Roads and Maritime Services

F6 Extension Stage 1

New M5 Motorway at Arncliffe to President Avenue at Kogarah

Environmental Impact Statement

Appendix M
Flooding Technical Report

Volume 7

M

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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 (or 1 in 20 chance) that there would be floods of greater magnitude each year. As another example, for a flood having a 20 year ARI, there would be floods of equal or greater magnitude once in twenty years on average. The approximate correspondence between these two systems is provided in the table below.

Annual Exceedance Probability (AEP) %	Annual Recurrence Interval (ARI) years
0.2	500
0.5	200
1	100
5	20
20	5
50	1.4
1 EY[1]	1
2 EY[1]	0.5

Notes:
1 Floods more frequent than 50% AEP are expressed in terms of the number of exceedances per year (EY).

In this technical report the frequency of floods is referred to in terms of their AEP, for example a 1% AEP 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 report 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 and defines the extent of flood prone land (i.e. the floodplain).

Glossary of terms and abbreviations

Term	Definition
AEP	Annual exceedance probability. The chance of a rainfall or a flood event exceeding a nominated level in any one year, usually expressed as a percentage. For example, if a peak flood level has an AEP of five per cent, it means that there is a five per cent chance (that is one-in-20 chance) of being exceeded in any one year. 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 AEP, for example a 1% AEP flood.
Afflux	Increase in water level resulting from a change in conditions. The change may relate to the watercourse, floodplain, flow rate, tailwater level etc.
AHD	Australian Height Datum. A common national surface level datum approximately corresponding to mean sea level.
ALS	Airborne Laser Scanning. A type of aerial survey used to measure the elevation of the ground surface.
ARI	Average recurrence interval. An indicator used to describe the frequency of a rainfall or a flood event, expressed as an average interval in years between events of a given magnitude. For example, over a long period of say 200 years, a flood equivalent to or greater than a 20 year ARI event would occur 10 times. A 20 year ARI flood has a one-in-20 chance of occurrence in any one year. See also AEP.
ARR 1987	Australian Rainfall and Runoff (Institute of Engineers Australia 1987).
ARR 2016	Australian Rainfall and Runoff (Geosciences Australia 2016).
BoM	Bureau of Meteorology
Box culvert	A culvert of rectangular cross section.
Catchment	The land area draining through the mainstream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
CEMP	Construction environmental management plan. A site specific plan developed for the construction phase of the project to ensure that all contractors and sub-contractors comply with the environmental conditions of approval for the project and that the environmental risks are properly managed
Climate change	A change in the state of the climate that can be identified (for example by statistical tests) by changes in the mean and/or variability of its properties, and that persists for an extended period of time, typically decades or longer (IPCC 2007)
Climate projection	A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which in turn is based on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised (IPCC 2007)
Construction footprint	The land above and below the ground that is required to construct the project.
DCP	Development control plan
DECC	Department of Environment and Climate Change (now OEH)
DECCW	Department of Environment, Climate Change and Water (formerly, DECC, but now OEH)

Term	Definition
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, for example metres per second (m/s).
DoP	NSW Department of Planning (former, now DPE)
DPE	NSW Department of Planning and Environment
DP	Deposited plan
Drainage	Natural of artificial means for the interception and removal of surface or subsurface water.
DRAINS	A simulation program which converts rainfall patterns to stormwater runoff and generates discharge hydrographs. These hydrographs can then be routed through networks of piped drainage systems, culverts, storages and open channels using the DRAINS software to calculate hydraulic grade lines and analyse the magnitude of overflows. Alternatively, discharge hydrographs generated by DRAINS can be used as inflows to alternative hydraulic models (such as the TUFLOW two-dimensional hydraulic modelling software) to calculate water surface levels and flooding patterns.
Earthworks	All operations involving the loosening, excavating, placing, shaping and compacting of soil or rock.
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.
EIS	Environmental impact statement
Embankment	An earthen structure where the road (or other infrastructure) is located above the natural surface.
Fill	The material place in an embankment.
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 immunity	Relates to the level at which a particular structure would be clear of a certain flood event.
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.

Term	Definition
Flow Velocity	A measure of how fast water is moving, for example, metres per second (m/s).
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.
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 future climate change. Freeboard is included in the FPL.
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.
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.
HHWSS	Highest high water solstice spring. The tide level reached on average once or twice per year.
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.
Hyetograph	A graph which shows how rainfall intensities or depths vary with time during a storm burst. A design hyetograph shows the distribution of rainfall over a design storm burst.
Local Drainage	Smaller scale drainage systems in urban areas. Commonly defined as areas where the depth of inundation along overland flow paths is less than 150 millimetres during a 1% AEP storm.
IFD	Intensity-Frequency-Duration
IPCC	Intergovernmental Panel on Climate Change
LGA	Local government area
LiDAR	Light Detection and Ranging. A form of aerial survey used to measure ground elevations.
m	Metres. Used to define a length.
m AHD	Metres above Australian Height Datum Used to define an elevation above Australian Height Datum.

Term	Definition
m^2	Square metres. Used to define an area.
m^3	Cubic metres. Used to define a volume.
m^3/s	Cubic metres per second. Used to quantify a flowrate.
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.
Merit approach	The merit 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.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
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.
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. A method prescribed on ARR 1987 for the estimation of peak discharges from a rural catchment.
Probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).
Project footprint	The land above and below ground required to construct the project, for temporary ancillary construction facilities, and the land required to accommodate permanent infrastructure including shared cycle and pedestrian pathways.
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 Floodplain Development Manual (DIPNR, 2005) 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.
Scour	The erosion of material by the action of flowing water.

Term	Definition
SEARs	Secretary's Environmental Assessment Requirements and specifications for an environmental assessment prepared by the Secretary of the NSW Department of Planning and Environment under section 115Y of the Environmental Planning and Assessment Act 1979 (NSW)
SES	NSW State Emergency Services
Spoil	Surplus excavated material
Stage	Equivalent to water level (both measured with reference to a specified datum)
Stockpile	Temporarily stored materials such as soil, sand, gravel and spoil/waste.
Surface water	Water flowing or held in streams, rivers and other water bodies in the landscape.
Swale	A shallow, grass-lined drainage channel.
Water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
Waterway	Any flowing stream of water, whether natural or artificially regulated (not necessarily permanent).

Executive summary

Overview

This report deals with the findings of an investigation which was undertaken to assess flooding and drainage related issues associated with the construction and operation of the F6 Extension Stage 1 from New M5 Motorway at Arncliffe to President Avenue at Kogarah project (project).

This report has been prepared to support the Environmental Impact Statement (EIS) for the project. **Chapters 1** to **3** provide details of the background to the assessment, as well as a description of the project works that have the potential to influence flooding and drainage patterns in the catchments through which it runs. A more detailed description of the project is contained in Chapter 6 (Project description) of the EIS.

Existing environment

The project traverses a number of highly urbanised catchments in the south of Sydney, all of which drain to Botany Bay. The investigation found that the stormwater drainage systems that control runoff from these catchments are typically of limited capacity. As a result, the land on which the project would be located is presently impacted by both mainstream flooding and major overland flow during periods of heavy rainfall. **Chapter 4** contains a brief description of the characteristics of the catchments through which the project runs, as well as a description of the nature of mainstream flooding and major overland flow under present day (or pre-project) conditions for events ranging between 1 Equivalent Year (EY) and 0.2% Annual Exceedance Probability (AEP), as well as for the Probable Maximum Flood (PMF). Mainstream flooding and major overland flow have been collectively termed ‘flooding’ within this report.

Assessment of construction related impacts

Table 5-1 in Chapter 5 sets out the assessed flood risk at the six temporary construction ancillary facilities (construction sites C1 to C6), as well as four additional construction areas (construction sites CA1 to CA4). **Table 5-2** shows the location of the nine construction sites, while a summary of the proposed construction activities within each site is provided in **Table 5-1**.

The assessment found that a number of the construction sites would be affected by flooding during storms as frequent as 1 EY. Inundation of these construction sites by flooding has the potential to:

- Cause damage to the project works
- Cause delays in construction programming
- Pose a safety risk to construction workers
- Detrimentally impact the downstream waterways through the transport of sediments and construction materials by floodwater
- Alter the characteristics of flooding in adjacent development.

Construction activities also have the potential to exacerbate flooding conditions in adjacent development. This arises due to the need to locate temporary measures on the floodplain outside the road footprint. A preliminary investigation was undertaken to assess the potential impacts the construction activities could have on the characteristics of flooding. The key findings of the investigation are summarised in **Table 5-2** in **Chapter 5**.

While all ten construction sites will involve works within the floodplain that will need to be managed, the preliminary investigation found that the greatest potential for adverse impacts on flood behaviour in adjacent development is associated with the Arncliffe construction ancillary facility (C1), the Rockdale construction ancillary facility (C2), President Avenue construction ancillary facility (C3) and the President Avenue to Civic Avenue pedestrian and cyclist pathways (construction site CA3).

Assessment of operational related impacts

Inundation of the project by floodwater during its operation has the potential to cause damage to infrastructure, impact on the safe operation of the motorway tunnels and pose a safety risk to road users and motorway operations staff. The project also has the potential to exacerbate flooding and drainage conditions in adjacent development. An assessment was undertaken of the flood risk to the project in its as-built form, as well as the impact it would have on the characteristics of flooding in adjacent development.

Table 6-1 in **Chapter 6** provides a summary of the assessed flood risk to the project. A recommended level of flood protection to each project element has been identified with due consideration of the consequences of flooding in accordance with the *NSW Floodplain Development Manual* (NSW Department of Infrastructure, Planning and Natural Resources (DIPNR), 2005) and current Roads and Maritime standards.

The investigation found that once constructed, the project would generally have only a minor impact on flood behaviour in adjacent development for storms with AEP's up to 1 per cent in intensity (refer **Table 6-2** for a summary of key findings). While it will be necessary to undertake further design development during detailed design which is aimed at further reducing the residual impacts of the project on flood behaviour, the nature of the changes in flooding patterns attributable to the project would not have a significant impact on the future development potential of land located outside the project boundary.

Projected changes in the intensity of flood producing rainfall, as well as a rise in sea level have the potential to impact on the characteristics of flooding in the vicinity of the project. The potential impacts of future climate change on flooding were assessed in accordance with the recommended procedures set out in the NSW Office of Environment and Heritage's (OEH) *Floodplain Risk Management Guideline – Practical Considerations of Climate Change* (NSW Department of Environment and Climate Change (DECC) 2007). **Table 3-4** in **Chapter 3** summarises the combination of design storm rainfalls and sea level conditions which were used to assess the potential impact of future climate change on the characteristics of flooding in the vicinity of the project.

The assessment found that there would be an increase in peak PMF levels at the tunnel ancillary facilities (Arncliffe motorway operations complex and Rockdale motorway operations complex (north) and (south)) and the President Avenue tunnel portal of between 0.06 metres and 0.40 metres due to a 0.9 metre rise in sea level. In order to manage the risk of flooding over the design life of the project, the impact of future sea level rise would need to be taken into consideration when setting the minimum level of entries to the tunnel ancillary facilities and tunnel portal. Based on this finding, the road level at the entry to the President Avenue tunnel portal has been designed to be above the PMF level including allowance for an increase in peak flood levels due to future sea level rise.

Assessment of cumulative impacts

Chapter 7 presents the findings of an investigation which was carried out to assess the potential cumulative impacts the project could have on flood behaviour in combination with other major motorway projects in its vicinity, as well as the following non-motorway projects:

- Residential development within the Cooks Cove Precinct that is identified in the *Bayside West Precincts Draft Land Use and Infrastructure Strategy* (Department of Planning and Environment, 2016).
- Renewal of the Muddy Creek channel that is proposed by Sydney Water.

The assessment found that due to the relatively localised nature of the project related flood impacts there would be either a minor or no cumulative impacts associated with it and other major motorway projects. While there is the potential for cumulative type impacts to occur should the future stages of the F6 Extension (President Avenue to Loftus) be built, it is expected that they could be managed through appropriate mitigation measures specific to the future project. The scope of these measures would need to be determined once the scope of the future project has been defined.

The Cooks Cove Precinct includes an area of land along the western bank of Muddy Creek to the north of Bestic Street, immediately downstream of the shared pedestrian and cyclist pathways that is proposed as part of the project. Planning for future residential development within the precinct is in its early stages and as such no environmental assessment was available for review at the time of the present investigation. It would be expected that the redevelopment within the precinct would be undertaken in a manner that minimises the potential for adverse flood impacts to adjacent properties. On this basis, and given the location of the precinct relative to the proposed pedestrian and cyclist pathways, the potential for the future development to impact flood behaviour is considered to be low.

It will be necessary to consult with Sydney Water during the detailed design stage to ensure that the design of the shared pedestrian and cyclist pathways is coordinated with the future plans for renewal of the Muddy Creek channel. It will also be necessary to ensure that the combined impacts of the two projects on flood behaviour are managed.

Management of impacts

Chapter 8 sets out the key requirements of a flood management strategy (FMS) that will be prepared prior to construction. The FMS would:

- document procedures and measures that are aimed at managing the risk of flooding to the project, as well as the potential for adverse impacts on existing flood behaviour within its vicinity
- identify appropriate design standards for managing the flood risk during the construction and operational phases of the project
- include procedures aimed at reducing the flooding threat to human safety and infrastructure
- include controls that are aimed at mitigating the impact of the project (during construction and operation) on flood behaviour.

While the findings of the initial assessment presented in **Chapter 5** provide an indication of the potential impact construction activities would have on flood behaviour, further investigations will need to be undertaken during detailed design with the benefit of more detailed site layouts and staging diagrams. **Table 8-1** contains a range of potential measures which could be implemented in order to reduce the impact of construction activities on flood behaviour.

Table 8-2 sets out the specific measures which would need to be incorporated into the detailed design in order to mitigate the operational related flood risks to the project. **Table 8-3** contains a summary of measures that could be incorporated into the detailed design in order to further mitigate the operational related impacts of the project on flooding in adjacent development. The nature and extent of impacts, and therefore the scope of mitigation measures required would be subject to further flood assessment during the detailed design phase. Subject to this further flood assessment, additional floor level survey may be required to confirm the extent to which the proposed works would increase flood damages in affected properties and therefore the scope of specific measures that may be required to mitigate the project related impacts.

1 Introduction

The project would comprise a new multi-lane road link between the New M5 Motorway tunnel underground at Arncliffe and an intersection at President Avenue at Kogarah.

1.1 Overview of the project

Key components of the project would include:

- An underground connection to the existing stub tunnels at the New M5 Motorway at Arncliffe
- Twin motorway tunnels (around four kilometres in length) between the New M5 Motorway at Arncliffe and President Avenue, Kogarah
- A tunnel portal and entry and exit ramps connecting the tunnels to a surface intersection with President Avenue
- Intersection improvements at the President Avenue / Princes Highway intersection
- Mainline tunnel stubs to allow for connections to future stages of the F6 Extension
- Shared pedestrian and cycle pathways connecting Bestic Street, Rockdale to Civic Avenue, Kogarah via Rockdale Bicentennial Park (including an on-road cycleway)
- An Operational Motorway Control Centre to be located off West Botany Street, Rockdale
- Ancillary infrastructure and operational facilities for signage (including electronic signage), ventilation structures and systems at Rockdale, fire and safety systems, and emergency evacuation and smoke extraction infrastructure
- A proposed permanent power supply connection from the Ausgrid Canterbury subtransmission substation
- Temporary construction ancillary facilities and temporary works to facilitate the construction of the project.

Once complete, the F6 Extension Stage 1 would improve connections and travel times between Sydney and the Princes Highway and enhance connections for residents and businesses within the broader regional area as well as promote and support economic development in areas to the south, such as Sutherland and the Illawarra.

Approval for the project is being sought under Part 5, Division 5.2 of the EP&A Act. Future stages of the F6 Extension would be subject to separate planning applications and assessments would be undertaken accordingly.

The configuration and design of the project will be further developed to take into consideration the outcomes of community and stakeholder engagement.

1.2 Project location

This project would be generally located within the Bayside local government area. The project commences about 8 kilometres south west of the Sydney central business district (CBD). The proposed President Avenue intersection would be located about 11 kilometres south east of the Sydney CBD.

1.3 Purpose of this report

This report presents the findings of an investigation which was undertaken to assess flooding and drainage related issues associated with the construction and operation of the project. This report has been prepared to support the EIS and to address the Secretary's Environmental Assessment Requirements (SEAR's) related to flooding and drainage. The report presents the state of the existing flooding and drainage environment as a baseline and then identifies the potential impacts that may arise from the construction and operation of the project, as well as measures that are aimed at managing the potential impacts.

1.4 SEARs and Agency comments

Table 1-1 sets out the flooding and drainage related SEAR's which were issued by the NSW Department of Planning and Environment (DP&E) and where they have been addressed in this report. Surface water impacts related to erosion and sediment transport/deposition, water quality, environmental flows and runoff volumes are presented in **Appendix L** (Surface water technical report) of the EIS.

Comments that were received from Sydney Water during the preparation of the SEAR's that are relevant to flooding and drainage have also been considered in the preparation of this report (refer to **Table 1-2**).

Table 1-1 SEARs – Flooding and drainage

SEARs	Where addressed in this report
9. Water – Hydrology Long term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised. The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved). Sustainable use of water resources.	
1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes and groundwater dependent ecosystems) likely to be impacted by the project, including rivers, streams, wetlands and estuaries as described in Appendix 2 of the Framework for Biodiversity Assessment – NSW Biodiversity Offsets Policy for Major Projects (OEH 2014).	Section 4.1 describes the catchments within the study area as well as the flooding and drainage patterns in the vicinity of the project under present day (i.e. pre-project) conditions. Refer Appendix L (Surface water technical report) and Appendix K (Groundwater technical report) of the EIS for further details of the existing surface water and groundwater regimes, respectively.
2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations (including mapping of these locations), volume, frequency and duration for both the construction and operational phases of the project.	Refer Appendix K (Groundwater technical report) and Appendix L (Surface water technical report) of the EIS for detailed water balance assessments for groundwater and surface water, respectively.
3. The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including: (a) natural processes within rivers, wetlands, estuaries and floodplains that affect the health of the fluvial, riparian and estuarine systems and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity, water-dependent fauna and flora and access to habitat for spawning and refuge; (b) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, change in ground water levels, barriers to flows, implications for groundwater dependent on surface flows, ecosystems and species, groundwater users and the potential settlement; (c) changes to environmental water availability and	(a) Sections 5 and 6 contain an assessment of the impact of the project on flooding and drainage behaviour, including changes in discharge velocities and the duration of inundation. Refer Appendix L (Surface water technical report) and Appendix H (Biodiversity development assessment report) of the EIS for further details of the assessment of impacts on natural processes within rivers, wetlands and floodplains that are crossed by the project. (b) Refer Appendix K (Groundwater technical report) of the EIS. (c) Refer Appendix K (Groundwater technical report) of the EIS. d) Sections 5 and 6 contain an assessment of the impact the project would have on flooding and drainage behaviour, including changes in flow velocities and the potential for increases in scour and erosion of riverbanks and watercourses. Refer Appendix L (Surface water technical report) of the EIS for further details of an assessment of the potential increase in erosion and siltation attributable to the project, while Appendix H (Biodiversity development assessment report) of the EIS contains an assessment of the potential impacts on

SEARs	Where addressed in this report
flows; (d) direct or indirect increases in erosion, siltation, destruction of aquatic and riparian vegetation or a reduction in the stability of river banks or watercourses; (e) minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of the existing stormwater systems where discharges are proposed through such systems or modifications are proposed to these systems; (f) measures to mitigate the impacts of the proposal and manage the disposal of produced and incidental water; and (g) water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	aquatic and riparian vegetation and the stability of riverbanks and watercourses. (e) Sections 5 and 6 contain an assessment of the impact of the project would have on flooding and drainage behaviour, including changes in flow rates and conveyance capacities. Refer Appendix L (Surface water technical report) of the EIS for further assessment of the impact of the project on the surface water attributes, including volumes. (f) Refer Appendix L (Surface water technical report) of the EIS. (g) Refer Appendix L (Surface water technical report) and Appendix K (Groundwater technical report) of the EIS for an assessment of water take from surface water and groundwater sources, respectively.
4. The assessment must provide details of the final landform of the sites to be excavated or modified (e.g. portals and cut and cover works), including final void management and rehabilitation measures.	Refer section 6 (Project description) of the EIS.
5. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Refer Appendix L (Surface water technical report) and Appendix K (Groundwater technical report) for identified requirements for baseline monitoring of surface water and groundwater related hydrologic attributes, respectively.
6. The assessment must include details of proposed surface and groundwater monitoring.	Refer Appendix L (Surface water technical report) and Appendix K (Groundwater technical report) for details of the proposed surface water and groundwater monitoring, respectively.
7. The proposed tunnels must be designed to prevent impacts on aquifers and minimise impacts on groundwater flows and groundwater dependent ecosystems.	Refer Appendix K (Groundwater technical report).
11. Flooding The project minimises adverse impacts on existing flooding characteristics. Construction and operation of the project avoids or minimises the risk of, and adverse impacts from, infrastructure flooding, flooding hazards, or dam failure.	
1. The EIS must map the following features relevant to flooding as described in the NSW Floodplain Development Manual 2005 (NSW Government 2005) including: (a) Flood prone land (b) Flood planning areas, the area below the flood planning level (c) Hydraulic categorisation (floodways and flood storage areas)	(a) Figure 4-5 shows the extent of flood prone land in the vicinity of the project (i.e. the extent of land that is susceptible to flooding during a Probable Maximum Flood (PMF) event). (b) Figure C-6 in Annexure C shows the extent of land which is located below the 1% Annual Exceedance Probability (AEP) flood level plus 0.5 m (defined in the Rockdale Local Environmental Plan 2011 (Rockdale City Council (RCC) 2011b) as the flood planning area (FPA)). (c) Figure C-8 in Annexure C shows a preliminary hydraulic categorisation of the 1% AEP design flood into floodway and flood storage areas.

SEARs	Where addressed in this report
2. The Proponent must assess and model the impacts on flood behaviour during construction and operation for a full range of flood events up to the probable maximum flood (taking into account sea level rise and increased storm intensity due to climate change) including: (a) how the tunnel entries and cut-and-cover sections of the tunnels would be protected from flooding during construction works; (b) any detrimental increases in the potential flood affectation of the project infrastructure and other properties, assets and infrastructure; (c) consistency (or inconsistency) with applicable Council floodplain risk management plans; (d) compatibility with the flood hazard of the land; (e) compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land; (f) whether there would be adverse effect to beneficial inundation of the floodplain environment, on, or adjacent to or downstream of the site; (g) downstream velocity and scour potential; (h) impacts the development may have upon existing community emergency management arrangements for flooding. These matters must be discussed with the State Emergency Services and Council; (i) any impacts the development may have on the social and economic costs to the community as consequence of flooding; (j) any mitigation measures required to offset potential flood risks attributable to the project (these mitigation measures must be discussed with the State Emergency Services and Council where appropriate).	Section 3 sets out the approach that was adopted to assess the impact the project would have on flood behaviour during both its construction and operation. (a) Section 5.2 summarises the findings of the assessed flood risk at the construction sites that would be used to support tunnel excavation and the construction of cut and cover sections of tunnel, while section 8.1 contains a set of measures which are aimed at managing the flood risk during tunnel construction. (b) Sections 5.2 and 6.1 present the findings of an assessment of the potential impacts on flood behaviour during the construction and operational phases of the project, respectively. (c) Section 6.2 presents the findings of an assessment of the proposed works and its impact on flood behaviour in terms of its consistency with Bayside Council flood policies and plans. (d) Section 4.2 describes the existing flood behaviour in the vicinity of the project, including an overview of the provisional flood hazard for a 1% AEP flood. (e) Section 4.2 describes the existing flood behaviour in the vicinity of the project, including an overview of the hydraulic categories for a 1% AEP flood. (f) Sections 5.2 and 6.1 present the findings of an assessment of the potential impacts of the project on flood behaviour, including changes in the extent of inundation. (g) Section 6.1.4 contains an assessment of the potential increase in velocity and therefore scour downstream of proposed drainage outlets that would discharge into Scarborough Ponds. (h) Section 6.2 provides an assessment of the proposed works and its impact on flood behaviour in terms of its consistency with the NSW State Emergency Services' (SES's) Rockdale City Council Local Flood Plan (SES 2009). (i) Sections 5.2 and 6.1 present the findings of an assessment of the potential impacts on flood behaviour during the construction and operational phases of the project, respectively, including consideration of social impacts (such as impacts on emergency response arrangements) and economic impacts (such as the potential for increases in flood damages in adjacent development). (j) Section 8 outlines potential measures to mitigate construction and operational related impacts of the project on flooding conditions (and therefore the potential for increased flood risk) in adjacent development and to manage the risk of flooding to the project.
3. The assessment should take into consideration any flood studies undertaken by local government councils, as available.	Section 3.4.2 contains details of previous flood studies that were considered as part of the present investigation.
4. The EIS must assess and model the effect of the proposed development (including fill) on current flood behaviour for the 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	Section 6.4.2 provides an assessment of the impact the project would have on flood behaviour under future climate change conditions.

Table 1-2 Agency comments – Flooding and drainage

Sydney Water	
Requirement	**Where addressed in this report**
1. The proponent must obtain endorsement and/or approval from Sydney Water to ensure that the proposed project does not adversely impact on any existing water, wastewater or stormwater assets, or other Sydney Water asset, including any easement or property. When determining landscaping options, the proponent should take into account that certain tree species can cause cracking or blockage of Sydney Water pipes and therefore should be avoided. 2. Strict requirements for Sydney Water's stormwater assets (for certain types of development) may apply to this project. The proponent should ensure that satisfactory steps/measures have been taken to protect the existing stormwater assets, such as avoiding building over and/or adjacent to stormwater assets and building bridges over stormwater assets. The proponent should consider taking measures to minimise or eliminate potential flooding, degradation of water quality, and avoid adverse impacts on any heritage items, and create pipeline easements where required. 3. As part of the assessment process, we would request early consultation with Sydney Water regarding potential relocation/adjustments etc., providing additional details as they become available.	1. Section 7.2 sets out the requirements for consultation with Sydney Water for proposed works in the vicinity of Sydney Water assets (i.e. the main channel of Muddy Creek). 2. Sections 5.2 and 6.1 describe potential impacts of the project on flood behaviour in Muddy Creek, while section 8 sets out measures that are aimed at mitigating the impact of the project on flood behaviour. Section 6 (Project description) of the EIS provides further details of the proposed works in the vicinity of Muddy Creek. 3. Section 7.2 sets out the requirements for consultation with Sydney Water for proposed works in the vicinity of Sydney Water assets (i.e. the Muddy Creek channel). Section 6 (Project description) of the EIS provides details of the proposed works in the vicinity of Muddy Creek, including potential adjustments to bridges and culverts that cross Muddy Creek.

1.5 Study area

The project is located within the following five catchments which form part of the larger Botany Bay catchment:

- Cooks River – Marsh Street to M5 East Motorway at Arncliffe
- Eve Street Wetland – M5 East Motorway to Avenal Street at Arncliffe
- Spring Street Drain – Avenal Street at Arncliffe to Bryant Street at Rockdale
- Muddy Creek – Bryant Street to West Botany Street at Rockdale
- Scarborough Ponds – West Botany Street at Rockdale to President Avenue at Brighton-Le-Sands.

Figure 1-1 shows the extent of the project works within each of the above five catchments. The project is in tunnel where it crosses the Eve Street Wetland and Spring Street Drain catchments and therefore would not result in any change to flooding and drainage patterns within these catchments.

1.6 Structure of this report

The layout of this report is as follows:

- **Section 1** provides a brief overview of the project and the purpose of this report. The chapter also sets out the flooding and drainage related SEAR's which were issued by the DPE for the preparation of the EIS.
- **Section 2** describes the project works which have the potential to alter flood behaviour in the highly urbanised catchments through which it runs.

- **Section 3** sets out the methodology which was adopted for undertaking the flooding and drainage assessment for the project, as well as the relevant government policies and industry standards / guidelines which were taken into consideration during the assessment.
- **Section 4** provides a brief description of the catchments through which the project runs, as well as the drainage systems which control runoff in its vicinity. The chapter also provides an overview of flooding and drainage patterns under present day (i.e. pre-project) conditions.
- **Section 5** deals with the flood risk at the proposed construction sites, as well as the impact construction activities would have on flood behaviour.
- **Section 6** deals with the impact the project would have on flood behaviour following its construction, as well as details of the hydrologic standard which is proposed for its various components. The chapter also presents the findings of an assessment of the potential impact of future climate change on flood behaviour, as well as the impacts that a partial blockage of major hydraulic structures would have on flood behaviour in the vicinity of the project.
- **Section 7** describes the potential cumulative impacts on flooding and drainage patterns that would result from the project in combination with other projects in its vicinity.
- **Section 8** outlines potential measures to mitigate the construction and operational (i.e. post-construction) related impacts of the project on flooding conditions in adjacent development and to manage the risk of flooding to the project.
- **Section 9** summarises the key findings of the investigation.
- **Section 10** contains a list of references.

Figures referred to in **sections 4** to **7** are located at the end of each chapter.

- **Annexures A** and **B** contain background to the development and testing of the hydrologic and hydraulic models (collectively referred to as 'flood models') that were used to define flood behaviour on the lower Cooks River floodplain and the Eve Street Wetland, Spring Street Drain, Muddy Creek and Scarborough Ponds floodplains, respectively.
- **Annexure C** contains a series of figures which show flooding patterns for design storms with AEP's of 20%, 5%, 0.5% and 0.2%. **Annexure C** also contains a series of figures that show the extent of land which is located below the peak 1% AEP flood level plus 0.5 metres (defined in RCC 2011b as the flood planning area), as well as provisional flood hazard and preliminary hydraulic categories for a 1% AEP flood.

The scales on figures referred to in **sections 4** to **7** and **Annexures A**, **B** and **C** are applicable when printed at A3 size.

2 The Project

2.1 Project features

The project would comprise a new multi-lane underground road link between the New M5 Motorway and a surface intersection at President Avenue, Kogarah.

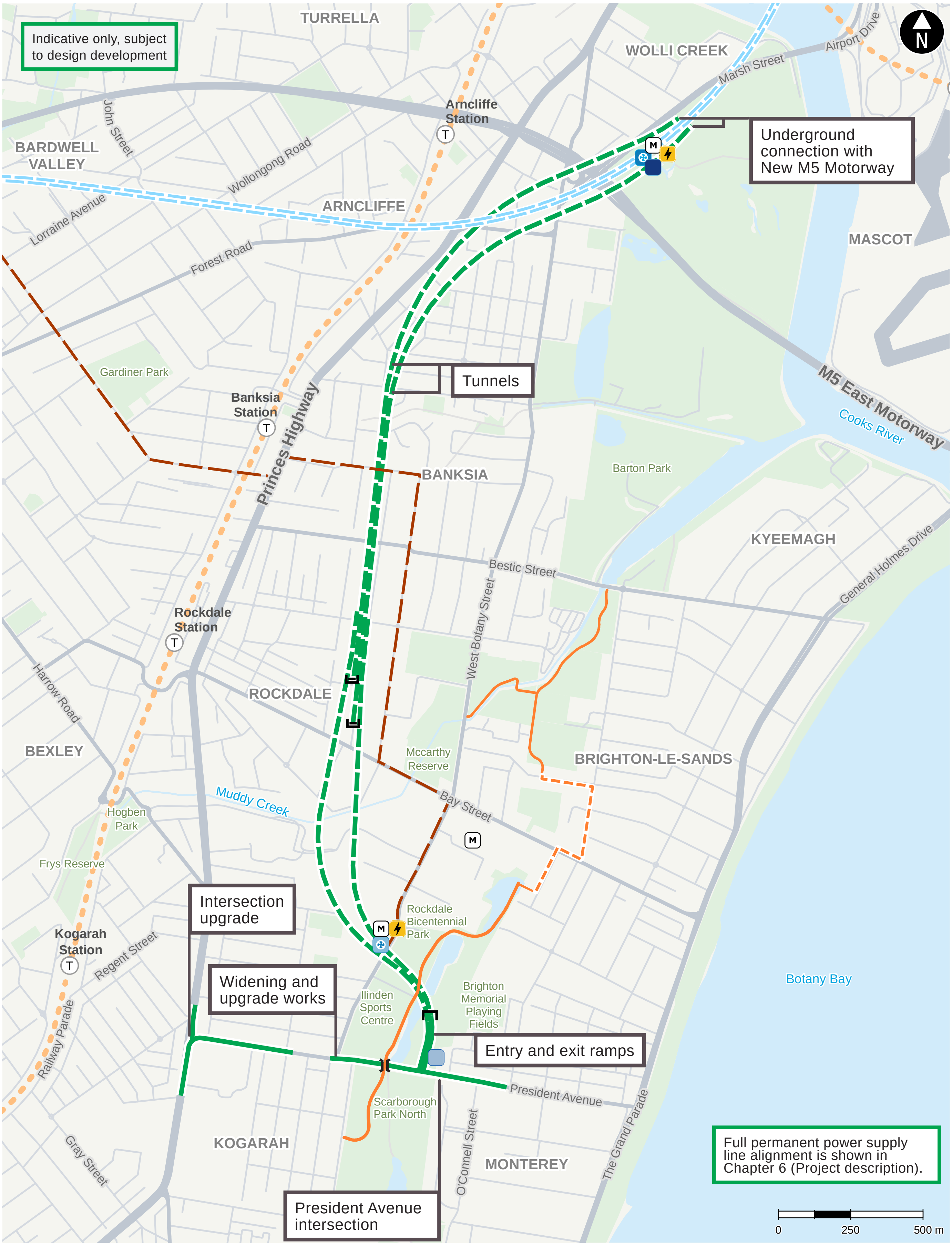
Key components of the project would include:

- Twin mainline tunnels. Each mainline tunnel would be around 2.5 kilometres in length, sized for three lanes of traffic, and line marked for two lanes as part of the project
- A tunnel-to-tunnel connection to the New M5 Motorway southern extension stub tunnels, including line marking of the New M5 Motorway tunnels from St Peters interchange to the New M5 Motorway stub-tunnels
- Entry and exit ramp tunnels about 1.5 kilometres long (making the tunnel four kilometres in length overall) and a tunnel portal connecting the mainline tunnels to the President Avenue intersection
- An intersection with President Avenue including entry and exit ramps and the widening and raising of President Avenue
- Upgrade of the President Avenue / Princes Highway intersection to improve intersection capacity
- Shared cycle and pedestrian pathways connecting Bestic Street, Brighton-Le-Sands to Civic Avenue, Kogarah (including an on-road cycleways)
- Three motorway operation complexes:
  - Arncliffe, including a water treatment plant, substation and fitout (mechanical and electrical) of a ventilation facility currently being constructed as part of the New M5 Motorway project
  - Rockdale (north), including a motorway control centre, deluge tanks, a workshop and an office
  - Rockdale (south), including a ventilation facility, substation and power supply.
- Reinstatement of Rockdale Bicentennial Park and recreational facilities
- In-tunnel ventilation systems including jet fans and ventilation ducts connecting to the ventilation facilities
- Drainage infrastructure to collect surface water and groundwater inflows for treatment
- Ancillary infrastructure for electronic tolling, traffic control and signage (both static and electronic signage)
- Emergency access and evacuation facilities (including pedestrian and vehicular cross and long passages); and fire and life safety systems
- New service utilities, and modifications and connections to existing service utilities
- A proposed permanent power supply connection from the Ausgrid Canterbury subtransmission substation, to Rockdale Motorway Operations Complex south.

The project does not include ongoing motorway maintenance activities during operation or future upgrades to other intersections in the vicinity of the project. These works are permitted under separate existing approvals and / or are subject to separate assessment and approval in accordance with the EP&A Act.

The above listed works are permitted under separate existing approvals and / or are subject to separate assessment and approval in accordance with the EP&A Act.

The key features of the project are shown on **Figure 2-1**.



LEGEND

- The project in tunnel
- The project on surface
- On-road cycleway
- Shared cycle and pedestrian pathways
- President Avenue shared cycle and pedestrian bridge
- Tunnel stub
- Tunnel portal
- Water quality basin
- Water treatment facility
- Rockdale ventilation facility
- Motorway operations complex
- Substation
- Permanent power supply line
- New M5 Tunnel
- Arncliffe ventilation facility*
- * Under construction as part of the New M5 Motorway project
- Road
- Waterway
- Railway line
- Railway station
- Parks and recreation

Figure 2-1 Project features

2.2 Construction

2.2.1 Construction activities

The proposed construction activities for the project would include:

- Preparatory investigations
- Site establishment and enabling work
- Tunnelling
- Surface earthworks and structures
- Construction of motorway operations complexes
- Drainage and construction of operational water management infrastructure
- Construction of the permanent power supply connection
- Road pavement works
- Finishing works.

These activities would generally be undertaken within the following construction ancillary facilities:

- Arncliffe construction ancillary facility (C1) at Arncliffe, within the Kogarah Golf Course currently being used for the construction of the New M5 Motorway
- Rockdale construction ancillary facility (C2) at Rockdale, within a Roads and Maritime depot at West Botany Street
- President Avenue construction ancillary facility (C3) at Rockdale, north and south of President Avenue within Rockdale Bicentennial Park and part of Scarborough Park North, and a site west of West Botany Street
- Shared cycle and pedestrian pathways construction ancillary facilities (C4 and C5) at Brighton-le-Sands, within the recreation area between West Botany Street and Francis Avenue, near Muddy Creek
- Princes Highway construction ancillary facility (C6), on the north-east corner of the President Avenue and Princes Highway intersection.

2.2.2 Construction boundary

The area required for project construction is referred to as the ‘construction boundary’. This comprises the surface construction works area, and construction ancillary facilities (refer to **Figure 2-2**). Utility works to support the project would occur within and outside the construction boundary (refer to **Chapter 7** (Construction) of the EIS).

In addition to these works, the underground construction boundary (including mainline tunnel construction and temporary access tunnels) is also shown on **Figure 2-2**.

C1

- Tunnelling and spoil handling
- Construction of MOC1 (Water treatment plant, substation)
- Fitout, testing and commissioning of tunnels and MOC 1

C2

- Construction of the decline tunnel
- Tunnelling and spoil handling
- Pavement works for internal access road
- Construction of MOC2
- Reconfiguration of the site to enable ongoing/future use for maintenance activities

C3

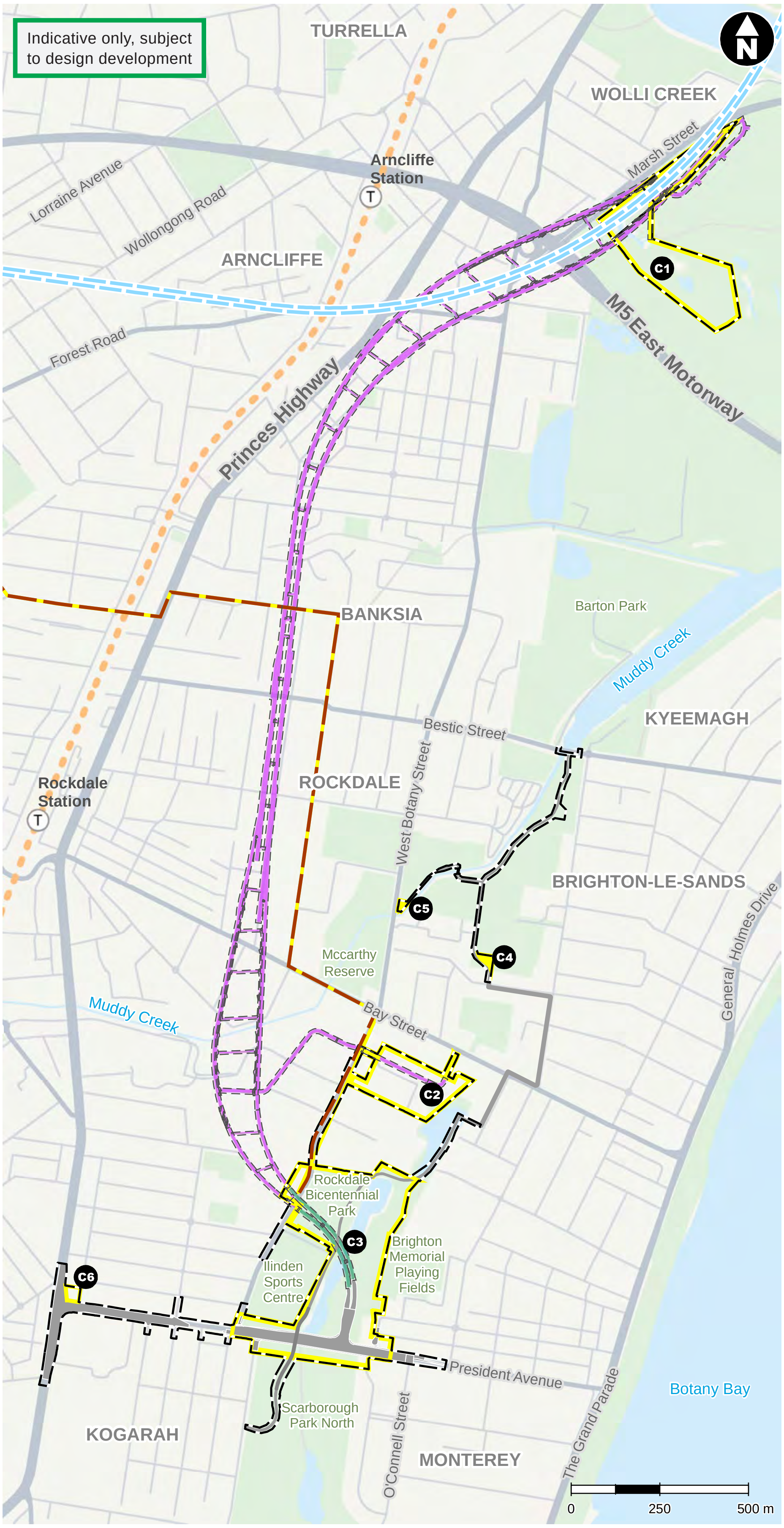
- Demolition of buildings and vegetation clearing and removal
- Relocation of utilities
- Temporary stockpiling of spoil and fill materials
- Management of any contaminated land, including acid sulphate soils
- Construction of cut-and-cover structures
- Construction of MOC3 (Rockdale ventilation facility and substation)
- President Avenue intersection upgrade works
- Construction of shared pedestrian and cyclist path and overpass

C4/C5

- Site establishment
- Vegetation clearing and removal, topsoil stripping areas and land-form shaping
- Temporary stockpiling of materials
- Construction of the shared pedestrian and cyclist path
- Finishing works including lighting, line marking and signage installation

C6

- Property adjustment and demolition
- Relocation of utilities, stormwater infrastructure, underground storage tanks and substation
- Laydown and parking of construction vehicles and equipment
- Reinstatement of site



LEGEND

- Surface works
- Construction boundary
- Cut-and-cover structures
- Underground construction
- Construction ancillary facility
- Permanent power supply line
- Permanent power supply construction route
- New M5 Tunnel
- Road
- Waterway
- Railway line
- Railway station
- Parks and recreation

Figure 2-2 Construction boundary and construction ancillary facilities

2.2.3 Construction program

The project would be constructed over a period expected to be around four years, including commissioning which would occur concurrently with the final stages of construction (refer to **Figure 2-3**).

The project is expected to be completed towards the end of 2024.

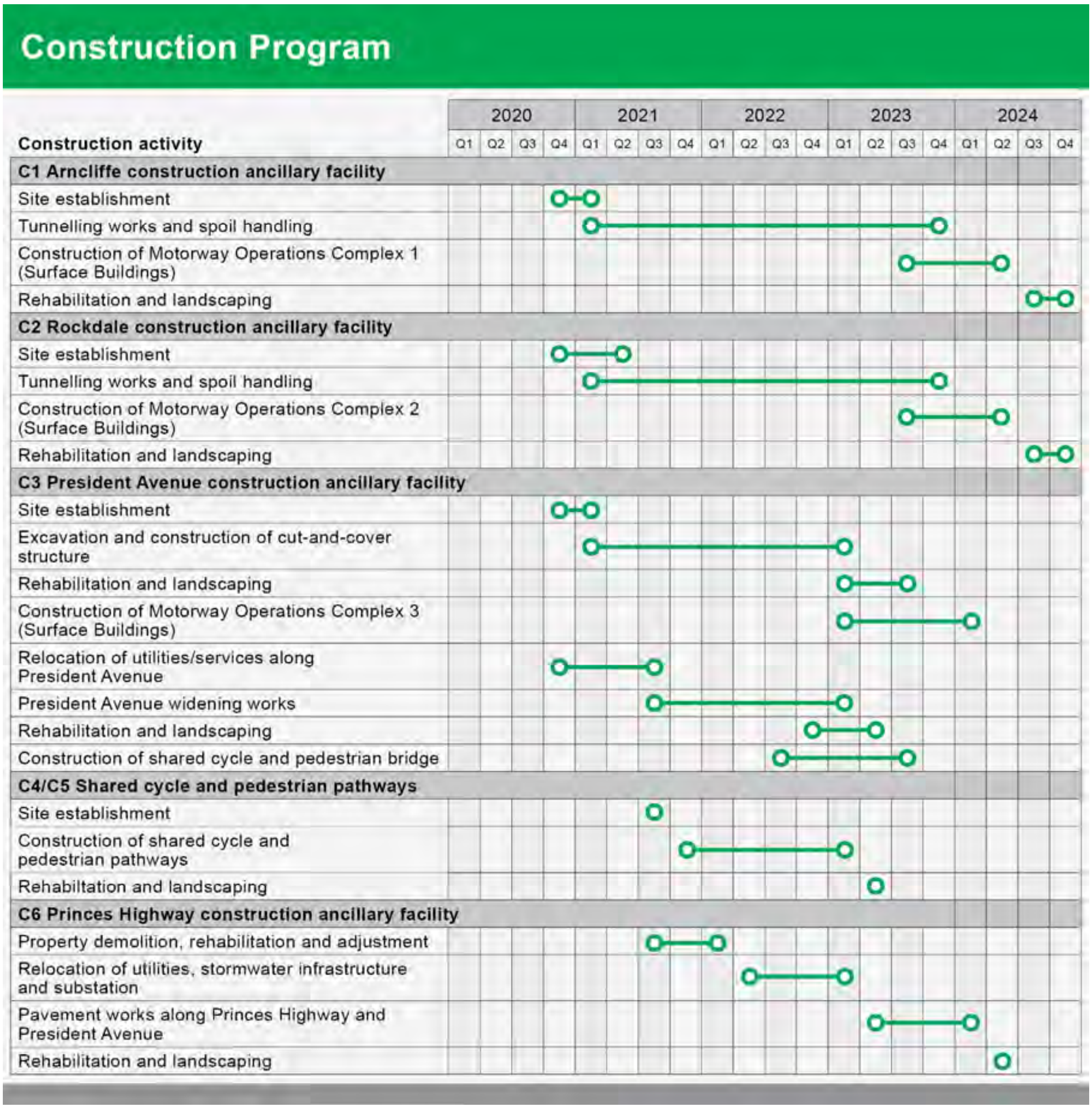


Figure 2-3 Indicative construction program

2.3 Flooding and drainage specific project features

2.3.1 Flood mitigation

A series of flood mitigation measures would be incorporated into the project works which would include:

- Improving the level of flood immunity of President Avenue by raising the road surface level and upgrading the existing box culvert structure that crosses beneath President Avenue at Scarborough Ponds
- Providing flood protection barriers around, or raising the level of the tunnel portals and tunnel ancillary facilities where there is a risk of inundation from flooding
- Lowering of ground elevations in the vicinity of the President Avenue intersection in order to control major overland flow and local drainage.

2.3.2 Surface water drainage

Surface works associated with the project are located in areas where existing stormwater drainage systems presently control runoff from the surrounding urbanised catchments. As a result it would be necessary to upgrade, alter or augment the existing stormwater drainage systems where they would be impacted by the project and there is insufficient existing capacity. This would include:

- Upgrading the existing stormwater drainage system along President Avenue between the Princes Highway and O'Connell Street to accommodate the proposed road widening
- Upgrading the existing stormwater drainage system along the eastern side of the Princes Highway between Green Street and South Street to accommodate the proposed intersection upgrade
- Altering the existing stormwater drainage systems at the point where they presently discharge to President Avenue from West Botany Street and Moorefield Avenue
- Upgrading and altering the existing stormwater drainage systems within sites where the proposed Rockdale motorway operations complexes would be constructed.

A new stormwater drainage system would also be required to control runoff at the President Avenue tunnel portal. Runoff collected at the tunnel portal would be directed to temporary storage tanks and pumped to a water quality basin before discharge into Scarborough Ponds.

3 Assessment methodology

3.1 Relevant guidelines and policies

3.1.1 Overview

This section of the report provides an overview of relevant design standards, policies and guidelines that have been considered as part of the current assessment. Relevant documents are listed in **section 3.1.2**, while key flooding and drainage related policies and guidelines are discussed further in **sections 3.1.3** to **3.1.7**, respectively.

3.1.2 Relevant government and industry documents

Government standards, policies and guidelines that have been considered as part of the current assessment include:

- *Australian Rainfall and Runoff* (ARR 1987) (Institution of Engineers Australia (IEAust) 1987)
- *Australian Rainfall and Runoff* (ARR 2016) (Geosciences Australia (GA) 2016)
- *AR&R Revision Projects – Project 11 – Blockage of Hydraulic Structures* (IEAust 2013)
- *Coastal Planning Guideline – Adapting to Sea Level Rise* (Department of Planning (DoP) 2010a)
- *Coastal Risk Management Guideline – Incorporating Sea Level Rise Benchmarks in Coastal Risk Assessments* (DoP 2010b)
- *Derivation of the NSW Government's Sea Level Rise Planning Benchmarks. Technical Note* (Department of Environment, Climate Change and Water (DECCW) 2009)
- *Flood Prone Land Policy* (NSW Government)
- *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW 2010)
- *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)
- *Guide to Road Design - Part 5 Drainage Design* (Austroads 2010a)
- *Guide to Road Tunnels – Part 1 Introduction to Road Tunnels* (Austroads 2010b)
- *Guide to Road Tunnels – Part 2 Planning, Design and Commissioning* (Austroads 2010c)
- *Guideline on Development Controls on Low Flood Risk Areas* (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)
- *Rockdale City Local Flood Plan* (SES 2009)
- *Rockdale Development Control Plan 2011* (RCC 2011a)
- *Rockdale Local Environmental Plan 2011* (RCC 2011b)
- *Rockdale Technical Specification - Stormwater Management* (RCC 2011c)
- *Section 117(2) Local Planning Direction 4.3 Flood Prone Land* (NSW Government)
- *Sydney Regional Environmental Plan No.33 - Cooks Cove* (SREP 33)
- *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method* (Bureau of Meteorology (BoM) 2003).

3.1.3 Floodplain development manual

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

DIPNR 2005 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, DIPNR 2005 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 DIPNR 2005. 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 its impact on the existing environment. In accordance with DIPNR 2005, the hydraulic and hazard categorisation of the floodplain was also considered when assessing the impact of the project on existing flood behaviour as well as the impact of flooding to the project and its users.

3.1.4 State planning directions and guidelines

In January 2007 the NSW Government 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 DIPNR 2005 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 subject to events above the 1% AEP flood and up to the PMF (i.e. land that is affected by flooding during events that are greater than 1% AEP in magnitude). 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 1% AEP 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 (such as aged care facilities and schools) in areas above the 1% AEP 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 DIPNR 2005 (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 DIPNR 2005 (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 AEP's up to 1% in intensity in the case of residential type development (and by default commercial and industrial type development) and for storms with AEP's greater than 1% in intensity in the case of critical infrastructure (such as hospitals) and vulnerable developments (such as aged care facilities and schools).

3.1.5 State 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 increased depths of rainfall. Future impacts on sea levels are likely to result in a continuation of the rise in levels 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 of between 10 and 30 per cent. Under present day climatic conditions, increasing the 1% AEP design rainfall intensities by 10 per cent would produce about a 0.5% AEP flood; and increasing those rainfalls by 30 per cent would produce about a 0.2% AEP 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.

In accordance with the SEARs, potential increases in rainfall intensities of 10 and 30 per cent (by reference to 1 in 200 year (0.5% AEP) and 1 in 500 year (0.2% AEP) flood events set out in the SEARs) have been adopted for assessing the impact future climate change could have on flooding conditions in the vicinity of the project. This range of potential increases also encompasses the values given in ARR 2016, which suggests a potential increase in rainfall intensities of between 9.1% and 18.6% by 2090.

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.

3.1.6 Council flood planning controls

While Rockdale City Council has joined with Botany Bay Council to form Bayside Council, it is assumed that Rockdale City Council standards and policies would still apply to development with the former Rockdale City Council area until such time as the newly formed council consolidates existing standards and policies from the two previous councils.

Rockdale Local Environmental Plan 2011 (RCC 2011b) sets out flood related planning controls for land that is located within the flood planning area as shown on *Rockdale Local Environmental Plan 2011 Flood Planning Maps*, as well as any other land that is located below the flood planning level (defined in RCC 2011b as the 1% AEP flood level plus 0.5 m). **Table 3-1** lists the map references contained in the *Rockdale Local Environmental Plan 2011 Flood Planning Maps* that show the presence of flood affected land in the vicinity of the project.

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

Clause 18 *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 *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 *"land that is susceptible to flooding by a 1% Annual Exceedance Probability flood event."* This definition is not consistent with DIPNR 2005, which defines flood prone land as land susceptible to flooding by the PMF event.

Table 3-1 Rockdale Local Environmental Plan 2011 Flood Planning Maps and the presence of flood affected land within the project footprint

Project component	Rockdale Local Environmental Plan 2011 Flood Planning Maps
Arncliffe motorway operations complex	• Flood Planning Map FLD_003 shows land to the north of Marsh Street on the western overbank of the Cooks River as FPA • Flood Planning Map FLD_003 does not show Kogarah Golf Course as FPA as the LEP does not apply to this land • Flood Planning Map FLD_007 shows a portion of Sydney Airport on the eastern overbank of the Cooks River as FPA
Rockdale motorway operations complex (north)	• Flood Planning Map FLD_004 shows the land on which the proposed Rockdale motorway operations complex would be located lies completely within the FPA
Rockdale motorway operations complex (south)	• Flood Planning Map FLD_004 shows the land on which the proposed Rockdale electrical substation would be located lies completely within the FPA
Reinstatement of Rockdale Bicentennial Park	• Flood Planning Map FLD_004 does not show the Rockdale Bicentennial Park as being located within the FPA.
President Avenue intersection and surface works	• Flood Planning Map FLD_004 shows the lots that contain the section of Scarborough Ponds to the north of President Avenue is located within the FPA • Flood Planning Map FLD_004 also shows residential properties along Civic Avenue, Colson Crescent and President Avenue, and industrial properties between Bay Street, West Botany Street and England Street are located within the FPA
Shared pedestrian and cyclist pathways between Bestic Street and Civic Avenue	• Flood Planning Maps FLD_004 and 005 show the Civic Avenue Reserve, as well as a number of residential properties to the east and west of the reserve are located within the FPA • Flood Planning Maps FLD_004 shows the C. A. Redmond Field, Whiteoak Reserve and Shiralee Caravan Park, which are located on land that adjoins Muddy Creek, are all located within the FPA • Flood Planning Maps FLD_004 also shows a number of residential properties within the area bounded by Bestic Street, West Botany Street, Francis Avenue and Bay Street are located within the FPA
Princes Highway and President Avenue intersection	• Flood Planning Map FLD_004 does not show the area associated with the proposed roadworks associated with the Princes Highway and President Avenue network enhancements as being located within the FPA

3.1.7 Council drainage related standards

The *Rockdale Technical Specification - Stormwater Management* (RCC 2011c) sets out requirements for the management of stormwater runoff from new developments within the former Rockdale City Council LGA. RCC 2011c requires the quantity of stormwater runoff from new developments to be managed through the use of either:

- on-site retention at sites with typically sandy soils with acceptable permeability rates, or
- on-site detention at sites with low absorption rates, or where other physical limitations prevent effective absorption.

RCC 2011c identifies the area overlying the Botany Bay Sand Aquifer as having permeability rates that are suitable for absorption systems. RCC 2011c states that while the majority of the area overlying the sand aquifer has significant flood problems, absorption systems are to be used for all developments where practical. It is noted that a significant portion of the project between Bestic Street and President Avenue overlies the Botany Bay Sand Aquifer.

RCC 2011c requires that on-site retention and detention systems are designed for a 2% AEP storm event. The absorption rate used in the design of on-site retention systems is to be established through an *in situ* falling head or constant head type infiltration test. RCC 2011c includes a set of maximum permissible site discharge rates and minimum site storage volumes for each catchment within the Rockdale City Council LGA for use in the design of on-site detention systems.

In the absence of *in situ* infiltration testing there is uncertainty as to the permeability of the underlying soil strata across the section of the project within the Rockdale City Council LGA. Furthermore, the volume of stormwater runoff from the motorway pavement is significantly greater than that from a typical property development to which the RCC 2011c requirements with regards to the provision of absorption systems would normally apply. For these reasons, the pavement drainage strategy for the project has been developed on the basis that stormwater runoff would be discharged into the receiving drainage lines and water bodies rather than into an absorption system.

Notwithstanding the above council requirements, there would be a general requirement of the project to manage adverse changes to existing flow behaviour. The assessment of flooding and drainage patterns under pre- and post-project conditions is presented in **sections 4** and **6** of this report.

3.1.8 Summary of adopted assessment criteria and hydrologic standards

Table 3-2 sets out the assessment criteria and hydrologic standards that have been established for the project with due consideration of the policies and guidelines outlined in the preceding sections of this report.

In accordance with the *NSW Floodplain Development Manual* the hydrologic standards adopted are based on matching the level of protection to the risk and consequence of flooding. A 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 its impact on the existing environment.

Table 3-2 Summary of adopted assessment criteria and hydrologic standards

Aspect	Requirement
Flooding of tunnel portals and ancillary facilities	• Tunnel portals are to be located above the PMF level or the 1% AEP flood level plus 0.5 metres (whichever is greater). This level of security against ingress is commensurate with the consequence of flooding to the tunnels and the risk to road users and is consistent with the current standard adopted in the design of road and rail tunnels in NSW. • The same hydrologic standard would apply to operational tunnel ancillary facilities such as tunnel ventilation and water treatment plants where the ingress of floodwater would have the potential to inundate the tunnel or infrastructure that it is reliant upon for its safe operation. • The same hydrologic standard would apply to emergency facilities such as disaster recovery sites and tunnel deluge systems as well as electrical substations that are reliant for the safe operation of the motorway and its ancillary facilities.

