Chapter 18

Flooding

January 2020

18 Flooding

This chapter outlines the potential flooding impacts associated with the project. Detailed flooding assessments have been carried out for the project and are included in Appendix R (Technical working paper: Flooding).

The Secretary's environmental assessment requirements as they relate to flooding, and where in the environmental impact statement these have been addressed, are detailed in Table 18-1.

The proposed environmental management measures relevant to flooding are included in Section 18.8.

Table 18-1 Secretary's environmental assessment requirements – flooding

Secretary's requirement	Where addressed in EIS
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; and c. Hydraulic categorisation (floodways and flood storage areas).	Figures containing maps of features relevant to flooding are listed below: a. Flood prone land – Figure 4.4 of **Appendix R** (Technical working paper: Flooding) b. Flood planning areas, the area below the flood planning level – Figure 4.7 of **Appendix R** (Technical working paper: Flooding) c. Hydraulic categorisation (floodways and flood storage areas) – Figure 4.5 of **Appendix R** (Technical working paper: Flooding).
2. The Proponent must assess (and model where required), 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 storm intensity due to climate change) including:	**Section 18.3** of this chapter sets out the approach that was adopted to assess the impact the project would have on flood behaviour during both its construction and operation. **Section 18.5** and **Section 18.6** detail the findings of the impact assessment during construction and operation respectively thereafter.
a. How the tunnel entries and cut-and-cover sections of the tunnels would be protected from flooding during construction works;	**Section 18.5.2** summarises the findings of the assessed flood risk at the construction support sites that would be used to support tunnel excavation and the construction of cut and cover sections of tunnel, while **Section 18.8** contains a set of measures which are aimed at managing the flood risk during tunnel construction.
b. Any detrimental increases in the potential flood affectation of the project infrastructure and other properties, assets and infrastructure;	**Section 18.5** and **Section 18.6** of this chapter present the findings of an assessment of the potential impacts on flood behaviour during the construction and operational phases of the project, respectively.

Secretary's requirement	Where addressed in EIS
c. Consistency (or inconsistency) with applicable Council floodplain risk management plans;	**Section 18.6.3** presents the findings of a review of the project in terms of its consistency with Council floodplain risk management plans.
d. Compatibility with the flood hazard of the land;	**Section 18.4** describes the existing flood behaviour in the vicinity of the project, including an overview of the provisional flood hazard for a 1% AEP flood. **Section 18.5.2** includes discussion on the potential flood hazard at proposed construction support sites, while **Section 18.6** includes discussion on the findings of the assessment in terms of the impact that the operation of the project would have on the hazard categorisation of the floodplain.
e. Compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land;	**Section 18.4** of this chapter describes the existing flood behaviour in the vicinity of the project, including the hydraulic categorisation of the floodplain into floodways, flood storage and flood fringe for a 1% AEP flood. **Section 18.5** and **Section 18.6** describe the impacts on flood behaviour as a result of changes to flow conveyance and flood storage across the floodplain.
f. Whether there will be adverse effect to beneficial inundation of floodplain environment, on, or adjacent to or downstream of the site;	Due to the urbanised nature of the floodplain no areas have been identified where there would be an adverse effect caused by a reduction in inundation. **Section 18.5** and **Section 18.6** present the findings of an assessment of more general impacts of the project on flood behaviour, including changes in the extent of inundation.
g. Downstream velocity and scour potential;	**Section 18.5** identifies potential impacts that the construction of the project could have on velocity and scour potential, while **Section 18.6** present the findings of an assessment of the corresponding impacts during the operation of the project.
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;	**Section 18.6** provides an assessment of the proposed works and its impact on transport infrastructure that may be relied upon as part of community emergency management arrangements. **Section 18.8** includes a recommendation for the incorporation of flood emergency management measures into the relevant environmental management document (construction and operation) of the project.

Secretary's requirement	Where addressed in EIS
i. Any impacts the development may have on the social and economic costs to the community as consequence of flooding;	**Section 18.5** and **Section 18.6** 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 disruption to the community) and economic impacts (such as the potential for increases in flood damages in adjacent development due to an increase in above floor inundation).
j. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; and;	**Section 18.5** identifies potential impacts that the construction of the project could have on erosion, siltation and the stability of watercourses, while **Section 18.6** presents the findings of an assessment of the corresponding impacts during the operation of the project.
k. 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 18.8** 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.	**Appendix R** (Technical working paper: Flooding) 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 18.6.2** of this chapter provides an assessment of the impact the project would have on flood behaviour under future climate change conditions.

18.1 Flooding terminology and concepts

18.1.1 Annual exceedance probability

The frequency of floods is generally referred to in terms of their Annual Exceedance Probability (AEP). For example, for a flood magnitude having 10% AEP, there is a ten per cent probability (or 1 in 10 chance) that there would be floods of greater magnitude each year. Similarly, for a flood magnitude having 1% AEP, there is a one per cent probability (or 1 in 100 chance) that there would be floods of greater magnitude each year.

18.1.2 Probable maximum flood

The Probable Maximum Flood (PMF) occurs as a result of the Probable Maximum Precipitation (PMP) on the study catchments. The PMF 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. Meaning, 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 (ie the floodplain).

18.2 Legislative and policy framework

The assessment of potential flooding impacts of the project on existing flood regimes has been conducted in accordance with relevant national, state and local government legislation, policies and technical guidelines. The assessment has adhered to:

- National level:
  - *Australian Rainfall Runoff* (ARR) 1987, with a sensitivity analysis of the recently released ARR 2019 edition
  - *Australian Disaster Resilience Handbook 7: Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR) 2017 edition
- State level:
  - *Floodplain Development Manual* (FDM) 2005
  - *Guideline on Development Controls on Low Risk Flood Areas* 2007
  - *Environmental Planning and Assessment Act* 1979
  - *Floodplain Risk Management Guidelines: Practical Considerations of Climate Change 2007*
- Local level:
  - Leichhardt Local Environment Plan (LEP) 2013
  - Willoughby LEP 2012
  - North Sydney Flood Study (WMAwater, 2016).

18.3 Assessment methodology

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

- Review of available data including existing flood studies and associated hydrologic and hydraulic models (collectively referred to as ‘flood models’) within the catchments that are crossed by the project
- Update of the existing flood models where required to more accurately define flooding and drainage behaviour in the vicinity of the project
- Preparation of exhibits showing flood behaviour under present day conditions for design floods with AEPs of 10%, 1%, 0.5% and 0.2%, as well as PMF
- Assessment of the potential flood risks during construction and the operational features of the project
- Assessment of the potential impact the project would have on flood behaviour while under construction and during operational conditions
- Assessment of the impact future climate change would have on flood behaviour under operational conditions

- Assessment of the impact a partial blockage of the local stormwater drainage system 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
- An application of the ARR 1987 methodology (and recently released 2019 ARR sensitivity analysis) to the design flood estimation.

Further detail and information in respect to the methodology for each of the key tasks above is outlined in Appendix R (Technical working paper: Flooding).

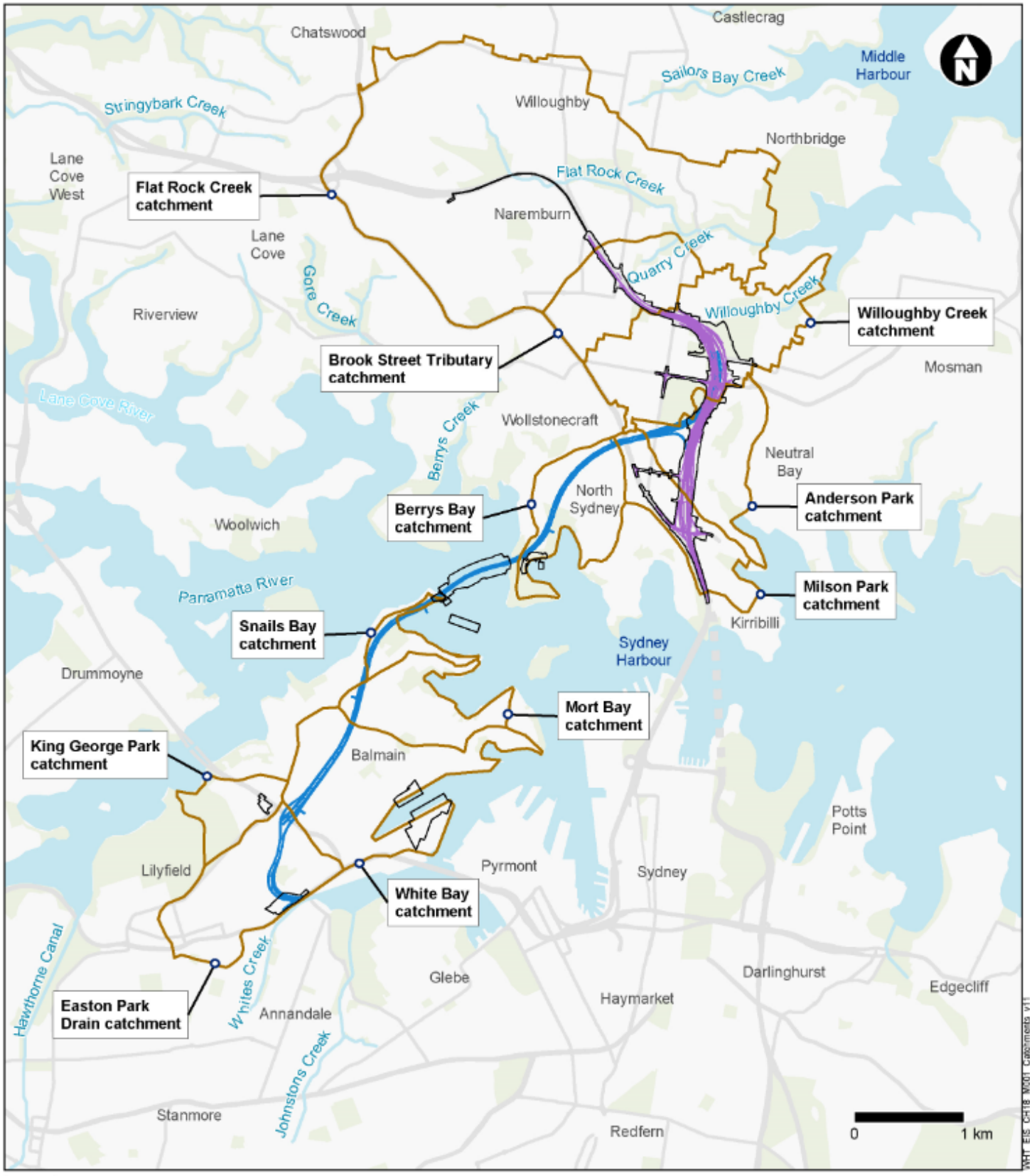
18.4 Existing environment

18.4.1 Overview

The following catchments presently contribute run off to the existing drainage systems and waterways that are located within the project footprint (Figure 18-1):

- Easton Park Drain
- King George Park
- White Bay
- Snails Bay
- Berrys Bay
- Milson Park
- Anderson Park
- Willoughby Creek
- Flat Rock Creek
- Brook Street Tributary (a sub-catchment of Flat Rock Creek).

Flat Rock Creek, Brook Street Tributary and Willoughby Creek drain to Middle Harbour, while the remainder of the catchments drain to Sydney Harbour. Section 18.4.2 provides a brief overview of each catchment, while Section 18.4.3 provides a description of the nature of mainstream flooding and major overland flow in the vicinity of the project under present day (ie pre-project) conditions. Mainstream flooding, major overland flow and ocean storm tide flooding have collectively been termed ‘flooding’ within this chapter.



Legend

Operational features
- Western Harbour Tunnel
- Warringah Freeway Upgrade

Construction features
- Construction footprint

Catchments and waterways
- Catchement boundary
- Waterways

Figure 18-1 Catchment areas

A general description of the geomorphology and water quality of the existing catchment and watercourse environments is provided in Chapter 17 (Hydrodynamics and water quality). Chapter 17 (Hydrodynamics and water quality) also details the existing drainage infrastructure and surface water and surface water management infrastructure of the study area. This section outlines:

- Catchments and their drainage characteristics
- The existing flood behaviour of each catchment.

18.4.2 Catchment description

The following sections provide an overview of each catchment that drains to and from the project corridor, including information regarding key drainage features, as well as the source of flows for the existing drainage lines that cross the project.

Figure 18-1 shows an overview of the catchment areas subject to the project while Figure 4.1 of Appendix R (Technical working paper: Flooding) shows more detail of the existing drainage systems and catchment features along the project corridor and should be read in conjunction with the information detailed below.

