the downstream drainage systems in accordance with local Council requirements.

The following sections of this chapter provide a brief overview of the approach which should be adopted to addressing the impact of the project on flooding behaviour in existing development which is located on the upper Wolli Creek and lower Cooks River floodplains.

6.3 Upper Wolli Creek floodplain

6.3.1 Flooding in existing residential development

The project would not exacerbate flooding conditions in existing residential development for events up to 100 year ARI. However, the assessment has was found that peak PMF levels would be increased in seven residential properties which are located immediately to the west of the Canterbury Golf Course in Elouera Street and Kirrang Street, Beverly Hills.

As evacuation of the seven residential properties would still be possible by foot for all events up to the PMF and given that their development potential for residential purposes would not be affected by the project (i.e. because these properties are located on land which lies above the Flood Planning Level (FPL), which in the Canterbury LGA is equal to the peak 100 year ARI flood level plus 0.5 metre freeboard), it is not considered necessary to implement measures which would be aimed at mitigating the effects of the project on peak PMF levels.

6.3.2 Flooding in existing commercial/industrial development

The assessment found that the project would increase peak 100 year ARI flood levels by a maximum of about 20 millimetres in two flood prone commercial/industrial properties that are located on the southern side of the motorway corridor opposite the outlet of transverse drainage structures XD3 and XD4 (refer **Figure 5.2**, sheet 1).

Further design development would be undertaken during detailed design which would be aimed at mitigating the impact of the project on flooding conditions in the two properties. Measures aimed at mitigating the impact of the project on flooding conditions in the two properties could include modification of entrance / exit channels to the transverse drainage structures to balance flow impacts upstream and downstream of the motorway and/or the inclusion of localised detention along the northern side of the corridor. The assessment would include consideration of whether the project would result in above-floor inundation of these properties.

6.4 Lower Cooks River floodplain

6.4.1 Flooding in existing residential development

The assessment has found that the loss of about 12,000 cubic metres of floodplain storage due to the construction of the Arncliffe motorway operations complex has the potential to increase peak 100 year ARI flood levels by up to about 10 millimetres in seven residential properties that are located along the northern (upstream) side of Marsh Street. The potential impacts would be confirmed during detailed design based on the final layout of the motorway operations complex and the finished floor levels of the buildings on Marsh Street.

The option of providing compensatory flood storage in the northern portion of the Kogarah Golf Course to recapture a portion of the 12,000 cubic metres of lost floodplain storage and the impacts that this would have on flooding conditions in the affected properties was assessed as part of the present investigation. A preliminary investigation found that it would be necessary to recapture about 8,000 cubic metres of lost floodplain storage in order to mitigate the impacts of the project on flooding conditions in the seven residential properties. This could be achieved by lowering natural surface levels within the construction footprint of the project by 200 millimetres on average. **Figure 6.1** shows the impact the lowering of natural surface levels within the northern portion of Kogarah Golf Course would have on flooding behaviour. However, the final design solution and requirement (and extent) for compensatory flood storage would be determined during detailed design.

Further design development would be undertaken during detailed design to confirm the extent of works required to mitigate the impact of the project on flooding conditions within existing residential development.

6.4.2 Flooding in existing commercial/industrial development

The investigation found that peak 100 year ARI flood levels would be increased by a maximum of about 30 millimetres in two commercial/industrial properties that are located on the western overbank of Alexandra Canal, immediately upstream of Campbell Road bridge.

Further design development would need to be undertaken during detailed design in order to mitigate the impact of the project on flooding conditions in the two properties. This would include further refinement of design of the relief drain, as well as the western approach to the Campbell Road bridge.

6.4.3 Flooding in TransGrid's Beaconsfield West Substation

The investigation found that peak 100 year ARI flood levels would be increased by a maximum of about 30 millimetres in the recently upgraded portion of TransGrid's Beaconsfield West Substation. As previously mentioned, TransGrid advised that while a conservative approach was adopted in the recent upgrade of the substation, whereby critical infrastructure was positioned metres AHD), all transformer switch bays and reactive plant were set at ground level (at about RL two metres AHD) as per the existing design philosophy for the site.

Further design development would need to be undertaken during detailed design in order to mitigate the impact of the project on flooding conditions in the TransGrid site. This would include further refinement of design of the relief drain, as well as the western approach to the Campbell Road bridge.