Aspect	Requirement
Flooding of motorway ramps and local road connections	• A 1% AEP hydrologic standard has been adopted for motorway ramp and local road connections, where feasible, based on the extent of upgrade requirements and the hydrologic standard of the local road network (e.g. President Avenue intersection).
Modifications to existing road network	• As a minimum, modifications to existing roads are to be configured to ensure the existing level of flood immunity is maintained. Ideally, local road modifications are to provide a minimum hydrologic standard of 10% AEP.
Shared pedestrian and cyclist pathways	• A 1 Exceedance per Year (EY) hydrologic standard has been adopted for shared cycle and pedestrian pathways in accordance with the current standard adopted by Roads and Maritime for cycleways and shared user paths that are separated from the road corridor. • Consideration is to also be given to the flood risk to cyclists and pedestrians during larger floods (e.g. 1% AEP event) as a result of high hazard flooding conditions.
Impact of project operation on flooding and existing development	• Floods up to 1% AEP in magnitude are to be considered in the assessment of measures which are required to mitigate any adverse impacts on flood behaviour attributable to the project. • Changes in flood behaviour under larger floods up to the PMF event are also to be assessed in order to identify impacts on critical infrastructure and vulnerable development, as well as to identify potentially significant changes in flood hazard as a result of the project.
Impact of flooding on proposed construction activities	• Construction related flood risks and impacts need to be evaluated in the context of the construction period in order to set requirements that are commensurate to the period of time that the risk exposure occurs. To this end, this report identifies the risks and impacts associated with each construction activity such that informed decisions can be made on the flood criteria that are set as part of the flood risk management plan for the construction of the project.
Impact of future climate change on flood behaviour	• The assessment of the potential impact future climate change could have on flood behaviour in the vicinity of the project was based on: – increases in 1% AEP design rainfall intensities ranging between 10 and 30 per cent in accordance with the NSW Government's Floodplain Risk Management Guideline: Practical Considerations of Climate Change (DECC 2007)[1]; and – rises in sea level of 0.4 metres by 2050 and 0.9 metres by 2100 in accordance with the NSW Government's Sea Level Rise Policy Statement (NSW Government 2009). • The assessment of the impact of the project on flood behaviour under future climate change was based on assessing the effect of the proposed works on present day flood behaviour during a 0.5 % and 0.2 % AEP event as proxies for assessing the sensitivity to an increase in rainfall intensity on the 1% AEP event due to climate change.

Notes:
1 For the purpose of this assessment the 0.5% and 0.2% AEP events were adopted as being analogous to increases in 1% AEP design rainfall intensities of 10 and 30 per cent, respectively.

3.2 Key assumptions

The flooding and drainage assessment was undertaken based on the following key assumptions:

- Hydrologic modelling was based on the procedures set out in Australian Rainfall and Runoff 1987. A comparison of results based on the procedures set out in Australian Rainfall and Runoff 2016 (which is currently in draft for industry consultation) is provided in **Annexure B**.
- The assessment of the flooding and drainage related impacts for the project was based on catchment flows resulting from the current level of development in the catchments in which it is proposed to be located. As noted in **section 4** of this report, the catchments upstream of the project footprint are highly urbanised in nature. As a result there is limited scope for additional infill development that could result in a significant increase in catchment runoff.
- The assessment of flooding and drainage related impacts in the vicinity of the President Avenue intersection has been based on a three-dimensional surface model of the proposed road design that was developed by AECOM (2017).

3.3 Available data

The following data was provided by Roads and Maritime:

- Ortho-rectified aerial photography covering the study area
- LiDAR survey data covering the study area, flown in 2013
- GIS datasets including property boundary information
- Design drawings and reports prepared as part of the detailed design for the New M5 Motorway project, including the report entitled *Hydrology Model Development Report – Cooks River Flood Modelling* (Aurecon Jacobs Joint Venture (AJJV) 2016).

The following additional information was obtained from other sources (as noted):

- GIS datasets containing details of drainage networks (pit, pipe and open channels), supplied by Rockdale City Council (now part of Bayside Council).
- Previous reports related to the study area obtained from Rockdale City Council comprising:
  - *Lower Muddy Creek and Scarborough Ponds Catchments Overland Flooding and Risk Assessment Study* (Brown Consulting 2004)
  - *Spring Street Drain – Piped Drainage and Overland Flow Analysis* (Brown Consulting 2007a)
  - *Spring Street Drain – Piped Drainage and Overland Flow Analysis Supplementary Report* (Brown Consulting 2007b)
  - *Sans Souci Drainage Catchments Floodplain Risk Management Plan. Floodplain Risk Management Study – Final Report* (Cardno Willing 2005)
  - *Floodplain Management Study, Spring Street Drain, Muddy Creek and Scarborough Ponds* (Willing and Partners 2000).
- Previous reports related to the study area obtained from Sydney Water Corporation (Sydney Water) comprising:
  - *Muddy Creek SWC 70 Capacity Assessment* (Sydney Water (SW) 2000)
  - *Cooks River Flood Study* (PB MWH 2009).

3.4 Methodology

3.4.1 Key tasks

The key tasks comprising the flooding and drainage assessment are broadly described as follows:

- Review of available data and existing flood studies within the catchments that are crossed by the project
- Development of a set of hydrologic and hydraulic models (collectively referred to as ‘flood models’) of the catchments that are located within the study area
- Flood modelling and preparation of exhibits showing flood behaviour under present day conditions for design floods with AEP’s of 20%, 10%, 5%, 1%, 0.5% and 0.2%, as well as the PMF
- Assessment of the potential impact the project would have on flood behaviour for the aforementioned design flood events
- Assessment of the impact a partial blockage of major hydraulic structures would have on flood behaviour under operational conditions
- Assessment of the impact future climate change would have on flood behaviour under operational conditions
- Assessment of potential measures which are aimed at mitigating the risk of flooding to the project and its impact on existing flood behaviour.

The followings sections of this report set out the methodology which was adopted in the assessment of flooding and drainage behaviour under present day conditions and during both the construction and operational phases of the project.

3.4.2 Definition of present day flooding and drainage patterns

In order to define the nature of flooding in the vicinity of the project it was necessary to develop a 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.

Table 3-3 shows the TUFLOW models that were developed for the catchments which contribute flow to the drainage systems along the project. The drainage systems of the Eve Street Wetland, Spring Street Drain, Muddy Creek and Scarborough Ponds were combined into a single TUFLOW model in order to assess the interaction of flow between the four catchments (referred to herein as the ‘Muddy Creek and Scarborough Ponds TUFLOW model’).

Table 3-3 TUFLOW hydraulic models

Catchment	TUFLOW model
Cooks River	Cooks River TUFLOW model
Eve Street Wetland	Muddy Creek and Scarborough Ponds TUFLOW model
Spring Street Drain	
Muddy Creek	
Scarborough Ponds	

In the case of both the Cooks River TUFLOW model and the Muddy Creek and Scarborough Ponds TUFLOW model it was necessary to decide upon coincident catchment and ocean flooding conditions from which design flood envelopes could be derived. Site specific ocean level data was used to define peak storm tide levels for ocean floods ranging between 1 in 5 and 1 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 extreme ocean flood event was also derived by extrapolation of the site specific data. **Section B4** in **Annexure B** of this technical report contains further background to the derivation of storm tide hydrographs which were used for defining design flood levels.

Results from the Cooks River TUFLOW model were compared to peak flood levels presented in the *Cooks River Flood Study* (SWC 2009), as well as the *Hydrology Model Development Report – Cooks River Flood Modelling* (AJJV 2016), while results from the Muddy Creek and Scarborough Ponds TUFLOW model were compared to peak flood levels presented in the *Spring Street Drain, Muddy Creek and Scarborough Ponds Floodplain Management Study* (Willing and Partners 2000). The findings of these comparisons are presented in **Annexures A** and **B**.

Flood behaviour in the vicinity of the project was defined for a range of events with AEP's of between 20% and 0.2% in magnitude, as well as the PMF, while flood behaviour in the Eve Street Wetland, Spring Street Drain, Muddy Creek and Scarborough Ponds catchments was also defined for a 1 Equivalent Year (EY) event. A description of flood behaviour in the vicinity of the project under present day conditions is presented in **section 4**.

3.4.3 Assessment of construction related impacts

A preliminary investigation was undertaken to assess the potential impacts of construction activities on flood behaviour during a 1% AEP event. This involved making adjustments to the structure of the TUFLOW models that were originally developed to define flood behaviour under present day conditions to reflect the proposed layout of the construction sites and the staging of works. The changes that were made to the structure of the hydraulic models are shown in **Table 5-2**, while a discussion of the potential construction impacts of the project on flood behaviour is contained in **section 5.3**.

3.4.4 Assessment of operational related impacts

The structure of the TUFLOW models that were originally developed to define flood behaviour under present day conditions was adjusted to incorporate details of the project under operational conditions. The results of modelling a range of events with AEP's of between 20% and 0.2% in magnitude, as well as the PMF were used to prepare a series of figures showing flooding patterns under operational conditions and afflux diagrams[1] showing the impact the project would have on flood behaviour.

Details of the concept design arrangements that were incorporated into the hydraulic models used to define flood behaviour in the vicinity of the project are summarised in **Table 6-2**, while a discussion on the potential operational impacts of the project on flood behaviour is contained in **section 6.2**.

3.4.5 Impact of future climate change on flood behaviour

The following sections describe the approach that was adopted to assess the potential impact of future climate change on flooding to the project, as well as the impact that the project may have on flood behaviour under future climate change conditions. The findings of this assessment are contained in **section 6.4** of this technical report.

Impact of future climate change on flooding to the project

Based on the adopted assessment criteria set out in **Table 3-2**, the following scenarios were adopted as being representative of the likely lower and upper estimates of climate change flooding impacts over the design life of the project:

[1] Afflux is an increase in peak flood levels caused by a change in floodplain or catchment conditions. 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 1 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 flood behaviour in areas where an afflux of ±0.01 metres is shown to be present.

- Scenario 1 – based on an assumed 10 per cent increase in currently adopted design rainfall intensities, together with a rise in sea level of 0.4 metres
- Scenario 2 – based on an assumed 30 per cent increase in currently adopted design rainfall intensities, together with a rise in sea level of 0.9 metres.

Table 3-4 shows the combinations of catchment and coincident storm tide conditions that were used to define the 1% AEP and PMF design flood envelopes under scenario 1 and 2 climatic conditions.

There are currently no guidelines which quantify the likely increase in probable maximum precipitation (PMP) associated with future climate change. By its definition, the PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism in regards to rainfall production. On this basis, no adjustment has been made to the PMP rainfall intensities for future climate change.

While future climate change also has the potential to increase the frequency and magnitude of flows surcharging the drainage systems along roads, this is likely to be of greater concern at the tunnel portal where surcharge flow would enter the road tunnels. During detailed design the impact of future climate change would also need to be considered in the sizing of the drainage system at the tunnel portal including the stormwater collection tanks and pumps.

Impact of the project on flood behaviour under potential future climate change conditions

In accordance with the SEARs, the predicted impact that the project may have on flood behaviour under potential future climate change conditions was based on assessing its effect on present day flood behaviour during a 0.5 % and 0.2 % AEP event as proxies for assessing the sensitivity to an increase in rainfall intensity on the 1% AEP event due to future climate change.

Table 3-4 Derivation of design flood envelopes for assessment of potential climate change impacts

Design flood envelope	Local catchment flood	Downstream boundary condition in Botany Bay[1,2]
Current conditions[1]		
1% AEP	1% AEP	1 in 20 year peak storm tide level [1.63 m AHD]
	5% AEP	1 in 100 year peak storm tide level [1.70 m AHD]
PMF	PMF	1 in 100 year peak storm tide level [1.70 m AHD]
	1% AEP	Extreme storm tide level [1.85 m AHD]
Scenario 1		
1% AEP	Based on 1% AEP rainfall intensities increased by 10%[3]	1 in 20 year peak storm tide level plus 0.4 m [2.03 m AHD]
	Based on 5% AEP rainfall intensities increased by 10%	1 in 100 year peak storm tide level plus 0.4 m [2.10 m AHD]
PMF	PMF	1 in 100 year peak storm tide level plus 0.4 m [2.10 m AHD]
	Based on 1% AEP rainfall intensities increased by 10%[3]	Extreme storm tide level plus 0.4 m [2.25 m AHD]
Scenario 2		
1% AEP	Based on 1% AEP rainfall intensities increased by 30%[3]	1 in 20 year peak storm tide level plus 0.9 m [2.53 m AHD]
	Based on 5% AEP rainfall intensities increased by 30%	1 in 100 year peak storm tide level plus 0.9 m [2.60 m AHD]
PMF	PMF	1 in 100 year peak storm tide level plus 0.9 m [2.60 m AHD]
	Based on 1% AEP rainfall intensities increased by 30%[3]	Extreme storm tide level plus 0.9 m [2.75 m AHD]

Notes:

1 Values in [ ] relate to adopted peak storm tide level.

2 All values include 0.25 m increase to allow for additional storm related components such as wind stress and wave action.

3 Design rainfall intensities for the 0.5% and 0.2% AEP events were adopted as being analogous to the 1% AEP design rainfall intensities increased by 10 per cent and 30 per cent respectively.

3.4.6 Impact of a partial blockage of major hydraulic structures

The assessment of the impact that a partial blockage of major hydraulic structures may have on flood behaviour was based on guidance provided in *Australian Rainfall and Runoff* (ARR 2016), as well as *AR&R Revision Projects – Project 11 – Blockage of Hydraulic Structures* (IEAust 2013).

In regards culvert structures, IEAust 2013 recommends the adoption of a 20 per cent blockage factor where the height of a culvert is less than three metres or its width is less than five metres, while ARR 2016 recommends that the adopted blockage factor be based on the size of the largest 10% of debris relative to the size of the waterway opening; the availability, mobility and transportability of the debris; and the magnitude of the flood event.

With due consideration to these guidelines, the structure of the hydraulic model which was used to define flood behaviour on the Scarborough Ponds floodplain was adjusted to include a 20 per cent blockage factor which was applied to all major culvert structures.

The impact an accumulation of debris on existing bridge structures over the Cooks River was also assessed given the potential for the Arncliffe motorway operations complex to be flooded due to a rise in flood levels. The impact a one metre thick raft of debris lodged beneath the underside of the existing bridge structures, in combination with a four metre wide raft of debris lodged on the upstream side of each pier over the full height of the clear opening, was assessed as part of the investigation.

The findings of the blockage related impact assessment are contained in **section 6.4** of this technical report.

4 Existing Environment

The following five catchments presently contribute runoff to the existing drainage systems and waterways that are located within the project footprint (refer **Figure 4-1**):

- Cooks River – Marsh Street to M5 East Motorway at Arncliffe
- Eve Street Wetland – M5 East Motorway to Avenal Street at Arncliffe
- Spring Street Drain – Avenal Street at Arncliffe to Bryant Street at Rockdale
- Muddy Creek – Bryant Street to West Botany Street at Rockdale
- Scarborough Ponds – West Botany Street at Rockdale to President Avenue at Brighton-Le-Sands.

All the above catchments form part of the larger Botany Bay catchment. Each system is described separately in **section 4.1** with information regarding the source of flows in the existing drainage lines that cross the project corridor, while **section 4.3** provides an overview of flooding and drainage patterns in the vicinity of the project under present day conditions.

Figure 4-2 shows details of the existing drainage arrangements and features within each catchment, and should be referred to when reading the descriptions in **section 4.1**.

4.1 Catchment Description

4.1.1 Cooks River

The Cooks River drains a catchment of about 100 square kilometres (10,000 hectares) in the southern suburbs of Sydney and discharges to Botany Bay at Kyeemagh, adjacent to Sydney Airport. The catchment has been extensively developed and the river channel highly modified. A significant length of the river is lined and has been straightened and re-aligned in several locations.

The Cooks River has two major tributaries: Wolli Creek and Sheas Creek (also referred to as Alexandra Canal). Smaller tributaries include Muddy Creek and Cup and Saucer Creek. **Figure 4-1** shows the extent of the Cooks River catchment in relation to the project footprint.

4.1.2 Eve Street Wetland

The Eve Street Wetland catchment (refer **Figure 4-2**, sheet 1) covers an area of about 28 hectares and drains in a westerly direction, extending from the Princes Highway in Arncliffe to the Eve Street Wetland which is located on the southern, side of the M5 East Motorway. The catchment is located within the suburb of Arncliffe in the Bayside Council LGA.

Land use within the catchment is predominantly low to medium density residential development. Areas of open space include Eve Street Reserve and Eve Street Wetland, both of which are located in the lower reaches of the catchment.

Runoff from the urbanised portion of the catchment is controlled by a network of pits and pipes that discharge into the Eve Street Wetland as shown in **Figure 4-2**, sheet 1. Two 900 mm diameter pipes discharge at the northern end of Eve Street, while a pipe of unknown diameter discharges at the eastern end of Brennans Road.

Flows that surcharge the Eve Street Wetland are conveyed via a 5 metre wide vegetated channel that runs in an easterly direction under the bridged section of the M5 East Motorway. The open channel then discharges into the Cooks River via a 1200 mm diameter pipe.

4.1.3 Spring Street Drain

The Spring Street Drain catchment (refer **Figure 4-2**, sheet 1) covers an areas of about 258 hectares and drains in an easterly direction, extending from Forest Road in Rockdale to Muddy Creek in Arncliffe. The catchment is located within the Bayside Council LGA and includes the suburbs of Arncliffe, Banksia and Rockdale.

The major transport corridors of the Eastern Suburbs and Illawarra Railway Line, and the Princes Highway run north-south across the middle reaches of the catchment.

Land use within the catchment predominantly comprises low to medium density residential development, with higher density residential and commercial development in the vicinity of the major transport corridors. The lower reach of the catchment comprises a significant portion of open space that includes Banksia Field.

The main arm of Spring Street Drain comprises a concrete lined channel that extends from Short Street in the west to Muddy Creek in the east. The section of channel east (downstream) of West Botany Street is about 12 metres wide by 1.5 metres deep.

A sub-branch of the Spring Street Drain runs in a north-easterly direction and joins the main arm approximately 160 metres upstream of West Botany Street. This sub-branch comprises a series of channel and culvert reaches, ending in a 2.1 metre wide by 1.5 metre deep concrete lined channel where it discharges into the main arm of the Spring Street Drain.

4.1.4 Muddy Creek

The Muddy Creek catchment (refer **Figure 4-2**, sheets 1 and 2) covers an area of about 614 hectares and drains in a north-easterly direction, extending from Forest Road in Hurstville to the Cooks River at Kyeemagh. The catchment spans the LGA's of Bayside Council and Georges River Council and includes the suburbs of Hurstville, Allawah, Carlton, Kogarah, Bexley, Rockdale, Brighton-Le-Sands and Kyeemagh.

The major transport corridors of the Eastern Suburbs and South Coast Railway Line and the Princes Highway run north-south across the middle reaches of the catchment.

The upper portion of the catchment, west of the Eastern Suburbs and Illawarra Railway Line, predominantly comprises low to medium density residential development. High density residential and commercial development is present along the major transport corridors, as well as at the Rockdale Town Centre, while an industrial area is centred on West Botany Street and Lindsay Street.

Open space is mainly located in the lower reaches of the Muddy Creek catchment and includes Rockdale Park, McCarthy Reserve, Whiteoak Reserve, Lance Stoddert Reserve and Barton Park. The Kyeemagh Market Gardens are also located on the eastern bank of Muddy Creek in the lower reach of the catchment.

The main arm of Muddy Creek has been highly modified as a result of urbanisation and consists of a series of Sydney Water owned concrete and brick lined channels and closed box culvert structures that extend from Willison Road in Carlton to Bestic Street in Kyeemagh. North (downstream) of Bestic Street the concrete lined channel discharges into an estuarine channel which runs through Barton Park to the Cooks River.

4.1.5 Scarborough Ponds

The Scarborough Ponds catchment (refer **Figure 4-2**, sheets 2) covers an area of about 400 hectares and drains in a southerly direction, extending from Bay Street in the north, Rocky Point Road in the west, Grand Parade in the east and Ramsgate Road in the south. The catchment spans the LGA's of Bayside Council and Georges River Council and includes the suburbs of Brighton-Le-Sands, Rockdale, Kogarah, Beverley Park, Monterey, Ramsgate and Ramsgate Beach.

Medium density residential development is the dominant land use along the western and eastern sides of the catchment. A considerable amount of open space is present along the central thread of the catchment, largely within land that had been reserved for the F6 Freeway, which includes Rockdale Bicentennial Park, A. S. Tanner Reserve, Scarborough Park, Leo Smith Reserve and Tonbridge Reserve.

Runoff from the urbanised portion of the catchment is controlled by a network of pits and pipes that discharge into Scarborough Ponds as shown in **Figure 4-2**, sheet 2.

Scarborough Ponds is comprised of a series of dredged ponds and semi-natural wetlands that are separated by President Avenue and Barton Street. The series of semi-natural wetlands to the north of President Avenue are also referred to as the Bicentennial Wetlands. Willing and Partners (2000) notes that an artificial outlet comprising three 1350 mm diameter pipes was constructed along Florence Street between the ponds and Botany Bay in the 1970's. Prior to this, the ponds originally had an outlet further to the south beyond Ramsgate Road.

4.2 Description of existing flooding and drainage behaviour

4.2.1 General

The following sections of the report provide a brief description of patterns of both mainstream flooding and major overland flow under present day conditions. The following figures are also referred to in the following discussion:

- **Figure 4-3** (2 sheets) shows design 1% AEP and PMF water surface profiles along the main arms of the Cooks River, Muddy Creek and Scarborough Ponds
- **Figures 4-4** and **4-5** (3 sheets each) show the indicative extent and depth of inundation in the vicinity of the project footprint for a 1% AEP design storm and the PMF event, respectively.

Annexure C contains a series of figures that show patterns of mainstream flooding and major overland flow in the vicinity of the project for design storms with an EY of 1[2] and AEP's of 20%, 5%, 0.5% and 0.2%. **Annexure C** also contains a series of figures that show the extent of land which is located below the 1% AEP flood level plus 0.5 metres (defined in RCC 2011b as the flood planning area), as well as the provisional hazard and preliminary hydraulic categorisation of land for a 1% AEP storm event.

4.2.2 Cooks River

In the lower reaches of the Cooks River, ocean flooding controls flood levels downstream of the Southern and Western Suburbs Ocean Outfall Sewer (SWSOOS) crossing. Upstream of the SWSOOS there is a crossover in the water surface profiles and levels associated with catchment flooding dominate.

Kogarah Golf Course is inundated by floodwater which surcharges the western bank of the Cooks River upstream of the Giovanni Brunnetti bridge and the SWOOS for events as frequent as 20% AEP.

The golf course principally acts as a temporary flood storage area for events up to 1% AEP whereby 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 1% AEP 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 1% AEP flood level in the river is about RL 2.1 m AHD, while in the ponding area it is about 0.5 metres lower at about RL 1.6 m AHD. Depths of ponding in the northern portion of the golf course are sufficient to result in hazardous conditions for persons and property during a flood of this recurrence interval.

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

High hazard flooding conditions and floodway areas are generally confined to the main channel of the Cooks River in the vicinity of the golf course and M5 East Motorway at the 1% AEP level of flooding (refer **Figure C-7**, sheet 2 and **Figure C-8**, sheet 2 in **Annexure C**).

4.2.3 Eve Street Wetland and Spring Street Drain

While the project is in tunnel where it crosses the Eve Street Wetland and Spring Street Drain catchments, it is noted that floodwater originating from the Spring Street Drain catchment discharges along Bestic Street to Muddy Creek.

4.2.4 Muddy Creek

Sheets 3 and 4 of **Figure 4-4** show that floodwater surcharges the main arm of Muddy Creek at a number of locations between Bay Street and Bestic Street during a 1% AEP storm event. Floodwater that surcharges the eastern bank of the creek at West Botany Street discharges in an easterly direction along Bruce Street to a maximum depth of about 1 m. Further downstream in the vicinity of C. A. Redmond Field and Whiteoak Reserve, floodwater extends onto the overbank areas either side of the main arm, inundating the area to a maximum depth of 1 m.

[2] Flood behaviour during a 1 EY was defined in the catchments of Eve Street Wetland, Spring Street Drain, Muddy Creek and Scarborough Ponds.

Floodwater originating from the Scarborough Ponds catchment discharges to Muddy Creek through several commercial / industrial properties that are located on the western side of West Botany Street opposite Rockdale Bicentennial Park for events as frequent as 20% AEP. Conversely, flow which surcharges the sag in Bay Street near its intersection with England Street in the Muddy Creek catchment discharges in a southerly direction where it combines with flow in the upper reaches of the Scarborough Ponds catchment for events larger than about a 20% AEP.

High hazard flooding conditions are generally confined to the main channel of Muddy Creek where it runs between West Botany Street and Bestic Street adjacent to the alignment of the proposed shared pedestrian and cyclist pathways.

A section of West Botany Street and Bruce Street to the south of Muddy Creek acts as a floodway during a 1% AEP to convey flow that surcharges the section of main channel that is located to the west of West Botany Street.

4.2.5 Scarborough Ponds

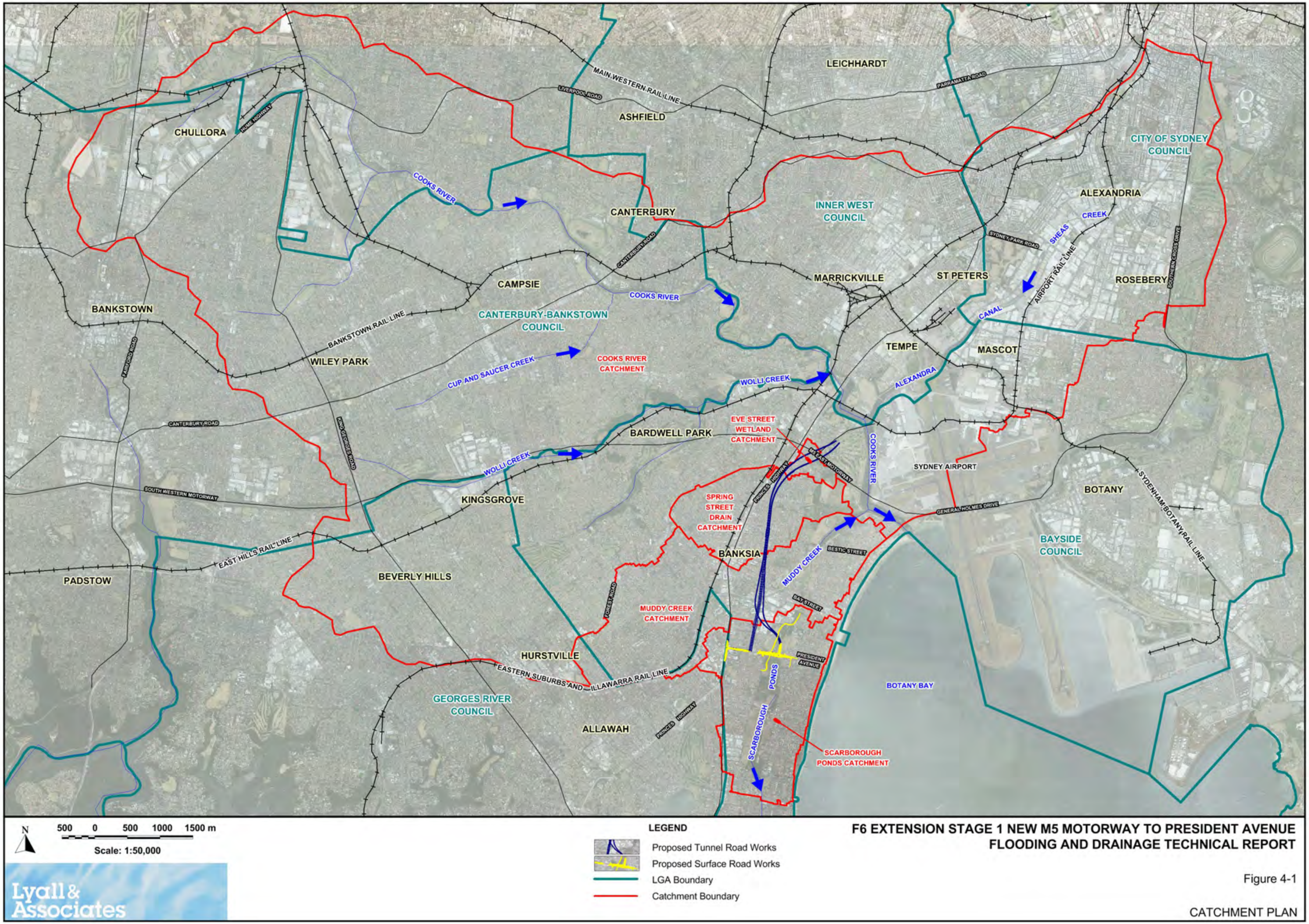
Capacity constraints in the piped drainage system which runs under Rockdale Bicentennial Park results in flooding being experienced in a number of commercial / industrial properties which are located on the western side of West Botany Street, for storms as frequent as 20% AEP. Existing commercial / industrial development located at the eastern end of Bermill Street is also impacted by flooding during storms as frequent as 20% AEP.

While existing residential development is not impacted by mainstream flooding along Scarborough Ponds Creek for events up to 5% AEP, several properties located along the eastern and western sides of the open space corridor through which the creek runs are impacted at the 1% AEP level of flooding.

The section of President Avenue that runs between Colson Crescent and Civic Avenue has a current hydrologic standard of about 50% AEP.

The reach of Scarborough Ponds that runs through the Rockdale Bicentennial Park acts principally as a flood storage area for events up to 1% AEP due to the relatively low velocity of the floodwater. Depths of ponding along this reach of Scarborough Ponds are sufficient to result in hazardous conditions for persons and property arising during a flood of this recurrence interval.

Runoff from the catchment that drains to the low point in the Princes Highway to the north of President Avenue surcharges the local stormwater drainage system during storms as frequent as 1 EY and discharges in an easterly direction through the adjoining properties and along Green Lane and Green Street before contributing to overland flow in French Street and West Botany Street.



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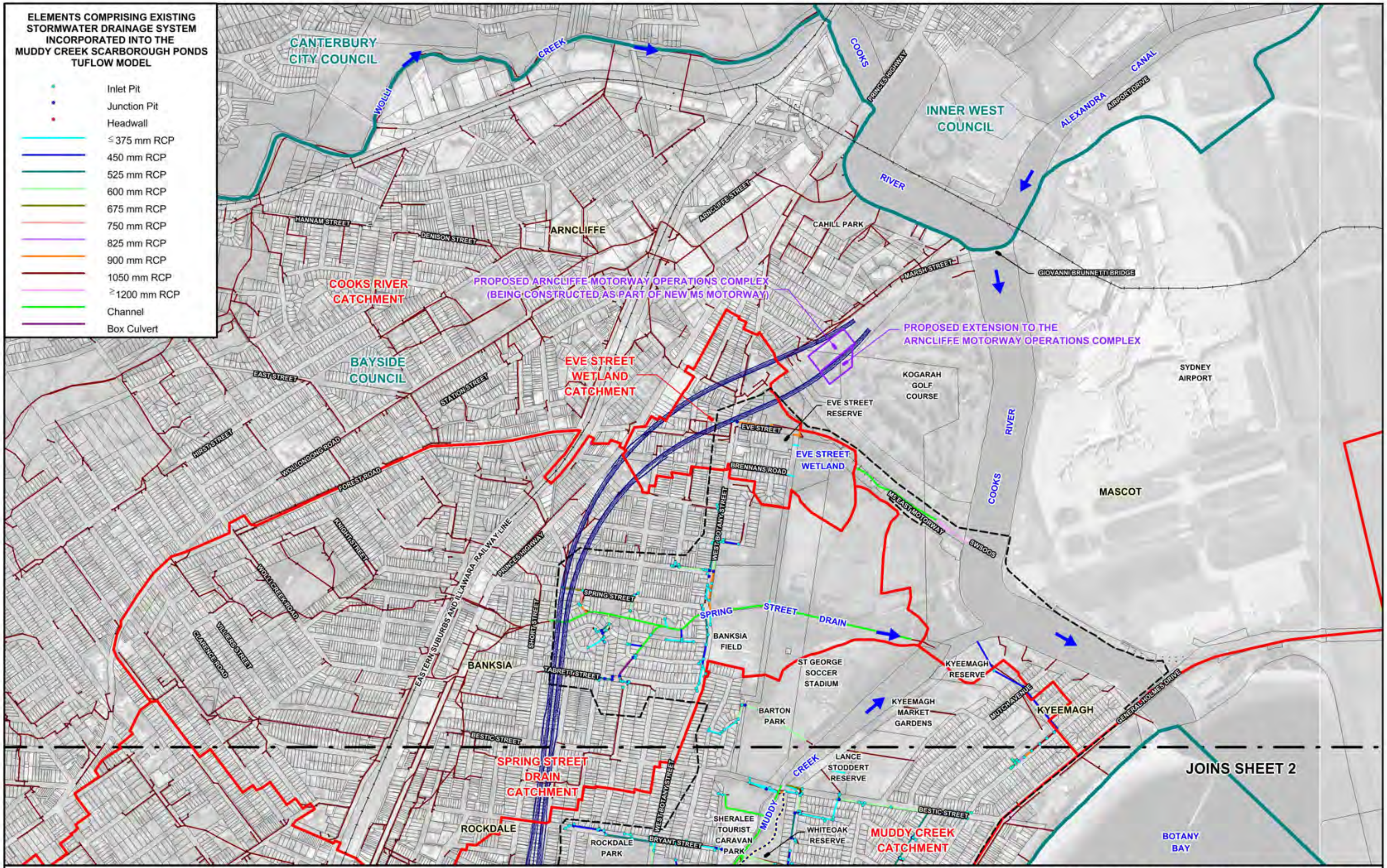
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-1

CATCHMENT PLAN



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Scale: 1:12,000

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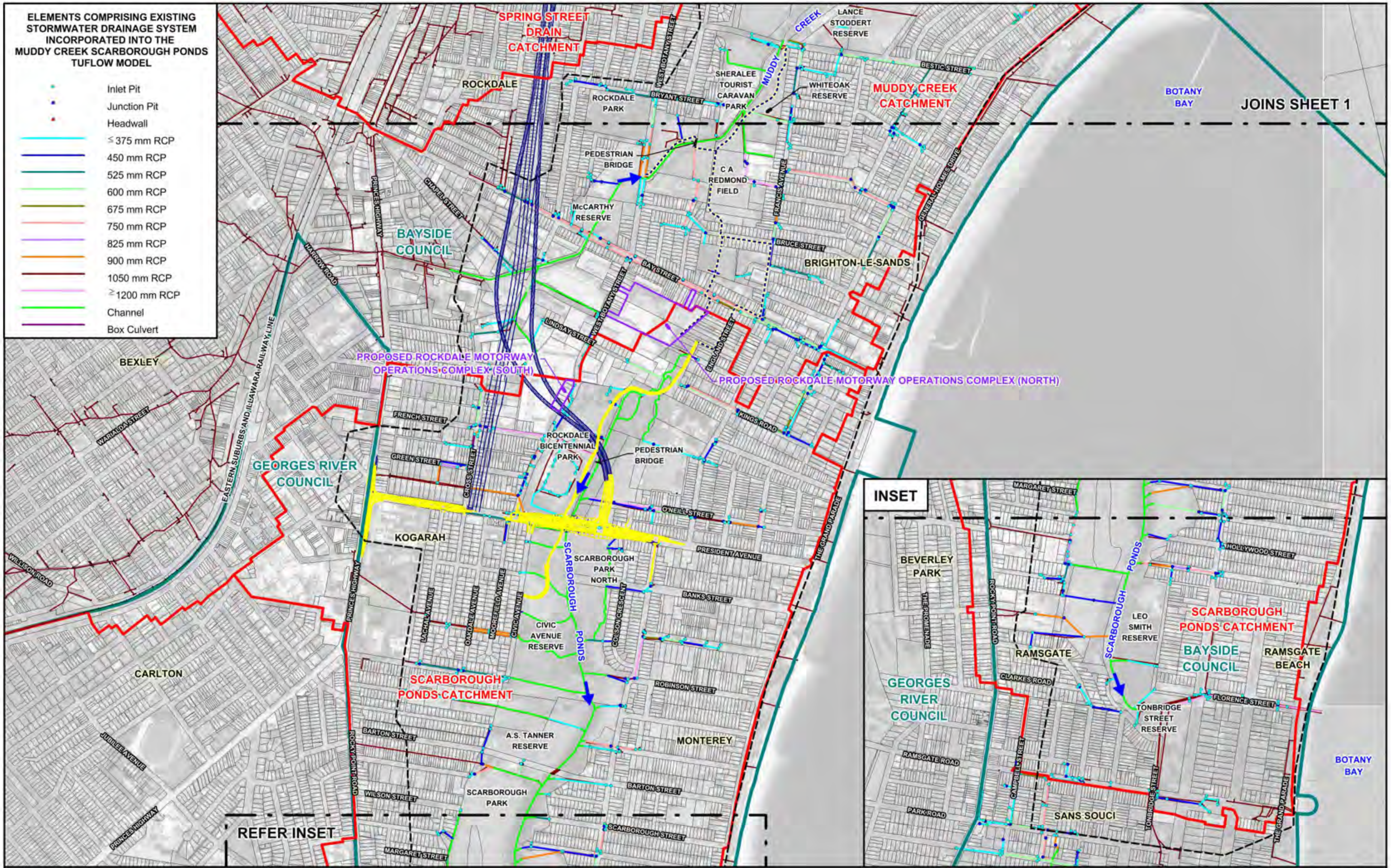
LEGEND

Proposed Tunnel Road Works
Proposed Cycle and Pedestrian Pathways
Extent of Proposed Tunnel Ancillary Facilities
Existing Drainage System
Channel
Muddy Creek Scarborough Ponds TUFLOW Model Extent
LGA Boundary
Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-2
Sheet 1 of 2

EXISTING DRAINAGE LAYOUT



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Scale: 1:12,000

LEGEND

Proposed Surface Road Works
Proposed Tunnel Road Works
Proposed Cycle and Pedestrian Pathways
Extent of Proposed Tunnel Ancillary Facilities
Existing Drainage System
Channel
Muddy Creek Scarborough Ponds TUFLOW Model Extent
LGA Boundary
Catchment Boundary

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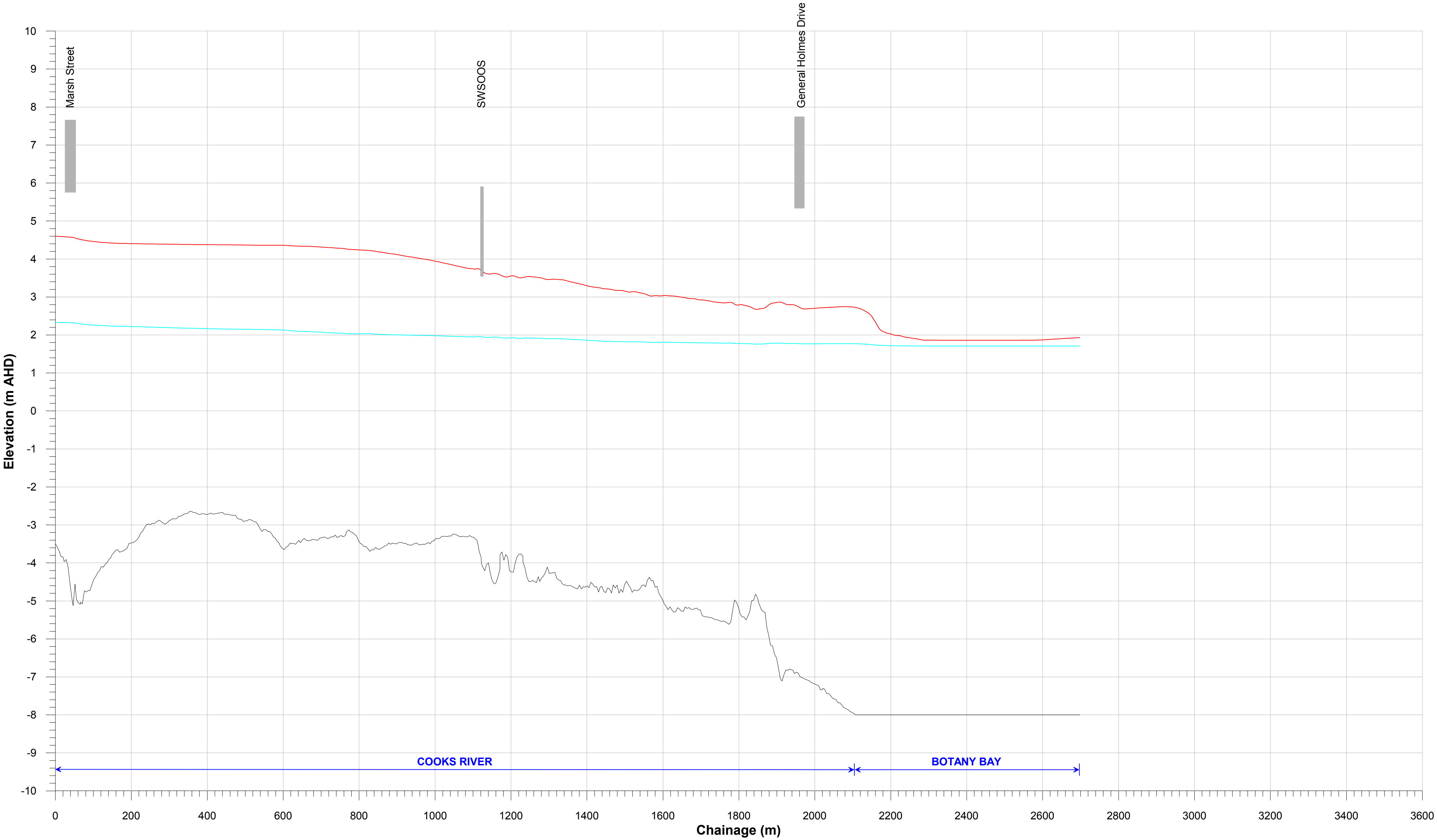
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-2
Sheet 2 of 2

EXISTING DRAINAGE LAYOUT



FLOOD EVENTS

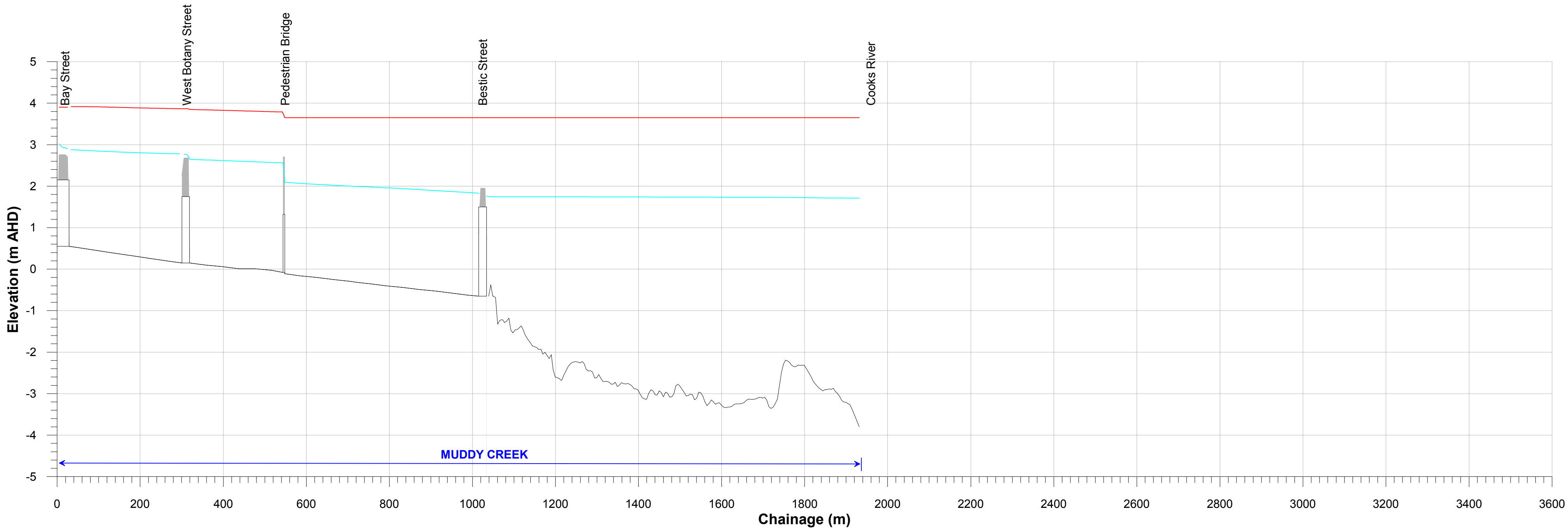
PMF

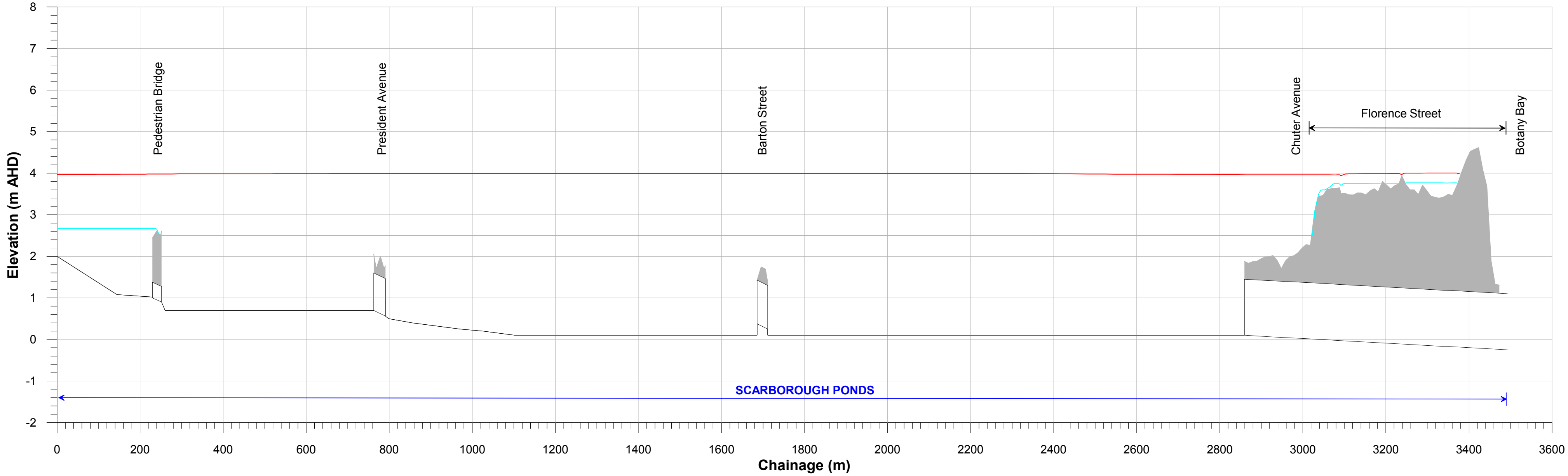
1% AEP

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-3
Sheet 1 of 2

DESIGN WATER SURFACE PROFILES
PRESENT DAY CONDITIONS





FLOOD EVENTS

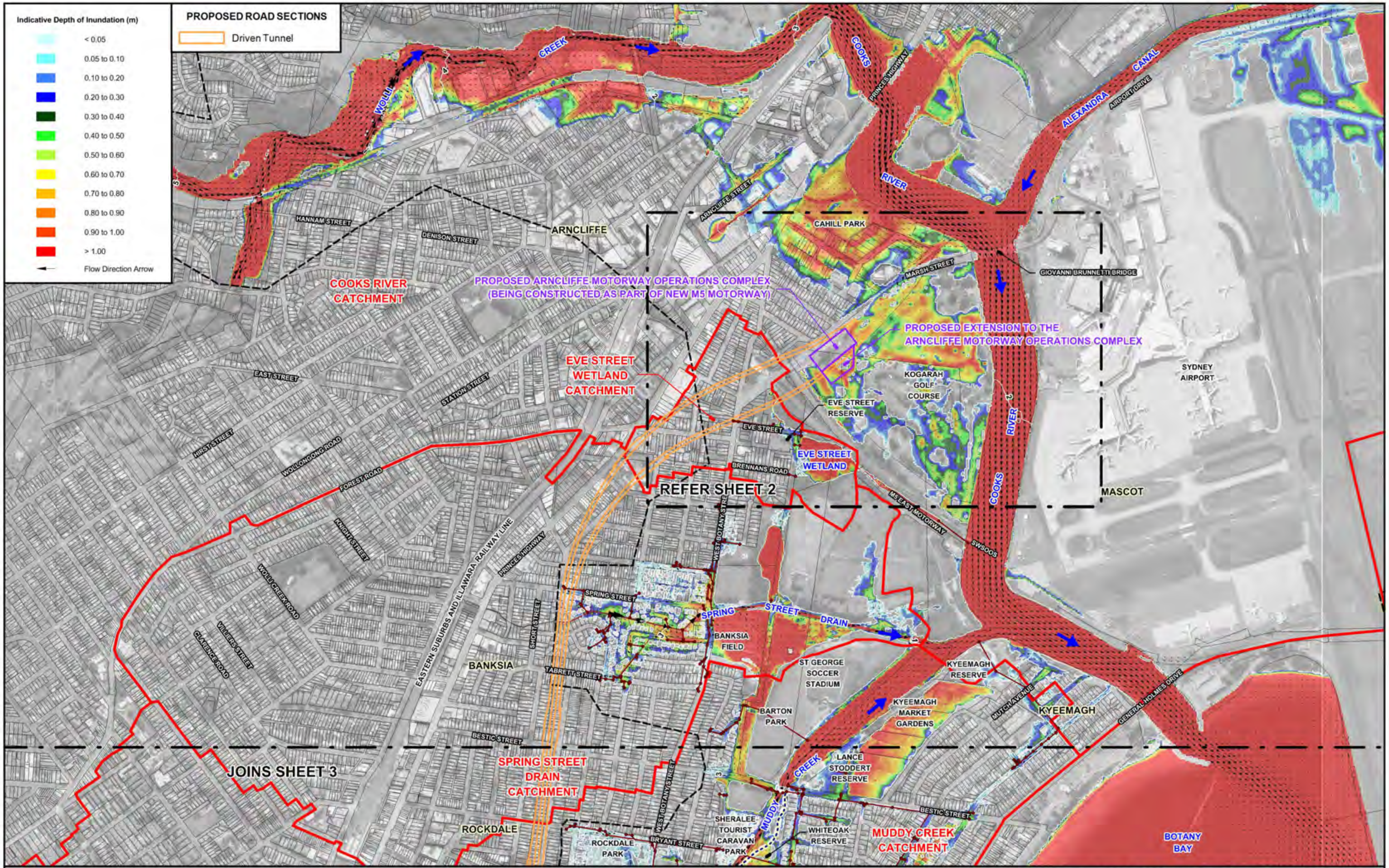
PMF

1% AEP

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-3
Sheet 2 of 2

DESIGN WATER SURFACE PROFILES
PRESENT DAY CONDITIONS



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Scale: 1:12,000

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Note:

The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

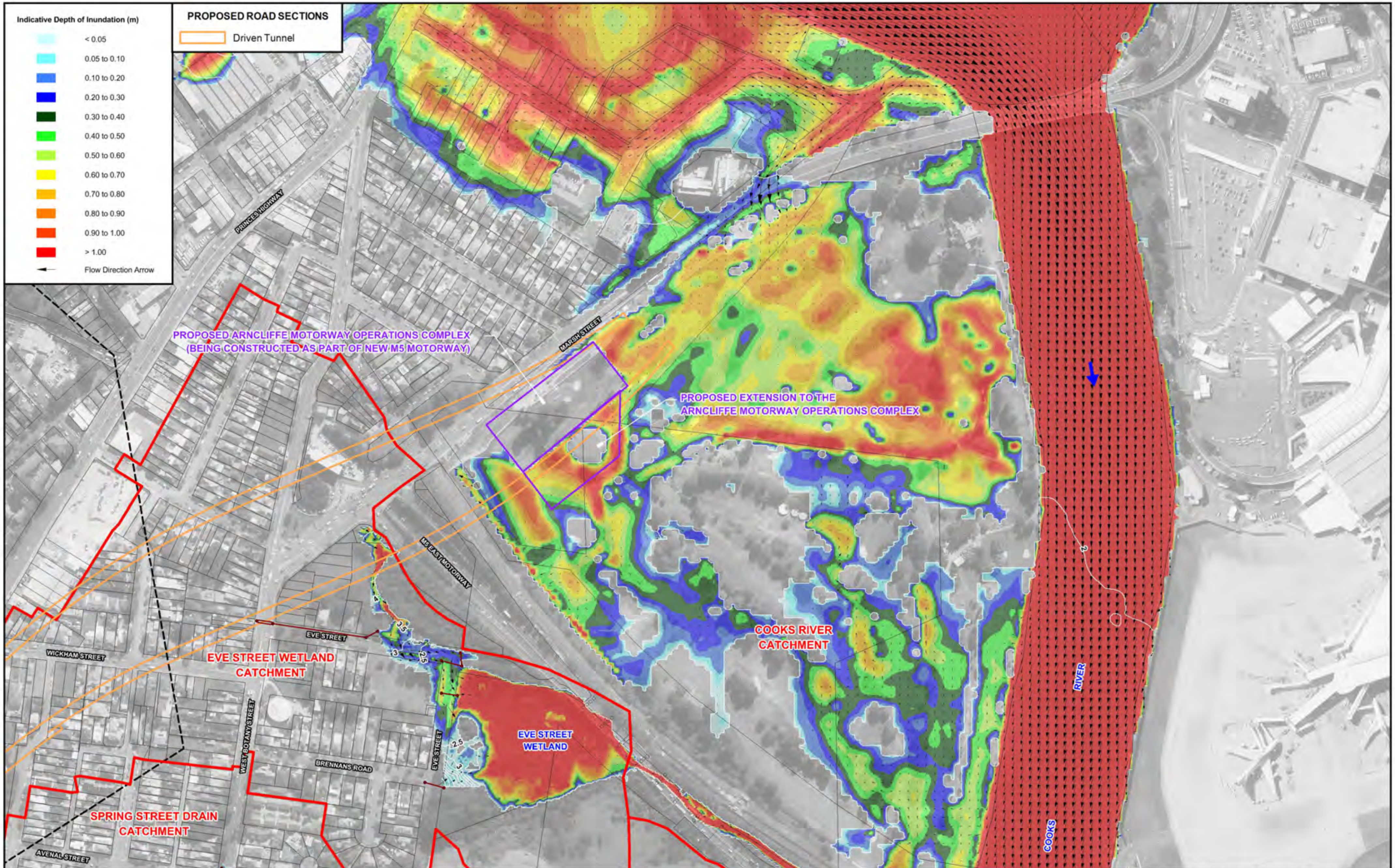
LEGEND

- Proposed Cycle and Pedestrian Pathways
- Project Boundary of Proposed Surface Works
- Extent of Proposed Tunnel Ancillary Facilities
- Water Surface Elevation Contours (m AHD)
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-4
Sheet 1 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRESENT DAY CONDITIONS - 1% AEP



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Scale: 1:4,000

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LEGEND
- Proposed Cycle and Pedestrian Pathways
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- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

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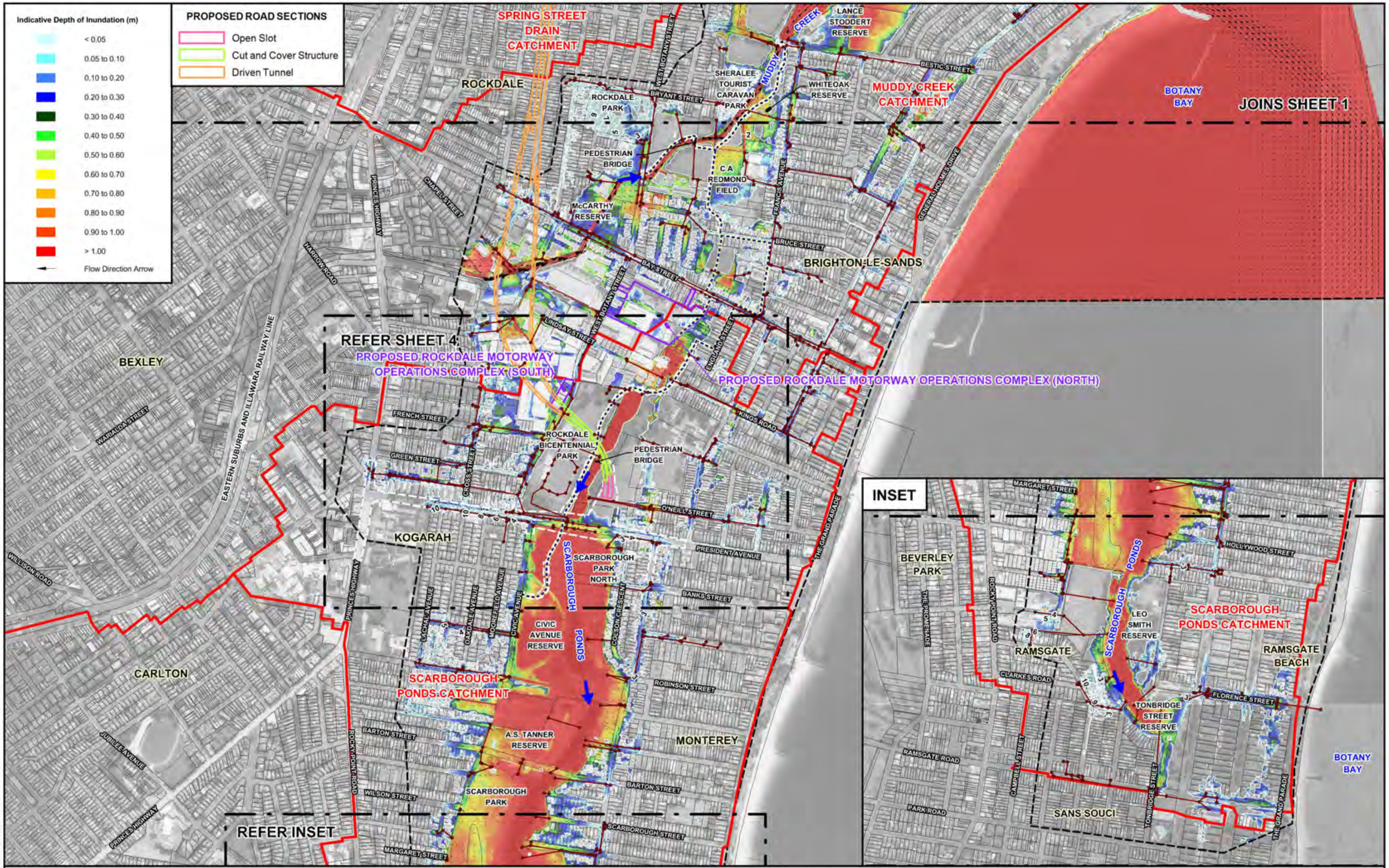
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-4
Sheet 2 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRESENT DAY CONDITIONS - 1% AEP