Easton Park Drain

The Easton Park Drain runs in an easterly direction from Easton Park in Rozelle and has a total catchment area of about 1.18 square kilometres (118 hectares) where it discharges into Rozelle Bay. The catchment is located within the Inner West local government area and includes the suburbs of Rozelle and Lilyfield.

A series of drainage systems comprising pipe and box culvert sections control runoff from the catchment converge at the Rozelle Rail Yards where they discharge into a vegetated channel that has recently been constructed as part of the M4-M5 Link project. The vegetated channel runs for about 600 metres before discharging into a box culvert that runs under City West Link and into Rozelle Bay.

The Rozelle Rail Yards construction support site (WHT1) is proposed to be located along the north-western side of the aforementioned vegetated channel that runs through the Rozelle Rail Yards.

King George Park

The King George Park catchment drains in a north-westerly direction, extending from Darling Street in Rozelle to King George Park, and has a total catchment area of about 0.43 square kilometres (43 hectares). The catchment is located within the Inner West local government area and includes the suburbs of Rozelle and Lilyfield.

The eastern portion of the catchment, where the Victoria Road construction support site (WHT2) is proposed to be located, mainly comprises medium density residential development, as well as commercial development along the main arterial roads of Darling Street and Victoria Road.

Runoff from the eastern portion of the catchment is controlled by a series of piped drainage systems that connect into a trunk drainage line that runs along the western side of King George Park and discharges into Iron Cove Bay.

White Bay

The White Bay catchment drains in a south-easterly direction, extending from Darling Street in Rozelle to White Bay, and has a total catchment of about 1.61 square kilometres (161 hectares).

The catchment is located within the Inner West local government area and includes the suburbs of Rozelle and Balmain.

The White Bay construction support site (WHT3) is proposed to be located along the northern and southern sides of the bay, about 200 metres east of the main trunk drainage line that controls runoff from the catchment.

Snails Bay

The Snails Bay catchment drains in a north-easterly direction, extending from Spring Street in Birchgrove to Snails Bay, and has a total catchment area of about 0.23 square kilometres (23 hectares). The catchment is located within the Inner West local government area and includes the suburb of Birchgrove.

The Yurulbin Point construction support site (WHT4) is proposed to be located at the northern end of the catchment within Yurulbin Park.

Berrys Bay

The Berrys Bay catchment drains in a southerly direction, extending from McHatton Street in North Sydney to Berrys Bay, and has a total catchment area of about 0.8 square kilometres (80 hectares). The catchment is located within the North Sydney local government area and includes the suburbs of Waverton, North Sydney and McMahons Point.

The western portion of the catchment, where the Berrys Bay construction support site (WHT7) is proposed to be located, comprises residential development and open space. A 525 millimetre diameter piped drainage line controls runoff from the residential area along Balls Head Road and discharges into Berrys Bay to the west of Carradah Park.

Milson Park

The Milson Park catchment drains in a south-easterly direction, extending from West Street in North Sydney to Milson Park, and has a total catchment area of about 0.63 square kilometres (63 hectares). The catchment is located within the North Sydney local government area and includes the suburbs of North Sydney and Kirribilli.

The Warringah Freeway runs north-south through the middle reach of the catchment. The upper portion of the catchment to the west of the freeway mainly comprises the North Sydney central business district, while the lower portion of the catchment to the east of the freeway mainly comprises medium to high density residential development, as well as commercial development within Kirribilli Village.

The main trunk drainage line controlling runoff from the catchment ranges in size from a 1500 millimetre wide by 1200 millimetre high box culvert where it runs under Mount Street west of Walker Street, to a three metre wide channel where it runs along the northern side of Milson Park and discharges into Careening Cove. The trunk drainage line crosses Warringah Freeway between Mount Street and High Street as a 1500 to 1900 millimetre by 1200 millimetre high box culvert.

Anderson Park

The Anderson Park catchment drains in a southerly direction, extending from Military Road in Neutral Bay to Anderson Park, and has a total catchment area of about 0.89 square kilometres (89 hectares). The catchment is located within the North Sydney local government area and includes the suburbs of North Sydney and Neutral Bay.

The Warringah Freeway runs north-south through the western portion of the catchment, which predominantly comprises medium density residential development with areas of higher density residential and commercial development also present along Military Road and the area to the west

of the Warringah Freeway. Areas of open space include Forsyth Park, Anderson Park and the eastern portion of St Leonards Park.

The main trunk drainage line controlling runoff from the catchment ranges in size from a 1500 millimetre diameter pipe where it runs under Forsyth Park to a four metre wide channel where it runs along the western side of Anderson Park and discharges into Neutral Bay Harbour.

The western portion of the catchment is drained by a series of piped drainage systems that cross the Warringah Freeway and discharge into the aforementioned trunk drainage line that runs through Forsyth Park and Anderson Park. The largest of these piped drainage systems comprises a 1200 millimetre diameter pipe where it crosses the Warringah Freeway to the south of Hampden Street.

Willoughby Creek

The Willoughby Creek catchment drains in a north-easterly direction, extending from the Pacific Highway in North Sydney and has a total catchment area of about 1.5 square kilometres (150 hectares) at Grafton Street. The catchment is located within North Sydney local government area and includes the suburbs of North Sydney, Crows Nest, Neutral Bay, Cremorne and Cammeray.

The Warringah Freeway runs north-south through the middle reaches of the catchment, which predominantly comprises medium density residential development with areas of higher density residential and commercial development also present within its upper reaches. Areas of open space include St Leonards Park, ANZAC Park, Cammeray Golf Course and Green Park. ANZAC Park School is located on the western (upstream) side of the Warringah Freeway, immediately north of ANZAC Park.

A series of drainage systems comprising pipe and box culvert sections control runoff from the catchment upstream of the Warringah Freeway and converge at ANZAC Park where they discharge into twin 2000 millimetre wide by 1500 millimetre high box culvert where it crosses under the Warringah Freeway. A series of piped drainage systems that control runoff from the Warringah Freeway discharge directly into the box culvert. This drainage line continues downstream through Cammeray Golf Course as a 2500 millimetre wide by 1500 millimetre high box culvert. At Grafton Street the box culvert outlets into a steep gully in the north-east corner of Primrose Park where it runs along the northern side of the park as a grassed channel before ultimately discharging into Middle Harbour.

Brook Street Tributary

The Brook Street Tributary runs in a north-easterly direction from Chandos Street in St Leonards and has a catchment area of about 0.9 square kilometres (90 hectares) where it joins the main arm of Flat Rock Creek (see Technical working paper: Flooding for more information). About 75 per cent of the Brook Street Tributary catchment lies in the North Sydney local government area, while the remainder is located in the Willoughby local government area.

The existing trunk drainage line controlling runoff from the catchment ranges in size from a 1200 millimetre diameter pipe at Chandos Street to a single 1350 millimetre diameter pipe where it discharges to an open channel near the intersection of Marks Street and Quarry Street. A number of minor lateral drainage lines discharge to the trunk drainage system along its length.

Flat Rock Creek

The Flat Rock Creek catchment drains in an easterly direction from the Pacific Highway in Artarmon and has a total catchment area of about 3.9 square kilometres (390 hectares) at Willoughby Road. The catchment is located within the Willoughby local government area and includes the suburbs of Artarmon, St Leonards, Naremburn, Willoughby, Northbridge, and Cammeray.

The catchment is completely urbanised, and the natural drainage characteristics have been altered by industrial, residential, and commercial development. The construction of the Gore Hill Freeway in 1991 along the route of the original creek has altered the natural drainage system and its flood storage characteristics. The North Shore railway line runs north-south through the middle reaches of the catchment.

A new trunk drainage system was constructed in conjunction with the Gore Hill Freeway, extending from the Pacific Highway to the North Shore railway line. The Gore Hill Freeway and its drainage system were later upgraded as part of the Lane Cove Tunnel project in 2006.

The trunk drainage system downstream of the North Shore railway line culvert to Willoughby Road was constructed in the 1930s and was not altered by the construction of the freeway. Between the railway and Chelmsford Avenue, the trunk drainage comprises a low level conduit running beneath a vegetated floodway which caters for surcharge (overflow) flows. A concrete and brick lined channel with a waterway area of 6.5 to 7.3 square metres comprises the main arm of Flat Rock Creek where it runs from Chelmsford Avenue to Willoughby Road.

At Willoughby Road, flows are conveyed through a stone arch bridge. During major flood events, the Willoughby Road bridge conveys flows derived from the Flat Rock catchment, as well as surcharges from one of its tributaries. A major box culvert commences at the downstream face of the bridge and runs beneath Hallstrom Park before discharging to an open channel 280 metres to the east of Flat Rock Drive.

18.4.3 Catchment areas and drainage characteristics

Provided below is a brief description of the patterns of both mainstream flooding and major overland flow in respect to present day (ie pre project) conditions within areas in the vicinity of construction and/or operational components of the project. Reference is also made in the following discussion of the proposed construction support sites, further details of which are outlined in Chapter 6 (Construction work).

The patterns of mainstream flooding and major overland flow are classified using Annual Exceedance Probability and Probable Maximum Flood which, as outlined in Section 18.1.1 above, are defined as follows:

- Annual Exceedance Probability (AEP) –
  - 10% AEP – there is a ten per cent probability (or 1 in 10 chance) that there would be floods of greater magnitude each year
  - 1% AEP – there is a one per cent probability (or 1 in 100 chance) that there would be floods of greater magnitude each year
- Probable Maximum Flood (PMF) – 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.

Flooding behaviour has been defined using the hydrologic and hydraulic models that were developed as part of the studies informing this assessment (see Appendix R (Technical working paper: Flooding) for more information). It should be noted that the discussion below only considers those flooding patterns in catchment areas for which impacts are predicted. As such, AEP and PMF flood impacts are not reported for all catchment areas.

Figure 18-2 to Figure 18-7 show the flooding behaviour for each of the catchments in the 1% AEP event (for the existing flooding behaviour in the 10% AEP, 1% AEP and PMF events for all catchments, refer to Figure 4.2 to 4.4 in Appendix R (Technical working paper: Flooding)).

Easton Park Drain

A channel has recently been constructed as part of the M4-M5 Link project that runs in an easterly direction along the southern side of Rozelle Rail Yards and discharges into Rozelle Bay via a culvert crossing at City West Link. While the channel has been designed to convey the 1% AEP flow from the catchment to the west of the Rozelle Rail Yards, a series of ill-defined overland flow paths are shown to also occur through the northern portion of the rail yards due to flow that surcharges the drainage system in Lilyfield Road. Flooding in the vicinity of the proposed Rozelle Rail Yards construction support site (WHT1) is a low hazard nature and is classified as flood fringe for storm events up to 1% AEP in intensity.

King George Park

Overland flow in the vicinity of the proposed Victoria Road construction support site (WHT2) is shown to be largely confined to the roadways of Victoria Road and Waterloo Street for all events up to the PMF. Flooding within the vicinity of the Victoria Road construction support site (WHT2) is principally of a low hazard nature, with floodway areas confined to the road reserve of Victoria Avenue for storm events up to 1% AEP in intensity.

White Bay

The White Bay construction support site (WHT3) would be located on foreshore land that is located above the PMF level due to elevated storm tides.

Snails Bay

While the area of Yurulbin Park where the Yurulbin Point construction support site (WHT4) is proposed to be located is not impacted by mainstream flooding or major overland flow, the area would be affected by local catchment runoff of a low hazard nature from the residential area to its west.

Berrys Bay

A series of ill-defined overland flow paths are shown to occur through the southern portion of Carradah Park where the Berrys Bay construction support site (WHT7) is proposed to be located. This overland flow is due to runoff from the residential area bounded by Balls Head Road and Larkin Street. Depths of flow through Carradah Park are typically less than 0.3 metres during a 1% AEP event. Flooding in this area is classified as low hazard flood fringe for storms up to 1% AEP in intensity.

Milson Park

Up to 1% AEP

An overland flow path is shown to occur due to surcharge of the drainage system in Mount Street and Walker Street during a 10% AEP event. Overland flow collects at the sag in Arthur Street between Mount Street and the Pacific Highway, where it surcharges onto the northbound carriageways of the Warringah Freeway. The northern section of Arthur Street near its intersections with Mount Street operates as a high hazard floodway during a 1% AEP storm event.

Flow that discharges onto the Warringah Freeway from Arthur Street and at St Leonards Park combines with local catchment runoff and pond at the sags in the northbound and southbound carriageways that are located to the north of the High Street overbridge (hereafter referred to and identified as ‘the southern Warringah Freeway sag’).