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FIGURES

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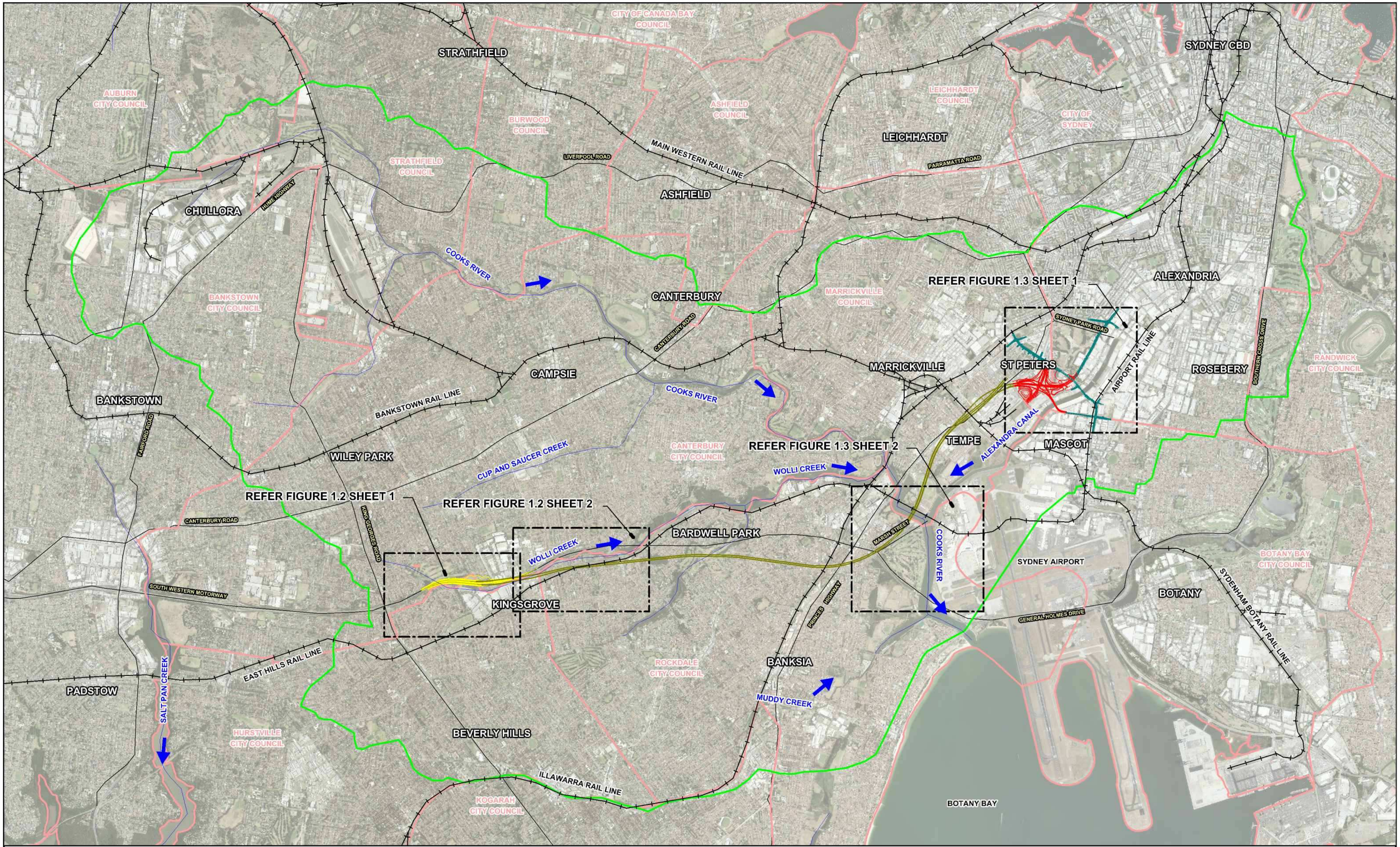

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LEGEND

- Cooks River Catchment Boundary
- Watercourse
- LGA Boundary
- Western Surface Works
- St Peters Interchange Works
- Local Road Works
- Tunnel Works