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Scale: 1:12,000

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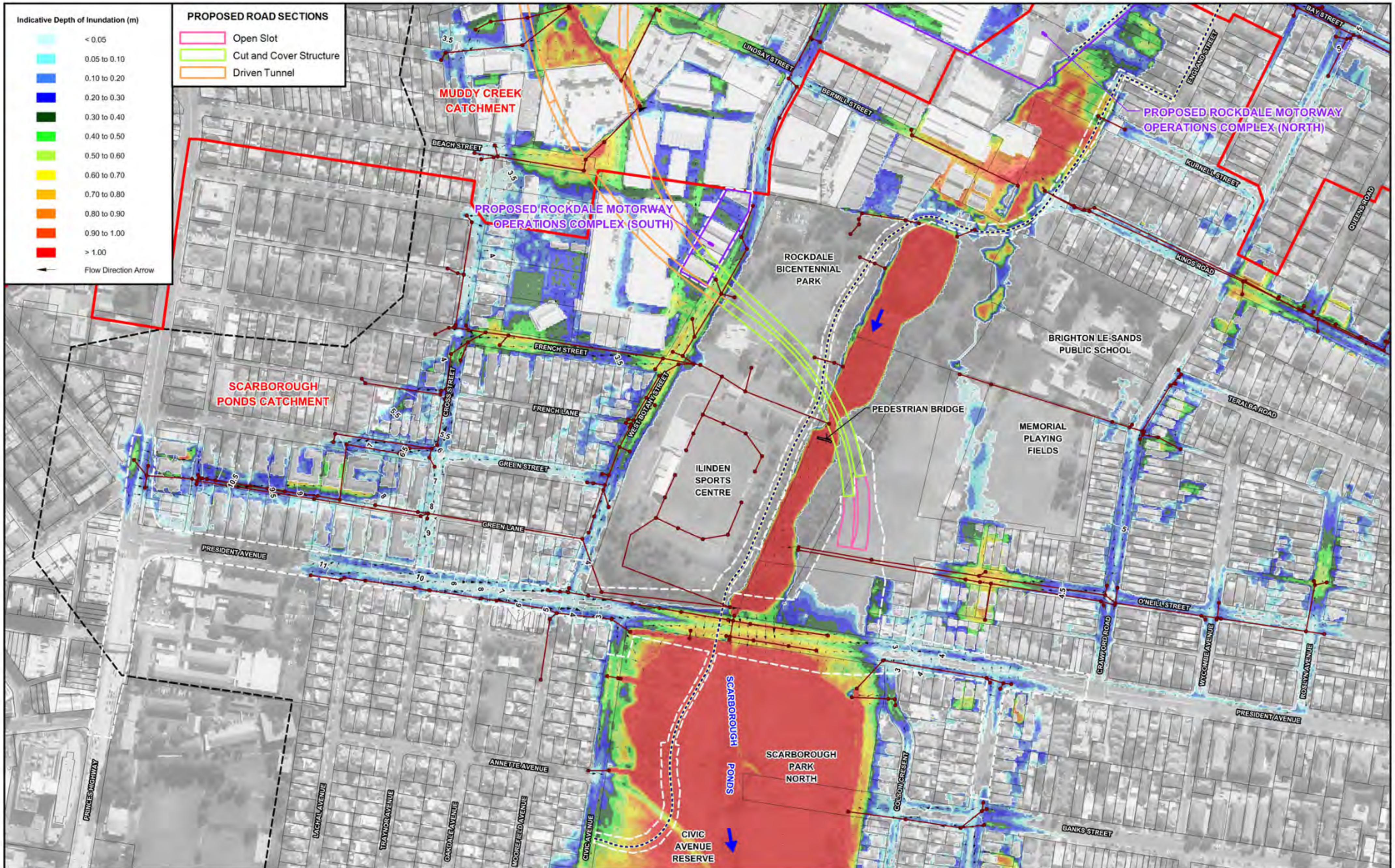
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-4
Sheet 3 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRESENT DAY CONDITIONS - 1% AEP



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Scale: 1:4,000

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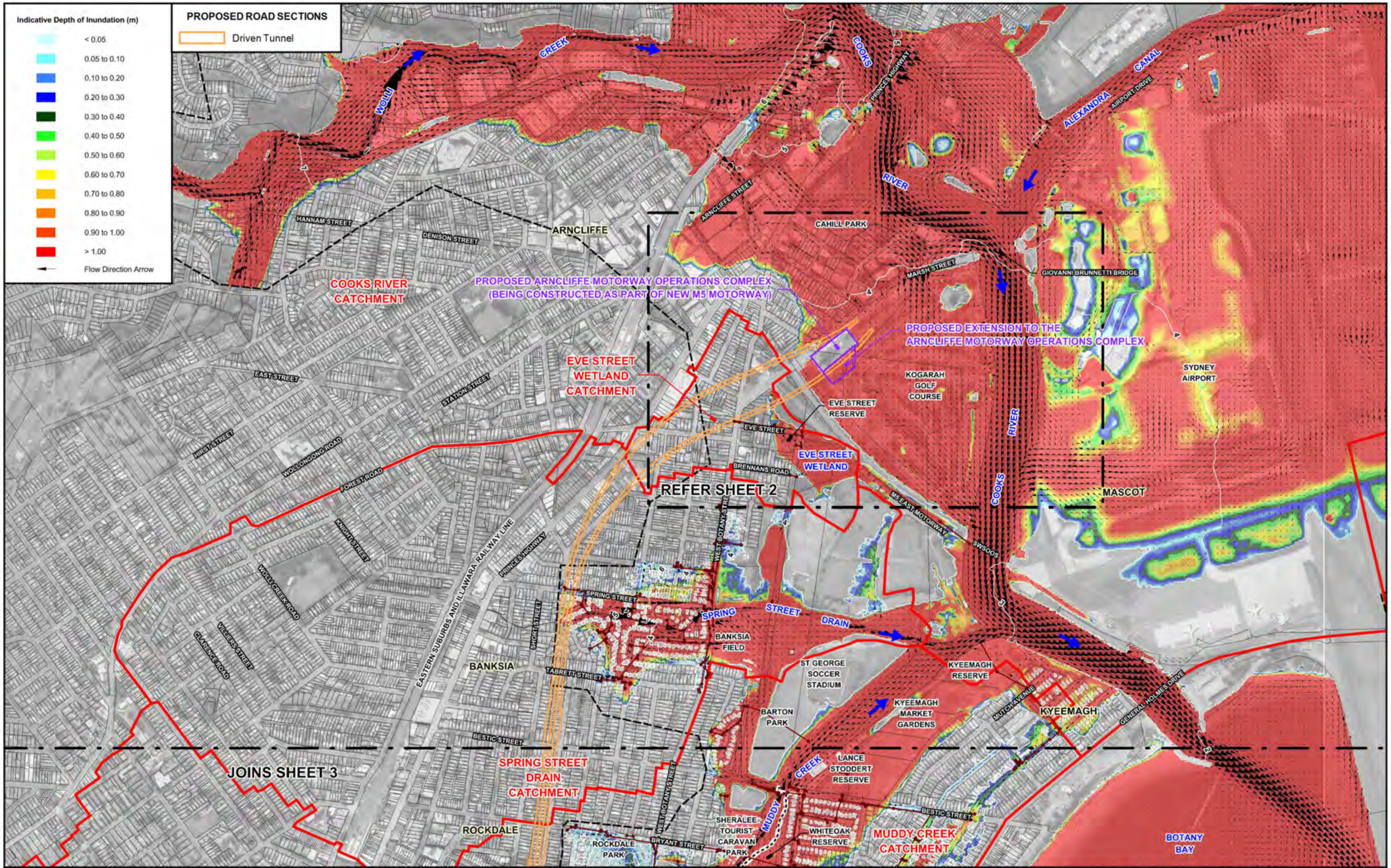
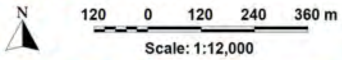
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-4
Sheet 4 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRESENT DAY CONDITIONS - 1% AEP





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- Water Surface Elevation Contours (m AHD)
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

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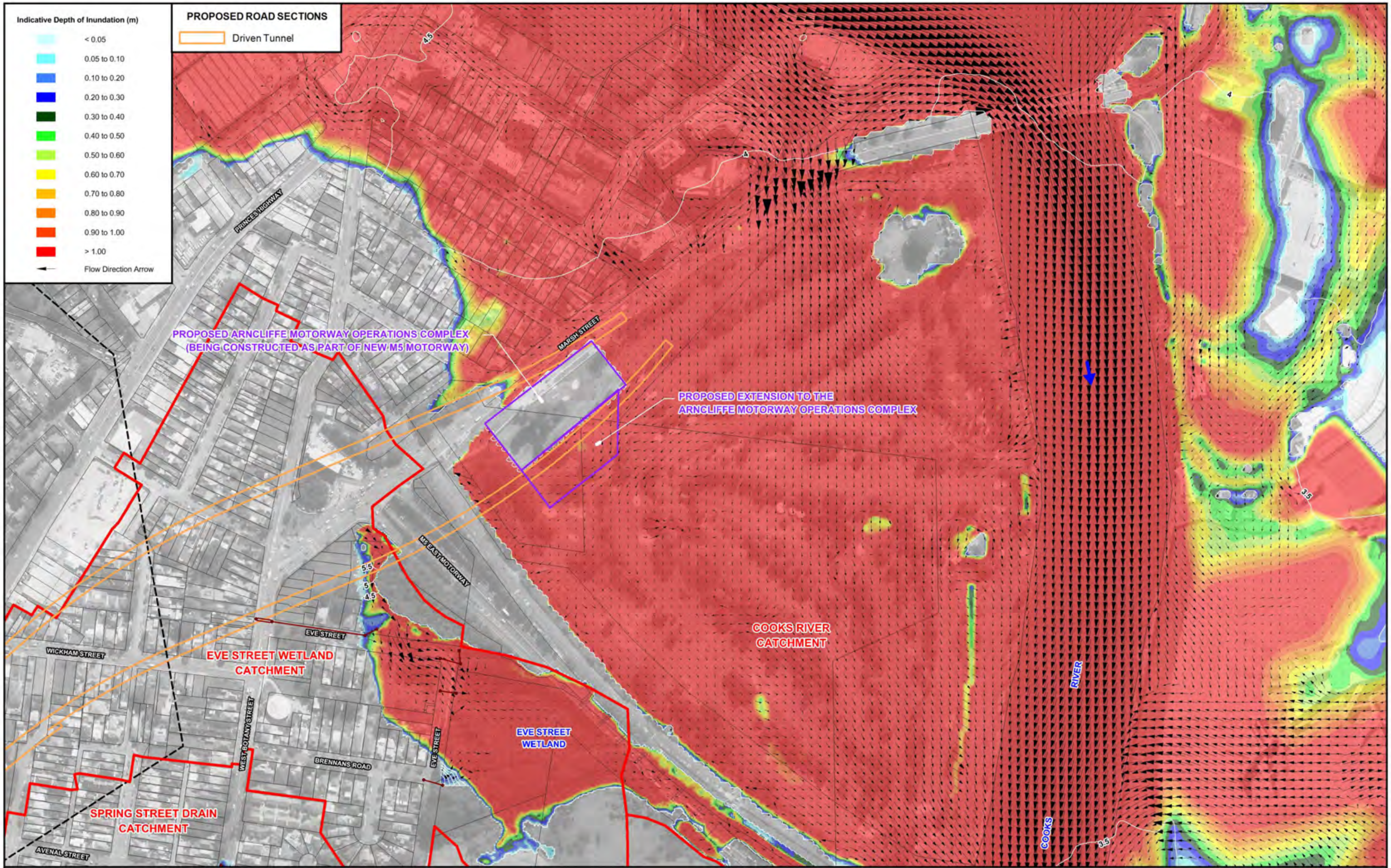
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-5
Sheet 1 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRESENT DAY CONDITIONS - PMF



40 0 40 80 120 m

Scale: 1:4,000

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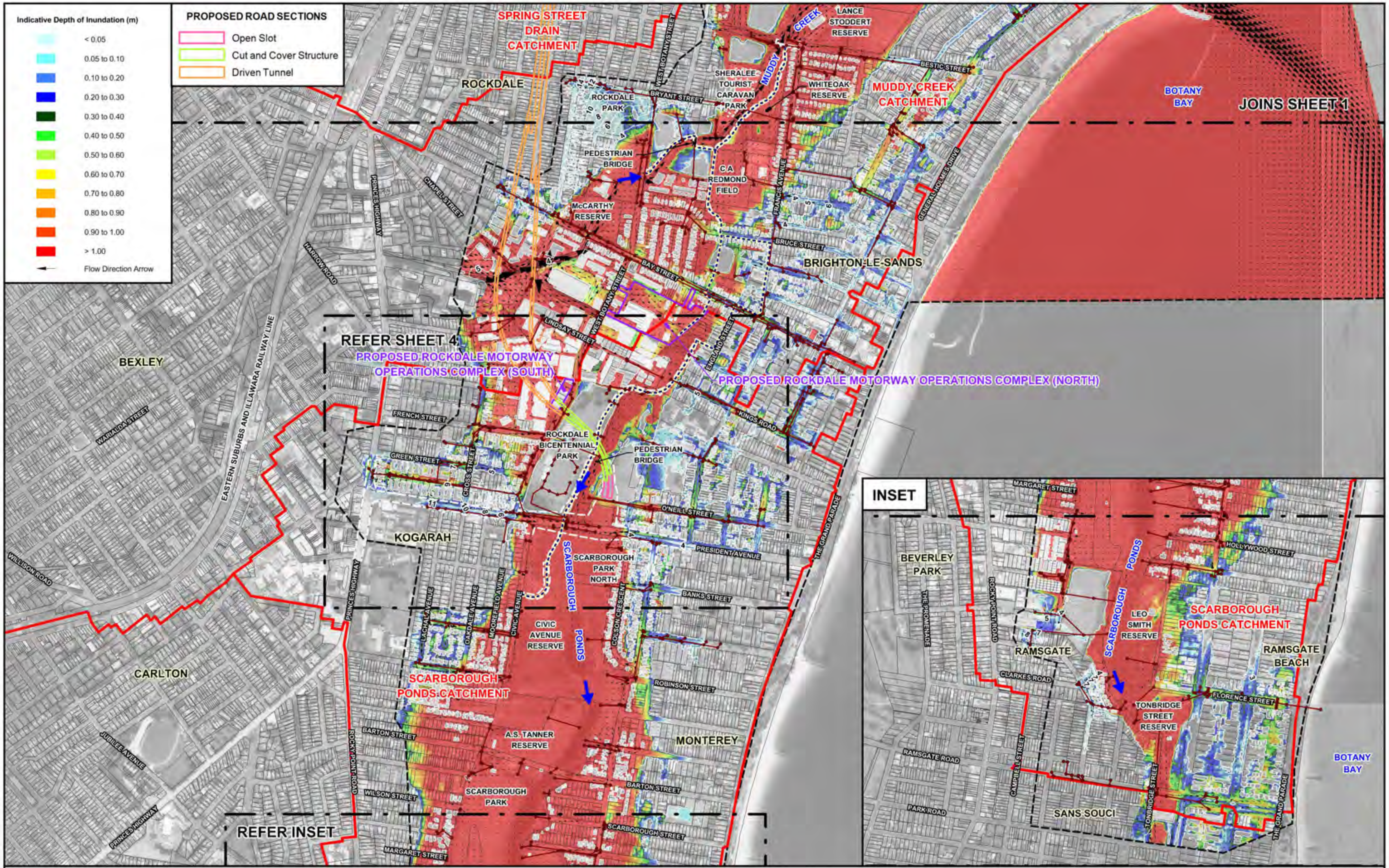
LEGEND

- Proposed Cycle and Pedestrian Pathways
- Project Boundary of Proposed Surface Works
- Extent of Proposed Tunnel Ancillary Facilities
- Water Surface Elevation Contours (m AHD)
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-5
Sheet 2 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRESENT DAY CONDITIONS - PMF



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LEGEND

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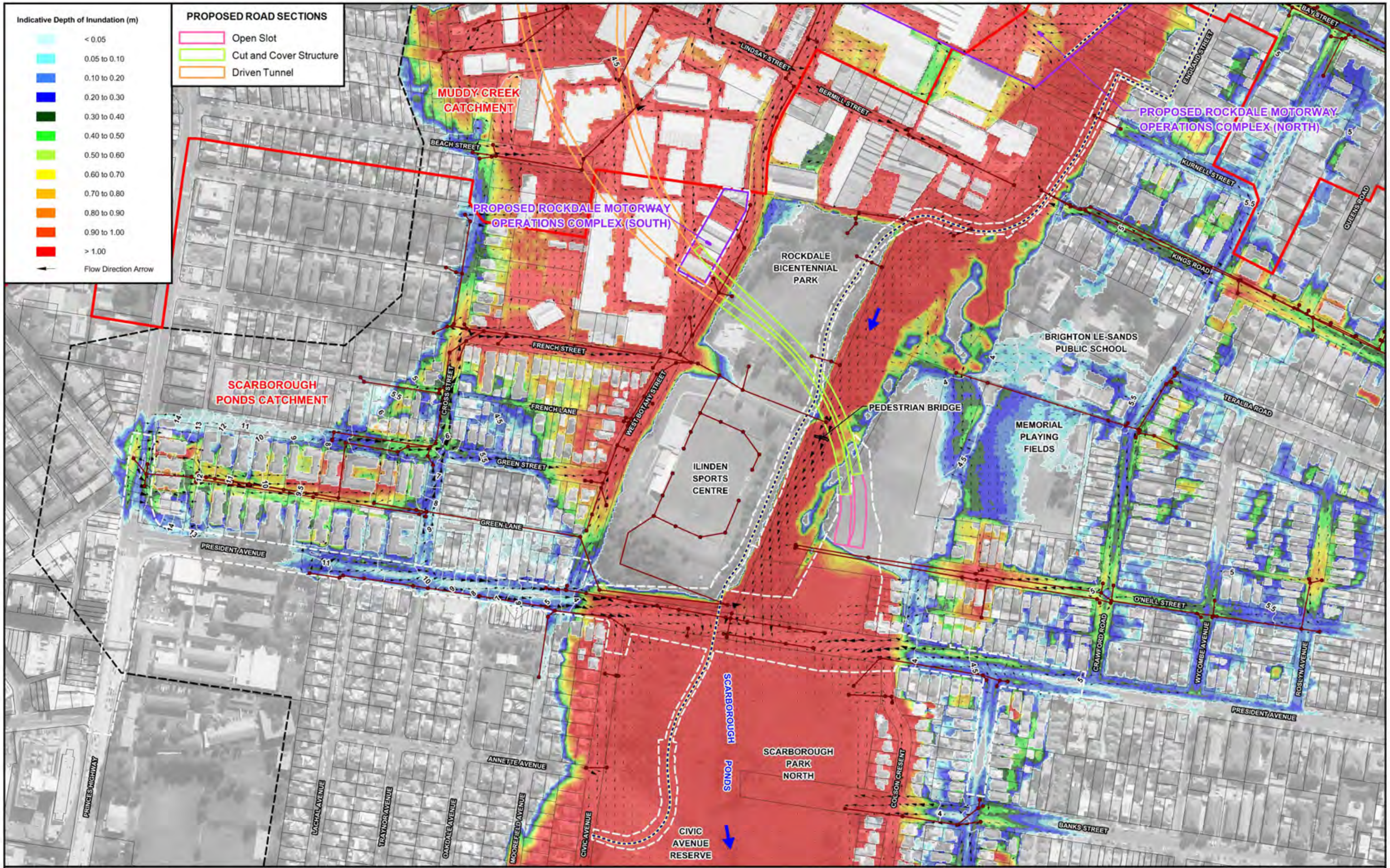
- Project Boundary of Proposed Surface Works
- Extent of Proposed Tunnel Ancillary Facilities
- Water Surface Elevation Contours (m AHD)
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-5
Sheet 3 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRESENT DAY CONDITIONS - PMF



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Scale: 1:4,000

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LEGEND

- Proposed Cycle and Pedestrian Pathways
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- Two-Dimensional Model Boundary
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 4-5
Sheet 4 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRESENT DAY CONDITIONS - PMF

5 Assessment of construction impacts

This chapter provides an assessment of the flood risk at the following six proposed construction ancillary facilities:

- Arncliffe construction ancillary facility (C1)
- Rockdale construction ancillary facility (C2)
- President Avenue construction ancillary facility (C3)
- Shared cycle and pedestrian pathways construction ancillary facilities (C4 and C5)
- Princes Highway construction ancillary facility (C6).

This chapter also provides an assessment of the flood risk at the following four additional areas of construction that are identified in section 7.3.6 of Chapter 7 (Construction) of the EIS (labelled construction area (CA) 1 to 4 in this report for ease of reference):

- Bestic Street to Bruce Street shared cycle and pedestrian pathway (CA1)
- England Street to Kings Road shared cycle and pedestrian pathway (CA2)
- President Avenue to Civic Avenue shared cycle and pedestrian pathway (CA3)
- Princes Highway and President Avenue intersection upgrade (CA4).

This chapter also provides an overview of the potential impacts that the proposed construction activities could have on flood behaviour.

A range of potential measures aimed at managing the flood risk and mitigating the impact of construction activities on flood behaviour are discussed in **section 8.2**.

An assessment of flood related impacts associated with the construction of the proposed permanent power supply connection from the Ausgrid Canterbury subtransmission substation to Rockdale Motorway Operations Complex south is provided in Chapter 18 of the EIS.

5.1 Potential flood risks at construction sites

Without the implementation of appropriate management measures, the inundation of the construction sites by floodwater has the potential to:

- cause damage to the project works and delays in construction programming
- pose a safety risk to construction workers
- detrimentally impact the downstream waterways through the transport of sediments and construction materials by floodwaters
- obstruct the passage of floodwater and overland flow through the provision of temporary measures such as site sheds, stockpiles, noise walls and flood protection walls, which in turn could exacerbate flooding conditions in existing development located outside the construction footprint.

Table 5-1 provides a summary of the proposed activities, as well as the assessed flood risk at each construction site, while **Figure 5-1** (4 sheets) shows the extent to which floods of varying magnitude affect each construction site. Further details of each construction site and its associated facilities and activities are provided in Chapter 7 (Construction work) of the EIS.

5.1.1 Construction site facilities

A range of site facilities including offices, staff amenities, workshops and parking are proposed at all six construction ancillary facilities (sites C1 to C6). Sites C1 and C2 would also include temporary substations to provide power to the site.

The proposed locations for all six construction ancillary facilities are affected by mainstream flooding and/or overland flow to varying degrees (refer **Table 5-1**). The Arncliffe construction ancillary facility (C1) would be inundated by floodwater during a 20% AEP storm, while there is also the potential for the site to be inundated by local catchment runoff that discharges from the Arncliffe motorway operations complex (being constructed as part of the New M5 Motorway). The Rockdale construction ancillary facility (C2) would be inundated during a 1% AEP storm due to overland flow that surcharges the drainage system in West Botany Street. Within the President Avenue construction ancillary facility (C3), land on the corner of President Avenue and O'Neill Street that has been identified as a potential location for site facilities is generally located above the 5% AEP flood. Shared cycle and pedestrian pathways construction ancillary facility east (C4) would be impacted by overland flow that surcharges Frances Street during storms in excess of 5% AEP in intensity, Shared cycle and pedestrian pathways construction ancillary facility west (C5) would be impacted by floodwaters that surcharge the main channel of Muddy Creek during storms as frequent as 1 EY.

Site facilities located on the floodplain, particularly in areas of high hazard, pose a safety risk to construction personnel. It would therefore be necessary to locate site facilities outside high hazard areas with safe evacuation routes. Construction sites C1, C2 and C3 all include land that is located outside areas of high hazard that would be suitable for site facilities.

5.1.2 Spoil management and stockpile areas

The construction of the project would generate a significant amount of spoil which would need to be temporarily stored in stockpile areas. Stockpiles located on the floodplain have the potential to obstruct floodwater and alter flooding patterns. Inundation of stockpile areas by floodwater can also lead to significant quantities of material being washed into the receiving drainage lines and waterways.

Stockpiling of spoil material is proposed at construction sites C1, C2, C3, C4 and C5. While all of these sites are affected by flooding to varying degrees (refer **Table 5-1**), there would typically be suitable areas outside the 5% AEP flood extent that could be used to stockpile material.

5.1.3 Tunnel excavation

Tunnel excavation would likely be carried out using road headers that would be launched from the Arncliffe construction ancillary facility (C1) and the Rockdale construction ancillary facility (C2). A description of the likely tunnel excavation process is provided in **Chapter 7** (Construction) of the EIS. The operation of the road headers would involve the use of pumps at the tunnel low points, and potentially mobile sumps at the cutting face to collect tunnelling water, groundwater ingress and stormwater runoff from the tunnel openings. Both sites would include a temporary water treatment plant to treat water that is collected in the tunnel during construction.

While the tunnel excavation arrangement would be designed to accommodate a nominal amount of stormwater runoff, the potential for the ingress of floodwater to the tunnel excavations during their construction poses a significant risk to personal safety. It also has the potential to cause damage to machinery and delays in the project timetable if not adequately managed.

The flood standard adopted at each tunnel opening during construction would need to be developed during detailed design, taking into consideration the duration of construction, the magnitude of potential inflows and the potential risks to the project works and personnel. Protection of the tunnel entries during construction through the provision of physical barriers, for example, would also need to be designed so as not to exacerbate flood behaviour in adjacent development. **Section 5.2** provides an assessment of the potential impacts of the proposed tunnel construction on existing flood behaviour, while **section 8.2** sets out measures which could be implemented to mitigate the impact of tunnelling activities on flood behaviour.

5.1.4 Construction of cut-and-cover structures

The construction of cut and cover structures would be carried out at the Rockdale construction ancillary facility (C2) and the President Avenue construction ancillary facility (C3). At the President Avenue construction ancillary facility (C3), the construction would involve the installation of stabilisation and excavation support (such as sheet pile or diaphragm walls), open excavation, installation of the tunnel structure and filling to finished ground level. Cut and cover construction methods would also be used for the initial length of the construction decline tunnel at the Rockdale construction ancillary facility (C2). Similar to the construction of the driven tunnels, the potential for ingress of floodwater into the open excavations poses a significant risk to personal safety, as well as having the potential to cause damage to machinery and delays to the project timetable. Barriers would therefore need to be provided to prevent overland flow from entering the open excavations at the Rockdale construction ancillary facility (C2) and the President Avenue construction ancillary facility (C3).

The eastern portion of the cut and cover structure at the President Avenue construction ancillary facility (C3) would cross the reach of Scarborough Ponds to the north of President Avenue and would need to be staged in order to temporarily divert the existing watercourse around the work area during its construction. The western portion of the structure would cross West Botany Street, which would also require the temporary diversion of the road and its associated drainage system around the work area.

Section 5.2 provides an assessment of the potential impacts of the proposed construction of the cut and cover structures on existing flood behaviour, while **section 8.2** sets out measures which could be implemented to mitigate the impact of tunnelling activities on flood behaviour.

5.1.5 Surface earthworks

The main area of surface earthworks for the project would be the construction of the proposed intersection at President Avenue and the associated widening and raising of the existing road (President Avenue construction ancillary facility (C3)). Surface earthworks would also be required to construct the sections of shared cycle and pedestrian pathways that are not located on elevated structures (construction sites C3, C4, C5, CA1, CA2 and CA3); for the widening of the Princes Highway and the western end of President Avenue as part of the intersection upgrade (construction site CA4); and for the building pads, access roads and carparks as part of the permanent works within the Rockdale motorway operations complexes (Rockdale construction ancillary facility (C2) and President Avenue construction ancillary facility (C3)).

Figure 5-1 (4 sheets) shows that the sections of President Avenue and the Princes Highway where surface earthworks are proposed (construction sites C3 and CA2) are inundated by floodwater during events as frequent as 1 EY. Sections of the shared cycle and pedestrian pathways (construction sites C3, CA1, CA2 and CA3) would also be inundated by floodwater during a 1 EY storm, while surface earthworks associated with the construction of permanent works at the Rockdale construction ancillary facility (C2) and the President Avenue construction ancillary facility (C3) would be inundated during a 1% and 5% AEP storm, respectively.

The inundation of the surface earthworks by floodwater has the potential to cause scour of disturbed surfaces and the transport of sediment and construction materials into the receiving waterways. It would therefore be necessary to plan, implement and maintain measures which are aimed at managing the diversion of floodwater either through or around the construction areas (refer **section 8.2** for further details).

5.1.6 Bridge construction

An elevated bridge structure would be constructed over President Avenue and a section of Scarborough Park North to accommodate the proposed shared pedestrian and cyclist pathways. Based on the concept design, the bridge would consist of a series of precast steel and concrete girders with spans of between 15 metres and 45 metres, which would be supported by piers of between 0.9 metres and 1.2 metres in diameter.

In order to construct the bridge structure it will be necessary to provide a temporary access road, as well as a series of working pads within Scarborough Park North in an area that is inundated by floodwater that surcharges Scarborough Ponds during storms as frequent as 1 EY. The inundation of the access road and working pads by floodwater has the potential to cause the transport of sediment and construction materials into the receiving waterways, as well as damage to machinery and delays to the project timetable. Conversely, raising the access road and working pads to reduce the potential for flooding to the work areas has the potential to displace floodwater and therefore exacerbate flood behaviour in adjacent development. An assessment was therefore carried out to assess the impact of the bridge construction on existing flood behaviour, whereby the access road and working pads were raised by 0.6 m above natural surface levels to improve its level of flood immunity to 2 EY. Further details of this assessment are provided in **section 5.2**.

5.2 Potential impacts of construction activities on flood behaviour

Construction activities have the potential to exacerbate flooding conditions when compared to both present day and operational conditions. This is because the construction activities typically impose a larger footprint on the floodplain due to the need to provide temporary structures outside the operational project footprint which would be removed following the completion of construction activities.

A preliminary investigation was undertaken to assess the potential impacts of construction activities on flood behaviour, which involved adjustment of the structure of the TUFLOW models to reflect the potential blocking effects of construction activities (refer **Annexure C** for further details of the development of the TUFLOW models).

The key findings of the assessment are summarised in **Table 5-2**, while **Figures 5-2** and **5-3** (5 sheets each) show flooding patterns and the afflux which could be caused by the proposed construction activities during a 1% AEP design storm.

While all nine construction sites will involve works within the floodplain that will need to be managed, the preliminary investigation found that the greatest potential for adverse impacts on flood behaviour in adjacent development is associated with construction sites C1, C2, C3 and CA3. There is also the potential for all construction ancillary facilities and construction areas to impact local catchment runoff, which would require appropriate local stormwater management controls to be implemented during the construction phase of the project.

While the findings of the initial assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would need to be undertaken during detailed design, as layouts and staging diagrams are further developed. Consideration would also need to be given to setting an appropriate hydrologic standard for mitigating the impacts of construction activities on flood behaviour, taking into account their temporary nature and therefore the likelihood of a flood of a given AEP occurring during the construction period.

While the assessment of the potential impact construction activities could have on flood behaviour represents a likely worst case scenario, it is recognised that measures will be implemented as part of the construction of the project which are aimed at reducing such impacts.

Prior to construction, a Flood Management Strategy will be prepared that sets out measures which are aimed at mitigating the impacts of construction activities on flood behaviour. Further details on the requirements of the Flood Management Strategy, as well as a range of measures which will be implemented to mitigate the potential construction related impacts of the project are outlined in **section 8.2**.

Table 5-1 Summary of assessed flood risk at proposed construction sites

Location	Threshold of flooding(1)	Proposed construction activities(2)						Description of existing flood behaviour (pre-mitigation)
		Site facilities (3)	Spoil management (4)	Tunnel launch and support	Cut-and-cover structures	Surface earthworks	Bridge structures	
Arncliffe tunnel site construction ancillary facility (C1)	20% AEP	✓	✓	✓		✓		• Refer Figure 5-1, sheet 1. • Floodwaters would surcharge Marsh Street and discharge in a southerly direction through the site and the adjacent section of the Kogarah Golf Course during a 20% AEP storm. • Should a 1% AEP event occur during the construction phase of the project, then floodwater would inundate the eastern third of the site and reach a maximum depth of over 1 m. • Runoff from the Arncliffe motorway operations complex that is being constructed as part of the New M5 Motorway project discharges into the northern end of the site.
Rockdale construction ancillary facility (C2)	5% to 1% AEP	✓	✓	✓	✓	✓		• Refer Figure 5-1, sheet 3. • The western portion of the site would be inundated by overland flow that surcharges the low point in West Botany Street adjacent to Rockdale Plaza Drive during storms in excess of 5% AEP in intensity. • Should a 1% AEP event occur during the construction phase of the project, then overland flow from West Botany Street would inundate the western portion of the site to a maximum depth of 0.7 m. An area within the eastern portion of the site would also be inundated by floodwater that originates from the upper reach of Scarborough Ponds, albeit to relatively shallow depths of 0.25 m or less.

Location	Threshold of flooding[1]	Proposed construction activities[2]						Description of existing flood behaviour (pre-mitigation)
		Site facilities [3]	Spoil management [4]	Tunnel launch and support	Cut-and-cover structures	Surface earthworks	Bridge structures	
President Avenue construction ancillary facility (C3)	< 20% AEP	✓	✓	✓	✓	✓	✓	• Refer Figure 5-1, sheet 4. • Site facilities are proposed to be located on the corner of President Avenue and O'Neill Street on land that is generally located above the 5% AEP flood. • Spoil management, including the treatment of acid sulphate soils, is proposed to be carried out on land to the north of President Avenue that lies above the 1% AEP flood. • The proposed alignment of the cut and cover structure crosses Scarborough Ponds at the location of an existing pedestrian bridge. Floodwaters discharge in a southerly direction where it is conveyed across President Avenue about 260 m to the south of the pedestrian bridge via a 1800 mm wide by 900 mm high box culvert. A weir that is located at the inlet to the box culvert controls water levels in Scarborough Ponds. • The western portion of the cut and cover structure crosses a section of West Botany Street that operates as an overland flow path during storms which surcharge the local stormwater drainage system. • While flow in Scarborough Ponds is largely confined to its main channel for storms up to 1% AEP in intensity, flow surcharges the box culvert at President Avenue and discharges across the road during storms more frequent than 20% AEP. Should a 1% AEP event occur during the construction phase of the project, then flow that

Location	Threshold of flooding(1)	Proposed construction activities(2)						Description of existing flood behaviour (pre-mitigation)
		Site facilities (3)	Spoil management (4)	Tunnel launch and support	Cut-and-cover structures	Surface earthworks	Bridge structures	
								surcharges the box culvert would inundate a 260 m length of President Avenue to a maximum depth of around 0.8 m. • The sections of President Avenue to the east and west of Scarborough Ponds also operate as overland flow paths during storms which surcharge the local stormwater drainage system.
Shared cycle and pedestrian pathways construction ancillary facility east (C4)	5% to 1% AEP	✓	✓			✓		• Refer Figure 5-1, sheet 3. • The northern portion of the site would be inundated by overland flow that surcharges the stormwater drainage system in Frances Street adjacent to Bruce Street during storms in excess of 5% AEP in intensity. • Should a 1% AEP event occur during the construction phase of the project, then overland flow from Frances Street would inundate the northern portion of the site, albeit to relatively shallow depths of 0.2 m or less.

Location	Threshold of flooding(1)	Proposed construction activities(2)						Description of existing flood behaviour (pre-mitigation)
		Site facilities (3)	Spoil management (4)	Tunnel launch and support	Cut-and-cover structures	Surface earthworks	Bridge structures	
Shared cycle and pedestrian pathways construction ancillary facility west (C5)	1 EY	✓	✓			✓		• Refer Figure 5-1, sheet 3. • The southwestern portion of the site is impacted by floodwaters that surcharge the main channel of Muddy Creek during storms as frequent as 1 EY. • Should a 1% AEP event occur during the construction phase of the project, then floodwaters that surcharge the main channel of Muddy Creek would inundate the southwestern portion of the site to a maximum depth of over 1 m. An area within the western portion of the site would also be inundated by overland flow that surcharges the stormwater drainage system in West Botany Street, albeit to relatively shallow depths of 0.2 m or less.
Princes Highway construction ancillary facility (C6)	1 EY	✓						• Refer Figure 5-1, sheet 4. • The northern portion of the site would be inundated by overland flow that surcharges the low point in the Princes Highway during storms as frequent as 1 EY. • Should a 1% AEP event occur during the construction phase of the project, then overland flow from the Princes Highway would inundate the northern portion of the site, albeit to relatively shallow depths of 0.15 m or less...

Location	Threshold of flooding[1]	Proposed construction activities[2]						Description of existing flood behaviour (pre-mitigation)
		Site facilities [3]	Spoil management [4]	Tunnel launch and support	Cut-and-cover structures	Surface earthworks	Bridge structures	
Bestic Street to Bruce Street (CA1)	1 EY					✓		• Refer Figure 5-1, sheet 3. • An area of the proposed shared pedestrian and cycle pathways between Bestic Street and Bruce Street is inundated by floodwater over a total length of around 370 m during a 1 EY event, increasing to 440 m during a 1% AEP event. Inundation of this section of the shared pedestrian and cycle pathways is predominantly caused by floodwater that surcharges the main channel of Muddy Creek.
England Street to Kings Road (CA2)	1 EY					✓		• Refer Figure 5-1, sheet 4. • An area of the proposed shared pedestrian and cycle pathways that crosses the upper reach of Scarborough Ponds to the north of Rockdale Bicentennial Park is inundated by floodwater over a length of about 180 m during a 1 EY event, increasing to about 420 m during a 1% AEP event.
President Avenue to Civic Avenue (CA3)	1 EY					✓	✓	• Refer Figure 5-1, sheet 4. • The section of the shared pedestrian and cycle pathways is inundated by floodwater that surcharges the main arm of Scarborough Ponds during storms as frequent as 1 EY.

Location	Threshold of flooding[1]	Proposed construction activities[2]						Description of existing flood behaviour (pre-mitigation)
		Site facilities [3]	Spoil management [4]	Tunnel launch and support	Cut-and-cover structures	Surface earthworks	Bridge structures	
Princes Highway and President Avenue intersection upgrade (CA4)	1 EY					✓		• Refer Figure 5-1, sheet 4. • The section of President Avenue between Lachal Avenue and Scarborough Ponds operates as an overland flow path, conveying flow that surcharges the stormwater drainage system during storms as frequent as 1 EY. • The area of proposed road works along the Princes Highway is impacted by flow in excess of the capacity of the stormwater drainage system that collects at the low point in the road to the north of President Avenue and surcharges through the adjoining properties to the east and along Green Lane during storms as frequent as 1 EY.

Notes:
1 The assessed threshold of flooding is based on present day conditions. Refer **Figure 5-1** for flood extent mapping under present day conditions.
2 Refer to **section 5.1** for a description of flood risks associated with each construction activity.
3 Site facilities include site offices, staff amenities, stores and laydown, workshops, temporary substations and parking.
4 Spoil management includes stockpiling and treatment of excavated material.

Table 5-2 Summary of assessed impacts of proposed construction activities on flood behaviour – 1% AEP flood event

Location	Preliminary peak flood level(1) (m AHD)	Preliminary assessment of construction activities	Potential impacts on flood behaviour
Arncliffe construction ancillary facility (C1)	1.8	• Construction site C1 would be located on land that is currently being used to as a construction ancillary facility for the New M5 Motorway. • The footprint of the facilities within construction site C1 was nominally raised above the 1% AEP flood level in the flood model in order to represent a complete obstruction to flow and thus represent a worse case of potential flood impacts due to obstructions caused by the site works (such as flood protection barriers around the decline opening), as well as acoustic sheds, site amenities, noise walls and hoarding along its perimeter. • Surface levels across the remainder of the site were estimated based on LIDAR survey that was flown in 2014 (i.e. prior to the commencement of construction for the New M5 Motorway project) and site observations. Surface levels across the construction site will need to be confirmed during detailed design.	• Figure 5-2, sheet 2 (left hand side) shows 1% AEP flooding patterns under construction phase conditions, while Figure 5-3, sheet 2 (left hand side) shows the afflux which could potentially be caused by the blocking effects of the construction site. • Should a 1% AEP event occur during the construction phase of the project, then peak flood levels in 16 residential and commercial properties and two lots currently being used for car parking to the north of Marsh Street could be increased by between 20 and 400 mm. Based on floor level survey contained in AJJV 2016, an additional two properties would experience above-floor inundation in comparison to pre-project conditions. • Subject to further hydraulic assessment during detailed design, additional floor level survey may be required to confirm the extent to which the proposed construction activities would increase above-floor inundation and flood damages in affected properties. While the scope of mitigation measures required would be subject to this further assessment during detailed design, possible measures to minimise flood impacts to properties that are already sensitive to flooding may include: – providing openings along the perimeter fencing to allow overland flow that surcharges Marsh Street to enter the site incorporating measures to manage overland flow internal to the site (for example a channel similar to that shown on Figure 5-2, sheet 2 (right hand side), bridge crossings over the decline opening or designating additional areas of access road and temporary car parking which could act as overland flow paths internal to the site) – designing the site surface grading to as far as practical balance cut and fill in areas located below the 1% AEP flood.

Location	Preliminary peak flood level[(1)] (m AHD)	Preliminary assessment of construction activities	Potential impacts on flood behaviour
Rockdale construction ancillary facility (C2)	2.8	• The footprint of the proposed facilities within construction site C2 was nominally raised above the 1% AEP flood level in the flood model in order to represent a complete obstruction to flow and thus represent a worse case of potential flood impacts due to obstructions caused by the site works (such as flood protection barriers around the decline opening), as well as acoustic sheds, site amenities, noise walls and hoarding along its perimeter.	• Figure 5-2, sheet 4 shows 1% AEP flooding patterns under construction conditions, while Figure 5-3, sheet 4 shows the afflux which could potentially be caused by the blocking effects of the construction site. • Should a 1% AEP event occur during the construction phase of the project, then peak flood levels in two residential properties in West Botany Street could be increased by a maximum of 120 mm. • Subject to further hydraulic assessment during detailed design, floor level survey may be required to confirm the extent to which the proposed construction activities would increase in above-floor inundation and flood damages in affected properties. Possible mitigation measures to minimise such increases may include: – designating additional areas of access road and car parking which could act as overland flow paths internal to the site – designing the site surface grading to as far as practical balance cut and fill in areas located below the 1% AEP flood – locating site buildings above the natural surface level on piers to minimise their impact on floodplain storage.
President Avenue construction ancillary facility (C3)	2.5	• The section of Scarborough Ponds that is crossed by the proposed cut and cover structure was blocked off and a 13 m wide channel incorporated into the flood model to reflect the temporary diversion of the watercourse, while the footprint for the construction of the cut and cover structure was raised above the 1% AEP flood to represent a complete obstruction to flow caused by temporary flood protection barriers around its perimeter. The modelled arrangement is shown on Figure 5-2, sheet 4. • Similarly, the section of West Botany Street that is crossed by the proposed cut and cover structure was blocked off and the road was realigned through the Rockdale Bicentennial Park to reflect its temporary diversion. The footprint for the construction of the cut and cover structure and the Rockdale motorway operations complex (south) was raised above the 1% AEP flood to represent a complete obstruction to flow caused by temporary flood protection barriers around its perimeter. The modelled	• Figure 5-2, sheet 5 shows 1% AEP flooding patterns under construction phase conditions, while Figure 5-3, sheet 5 shows the afflux which could potentially be caused by proposed construction activities within construction site C3 in combination with other construction activities that are proposed on the Scarborough Ponds floodplain. • Should a 1% AEP event occur during the temporary diversion of West Botany Street for the construction of the cut and cover structure, then peak flood levels in 12 residential properties and one industrial property could be increased by a maximum of 20 mm. • While there would be an increase in peak 1% AEP flood levels within the section of Scarborough Ponds to the north (upstream) of President Avenue by a maximum of 50 mm, impacts would be confined to the Rockdale Bicentennial Park reserve.

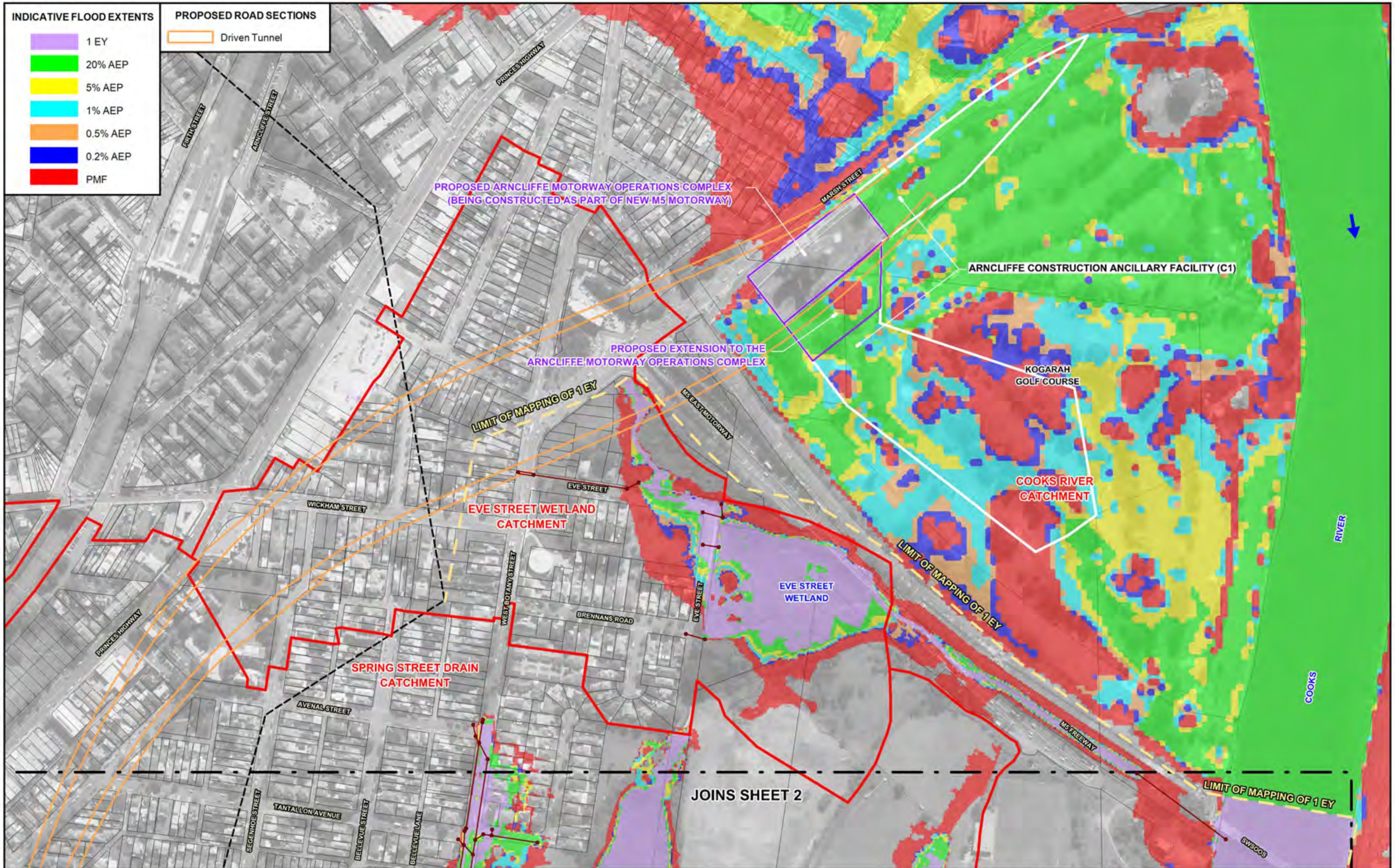
Location	Preliminary peak flood level(1) (m AHD)	Preliminary assessment of construction activities	Potential impacts on flood behaviour
		arrangement is shown on Figure 5-2, sheet 4. • The footprint of the proposed construction site facilities on the corner of President Avenue and O'Neill Street was nominally raised above the 1% AEP flood level in the flood model in order to represent a complete obstruction to flow, with the exception of a 15 m wide corridor to the east and west of O'Neill Street. This corridor, which was maintained to provide a path for overland flow that surcharges the low point in O'Neill Street, could be incorporated into areas designated for car parking. • The full extent of the raised fill embankment along President Avenue and at the President Avenue intersection was incorporated into the flood model in order to reflect the worst case scenario for construction staging. The proposed upgrade to the transverse drainage structure in President Avenue at Scarborough Ponds was also included on the basis that it would need to be installed prior to the construction of the raised roadway. • Similarly, the extent of fill embankment for the shared pedestrian and cycle pathways was also incorporated into the flood model in order to reflect the worst case scenario for construction staging. The proposed waterway crossings along Scarborough Ponds were also included on the basis that they would need to be installed prior to the construction of the raised sections of path.	• Two residential properties in President Avenue to the east of the new intersection could experience localised increases in peak 1% AEP flood levels within their front yards by a maximum of 20 mm as a result of construction of the proposed surface earthworks. • Subject to further hydraulic assessment during detailed design, floor level survey may be required to confirm whether the proposed construction activities, particularly the temporary diversion of West Botany Street for the construction of the cut and cover structure, would increase above-floor inundation and flood damages in the affected properties. Possible mitigation measures to minimise such impacts may include: – staging the construction of the cut and cover structure to minimise the extent of works within the floodplain at any one time – providing compensatory floodplain storage within the Rockdale Bicentennial Park to offset the displacement of floodwater caused by flood protection barriers around the cut and cover construction. • Refer to 'President Avenue to Civic Avenue pedestrian and cycle pathways (CA3)' for a description of the impact that construction site C3 in combination with other proposed construction activities within construction sites CA2, CA3 and CA4 would have on flood behaviour in the section of Scarborough Ponds to the south of President Avenue.
Shared cycle and pedestrian pathways construction ancillary facility east (C4)	Varies	• The footprint of construction site C4 was nominally raised above the 1% AEP flood level in the model in order to represent a complete obstruction to flow, with the exception of a 2 m wide corridor along the northern boundary of the site to provide a path for overland flow that surcharges Frances Street. Hoarding or perimeter fencing adjoining this corridor would need to be provided with gaps along their base to allow flow to enter the site. The modelled arrangement is shown on Figure 5-2, sheet 3.	• Figure 5-2, sheet 4 shows 1% AEP flooding patterns under construction phase conditions, while Figure 5-3, sheet 4 shows the afflux which could potentially be caused by the blocking effects of the construction site. • Figure 5-3, sheet 4 shows that with the provision of a 2 m wide corridor along the northern boundary of the construction site there would be negligible impact on existing flood behaviour.

Location	Preliminary peak flood level[1] (m AHD)	Preliminary assessment of construction activities	Potential impacts on flood behaviour
Shared cycle and pedestrian pathways construction ancillary facility west (C5)	2.6	• The footprint of construction site C5 was nominally raised above the 1% AEP flood level in the flood model in order to represent a complete obstruction to flow, with the exception of a 6 m wide corridor along the south-eastern boundary of the site adjoining the Muddy Creek channel Perimeter fencing adjoining this corridor would need to be of an open type that minimises the obstruction to flow that surcharges the main channel of Muddy Creek. The modelled arrangement is shown on Figure 5-2, sheet 3.	• Figure 5-2, sheet 4 shows 1% AEP flooding patterns under construction phase conditions, while Figure 5-3, sheet 4 shows the afflux which could potentially be caused by the blocking effects of the construction site. • Figure 5-3, sheet 4 shows that with the provision of a 6 m wide corridor along the south-eastern boundary of the construction site there would be negligible impact on existing flood behaviour.
Princes Highway construction ancillary facility (C6)	14.8	• The footprint of the proposed buildings within construction site C6 was nominally raised above the 1% AEP flood level in the flood model in order to represent a complete obstruction to flow and thus represent a worse case of potential flood impacts due to their obstruction.	• Figure 5-2, sheet 5 shows 1% AEP flooding patterns under construction conditions, while Figure 5-3, sheet 5 shows the afflux which could potentially be caused by the blocking effects of the construction site. • Figure 5-3, sheet 4 shows that the proposed construction site is expected to have a negligible impact on existing flood behaviour in its immediate vicinity.
Bestic Street to Bruce Street (CA1)	Varies	• Due to the level of design development for the proposed shared pedestrian and cycle pathways between Bestic Street and Bruce Street, a preliminary assessment of potential flood impacts has been carried out based on an understanding of flooding and drainage patterns under present day conditions and an initial review of the proposed alignment of the shared pedestrian and cycle pathways.	• As noted in Table 5-1, sections of the proposed alignment of the shared pedestrian and cycle pathways between Bestic Street and Bruce Street are inundated during a 1% AEP flood. Temporary works within these areas to facilitate the construction of the shared pedestrian and cycle pathways, such as fencing, safety barriers and formwork all have the potential to obstruct flow and impact on flood behaviour in adjacent properties. The construction of the shared pedestrian and cycle pathways would therefore need to be staged in a manner that manages the extent of temporary works within flood prone areas and/or includes procedures for their removal during times of flood.

Location	Preliminary peak flood level[1] (m AHD)	Preliminary assessment of construction activities	Potential impacts on flood behaviour
England Street to Kings Road (CA2)	Varies	• The extent of fill embankment for the shared cycle and pedestrian pathways between England Street and Kings Road was incorporated into the flood model in order to reflect the worst case scenario for the impact of construction staging on flood behaviour in Scarborough Ponds. The proposed waterway crossings along the fill embankment were also included on the basis that they would need to be installed prior to the construction of the raised sections of path.	• Figure 5-2, sheet 5 shows 1% AEP flooding patterns under construction phase conditions, while Figure 5-3, sheet 5 shows the afflux which could potentially be caused by the construction of the shared pedestrian and cycle pathways in combination with other construction activities that are proposed on the Scarborough Ponds floodplain. • Subject to the management of temporary works within flood prone land (such as fencing, safety barriers and formwork), then construction of the shared pedestrian and cycle pathways is expected to have only a minor impact on existing flood behaviour in its immediate vicinity. • Refer to 'President Avenue to Civic Avenue (CA3)' for a description of the impact that construction site CA2 in combination with other proposed construction activities within construction sites C3, CA3 and CA4 would have on flood behaviour in the section of Scarborough Ponds to the south of President Avenue.

Location	Preliminary peak flood level(1) (m AHD)	Preliminary assessment of construction activities	Potential impacts on flood behaviour
President Avenue to Civic Avenue CPP (CA3)	2.5	• The temporary access road and working pads that would support the construction of the bridge for the shared cycle and pedestrian pathways were incorporated into the flood model. For the purpose of this assessment it was assumed that the access road would be 10 m wide and the working pads at each pier would be 10 m wide by 10 m long. The footprint of the access road and working pads were nominally raised 0.6 m above the natural surface level, while 4 m wide waterway crossings were incorporated into the access road where its crosses two drainage lines that discharge into Scarborough Ponds from Civic Avenue. The modelled arrangement is shown on Figure 5-2, sheet 4. • The extent of fill embankment for the section of shared cycle and pedestrian path to the south of the proposed bridge was also incorporated into the flood model in order to reflect the worst case scenario for construction staging. The proposed waterway crossings along the fill embankment were also included on the basis that they would need to be installed prior to the construction of the raised sections of path.	• Figure 5-2, sheet 5 shows 1% AEP flooding patterns under construction phase conditions, while Figure 5-3, sheet 5 shows the afflux which could potentially be caused by the construction of the shared cycle and pedestrian pathways in combination with other construction activities that are proposed on the Scarborough Ponds floodplain. • Should a 1% AEP event occur during the construction phase of the project, then peak 1% AEP flood levels would be increased by 12 mm in the section of Scarborough Ponds to the south of President Avenue, as well as a significant number of properties that are located along the eastern and western sides of the open space corridor through which the watercourse runs. The increase in flood levels is due to the combined impact of proposed activities within construction sites C3, CA2, CA3 and CA4. These construction related impacts could be managed by: – staging the construction within each construction site to manage the extent of works within the Scarborough Ponds floodplain at any one time, and/or – implementing compensatory floodplain storage that is proposed along the eastern bank of Scarborough Ponds to the north of President Avenue as early in the construction phases as possible (refer to Chapter 6 for further details of the proposed compensatory floodplain storage). • Subject to further hydraulic assessment during detailed design, floor level survey may be required to confirm whether the construction of the bridge would increase above-floor inundation and flood damages in the affected properties. Possible mitigation measures to minimise such impacts may include: – staging the construction of the bridge in order to minimise the extent of access road and working pads on the floodplain at any one time – developing emergency response procedures that provide for the removal of temporary works on the floodplain during times of flood.

Location	Preliminary peak flood level[1] (m AHD)	Preliminary assessment of construction activities	Potential impacts on flood behaviour
Princes Highway and President Avenue intersection upgrade (CA4)	Varies	• The full extent of the proposed road widening along the Princes Highway and President Avenue was incorporated into the flood model in order to reflect the worst case scenario for construction staging. The proposed upgrade to the existing drainage line that runs from the low point in the Princes Highway in an easterly direction along Green Lane to West Botany Street was also included on the basis that these flood mitigation works would need to be installed prior to the proposed road widening. The modelled arrangement is shown on Figure 5-2, sheet 4.	• Figure 5-2, sheet 5 shows 1% AEP flooding patterns under construction phase conditions, while Figure 5-3, sheet 5 shows the afflux which could potentially be caused by the blocking effects of the construction of the Princes Highway and President Avenue intersection upgrade in combination with other construction activities that are proposed on the Scarborough Ponds floodplain. • The construction of the Princes Highway and President Avenue intersection upgrade is expected to have only a minor impact on existing flood behaviour in its immediate vicinity providing: – the upgrade of the existing drainage line that runs from the low point in the Princes Highway in an easterly direction along Green Lane to West Botany Street is installed prior to the proposed road widening – temporary works within flood prone land (such as fencing, safety barriers and formwork) is appropriately managed. • Refer to 'President Avenue to Civic Avenue CPP (CA3)' for a description of the impact that construction site CA4 in combination with other proposed works within construction sites C3, CA2 and CA3 would have on flood behaviour in the section of Scarborough Ponds to the south of President Avenue.