Surcharge of the existing trunk drainage line which runs from the southern side of the High Street southbound on ramp to the Cahill Expressway to Careening Bay causes flooding in a number of

residential unit block and terrace-type developments during storms as frequent as 10% AEP. It also causes flooding of the James Milson Village (Retirement and Residential Care) development which is located on Clark Street in North Sydney. Areas within the village that are impacted by flow which surcharges the trunk drainage line include existing basement car parking and below-ground storage facilities.

During a 1% AEP storm event, several low and high hazard floodway areas would develop along the section of the Warringah Freeway which runs through the Milson Park catchment, while a flood storage area would form at the location of the southern Warringah Freeway sag. Two flood storage areas would also develop beneath the elevated section of the Cahill Expressway west of Broughton Street during a storm of this intensity.

PMF

Flow that discharges onto Warringah Freeway from Arthur Street, Hampden Street and St Leonards Park would combine with local catchment runoff and pond at the sags in the northbound carriageways to a maximum depth of over two metres. The depth of ponding at this location is sufficient to overlap the adjacent concrete barriers where floodwater would enter the tunnel portals to the Sydney Harbour Tunnel[1].

Anderson Park

Up to 1% AEP

Flow would surcharge onto the Warringah Freeway from St Leonards Park where it runs in a southerly direction along the northbound and southbound carriageways at depths that are typically less than 0.2 metres during a 1% AEP event.

Overland flow that surcharges the drainage system between McLaren Street and Ridge Street would pond at the sag that is located on the western side of the Berry Street on ramp to the Warringah Freeway to a maximum depth of 1.7 metres during a 10% AEP event, increasing to 2.4 metres during a 1% AEP event. The level of ponding during a 1% AEP event is about four metres below the adjacent level of the northbound on-ramp from Berry Street.

Similar to the Milson Park catchment, several low and high hazard floodway areas would develop along the section of the Warringah Freeway which runs through the Anderson Park catchment during a 1% AEP storm event. A high and low hazard flood storage area would also develop immediately to the west of the Berry Street on ramp to the Warringah Freeway during a storm of this intensity.

PMF

Flow that discharges onto the Warringah Freeway from St Leonards Park runs in a southerly direction along the northbound and southbound carriageways at a maximum depth of about 0.4 metres.

Overland flow from McLaren Street and Walker Street that collects at the sag located on the western side of the Berry Street on ramp to the Warringah Freeway would pond to a maximum depth of about five metres, which is sufficient to cause floodwaters to surcharge onto the Warringah Freeway.

[1] Unlike the current project, the flood immunity requirement for the Sydney Harbour Tunnel was to prevent the ingress of floodwater to the tunnel system for storm events up to 1% AEP in intensity.

Willoughby Creek

Up to 1% AEP

During a 10% AEP event, flow would surcharge the trunk drainage system that forms the main arm of Willoughby Creek and overtop the sag in Ernest Street to the east of Lytton Street to a maximum depth of about 0.5 metres, increasing to 0.7 metres during a 1% AEP. Existing residential development located on the southern side of Ernest Street is also affected by flooding due to surcharge of the trunk drainage system. The main flow path which runs between St Leonards Park and ANZAC Park principally operates as a low hazard floodway, although high hazard areas are located in the vicinity of ANZAC Park, principally due to the depth of ponding that occurs in this area.

Flow that surcharges the tributary branch of Willoughby Creek that runs between Miller Street and ANZAC Avenue along the northern boundary of ANZAC Park Public School would overtop ANZAC Avenue to a maximum depth of about 0.2 metres during a 10% AEP event, increasing to 0.5 metres during a 1% AEP event.

Overland flow from Ernest Street and ANZAC Avenue would collect at the low point in ANZAC Park before entering the trunk drainage system that runs under the Warringah Freeway. The depth of ponding in ANZAC Park would occur to a maximum of 2.1 metres and 3.5 metres during a 10% and 1% AEP event, respectively, which is sufficient to result in hazardous flooding conditions to people and property.

Floodwaters that collect in ANZAC Park would pond against the noise wall that runs along the western side of the Warringah Freeway to a maximum depth of about three metres during a 1% AEP event. If the noise wall were to fail under this weight of water then floodwater would inundate the Miller Street off-ramp to a maximum depth of about two metres and would also extend across the northbound carriageways of the freeway.

During a 1% AEP storm event, a low and high hazard floodway would form to the north (downstream) of the road corridor near Cammeray Golf Course. The floodway area also extends east into an existing residential development located along Fall Street and Grafton Street.

PMF

Floodwaters that collect in ANZAC Park would build up to a level that overtops the noise wall that runs along the western side of the Warringah Freeway, where it would pond across the full width of the freeway before surcharging across its eastern side and into Cammeray Golf Course.

ANZAC Park would be inundated to a maximum depth of seven metres, while the carriageways of the Warringah Freeway would be inundated over a length of about 350 metres and to a maximum depth of five metres.

Brook Street Tributary

Up to 1% AEP

Flow surcharges the sag in Atchison Street to the west of Willoughby Road during a 10% AEP event where it discharges in a north-easterly direction along Chandos Street and Wheatleigh Street to the underpass of the Gore Hill Freeway at Brook Street. From the Brook Street underpass overland flow continues along Palmer Street and Hamilton Lane and discharges into Flat Rock Creek to the north of Hamilton Reserve. Depths of overland flow immediately to the north and south of the Gore Hill Freeway are greater than one metre in a 1% AEP event, which is sufficient to result in hazardous flooding conditions to persons and property.

While a low and high hazard floodway would form along the valley of the catchment during a 1% AEP storm event, flooding along the section of the Warringah Freeway which runs through the Brook Street Tributary catchment is generally classified as low hazard flood fringe. The notable exception is a low and high hazard floodway area which would form along the southbound Brook Street on ramp to the freeway during a storm of this intensity.

PMF

Depths of flow would be greater than one metre along the full length of the overland flow path that runs along Brook Street Tributary between Atchison Street and Flat Rock Creek.

Flat Rock Creek

Up to 1% AEP

During a 10% AEP event flow in excess of the capacity of the existing stormwater drainage system would pond in the cul-de-sac of George Place to a maximum depth of about 1 metre. During a 1% AEP event, flow would pond to a maximum depth of 1.5 metres before discharging in a south-easterly direction through the adjoining industrial development and onto the eastbound carriageway of the Gore Hill Freeway.

The eastbound carriageway of the Gore Hill Freeway acts as an overland flowpath during a 1% AEP event, conveying flows that surcharge the existing transverse drainage structures that are located in the vicinity of George Place and Reserve Road. Depths of overland flow would typically be less than 0.2 metres, but would reach up to 0.4 metres at two locations.

During a 10% AEP event, flow that surcharges the trunk drainage system in McLachlan Avenue travels in an easterly direction along the shared bicycle path to the south of the Gore Hill Freeway before discharging onto the westbound carriageway north of Hotham Street.

The westbound carriageway of the Gore Hill Freeway acts as an overland flowpath during a 1% AEP event, conveying flow that surcharges the drainage systems in McLachlan Avenue, Hotham Parade and Whiting Street. Flow along the eastbound carriageway collects at the sag below the Reserve Road overpass and ponds to a maximum depth of 0.7 metres before continuing in a southerly direction.

During a 1% AEP event, flow that surcharges the existing transverse drainage structures that are located between Herbert Street and the North Shore railway line also contributes to overland flow travelling east along the eastbound carriageway of the Gore Hill Freeway.

Flooding along the Gore Hill Freeway is of a low hazard nature, with floodway areas forming along the edge of several of the carriageways during a 1% AEP storm event.

PMF

The main carriageways and various entry and exit ramps of the Gore Hill Freeway are inundated by floodwater that discharges from the north at George Place, Reserve Road and Simpson Street, and from the south at McLachlan Avenue, Hotham Parade, Whiting Street, Herbert Street and Punch Street.

The section of Gore Hill Freeway between Reserve Road and the North Shore railway line is inundated across its full width. Depths of flow are typically 1.2 metres or less but would reach a maximum of 1.8 metres at one location.

Flood levels upstream (west) of the North Shore railway line are controlled by the rail underpass, which constricts overland flow travelling along the Gore Hill Freeway.

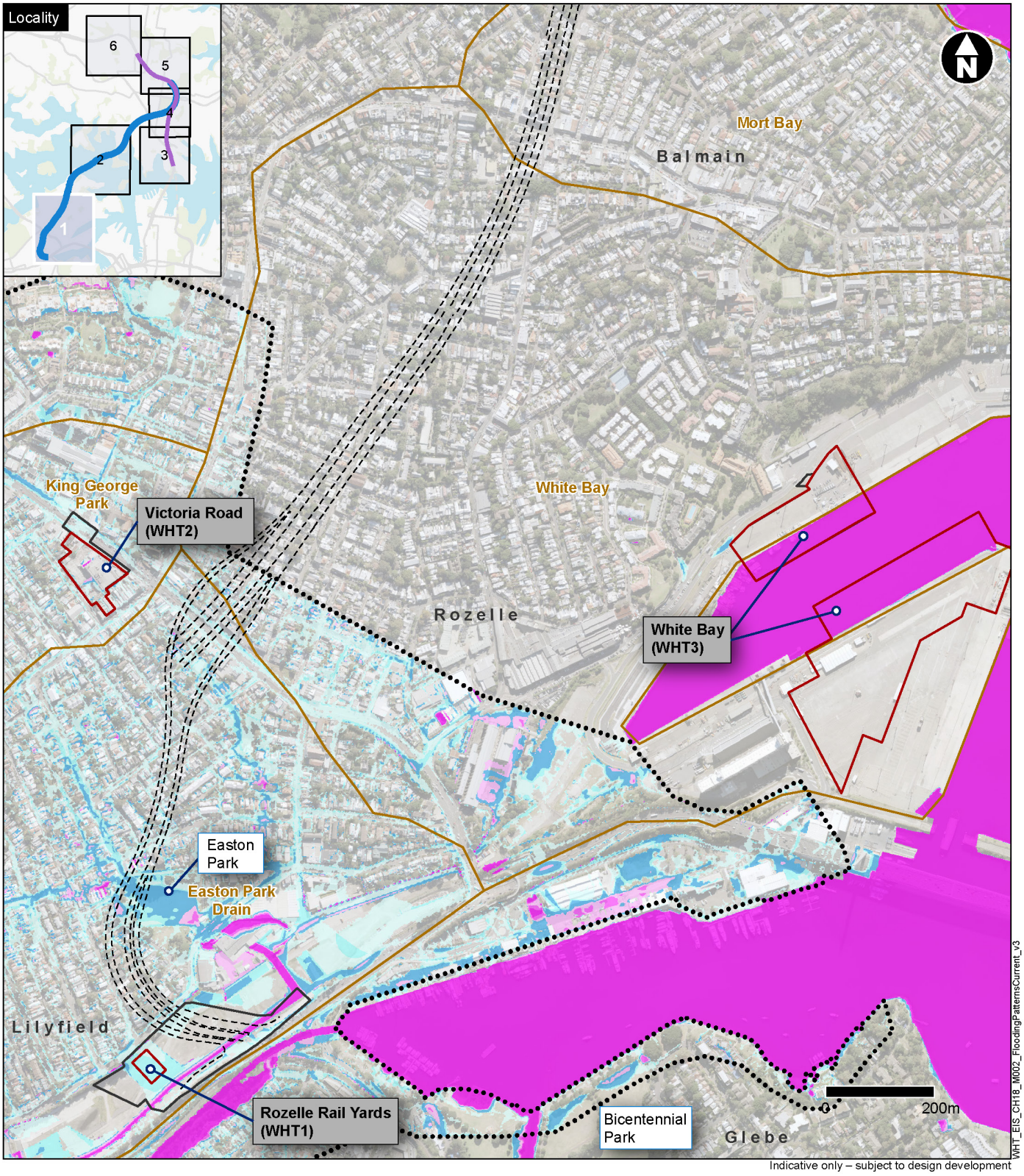
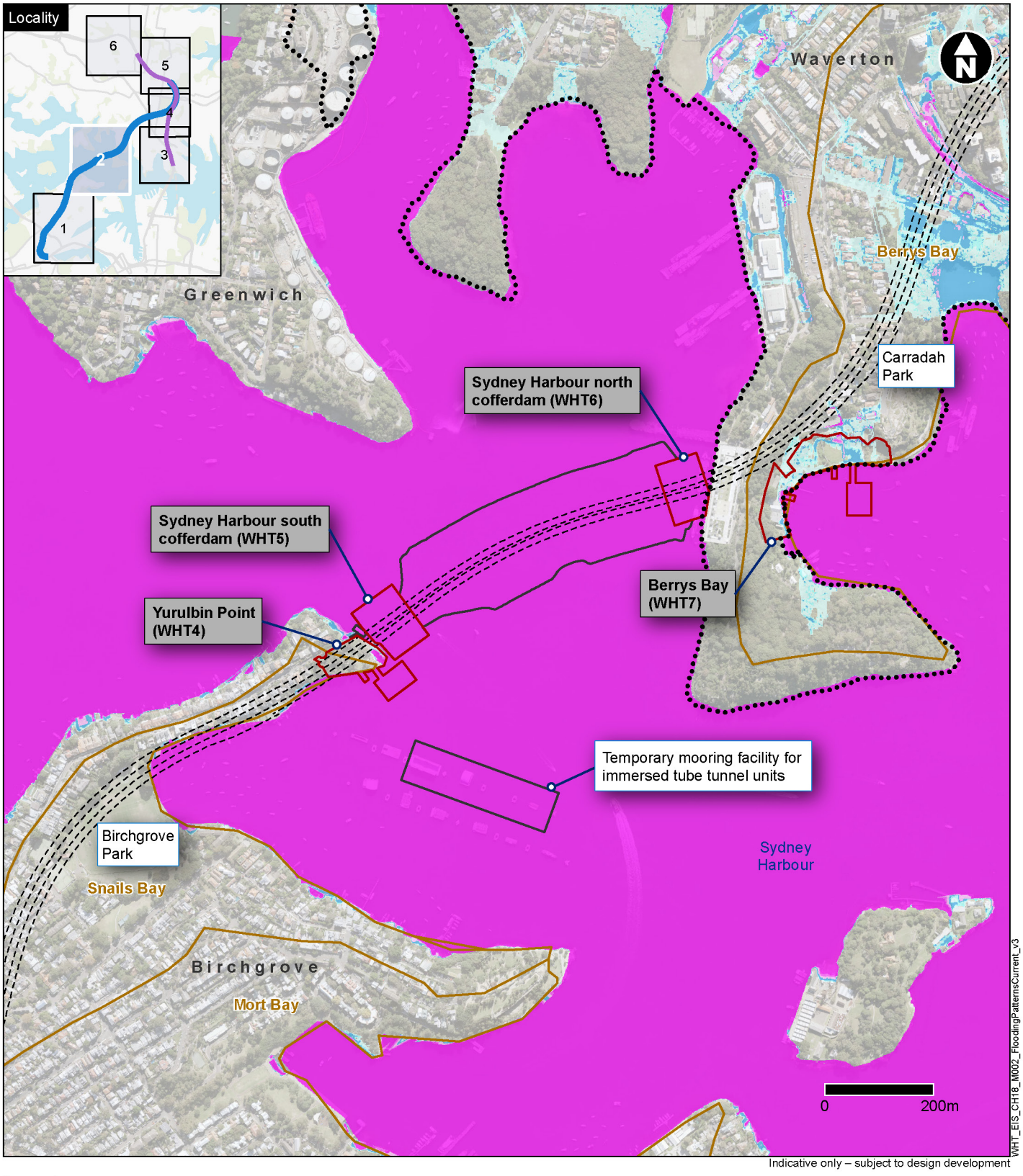