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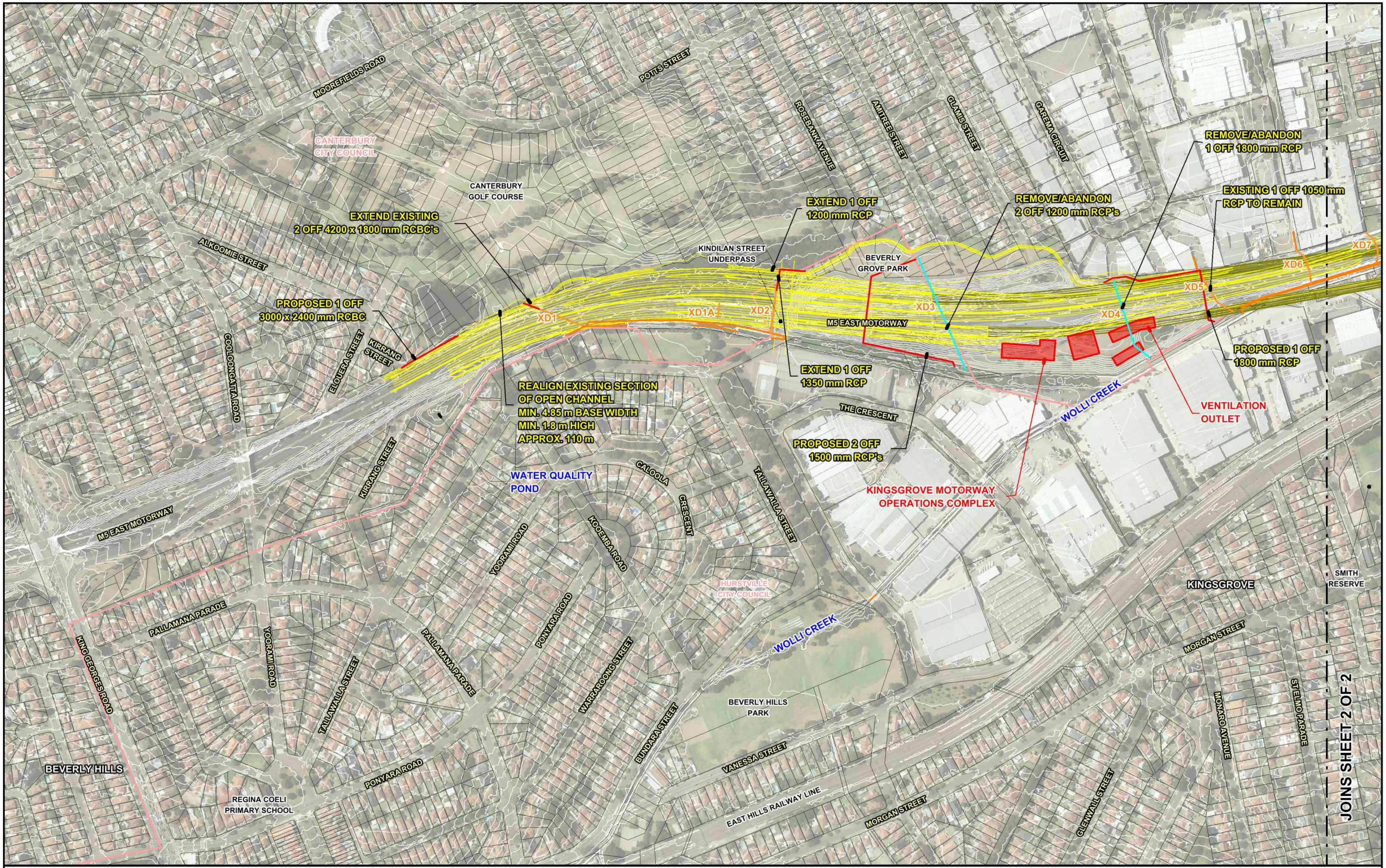
TECHNICAL WORKING PAPER: FLOODING

Figure 1.1

LOCATION AND CATCHMENT PLAN



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LEGEND

- Existing Motorway Transverse Drainage Structure to be Retained
- Existing Motorway Transverse Drainage Structure to be Abandoned/Removed
- New/Upgraded Motorway Transverse Drainage Structure
- Natural Surface Elevation Contours (1m Intervals)
- LGA Boundary
- Western Surface Works
- Tunnel Works