N

40 0 40 80 120 m

Scale: 1:4,000

Note:

The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

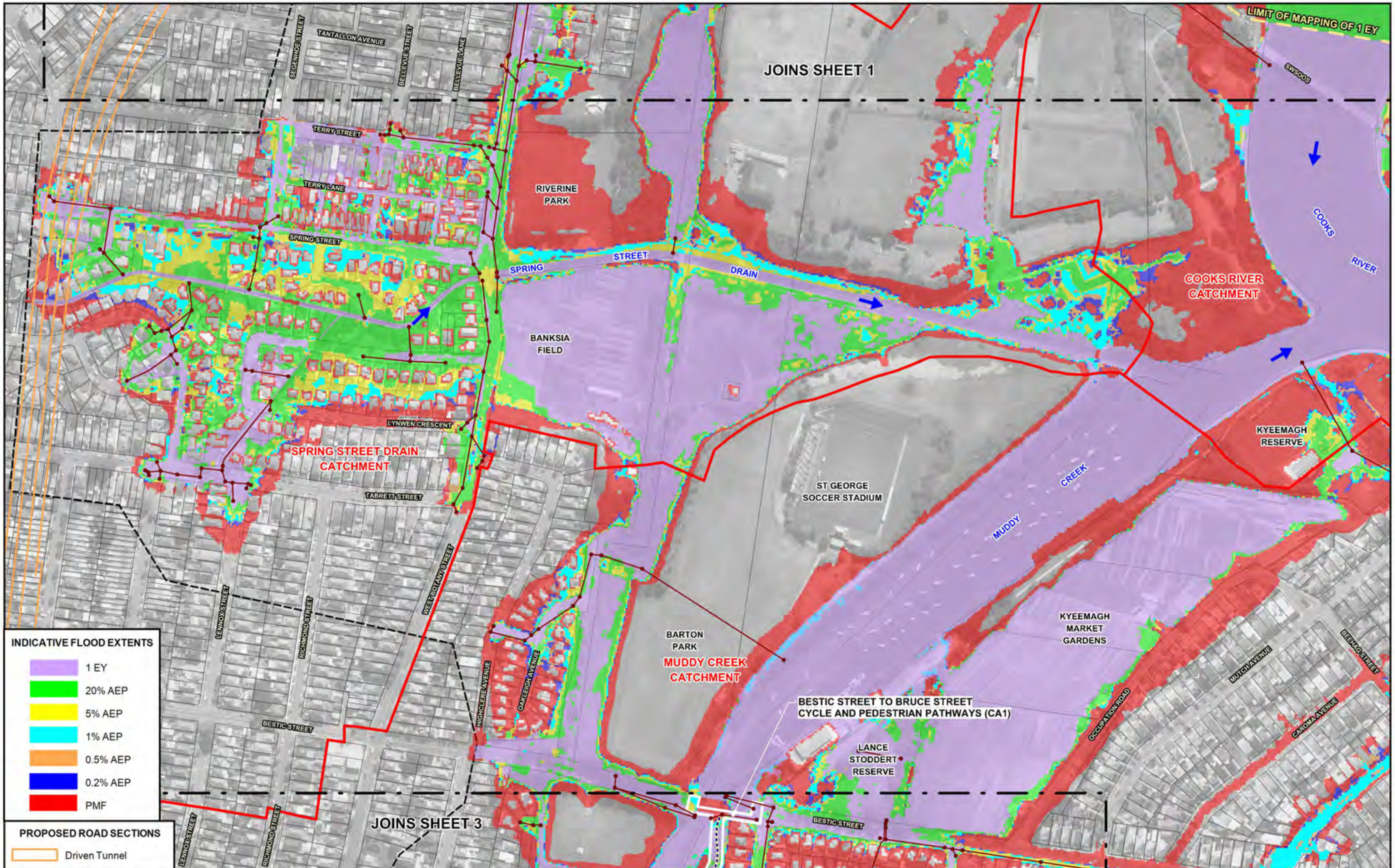
- Extent of Proposed Tunnel Ancillary Facilities
- Construciton Footprint
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

Lyall & Associates

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-1
Sheet 1 of 4

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SITES
PRESENT DAY CONDITIONS



N

40 0 40 80 120 m

Scale: 1:4,000

Note:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

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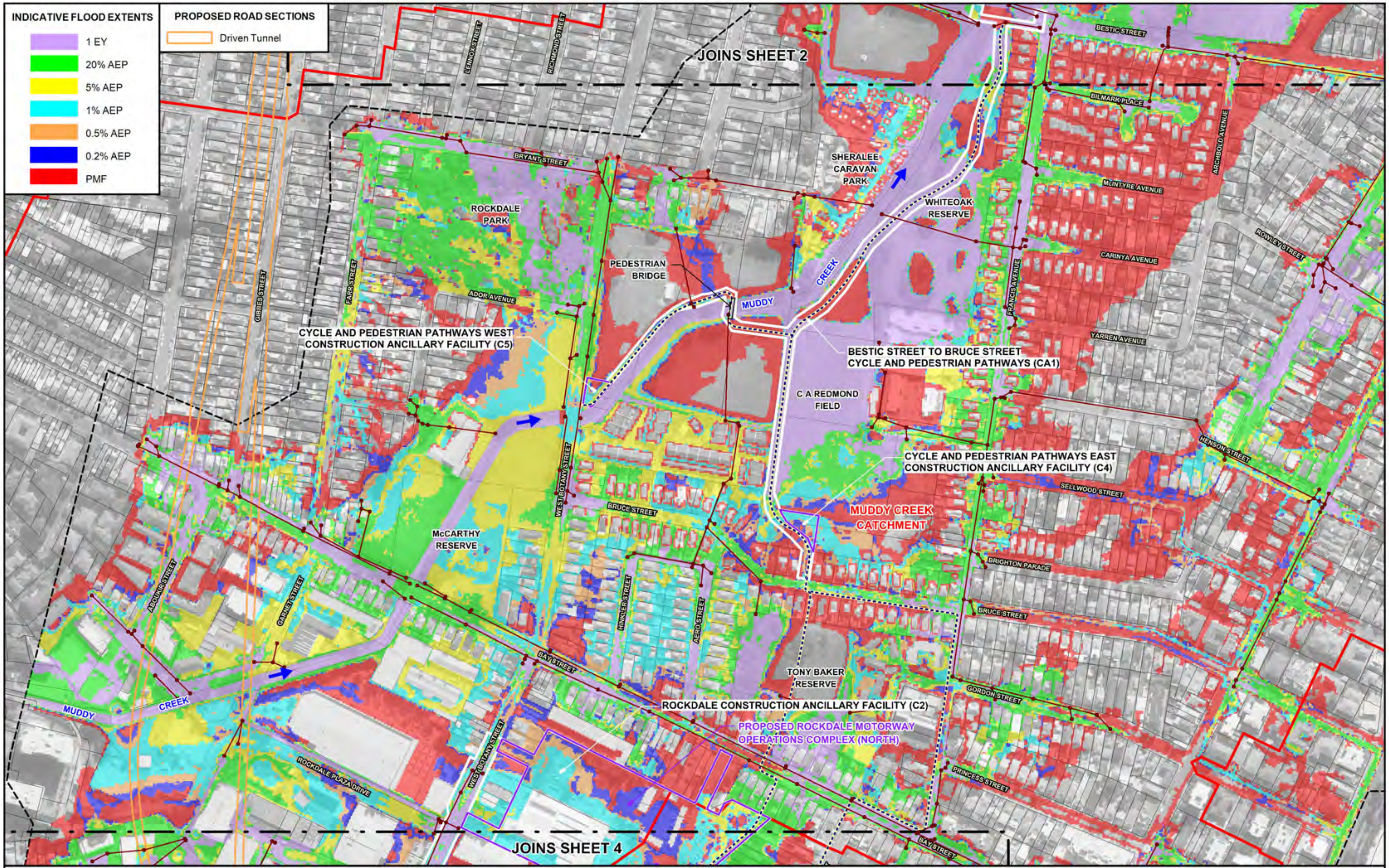
LEGEND

- Proposed Cycle and Pedestrian Pathways
- Construction Footprint
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-1
Sheet 2 of 4

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SITES
PRESENT DAY CONDITIONS



Note:
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Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

- Proposed Cycle and Pedestrian Pathways
- Construction Footprint
- Extent of Proposed Tunnel Ancillary Facilities
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

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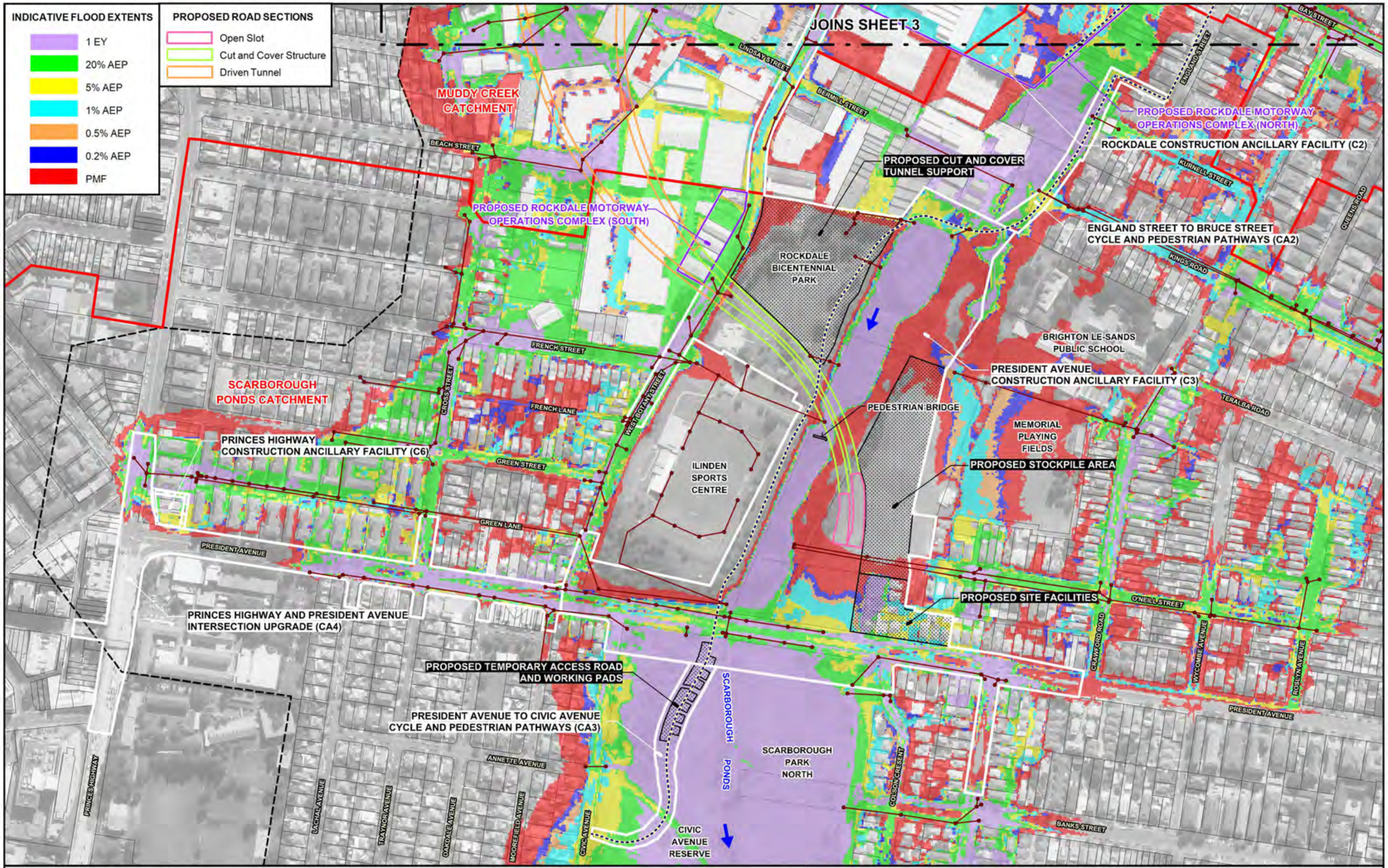
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-1
Sheet 3 of 4

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SITES
PRESENT DAY CONDITIONS



N

40 0 40 80 120 m

Scale: 1:4,000

Lyall & Associates

Note:

The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

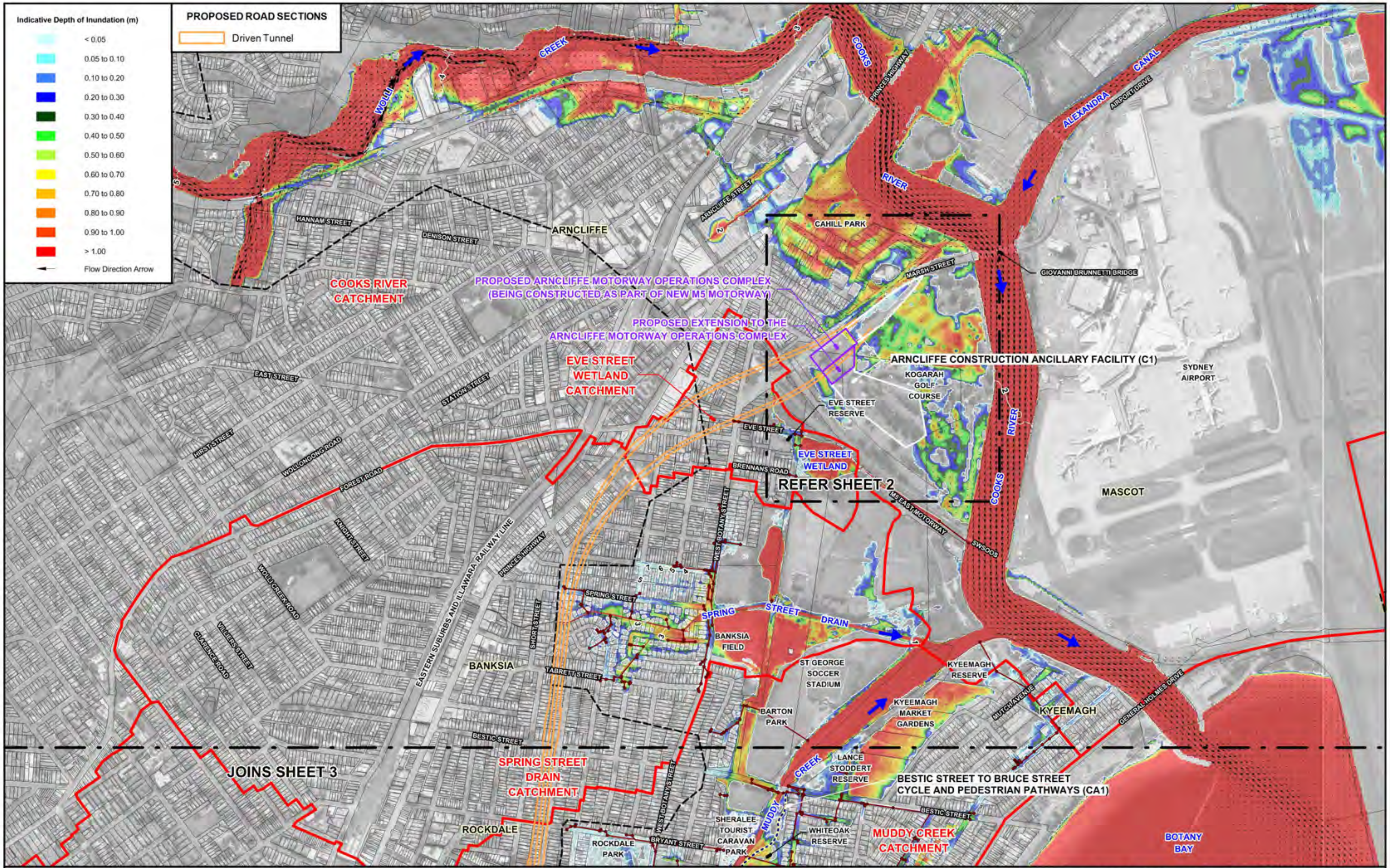
LEGEND

Proposed Cycle and Pedestrian Pathways	Existing Drainage System
Construction Footprint	Two-Dimensional Model Boundary
Extent of Proposed Tunnel Ancillary Facilities	Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-1
Sheet 4 of 4

INDICATIVE FLOOD EXTENTS IN VICINITY OF PROPOSED CONSTRUCTION SITES
PRESENT DAY CONDITIONS



N

120 0 120 240 360 m

Scale: 1:12,000

Lyall & Associates

Note:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

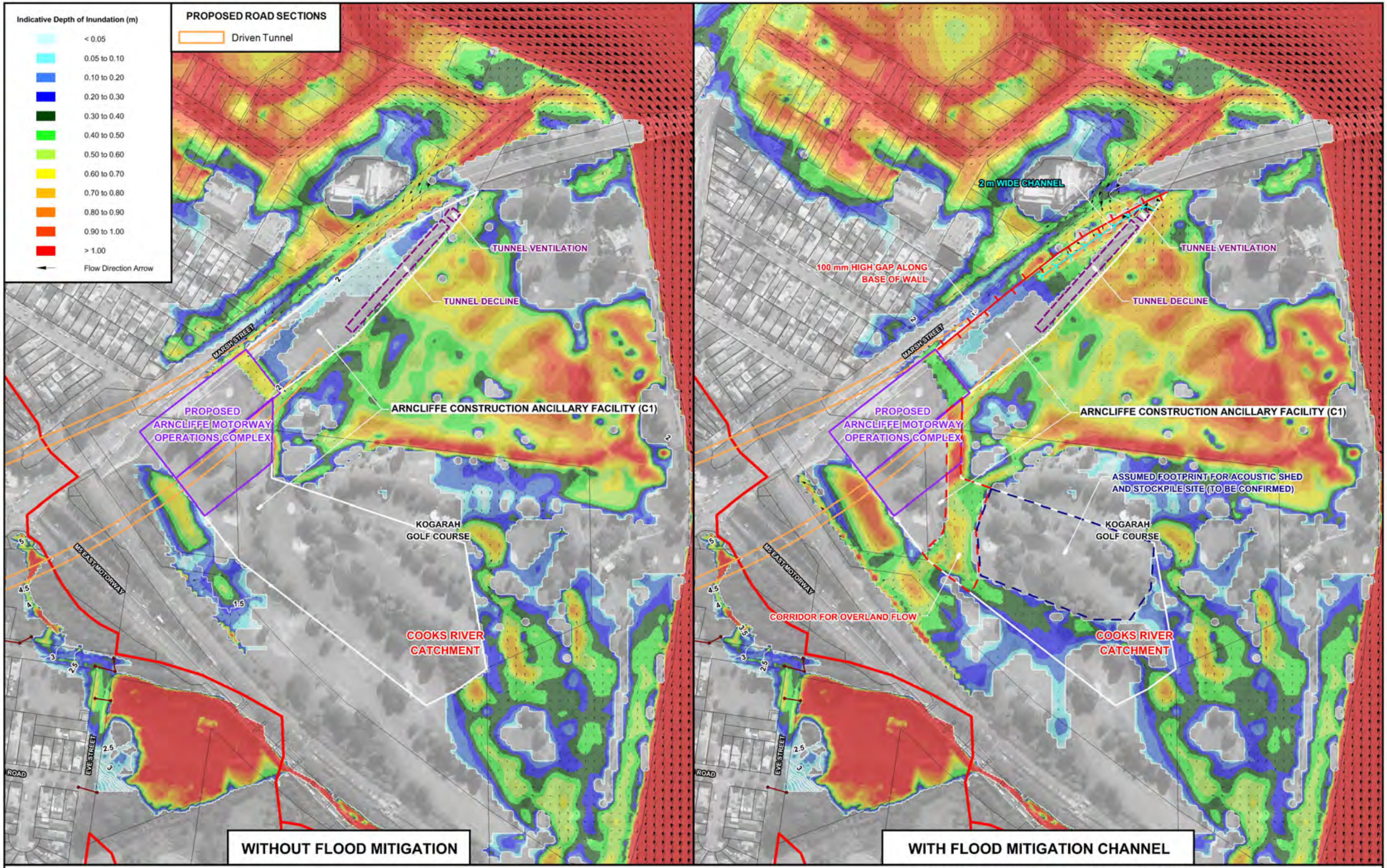
LEGEND

- Proposed Cycle and Pedestrian Pathways
- Construction Footprint
- Extent of Proposed Tunnel Ancillary Facilities
- Water Surface Elevation Contours (m AHD)
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-2
Sheet 1 of 5

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
CONSTRUCTION CONDITIONS - 1% AEP



N

40 0 40 80 120 m

Scale: 1:4,000

Note:

The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

- Proposed Cycle and Pedestrian Pathways
- Construction Footprint
- Extent of Proposed Tunnel Ancillary Facilities
- Water Surface Elevation Contours (m AHD)
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

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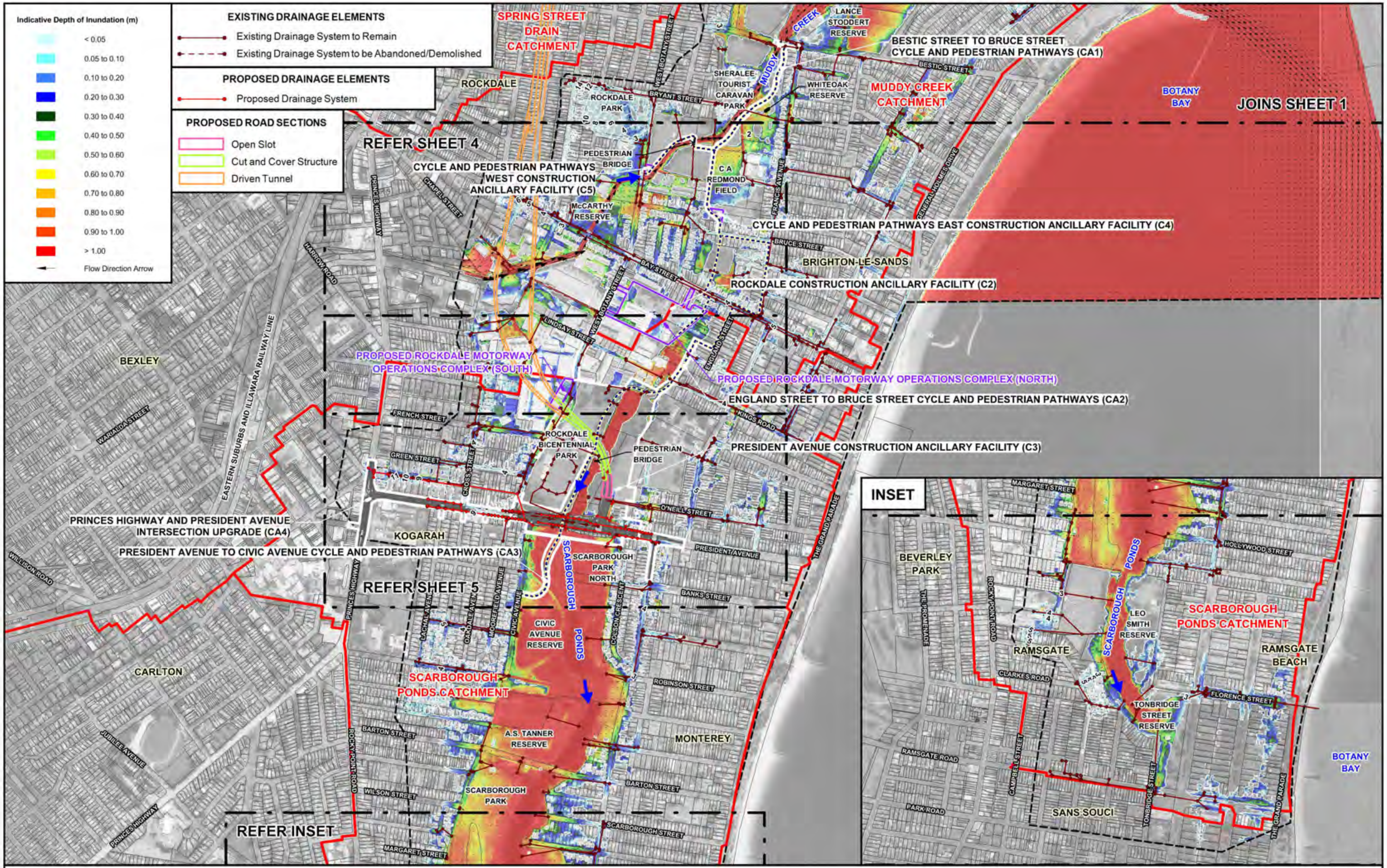
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-2
Sheet 2 of 5

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
CONSTRUCTION CONDITIONS - 1% AEP



N

120 0 120 240 360 m

Scale: 1:12,000

Note:

The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

- Proposed Surface Road Works
- Proposed Cycle and Pedestrian Pathways
- Construction Footprint
- Extent of Proposed Tunnel Ancillary Facilities
- Two-Dimensional Model Boundary
- Catchment Boundary
- Water Surface Elevation Contours (m AHD)

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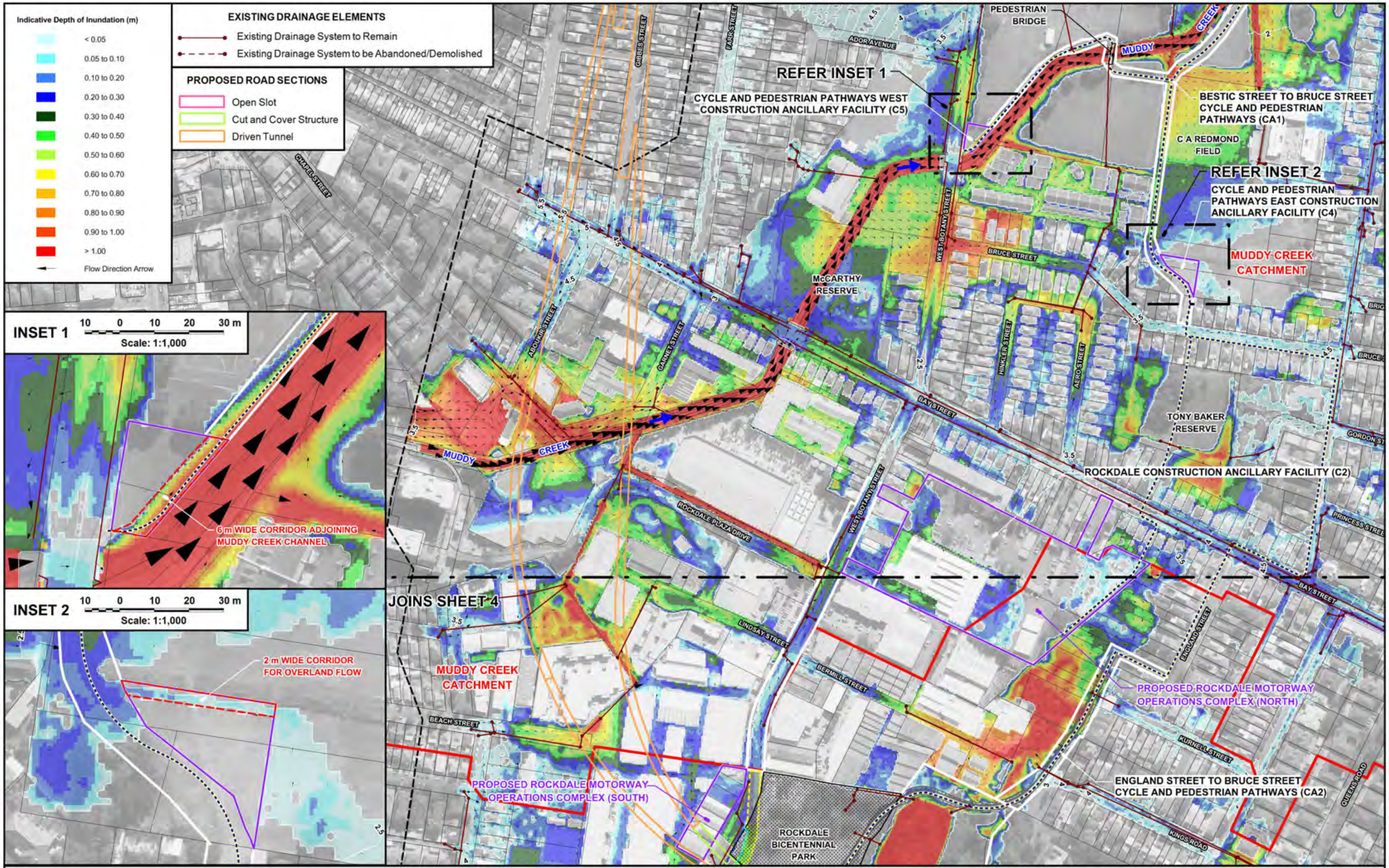
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-2
Sheet 3 of 5

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
CONSTRUCTION CONDITIONS - 1% AEP



Note:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

- Proposed Surface Road Works
- Proposed Cycle and Pedestrian Pathways
- Construction Footprint
- Extent of Proposed Tunnel Ancillary Facilities
- Two-Dimensional Model Boundary
- Catchment Boundary
- Water Surface Elevation Contours (m AHD)

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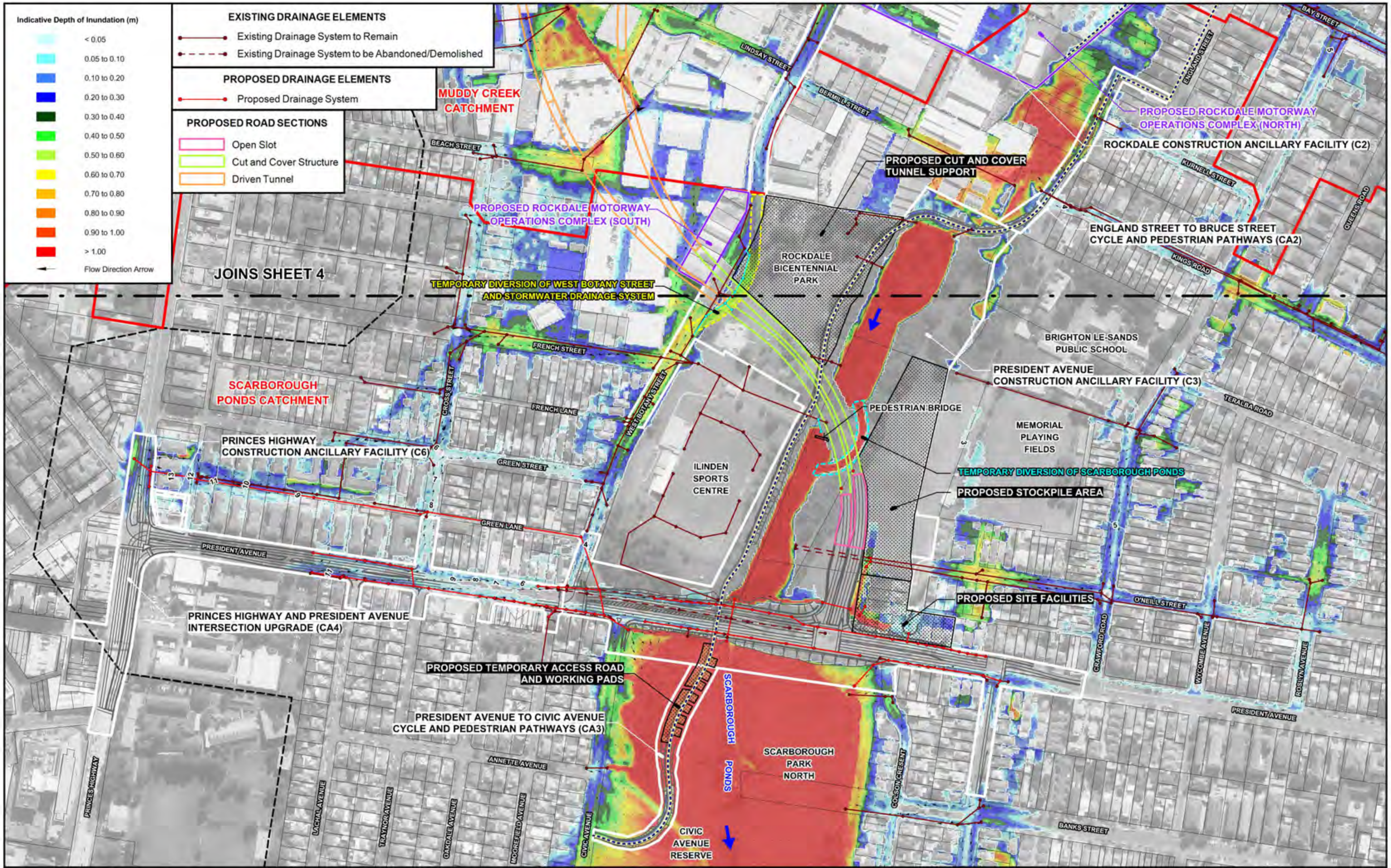
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-2
Sheet 4 of 5

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
CONSTRUCTION CONDITIONS - 1% AEP



N
40 0 40 80 120 m
Scale: 1:4,000

Note:

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LEGEND

- Proposed Surface Road Works
- Proposed Cycle and Pedestrian Pathways
- Construction Footprint
- Extent of Proposed Tunnel Ancillary Facilities
- Two-Dimensional Model Boundary
- Catchment Boundary
- Water Surface Elevation Contours (m AHD)

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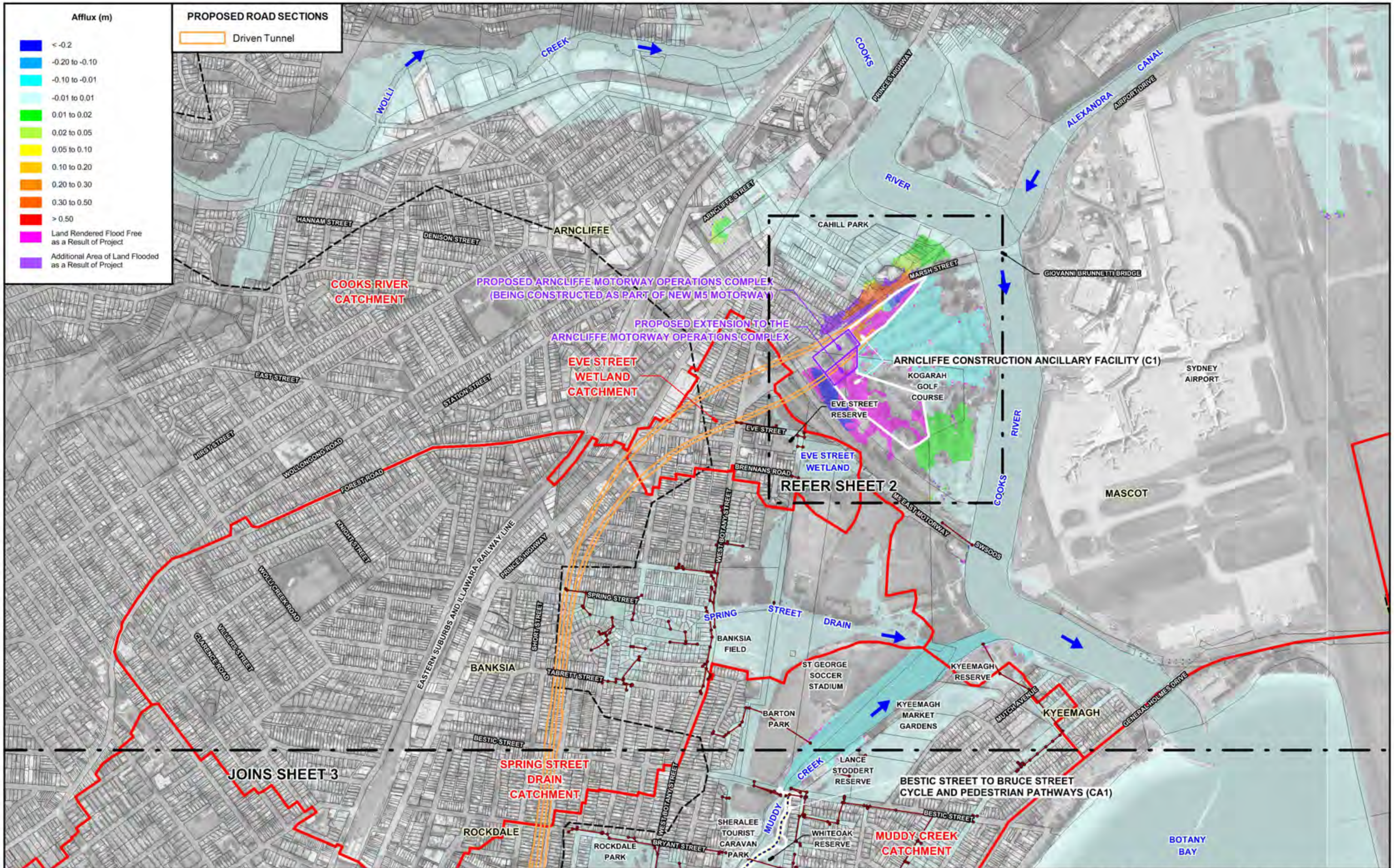
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-2
Sheet 5 of 5

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
CONSTRUCTION CONDITIONS - 1% AEP



N

120 0 120 240 360 m

Scale: 1:12,000

Lyall & Associates

Note:

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Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

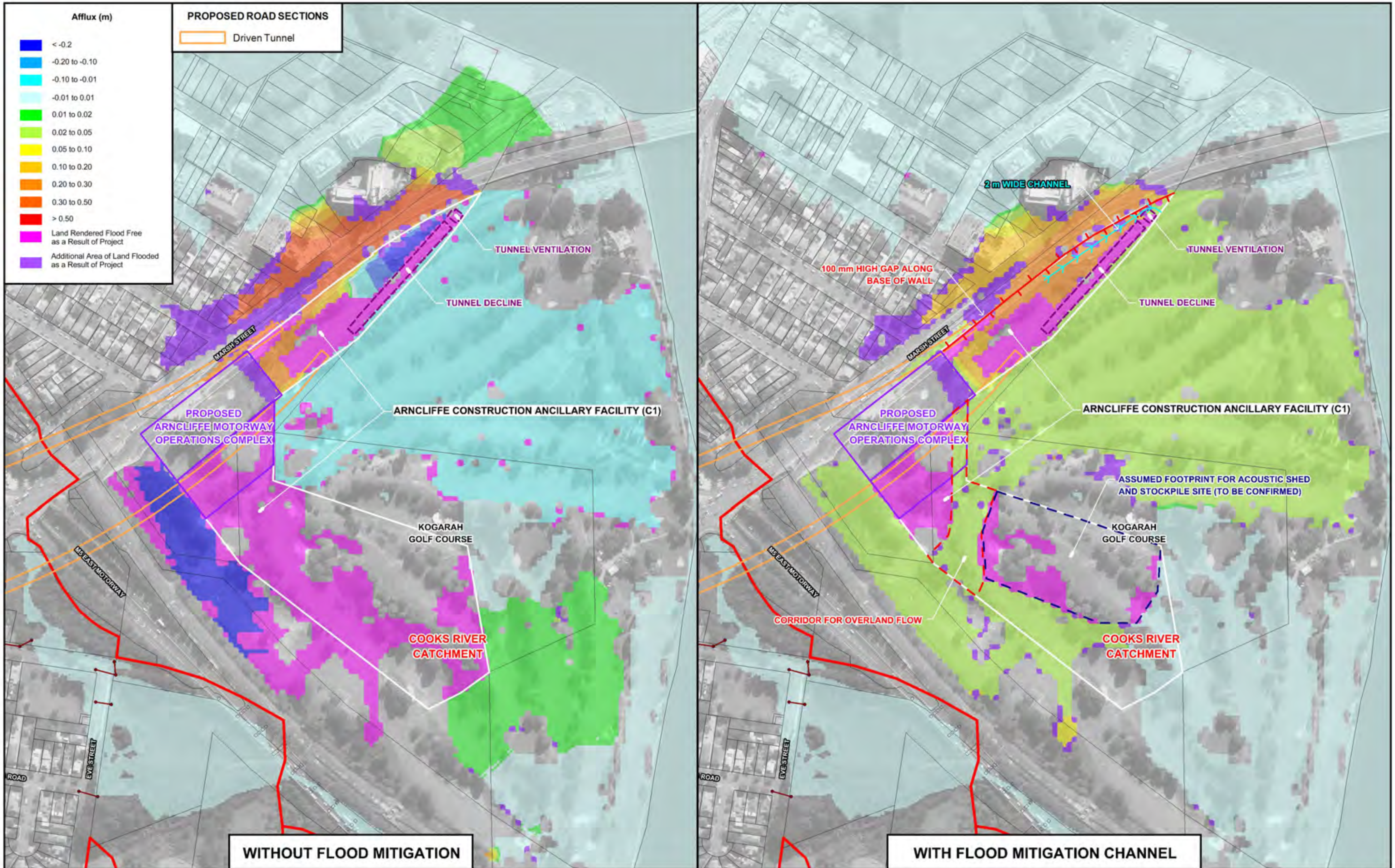
LEGEND

Proposed Cycle and Pedestrian Pathways
Construction Footprint
Extent of Proposed Tunnel Ancillary Facilities
Existing Drainage System
Two-Dimensional Model Boundary
Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-3
Sheet 1 of 5

IMPACT OF PROJECT CONSTRUCTION ON FLOODING BEHAVIOUR
1% AEP



N

40 0 40 80 120 m

Scale: 1:4,000

Lyall & Associates

Note:

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Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

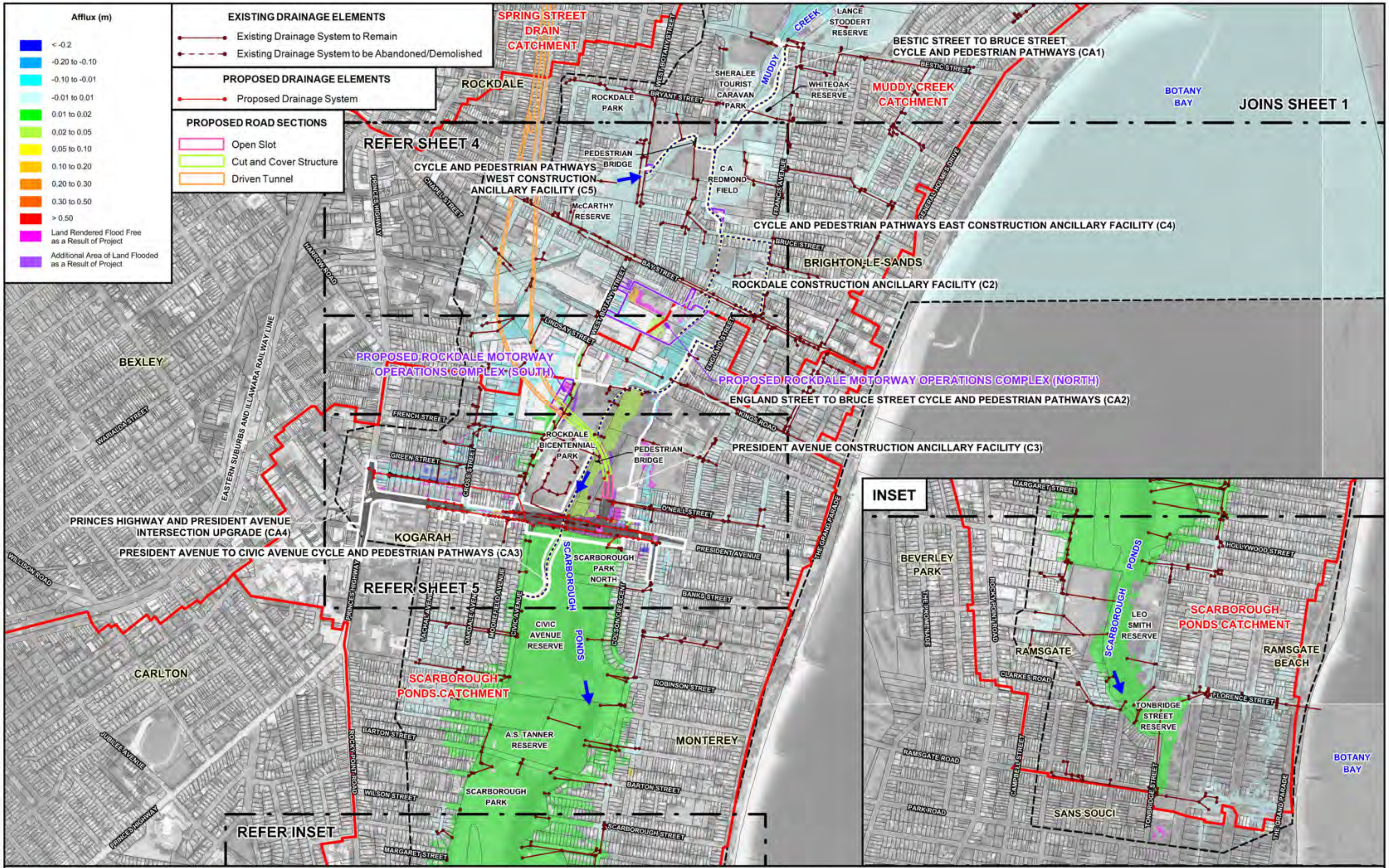
LEGEND

- Proposed Cycle and Pedestrian Pathways
- Construction Footprint
- Extent of Proposed Tunnel Ancillary Facilities
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-3
Sheet 2 of 5

IMPACT OF PROJECT CONSTRUCTION ON FLOODING BEHAVIOUR
1% AEP



120 0 120 240 360 m

Scale: 1:12,000

Note:
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Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND
- Proposed Surface Road Works
- Proposed Cycle and Pedestrian Pathways
- Construction Footprint
- Extent of Proposed Tunnel Ancillary Facilities
- Two-Dimensional Model Boundary
- Catchment Boundary

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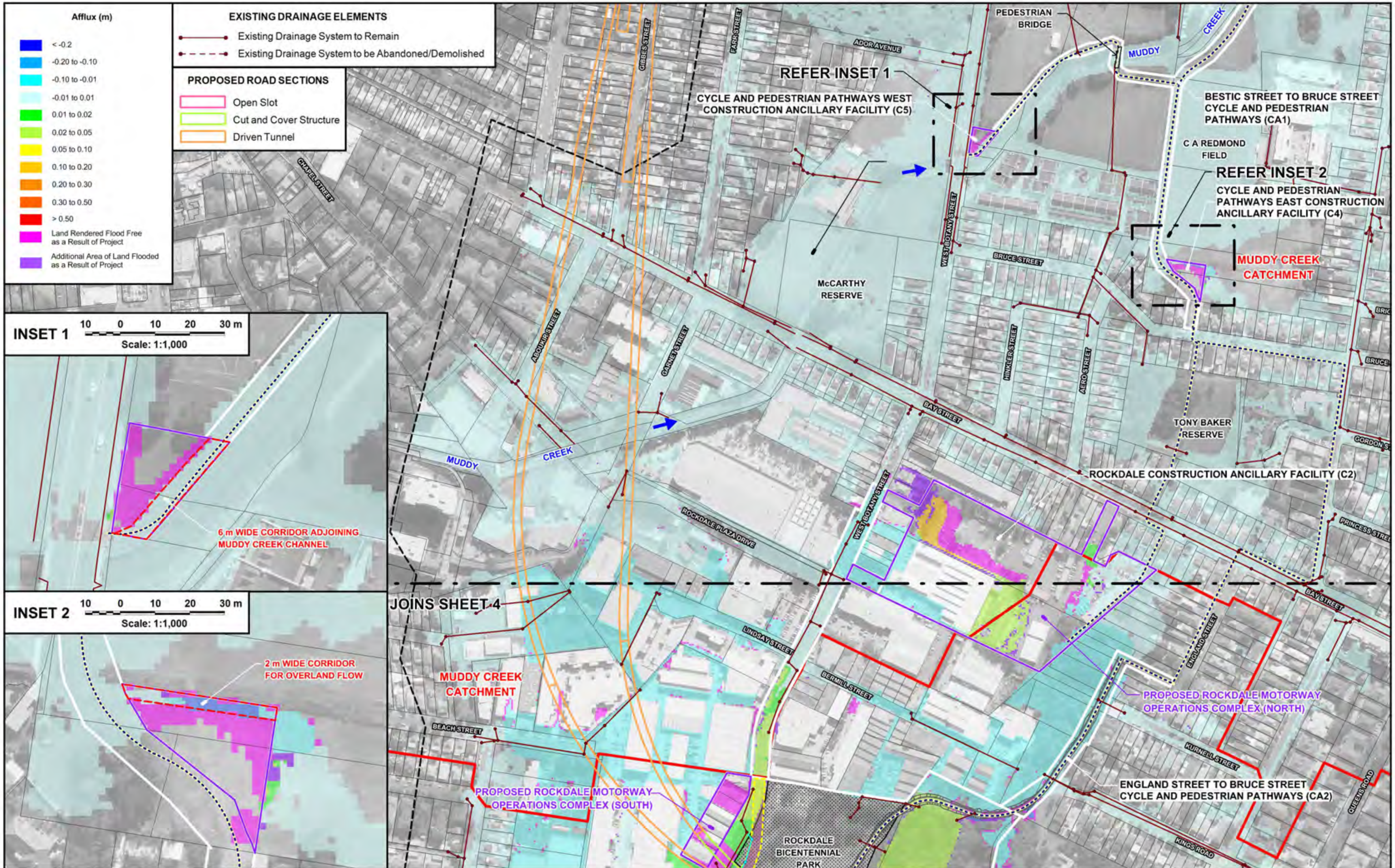
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-3
Sheet 3 of 5

IMPACT OF PROJECT CONSTRUCTION ON FLOODING BEHAVIOUR
1% AEP



N
40 0 40 80 120 m
Scale: 1:4,000

Note:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND
- Proposed Surface Road Works
- Proposed Cycle and Pedestrian Pathways
- Construction Footprint
- Extent of Proposed Tunnel Ancillary Facilities
- Two-Dimensional Model Boundary
- Catchment Boundary

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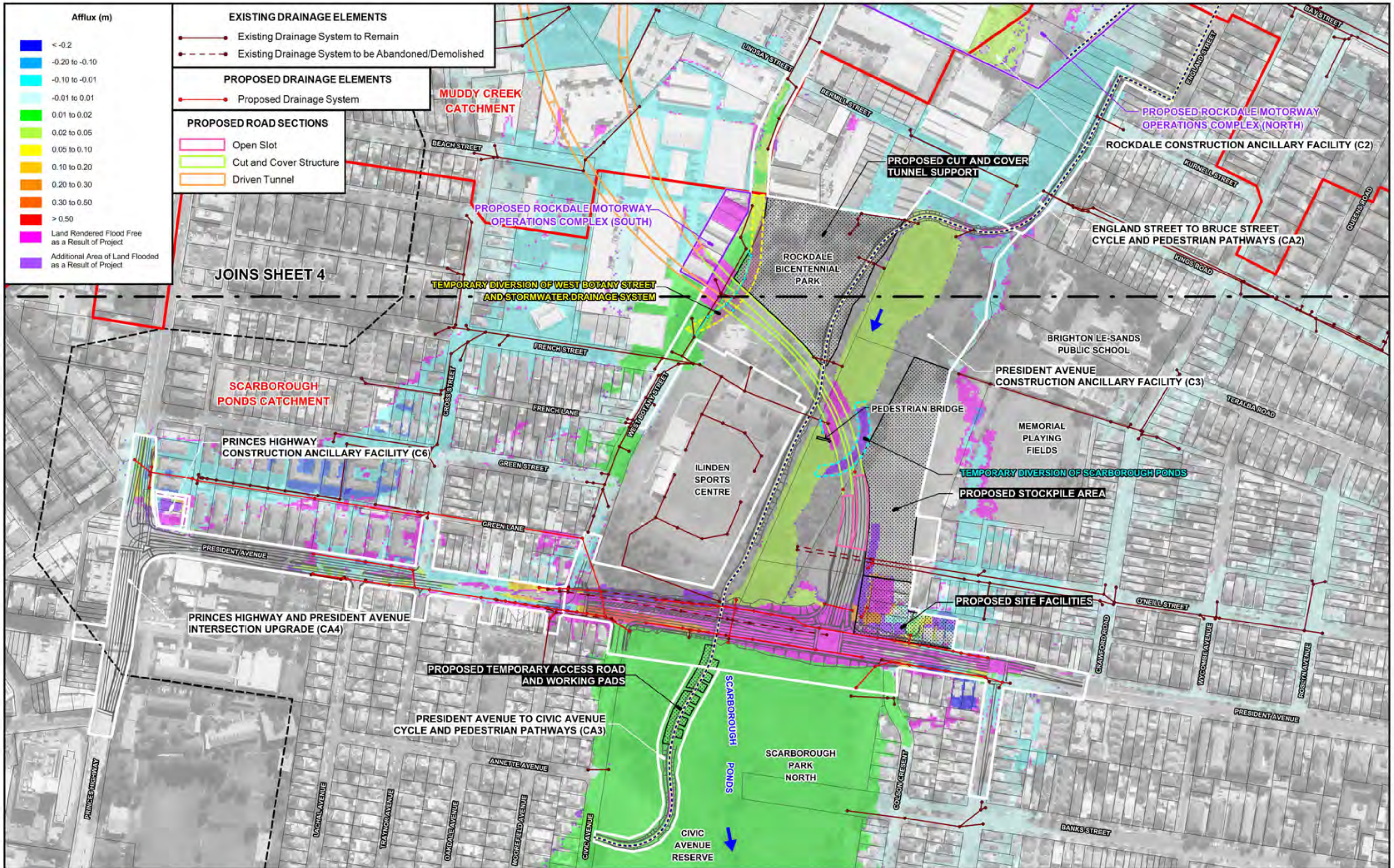
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-3
Sheet 4 of 5

IMPACT OF PROJECT CONSTRUCTION ON FLOODING BEHAVIOUR
1% AEP



N

40 0 40 80 120 m

Scale: 1:4,000

Lyall & Associates

Note:

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Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

- Proposed Surface Road Works
- Proposed Cycle and Pedestrian Pathways
- Construction Footprint
- Extent of Proposed Tunnel Ancillary Facilities
- Two-Dimensional Model Boundary
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 5-3
Sheet 5 of 5

IMPACT OF PROJECT CONSTRUCTION ON FLOODING BEHAVIOUR
1% AEP

6 Assessment of operational impacts

This chapter provides an assessment of the flood risk to the project and the impact it would have on flood behaviour during operation if appropriate mitigation measures are not incorporated into its design. The findings of an assessment into the potential impact of future climate change and impacts of a partial blockage of major hydraulic structures on flood behaviour under operational conditions are also presented.

6.1 Potential flood risk to the project and its impacts on flood behaviour

For the purpose of the following discussion, the operational related surface features of the project have been divided into the following seven components:

- Arncliffe motorway operations complex
- Rockdale motorway operations complex (north)
- Rockdale motorway operations complex (south)
- President Avenue intersection and surface works
- Bestic Street to Bruce Street pedestrian and cycle pathways
- England Street to Civic Avenue pedestrian and cycle pathways
- Princes Highway and President Avenue intersection upgrade.

Figure 6-1 (4 sheets) shows the general design arrangement associated with each of these above ground project components. **Figure 6-1** (4 sheets) also shows flooding patterns under operational conditions during a 1% AEP design storm, while **Figure 6-2** (4 sheets) shows the impact that the project would have on flood behaviour in terms of changes in peak 1% AEP flood levels. Corresponding results for a PMF event are provided in **Figures 6-3** (4 sheets) and **6-4** (4 sheets), while figures showing flooding patterns and impacts under operational conditions during storms with AEP's of 20%, 5%, 0.5% and 0.2% are provided in **Annexure C**.

Table 6-1 summarises the assessed flood risk at the various project components and the recommended level of flood protection based on the adopted hydrologic standards outlined in **section 3.1.8**.

Table 6-2 provides details of the concept design which formed the basis of the assessment of flood behaviour and presents the potential impacts of the project. The assessed concept design would be subject to further development during the detailed design stage.

Table 6-1 Summary of flood risks to the project

Location	Project infrastructure	Peak flood level (m AHD)(1)		Required level of flood protection	Assessed flood risk
		1% AEP	PMF		
Arncliffe motorway operations complex	Motorway ancillary facility comprising ventilation exhaust and supply, electrical substation and water treatment plant	1.8	3.9	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Figure 6-1, sheet 1 and Figure 6-3, sheet 1 show operational flooding patterns during 1% AEP and PMF events, respectively. • Figure 6-1, sheet 1 and Figure 6-3, sheet 1 also show the extent of the motorway operations complex that is currently being designed and constructed as part of the New M5 Motorway project, as well as an additional area of land to the south where the complex would be extended as part of the current project. The New M5 Motorway section of the complex would contain the ventilation facilities that would be utilised by the project, while the proposed extension would contain an electrical substation and water treatment plant. • The New M5 Motorway section of the complex is being designed and constructed under the requirements of that projects Conditions of Approval issued by the NSW Minister for Planning. The New M5 Motorway EIS identified that tunnel ancillary facilities for that project would be protected against flooding up to the PMF or 1% AEP plus 0.5 m (whichever is greater). • The proposed project operational footprint at the complex is located on land that is presently impacted by floodwaters that surcharge Marsh Street during a 20% AEP storm. Critical ground levels and/or structure levels within this area would need to be raised by 2.7-3.0 m in order to locate the tunnel ancillary facilities above the PMF level.

Location	Project infrastructure	Peak flood level (m AHD)[1]		Required level of flood protection	Assessed flood risk
		1% AEP	PMF		
Rockdale motorway operations complex (north)	Motorway ancillary facility comprising motorway control centre, tunnel deluge system comprising tanks and pump station, maintenance and storage facilities	3.1	4.1	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Figure 6-1, sheet 3 and Figure 6-3, sheet 3 show operational flooding patterns during 1% AEP and PMF events, respectively. • The Rockdale motorway operations complex (north) lies on land which is impacted by overland flow that surcharges the low point in West Botany Street adjacent to Rockdale Plaza Drive during storms in excess of 5% AEP in intensity. The eastern portion of the site would also be inundated by floodwater that originates from the upper reach of Scarborough Ponds, albeit to relatively shallow depths of 0.2 m during a 1% AEP event. • Critical ground levels and/or structure levels on the site would need to be raised by 1.2-1.7 m in order to locate the tunnel ancillary facilities above the PMF level.
Rockdale motorway operations complex (south)	Motorway ancillary facility comprising ventilation exhaust and supply, electrical substation and disaster recovery facility	3.5	4.5	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Figure 6-1, sheet 4 and Figure 6-3, sheet 4 show operational flooding patterns during 1% AEP and PMF events, respectively. • The Rockdale motorway operations complex (south) lies on land which is impacted by overland flow that surcharges the low point in West Botany Street adjacent to French Street during a 1% AEP storm. • Critical ground levels and/or structure levels on the site would need to be raised by 1.2-1.6 m in order to locate the tunnel ancillary facilities above the PMF level.