Figure 18-2 Flood behaviour under present day conditions – 1% AEP event (Rozelle) (map 1)



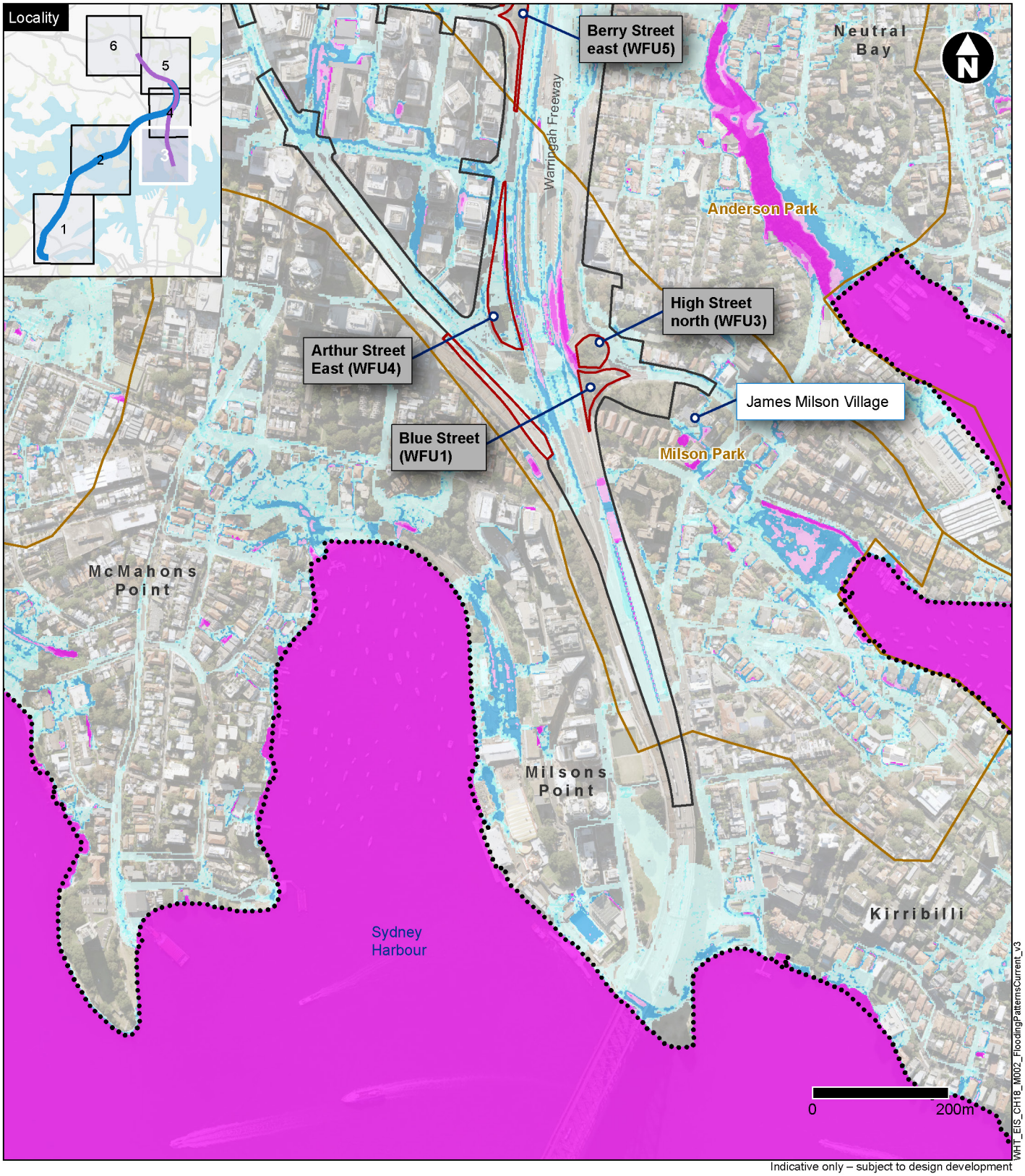
Legend

- Limit of main stream flooding and major overland flow mapping
- Tunnel section
- Construction footprint
- Construction support site
- Catchment boundary

Indicative depth of inundation (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- >0.7

Figure 18-3 Flood behaviour under present day conditions – 1% AEP event (Sydney Harbour) (map 2)



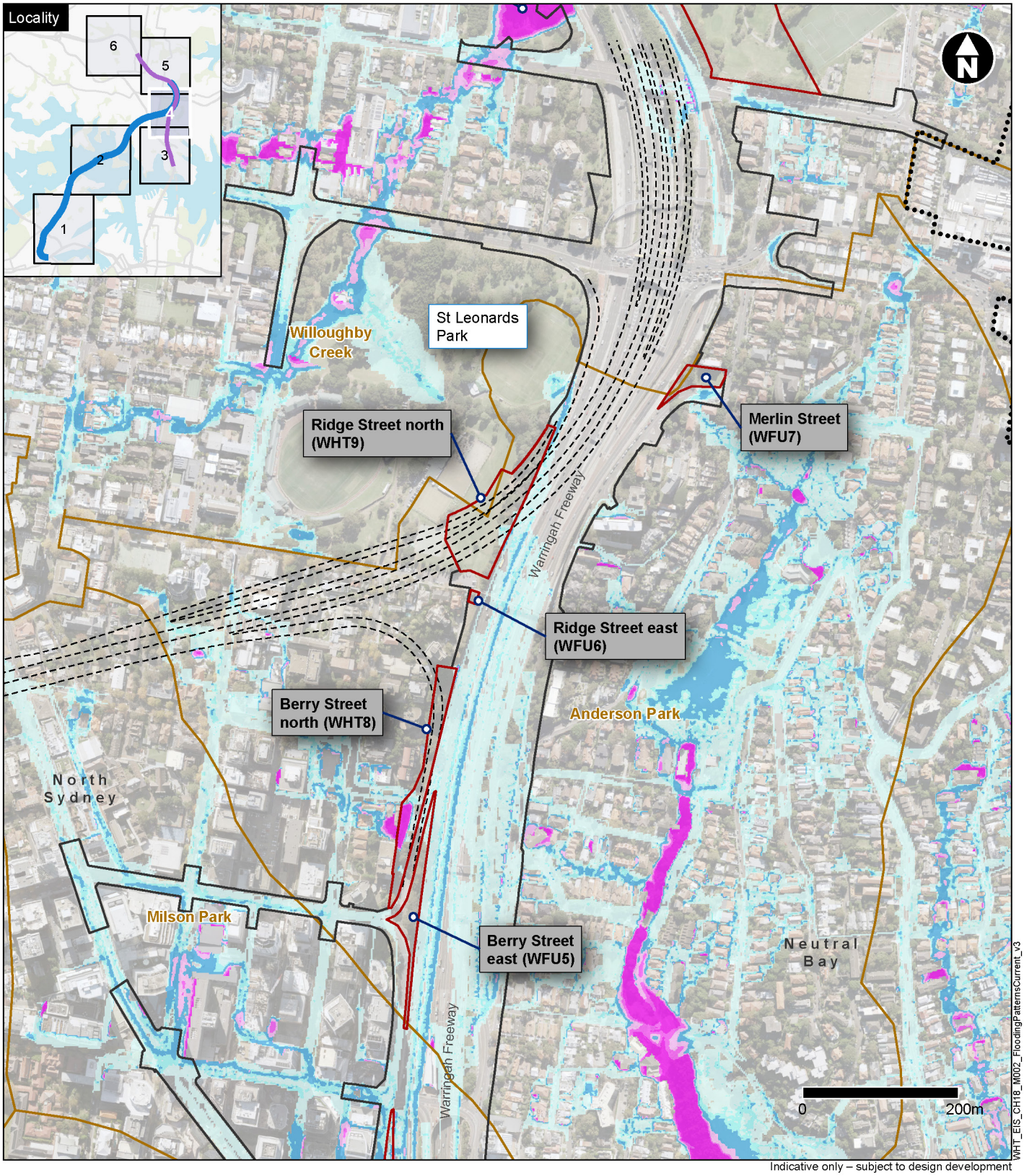
Legend

- Limit of main stream flooding and major overland flow mapping
- Tunnel section
- Construction footprint
- Construction support site
- Catchment boundary

Indicative depth of inundation (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- >0.7

Figure 18-4 Flood behaviour under present day conditions – 1% AEP event (North Sydney, south) (map 3)