WESTCONNEX NEW M5 EIS
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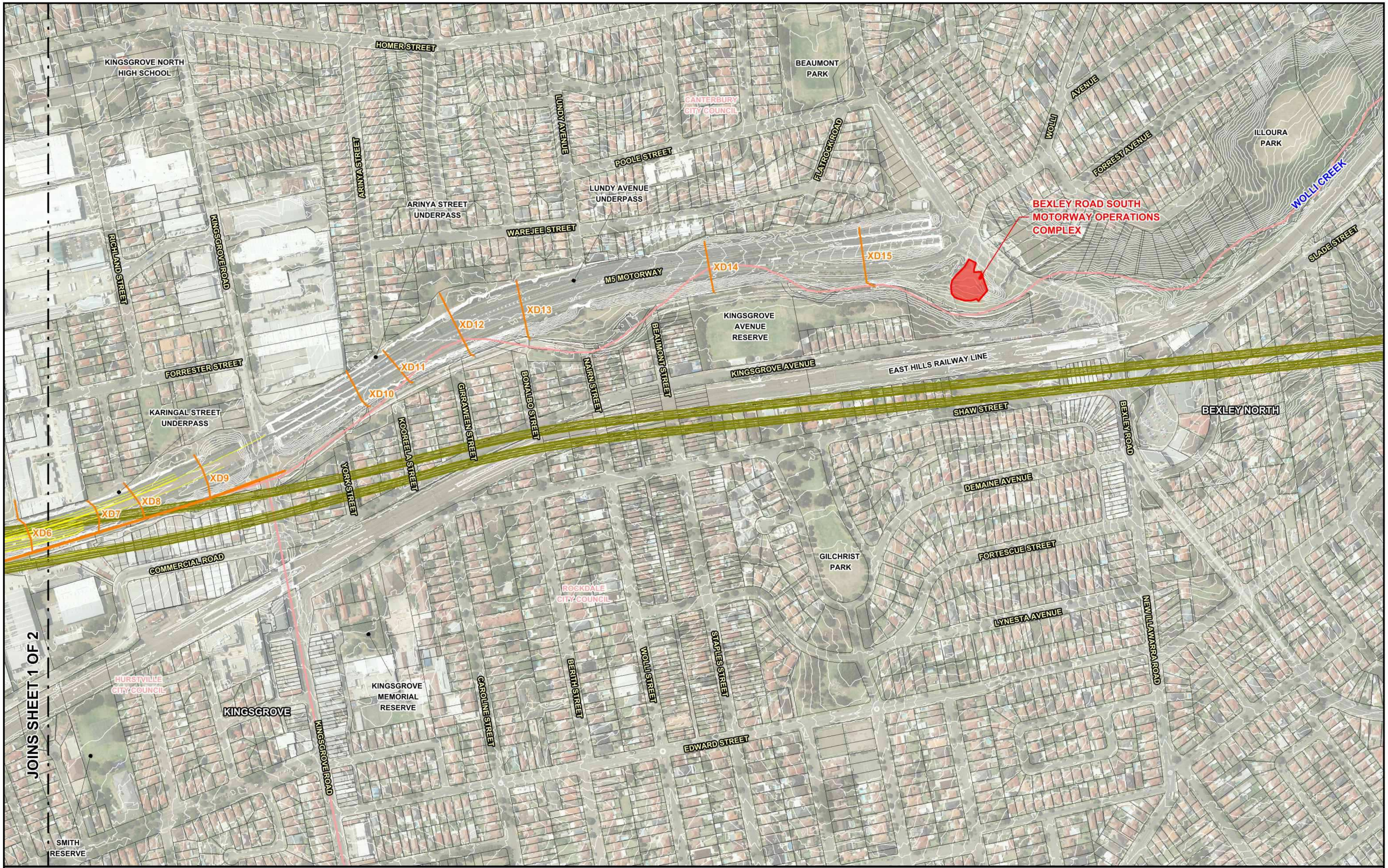
Figure 1.2
Sheet 1 of 2

KEY FEATURES OF PROJECT ON UPPER WOLLI CREEK FLOODPLAIN



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LEGEND

- Existing Motorway Transverse Drainage Structure to be Retained
- LGA Boundary
- Natural Surface Elevation Contours (1m Intervals)
- Western Surface Works
- Tunnel Works