Location	Project infrastructure	Peak flood level (m AHD)[1]		Required level of flood protection	Assessed flood risk
		1% AEP	PMF		
President Avenue intersection and surface works	President Avenue tunnel portal	2.5	4.0	PMF or 1% AEP plus 0.5 m (whichever is greater)	• Figure 6-1, sheet 4 and Figure 6-3, sheet 4 show operational flooding patterns during 1% AEP and PMF events, respectively. • The entry to the President Avenue tunnel portal has been designed to be above the PMF level and therefore over 1.5 m above the 1% AEP flood level.
	President Avenue road upgrade	2.5	4.0	1% AEP	• Figure 6-1, sheet 4 and Figure 6-3, sheet 4 show operational flooding patterns during a 1% AEP and PMF event, respectively. • The upgrade of President Avenue has been designed to raise the existing road by a minimum of 0.9 m in order to provide a 1% AEP level of flood immunity.
Bestic Street to Bruce Street pedestrian and cycle pathways	Shared user path for pedestrians and cyclists	Varies	Varies	1 EY or Low Provisional Flood Hazard during a 1% AEP event	• Figure 6-1, sheet 3 and Figure 6-3, sheet 3 show operational flooding patterns during 1% AEP and PMF events, respectively, while Figure C-9, sheet 3 in Annexure C shows corresponding results for a 1 EY event. Figure C-7, sheet 3 in Annexure C shows the provisional flood hazard classification for a 1% AEP event under present day conditions. • A section of the shared pedestrian and cycle pathways between Bruce Street and Bestic Street is inundated by floodwater over a total length of about 370 m during a 1 EY event, increasing to 440 m during a 1% AEP event. Inundation of this section of the shared pedestrian and cycle pathway is predominantly caused by floodwater that surcharges the main channel of Muddy Creek. • Areas of high hazard along the section of the shared pedestrian and cycle pathways between Bruce Street and Bestic Street during a 1% AEP flood are confined to the in bank area of Muddy Creek (i.e. the section of the creek between its top of banks) and two incoming channels where waterway crossings would be required to raise the shared pedestrian and cycle pathways above the 1 EY flood level.

Location	Project infrastructure	Peak flood level (m AHD)(1)		Required level of flood protection	Assessed flood risk
		1% AEP	PMF		
England Street to Civic Avenue cycle and pedestrian pathways	Shared user path for pedestrians and cyclists	Varies	Varies	1 EY or Low Provisional Flood Hazard during a 1% AEP event	• Figure 6-1, sheet 4 and Figure 6-3, sheet 4 show operational flooding patterns during 1% AEP and PMF events, respectively, while Figure C-9, sheet 3 in Annexure C shows corresponding results for a 1 EY event. Figure C-7, sheet 4 in Annexure C shows the provisional flood hazard classification for a 1% AEP event under present day conditions. • A section of the shared pedestrian and cycle pathways where it crosses the upper reach of Scarborough Ponds to the north of Rockdale Bicentennial Park is inundated by floodwater over a length of about 180 m during a 1 EY event, increasing to about 420 m during a 1% AEP event. • A section of the shared pedestrian and cycle pathways where it crosses Scarborough Park North between President Avenue and Civic Avenue is inundated by floodwater over a length of about 250 m during a 1 EY event, increasing to about 340 m during a 1% AEP event. • Depths of ponding along the section of the shared pedestrian and cycle pathways where it crosses the upper reach of Scarborough Ponds and Scarborough Park North are sufficient to result in hazardous conditions arising during a 1% AEP storm event. It would therefore be necessary to raise the alignment of the shared user path along these sections of the corridor in order to reduce the depth of inundation and therefore the flood risk to pedestrians and cyclists.

Location	Project infrastructure	Peak flood level (m AHD)(1)		Required level of flood protection	Assessed flood risk
		1% AEP	PMF		
Princes Highway and President Avenue intersection upgrade	Widening of the Princes Highway and the western end of President Avenue	Varies	Varies	Maintain existing level of flood immunity	• Figure 6-1, sheet 4 and Figure 6-3, sheet 4 show operational flooding patterns during 1% AEP and PMF events, respectively. • The area of proposed road works along the Princes Highway is impacted by flow in excess of the capacity of the stormwater drainage system that collects at the low point in the road to the north of President Avenue and surcharges through the adjoining properties to the east and along Green Lane during storms more frequent than 1 EY under present day conditions. The proposed upgrades to the existing stormwater drainage system to accommodate the proposed road widening will improve the hydrologic standard of the drainage system in the Princes Highway to more than 1 EY. • The section of President Avenue between Lachal Avenue and Scarborough Ponds operates as an overland flow path to convey flow that surcharges the stormwater drainage system during storms as frequent as 1 EY under present day conditions.

Notes:

1 Peak flood levels are based on current climate conditions and no blockage to major hydraulic structures. Refer **sections 6.3** and **6.4** for an assessment of the impact of future climate change and a partial blockage of major hydraulic structures on peak flood levels at key locations along the length of the project.

Table 6-2 Summary of impacts of the project on flood behaviour

<table>
<tr><th>Location</th><th>Assessed concept design arrangement</th><th>Assessed impacts on flood behaviour</th></tr>
<tr><td>Arncliffe motorway operations complex</td><td>Refer Figure 6-1, sheet 1.
The motorway operations complex that is being designed and constructed as part of the New M5 Motorway project would be extended to accommodate a new electrical substation and water treatment plant that would be constructed as part of the current project.
The project's operational area would be raised relative to existing ground levels so that the entry to the new electrical substation and water treatment plant are located above the PMF level.</td><td>Figure 6-2, sheet 2 and Figure 6-4, sheet 2 show flood impacts under operational conditions during 1% AEP and PMF events, respectively.
Increases in peak 1% AEP flood levels, by a maximum of 11 mm, are confined to the open space of the Kogarah Golf Course and the road reserve of Marsh Street.</td></tr>
<tr><td>Rockdale motorway operations complex (north)</td><td>Refer Figure 6-1, sheet 2.
Motorway ancillary facility comprising motorway control centre, tunnel deluge system, maintenance and storage facilities.
The motorway ancillary facility would be raised relative to existing ground levels so that the entry to the motorway control centre and the tunnel deluge system are located above the PMF level.
For the purpose of the present investigation it was assumed that internal roads adjacent to the above facilities would be raised to a similar level in order to provide access.</td><td>Figure 6-2, sheet 3 and Figure 6-4, sheet 3 show flood impacts under operational conditions during 1% AEP and PMF events, respectively.
Without appropriate mitigation measures, peak flood levels in two residential properties in West Botany Street would be increased by a maximum of 120 mm. Subject to further hydraulic assessment during detailed design, floor level survey may be required to confirm the extent to which the proposed works would increase above-floor inundation and flood damages in affected properties. Potential mitigation measures to minimise such increases may include:
designating areas of carpark and internal roads which could act as overland flow paths, noting that the site is only impacted by overland flow from West Botany Street during storms in excess of 5% AEP in intensity
upgrading the site drainage system to control a portion of the overland flow that presently surcharges onto the site from West Botany Street
designing the site surface grading to as far as practical balance cut and fill in areas located below the 1% AEP flood.
Refer to 'President Avenue intersection and surface works' for a description of the impact that the Rockdale motorway operations complex (north) in combination with other proposed works would have on flood behaviour during a PMF event.</td></tr>
</table>

Location	Assessed concept design arrangement	Assessed impacts on flood behaviour
Rockdale motorway operations complex (south)	• Refer Figure 6-1, sheet 3. • Motorway ancillary facility comprising ventilation exhaust and supply, electrical substation and disaster recovery facility. • The tunnel ancillary facility would be raised relative to existing ground levels so that the entry to the elements listed above is located above the PMF level. • Lowering of ground levels within an area of the Rockdale Bicentennial Park adjoining West Botany Street by an average of 1.2 m to provide compensatory floodplain storage to offset the impact that filling associated with the tunnel ancillary facilities would have on flood behaviour. The required volume of compensatory floodplain storage could be provided as part of the re-establishment of Rockdale Bicentennial Park following the construction of the cut and cover structure.	• Figure 6-2, sheet 4 and Figure 6-4, sheet 4 show flood impacts under operational conditions during 1% AEP and PMF events, respectively. • While there would be an increase in peak 1% AEP flood levels along West Botany Street by a maximum of 20 mm, impacts would be confined to the road reserve. • Refer to 'President Avenue intersection and surface works' for a description of the impact that the Rockdale motorway operations complex (south) in combination with other proposed works would have on peak flood levels during a PMF event.
President Avenue intersection and surface works	• Refer Figure 6-1, sheet 3. • Surface road works and tunnel portal to connect President Avenue to proposed road tunnels. • The entry to the tunnel portal would be located above the PMF level, while flood protection barriers would be provided around the open slot to the same minimum elevation in order to prevent the ingress of floodwater. • The level of President Avenue would be raised to improve its level of flood immunity to 1% AEP. • The existing single cell 1800 mm wide by 900 mm high box culvert that crosses President Avenue at Scarborough Ponds would be replaced with three 2700 mm wide by 1200 mm high box culverts (refer transverse drainage structure XD01 on Figure 6-1, sheet 3). • In order to maintain the existing permanent water level in the section of Scarborough Ponds upstream of President Avenue, the weir that is located upstream of the existing single cell 1800 mm wide by 900 mm high box culvert would be replaced with a similar arrangement at the inlet to the new three cell 2700 mm wide by 1200 mm high box culverts. • The western overbank of Scarborough Ponds immediately upstream of President Avenue would be regraded in order to provide an overland flow path to control flow that surcharges the new box culvert structure.	• Figure 6-2, sheet 4 and Figure 6-4, sheet 4 show flood impacts under operational conditions during 1% AEP and PMF events, respectively. • While there would be an increase in peak 1% AEP flood levels within the section of Scarborough Ponds to the north (upstream) of President Avenue by a maximum of 30 mm, impacts would be confined to the Rockdale Bicentennial Park reserve. • There would be a localised increase in peak 1% AEP flood levels by a maximum of 20 mm within the front yards of two residential properties that are located on the northern and southern side of President Avenue, to the east of the new intersection. Floor level survey would be required to confirm the potential for above-floor inundation in these properties and to allow the scope of any mitigation measures that may be required to be determined. Such measures may involve: – lowering of President Avenue to convey overland flow that presently surcharges onto the road from the affected properties – lowering ground levels within the three properties that are to be acquired as part of the project to the north of the new O'Neill Street cul-de-sac in order to convey overland flow that presently surcharges at its low point – upgrading the stormwater drainage system on the corner of O'Connell

Location	Assessed concept design arrangement	Assessed impacts on flood behaviour
	• The eastern overbank of Scarborough Ponds in the vicinity of the President Avenue tunnel portal would be lowered to provide compensatory floodplain storage. • A new pavement drainage system would intercept runoff generated by direct rainfall at the tunnel portal. Runoff from the tunnel portal would be pumped to a water quality basin (refer basin BC_WQ01 on Figure 6-1, sheet 3) where it would be treated prior to discharge into Scarborough Ponds. • The existing stormwater drainage system along President Avenue would be upgraded to accommodate the proposed road widening. Subject to detailed design, the existing stormwater drainage outlet that discharges from President Avenue at Civic Avenue would be increased from a 525 mm diameter pipe to two 1350 mm diameter pipes, while the existing stormwater drainage outlet that discharges from President Avenue at Colson Crescent would be increased from a 450 mm diameter pipe to a 900 mm diameter pipe (denoted pavement drainage outlets 1 and 2, respectively on Figure 6-1, sheet 3).	Street and President Avenue in order to reduce the magnitude of flow that would surcharge the road corridor into the adjoining properties along the southern side of President Avenue. • Flow that would surcharge the new sag in President Avenue to the east of the tunnel portals (should the inlet pits along the road experience a partial blockage) has the potential to impact on an adjoining property that is located on the southern side of President Avenue east of Colson Crescent. In order to mitigate the impact of flooding on the adjoining property, it will be necessary to undertake further design development during the detailed design stage. This may involve regrading the section of footpath adjacent to the sag to fall toward the Colson Crescent road reserve thereby increasing its capacity, and/or refinement of the vertical road alignment design to shift the new sag in President Avenue further west. • There would be an increase in PMF levels across the upper reaches of the Scarborough Ponds and Muddy Creek floodplains. Increases in PMF levels would be typically 50 mm or less, with the exception of some localised increases to a maximum of 80 mm in the vicinity of Bay Street and President Avenue. There would be no significant increase in the extent of inundation during a PMF event. • There would be negligible change in PMF levels along the reach of Scarborough Ponds to the south of President Avenue. • Table 6-3 provides a summary of changes in velocities at the outlets to the stormwater drainage in President Avenue and the section of Scarborough Ponds immediately downstream of the project. The upgrade of the stormwater drainage system and the relocation of its outlets to accommodate the proposed widening of President Avenue would have the potential for localised increases in flow velocities within Scarborough Ponds. Scour protection and energy dissipation would be provided on the outlets of the upgraded stormwater drainage system to manage the potential for increased scour.

Location	Assessed concept design arrangement	Assessed impacts on flood behaviour
Bestic Street to Bruce Street pedestrian and cycle pathways	• Refer Figure 6-1, sheet 2. • Due to the level of design development for the section of the shared pedestrian and cycle pathways between Bestic Street and Bruce Street, a preliminary assessment of potential flood impacts has been carried out based on an understanding of flooding and drainage patterns under present day conditions and an initial review of the proposed alignment of the shared pedestrian and cycle pathways.	• As noted in Table 6-1, sections of the proposed alignment of the shared pedestrian and cycle pathways to the north of the Rockdale Bicentennial Park and between Bruce Street and Bestic Street are inundated during a 1% AEP flood. Within these areas, the construction of the shared user path above the natural surface has the potential to exacerbate flooding conditions in adjacent properties unless adequate waterway area is provided. Conversely, the construction of the shared user path at natural surface would lead to its frequent inundation to depths that would be hazardous to users. It will therefore be necessary to locate sections of the shared user path above natural surface and with sufficient waterway area beneath it to minimise adverse impacts on flood behaviour in adjacent properties.
England Street to Civic Avenue shared pedestrian and cycle pathways	• Refer Figure 6-1, sheet 3. • New shared pedestrian and cycle pathways between England Street and Civic Avenue. • A bridge overpass would be provided where the shared pedestrian and cycle pathways cross President Avenue and a section of Scarborough Park North. • A series of waterway crossings would be provided where the shared pedestrian and cycle pathways cross the upper reach of Scarborough Ponds. For the purpose of the assessment these waterway crossings were assumed to comprise raised platform structures. • A waterway crossing would also be required where the shared pedestrian and cycle pathways cross an existing drainage line that discharges into Scarborough Ponds from Civic Avenue. Subject to detailed design this waterway crossing may be incorporated into an extension to the length of the bridge overpass.	• Figure 6-2, sheet 4 and Figure 6-4, sheet 4 show flood impacts under operational conditions during 1% AEP and PMF events, respectively. • The proposed extent of waterway crossings across the upper reach of Scarborough Ponds would mitigate the impact of the shared pedestrian and cycle pathways on peak flood levels within the watercourse during a 1% AEP event. • Refer to 'President Avenue intersection and surface works' for a description of the impact that filling associated within the shared pedestrian and cycle pathways in combination with other proposed works would have on flood behaviour in the section of Scarborough Ponds to the south of President Avenue.

Location	Assessed concept design arrangement	Assessed impacts on flood behaviour
Princes Highway and President Avenue intersection upgrade	• Refer Figure 6-1, sheet 3. • Widening of Princes Highway and the western end of President Avenue to provide additional northbound and southbound turning lanes from the Princes Highway into President Avenue. • The existing stormwater drainage system in Princes Highway and President Avenue would be upgraded to accommodate the proposed road widening. • Subject to detailed design, the existing stormwater drainage line that runs from the low point in Princes Highway to the north of President Avenue, along Green Lane and West Botany Street to President Avenue would be upgraded from a 900 mm diameter pipe to a 1200 mm diameter pipe.	• Figure 6-2, sheet 4 and Figure 6-4, sheet 4 show flood impacts under operational conditions during 1% AEP and PMF events, respectively. • While the proposed upgrade of the drainage systems that presently control runoff from the Princes Highway and President Avenue would mitigate the impact of the proposed road widening on peak flood levels in adjacent properties during a 1% AEP event, the increase in the capacity of the stormwater drainage system has the potential to impact on flood behaviour where it discharges into Scarborough Ponds to the south of President Avenue. • Refer to 'President Avenue intersection and surface works' for a description of the impact that the upgrade of the above mentioned drainage systems in combination with other proposed works would have on flood behaviour in the section of Scarborough Ponds to the south of President Avenue.

6.1.1 Arncliffe motorway operations complex

Figure 6-1, sheet 2 shows the extent of the Arncliffe motorway operations complex that is currently being designed and constructed as part of the New M5 Motorway project, as well as an additional area of land to the south where the complex would be extended as part of the current project to accommodate an electrical substation and water treatment plant. Ventilation supply and exhaust facilities utilised by the project would be contained within the New M5 Motorway section of the complex.

The design and construction of the New M5 Motorway section of the Arncliffe motorway operations complex is currently being undertaken under the requirements of that project approval issued by the NSW Minister for Planning in April 2016.

The New M5 Motorway EIS identified that tunnel ancillary facilities would be located above the PMF or the 1% AEP plus 0.5 metres (whichever is greater) in order to prevent the ingress of floodwater into the tunnel. Condition B23(a) of the New M5 Motorway Infrastructure approval that was issued by the NSW Minister for Planning requires that the flood mitigation strategy that is developed for the New M5 Motorway considers the impact of future climate change on flooding and drainage behaviour, while Condition B23(e) requires that where feasible and reasonable flood impacts on adjacent properties are limited to:

"- a maximum increase in inundation time of one hour in a 1 in 100 year ARI rainfall event,

- a maximum increase of 10 mm in inundation at properties where floor levels are currently exceeded in a I in 100 year ARI rainfall event,

- a maximum increase of 50 mm in inundation at properties where floor levels would not be exceeded in a 1 in 100 year ARI rainfall event, and

- no inundation of floor levels which are currently not inundated in a 1 in 100 year ARI rainfall event."

Subject to the design and construction of the New M5 Motorway project being compliant with the requirements of Condition B23 set out above, no additional flood mitigation measures would be required for those components of the current project that would be contained within the New M5 Motorway section of the Arncliffe motorway operations complex.

For the present investigation, the footprint of the proposed extension to the Arncliffe motorway operations complex was raised above the PMF level in the flood model in order to assess the impact that it would have on flooding behaviour. **Figure 6-1**, sheet 2 and **Figure 6-2**, sheet 2 show 1% AEP flooding patterns and impacts, respectively, under operational conditions.

The investigation found that the loss of floodplain storage associated with the proposed extension of the Arncliffe motorway operations complex would result in a minor increase in peak 1% AEP flood levels, by a maximum of 11 millimetres, within the Kogarah Golf Course and road reserve of Marsh Street. There would be negligible change in PMF levels.

6.1.2 Rockdale motorway operations complex (north)

Figure 6-1, sheet 3 shows a motorway operations complex is proposed to be located on the eastern side of West Botany Street that would comprise:

- A motorway control centre
- A tunnel deluge system to supply water to the tunnels
- Maintenance and storage facilities
- Car parking and site amenities.

For the present investigation, the footprints of the proposed motorway control centre and tunnel deluge system were raised above the PMF level in the flood model, while it was also assumed that the sections of internal road adjacent to these facilities would also need to be raised to the same level in order to provide access.

Figure 6-1, sheet 3 and **Figure 6-2**, sheet 3 show 1% AEP flooding patterns and impacts, respectively, under operational conditions.

The investigation found that if ground levels across the site were to be raised to accommodate the proposed facilities without appropriate mitigation measures, then peak 1% AEP flood levels in two residential properties in West Botany Street would be increased by 120 mm. It would therefore be necessary to undertake further hydraulic assessment during detailed design in order to ensure that measures are incorporated into the detailed layout and surface grading of the site to manage overland flow that presently discharges onto the site from West Botany Street. These measures may involve:

- Designating areas of carpark and internal roads which could act as overland flow paths, noting that the site is only impacted by overland flow from West Botany Street during storms in excess of 5% AEP in intensity
- Upgrading the site drainage system to control a portion of the overland flow that presently surcharges onto the site from West Botany Street
- Designing the site surface grading to as far as practical balance cut and fill in areas located below the 1% AEP flood.

Subject to this further hydraulic assessment, it may be necessary to collect floor level survey in order to confirm the extent to which the proposed works would increase above-floor inundation and flood damages in affected properties.

Figure 6-3, sheet 3 and **Figure 6-4**, sheet 3 show flooding patterns and impacts for a PMF event, respectively, under operational conditions. The entries to the motorway control centre and tunnel deluge system would be located above the PMF level in order to prevent the ingress of floodwater to the tunnels and to ensure the safe operation of the motorway.

An assessment of the impact that the Rockdale motorway operations complex (north) in combination with other proposed works would have on peak flood levels during a PMF event is provided in **section 6.1.4**.

6.1.3 Rockdale motorway operations complex (south)

Figure 6-1, sheet 4 shows a motorway operations complex is proposed to be located on the western side of West Botany Street that would comprise:

- ventilation exhaust and supply facilities
- an electrical substation to supply power to the complex
- a disaster recovery site
- car parking and site amenities.

As the site of the Rockdale motorway operations complex (south) is presently impacted by overland flow that collects at the low point in West Botany Street at the corner of Rockdale Plaza Drive it was identified that it would be necessary to provide compensatory floodplain storage in order to mitigate the impact that filling on the site would have on flood behaviour in adjacent development. **Figure 6-1**, sheet 4 shows an area where it is proposed to provide the required volume of compensatory floodplain storage as part of the re-establishment of Rockdale Bicentennial Park following the construction of the cut and cover structure.

Figure 6-1, sheet 4 and **Figure 6-2**, sheet 4 show 1% AEP flooding patterns and impacts, respectively, under operational conditions.

The investigation found that while peak 1% AEP flood levels along West Botany Street would be increased by a maximum of 20 mm, impacts would be confined to the road reserve

Figure 6-3, sheet 4 and **Figure 6-4**, sheet 4 show flooding patterns and impacts for a PMF event, respectively, under operational conditions. The ventilation exhaust and supply facility, the electrical substation and the disaster recovery site would be located above the PMF level in order to prevent the ingress of floodwater to the tunnels and to ensure the safe operation of the motorway.

An assessment of the impact that the Rockdale motorway operations complex (south) in combination with other proposed works would have on peak flood levels during a PMF event is provided in **section 6.1.4**.

6.1.4 President Avenue intersection and surface works

A new intersection would be built at President Avenue to provide access to the proposed road tunnels via a tunnel portal (referred to as the 'President Avenue tunnel portal' on **Figure 6-1**, sheet 4). The tunnel portal would cross Scarborough Ponds in a cut and cover arrangement to the north of President Avenue which would extend across West Botany Street and into the industrial land to the west. The section of President Avenue between O'Connell Street and Oakdale Avenue would be upgraded to accommodate the new intersection.

In **section 4.2.5** it was noted that under present day conditions, the section of President Avenue that runs between Colson Crescent and Civic Avenue has a hydrologic standard of around 50% AEP. It will therefore be necessary to implement a set of design measures to improve the hydrologic standard of President Avenue in the vicinity of President Avenue intersection.

Figure 6-1, sheet 4 shows the layout of the concept flood and stormwater management strategy proposed for the project in the vicinity of the President Avenue intersection. Key features of the strategy include:

- Locating the entry to the tunnel portal above the PMF level, and providing flood protection barriers around the open slot to the same minimum elevation, in order to prevent the ingress of floodwater
- Raising President Avenue between Colson Crescent and Civic Avenue to provide a 1% AEP level of flood immunity
- Replacing the existing single 1800 mm wide by 900 mm high box culvert, which is located at the low point in President Avenue, with three 2700 mm wide by 1200 mm high box culverts (referred to as transverse drainage culvert XD01 on **Figure 6-1**, sheet 4) in order to accommodate the additional flow which presently overtops President Avenue
- Replacing the weir that is located upstream of the existing single 1800 mm wide by 900 mm high box culvert with a similar arrangement upstream of the new three 2700 mm wide by 1200 mm high box culverts in order to maintain the existing permanent water level in the section of Scarborough Ponds north (upstream) of President Avenue
- Lowering existing ground levels along the western bank of Scarborough Ponds immediately upstream of President Avenue in order to provide an overland flow path to control flow that surcharges the transverse drainage culvert XD01
- Lowering existing ground levels along the eastern bank of Scarborough Ponds in the vicinity of the President Avenue tunnel portal in order to provide compensatory floodplain storage to offset the combined impact of the President Avenue intersection and surface works, the England Street to Civic Avenue cycle and pedestrian pathways and the Princes Highway and President Avenue intersection upgrade on flood behaviour in Scarborough Ponds (refer to areas of compensatory floodplain storage denoted on **Figure 6-1**, sheet 4).
- Diverting the existing drainage line that discharges into Scarborough Ponds from O'Neill Street around the open slot via a 1050 mm diameter pipe crossing located immediately north of the President Avenue intersection.
- Providing a new pavement drainage system to intercept runoff generated by direct rainfall at the tunnel portal, which would then be pumped to a water quality basin (referred to as basin WQ01 on **Figure 6-1**, sheet 4) where it would be treated prior to its discharge into Scarborough Ponds
- Upgrading the existing stormwater drainage system along President Avenue to accommodate the proposed road widening. The existing stormwater drainage outlet that discharges from President Avenue at Civic Avenue would be increased from a 525 mm diameter pipe to two 1350 mm diameter pipes, while the existing stormwater drainage outlet that discharges from President Avenue at Colson Crescent would be increased from a 450 mm diameter pipe to a 900 mm diameter pipe (denoted pavement drainage outlets 1 and 2, respectively on **Figure 6-1**, sheet 4).

The concept flood and stormwater management strategy will be further developed during the detailed design stage in consultation with Bayside Council.

Figure 6-1, sheet 4, and **Figure 6-2**, sheet 4 respectively show 1% AEP flooding patterns and impacts under operational conditions. Corresponding results for a PMF event are shown on **Figure 6-1**, sheet 4, and **Figure 6-2**, sheet 4.

The proposed raising of President Avenue along with the upgrade of transverse drainage culvert XD01 would prevent the surcharge of the roadway during a 1% AEP flood, while the upgrades to the pavement drainage system will intercept gutter flows approaching the low point in President Avenue from the east and west.

While there would also be an increase in peak 1% AEP flood levels within the section of Scarborough Ponds to the north (upstream) of President Avenue by a maximum of 30 mm, impacts would be confined to the Rockdale Bicentennial Park reserve.

The raising of the section of President Avenue to the east of the new intersection would result in a localised increase in peak 1% AEP flood levels by a maximum of 20 mm within the front yards of two residential properties located to the north and south of President Avenue, immediately west of O'Connell Street. Floor level survey would be required to confirm the potential for above-floor inundation in these properties and to allow the scope of any mitigation measures that may be required to be determined. Such measures may involve:

- Lowering of President Avenue to convey overland flow that presently surcharges onto the road from the affected properties
- Lowering ground levels within the three properties that are to be acquired as part of the project to the north of the new O'Neill Street cul-de-sac in order to convey overland flow that presently surcharges at its low point
- Upgrading the stormwater drainage system on the corner of O'Connell Street and President Avenue in order to reduce the magnitude of flow that would surcharge the road corridor into the adjoining properties along the southern side of President Avenue.

Flow that would surcharge the new sag in President Avenue to the east of the tunnel portals should the inlet pits along the road experience a partial blockage also has the potential to impact on an adjoining property that is located on the southern side of President Avenue east of Colson Crescent. In order to mitigate the impact of flooding on the adjoining property it will be necessary to undertake further design development during the detailed design stage. This may involve:

- Regrading the section of footpath adjacent to the sag to fall toward the Colson Crescent road reserve thereby increasing its capacity
- Refinement of the vertical road alignment to shift the new sag in President Avenue further west.

There would be no change in the duration of flooding within the Scarborough Ponds catchment as a result of the project.

There is the potential for an increase in scour potential in the section of Scarborough Ponds immediately downstream of President Avenue due to:

- The relocation of the existing stormwater drainage outlets further south (downstream) to accommodate the proposed road widening (denoted pavement drainage outlets 1 and 2 and transverse drainage structure XD01 on **Figure 6-1**, sheet 4)
- An increase in peak discharges due to the upgrade of the stormwater drainage system.

Scour protection and energy dissipation would be provided at the stormwater drainage outlets that would discharge into Scarborough Ponds. **Table** 6-3 shows that while there will be a significant increase in the rate of flow discharging into Scarborough Ponds at pavement drainage outlets 1 and 2, as well as transverse drainage structure XD01, the total peak flow in Scarborough Ponds downstream of President Avenue will be slightly reduced. This is primarily due to the upgrade of transverse drainage culvert XD01 and the raising of President Avenue which will increase the early release of flow from the section of Scarborough Ponds upstream of President Avenue and prevent the relatively large rate of discharge due to the surcharge of President Avenue that occurs under present day conditions.

Table 6-3 Summary of peak flows and velocities in Scarborough Ponds at President Avenue during a 1% AEP 60 minute storm

Location[(1)]	Present day conditions		Operational conditions		Change[(2)]	
	Flow (m^3/s)	Velocity (m/s)	Flow (m^3/s)	Velocity (m/s)	Flow (m^3/s)	Velocity (m/s)
Pavement drainage outlet 1	0.5	2.5	7.2	2.5	+6.7	-
Transverse drainage culvert XD01	2.2	1.3	7.9	0.8	+5.7	-0.5
Pavement drainage outlet 2	0.3	1.7	1.3	2.0	+1.0	+0.3
Surcharge across President Avenue	11.7	1.0	-	-	-11.7	-
Immediately south (downstream) of President Avenue	14.7	<0.2	14.5	<0.2	-0.2	0.0

Notes:
1 Refer **Figure 6-1**, sheet 3 for locations of pavement drainage outlets 1 and 2 and transverse drainage culvert XD01.
2 A positive value represents an increase and conversely a negative value represents a decrease relative to present day conditions.

Figure 6-4, sheet 4 shows that there would be an increase in PMF levels across the upper reaches of the Scarborough Ponds and Muddy Creek floodplains. Increases in PMF levels would be typically 50 millimetres or less, with the exception of some localised increases to a maximum of 80 millimetres in the vicinity of Bay Street and President Avenue. There would be no significant increase in the extent of inundation during a PMF event.

There would be negligible change in PMF levels along the reach of Scarborough Ponds to the south of President Avenue as a result of the project.

6.1.5 Bestic Street to Bruce Street cycle and pedestrian pathways

New shared pedestrian and cycle pathways would be provided between Bestic Street and Bruce Street. **Figure 6-1**, sheet 3 shows the proposed shared pedestrian and cycle pathways would follow the alignment of the main channel of Muddy Creek between Bestic Street and West Botany Street, while an additional section of corridor would be located within C. A. Redmond Field between Muddy Creek and Bruce Street.

Due to the concept level of design development for this section of the shared pedestrian and cycle pathways, a preliminary assessment of potential flood impacts has been carried based on an understanding of flooding and drainage patterns under present day conditions and an initial review of the proposed alignment of the shared pedestrian and cycle pathways. The design of the new shared path would be undertaken in consultation with Sydney Water to ensure that the proposed works are integrated with their future plans for the naturalisation of the Muddy Creek channel. **Section 7.2** provides further details of Sydney Water's plans for the Muddy Creek channel.

Figure 5-1, sheet 3, shows that a section of the shared pedestrian and cycle pathways between Bruce Street and Bestic Street is inundated by floodwater over a total length of about 370 metres during a 1 EY event, increasing to 440 metres during a 1% AEP event. Inundation of this section of the shared pedestrian and cycle pathways is predominantly caused by floodwater that surcharges the main channel of Muddy Creek.

Within this area identified above, there is the potential for adverse flooding impacts on adjacent properties should the shared user path be constructed above the existing ground levels without adequate waterway area. Conversely, constructing the shared user path completely at existing ground level would lead to the frequent flooding to sections of the path at depths that would be hazardous to users. It is therefore proposed that the detailed design and construction of the shared user path be undertaken based on the following general principles:

- Sections of shared user path within the 1% AEP flood extent are to be constructed at existing surface level or on elevated structures which incorporate sufficient waterway area to minimise its impact on flood behaviour in adjacent properties
- As a minimum, areas of shared user path within the 1 EY flood extent are to be elevated above natural surface level to prevent its frequent inundation. Sufficient waterway area should be provided below the elevated structure to minimise its impact on flood behaviour in adjacent properties
- Existing waterway crossings over Muddy Creek should be utilised for the shared pedestrian and cycle pathways where practicable in order to minimise the potential for increases in hydraulic losses. The upgrade of existing crossings to accommodate the new shared user path should be located no lower than the soffit level of the existing structure and maintain the same structure thickness where feasible.

Measures would also be incorporated into the shared pedestrian and cycle pathways to control the quantity of runoff from new hardstand areas. This may involve the provision of water sensitive urban design type features such as vegetated swales and raingardens within the proposed landscape zone along the alignment of the shared pedestrian and cycle pathways.

6.1.6 England Street to Civic Avenue cycle and pedestrian pathways

New shared pedestrian and cycle pathways would be provided between England Street and Civic Avenue. **Figure 6-1**, sheet 4 shows that the proposed shared pedestrian and cycle pathways would run from England Street across the upper reach of Scarborough Ponds to the north of Rockdale Bicentennial Park before continuing in a southerly direction along its western bank across President Avenue to Civic Avenue.

Detailed flood modelling was carried out to assess the impact of the proposed shared pedestrian and cycle pathways on flood behaviour in combination with other works proposed on the Scarborough Ponds floodplain (i.e. the Rockdale motorway operations complexes (north and south), President Avenue intersection and surface works and the Princes Highway and President Avenue intersection upgrade).

Figure 6-1, sheet 4 shows the general layout of the assessed concept design, which comprised the following key features:

- A series of waterway crossings where the shared pedestrian and cycle pathways cross the upper reach of Scarborough Ponds to the north of Rockdale Bicentennial Park. For the purpose of the assessment these waterway crossings were assumed to comprise raised platform structures. The sections of shared pedestrian and cycle pathways adjoining the water crossings would be located on fill embankment above the 1 EY flood level
- A 250 m long bridge overpass where the shared pedestrian and cycle pathways cross President Avenue and a section of Scarborough Park North
- A waterway crossing where the shared pedestrian and cycle pathways span an existing drainage line that discharges into Scarborough Ponds from Civic Avenue. Subject to detailed design this waterway crossing may be incorporated into an extension to the length of the bridge overpass.

Figure 6-1, sheet 4 and **Figure 6-2**, sheet 4 show 1% AEP flooding patterns and impacts, respectively, under operational conditions. Corresponding results for a PMF event are provided in **Figure 6-3**, sheet 4 and **Figure 6-4**, sheet 4, while corresponding results for a 1 EY event are provided in **Annexure C**.

The investigation found that the concept design for the shared pedestrian and cycle pathways would provide a minimum 1 EY level of flood immunity.

Figure 6-1, sheet 4 shows that depths of ponding along the shared user path would be 0.5 m or less during a 1% AEP flood, which would be classified as low provisional hydraulic hazard in accordance with DIPNR, 2005.

Figure 6-2, sheet 4 shows that the proposed extent of waterway crossings across the upper reach of Scarborough Ponds would mitigate the impact of the shared pedestrian and cycle pathways on peak 1% AEP flood levels within this section of the watercourse.

An assessment of the impact that the proposed filling along the section of the shared pedestrian and cycle pathways adjacent to Civic Avenue in combination with other proposed works would have on flood behaviour in Scarborough Ponds is provided in **section 6.1.4**.

6.1.7 Princes Highway and President Avenue intersection upgrade

In order to improve the connectivity to the new motorway, the Princes Highway and President Avenue would be upgraded to provide additional northbound and southbound turning lanes from the former into the latter. The Princes Highway would be widened along its eastern side between South Street and Green Street, while President Avenue would be widened along both sides between the Princes Highway and Cross Street.

In **section 4.2.5** it was noted that under present day conditions the section of the Princes Highway to the north of President Avenue has a hydrologic standard of around 1 EY, with flows in excess of the capacity of the local stormwater drainage system discharging in an easterly direction through the adjoining properties. It will therefore be necessary to implement a set of design measures that, as a minimum, maintains the existing hydrologic standard of the road and minimises the impact of the proposed works on flood behaviour in adjacent development.

Figure 6-1, sheet 4 shows the concept layout of proposed upgrades to the stormwater drainage system in the vicinity of the Princes Highway and President Avenue intersection. Key features of the concept layout include:

- Upgrading the existing stormwater drainage system that runs from the low point in Princes Highway to the north of President Avenue, along Green Lane and West Botany Street to President Avenue from a 900 mm diameter pipe to a 1200 mm diameter pipe
- Upgrading and extending the existing stormwater drainage system along President Avenue between Princes Highway and Cross Street. The upgraded drainage system would connect into the new drainage system proposed as part of the President Avenue intersection and surface works (refer **section 6.1.4**).

The concept layout of proposed stormwater upgrades outlined above would be further developed during the detailed design stage in consultation with Bayside Council. During detailed design it would also be necessary to design a new pit and pipe drainage system to control local catchment runoff from the widened section of the Princess Highway to the south of President Avenue

Figure 6-1, sheet 4 and **Figure 6-2**, sheet 4 show 1% AEP flooding patterns and impacts, respectively, under operational conditions. Corresponding results for a PMF event are provided in **Figure 6-3**, sheet 4 and **Figure 6-4**, sheet 4.

The investigation found that while the proposed upgrades to the drainage systems that presently control runoff from the Princes Highway and President Avenue would mitigate the impact of the proposed road widening on peak flood levels in adjacent properties, it would also contribute to an increase in the rate of discharge from the pavement drainage outlet 1 into Scarborough Ponds (refer **Figure 6-2**, sheet 4 for location of pavement drainage outlet 1). **Section 6.1.4** presents the findings of an assessment of the impact that the upgrade of the stormwater drainage systems associated with both the President Avenue intersection and surface works and the Princes Highway and President Avenue intersection upgrade would have on flood behaviour in Scarborough Ponds.

6.2 Consistency with council and state government flood plans and policies

Rockdale Local Environmental Plan 2011 (RCC 2011b) sets out flood related planning controls for land that is located within the flood planning area as shown on *Rockdale Local Environmental Pan 2011 Flood Planning Map*, as well as any other land that is located below the flood planning level.

In accordance with the SEARs, a flood planning area has also been defined by the current assessment through mapping the extent of land which lies below the peak 1% AEP flood level plus 0.5 metres under present day conditions. The flood planning area shown on **Figure C-8** in **Annexure C** is based on mainstream flooding along the major rivers, creeks and tributaries that are crossed by the project, as well as the main paths associated with major overland flow. It should be noted that the flood modelling undertaken for the assessment was developed for the specific purpose of assessing the flood risks and impacts associated with the project and therefore should be taken as preliminary only in terms of defining the flood planning area across the broader extent of flood prone land within the catchments that are crossed by the project.

The findings of the assessment presented in **section 6.1** of this technical report show that, subject to the provision of appropriate mitigation measures, the project will have only a minor impact on peak 1% AEP flood levels. As a result, the project will have no significant impact on the extent of the flood planning area and therefore the area of land to which the flood planning controls set out in RCC 2011b would apply.

Spring Street Drain, Muddy Creek and Scarborough Ponds Floodplain Management Study (WP 2000) contains a draft floodplain management plan that defines the hydraulic and hazard categorisation of the floodplain and sets out general, non-structural and location specific structural measures with varying priority rankings to manage the flood risk associated with development on the floodplains of Spring Street Drain, Muddy Creek and Scarborough Ponds. General non-structural measures include the adoption of flood and stormwater management policies (such as RCC 2011a, RCC 2011b and RCC 2011c), the development of flood warning and response measures (such as SES 2009) and improved management and maintenance of drainage assets. Structural measures relevant to Scarborough Ponds include enlarging the outlet to Botany Bay and the flood proofing of flood liable properties. However WP 2000 notes that the low value of average annual damages within the Scarborough Ponds catchment due to the shallow depth of flooding "makes it difficult to justify any of the structural options on benefit-cost grounds".

The findings of the assessment presented in **section 6.1** of this technical report show that the project will have only a minor impact on peak 1% AEP flood levels and velocities. Increases in PMF levels, which would occur to a maximum of 60 millimetres on depths of flooding that exceed one metre, are also considered minor in terms of the relative increase in flood hazard. As a result, the project would have no significant impact on the hazard categorisation of the floodplain.

Given the extent of works that are proposed as part of the project and the relatively minor nature of their impact on flood behaviour under present day conditions, the project would not preclude or limit any of the measures identified in the draft floodplain management plan that is contained in WP 2000.

Rockdale City Local Flood Plan (SES 2009) provides a plan for the operation of emergency response to flooding within the Rockdale City Council LGA (now part of Bayside Council), including the catchments of the Cooks River, Spring Street Drain, Muddy Creek and Scarborough Ponds. The plan sets out the preparedness measures, the process for carrying out response operations and the coordination of immediate recovery measures from flooding.

As noted above, the findings of the assessment presented in **section 6.1** of this technical report show that the project will have only a minor impact on peak 1% AEP flood levels. Increases in PMF levels, which would occur to a maximum of 60 millimetres on depths of flooding that exceed 1 metre, are also considered minor in terms of the relative increase in flood hazard. As a result, the project will have no adverse impact on the emergency response arrangements set out in SES 2009. Furthermore, the upgrade of President Avenue would improve its hydrologic standard from less than 1 EY under present day conditions to a minimum of 1% AEP following the construction of the project, thereby having the beneficial effect of improving access across the floodplain during times of flood.

6.3 Impact of future climate change on flood behaviour

6.3.1 Impact of future climate change on flooding to the project

Peak flood levels at key locations along the project for current climate conditions, as well as for the assessed climate change scenarios set out in **Table 3-4,** are shown in **Table 6-4** at the end of this chapter.

Potential impacts of future climate change on flood behaviour for a storm with an AEP of 1% are as follows:

- Arncliffe motorway operations complex – Peak 1% AEP flood levels could potentially be increased by between 0.6 metres and 1.1 metres under future climate change conditions. The upper bound estimate of the 1% AEP post-climate change flood level would still be approximately 1.0 metre below the PMF level, which sets the minimum level of the tunnel ancillary facilities
- Rockdale motorway operations complex (north) – Peak 1% AEP flood levels could potentially be increased by between 0.1 metres and 0.6 metres under future climate change conditions which is primarily due to an increase in rainfall intensities. The upper bound estimate of the 1% AEP post-climate change flood level would still be approximately 0.7 metres below the PMF level, which sets the minimum level of the tunnel ancillary facilities
- Rockdale motorway operations complex (south) – There could potentially be a minor increase in peak 1% AEP flood levels of between 0.04 metres and 0.09 metres under future climate change conditions, which would still be around 1 metre below the PMF level, which sets the minimum level of the tunnel ancillary facilities
- President Avenue tunnel portal - There could potentially be a minor increase in peak 1% AEP flood levels of between 0.04 metres and 0.09 metres under future climate change conditions, which would still be over 1 metre below the PMF level which sets the minimum level of the tunnel portal
- President Avenue road upgrade - Peak 1% AEP flood levels could potentially be increased by between 0.3 metres and 0.7 metres under future climate change conditions. While President Avenue would be inundated to a maximum depth of 0.2 metres under the lower bound estimate, one lane would be accessible to traffic in each direction. Under the upper bound estimate, President Avenue would be inundated across its full width to a maximum depth of 0.6 m
- England Street to Civic Avenue pedestrian and cycle pathways – Peak 1% AEP flood levels could potentially be increased by between 0.3 metres and 0.7 metres under future climate change conditions
- Princes Highway and President Avenue intersection upgrade – There would be a minor increase in peak 1% AEP flood levels at the low point in the Princes Highway to the north of President Avenue of between 0.01 metres and 0.02 metres under future climate change conditions.

The assessment found that peak PMF levels at the tunnel ancillary facilities (Arncliffe motorway operations complex, Rockdale motorway operations complex (north) and (south)) and the President Avenue tunnel portal would be increased by between 0.06 m and 0.40 metres due to a 0.9 metres rise in sea level (Scenario 2). In order to manage the risk of flooding to the tunnels over the design life of the project, the impact of future sea level rise would need to be taken into consideration when setting the minimum level of entries to the tunnel ancillary facilities and tunnel portal. Based on the concept design of the President Avenue intersection and surface works the road level at the entry to the President Avenue tunnel portal has been designed to be above the PMF level including allowance for an increase in PMF level under Scenario 2.

6.3.2 Impact of the project on flood behaviour under future climate change conditions

The impact of the project on flood behaviour during a 0.5% and 0.2% AEP event (adopted as proxies for assessing the sensitivity to an increase in 1% AEP design rainfall intensities of between 10% and 30% due to climate change) is shown on **Figures C-16** and **C-18** in **Annexure C** and can be summarised as follows:

- Arncliffe motorway operations complex – Increases in peak 0.5% and 0.2% AEP flood levels are typically 10 mm or less and occur over a significantly smaller area when compared to those during a 1% AEP event. While **Figure C-18** also shows a localised area to the north of Marsh

Street where peak 0.2% AEP flood levels would be increased by a maximum of 50 mm, this increase is a function of the volume of flow surcharging the road and partially filling localised depressions. It is likely that flood levels within these localised depressions would be influenced by local drainage features that are not included in the model, which would have the effect of reducing the impact presented in **Figure C-18**

- Rockdale motorway operations complex (north) – There would be an increase in peak flood levels in two residential properties in West Botany Street of between 0.1 to 0.12 metres during a 0.5% and 0.2% AEP event, which is similar to those during a 1% AEP event
- Rockdale motorway operations complex (south) - There would be an increase in peak flood levels in West Botany Street by a maximum of 0.02 metres during both a 0.5% and 0.2% AEP event, which is similar to those during a 1% AEP event
- President Avenue intersection and surface works – There would be an increase in peak flood levels within Scarborough Ponds by a maximum of 0.04 metres during both a 0.5% and 0.2% AEP event, which is similar to those during a 1% AEP event. While increases in peak flood levels during a 0.5% AEP event would be confined to the Rockdale Bicentennial Park reserve, increases in peak flood levels during a 0.2% AEP event would extend into three industrial properties that are located in Bermill Street

  During both a 0.5% and 0.2% AEP event there would be localised increase in peak flood levels by a maximum of 0.03 metres within the front yards of two residential properties that are located to the north and south of President Avenue, immediately west of O'Connell Street, which is slightly greater than the increases in peak flood levels during a 1% AEP event
- England Street to Civic Avenue cycle and pedestrian pathways – There would be no significant change in peak flood levels during both a 0.5% and 0.2% AEP event, which is consistent with the findings of the assessment for a 1% AEP event
- Princes Highway and President Avenue intersection upgrade – The proposed upgrades to the stormwater drainage system would mitigate the impact of the proposed road widening on peak flood levels in adjacent properties during both a 0.5% and 0.2% AEP event, which is consistent with the findings of the assessment for a 1% AEP event.

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

Table 6-5 shows the impact a partial blockage of major hydraulic structures would have on peak flood levels at key locations along the project. The assessment showed that a partial blockage of major hydraulic structures would have only a minor impact on peak flood levels in the vicinity of the project.

Table 6-4 Summary of peak flood levels – current and future climate change conditions(1)

Location(2)	Project infrastructure	1% AEP					PMF				
		Current conditions	Scenario 1		Scenario 2		Current conditions	Scenario 1		Scenario 2	
		Level (m AHD)	Level (m AHD)	Change (m)(3)	Level (m AHD)	Change (m)(3)	Level (m AHD)	Level (m AHD)	Change (m)(3)	Level (m AHD)	Change (m)(3)
Arncliffe motorway operations complex	Extension of New M5 Motorway complex to accommodate electrical substation and water treatment plant	1.79	2.40	+0.61	2.85	+1.06	3.88	4.06	+0.18	4.28	+0.40
Rockdale motorway operations complex (north)	Motorway ancillary facility comprising motorway control centre, tunnel deluge, maintenance and storage facilities	3.11	3.22	+0.11	3.33	+0.22	4.11	4.14	+0.03	4.20	+0.09
Rockdale motorway operations complex (south)	Motorway ancillary facility comprising ventilation exhaust and supply, electrical substation and disaster recovery facility	3.49	3.53	+0.04	3.57	+0.08	4.54	4.56	+0.02	4.60	+0.06
President Avenue intersection and surface works	President Avenue tunnel portal	3.70	3.74	+0.04	3.77	+0.07	3.99	4.04	+0.05	4.12	+0.13
	President Avenue road upgrade	2.54	2.85	+0.31	3.20	+0.66	3.97	4.03	+0.06	4.12	+0.15
England Street to Civic Avenue pedestrian and cycle pathways	Section of pedestrian and cycle pathways north of President Avenue	2.54	2.85	+0.31	3.20	+0.66	3.97	4.03	+0.06	4.12	+0.15
	Section of pedestrian and cycle pathways south of President Avenue	2.51	2.82	+0.31	3.19	+0.68	3.97	4.03	+0.06	4.12	+0.15
Princes Highway and President Avenue intersection	Princes Highway road upgrade at low point north of President Avenue	14.96	14.97	+0.01	14.98	+0.02	15.06	15.06	0.00	15.06	0.00

Notes:
1 Peak flood levels quoted to two decimal places for ease of comparison only. Adopted flood levels for design purposes should be rounded off to the nearest 0.1 m.
2 Refer **Figure 6-1** for location of project infrastructure.
3 A positive value represents an increase and conversely a negative value represents a decrease relative to current climate conditions.

Table 6-5 Impact of a partial blockage of major hydraulic structures on peak flood levels [1]

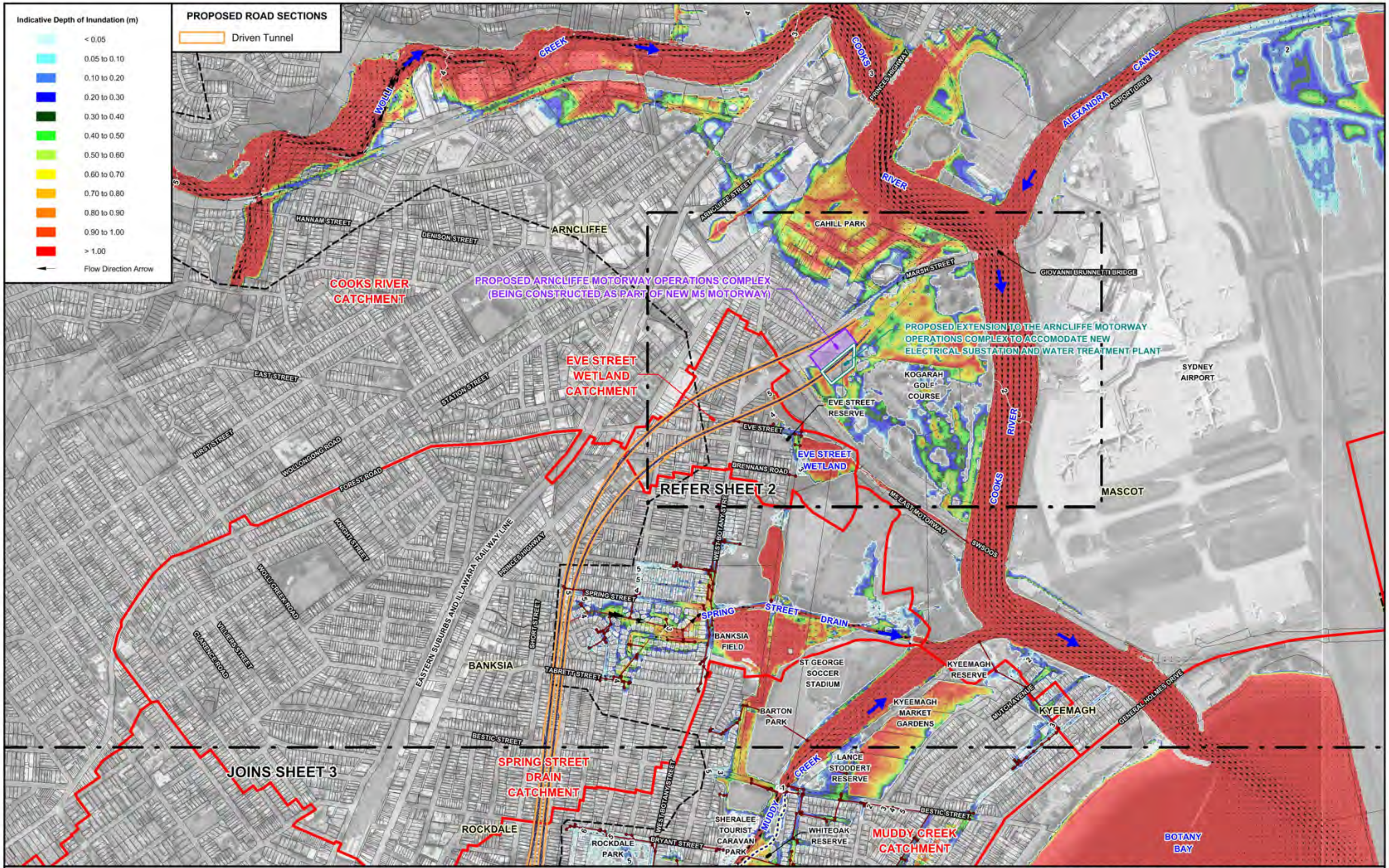
Location[2]	Project infrastructure	1% AEP			PMF		
		Without blockage	With blockage		Without blockage	With blockage	
		Level (m AHD)	Level (m AHD)	Change (m)[3]	Level (m AHD)	Level (m AHD)	Change (m)[3]
Arncliffe motorway operations complex	Extension of New M5 Motorway complex to accommodate electrical substation and water treatment plant	1.79	1.80	+0.01	3.88	3.93	+0.05
Rockdale motorway operations complex (north)	Motorway ancillary facility comprising motorway control centre, tunnel deluge, maintenance and storage facilities	3.49	3.49	0.00	4.54	4.54	0.00
Rockdale motorway operations complex (south)	Motorway ancillary facility comprising ventilation exhaust and supply, electrical substation and disaster recovery facility	3.11	3.12	+0.01	4.28	4.28	0.00
President Avenue intersection and surface works	President Avenue tunnel portal	3.70	3.70	0.00	3.99	3.99	0.00
	President Avenue road upgrade	2.54	2.59	+0.05	3.97	3.97	0.00
England Street to Civic Avenue pedestrian and cycle pathways	Section of pedestrian and cycle pathways north of President Avenue	2.54	2.59	+0.05	3.97	3.97	0.00
	Section of pedestrian and cycle pathways south of President Avenue	2.51	2.54	+0.03	3.97	3.97	0.00
Princes Highway and President Avenue intersection	Princes Highway road upgrade at low point north of President Avenue	14.96	14.96	0.00	15.06	15.06	0.00

Notes:

1 Peak flood levels quoted to two decimal places for ease of comparison only. Adopted flood levels for design purposes should be rounded off to the nearest 0.1 m.

2 Refer **Figure 6-1** (3 sheets) for location of project infrastructure.

3 A positive value represents an increase and conversely a negative value represents a decrease relative to unblocked conditions.