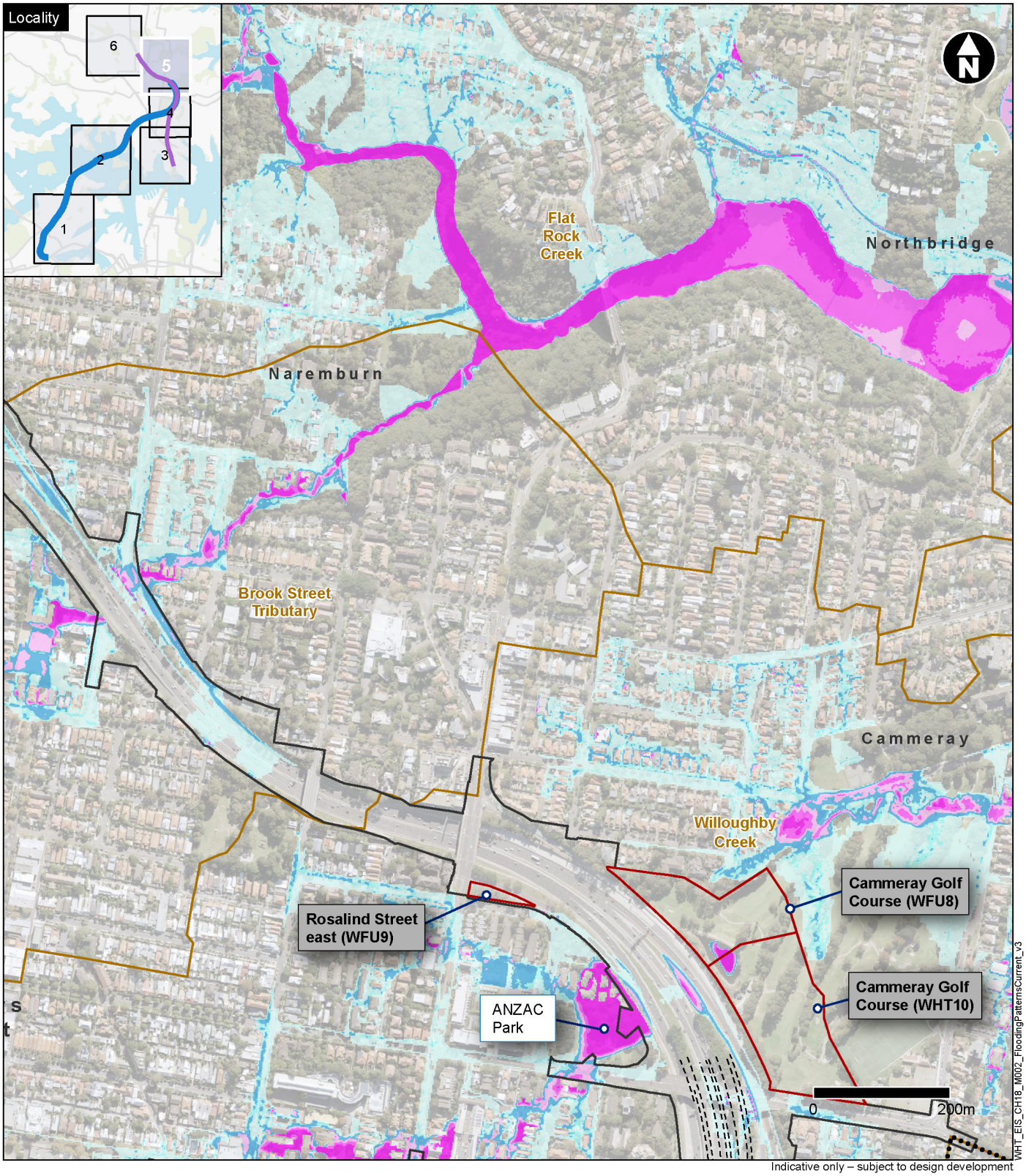
Legend

- Limit of main stream flooding and major overland flow mapping
- Tunnel section
- Construction footprint
- Construction support site
- Catchment boundary

Indicative depth of inundation (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- >0.7

Figure 18-5 Flood behaviour under present day conditions – 1% AEP event (North Sydney, north) (map 4)



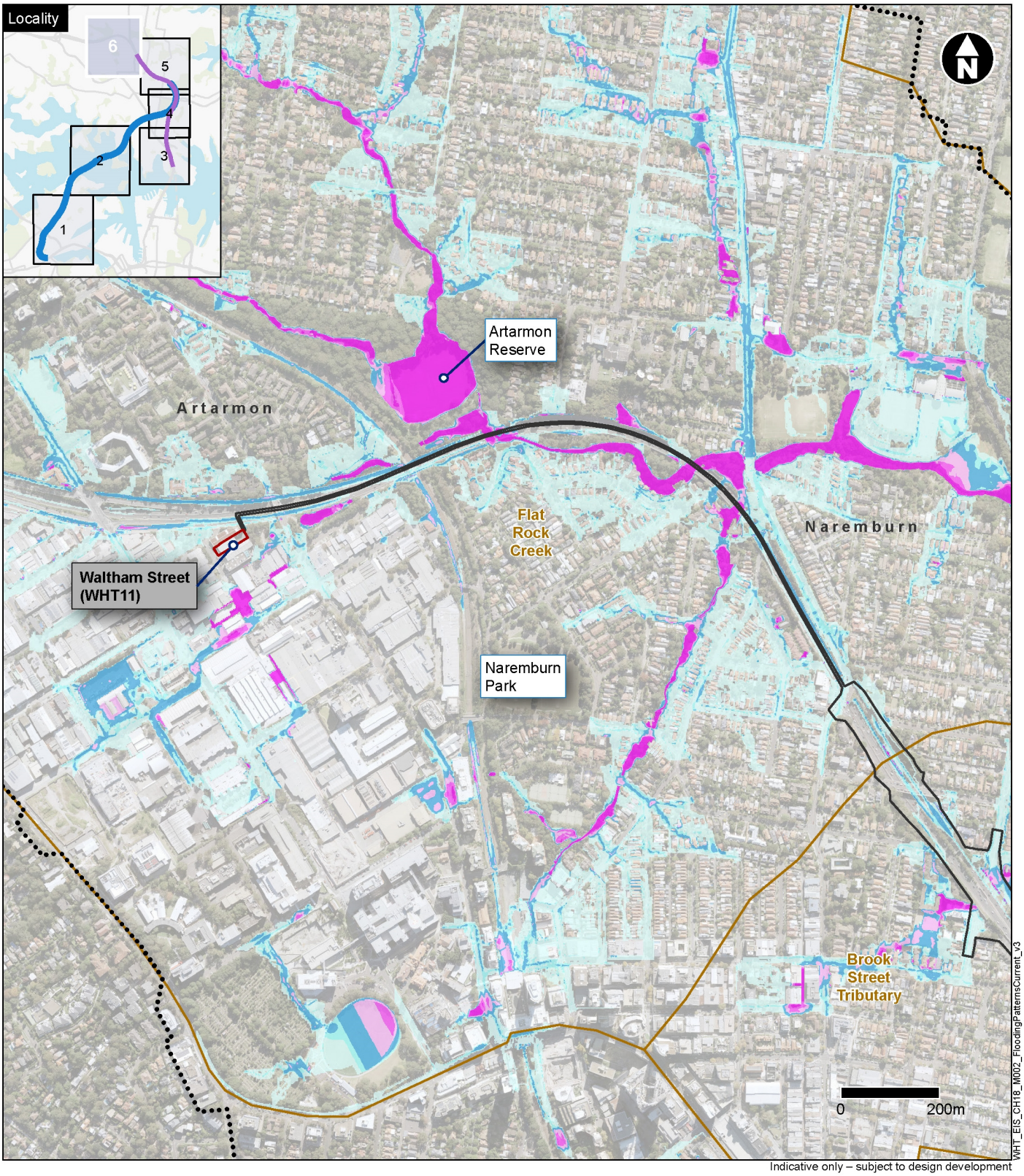
Legend

- Limit of main stream flooding and major overland flow mapping
- Tunnel section
- Construction footprint
- Construction support site
- Catchment boundary

Indicative depth of inundation (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- >0.7

Figure 18-6 Flood behaviour under present day conditions – 1% AEP event (Cammeray) (map 5)



Legend

- Limit of main stream flooding and major overland flow mapping
- Tunnel section
- Construction footprint
- Construction support site
- Catchment boundary

Indicative depth of inundation (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- >0.7

Figure 18-7 Flood behaviour under present day conditions – 1% AEP event (St Leonards/Artarmon) (map 6)

18.5 Assessment of potential construction impacts

This section provides an assessment of the flood risk at the proposed construction support sites which would be associated with the construction of the Western Harbour Tunnel and Warringah Freeway Upgrade project. Details of the proposed construction support sites, including proposed activities, are outlined in Chapter 6 (Construction works).

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

18.5.1 Potential impacts of construction activities on flood behaviour

Construction activities have the potential to increase flooding conditions when compared to both present day and operational conditions. This is because 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 qualitative assessment was carried out of the potential impacts construction activities could have on flood behaviour. The key findings are summarised in Table 18-2.

While the majority of the construction support sites would involve works within the floodplain that would need to be managed, the assessment found that the greatest potential for adverse impacts on flood behaviour in adjacent development is associated with the Berry Street north (WHT8) and Cammeray Golf Course (WFU8) construction support sites. There is also the potential for construction activities to impact local catchment runoff, which would be managed through appropriate local stormwater management controls to be implemented during the construction phase of the project.

While the findings of the assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would be carried out during detailed design as layouts and staging diagrams are further developed. Consideration would also 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.

Prior to construction, further investigation would be carried out to develop measures which are aimed at mitigating the impacts of construction activities on flood behaviour. A range of measures which would be implemented to mitigate the potential construction related impacts of the project are outlined in Section 18.8.

Tunnel construction

The key activities associated with tunnel construction are carried out from the Western Harbour Tunnel construction support sites, including:

- Tunnel excavation
- Cut and cover structures.

Refer to Table 18-2 for details on the assessed potential impacts of flooding behaviour resulting from these activities.

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 receiving drainage lines and waterways.

Stockpiling of spoil material is proposed at all construction support sites with the exception of Sydney Harbour south cofferdam (WHT5) and Sydney Harbour north cofferdam (WHT6). While the majority of these sites are affected by flooding to varying degrees (refer to Table 18-2), there would typically be suitable areas outside the 10% AEP flood extent that could be used to stockpile material.

Surface earthworks

While surface earthworks are associated with activities within the confines of most construction support sites, the main area of surface earthworks is associated with the Warringah Freeway Upgrade project.

The nature of the flooding that could be experienced within the project surface works footprint during the construction of the Warringah Freeway Upgrade project would generally be shallow and of a short duration. The exception to this would be the major ponding areas that are located adjacent to ANZAC Park in the Willoughby Creek catchment and the Sydney Harbour Tunnel portals in the Anderson Park catchment. Figures 4.2, 4.3 and 4.4 of Appendix R (Technical working paper: Flooding) show the indicative extent and depth of inundation over the extent of project surface works footprint under present day (ie pre-project) conditions.

The inundation of the surface earthworks by floodwater has the potential to cause scour of disturbed surfaces and transport 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.

Bridge construction

New bridge works are limited to the Warringah Freeway Upgrade project, the construction of which would be managed from the Blue Street (WFU1), High Street south (WFU2), High Street north (WFU3), Ridge Street east (WFU6), Merlin Street (WFU7) and Cammeray Golf Course (WFU8) construction support sites.

Proposed bridge works at both the High Street and Mount Street overpasses of the Warringah Freeway could be impacted by floodwater during storms that result in the surcharge of the existing stormwater drainage system which controls surface runoff in the Milson Park catchment.

Works associated with the proposed demolition of the existing Ridge Street shared user bridge and the construction of the upgraded Ridge Street shared user bridge could be impacted by relatively shallow overland flow which occurs during stormwater which result in the surcharge of the existing drainage system of the Warringah Freeway where it runs through the Anderson Park catchment.

The proposed bridge works around the Falcon Street overpass of the Warringah Freeway are not at risk of being flooded during construction.

The proposed bridge works adjacent to Cammeray Golf Course would be subject to flooding during very rare and extreme flood events when the noise wall which runs along the western side of the Warringah Freeway would be overtopped.

18.5.2 Potential flood risk at construction support sites

Without the implementation of appropriate management measures, the inundation of the construction support 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 increase flooding conditions in existing development located outside the construction footprint.

Table 18-2 provides a summary of the proposed activities, as well as the assessed flood risk at the construction support sites that are associated with the construction of the Western Harbour Tunnel and Warringah Freeway Upgrade projects, respectively. Figure 5.1 of Appendix R (Technical working paper: Flooding) shows the extent to which floods of varying magnitude affect each construction support site, while Figure 5.2 shows the indicative depth and extent of inundation in their vicinity for floods with AEPs of 10% and 1%. Figure 5.3 of Appendix R (Technical working paper: Flooding) shows the provisional flood hazard and preliminary hydraulic categorisation of the floodplain in the vicinity of each construction support site for a 1% AEP flood event. Further details of each construction support site and its associated facilities and activities is provided in Chapter 6 (Construction work) of the environmental impact statement. A range of measures which would be implemented to mitigate the potential construction related impacts of the project are outlined in Section 18.8.