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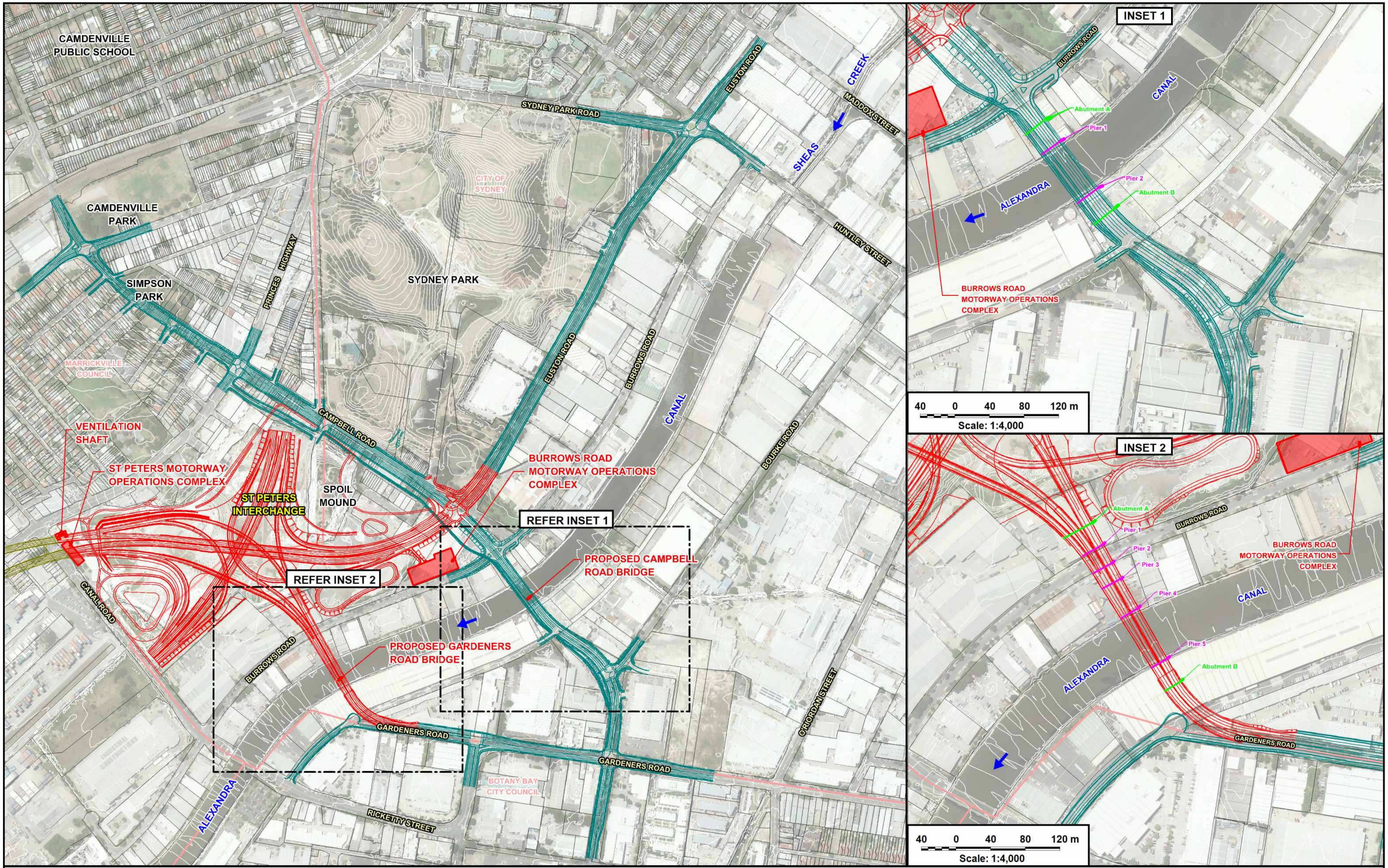
Figure 1.2
Sheet 2 of 2

KEY FEATURES OF PROJECT ON UPPER WOLLI CREEK FLOODPLAIN



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Scale: 1:7,500

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LEGEND

- LGA Boundary
- Natural Surface Elevtion Contours (1m Intervals)
- Local Road Works
- St Peters Interchange Works
- Tunnel Works

WESTCONNEX NEW M5 EIS
TECHNICAL WORKING PAPER: FLOODING

Figure 1.3
Sheet 1 of 2

KEY FEATURES OF PROJECT ON LOWER COOKS RIVER FLOODPLAIN

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Scale: 1:7,500

Lyall & Associates

LEGEND

- LGA Boundary
- Natural Surface Elevation Contours (1m Intervals)
- Tunnel Works