N

120 0 120 240 360 m

Scale: 1:12,000

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Note:

The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

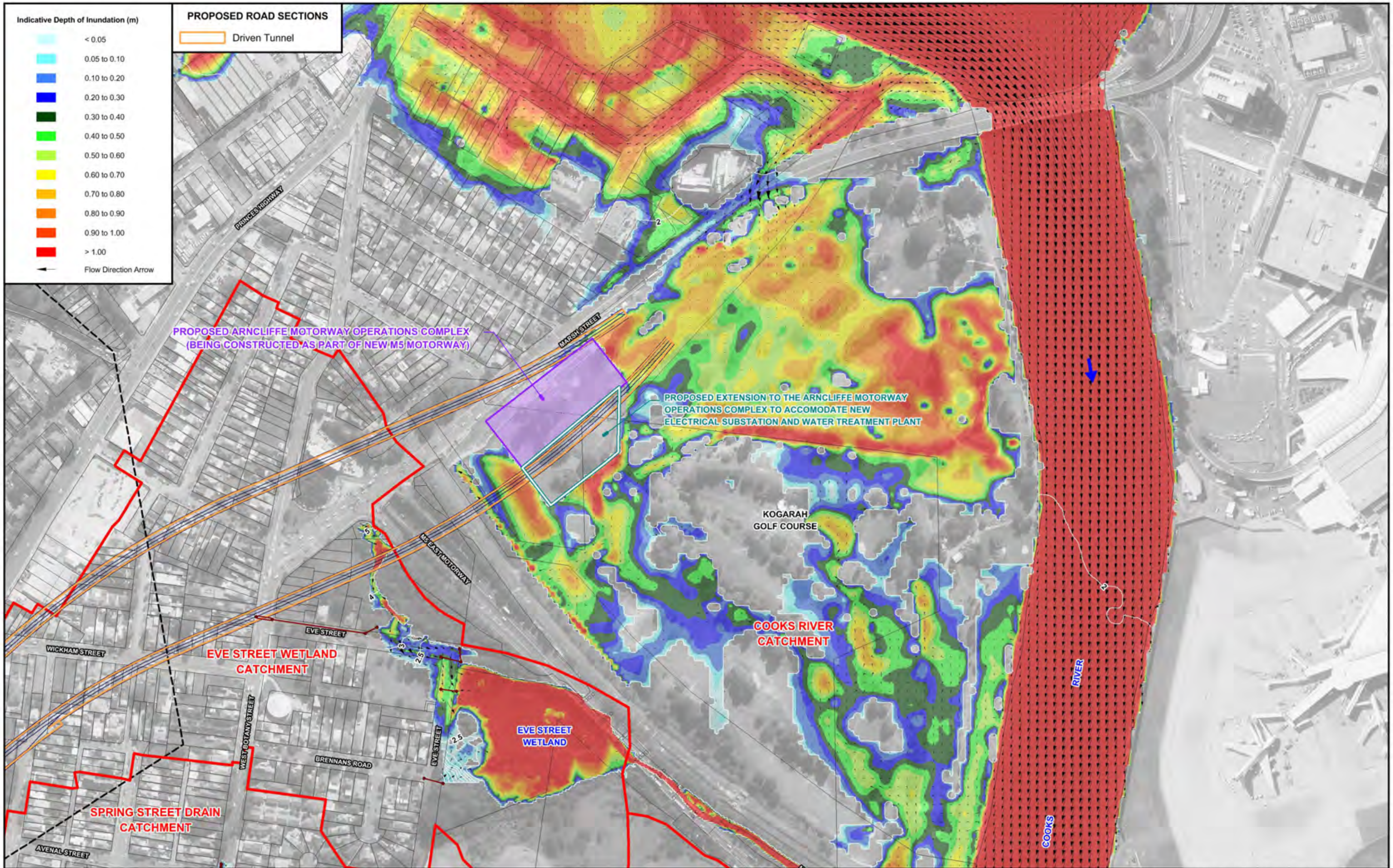
LEGEND

- Proposed Tunnel Road Works
- Proposed Cycle and Pedestrian Pathways
- Project Boundary of Proposed Surface Works
- Water Surface Elevation Contours (m AHD)
- Catchment Boundary
- Existing Drainage System
- Two-Dimensional Model Boundary
- Proposed Motorway Operations Complex and Footprint of Tunnel Ancillary Facilities

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-1
Sheet 1 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - 1% AEP



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Scale: 1:4,000

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LEGEND

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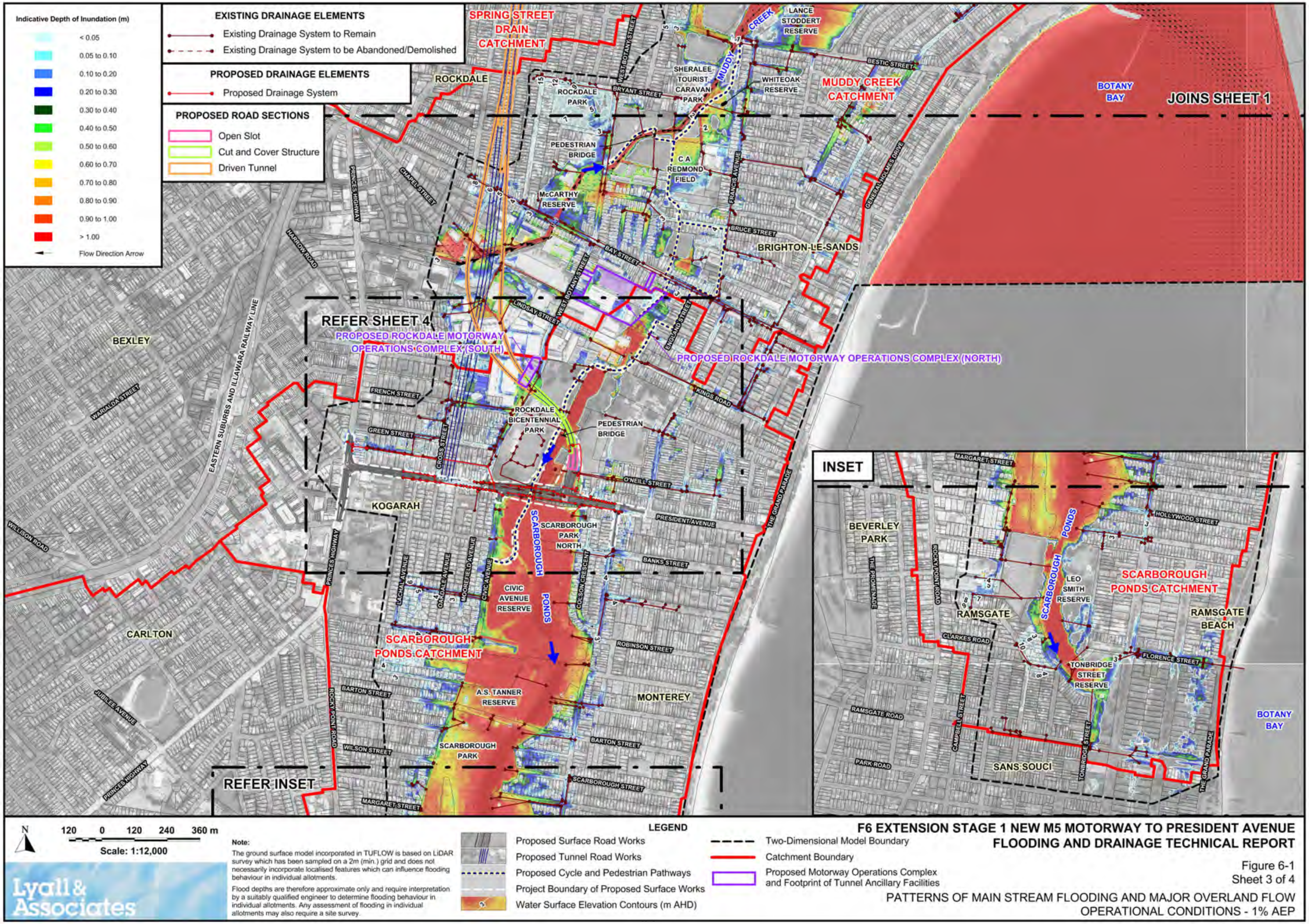
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-1
Sheet 2 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - 1% AEP



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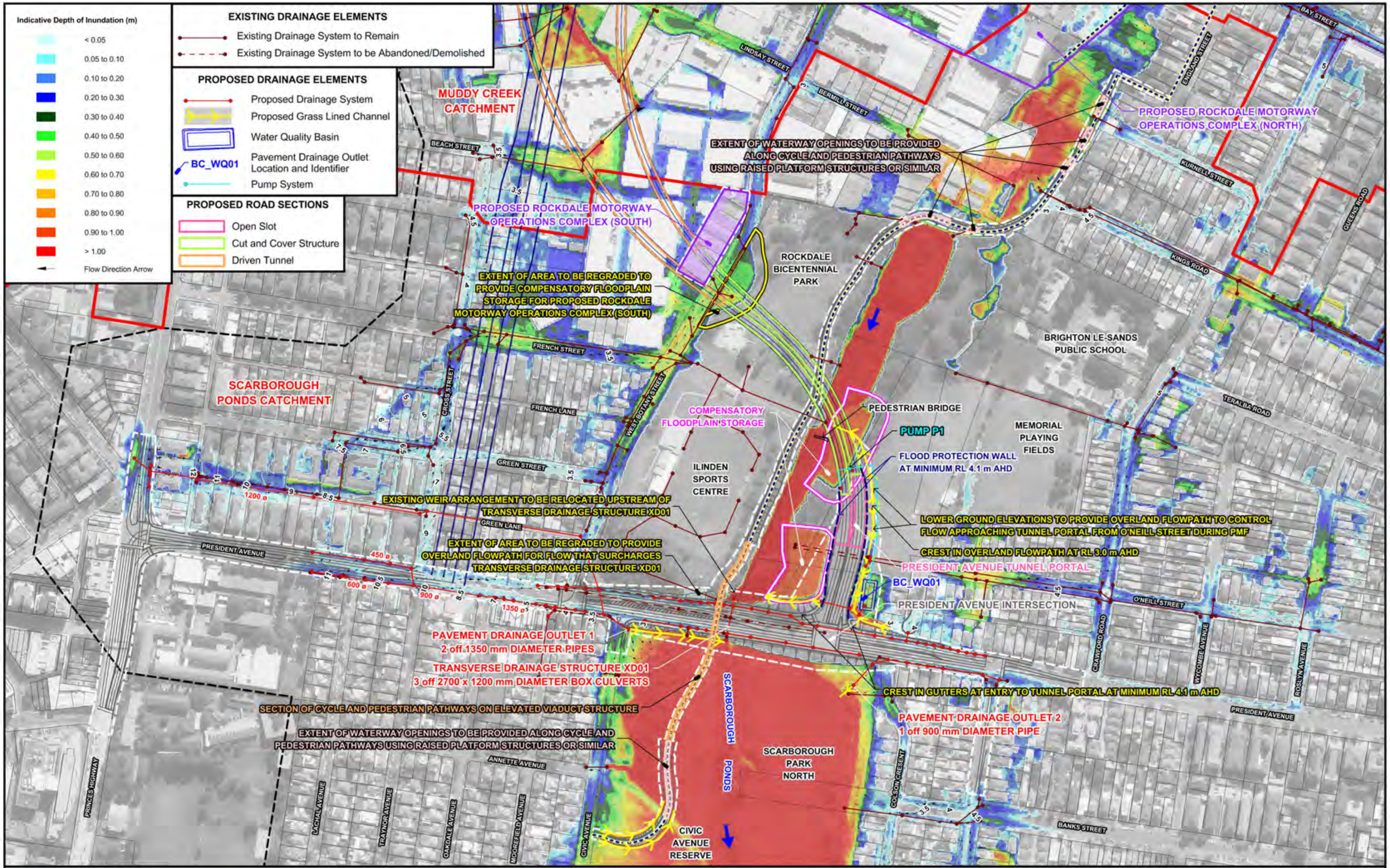
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-1
Sheet 3 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - 1% AEP



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Scale: 1:4,000

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LEGEND
- Proposed Surface Road Works
- Proposed Tunnel Road Works
- Proposed Cycle and Pedestrian Pathways
- Project Boundary of Proposed Surface Works
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- Catchment Boundary
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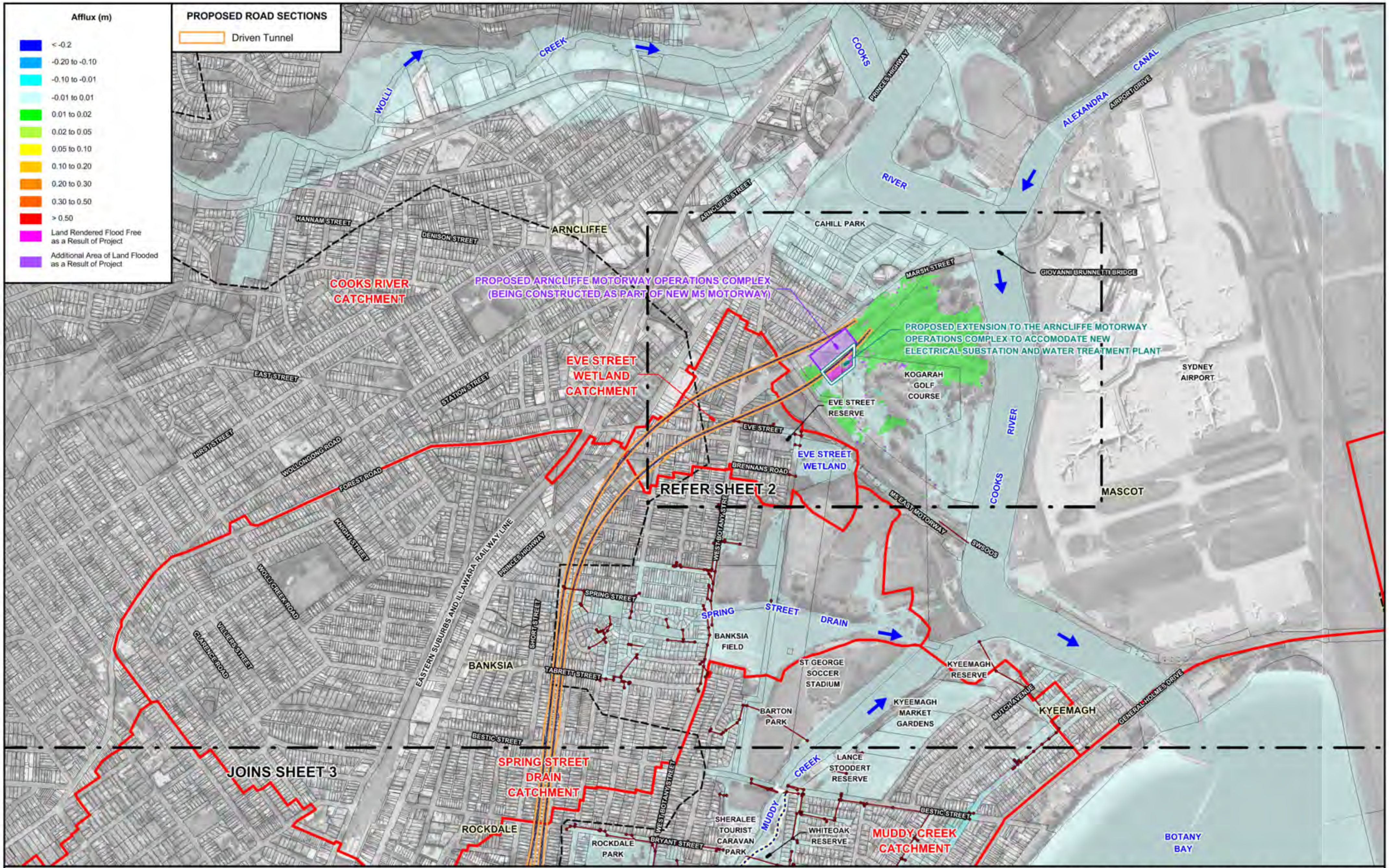
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-1
Sheet 4 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - 1% AEP



N

120 0 120 240 360 m

Scale: 1:12,000

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LEGEND

- Proposed Tunnel Road Works
- Proposed Cycle and Pedestrian Pathways
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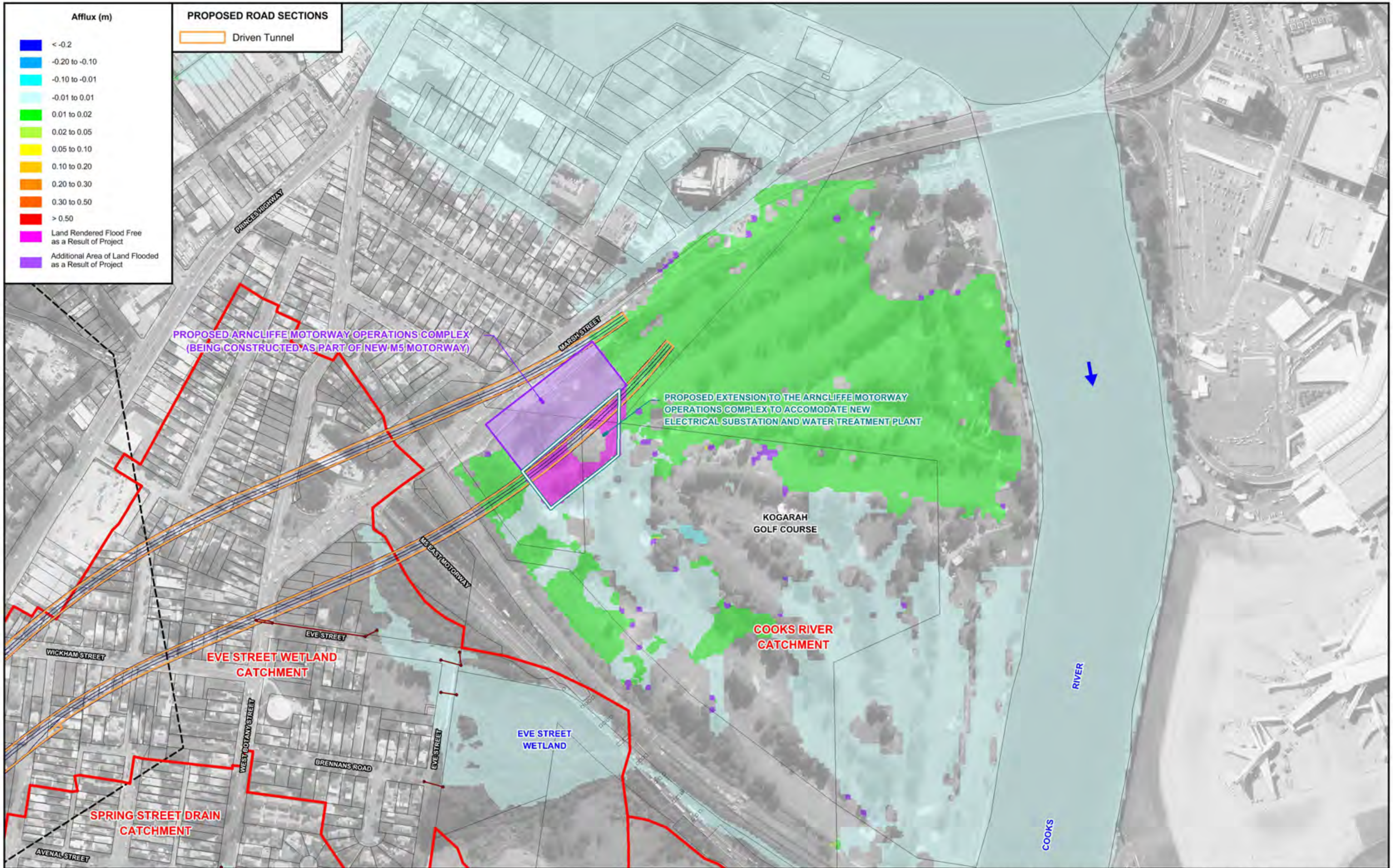
- Two-Dimensional Model Boundary
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-2
Sheet 1 of 4

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
1% AEP



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- Catchment Boundary

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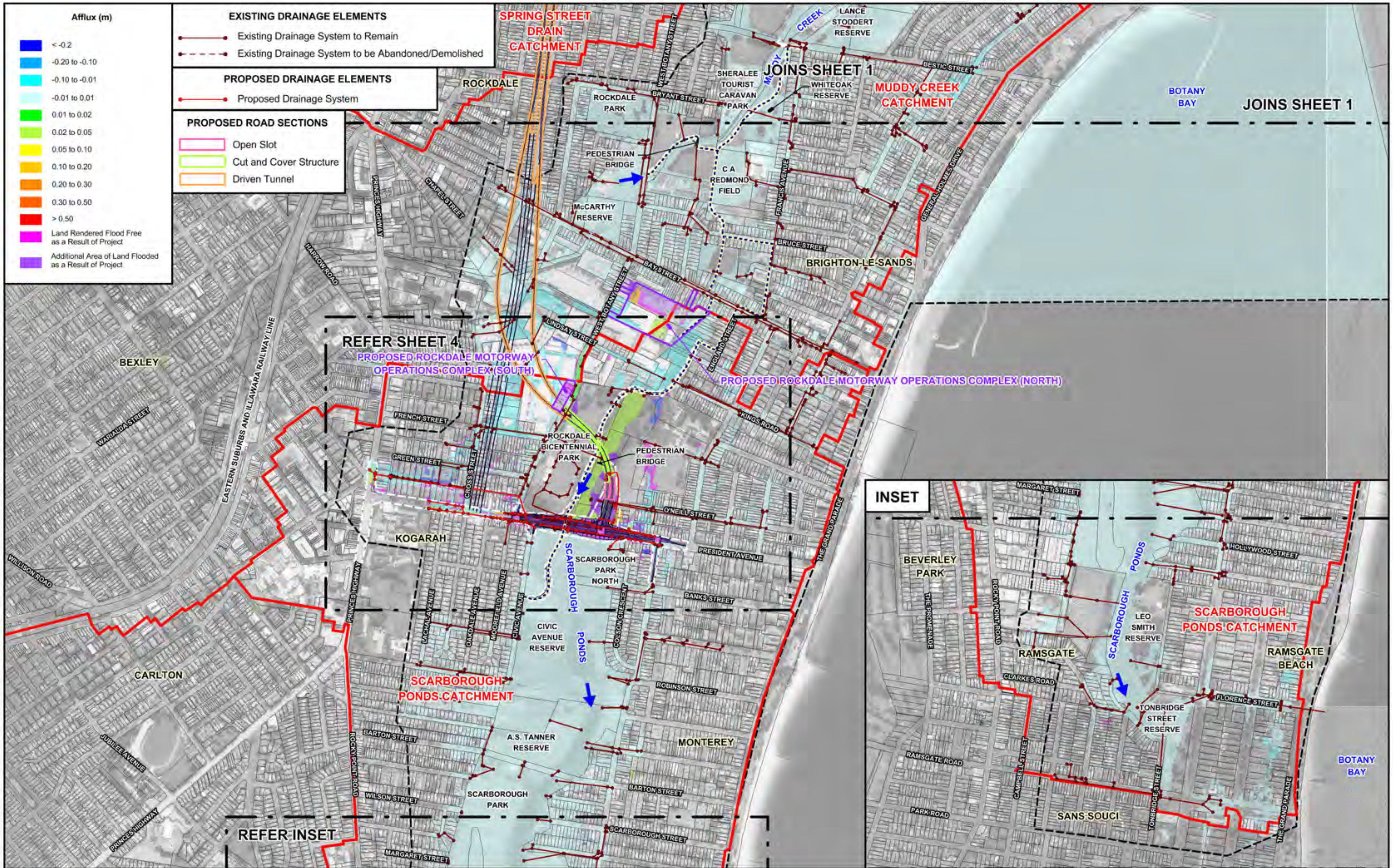
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-2
Sheet 2 of 4

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
1% AEP



N

120 0 120 240 360 m

Scale: 1:12,000

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LEGEND

- Proposed Surface Road Works
- Proposed Tunnel Road Works
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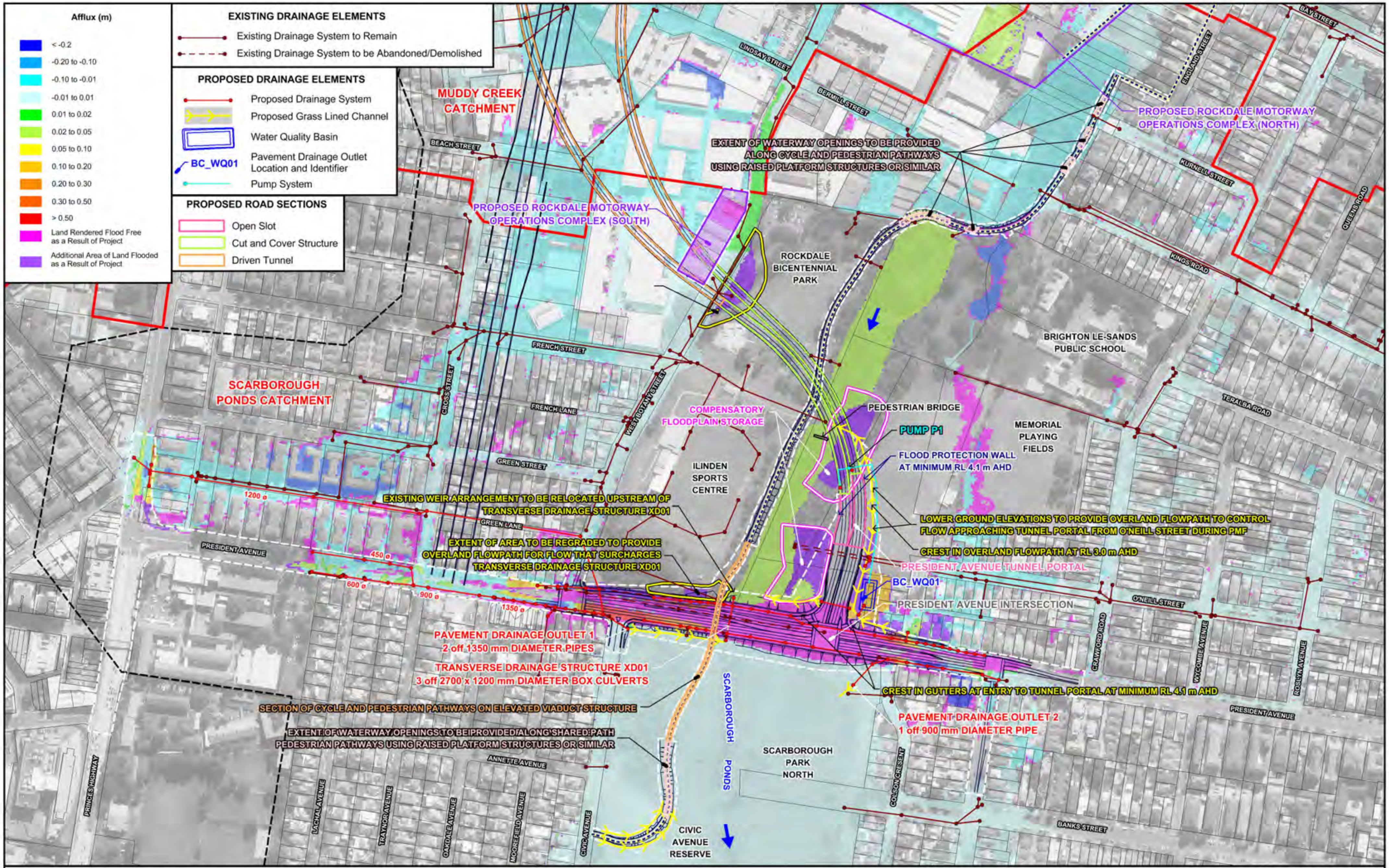
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-2
Sheet 3 of 4

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
1% AEP



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LEGEND

Proposed Surface Road Works	Two-Dimensional Model Boundary
Proposed Tunnel Road Works	Catchment Boundary
Proposed Cycle and Pedestrian Pathways	Proposed Motorway Operations Complex and Footprint of Tunnel Ancillary Facilities
Project Boundary of Proposed Surface Works	

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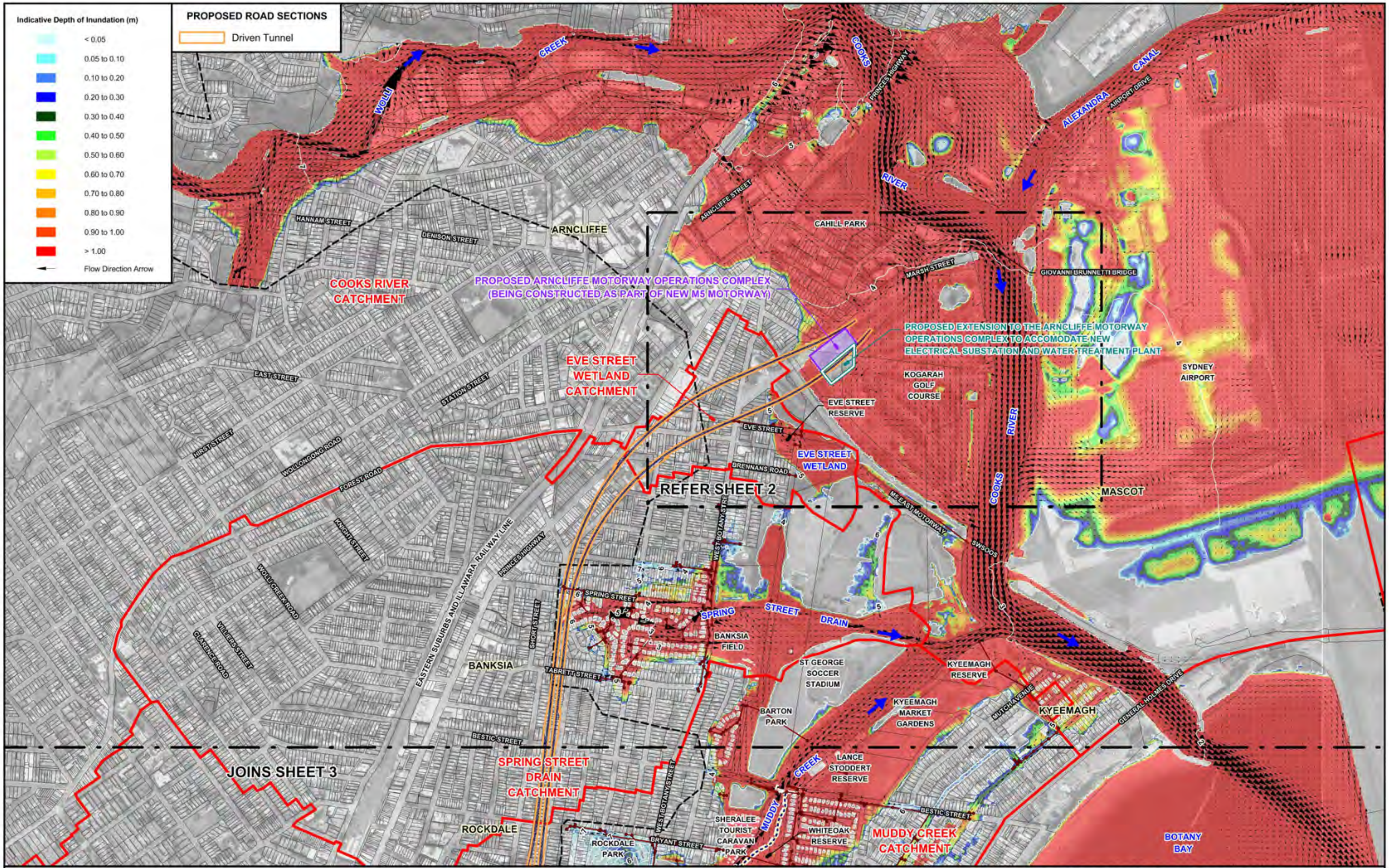
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-2
Sheet 4 of 4

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
1% AEP



N

120 0 120 240 360 m

Scale: 1:12,000

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Note:

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LEGEND

- Proposed Tunnel Road Works
- Proposed Cycle and Pedestrian Pathways
- Project Boundary of Proposed Surface Works
- Water Surface Elevation Contours (m AHD)
- Catchment Boundary
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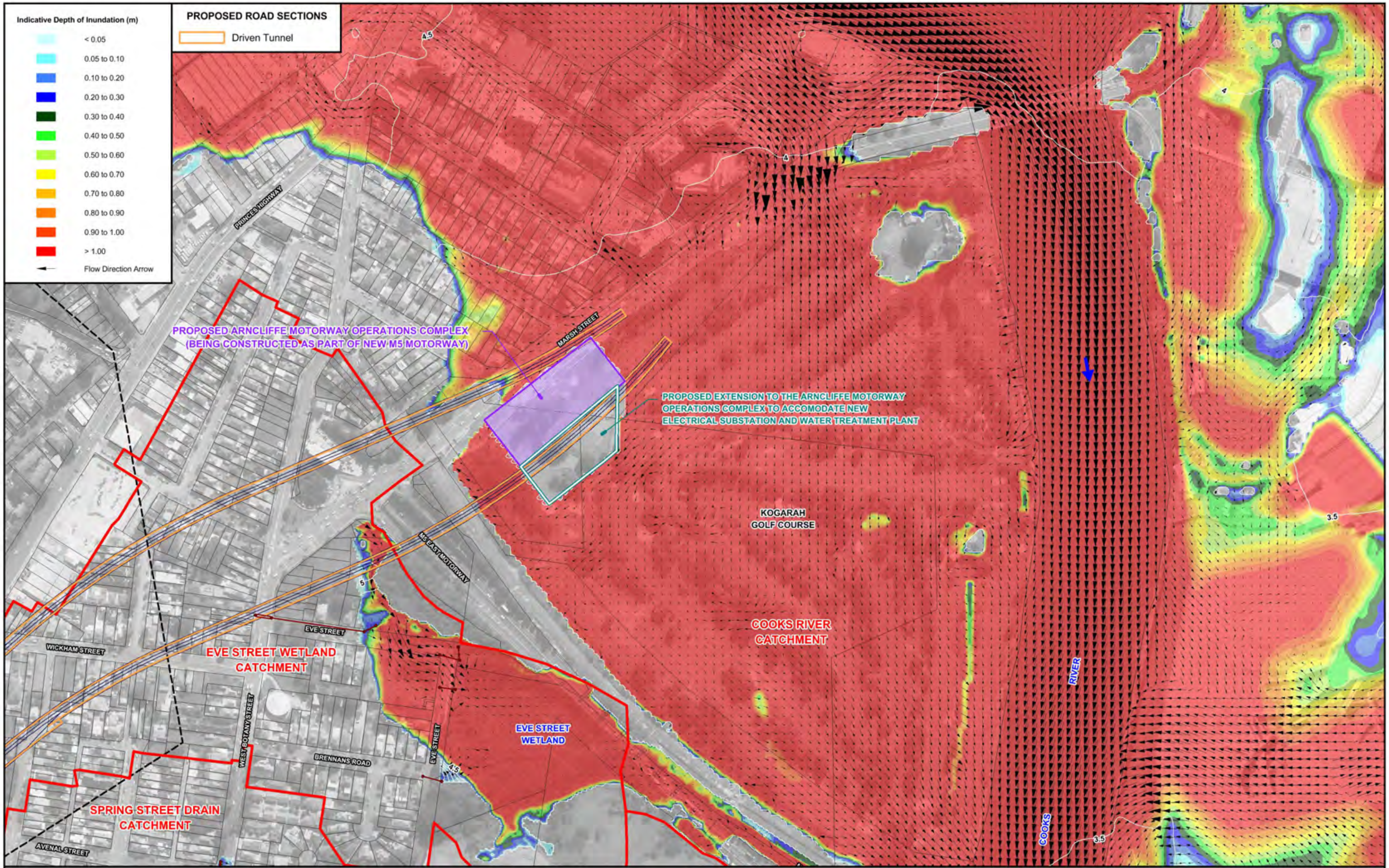
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-3
Sheet 1 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - PMF



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LEGEND

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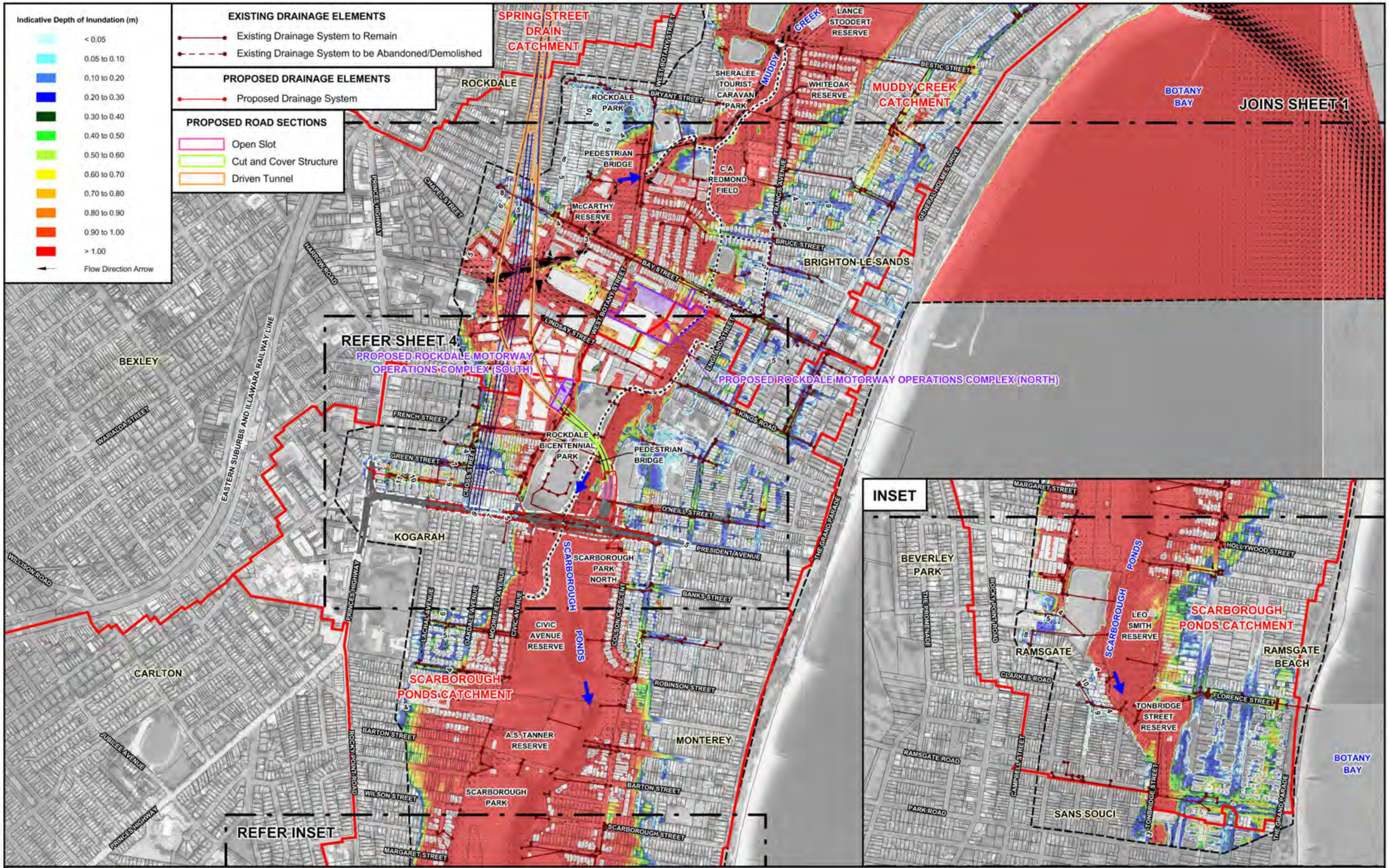
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-3
Sheet 2 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - PMF



120 0 120 240 360 m

Scale: 1:12,000

Note:

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LEGEND

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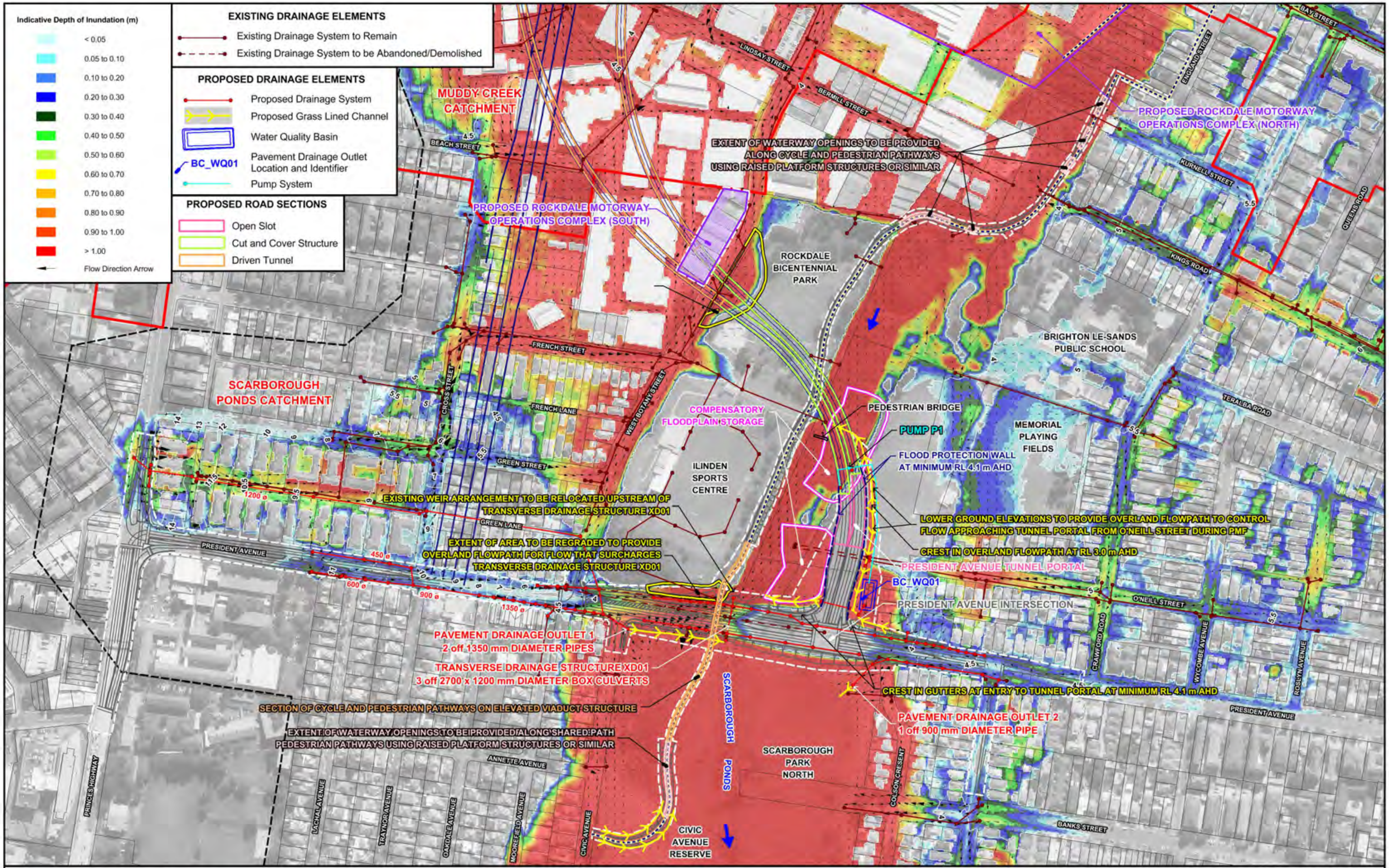
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-3
Sheet 3 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - PMF



Note:

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Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

- Proposed Surface Road Works
- Proposed Tunnel Road Works
- Proposed Cycle and Pedestrian Pathways
- Project Boundary of Proposed Surface Works
- Water Surface Elevation Contours (m AHD)
- Two-Dimensional Model Boundary
- Catchment Boundary
- Proposed Motorway Operations Complex and Footprint of Tunnel Ancillary Facilities

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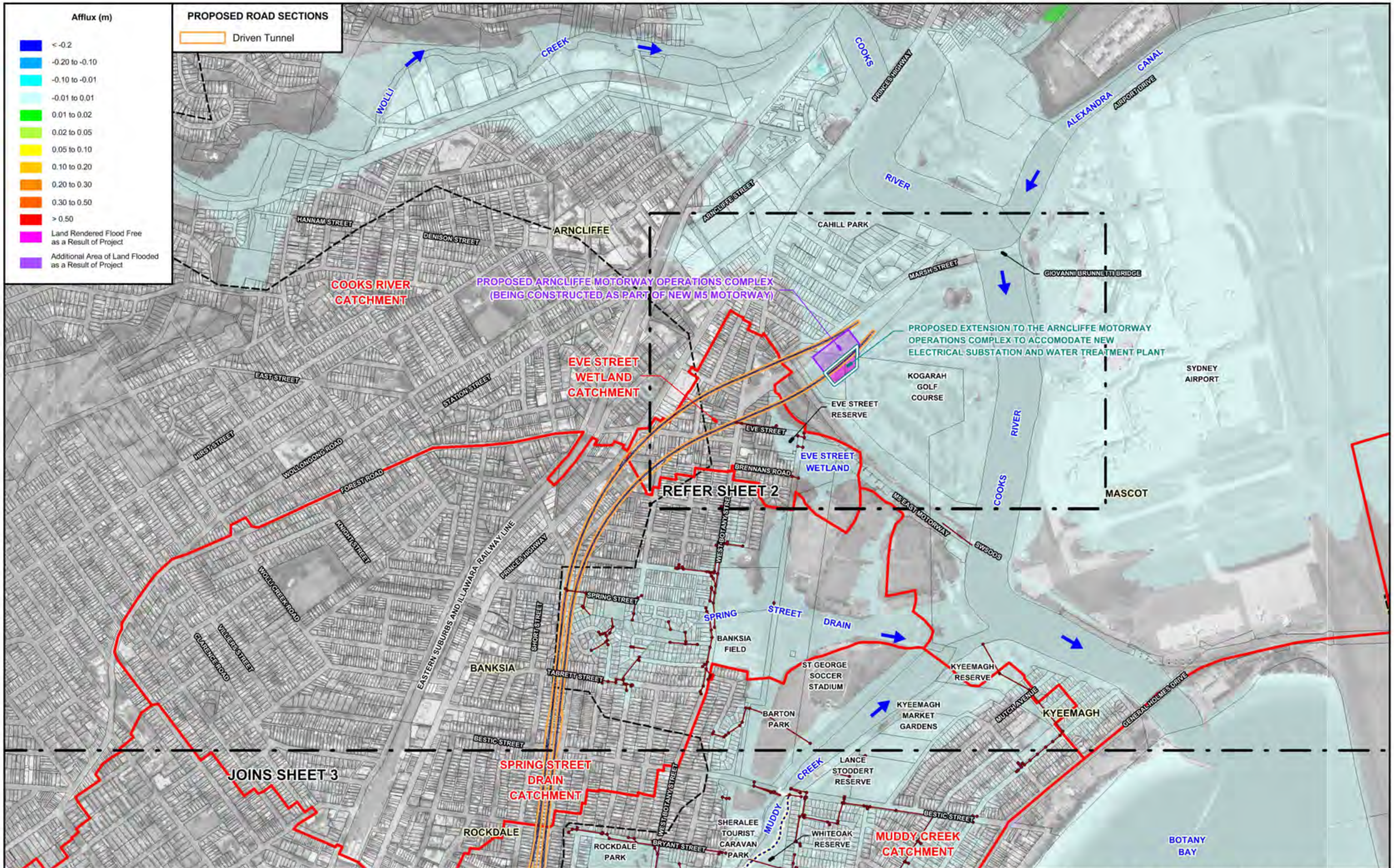
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-3
Sheet 4 of 4

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - PMF



N

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Scale: 1:12,000

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Lyall & Associates

LEGEND

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- Existing Drainage System
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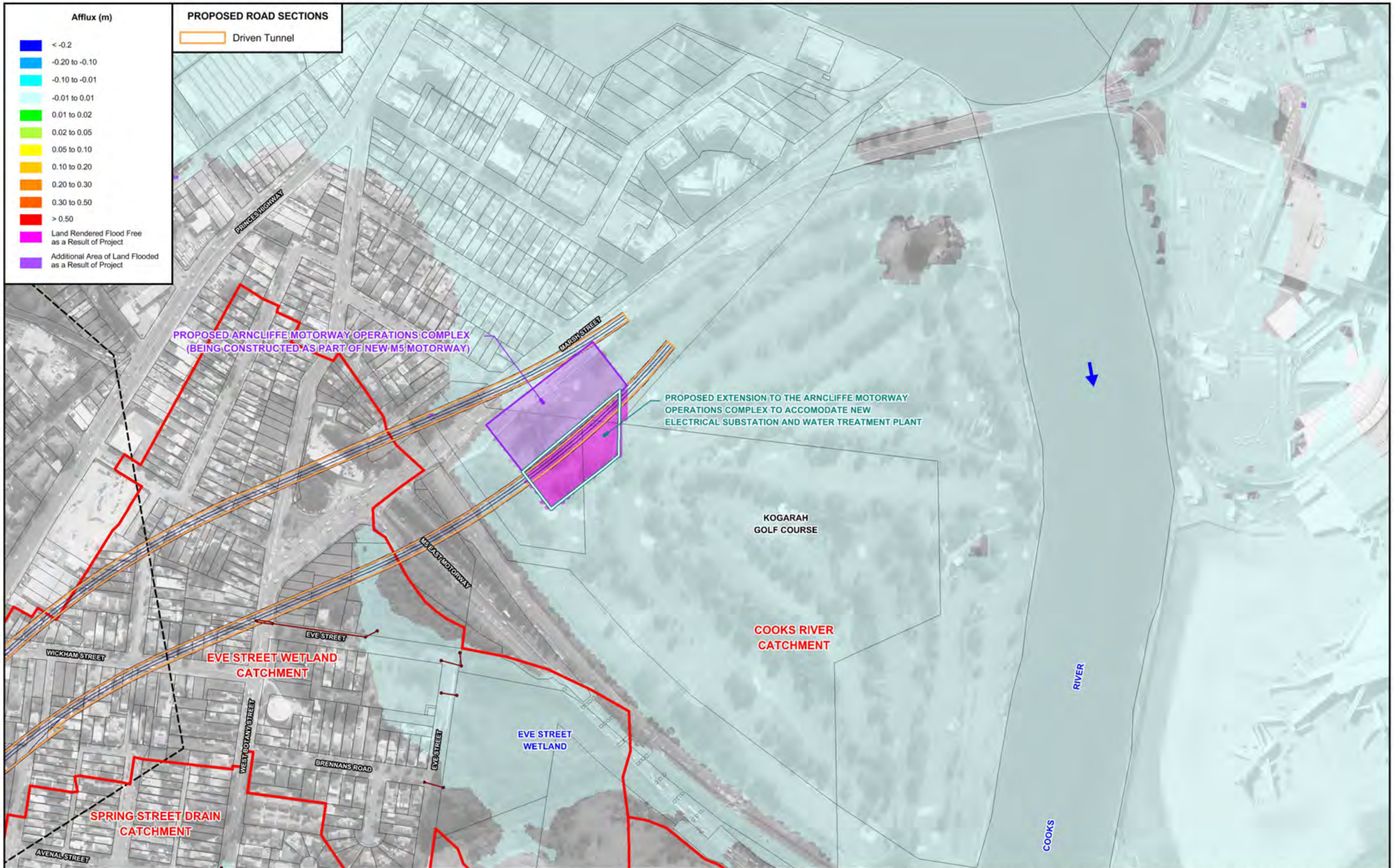
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-4
Sheet 1 of 4

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
PMF



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40 0 40 80 120 m

Scale: 1:4,000

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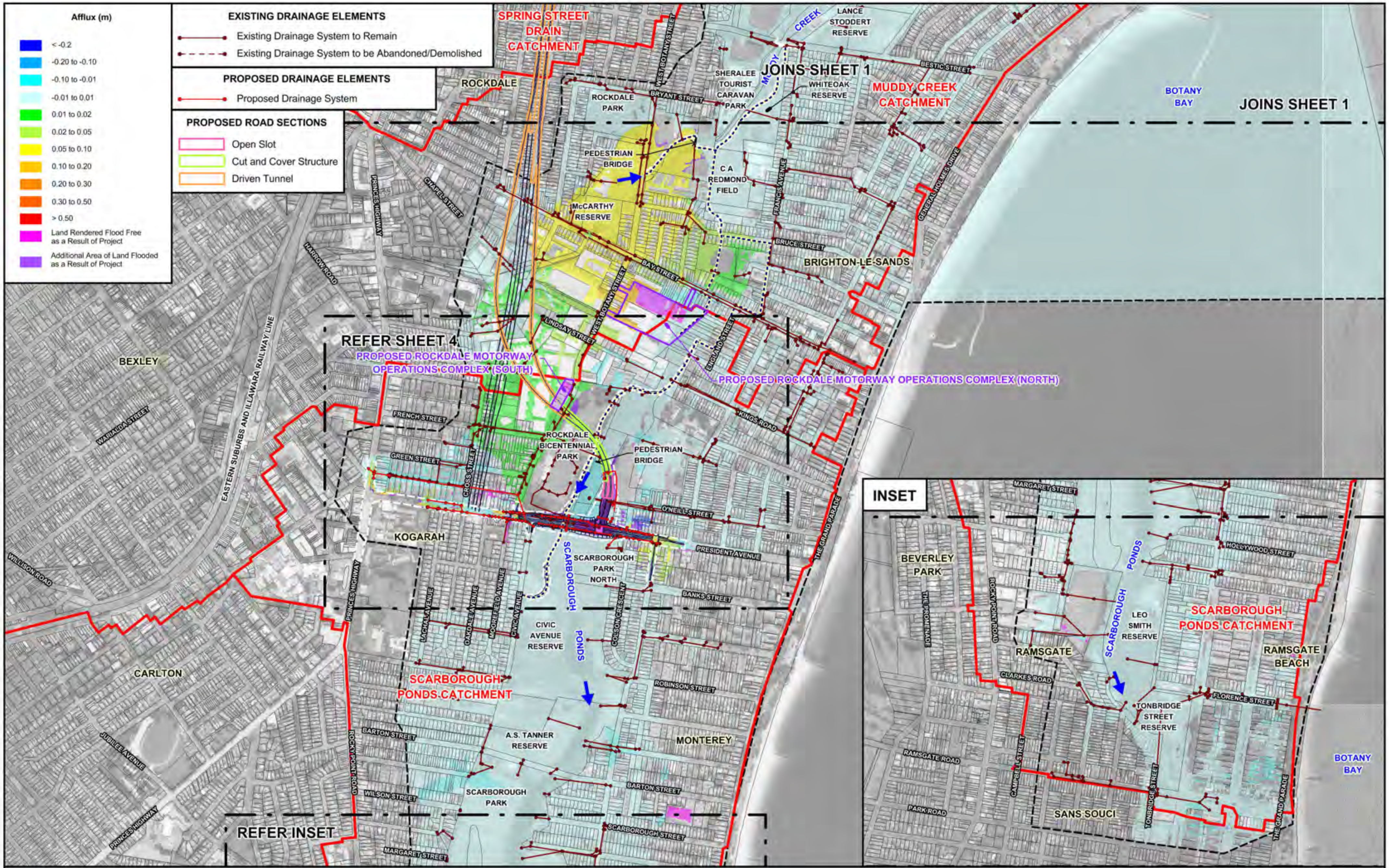
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-4
Sheet 2 of 4

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
PMF



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Scale: 1:12,000

Lyall & Associates

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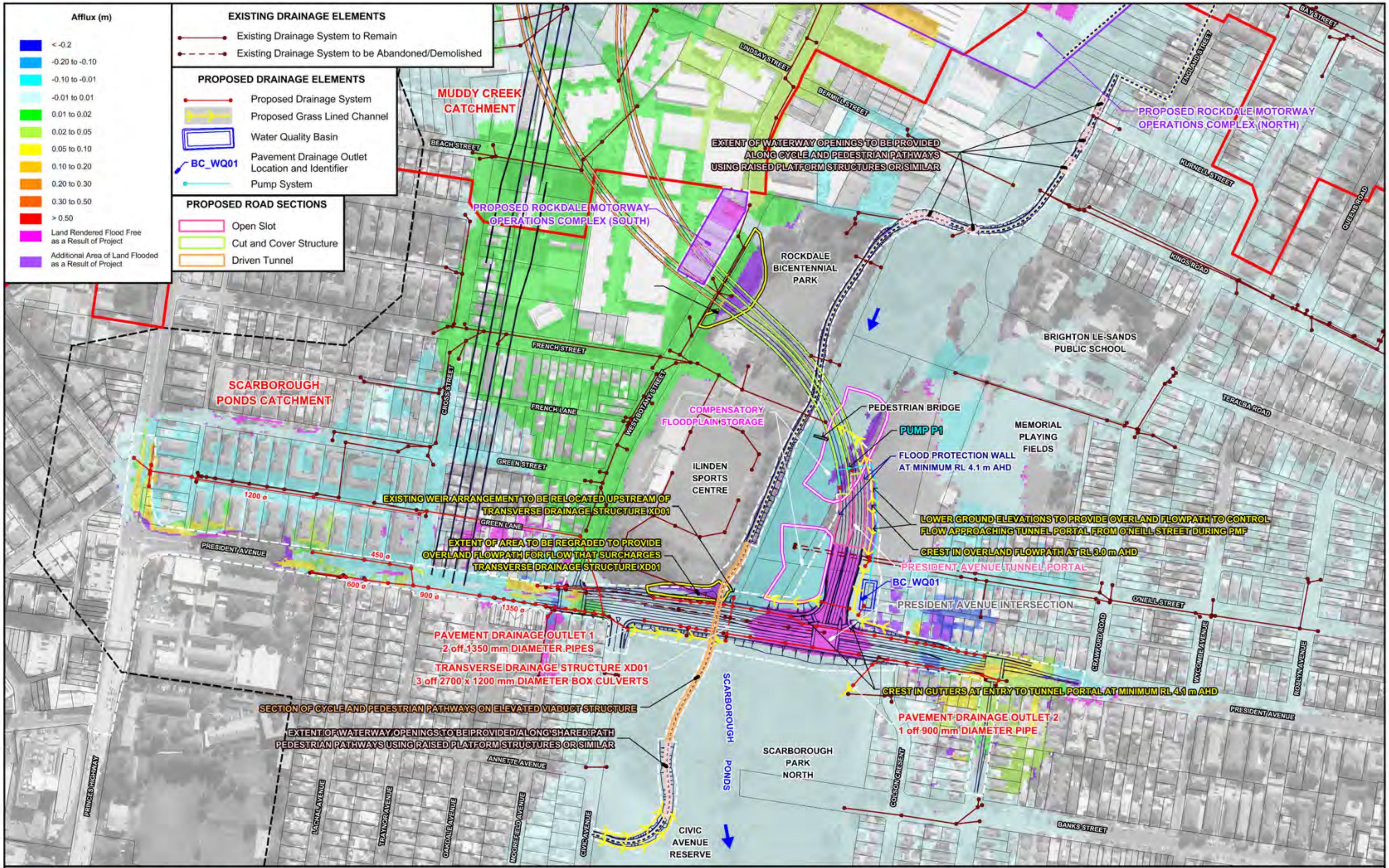
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-4
Sheet 3 of 4

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
PMF



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LEGEND

Proposed Surface Road Works
Proposed Tunnel Road Works
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Catchment Boundary
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F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 6-4
Sheet 4 of 4

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
PMF

7 Assessment of cumulative impacts

This section presents the findings of an assessment of the potential impacts the project would have on flood behaviour in combination with other projects in its vicinity. The assessment was based on impacts during the operation of the project only, given the short term nature of exposure to potential flood impacts during the construction of the project together with the general requirement to manage adverse impacts on existing development.

7.1 Other motorway projects

Table 7-1 summarises the key findings of an assessment of potential cumulative impacts on flood behaviour as a result of the project with other motorway projects in its vicinity.

The assessment found that while the cumulative impact of the project with the New M5 Motorway project would increase peak 1% AEP flood levels by a maximum of 30 mm, increases would be confined to the open space of the Kogarah Golf Course and the road reserve of Marsh Street.

The assessment also found that due to the localised nature of the project related flood impacts there would be no cumulative impacts associated with it and other major motorway projects. While there is the potential for cumulative type impacts with potential future stages of the F6 Extension (President Avenue to Loftus), given the minor nature of the project related flood impacts it is expected that the impacts attributable to the future project can be managed through the implementation of appropriate mitigation measures. The potential for impacts associated with the potential future stages of the F6 Extension (President Avenue to Loftus) would need to be assessed once its scope has been defined.

7.2 Other projects

An assessment was carried out of the potential impact that the project would have on flood behaviour in combination with the following non-motorway projects in its vicinity:

- Residential development within the Cooks Cove Precinct that is identified in the *Bayside West Precincts Draft Land Use and Infrastructure Strategy* (Department of Planning and Environment, 2016).
- Renewal of the Muddy Creek channel that is proposed by Sydney Water.