Table 18-2 Summary of assessed flood risks and potential impacts associated with activities at proposed construction support sites

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
Western Harbour Tunnel									
Rozelle Rail Yards (WHT1)	Easton Park Drain	✓	✓			✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • Floodwater surcharges the southern kerb line of Lilyfield Road where it discharges through the construction support site during storms more frequent than 10% AEP, albeit at relatively shallow depths • Overland flow discharging through the Rozelle Rail Yards construction support site (WHT1) during storms up to 1% AEP in intensity is classified as low hazard flood fringe.	• Activities within the confines of the Rozelle Rail Yards construction support site (WHT1) have the potential to alter patterns of overland flow in this area.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
Victoria Road (WHT2)	King George Park	✓	✓	✓		✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The construction support site is subject to relatively shallow overland flow which originates from the rear of several properties that are located along Darling Street • Overland flow discharging through the Victoria Road construction support site (WHT2) during storms up to 1% AEP in intensity is classified as low hazard flood fringe.	• Activities along the southern boundary of the Victoria Road construction support site (WHT2) have the potential to obstruct the passage of overland flow which discharges from the rear of the adjacent properties in Darling Street.
White Bay (WHT3)	White Bay	✓	✓	✓				• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • Flooding of the White Bay construction support site	• Activities within the confines of the White Bay construction support site (WHT3) would not have an impact on water levels in Sydney Harbour.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								(WHT3) is principally limited to elevated water levels in Sydney Harbour • Wave action due to coincident high winds could increase flooding conditions at the construction support site during periods of elevated water levels in Sydney Harbour.	
Yurulbin Point (WHT4)	Snails Bay	✓	✓	✓		✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • Inundation of the Yurulbin Point construction support site (WHT4) is principally limited to elevated water levels in Sydney Harbour • Wave action due to coincident high winds could increase flooding conditions at the	• Activities within the confines of the Yurulbin Point construction support (WHT4) site would not have an impact on water levels in Sydney Harbour.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								construction support site during periods of elevated water levels in Sydney Harbour.	
Sydney Harbour south cofferdam (WHT5)	-			✓		✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • Inundation of the Sydney Harbour south cofferdam (WHT5) is principally limited to elevated water levels in Sydney Harbour • Wave action due to coincident high winds could increase flooding conditions at the construction support site during periods of elevated water levels in Sydney Harbour.	• Activities within the confines of the Sydney Harbour south cofferdam (WHT5) would not have an impact on water levels in Sydney Harbour.
Sydney Harbour north	-			✓		✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R	• Activities within the confines of the Sydney Harbour north cofferdam

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
cofferdam (WHT6)								(Technical working paper: Flooding) • Flooding of the Sydney Harbour north cofferdam (WHT6) is principally limited to elevated water levels in Sydney Harbour • Wave action due to coincident high winds could increase flooding conditions at the construction support site during periods of elevated water levels in Sydney Harbour.	(WHT6)would not have an impact on water levels in Sydney Harbour.
Berrys Bay (WHT7)	Berrys Bay	✓	✓	✓		✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • While flooding of the Berrys Bay construction support site (WHT7) principally occurs as a result of flow which	• Activities within the confines of the Berrys Bay construction support site (WHT7) would not have an impact on water levels in Sydney Harbour.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								surcharges the existing stormwater drainage system to its north, its subject to flooding as a result of elevated water levels in Sydney Harbour • Wave action due to coincident high winds could also increase flooding conditions at the construction support site during periods of elevated water levels in Sydney Harbour • Overland flow discharging through the Berrys Bay construction support site (WHT7) during storms up to 1% AEP in intensity is classified as low hazard flood fringe.	
Berry Street north (WHT8)	Anderson Park	✓	✓		✓	✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper:	• Construction activities within the confines of the Berry Street north construction support site (WHT8) have

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								Flooding) • Flooding of the Berry Street north construction support site (WHT8) occurs during storms which result in the surcharge of the existing stormwater drainage system which control surface runoff to its west • Overland flow would pond on the western side of the Berry Street on ramp to the Western Harbour Tunnel to depths greater than 1 metre during storms more frequent than 10% AEP • Overland flow discharging through the Berry Street north construction support site (WHT8) during storms up to 1% AEP in intensity is generally classified as low hazard flood fringe, although a high and low	the potential to increase the depth of ponding on the western side of the Berry Street on ramp to the Western Harbour Tunnel which would increase flooding conditions in existing residential development • Changes in the level of the Berry Street on ramp to the Western Harbour Tunnel have the potential to increase flooding conditions in existing development that is located to its west, as well as in the vicinity of the existing Sydney Harbour Tunnel portals.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								hazard flood storage area would form on the western side of the Berry Street on ramp to the Warringah Freeway during storms that surcharge the existing stormwater drainage system.	
Ridge Street north (WHT9)	Anderson Park	✓	✓		✓		✓	• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The construction support site would be subject to very shallow sheet flow during heavy rainfall events, principally due to runoff generated from within its extent • Overland flow discharging through the Ridge Street north construction support site (WHT9) during storms up to 1% AEP in intensity	• The provision of hard stand areas within the confines of the Ridge Street north construction support site (WHT9) would increase the runoff potential of the area, which in turn would increase the rate at which flow discharges onto the Warringah Freeway • Runoff discharging from St Leonards Park has the potential to impact excavation for the adjacent cut and cover, and tough sections of the Western Harbour Tunnel northbound off ramp.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								is classed as low hazard flood fringe.	
Cammeray Golf Course (WHT10)	Willoughby Creek	✓	✓	✓	✓	✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The Cammeray Golf Course construction support site (WHT10) would be subject to very shallow sheet flow during heavy rainfall events, principally due to runoff generated from within its extent (*Note that it is assumed that the existing golf course dam would be filled as part of the construction of the Western Harbour Tunnel and Warringah Freeway Upgrade projects*) • Overland flow discharging through the construction	• If appropriate connections to existing trunk drainage system are not incorporated into the design of the project, then the provision of hard stand areas within the confines of the Cammeray Golf Course construction support site (WHT10) has the potential to increase flooding conditions in existing residential development that is located along Warringa Road, Falls Street, Cammeray Road and Grafton Street • Construction activities within the confines of the Cammeray Golf Course construction support site (WHT10) have the potential to obstruct flow which surcharges the Warringah Freeway during a PMF, thereby increasing flooding conditions in existing development that is located on the western side of the freeway • Floodwater originating from ANZAC

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								support site during storms up to 1% AEP in intensity is classified as low hazard flood fringe • During a PMF event, floodwater would surcharge the Warringah Freeway where it would discharge through the Cammeray Golf Course construction support site (WHT10) at depths exceeding 0.5 metres.	Park as well as from within Warringah Freeway corridor has the potential to impact tunnel works that are proposed adjacent to Cammeray Golf Course • The staging of the works associated with the replacement of the major trunk drainage line which crosses the Warringah Freeway from ANZAC Park to the Cammeray Golf Course has the potential to increase flooding behaviour in existing residential development that is located on the western (upstream) side of the road corridor.
Waltham Street (WHT11)	Flat Rock Creek	✓	✓			✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The Waltham Street construction support site (WHT11) is subject to relatively shallow overland flow along its eastern boundary in a PMF event.	• Activities within the confines of the Waltham Street construction support site (WHT11) would not impact flood behaviour.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
Warringah Freeway Upgrade									
Blue Street (WFU1)	Milson Park	✓	✓			✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The Blue Street construction support site (WFU1) is not subject to flooding.	• Activities within the confines of the Blue Street construction support site (WFU1) would not impact flood behaviour.
High Street south (WFU2)	Milson Park	✓	✓			✓	✓	• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The High Street south construction support site (WFU2) is not subject to flooding.	• Activities within the confines of the High Street south construction support site (WFU2) would not impact flood behaviour.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
High Street north (WFU3)	Milson Park	✓	✓			✓	✓	• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The High Street north construction support site (WFU3) is not subject to flooding.	• Activities within the confines of the High Street north construction support site (WFU3) would not impact flood behaviour.
Arthur Street east (WFU4)	Milson Park	✓	✓			✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • Flooding of the Arthur Street east construction support site (WFU4) occurs during storms which result in the surcharge of the existing stormwater drainage system which control surface runoff to its west • Two low hazard floodway areas would develop	• Activities within the confines of the Arthur Street east construction support site (WFU4) have the potential to obstruct overland flow which surcharges the eastern kerb line of Arthur Street. Obstructions to the passage of overland flow through the Arthur Street east construction support site (WFU4) have the potential to increase the depth of inundation on Arthur Street and along the frontage of several commercial properties that located on its western side.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								through the Arthur Street east construction support site (WFU4) during storm events which surcharge the existing stormwater drainage system.	
Berry Street east (WFU5)	Anderson Park	✓	✓			✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The Berry Street east construction support site (WFU5) would be subject to relatively shallow overland flow at its northern and southern ends during storms which result in the surcharge of the existing stormwater drainage system which control surface runoff to its west. • Overland flow discharging through the Berry Street	• The provision of hard stand areas within the confines of the Berry Street east construction support site (WFU5) would increase the runoff potential of the area, which in turn would increase the rate at which flow discharges onto the Warringah Freeway.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								east construction support site (WFU5) during storms up to 1% AEP in intensity is classed as low hazard flood fringe.	
Ridge Street east (WFU6)	Anderson Park	✓	✓			✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The Ridge Street east construction support site (WFU6) is not subject to flooding.	• Activities within the confines of the Ridge Street east construction support site (WFU6) would not impact flood behaviour.
Merlin Street (WFU7)	Anderson Park	✓	✓			✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The Merlin Street construction support site (WFU7) is not subject to flooding.	• Activities within the confines of the Merlin Street construction support site (WFU7) would not impact flood behaviour.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
Cammeray Golf Course (WFU8)	Anderson Park	✓	✓			✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The Cammeray Golf Course construction support site (WFU8) would be subject to very shallow sheet flow during heavy rainfall events, principally due to runoff generated from within its extent (Note that it is assumed that the existing golf course dam would be filled as part of the construction of the Western Harbour Tunnel and Warringah Freeway Upgrade projects). • Overland flow discharging through the Cammeray Golf Course construction support site (WFU8) during storms up to 1% AEP in intensity is classified as	• If appropriate connections to existing trunk drainage system are not incorporated into the design of the project, then the provision of hard stand areas within the confines of the Cammeray Golf Course construction supports site (WFU8) has the potential to increase flooding conditions in existing residential development that is located along Warringa Road, Falls Street, Cammeray Road, and Grafton Street • Floodwater originating from ANZAC Park as well as from within the Warringah Freeway corridor has the potential to impact tunnel works that are proposed adjacent to Cammeray Golf Course.

Construction support site	Catchment	Site facilities[1]	Spoil management[1]	Tunnel launch support[1]	Cut-and-cover structures[1]	Surface earthworks[1]	Bridge structures[1]	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								low hazard flood fringe • During a PMF event, floodwater would surcharge the Warringah Freeway where it would discharge through the construction support site at depths exceeding 0.5 metres.	
Rosalind Street east (WFU9)	Anderson Park	✓	✓			✓		• Refer to Figures 5.1, 5.2 and 5.3 of Appendix R (Technical working paper: Flooding) • The Rosalind Street east construction support site (WFU9) is not subject to flooding.	• Activities within the confines of the Rosalind Street east construction support site (WFU9) would not impact flood behaviour.

[1] Proposed construction activities.

18.6 Assessment of potential operational impacts

This section provides an assessment of the flood risk to the project, and the impact it would have on flood behaviour during operation if appropriate management measures are not incorporated into its design. Consistency of the impacts with state government and local council flood plans and policies has also been carried out (Section 18.6.3). The findings of the assessment of potential impact of future climate change and impacts of a partial blockage of the local stormwater drainage system on flooding behaviour under operational conditions are also presented. Furthermore, the application of the ARR 2019 methodology to the design flood estimation is also detailed below in Section 18.6.6.

The assessment outlined below only deals with areas to the north of Sydney Harbour where the proposed tunnel portal, bridge and surface road works have the potential to impact flooding behaviour (ie the scope of permanent works to the south of Sydney Harbour is limited to subsurface works as the tunnel portal and initial tunnelling at Rozelle Rail Yards would be carried out within the scope of the adjacent M4-M5 Link project).

18.6.1 Potential flood risk to the project

Tunnel portals

A series of flood walls have been incorporated into the design of the project in the vicinity of the tunnel portals which would prevent the ingress of floodwater to the Western Harbour Tunnel for events up to the PMF. The existing stormwater drainage system has also been upgraded so as to divert local catchment runoff around the proposed trough structures.