WESTCONNEX NEW M5 EIS
TECHNICAL WORKING PAPER: FLOODING

Figure 1.3
Sheet 2 of 2

KEY FEATURES OF PROJECT ON LOWER COOKS RIVER FLOODPLAIN

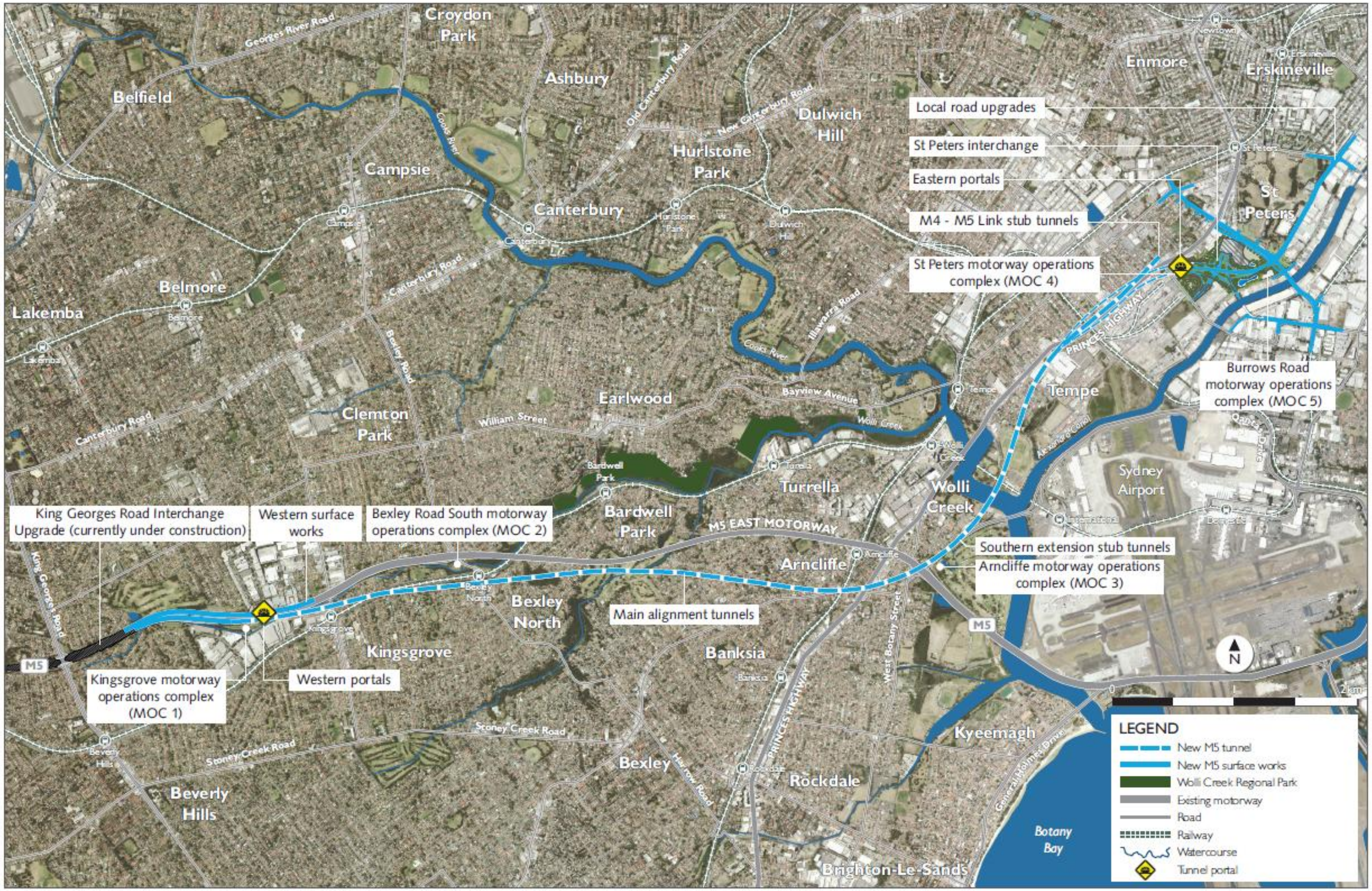

Figure 1.4 The New M5 project (AECOM, 2015)