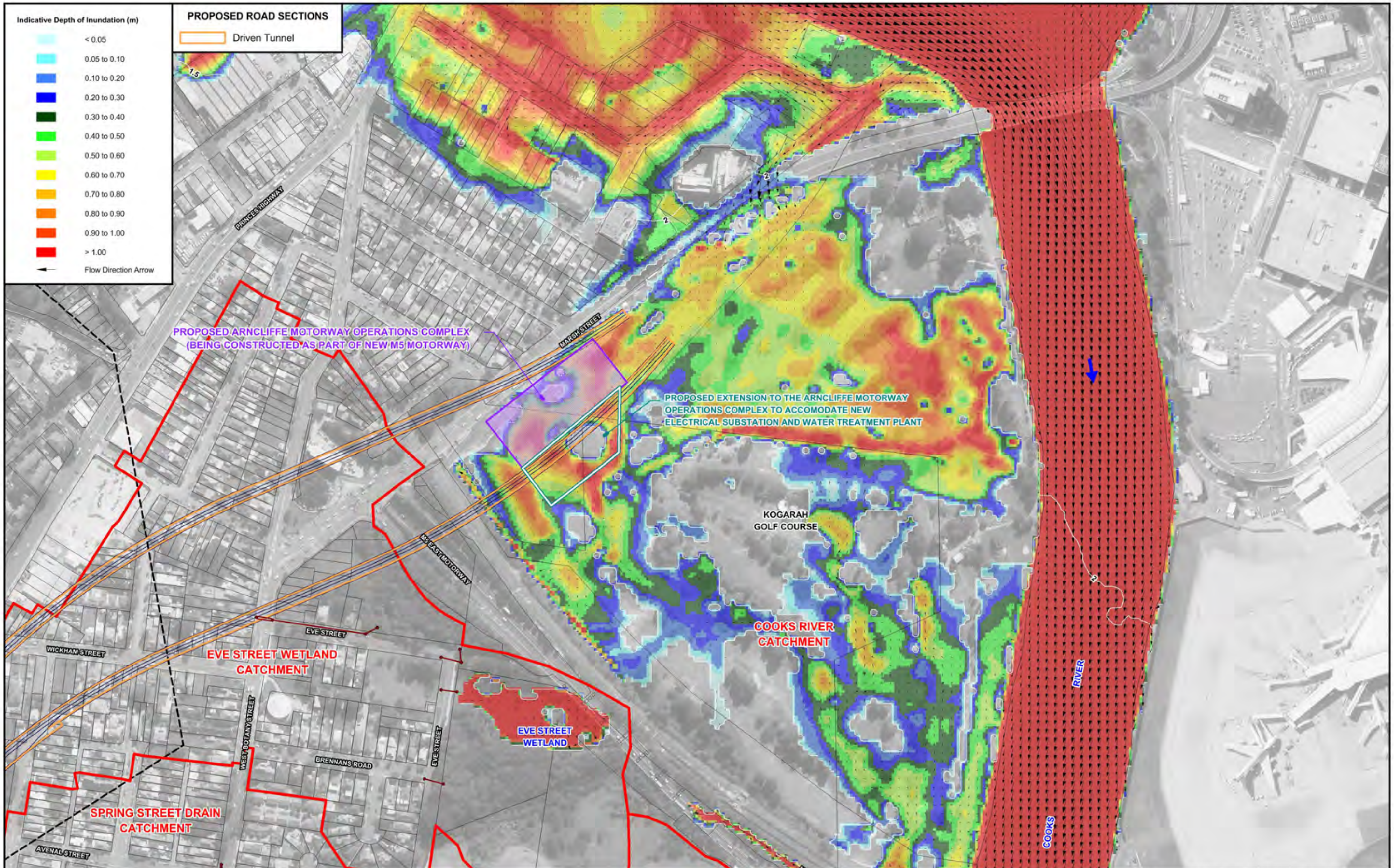
The Cooks Cove Precinct covers an area of around 135 hectares which is mostly open space associated with the Kogarah Golf Course and Barton Park. The precinct is bound by Marsh Street to the north, the Cooks River and Sydney Airport to the east, West Botany Street to the west and Bestic Street to the south.

The precinct includes an area of land along the western bank of Muddy Creek to the north of Bestic Street, immediately downstream of the shared cycle and pedestrian pathways that is proposed for future development. Planning for future residential development within the precinct is in its early stages and as such no environmental assessment was available for review at the time of the present investigation. It would be expected that the redevelopment within the precinct would be undertaken in a manner that minimises the potential for adverse flood impacts in adjacent properties. On this basis, and given the location of the precinct relative to the proposed shared cycle and pedestrian pathways, the potential for the future development to impact flood behaviour is considered to be low.

The extent of the Muddy Creek channel renewal project includes part of the proposed alignment of the shared cycle and pedestrian pathways between Bestic Street and West Botany Street. The Muddy Creek channel renewal project is in its early planning stages and as such no environmental assessment was available for review at the time of the present investigation. It would be expected that the creek naturalisation works would be designed and constructed in a manner that minimises the potential for adverse flood impacts in adjacent properties. Consultation would be undertaken with Sydney Water during the detailed design stage of the project to ensure that the design of the shared pedestrian and cycle pathways is coordinated with the future plans for renewal of the Muddy Creek channel. As part of this process it would also be necessary to assess the cumulative impacts of the project with the Muddy Creek channel renewal project in order to ensure that their combined impact on flood behaviour is managed.

Table 7-1 Summary of potential cumulative flood impacts with other motorway projects

Motorway project	Assessed potential for cumulative impacts on flood behaviour
WestConnex Stage 1 (M4 Widening / M4 East)	• No cumulative impacts on flood behaviour as the M4 Widening / M4 East projects are located in adjacent catchments that are remote from the project.
WestConnex Stage 2 (New M5 Motorway)	• The flood model developed of the Cooks River floodplain was used to assess the cumulative impact of the current project with the New M5 Motorway project as a result of the combined Arncliffe motorway operations complex, which accommodates additional tunnel ancillary facilities for the project • Figure 7.1 shows 1% AEP flooding patterns prior to the construction of the Arncliffe motorway operations complex, while Figure 7.2 shows the cumulative impact that the total footprint of the Arncliffe motorway operations complex would have on flooding behaviour in terms of changes in peak flood levels • The cumulative impact of the two projects would result in an increase in peak 1% AEP flood levels in the Kogarah Golf Course and the road reserve of Marsh Street by a maximum of 30 mm, which is 19 mm greater than the current project alone.
WestConnex Stage 3 (M4-M5 Link)	• No cumulative impacts on flood behaviour as the M4-M5 Link project is located in adjacent valleys that are remote from the project.
King Street Gateway	• No cumulative impacts on flood behaviour as the King Street Gateway project is located in adjacent catchments that are remote from the project.
Sydney Gateway	• No cumulative impacts on flood behaviour as the Sydney Gateway project is located in adjacent catchments that are remote from the project.
Western Harbour Tunnel and Beaches Link	• No cumulative impacts on flood behaviour as the Western Harbour Tunnel and Beaches Link project is located in catchments that are remote from the project.
Potential future stages of the F6 Extension (President Avenue to Loftus)	• Potential future stages of the F6 Extension (President Avenue to Loftus) project would likely involve works on the Scarborough Ponds floodplain that, in combination with the project, have the potential for cumulative impacts on flood behaviour • While subject to future design development and environmental approvals, the potential future stages of the F6 Extension (President Avenue to Loftus) project is likely to include an additional surface connection on the Scarborough Ponds floodplain to the south of the President Avenue intersection. Cumulative impacts will need to be assessed as part of the environmental approvals process for the potential future stages of the F6 Extension (President Avenue to Loftus) project once its details are known. However, given the minor nature of flood impacts associated with the project, it is expected that the cumulative impacts of the multiple stages can be managed through appropriate mitigation measures. Such measures may include, for example, the provision of compensatory floodplain storage within the Scarborough Ponds floodplain.



N

40 0 40 80 120 m

Scale: 1:4,000

Lyall & Associates

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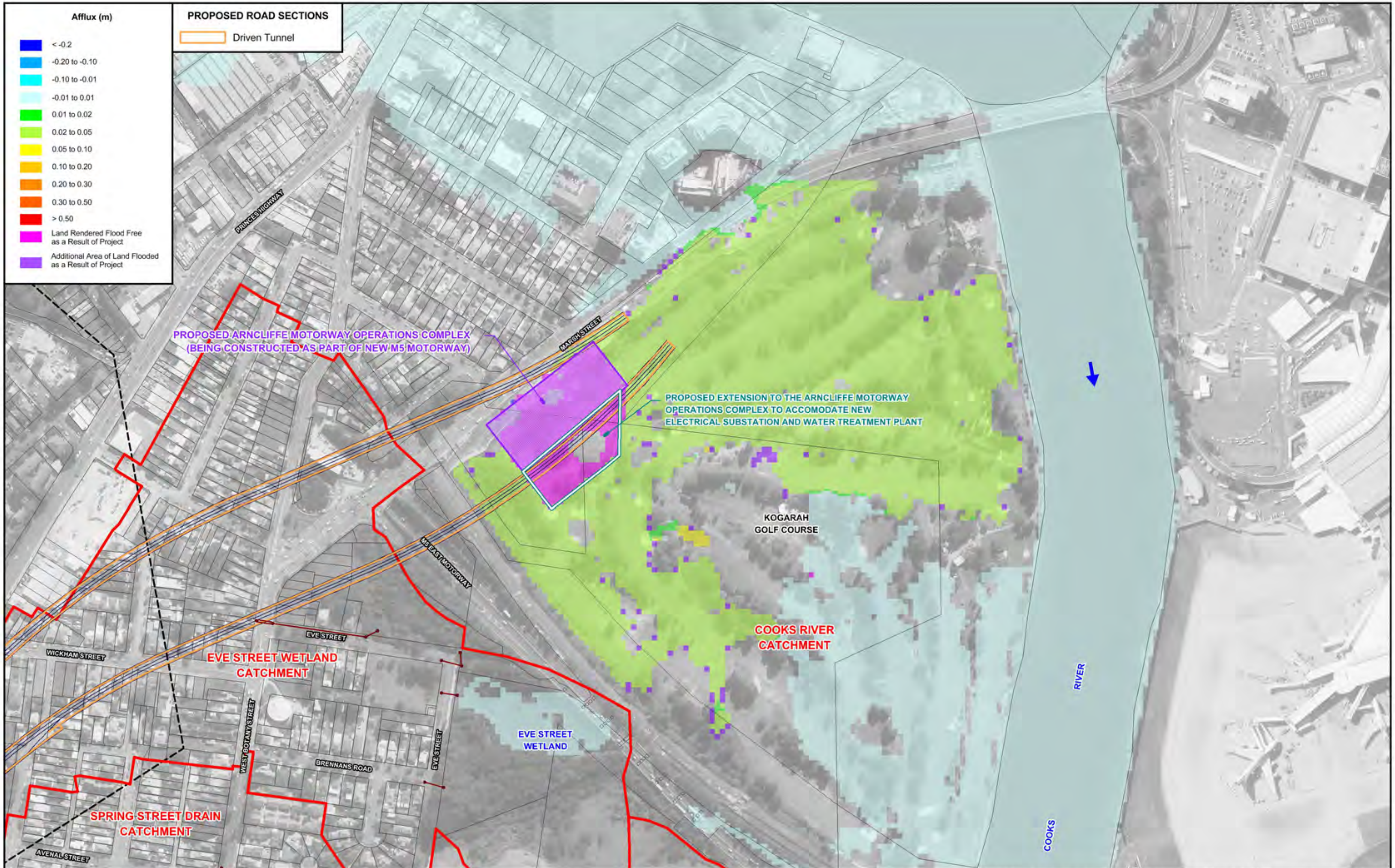
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 7-1

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-WESTCONNEX NEW M5 MOTORWAY CONDITIONS - 1% AEP



N

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F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure 7-2

CUMULATIVE IMPACT OF PROJECT WITH WESTCONNEX NEW M5 MOTORWAY ON FLOOD BEHAVIOUR
1% AEP

8 Management of impacts

8.1 General requirements

A Flood Management Strategy (FMS) will be prepared to demonstrate how the risk of flooding to the project, as well as the impact it would have on flood behaviour under present day conditions, will be mitigated during both the construction and operational phases. The FMS will build on the flood assessment presented in this technical report and will be based on further design development and flood modelling that will be undertaken during the detailed design stage. It will also include but not be limited to:

- The identification of flood risks to the project, including the consideration of local drainage characteristics and the potential impacts of future climate change and a partial blockage of waterway structures on flood behaviour
- The identification of potential flood impacts on the existing environment and future development potential of land, including the collection of floor level survey where required to confirm whether there would be an increase in the frequency and depth of above-floor inundation to existing residential, commercial and industrial buildings
- The identification of design and flood mitigation measures that will be implemented to manage the risk of flooding to proposed operations and not worsen existing flooding characteristics during construction and operation, including erosion and scour
- The preparation of a flood emergency management plan that will set out the measures to be implemented in order to prepare for a flood, as well as the procedures that will need to be implemented during a flood.

The FMS would be prepared by a suitably qualified and experienced person in consultation with directly affected landowners, Sydney Water, OEH, SES and relevant councils.

The following sections outline measures which should be considered during the preparation of the FMS.

8.2 Management of construction impacts

The FMS will need to include consideration of the following in regards to managing the impact of flooding during the construction of the project:

Tunnel construction

- Entries to tunnel excavations, including cut and cover sections of tunnel, will be protected against frequent flooding to an appropriate standard through site planning and by locating openings outside flood prone areas, and/or the provision of local bunding and flood protection barriers
- The flood standard adopted at each tunnel entry during construction will need to be developed taking into consideration the duration of construction, the magnitude of inflows and the potential risks to personal safety and the project works.

Surface earthworks

- Surface earthworks associated with the construction of the Rockdale motorway operations complexes (north and south), the President Avenue intersection and surface works, the shared pedestrian and cycle pathways and the Princes Highway and President Avenue intersection upgrade are located in areas affected by mainstream flooding and/or major overland flow. Concentrated flow, which currently discharges onto the land proposed for project surface earthworks has the potential to cause scour of disturbed surfaces, as well as the transport of sediment and construction materials. It will therefore be necessary to plan, implement and maintain measures which are aimed at intercepting this concentrated flow and diverting it in a controlled manner whether through or around the construction sites.

Spoil management

- Spoil stockpiles will need to be located in areas which are not subject to frequent inundation by floodwater and ideally outside the 1% AEP flood extent. The exact level of flood risk accepted at stockpile sites will depend on the duration of stockpiling operations, the type of material stored, the nature of the receiving drainage lines and also the extent to which that would impact flooding conditions in adjacent development. The frequency at which each construction site is impacted by flooding is summarised in **Table 5-1**.

Site facilities and flood emergency management

- As a minimum, site facilities are to be located outside high flood hazard areas based on a 1% AEP flood
- For site facilities located within the floodplain, the FMS is to identify how risks to personal safety and damage to construction facilities and equipment will be managed
- The FMS will need to include details of:
  - how the contractor will monitor weather conditions and also disseminate warnings to construction personnel of impending flood producing rain
  - an evacuation plan for construction personnel should a severe weather warning be issued.

Management of adverse flood impacts on existing development

- The FMS will need to include details and procedures to manage the potential for proposed construction activities to adversely impact on flood behaviour in adjacent development
- A more detailed assessment into the impact that construction activities would have on flood behaviour, as well as the scope of measures which will be required to mitigate those impacts, will need to be undertaken during the preparation of the FMS with the benefit of more detailed site layouts and staging diagrams
- Subject to more detailed assessment during the preparation of the FMS, a floor level survey will need to be undertaken of affected properties (i.e. in properties where there is a potential increase in flood levels) to determine whether construction activities will increase flood damages in adjacent development and if mitigation measures are required
- The layout of the construction sites and their associated ancillary facilities will need to be designed to:
  - limit the extent of works located in high hazard and/or floodway areas
  - divert overland flow either through or around work areas in a controlled manner
  - minimise adverse impacts on flood behaviour in adjacent development.
- Measures to manage residual flood impacts may include:
  - staging construction to limit the extent and duration of temporary works on the floodplain
  - ensuring construction equipment and materials are removed from floodplain areas at the completion of each work activity or should a weather warning be issued of impending flood producing rain
  - providing temporary flood protection to properties identified as being at risk of adverse flood impacts during any stage of construction of the project
  - developing flood emergency response procedures to remove temporary works during periods of heavy rainfall.

Table 8-1 contains a list of measures which could be implemented in order to mitigate the potential impact of proposed construction activities on flood behaviour. The nature and extent of impacts and therefore the scope of mitigation measures required will be subject to further flood assessment during the detailed design phase with the benefit of more detailed construction site layouts and staging plans. Subject to this further flood assessment, additional floor level survey may be required to confirm the extent to which the proposed construction activities would increase flood damages in affected properties and to allow the scope of mitigation measures that may be required to be determined.

Table 8-1 Summary of potential construction phase mitigation measures – 1% AEP flood

Location	Potential mitigation measures
Arncliffe tunnel site construction ancillary facility (C1)	• The extent of the potential construction impacts on flood behaviour in existing development could be minimised by: – providing openings along the perimeter fencing to allow flow that surcharges Marsh Street to enter the site – incorporating measures into the layout of the construction ancillary facility to manage overland flow internal to the site – designing the site surface grading to as far as practical balance cut and fill in areas located below the 1% AEP flood.
Rockdale construction ancillary facility (C2)	• Similar as those for construction site C1.
President Avenue construction ancillary facility (C3)	• The assessment presented in section 5.2 has demonstrated that it would be feasible to mitigate the impact of the proposed cut and cover tunnel construction on flooding in Scarborough Ponds through the appropriate staging and temporary diversion of the ponds around the area of construction. • The impact that construction activities, particularly the temporary diversion of West Botany Street for the construction of the cut and cover structure could have on flood behaviour in existing development could be managed by: – staging the construction of the cut and cover structure to minimise the extent of works within the floodplain at any one time – providing compensatory floodplain storage within the Rockdale Bicentennial Park to offset the displacement of floodwater that would be caused by the provision of flood protection barriers around the cut and cover construction.
Shared cycle and pedestrian pathways construction ancillary facility east (C4)	• The assessment presented in section 5.2 has demonstrated that it would be feasible to mitigate the impact of the proposed construction ancillary facility on flood behaviour through the provision of a 2 m wide corridor along the northern boundary of the site to convey overland flow through the site.
Shared cycle and pedestrian pathways construction ancillary facility west (C5)	• The assessment presented in section 5.2 has demonstrated that it would be feasible to mitigate the impact of the proposed construction ancillary facility on flood behaviour through the provision of a 6 m wide corridor along the south-eastern boundary of the site to convey floodwaters that surcharge the main channel of Muddy Creek.
Princes Highway construction ancillary facility (C6)	• Based on the assessment presented in section 5.2 the proposed construction site is expected to have a negligible impact on existing flood behaviour in its immediate vicinity.
Bestic Street to Bruce Street (CA1)	• The impact that construction activities could have on flood behaviour in existing development could be managed by staging the works to: – implement waterway crossings, drainage channels and other mitigation measures identified as part of the operational flood management strategy as early in the construction timetable as feasible – managing the extent of temporary works on flood prone land and/or including procedures for their removal prior to the occurrence of a flood event.
England Street to Kings Road (CA2)	• Similar as those for construction site CA1.
President Avenue to Civic Avenue (CA3)	• The impact that the construction of the bridge for the shared cycle and pedestrian pathways could have on flood behaviour in existing development could be managed by: – staging the construction of the bridge in order to minimise the extent of the access road and working pads within the floodplain at any one time – developing emergency response procedures that provide for the removal of temporary works on the floodplain during times of flood.

Location	Potential mitigation measures
Princes Highway and President Avenue intersection upgrade (CA4)	• The impact that the construction of the proposed road works could have on flood behaviour in existing development could be managed by: – installing the upgrade of the existing drainage line that runs from the low point in the Princes Highway in an easterly direction along Green Lane to West Botany Street prior to the proposed road widening works – managing the extent of temporary works on flood prone land and/or including procedures for their removal prior to the occurrence of a flood event.

8.3 Management of operational impacts

The FMS will need to include consideration of the following in regards to managing the impact of flooding during the operation of the project:

Tunnel portals and ancillary facilities

- Tunnel entries and associated flood protection barriers are to be located above the PMF level or the 1% AEP flood level plus 0.5 metres (whichever is greater)
- The same hydrologic standard will be applied to tunnel ancillary facilities such as tunnel ventilation buildings, operational water treatment plants, emergency facilities and electrical substations.

President Avenue upgrade

- A 1% AEP level of flood immunity is to be provided to the upgraded section of President Avenue between O'Connell Street and Oakdale Avenue.

Modifications to the Princes Highway and western end of President Avenue

- Modifications to existing roads are to be configured to ensure that the existing level of flood immunity is maintained and increases in flood depths and hazards are minimised.

Shared pedestrian and cycle pathways

- A minimum level of flood immunity of one exceedance per year would be provided to shared user paths within the project footprint.
- Consideration is to also be given to the flood risk to cyclists and pedestrians which may arise due to hazard flooding conditions occurring along the corridor during larger floods (e.g. 1% AEP event).

Potential impacts of future climate change on flood behaviour

- The project will be designed to manage the potential impacts of future climate change on flood behaviour in accordance with the procedures set out in *Practical Considerations of Climate Change – Floodplain Risk Management Guideline* (DECC 2007) and in *Australian Rainfall and Runoff* (GA 2016).

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 flood behaviour when setting finished road level and flood wall heights.

Management of adverse flood impacts on the existing environment

- A detailed hydrologic and hydraulic assessment of the impacts of the project on flood behaviour and the associated measures which are required to mitigate those impacts will be undertaken during detailed design
- Works within the floodplain would be designed to minimise adverse impacts on surrounding development for flooding up to the 1% AEP event in magnitude. Assessment would also be made of impacts during floods 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 1% AEP in magnitude)
- The design of the project would need to incorporate measures that are aimed at mitigating the impact on flood behaviour in properties where existing buildings would experience above-floor inundation under present day conditions during storms of up to 1% AEP in intensity
- The project and associated drainage arrangements would be designed to limit increases in peak discharges in receiving drainage lines in accordance with local council requirements
- Localised increases in velocities due to the upgrade, relocation or provision of new stormwater drainage systems would be mitigated through the provision of scour protection and energy dissipation measures.

Table 8-2 sets out the specific measures which will need to be incorporated into the detailed design in order to mitigate the operational related flood risks to the project, while **Table 8-3** contains a summary of measures that could be incorporated into the detailed design in order to mitigate the impact of the project on flooding in adjacent development. The nature and extent of impacts and therefore the scope of mitigation measures required will be subject to further flood assessment during the detailed design phase. Subject to this further flood assessment, additional floor level survey may be required to confirm the extent to which the proposed works would increase flood damages in affected properties and therefore the scope of mitigation measures that may be required.

Table 8-2 Summary of measures aimed at reducing the operational related flood risk to the project

Location	Project infrastructure	Mitigation requirements
Arncliffe motorway operations complex	Motorway ancillary facility comprising ventilation exhaust and supply, electrical substation and water treatment plant	• Subject to the section the Arncliffe motorway operations complex that is being designed and constructed as part of the New M5 Motorway project being confirmed as meeting the requirements of that project's Infrastructure approval, no additional flood mitigation measures would be required for those components of the project that would be contained within this section of the motorway operations complex at Arncliffe. • Critical ground levels and/or structure levels over the proposed extension to the motorway operations complex would need to be raised by 3.1-3.4 m in order to locate the electrical substation and water treatment plant above the PMF level, taking into consideration an increase in flood levels due to sea level rise (section 6.3.1).
Rockdale motorway operations complex (north)	Motorway ancillary facility comprising motorway control centre, tunnel deluge system comprising tanks and pump station, maintenance and storage facilities	• Critical ground levels and/or structure levels on the site would need to be raised by 1.3-1.8 m in order to locate the tunnel ancillary facilities above the PMF level, taking into consideration an increase in flood levels due to sea level rise (section 6.3.1).
Rockdale motorway operations complex (south)	Motorway ancillary facility comprising ventilation exhaust and supply, electrical substation and disaster recovery facility	• Critical ground levels and/or structure levels on the site would need to be raised by 1.3-1.7 m in order to locate the tunnel ancillary facilities above the PMF level, taking into consideration an increase in flood levels due to seal level rise (section 6.3.1).
President Avenue intersection and surface works	President Avenue tunnel portal	• The assessment presented in Chapter 6.1 demonstrates that the proposed road level at the entry to the President Avenue tunnel portal has been designed to be located at the PMF level, taking into consideration an increase in flood levels due to sea level rise. Barrier walls around the tunnel portal would also need to be set to the same level to prevent the ingress of floodwater during a PMF event.
	President Avenue road upgrade	• The assessment presented in Chapter 6.1 demonstrates that the proposed raising of President Avenue by a minimum of 0.9 m would provide a 1% AEP level of flood immunity.
Bestic Street to Bruce Street pedestrian and cycle pathways	Shared user path for pedestrians and cyclists	• Areas of shared pedestrian and cycle pathways within the 1 EY flood extent would need to be elevated above natural surface level to prevent its frequent inundation. This would require a section of the shared pedestrian and cycle pathways between Bruce Street and Bestic Street to be raised over a length of about 370 m and by a maximum of 0.7 m. The raised section of shared pedestrian and cycle pathways would need to incorporate sufficient waterway area to minimise its impact on flood behaviour in adjacent properties. • Areas of high hazard along the section of the shared pedestrian and cycle pathways between Bruce Street and Bestic Street during a 1% AEP flood are confined to the in bank area of Muddy Creek and two incoming channels where waterway crossings would be required.

Location	Project infrastructure	Mitigation requirements
England Street to Civic Avenue pedestrian and cycle pathways	Shared user path for pedestrians and cyclists	• The assessment presented in Chapter 6.1 demonstrates that the concept design of the shared pedestrian and cycle pathways would provide a minimum 1 EY level of flood immunity. Depths of ponding during a 1% AEP flood would be 0.5 m or less, which would be classified as low provisional hydraulic hazard.
Princes Highway and President Avenue intersection upgrade	Widening of the Princes Highway and the western end of President Avenue	• The upgrade of the stormwater drainage system would maintain the existing hydrologic standard and limit increases in the depth of overland flow that would otherwise lead to an increase in flood hazard.

Table 8-3 Summary of potential operational phase mitigation measures

Location	Potential mitigation measures
Arncliffe motorway operations complex	• It would be feasible to mitigate the impact of the proposed motorway operations complex on flood behaviour in adjacent development by managing the extent of additional filling on the floodplain for the project.
Rockdale motorway operations complex (north)	• Subject to further hydraulic assessment during detailed design, floor level survey may be required to confirm the extent to which the proposed works would increase above-floor inundation and flood damages in affected properties. Potential mitigation measures to minimise such increases may include: – designating areas of carpark and internal roads which could act as overland flow paths, noting that the site is only impacted by overland flow from West Botany Street during storms with intensities in excess of 5% AEP – upgrading the site drainage system to control a portion of the overland flow that presently surcharges onto the site from West Botany Street – designing the site surface grading to as far as practical balance cut and fill in areas located below the 1% AEP flood.
Rockdale motorway operations complex (south)	• The assessment presented in Chapter 6 demonstrates that it would be feasible to mitigate the impact of the proposed motorway operations complex on flood behaviour in adjacent development through the provision of compensatory floodplain storage within the Rockdale Bicentennial Park.
President Avenue intersection and surface works	• The assessment presented in Chapter 6 has demonstrated that it would be feasible to mitigate the combined impact of the President Avenue intersection and surface works, the England Street pedestrian and cycle pathways and the Princes Highway and President Avenue intersection upgrade on flood behaviour in Scarborough Ponds through the provision of compensatory floodplain storage. Figure 6-1, sheet 3 shows two potential areas where compensatory excavation could be undertaken along the eastern bank of Scarborough Ponds to the north of President Avenue to offset floodplain storage that would be displaced by the project. • Subject to further hydraulic assessment during detailed design, floor level survey may be required to confirm the extent to which the proposed works would increase above-floor inundation and flood damages in affected properties in President Avenue to the east of the new intersection. Potential mitigation measures to minimise such increases may include: – lowering the proposed level of President Avenue between O'Connell Street and O'Neill Street to convey overland flow that presently surcharges onto the road from the affected properties – lowering ground levels within the three properties that are to be acquired as part of the project to the north of the new O'Neill Street cul-de-sac in order to convey overland flow that presently surcharges at its low point – upgrading the stormwater drainage system on the corner of O'Connell Street and President Avenue in order to reduce the magnitude of flow that would surcharge the road corridor into the adjoining properties along the southern side of President Avenue – regrading the section of footpath adjacent to the sag in President Avenue to fall toward the Colson Crescent road reserve, thereby increasing its capacity to convey flow that surcharges the road, and/or refinement of the vertical road alignment design to shift the new sag in President Avenue further west. • Scour protection and energy dissipation would need to be provided on the outlets of the upgraded stormwater drainage system to manage the potential for increased scour.

Location	Potential mitigation measures
Bestic Street to Bruce Street pedestrian and cycle pathways	• Sections of the shared user path that are to be raised above natural surface would need to be provided with sufficient waterway area beneath it to minimise any adverse impacts on flood behaviour in adjacent properties.
England Street to Civic Avenue pedestrian and cycle pathways	• The assessment presented in Chapter 6 demonstrates that it would be feasible to mitigate the impact of the shared pedestrian and cycle pathways on flood behaviour in adjacent development through the provision of a series of waterway crossings along the sections of shared user path that cross the Scarborough Ponds floodplain.
Princes Highway and President Avenue intersection upgrade	• The assessment presented in Chapter 6 demonstrates that it would be feasible to mitigate the impact of the proposed roads works on flood behaviour in adjacent development through the upgrade of the stormwater drainage systems that presently control runoff along the Princes Highway and President Avenue.

8.4 Management of cumulative impacts

Other motorway projects

- The potential for cumulative impacts due to the project in combination with the potential future stages of the F6 Extension (President Avenue to Loftus) would need to be assessed once design details of the latter are known.

Non-motorway projects

- Consultation will be undertaken with Sydney Water during the detailed design stage to ensure that the design of the shared pedestrian and cycle pathways is coordinated with the future plans for renewal of the Muddy Creek channel. As part of this process it would be necessary to assess the cumulative impacts of the two projects in order to ensure that their combined impact on flood behaviour is managed.

9 Conclusion

This report has documented the findings of a flooding and drainage related assessment that has been carried out to support the F6 Extension Stage 1 New M5 Motorway, at Arncliffe, to President Avenue, at Kogarah EIS. Baseline conditions with respect to existing flood behaviour were established and the nature and extent of the potential impacts associated with the proposed works identified. The potential impacts associated with both the construction and operational phases of the project were considered as part of the assessment.

The assessment of flood risks to the project and its impact on the surrounding environment, as well as development of appropriate flood standards and mitigation measures has been carried out in accordance with the *NSW Floodplain Development Manual* (DIPNR, 2005), the requirements of the environmental approvals process and industry guidelines.

Table 5-1 presents a summary of the construction related flood risk at the six proposed construction facilities and four other areas of work. The assessment found that all proposed construction facilities and areas of work have the potential to be impacted by flooding to some degree, while construction sites C3, C4, C5, CA1 and CA2 would be affected by flooding during storms as frequent as 1 EY. It would therefore be necessary to develop a Flood Management Strategy (FMS) which deals with the flooding and stormwater related issues that are specific to each construction site. The FMS would need to include procedures that are aimed at reducing the risks to human safety and damage to infrastructure that would be associated with heavy rainfall or a flood event were they to occur during the construction period.

A preliminary investigation into the impacts of the construction ancillary facilities on flooding (refer **Table 5-2** which summarises the key findings of the investigation) identified that the greatest potential impacts are associated with construction ancillary facilities C1 and CA1. However, the investigation also found that all seven sites would involve works within the floodplain that have the potential for adverse flooding conditions to arise in adjacent development if appropriate mitigation measures were not implemented during the construction of the project. There is also the potential for all construction ancillary facility sites and areas of work to impact local catchment runoff, requiring appropriate local stormwater management controls to be implemented during the construction phase of the project. The FMS would therefore need to include details and procedures to manage the risk of adverse flood impacts being experienced in adjacent development during the construction period. A range of measures aimed at mitigating the impact of construction activities on flood behaviour are set out in **Table 8-1**.

Section 3.1.8 sets out the recommended level of flood protection associated with the key elements of the project based on consideration of the consequences of flooding in accordance with DIPNR, 2005 and current Roads and Maritime standards. In particular, tunnel portals, as well as ancillary facilities such as substations, ventilation buildings and emergency response facilities are to be located above the PMF level or the 1% AEP flood level plus 0.5 metres (whichever is greater). **Table 6-1** sets out the operational related flood risks associated with key elements of the project, while **Table 8-2** sets out measures which would need to be incorporated in the detailed design in order to mitigate these risks.

The investigation found that once constructed, the project would generally have only a minor impact on flood behaviour in adjacent development for storms with AEP's up to 1 per cent in intensity (refer **Table 6-2** for a summary of key findings). The nature and extent of the project related impacts and also the scope of the required mitigation measures would be subject to further flood assessment which would be undertaken during the detailed design phase. Subject to this further flood assessment, additional floor level survey may be required to confirm the extent to which the proposed works would increase flood damages in affected properties and therefore the scope of mitigation measures that may be required.

Table 8-3 sets out measures which could be incorporated in the detailed design in order mitigate the assessed residual flood related impacts of the project.

While it will be necessary to undertake further design development during detailed design aimed at further reducing the residual impacts of the project on flood behaviour, it is concluded that the minor nature of the changes in flooding patterns attributable to the project would not have a significant impact on the future development potential of land located outside the project footprint for storms with AEP's up to 1 per cent in intensity. It is also concluded that the project would not have a significant impact on the development potential of land which lies above the flood planning level (i.e. in regards the provision of critical infrastructure (such as hospitals) and vulnerable developments (such as aged care facilities)).

While the investigation found that there would either be minor or no cumulative impacts on flood behaviour as a result of the other motorway projects (i.e. WestConnex Stages 1, 2 and 3, King Street Gateway, Sydney Gateway and Western Harbour Tunnel and Beaches Link), there is the potential for cumulative impacts on flood behaviour when the potential future stage of the F6 Extension (President Avenue to Loftus) are taken into consideration. While these potential cumulative impacts would need to be assessed as part of the EIS for the potential future stage of the F6 Extension when its details are available, given the minor flood impacts associated with the project it is expected that the cumulative impacts of the two projects can be managed through appropriate mitigation measures. It will also be necessary to consult with Sydney Water during the detailed design stage to ensure that the design of the shared pedestrian and cycle pathways is coordinated with the future plans for renewal of the Muddy Creek channel in order to ensure that their combined impact on flood behaviour is managed.

The investigation also found that changes in the characteristics of flooding associated with future climate change would not lead to a significant increase in the flood risk to the project and could be accommodated by setting the levels of tunnel portals and tunnel ancillary facilities to make allowance for a predicted increase in PMF levels due to sea level rise.

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Annexure A Background to the development of the Cooks River flood models

A1. Overview

This annexure provides background to the development of the hydrologic and hydraulic computer models that were developed to define flood behaviour in the lower reaches of the Cooks River upstream of its point of discharge to Botany Bay.

The hydrologic and hydraulic models relied upon for the present investigation were originally developed as part of a series of flooding investigations that were undertaken for the New M5 Motorway and associated projects which were previously documented in the *WestConnex New M5 EIS Technical Working Paper: Flooding* (Lyall and Associates(L&A) 2015).

The hydrologic models that were developed as part of these earlier investigations included a RAFTS model of the Cooks River catchment (**Cooks River RAFTS Model**) and a DRAINS model of the Alexandra Canal catchment (**Alexandra Canal DRAINS Model**). The hydraulic model was developed using the TUFLOW software (**Cooks River TUFLOW Model**).

This annexure also includes a comparison of the results of the present investigation with those of previous studies.

A2. Cooks River RAFTS Model

A2.1. Background to hydrologic model development

The Cooks River catchment was divided into 44 sub-catchments using available GIS based two metre contour data. Data such as sub-catchment land use and percentage imperviousness of the surfaces due to urbanisation, were developed from the underlying aerial photography. **Figure A-1** shows the sub-catchments which comprised the Cooks River RAFTS Model.

A2.2 Design storms

Design storms for intensities between 20% and 0.2% AEP were derived from *Australian Rainfall and Runoff* (ARR87) (Institution of Engineers Australia (IEAust) 1987) for storm durations ranging between 1 hour and 6 hours. The design rainfall depths were then converted into rainfall hyetographs using the temporal patterns presented in ARR 1987.

The rainfalls derived using the processes outlined in ARR 1987 are applicable strictly to a point. In the case of a large catchment of over tens of square kilometres, it is not realistic to assume that the same rainfall intensity can be maintained over a large area. An areal reduction factor (ARF) is typically applied to obtain an intensity that is applicable over the entire area.

The ARF data contained in ARR 1987 were originally published by the US National Weather Service in 1980 and were derived from recorded storm data in the Chicago area. The paper entitled *Derivation of Areal Reduction Factors for Design Rainfalls in Victoria* (Siriwardene and Weinmann 1996) presents the findings of research undertaken by the Cooperative Research Centre for Catchment Hydrology (CRCCH) for deriving ARF's in an Australian setting. Siriwardene and Weinmann 1996 undertook this analysis for Victorian catchments for a range of catchments from 1 to 10,000 square kilometres in area and storm durations from 18 to 120 hours. The conclusion of this investigation was that ARF's were related to rainfall frequency and that the values in ARR should be reduced by 5-8 per cent for storm durations in this range.

The paper entitled *A Hydroinformatic Approach to the Development of Areal Reduction Factors* (Catchlove and Ball 2003) presents the findings of a study on the 112 square kilometres catchment of the Upper Parramatta River where the records at 8 pluviometers were analysed. The key finding of this investigation was that for storm durations in excess of 2 hours, the best estimate of ARF for this catchment was 1.0. Application of relationships derived by ARR 1987 and CRCCH gave similar results for the Upper Parramatta River catchment, because the variations for different exceedance probabilities for a small catchment of this size are minimal. In practice, adoption of a single ARF unrelated to frequency is more appropriate.

For the present investigation, ARR 1987 indicates that a value of 0.85 could have been adopted for the ARF on the Cooks River catchment as an appropriate value for the 2 hour storm duration found to be critical on this catchment. However, a value of 1 was selected for design purposes, in keeping with the more recent results of Catchlove and Ball 2003.

Estimates of probable maximum precipitation were derived using the Generalised Short Duration Method (GSDM) as described in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method* (BoM 2003). This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 square kilometres in area and storm durations up to six hours.

A2.3. RAFTS model parameters

RAFTS requires losses to be applied to storm rainfall to determine the depth of surface runoff, as well as information on the time of travel of the flood wave through the catchment.

Infiltration losses are of two types: initial loss arising from water which is held in depressions which must be filled before runoff commences, and a continuing loss rate which depends on the type of soil and the duration of the storm event. The split catchment option was used for estimating hydrographs from each sub-catchment. This option separately models runoff from the pervious and impervious portions of the sub-catchment.

Losses from the impervious portion of the catchment are subject to less uncertainty resulting from antecedent rainfall conditions than from the pervious portion. Values of 2 millimetres for initial loss and zero continuing loss were adopted for impervious surfaces. The response of the model to initial losses from the pervious portion ranging between zero and 20 millimetres was tested for the 1% AEP 2 hour critical storm (**Figure A-2**). The results showed that the peak discharge was not particularly sensitive to pervious initial loss, because about 50 per cent of the total catchment surface was impervious. Loss values adopted for design flood estimation are shown in **Table A-1**.

Table A-1 Design loss values

Type of surface	Initial loss (mm)	Continuing loss (mm/h)
Pervious areas	10	2.5
Impervious areas	2	0

A simple lagging of the ordinates was adopted to describe the translation of the discharge hydrograph generated at each sub-catchment outlet along the various links to the next downstream sub-catchment. This approach required specifying a velocity of the flow along the link. The sensitivity of the results to assumed velocities ranging between 1 and 3 metres per second was tested for the 1% AEP critical storm (**Figure A-2**). The 1 metre per second velocity resulted in peak discharges that were much smaller than peaks estimated in any of the other studies of flooding on the Cooks River (**Table A-2** over the page). After consideration a velocity of 2 metres per second was adopted for design.

A2.4. Design discharge hydrographs

Figure A-3 shows design discharge hydrographs that were adopted for input at the upstream boundaries of the Cooks River TUFLOW Model. The peaks of the PMF are between two and four times those of the 1% AEP flood, depending on location. The PMF is the largest flood that could reasonably be expected to occur and is generally considered to have a return period between 1 in 10^5 and 1 in 10^6 years.

Table A-2 compares peak discharges derived from both the present and previous investigations. The peak discharges derived from the Cooks River RAFTS Model as part of the present investigation are given in column B of the table. The peaks derived from the Cooks River TUFLOW Model are given in column C. The differences between the peak flows at each of the locations represent the routing effects of channel and floodplain storage which are incorporated in the TUFLOW analysis but which are not modelled by RAFTS. The effects of storage are represented by a reduction in peak flow at the outlet for TUFLOW when compared with the RAFTS result.

Both of the *Cooks River Flood Study* (Sydney Water Corporation (SWC) 2009) and the *Cooks River Floodplain Management Study* (Webb, McKeown and Associates (WMA) 1994) (refer peak flows given in columns D and E of **Table A-2**, respectively) used the WBNM hydrologic modelling software. WBNM is a rainfall-runoff hydrologic model similar to RAFTS and would be expected to give similar results, provided that the model layout and adopted parameters were similar.

Table A-2 Peak discharges – 1% AEP storm (m^3/s)

Location	Cooks River RAFTS Model	Cooks River TUFLOW Model	Cooks River Flood Study (SWC, 2009)	Cooks River Floodplain Management Study (WMA, 1994)
[A]	[B]	[C]	[D]	[E]
Wolli Creek at SWSOOS Crossing	431	430	348	290
Alexandra Canal Discharge to Cooks River	353	203	286	160
Muddy Creek Discharge to Cooks River	262	178	145	150
Cooks River Outfall to Botany Bay	1440	1145	1596	1010

A3. Alexandra Canal DRAINS Model

A3.1. Background to Hydrologic Model Development

As part of a series of flooding investigations for the New M5 Motorway and associated projects it was necessary to develop an understanding of the magnitude of flow in Sheas Creek (the major contributor to flow in Alexandra Canal), as well as the minor lateral drainage lines which discharge to the canal along its length. Rather than further sub-divide the Cooks River RAFTS Model, a separate DRAINS model was developed of the catchments which contribute flow to Alexandra Canal. **Figure A-4** shows the sub-catchments which comprised the Alexandra Canal DRAINS Model.

A3.2. DRAINS model parameters

Adopted DRAINS model parameters comprised initial losses of 2 and 20 millimetres for paved and grassed areas, respectively. An antecedent moisture condition of 3 was adopted, reflecting rather wet conditions prior to the occurrence of storm events and the soil type was set equal to 2, which corresponds with a soil of comparatively low runoff potential.

The outlets of the sub-catchments were linked using a trapezoidal channel arrangement which reflected prototype conditions (e.g. the concrete lined section of Sheas Creek and the man-made canal). The length of the channels was taken from the available aerial photography. Each reach of channel was assigned a Manning's n value of 0.03.

Design storms were derived using the same approach that was adopted for the Cooks River RAFTS Model, which is described in **section A2.2**.

A3.3. Design discharge hydrographs

Figure A-3 shows the design discharge hydrographs that were applied to the upstream boundary of the Cooks River TUFLOW Model on Sheas Creek. The peak 1% AEP flow generated by the Alexandra Canal DRAINS Model at the location where Sheas Creek discharges to Alexandra Canal of 162 cubic metres per second compares closely with the peak flow of 160 cubic metres per second given in the *Sheas Creek Flood Study* (Webb, McKeown and Associates (WMA), 1991) at the same location.

A4. Cooks River TUFLOW Model

A4.1 Background to hydraulic model development

The Cooks River TUFLOW Model was originally developed as part of the New M5 Motorway and its associated projects. For the present investigation the model was extended upstream along the Cooks River and Wolli Creek to include the attenuating effects of floodplain storage on peak flows in these watercourses. The extended model covers the Cooks River floodplain from Centenary Drive in Strathfield to its outlet into Botany Bay and includes the proposed location of the Arncliffe tunnel ancillary facility.

A4.2 Sources of topographic data

Figure A-5 shows the various sources of topographic data available to construct the model. The data included:

- Cross sections of the streams which had been included in the TUFLOW model that was originally developed for Sydney Water by the PB-MWH Joint Venture study of Cooks River catchment in 2009 (SWC, 2009), and was subsequently updated as part of hydraulic assessment that was undertaken as part of the detailed design for the New M5 Motorway project (AJJV, 2016).
- A hydrographic survey of the lower reaches of Cooks River and the confluence with Alexandra Canal, including several isolated sections of the canal; provided by Roads and Maritime.
- Detailed ground survey along the road reserve of Marsh Street west of the Cooks River.
- Details of the various bridge crossings provided by Roads and Maritime, which were later included in the model.
- LiDAR survey data provided by Roads and Maritime to define natural surface levels on the floodplain.
- Levels along the shoreline based on LiDAR survey provided by Roads and Maritime which were used in conjunction with estimated depths of Botany Bay to extend the model into the bay below the Cooks River outlet.

A4.3 TUFLOW model layout

The layout of the TUFLOW model is shown on **Figure A-5**. Both the floodplain and stream beds of Alexandra Canal and the lower reaches of the Cooks River and Wolli Creek were modelled as a grid of two-dimensional elements. The grid levels comprising the stream beds were interpolated from the cross sections shown on **Figure A-5** in areas where there was no hydrographic survey. The upper reach of the Cooks River and Wolli Creek were modelled as one-dimensional elements that were defined using a series of cross sections taken normal to the direction of flow. Cross sections were obtained from the TUFLOW model that was originally developed as part of SWC, 2009. The model includes twenty three road and rail crossings on the main arms of the Cooks River, Wolli Creek and Alexandra Canal. The model also includes the two SWSOOS crossings of the Cooks River that are located 800 m upstream of Bayview Avenue and 830 m upstream of General Holmes Drive.

All of the features which influence the passage of flow on the floodplain were included in the model. An important consideration of two-dimensional modelling is how best to represent the roads, fences, buildings and other features which influence the passage of flow over the natural surface. Two-dimensional modelling is very computationally intensive and it is not practicable to use a mesh of very fine elements without incurring very long times to complete the simulation, particularly for long duration flood events. The requirement for a reasonable simulation time influences the way in which these features are represented in the model.

Earlier versions of the Cooks River TUFLOW Model incorporated a 5 metre grid. However, later studies required a nested grid to be developed which covered the Alexandra Canal. The latest version of the model comprises a 2 metre grid which covers areas that are affected by flooding along Alexandra Canal and a 6 m grid which covers the remainder of the two-dimensional model domain. Ridge and gully lines were added to the model where the grid spacing was considered too coarse to accurately represent important topographic features which influence the passage of overland flow, such as road centrelines and footpaths. It was important that the model recognised the ability of roads to capture overland flow and act as floodways.

The footprints of a large number of individual buildings were digitised and assigned a high hydraulic roughness value relative to the more hydraulically efficient roads and flow paths through allotments. This accounted for their blocking effect on flow whilst maintaining a correct estimate of floodplain storage in the model. It was not practicable to model the individual fences surrounding the many allotments in the study area. They comprised many varieties (brick, paling, colorbond, etc) of various degrees of permeability and resistance to flow. It was assumed that there would be sufficient openings in the fences to allow water to enter the properties, whether as flow under or through fences and via openings at driveways.

A4.4 TUFLOW model boundary conditions

A4.4.1. Upstream boundary

Discharge hydrographs generated by both the Cooks River RAFTS Model and Alexandra Canal DRAINS Model were applied at the inflow boundaries of the Cooks River TUFLOW Model.

A4.4.2. Storm tides at Botany Bay

The NSW Government's guideline entitled *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (Department of Environment, Climate Change and Water (DECCW), 2010) was prepared to assist councils, the development industry and consultants to incorporate the sea level rise planning benchmarks in floodplain risk management planning for new development. The guideline contains an appendix on modelling the interaction of catchment and coastal flooding for different classes of tidal waterway. The appendix may be used to derive scenarios for coincident flooding from those two sources for both present day conditions and conditions associated with future climate change.

For a catchment draining directly to the ocean via trained or otherwise stable entrances such as is the case for the Cooks River at Botany Bay, the guideline offers the following alternative approaches for selecting storm tidal conditions under present day conditions. In order of increasing sophistication they are:

- A default tidal hydrograph which has a peak of 2.6 metres AHD for the 1 in 100 year event; or 2.3 metres AHD for the 1 in 20 year event. This default option is acknowledged by DECCW as providing a conservatively high estimate of tides for these types of entrances.
- A detailed site-specific analysis of elevated water levels at the ocean boundary. The analysis should include contributions to the water levels such as tides, storm surge wind and wave set up. The analysis should examine the duration of high tidal levels, as well as their potential coincidence with catchment flooding. This approach requires a more detailed consideration of historic tides and the entrance characteristics, but provides information which is more directly relevant to a particular entrance. It has been adopted for design purposes in the present investigation.

A4.4.3. Consideration of historic storm tides

The Highest Astronomical Tide (HAT) level recorded in Botany Bay was 1.45 metres AHD on 25 May 1974. This level was recorded at Kurnell and was considered to have a return period of 1 in 100 years. In the WMA, 1994 investigation an allowance of 0.25 metres was adopted for additional storm related components such as wind stress and wave action, yielding a peak of 1.7 metres AHD at the Cooks River entrance. By comparison the High High Water Solstice Spring (HHWSS) tide which occurs once or twice a year has a peak of about RL 1.02 metres AHD. Given the availability of site specific data, a storm tide level of 1.7 m AHD was adopted in preference to DECCW's default level of 2.6 m AHD.

Peak storm tide levels for events with frequencies of 1 in 5 and 1 in 20 years were derived by adding 0.25 metres to design still water levels for Fort Denison which are given in *Fort Denison Sea Level Rise Vulnerability Study* (Department of Environment and Climate Change (DECC), 2008), while the upper limit of ocean flooding (referred to herein as an "extreme ocean flood event" and assigned a probability of 10,000 year ARI) was determined by extrapolation of the data presented in DECC, 2008.

Table A-3 sets out the peak tide levels that were adopted for design flood modelling. Tidal hydrographs were generated with the peak levels for application to the downstream boundary of the TUFLOW model based on the stage hydrographs presented in DECCW, 2010.

Table A-3 Adopted peak storm tide levels in Botany Bay

Storm Frequency	Peak Storm Tide Level (metres AHD)
1 in 5 years	1.57
1 in 20 years	1.63
1 in 100 years	1.70
Extreme	1.85

A4.4.4. Envelope Scenarios for Determining Flood Levels in Cooks River

According to DECCW, 2010, determining 1% AEP flood levels in tidal waterways requires consideration of the interaction of catchment and ocean flooding from the following scenarios:

- 5% AEP catchment flooding, with 1 in 100 year ocean flooding and coincident peaks.
- 1% AEP catchment flooding, with 1 in 20 year ocean flooding and coincident peaks.
- 1% AEP catchment flooding, with normal tidal cycle and coincident peaks.

Table A-4 sets out the coincident catchment and ocean flooding conditions which were used to define the design flood envelopes.

Table A-4 Adopted coincident catchment and ocean flooding conditions

Design flood envelope	Local catchment flood	Downstream boundary condition in Botany Bay[(1,2)]
20% AEP	20% AEP	HHWSS [1.63 m AHD]
	50% AEP	1 in 5 year peak storm tide level [1.57 m AHD]
5% AEP	5% AEP	1 in 5 year peak storm tide level [1.57 m AHD]
	20% AEP	1 in 20 year peak storm tide level [1.63 m AHD]
1% AEP	1% AEP	1 in 20 year peak storm tide level [1.63 m AHD]
	5% AEP	1 in 100 year peak storm tide level [1.70 m AHD]
0.5% AEP	0.5% AEP	1 in 20 year peak storm tide level [1.63 m AHD]
	5% AEP	1 in 100 year peak storm tide level [1.70 m AHD]
0.2% AEP	0.2% AEP	1 in 20 year peak storm tide level [1.63 m AHD]
	5% AEP	1 in 100 year peak storm tide level [1.70 m AHD]
PMF	PMF	1 in 100 year peak storm tide level [1.70 m AHD]
	1% AEP	Extreme storm tide level [1.85 m AHD]

Notes:
1 Values in [ ] relate to adopted peak storm tide level.
2 All values include 0.25 m increase to allow for additional storm related components such as wind stress and wave action.

A4.5. TUFLOW model parameters

A4.5.1. General

The main physical parameter for TUFLOW is the hydraulic roughness, which is required for each of the various types of surfaces comprising the overland flow paths, as well as for the streams. In addition to the energy lost by bed friction, obstructions to flow also dissipate energy by forcing water to change direction and velocity, and by forming eddies. Hydraulic modelling traditionally represents all of these effects via the surface roughness parameter known as “Manning’s n”.

A4.5.2. Channel roughness

There are very limited historic flood level data available in the lower reaches of the Cooks River to assist with the calibration of the model for roughness. Channel roughness values were estimated from site inspection, past experience and values contained in the engineering literature.

Initial runs of the TUFLOW model were carried out with channel roughness values of 0.025 and 0.03, with the latter value resulting in peak flood levels about 0.2 metres higher than the former. After consideration a value of 0.025 was adopted for design purposes.

A4.5.3. Floodplain roughness

The adoption of a value of 0.02 for the surfaces of roads, along with an adequate description of their widths and centreline and kerb elevations, allowed an accurate assessment of their conveyance capacity to be made. Similarly the high value of roughness adopted for buildings recognised that they completely blocked the flow but were capable of storing water when flooded.

A4.5.4. Design roughness Values

Table A-5 summarises the hydraulic roughness values adopted for design purposes.

Table A-5 Best estimate of hydraulic roughness values adopted for TUFLOW modelling

Surface Treatment	Manning’s n value
Asphalt or concrete road surface	0.02
Well Maintained Grassed Cover e.g. sporting oval	0.03
Grass or Lawns	0.045
Trees	0.08
Concrete lined channels	0.015
River bed	0.025
Macrophytes (river bank)	0.06
Fenced Properties	1.0
Buildings	10

A4.6. Sensitivity analyses

A4.6.1. Increase in hydraulic roughness

A sensitivity analysis was undertaken to assess the impact of a 20 per cent increase in the ‘best estimate’ values of hydraulic roughness (refer **Table A-5**) on flood behaviour during a 1% AEP storm. The assessment found that peak 1% AEP flood levels are generally increased in the range 0.1-0.2 metres along the Cooks River upstream of its confluence with Alexandra Canal. Peak 1% AEP flood levels in the northern portion of the Kogarah Golf Course (i.e. at the proposed location of the Arncliffe construction ancillary facility) are also increased in the range 0.1-0.2 metres.

A4.6.2. Partial blockage of hydraulic structures

An assessment of the impact that a partial blockage of major hydraulic structures would have on flood behaviour in the vicinity of the project is provided in **section 6.4** of this report.

A4.6.3. Increases in design rainfall intensities and tailwater levels

An assessment of the impact that a potential increase in rainfall intensities and tailwater levels as a result of future climate change would have on flood behaviour in the vicinity of the project is presented in **section 6.3.1** of this report.

A4.6. Comparison with results of previous studies

Table A-6 compares peak flows and flood levels during a 1% AEP and PMF event derived using the Cooks River TUFLOW Model that was used for the present investigation with results presented in the *Cooks River Flood Study* (SWC, 2009) and the *Hydrology Model Development Report – Cooks River Flood Modelling* (AJJV 2016).

Key findings of the comparison of 1% AEP results were as follows:

- Peak 100 year ARI flows derived for the present investigation are within 3 per cent of the corresponding results from AJJV, 2016.
- Peak 100 year ARI flood levels derived for the present investigation along the main arm of the Cooks River are within 0.1 metres of corresponding results presented in AJJV, 2016, but are 0.3 metres higher at Marsh Street when compared to the results presented in SWC, 2009.
- A greater difference in results occurs at the Kogarah Golf Course (Location 3) on the western overbank of the Cooks River where the results of the present investigation are 0.13 metres higher than AJJV, 2016 and 0.65 metres higher than SWC, 2009. Peak floods levels within the Kogarah Golf Course are a function of the filling of the temporary flood storage within the golf course and are therefore sensitive to changes in the volume of flow that surcharges the main arm of the Cooks River across Marsh Street into the golf course.

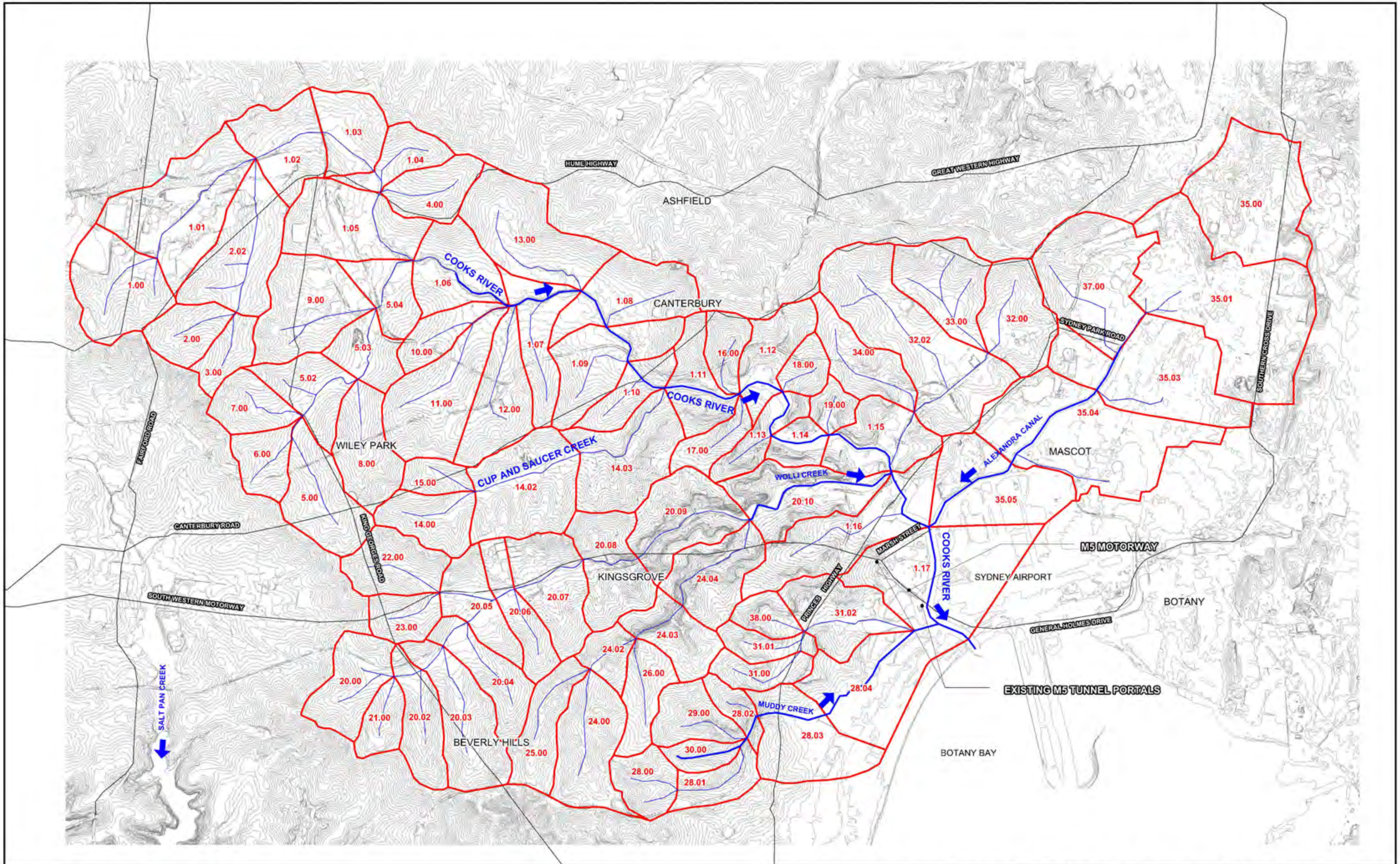
Key findings of the comparison of PMF results were as follows:

- Peak PMF flows derived for the present investigation are within 10 per cent of the corresponding results from AJJV, 2016.
- The peak PMF flood level derived for the present investigation along the main arm of the Cooks River at General Holmes Drive is 0.3 metres lower than the corresponding results from both SWC, 2009 and AJJV, 2016.
- The peak PMF flood level derived for the present investigation along the main arm of the Cooks River at Marsh Street is 0.4 metres higher than the corresponding result from AJJV, 2016, and 0.9 m higher than the corresponding result from SWC, 2009.
- The steeper flood gradient from the present investigation can be largely attributed to the approach to modelling the main arm of the Cooks River. While SWC, 2009 and AJJV, 2016 modelled the channel of the Cooks River as one-dimensional elements, the present investigation modelled the channel as a two-dimensional grid. The latter approach ensured that the two-dimensional effects associated with bends in the river are incorporated in the analysis.