Road and pedestrian bridges

The road and pedestrian bridges that are proposed over the Warringah Freeway at High Street, Mount Street, Ridge Street and Falcon Street, as well as the proposed bridge over the southbound lane at Miller Street, are all high level structures that would only be subject to relatively shallow sheet flow during storms which surcharge the pavement drainage system.

Provision has been incorporated in the design of the proposed bridge over the southbound lane at Miller Street for floodwater to discharge unobstructed across the Warringah Freeway for events up to the PMF (Figure 6.3 (Sheet 4) of Appendix R (Technical working paper: Flooding)).

Surface road works

The majority of the Warringah Freeway would be subject to relatively shallow inundation during storms up to 1% AEP in intensity. Major ponding would occur across the northbound and southbound lanes at the location of the southern Warringah Freeway sag during storms more frequent than 10% AEP (Figure 6.4 (Sheet 2) of Appendix R (Technical working paper: Flooding)). Constraints imposed by the capacity of the existing stormwater drainage system downstream of the road corridor would likely mean that ponding at the location of the southern Warringah Freeway sag could not be prevented from occurring during storms up to 1% AEP in intensity.

Further north, flooding of the Warringah Freeway during storms up to 1% AEP in intensity is prevented by the presence of a continuous solid concrete noise wall which runs along the northern side of ANZAC Park (Figure 6.5 (Sheet 4) of Appendix R (Technical working paper: Flooding)). Depths of ponding in ANZAC Park increase from a maximum of about two metres during a 10% AEP storm event to a maximum of about 3.2 metres during a 1% AEP storm event. Overtopping of the noise wall would occur during a PMF event, when floodwater would pond to a maximum depth of about five metres and extend across the full width of the Warringah Freeway.

Motorway facilities

Finished ground levels would be raised above the level of the PMF at the location of the motorway facility that would be constructed on the northern side of the Warringah Freeway adjacent to Cammeray Park.

Motorway control centre

The motorway control centre that is proposed on Waltham Street in the Flat Rock Creek catchment is located on land which generally lies above the level of the PMF. Provision has been incorporated into the design of the motorway control centre to prevent the ingress of floodwater to the building for events up to the PMF.

18.6.2 Potential impacts of the project on flood behaviour

The changes to flood behaviour external and internal to the road corridor as a result of the project in the 1% AEP event are shown in Figure 18-8 to Figure 18-11. Changes in flood depth as a result of the project in the 1% AEP event are shown in Figure 18-12 to Figure 18-15. Refer to Figures 6.1 to 6.6 in Appendix R (Technical working paper: Flooding) for the changes to flood behaviour resulting from the project in the 10% AEP, 1% AEP and PMF events, for all catchments situated north of Sydney Harbour.

External to the road corridor

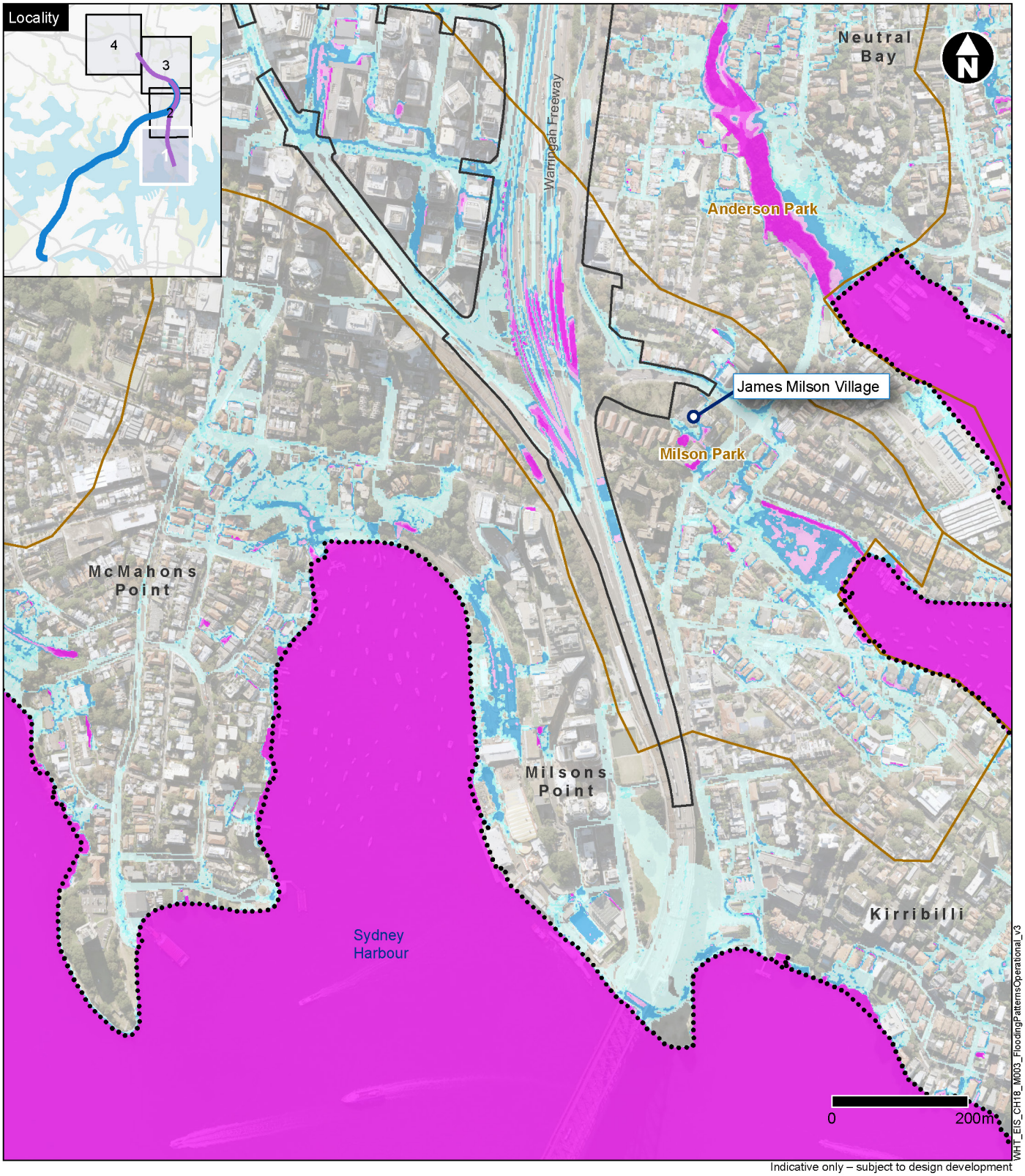
The project would generally result in a neutral or beneficial effect on flood behaviour external to the road corridor for storm events up to 1% AEP in intensity with the following exceptions:

- On the eastern side of the road corridor along the trunk drainage line which runs from the southern Warringah Freeway sag to Careening Cove in North Sydney and Kirribilli. Peak flood levels would be increased by up to 75 millimetres in the James Milson Village (Retirement and Residential Care) development, located on Clark Street in North Sydney, which would already be flooded during storms up to 1% AEP in intensity. Areas within the village which would be affected by the project include existing basement car parking and below-ground storage facilities. Increases of up to 16 millimetres would occur along the rear of several residential terraces that are located along Hipwood Street in Kirribilli
- On the eastern side of the Warringah Freeway corridor adjacent to an existing channel which is located at the eastern end of Nook Avenue in Neutral Bay. Peak flood levels would be increased by up to 55 millimetres in four at-grade garages that are connected to a three-storey residential unit block type development located on the northern side of Nook Avenue, which would already be flooded during storms up to 1% AEP in intensity. Similar increases in peak flood levels would also be experienced on the southern side of Nook Avenue within an already flooded allotment that has been subdivided for residential purposes
- Immediately downstream of the stormwater detention and reuse basin that is proposed on the northern side of the Warringah Freeway in the Willoughby Creek catchment. Flood modelling carried out as part of the present investigation showed that the basin would surcharge during a 1% AEP. However, the flood waters would be contained within the existing Cammeray Golf Course.

In the above cases, a floor level survey would be required to determine whether the minor increase in peak flood levels attributable to the project would result in an increase in above floor inundation in existing habitable areas.

The project would increase flow velocities in the following locations:

- East of the Warringah Freeway along the trunk drainage line that runs from the southern Warringah Freeway sag to Careening Bay in the Milson Park catchment. Flow velocities in existing development, including the James Milson Village (Retirement and Residential Care) development would be increased by up to 0.9 m/s, which could cause scour of unsealed areas that are located along the flow path
- Along a short reach of the existing channel which is located at the eastern end of Nook Avenue in the Anderson Park catchment. Flow velocities in the channel would be increased by up to about 0.2 m/s, which would not increase scour potential within the existing watercourse
- The flow path which would form downstream of the stormwater detention and reuse basin that is proposed on the northern side of the Warringah Freeway in the Willoughby Creek catchment would reach a maximum of about 1.5 m/s.



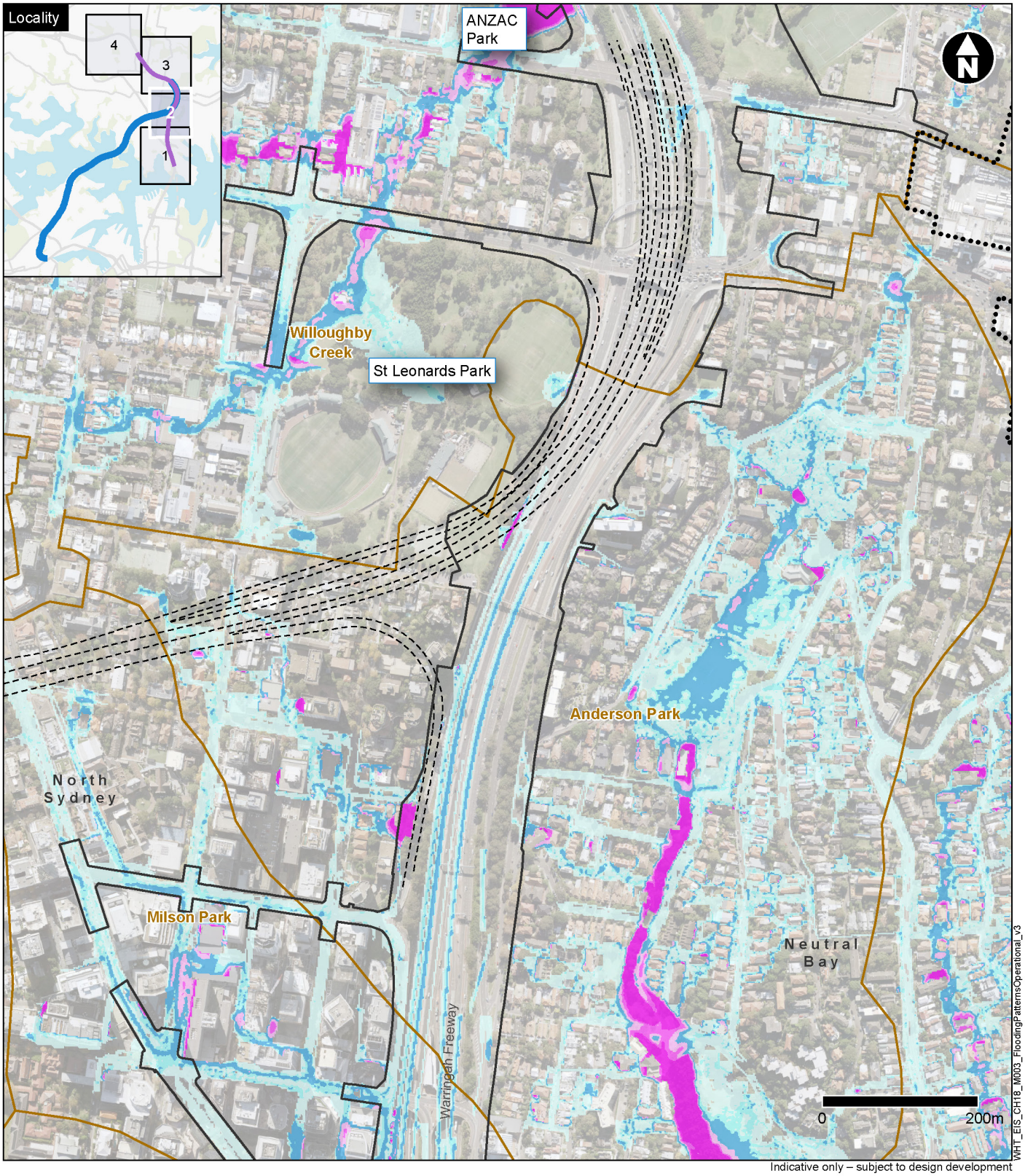
Legend

- Limit of main stream flooding and major overland flow mapping
- Tunnel section
- Construction footprint
- Catchment boundary