Table A-6 Comparison of results with previous investigations

Location		Cooks River TUFLOW model		SWC 2009		AJJV 2016	
I.D.(1)	Description	Peak Flow (m^3/s)	Peak Flood Level (m AHD)	Peak Flow(2) (m^3/s)	Peak Flood Level (m AHD)	Peak Flow (m^3/s)	Peak Flood Level (m AHD)
100 year ARI							
1	Cooks River at General Holmes Drive	1,020	1.77	-	1.73	988	1.86
2	Cooks River at the SWSOOS crossing	910	1.90	-	1.90	890	1.98
3	Kogarah Golf Course adjacent to Marsh Street	-	1.78	-	1.13(3)	-	1.65
4	Cooks River at Marsh Street	910	2.19	-	2.00	890	2.18
PMF							
1	Cooks River at General Holmes Drive	2,780	2.46	-	2.78	2,520	2.78
2	Cooks River at the SWSOOS crossing	2,520	3.35	-	2.90	2,340	3.23
3	Kogarah Golf Course adjacent to Marsh Street	-	3.88	-	3.20	-	3.56
4	Cooks River at Marsh Street	1,940	4.08	-	3.19	1,890	3.66

Note:
1 Refer to **Figure A-6** for Location I.D's.
2 Peak flows from SWC, 2009 not available for comparison purposes.
3 Reported in AJJV, 2016



N

500 0 500 1000 1500 m

Scale: 1:50,000

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LEGEND

1.06 RAFTS Node Number and Catchment Boundary

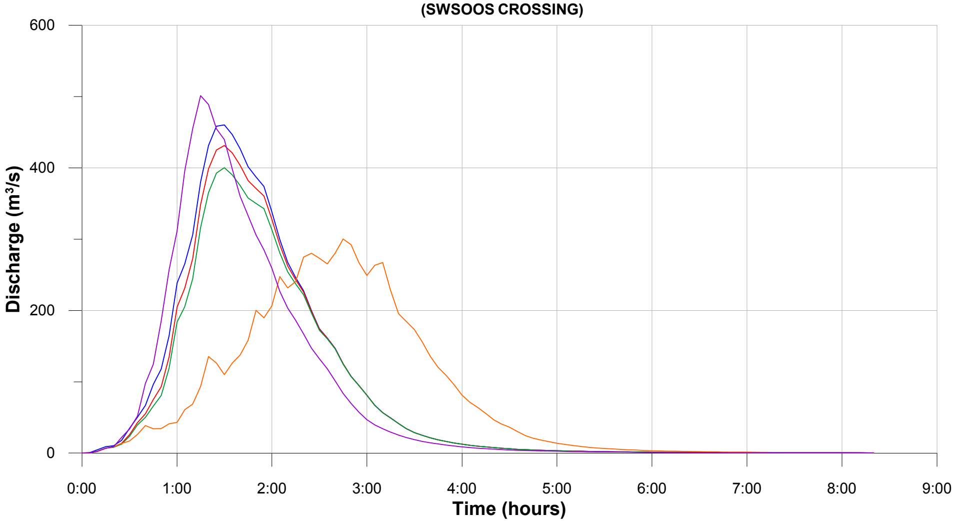
Watercourse/Flowpath

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

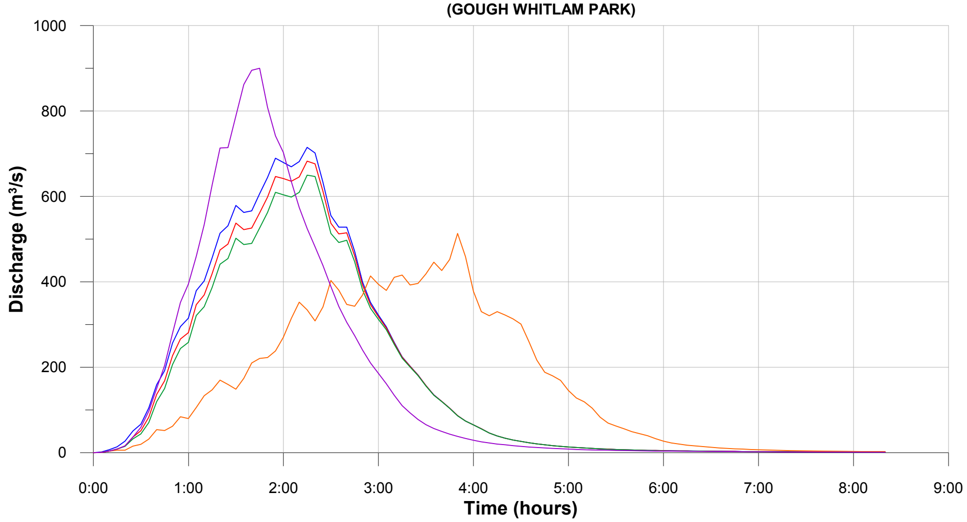
Figure A-1

COOKS RIVER RAFTS MODEL LAYOUT

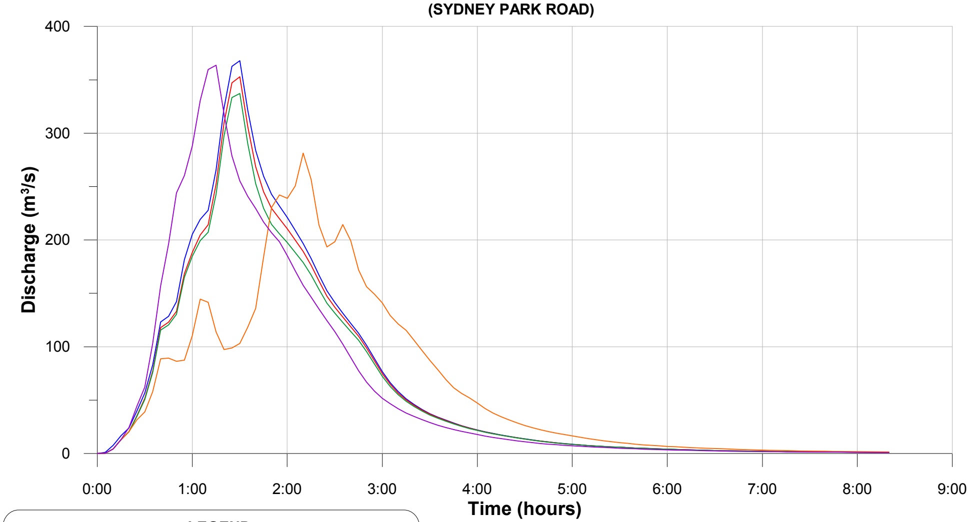
20.10
WOLLI CREEK
(SWSOOS CROSSING)



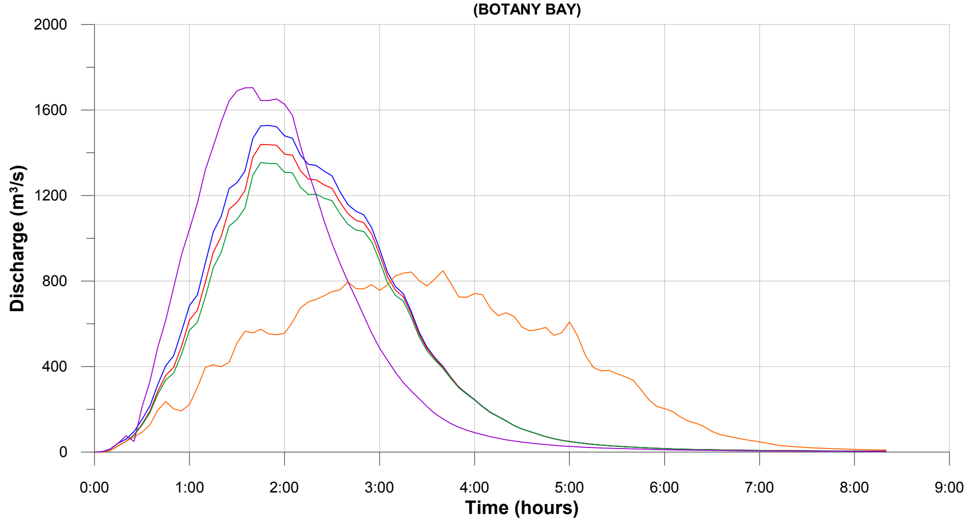
1.14
COOKS RIVER
(GOUGH WHITLAM PARK)



35.05
ALEXANDRA CANAL
(SYDNEY PARK ROAD)



1.17
COOKS RIVER
(BOTANY BAY)



LEGEND

	INITIAL LOSS (mm)	VELOCITY (m/s)
blue	0	2
red	10	2
green	20	2
orange	10	1
purple	10	3

NOTE:

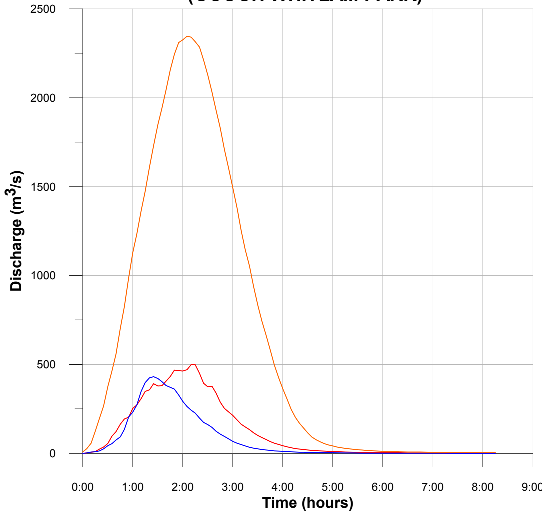
RESULTS APPLY FOR 2 HOUR CRITICAL STORM.

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

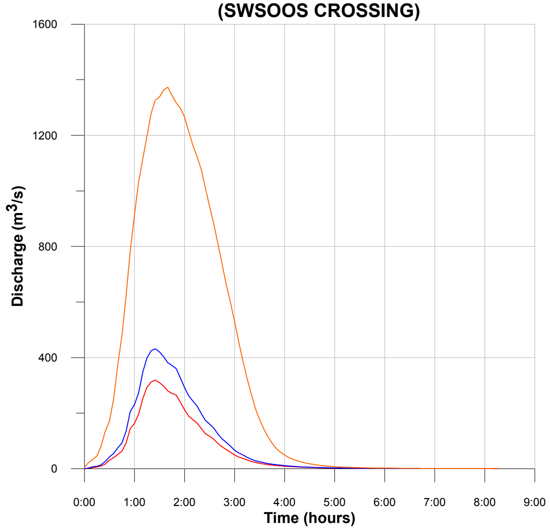
Figure A-2

SENSITIVITY STUDY - 1% AEP
RAFTS DISCHARGE HYDROGRAPHS

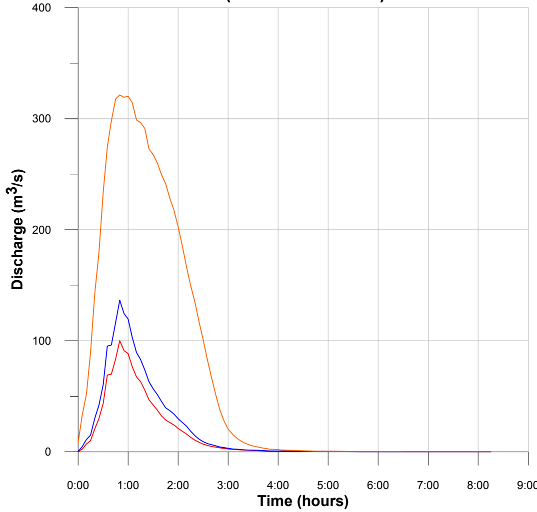
1.14_TOT
COOKS RIVER
(GOUGH WHITLAM PARK)



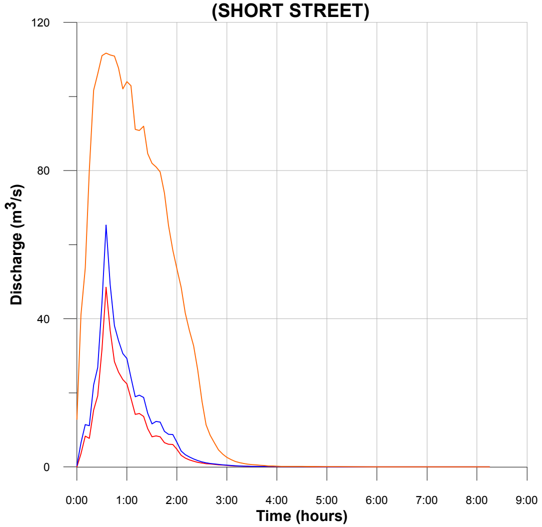
20.10_TOT
WOLLI CREEK
(SWSOOS CROSSING)



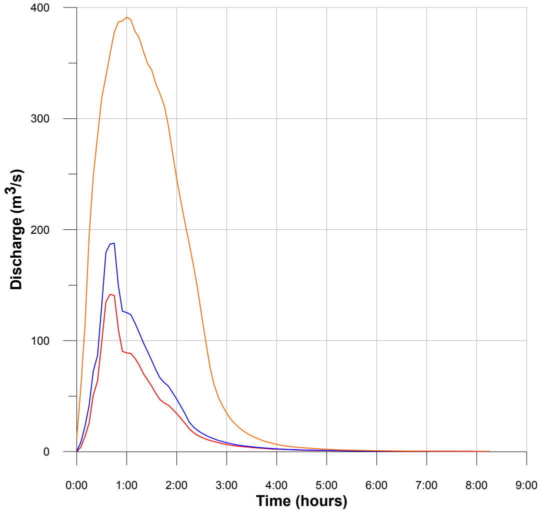
28.04_TOT
MUDDY CREEK
(BESTIC STREET)



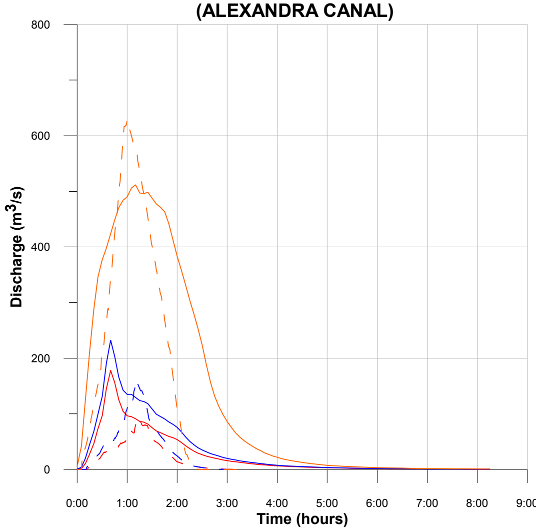
31.01_TOT
BANKSIA
(SHORT STREET)



32.02_TOT
MACKEY PARK,TEMPE
(MARRICKVILLE TRIBUTARY)



CHNL_8
UPSTREAM OF MADDOX STREET
(ALEXANDRA CANAL)



NOTE:

UNLESS OTHERWISE NOTED, FLOWS WERE DERIVED BY RAFTS AND APPLIED AS BOUNDARY CONITIONS TO TUFLOW.

CRITICAL DURATION FOR 5%, 1%, 0.5% AND 0.2% AEP STORMS IS 2 HOURS. CRITICAL DURATION FOR PMF IS 2.5 HOURS.

LEGEND

Cooks River RAFTS Model	Alexandra Canal DRAINS Model	
———	– – – – –	PMF
———	– – – – –	1% AEP
———	– – – – –	5% AEP

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure A-3

DESIGN DISCHARGE HYDROGRAPHS
COOKS RIVER AND TRIBUTARIES

N

300 0 300 600 900 m

Scale: 1:30,000

Lyall & Associates

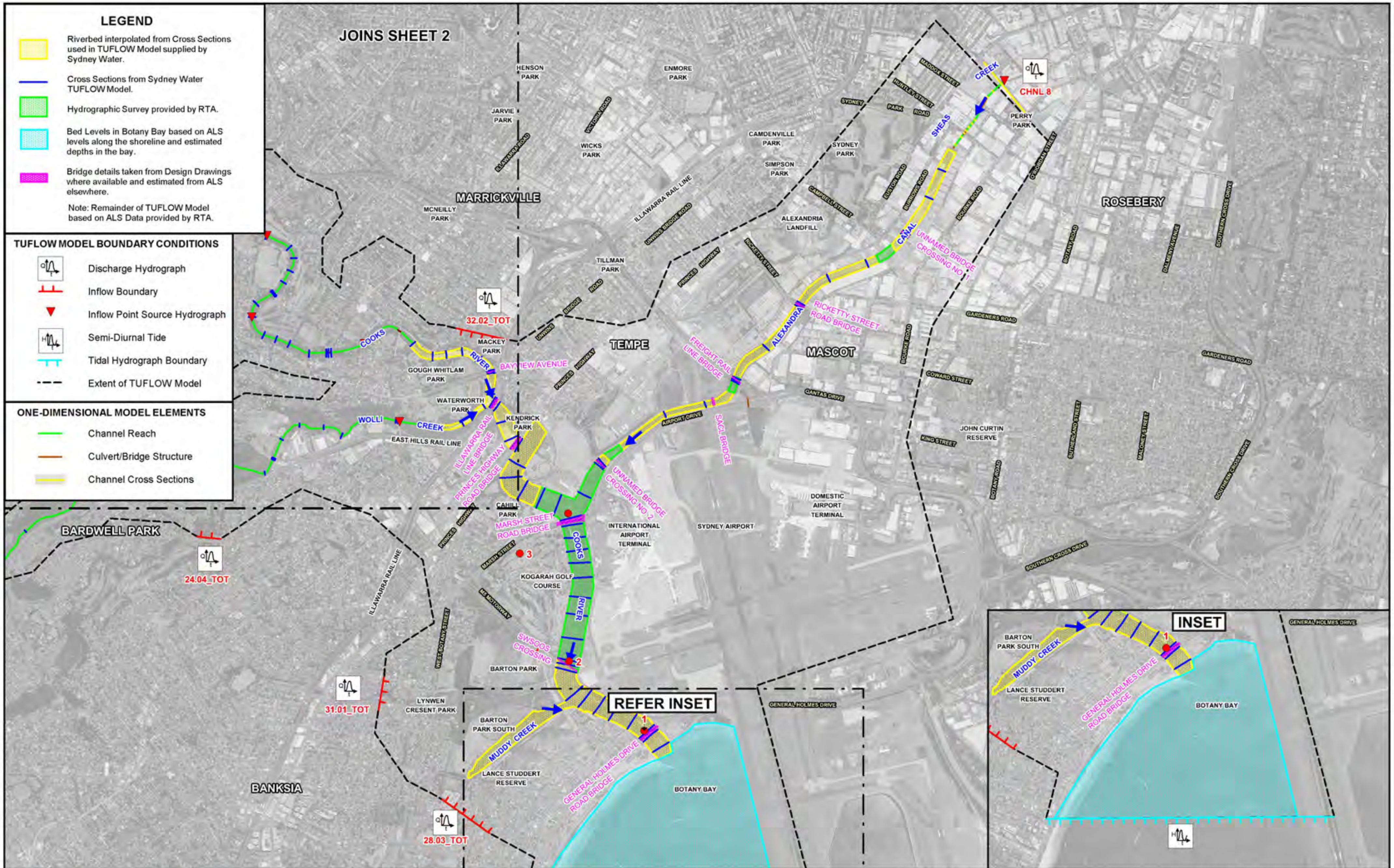
LEGEND

D_1.13 Sub-Catchment Boundary and Identifier

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure A-4

ALEXANDRA CANAL DRAINS MODEL LAYOUT



N

250 0 250 500 750 m

Scale: 1:25,000

LEGEND

1 Location Identifier

Lyall & Associates

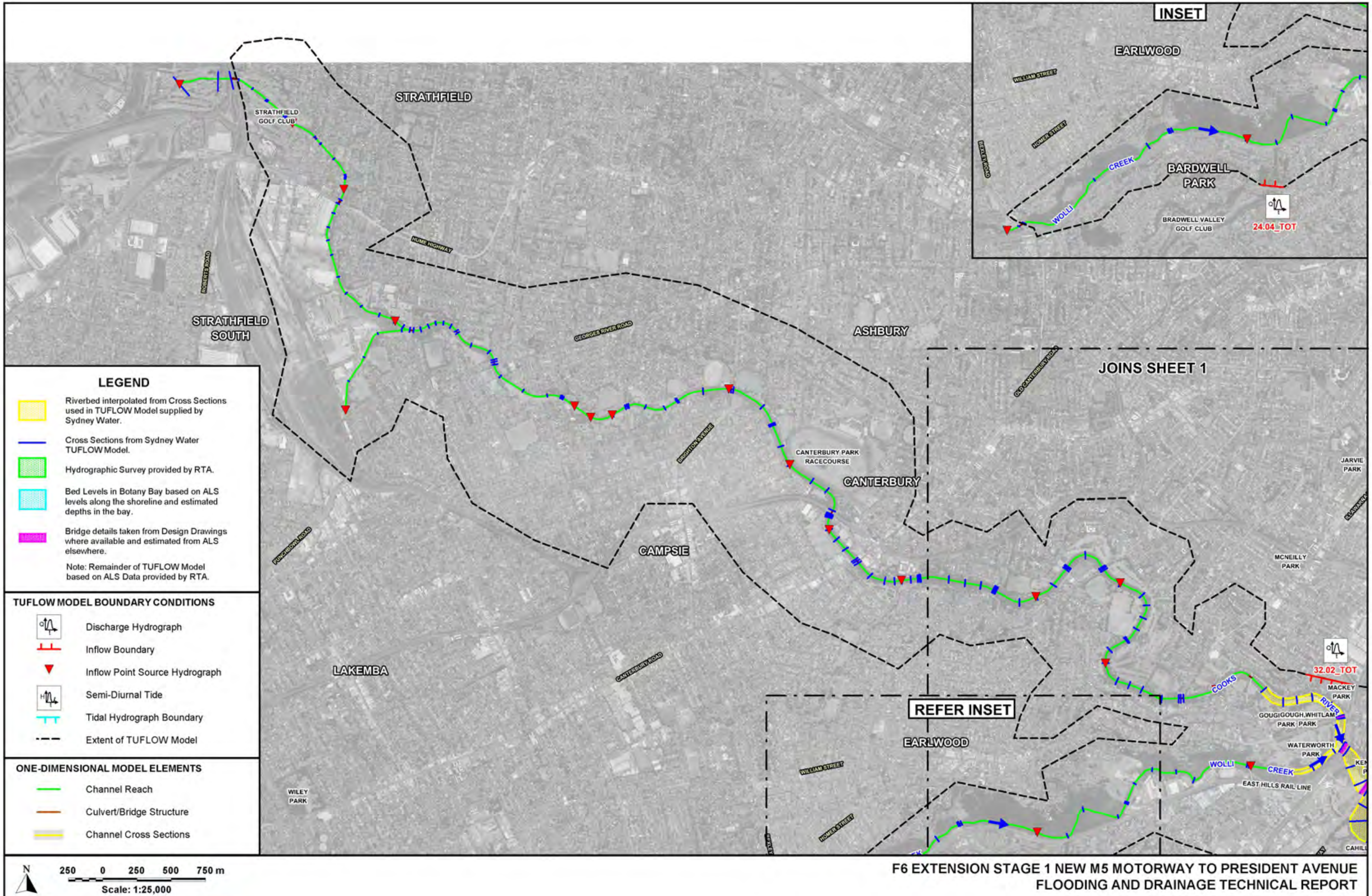
NOTE:

TUFLOW MODEL SHOWN ON THIS FIGURE IS REPRESENTATIVE OF PRESENT DAY CONDITIONS

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure A-5
Sheet 1 of 2

LOWER COOKS RIVER TUFLOW MODEL LAYOUT



Lyall & Associates

NOTE:
TUFLOW MODEL SHOWN ON THIS FIGURE IS REPRESENTATIVE OF PRESENT DAY CONDITIONS

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure A-5
Sheet 2 of 2

LOWER COOKS RIVER TUFLOW MODEL LAYOUT

Annexure B Background to the development of the Muddy Creek and Scarborough Ponds flood models

B1. Overview

This annexure provides background to the development of the hydrologic and hydraulic computer models that were developed to define flood behaviour in the Eve Street Wetland, Spring Street Drain, Muddy Creek and Scarborough Ponds catchments.

A hydrologic model was developed of the above four catchments using the DRAINS software (**Muddy Creek and Scarborough Ponds DRAINS Model**). The drainage systems of the Eve Street Wetland, Spring Street Drain, Muddy Creek and Scarborough Ponds were then combined into a single TUFLOW model in order to assess the interaction of flow between the four catchments (**Muddy Creek and Scarborough Ponds TUFLOW Model**).

This annexure also includes a comparison of results from the present investigation with those of previous studies.

B2. Muddy Creek and Scarborough Ponds DRAINS Model

B2.1. Background to hydrologic model development

A number of hydrologic sub-models are available within DRAINS to simulate the conversion of rainfall to runoff. For the purpose of this present investigation, the ILSAX sub-model was selected as it is well suited to the urbanised nature of the catchments that comprise the Eve Street Wetland, Spring Street Drain, Muddy Creek and Scarborough Ponds catchments.

Figure B-1 shows the layout of the various sub-catchments which comprised the Muddy Creek and Scarborough Ponds DRAINS Model. Sub-catchment boundaries were digitised based on available contour information, which comprised LiDAR survey data and two metre contour data. Sub-catchment slopes used for input to the DRAINS model were derived using the average sub-catchment slope, which were computed using available contour data. Aerial photography and site observations were used to assess the degree of urbanisation which is present in the study catchments.

B2.2. Design storms

Design storms for intensities between 1 EY and 0.2% AEP were derived from ARR 1987 for storm durations ranging between 25 minutes and six hour. The design rainfall depths were then converted into rainfall hyetographs using the temporal patterns presented in ARR 1987.

No ARF was applied to the design rainfall intensities obtained from ARR 1987 due to the size of the catchments within the study area (the largest of which is Muddy Creek with an area of 6.1 square kilometres at its confluence with the Cooks River.

Estimates of probable maximum precipitation were derived using the Generalised Short Duration Method (GSDM) as described in BoM 2003. This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 square kilometres in area and storm durations up to six hours.

B2.3. DRAINS model parameters

Adopted DRAINS model parameters comprised initial losses of one and five millimetres for paved and grassed areas, respectively. The soil type was set equal to three, which corresponds with a soil of comparatively high runoff potential. An AMC of three was adopted, reflecting rather wet conditions prior to the onset of runoff producing rainfall.

Lagging was adopted to describe the translation of the hydrograph generated at each sub-catchment outlet along the various links to the next downstream sub catchment. This approach required specifying a flow velocity of the flow along the link. The sensitivity of the results to assumed flow velocities ranging between one and three metres per second was tested for the 1% AEP critical storm. After consideration a velocity of two metres per second was adopted for design.

In the absence of gauged streamflow data that could otherwise be used to calibrate the DRAINS model, peak 1% AEP flows arriving at the project road corridor were compared to peak flow estimates derived using the Rational Method for urban catchments presented in ARR87.

B2.4. Peak flow estimates for present day conditions

Table B-1 compares peak discharges derived from the present investigation with those from previous studies, as well as the Rational Method approach at select locations within the catchments that contribute runoff in the drainage lines that cross the project corridor. These locations were selected to provide a comparison to previous studies and provide a range of catchment areas and types for comparison to the Rational Method approach.

Lower Muddy Creek and Scarborough Ponds Catchments Overland Flooding and Risk Assessment Study (Brown Consulting 2004) and *Spring Street Drain – Piped Drainage and Overland Flow Analysis* (Brown Consulting 2007) both used DRAINS for hydrologic modelling, while the *Spring Street Drain, Muddy Creek and Scarborough Ponds Floodplain Management Study* (Willing and Partners (WP) 2000) was based on a WBNM hydrologic model.

Peak 1% AEP flows derived by Muddy Creek and Scarborough Ponds DRAINS Model compared closely with both those derived from the previous investigations and the Rational Method approach. Differences in peak flow estimates were 20 per cent or less compared to both the previous investigations and the Rational Method approach.

B3. Muddy Creek and Scarborough Ponds TUFLOW model

B3.1. Background to hydraulic model development

Previous studies undertaken within the Muddy Creek and Scarborough Ponds catchments used DRAINS and HEC-RAS (Brown Consulting 2004), as well as MIKE-11 (WP, 2000) to define flood behaviour. Since the preparation of these earlier studies, more sophisticated modelling techniques have been developed which more accurately simulate the passage of the flood wave through a drainage system.

For the purpose of the present investigation, the TUFLOW software was used to convert the design discharge hydrographs generated by the DRAINS model into two-dimensional (in plan) flooding patterns.

B3.2. TUFLOW model layout

The layout of the Muddy Creek and Scarborough Ponds TUFLOW model that were developed as part of the present investigation are shown on **Figure B-2**.

An important consideration of two-dimensional modelling in an urbanised area is to ensure adequate representation of the roads, fences, buildings and other features which influence the passage of flow over the natural surface. A grid spacing of 2 m was adopted to provide an appropriate level of definition of those features whilst maintaining a reasonable simulation run time.

Grid elevations were based on LiDAR survey data that was captured in 2014. Ridge and gully lines were added to the model where the grid spacing was considered too coarse to accurately represent important topographic features which influence the passage of overland flow, such as road centrelines, bridge approaches and vegetated channels.

Drainage channels and culverts, as well as pit and pipe networks were typically defined using GIS based data that were obtained from Sydney Water and the local councils, as well as details contained in Brown Consulting, 2004 and Brown Consulting, 2007. This information typically included dimensions of channels, culverts and pipes and locations of pits, headwalls and channel junctions.

The above drainage data contained only limited information in regard to inlet pit types and dimensions. Inlet pit capacity relationships were therefore defined based on a visual inspection of the existing stormwater drainage system.

An assumed cover of 700 millimetres was adopted for those drainage elements where invert levels were not available (this limitation applied to most of the system). The assumed cover was adjusted where required, to ensure that the drainage system had positive fall in the downstream direction.

Table B-1 Peak discharges – 1% AEP storm (m^3/s)

Catchment	Location		Catchment Area (ha)	Peak Flow		
	Identifier(1)	Description		Muddy Creek and Scarborough Ponds DRAINS Model	Previous Study(2)	Rational Method
[A]	[B]	[C]	[D]	[E]	[F]	[G]
Eve Street Wetland	ES1	North of Marsh Street	7.2	3.8	-	4.2
	ES2	West Botany Street	15.0	7.4	-	8.2
Spring Street Drain	SS1	Somerville Street at South Coast Railway Line	7.6	4.3	5.4(a)	4.8
	SS2	Tabrett Street east of Chestnut Drive	22.8	11.1	10.7(a)	10.9
Muddy Creek	M1	Main branch upstream of South Coast Railway Line	294	90	85(b)	95
	M2	Main branch upstream of Princes Highway	367	120	-	106
	M3	Frances Avenue and Archbold Avenue	1.7	1.0	-	1.1
Scarborough Ponds	SP1	President Avenue west of Princes Highway	15.1	8.6	-	8.5
	SP2	Lachlan Avenue at Fairway Avenue	15.9	7.9	-	8.2
	SP3	Western end of Austral Street	4.2	2.1	1.5(c)	2.6

Notes:

1 Refer **Figure B-1** for location identifiers.

2 Previous study references:

a. Brown Consulting, 2007.

b. Willing and Partners, 2000.

c. Brown Consulting, 2004.

The dimensions of the Muddy Creek channel were defined using GIS based data obtained from Sydney Water, while the dimensions of the open channel that forms the main arm of Spring Street Drain were measured during a field inspection.

Bridge crossings over Spring Street Drain downstream of Short Street and at Beehag Reserve, Lynwen Crescent Reserve, West Botany Street and Barton Park were defined using a combination of LiDAR survey data (to set bridge deck levels) and measurements taken during a field inspection where the thickness of the bridge deck and depth of the channel below bridge deck level we measured.

Bridges over the Muddy Creek channel at Bay Street, West Botany Street and Bestic Street were also defined based on the LiDAR survey data and the field measurements described above.

The above approach was also used to define culverts draining to Scarborough Ponds at President Avenue, Barton Street and Tonbridge Street Reserve.

Invert levels along Spring Street Drain and the Muddy Creek channels were defined using a combination of LiDAR survey data and measurements taken during a field inspection when the depth of the channel below bridge deck level were measured.

B3.3. TUFLOW model boundary conditions

B3.3.1. Upstream boundary

Discharge hydrographs generated by both the Muddy Creek and Scarborough Ponds DRAINS Model were applied as both external TUFLOW model boundary and internal point source and region inflows as shown on **Figure B-2**.

B3.3.2. Downstream boundary

Design flood envelopes were derived using the combination of coincident catchment and ocean flooding conditions described in **section A4.4** of **Annexure A**.

B3.4. TUFLOW model parameters

Table B-2 sets out the hydraulic roughness values that were adopted for design purposes based on site inspection, past experience and values contained in the engineering literature.

Table B-2 Best estimate of hydraulic roughness values adopted for TUFLOW modelling

Surface Treatment	Manning's n value
Reinforced concrete pipes and box culverts	0.015
Concrete lined channels	0.015 – 0.02
Heavily vegetated channels	0.12
Asphalt or concrete road surface	0.02
Grassed reserves and playing fields	0.03 – 0.045
Treed areas	0.08
Fenced Properties	0.1
Buildings	10

B3.5. Sensitivity analyses

B3.5.1. Increase in hydraulic roughness

A sensitivity analysis was undertaken to assess the impact of a 20 per cent increase in the 'best estimate' values of hydraulic roughness (refer **Table B-2**) on flood behaviour in the vicinity of the proposed President Avenue tunnel portal and Rockdale motorway operations complexes (north and south) during a PMF event. The findings of the sensitivity analyses were as follows:

- Rockdale motorway operations complex (north and south) - peak flood levels along the section of West Botany Street adjacent to the motorway operations complexes would be increased by a maximum of 80 millimetres.
- President Avenue tunnel portal - peak flood levels in Scarborough Ponds adjacent to the proposed tunnel portal would be increased by a maximum of 0.04 metres.

B3.5.2. Partial blockage of hydraulic structures

An assessment of the impact that a partial blockage of major hydraulic structures would have on flood behaviour in the vicinity of the project is provided in **section 6.4** of this report.

B3.5.3. Increases in design rainfall intensities and tailwater levels

An assessment of the impact that a potential increase in rainfall intensities and tailwater levels as a result of future climate change would have on flood behaviour in the vicinity of the project is presented in **section 6.3.1** of this report.

B3.6. Comparison with results using ARR 2016

B3.6.1. General

As noted in **section B2.2**, the DRAINS model used to generated inflow hydrographs to the TUFLOW model was based on design storms that were derived using the procedures set out in Australian Rainfall and Runoff (ARR 1987). While an update of ARR was released in 2016 (i.e. ARR 2016) the document is currently in 'draft for industry consultation'. The latest advice from Geosciences Australia is that a revision of ARR 2016 will be issued in the first quarter of 2018.

Given the potentially imminent release of a final revision of ARR 2016, a comparison has been made of flood behaviour in the vicinity of the project with ARR 1987 in order to assess potential changes to defined flood behaviour.

B3.6.2. Assessment Approach

Separate DRAINS models were developed using the procedures in ARR 1987 and ARR 2016 in order to generate discharge hydrographs which were then applied as inflows to the Muddy Creek TUFLOW model. This involved the following tasks:

1. Rainfall depths for a 1% AEP event were derived for storm durations ranging between 30 minutes and 9 hours using the procedures outlined in ARR 1987 and ARR 2016. **Table B-3** over the page shows that ARR 1987 design rainfall depths are between 22 to 29 per cent higher than the corresponding ARR 2016 values for storm durations up to 180 minutes. For storms durations of 360 and 540 minutes the differences are less, with ARR 1987 rainfall depths being 17 and 11 per cent higher than the corresponding ARR 2016 values, respectively.
2. The design rainfalls were then converted into rainfall hyetographs using the temporal patterns presented in ARR 1987 and ARR 2016. While ARR 1987 prescribes a single temporal pattern for each storm duration, ARR 2016 requires an analysis of 10 temporal patterns for each storm duration. The application of these ten temporal patterns to the Muddy Creek and Scarborough Ponds TUFLOW Model is discussed further under Task 4.
3. While ARR 2016 recommends the use of a new urban loss model in lieu of the ILSAX model within DRAINS, clear guidance on the application of the new model is limited until the release of the chapter on urban catchment modelling (Book 9, Chapter 6 of ARR 2016). For this reason, the ILSAX sub-model was used to model the urbanised areas within the DRAINS models established for both ARR 1987 and ARR 2016. The new guidelines recommend the division of impervious areas into directly and indirectly connected impervious areas, with losses applied to the indirectly connected area closer to the values for rural pervious areas. On this basis the use of the ILSAX sub-model is likely to produce a higher peak flow estimate in comparison to the new urban loss model recommended in ARR 2016.

4. The Muddy Creek and Scarborough Ponds TUFLOW Model was run for a 1% AEP design event for storm durations ranging between 30 minutes and 9 hours using the inflow hydrographs generated from the DRAINS models. While ARR 2016 recommends that ten temporal patterns for each storm duration are run through the hydrologic model in order to select the pattern that produces a peak flow estimate that is closest to the mean, this approach is not practical for investigations where the hydrologic model is being used to generate inflow hydrographs to a hydrodynamic model which is then used to assess flood behaviour at multiple locations across a study area (such as the present investigation). For this reason, the assessment of flood behaviour using ARR 2016 involved the generation of discharge hydrographs for all ten temporal patterns which were then applied to the Muddy Creek and Scarborough Ponds TUFLOW Model. A representative set of water surface elevations and depths were then developed for each storm duration based on the median values which were derived by running the ten temporal patterns. The representative water surface elevations and depths for each duration were then enveloped to derive a design flood envelope. For six durations between 30 minutes and 9 hours this requires 60 runs of the TUFLOW model for a 1% AEP design storm which is a tenfold increase when compared to the number of runs required for ARR 1987.

Table B-3 Comparison of 1% AEP design rainfall depths (mm)

Storm Duration (minutes)	ARR 1987	ARR 2016	Difference[(1)]
30	65.5	50.8	-22%
60	93	66.1	-29%
120	118	86	-27%
180	135	102	-24%
360	169	140	-17%
540	194	172	-11%

Note:

1 A positive value represents an increase and conversely a negative value represents a decrease relative to ARR 1987 design rainfall depths.

B3.6.3. Summary of Key Findings

Figure B-3 shows the impact that the application of ARR 2016 has on flood behaviour in terms of changes in peak flood levels and the extent of inundation during a 1% AEP storm.

While the adoption of ARR 2016 design storms would result in a significant reduction in both the extent and depth of inundation in the upper reaches of the Scarborough Ponds catchment, the differences are much smaller along its main arm. This is due to the smaller relative difference between the design rainfall depths derived using ARR 1987 and ARR 2016 for a 9 hour storm, which is critical for generating peak flood levels along the main arm of Scarborough Ponds.

B3.7. Comparison with results of previous study

Table B-4 compares 1% AEP peak flood levels derived using the Muddy Creek and Scarborough Ponds TUFLOW Model with levels presented in the *Spring Street Drain, Muddy Creek and Scarborough Ponds Floodplain Management Study* (WP 2000).

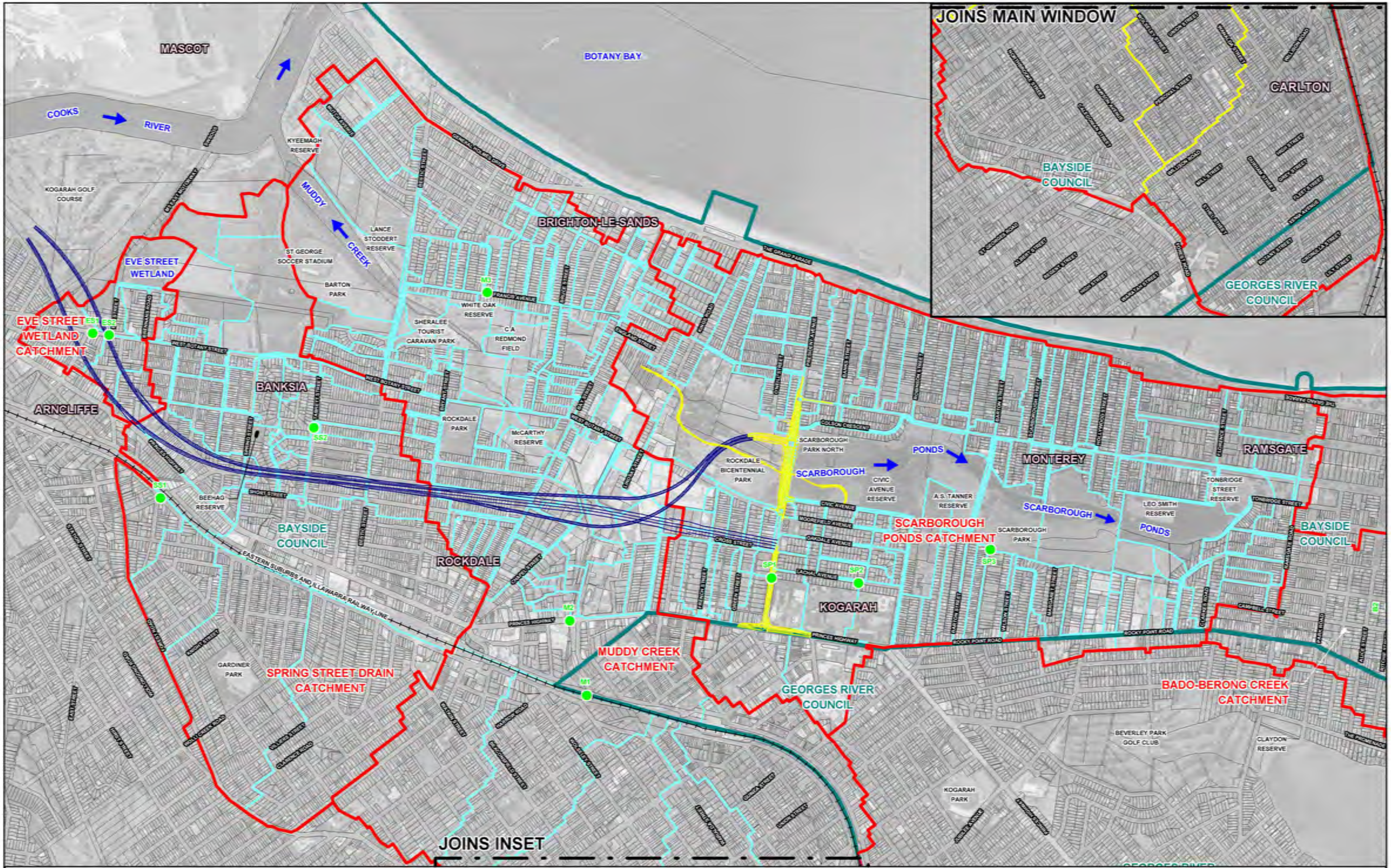
While peak flood levels derived for the present investigation along the main arm of Muddy Creek at Bestic Street are within 0.1 metres of the corresponding result presented in WP, 2000, a greater difference occurs at West Botany Street where the peak flood level from the present investigation is 0.4 m higher than the corresponding value presented in WP, 2000. It would appear that this difference is due to the inclusion of a pedestrian bridge in the Muddy Creek and Scarborough Ponds TUFLOW Model, which generates a headloss of 0.5 m across the structure during a 1% AEP flood.

Peak flood levels derived for the present investigation along the main arm of Scarborough Ponds at President Avenue match closely with the corresponding values presented in WP, 2000in Scarborough Ponds at President Avenue.

Table B-4 1% AEP peak flood levels – comparison with previous investigation (m)

Location		Muddy Creek and Scarborough Ponds TUFLOW model	WP, 2000
I.D.[1]	Description		
1	Muddy Creek at Bestic Street	1.9	2.0
2	Muddy Creek at West Botany Street	2.8	2.4
3	Scarborough Ponds at President Avenue	2.5	2.5

Note:
1 Refer to **Figure B-2** for location I.D.'s.
2 A positive value represents an increase and conversely a negative value represents a decrease relative to the Muddy Creek and Scarborough Ponds TUFLOW Model.



150 0 150 300 450 m

Scale: 1:15,000

LEGEND

- ILSAX Sub-catchment Boundary
- Catchment Boundary
- LGA Boundary
- ES2 Peak Flow Location and Identifier
- Proposed Tunnel Road Works
- Proposed Surface Road Works

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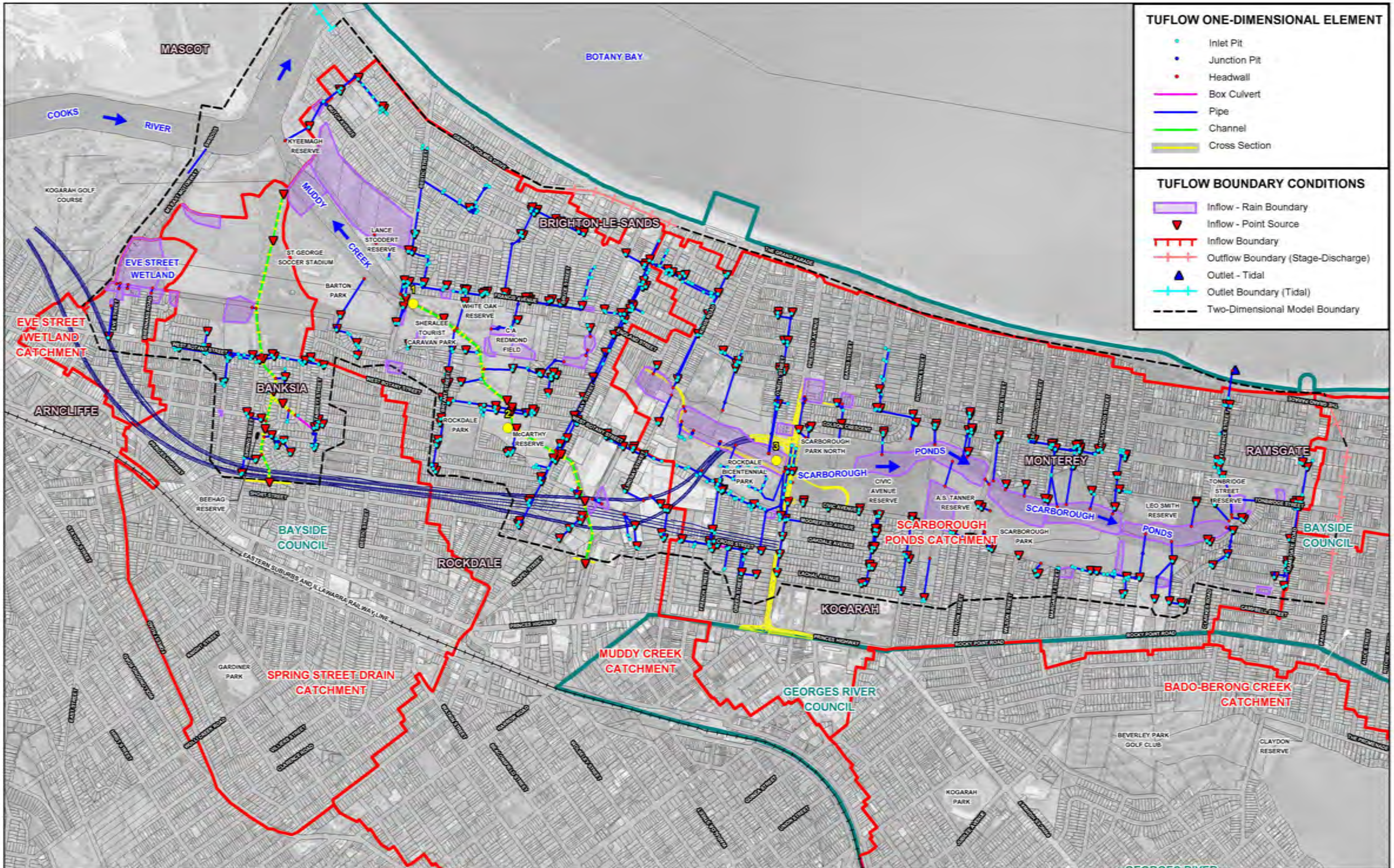
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure B-1

MUDDY CREEK AND SCARBOROUGH PONDS
DRAINS MODEL LAYOUT



150 0 150 300 450 m

Scale: 1:15,000

LEGEND

- Catchment Boundary
- LGA Boundary
- 1 Location Identifier
- Proposed Tunnel Road Works
- Proposed Surface Road Works

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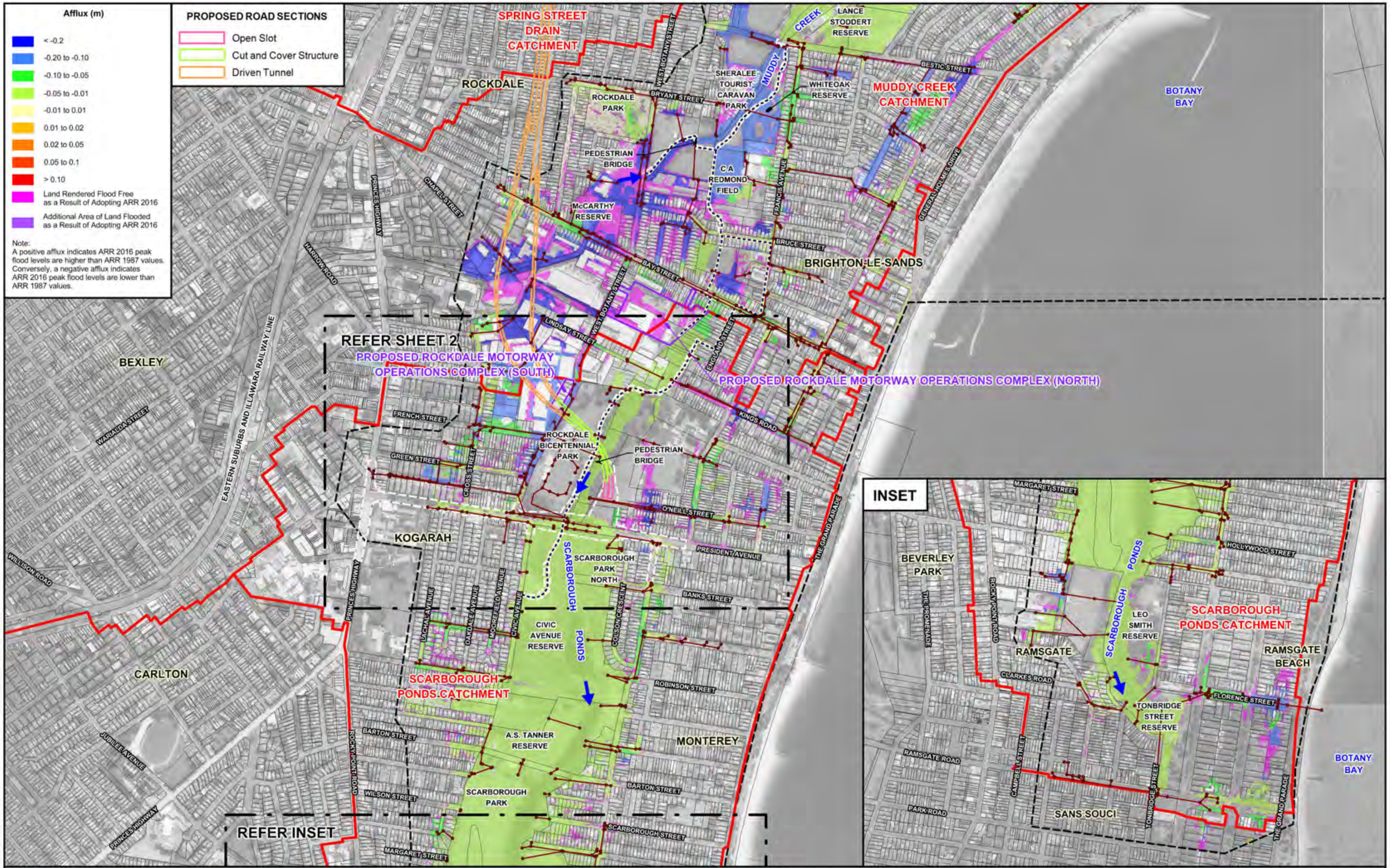
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure B-2

MUDDY CREEK AND SCARBOROUGH PONDS
TUFLOW MODEL LAYOUT



120 0 120 240 360 m

Scale: 1:12,000

Note:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

- Proposed Cycle and Pedestrian Pathways
- Project Boundary of Proposed Surface Works
- Extent of Proposed Tunnel Ancillary Facilities
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

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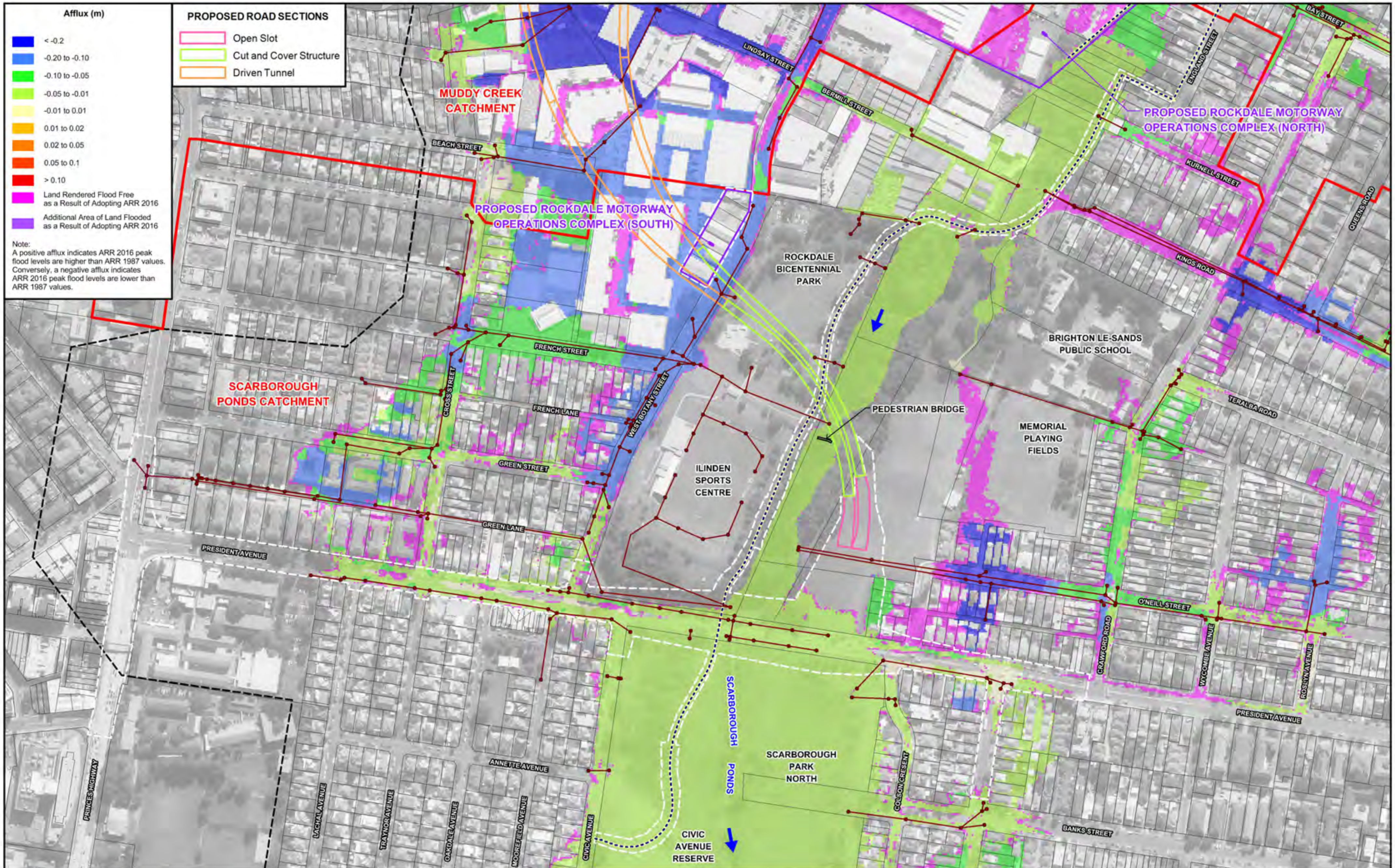
F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure B-3
Sheet 1 of 2

DIFFERENCE IN FLOOD BEHAVIOUR IN VICINITY OF PROJECT
ARR 2016 MINUS ARR 1987 - PRESENT DAY CONDITIONS - 1% AEP



N

40 0 40 80 120 m

Scale: 1:4,000

Lyall & Associates

Note:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

- Proposed Cycle and Pedestrian Pathways
- Project Boundary of Proposed Surface Works
- Extent of Proposed Tunnel Ancillary Facilities
- Existing Drainage System
- Two-Dimensional Model Boundary
- Catchment Boundary

F6 EXTENSION STAGE 1 NEW M5 MOTORWAY TO PRESIDENT AVENUE
FLOODING AND DRAINAGE TECHNICAL REPORT

Figure B-3
Sheet 2 of 2

DIFFERENCE IN FLOOD BEHAVIOUR IN VICINITY OF PROJECT
ARR 2016 MINUS ARR 1987 - PRESENT DAY CONDITIONS - 1% AEP