Indicative depth of inundation (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- >0.7

Figure 18-8 Flood behaviour under operational conditions – 1% AEP event (North Sydney, south) (map 1)



Legend

- Limit of main stream flooding and major overland flow mapping
- Tunnel section
- Construction footprint
- Catchment boundary

Indicative depth of inundation (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- >0.7

Figure 18-9 Flood behaviour under operational conditions – 1% AEP event (North Sydney, north) (map 2)

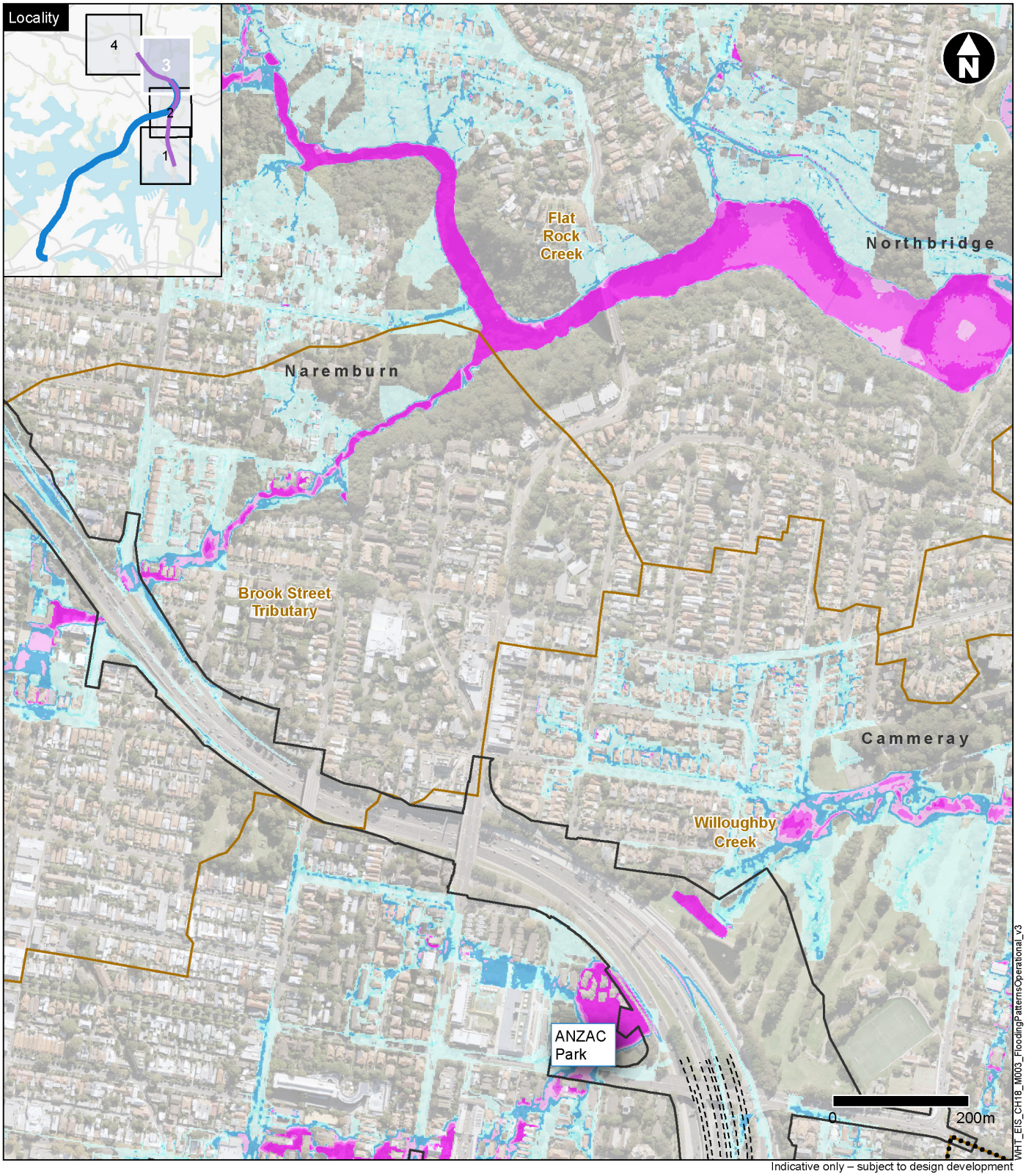
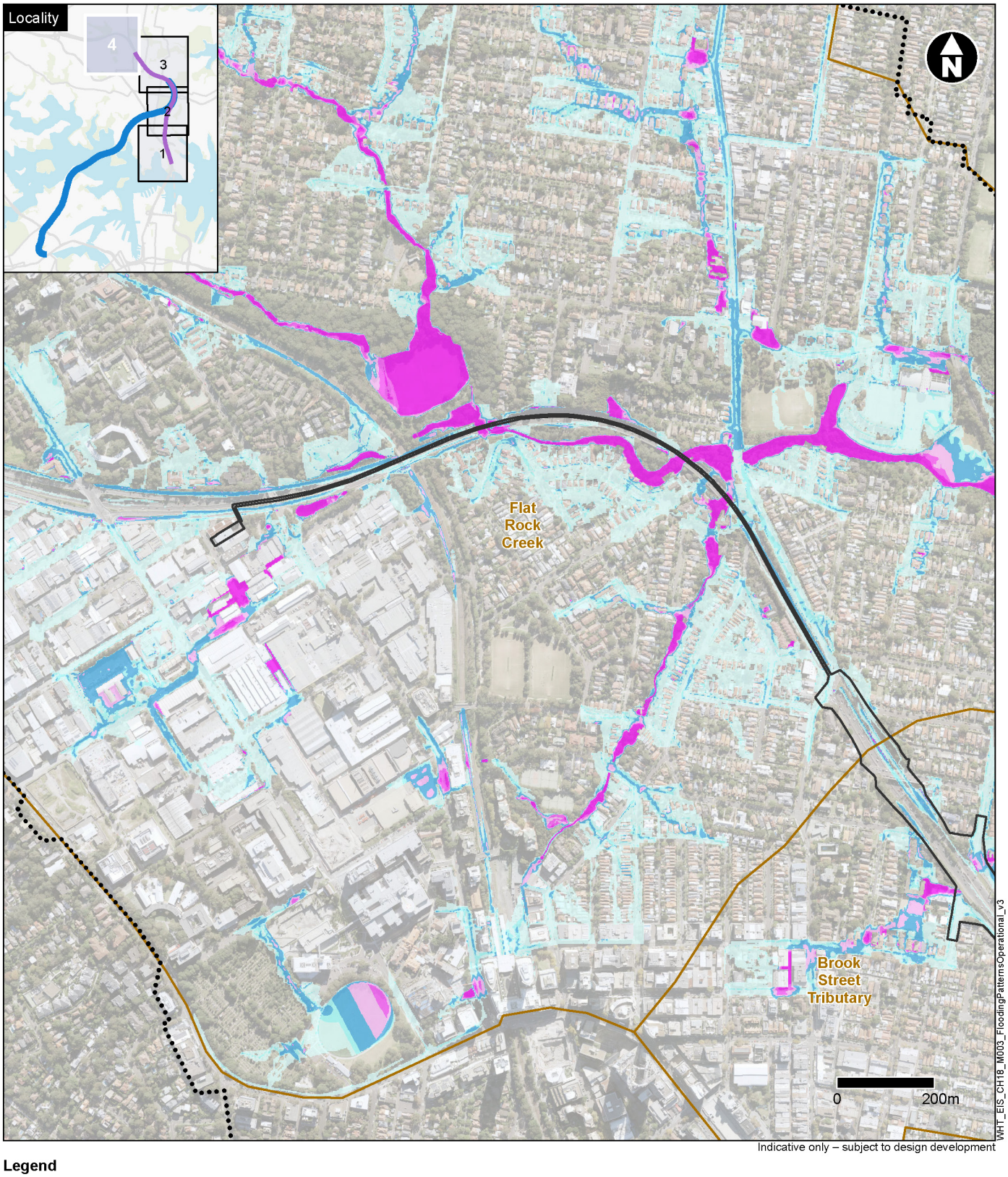


Figure 18-10 Flood behaviour under operational conditions – 1% AEP event (Cammeray) (map 3)



Legend

- Limit of main stream flooding and major overland flow mapping
- Tunnel section
- Construction footprint
- Catchment boundary

Indicative depth of inundation (m)

- <0.05
- 0.05 - 0.1
- 0.1 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- >0.7

Figure 18-11 Flood behaviour under operational conditions – 1% AEP event (St Leonards/Artarmon) (map 4)

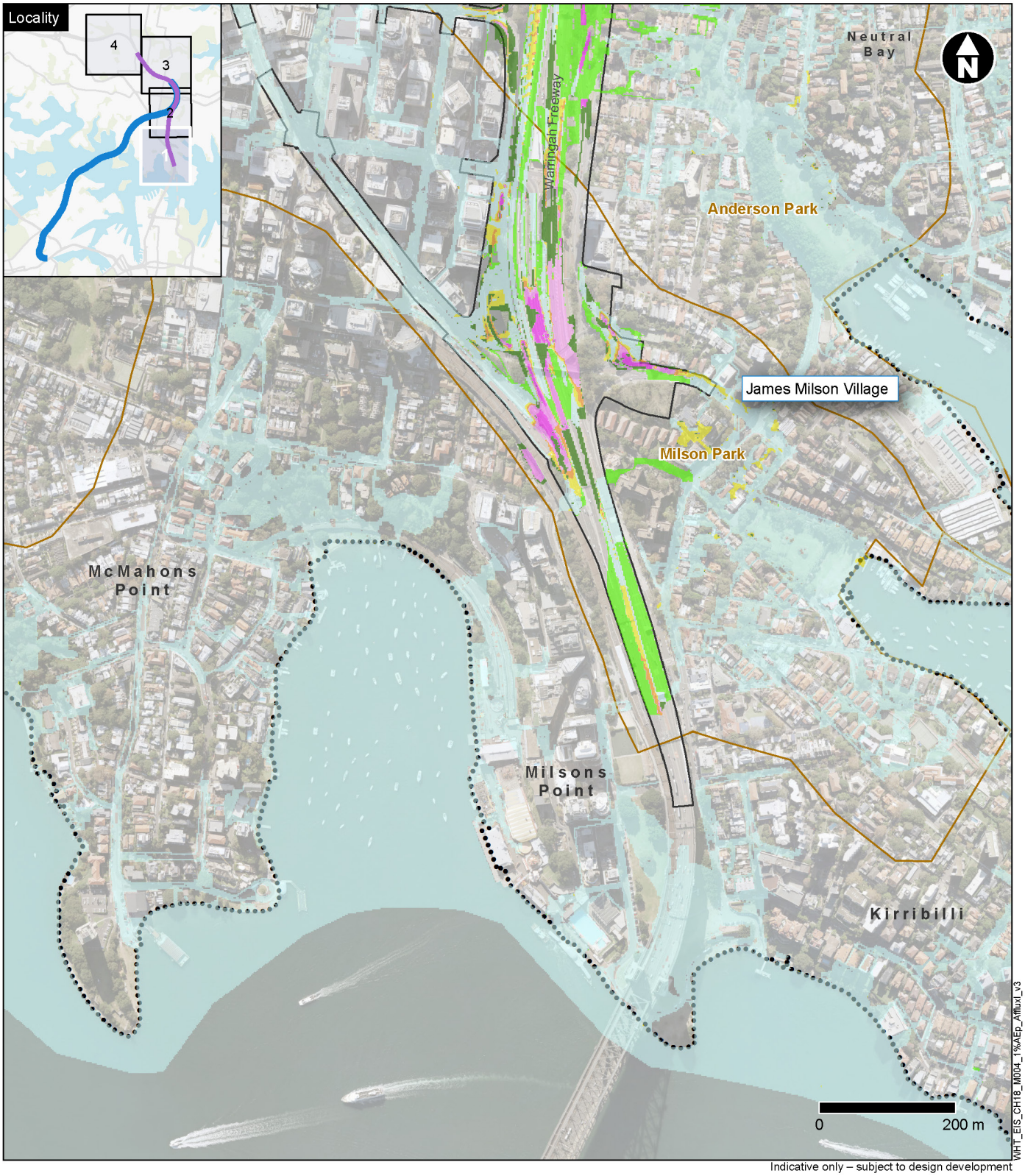
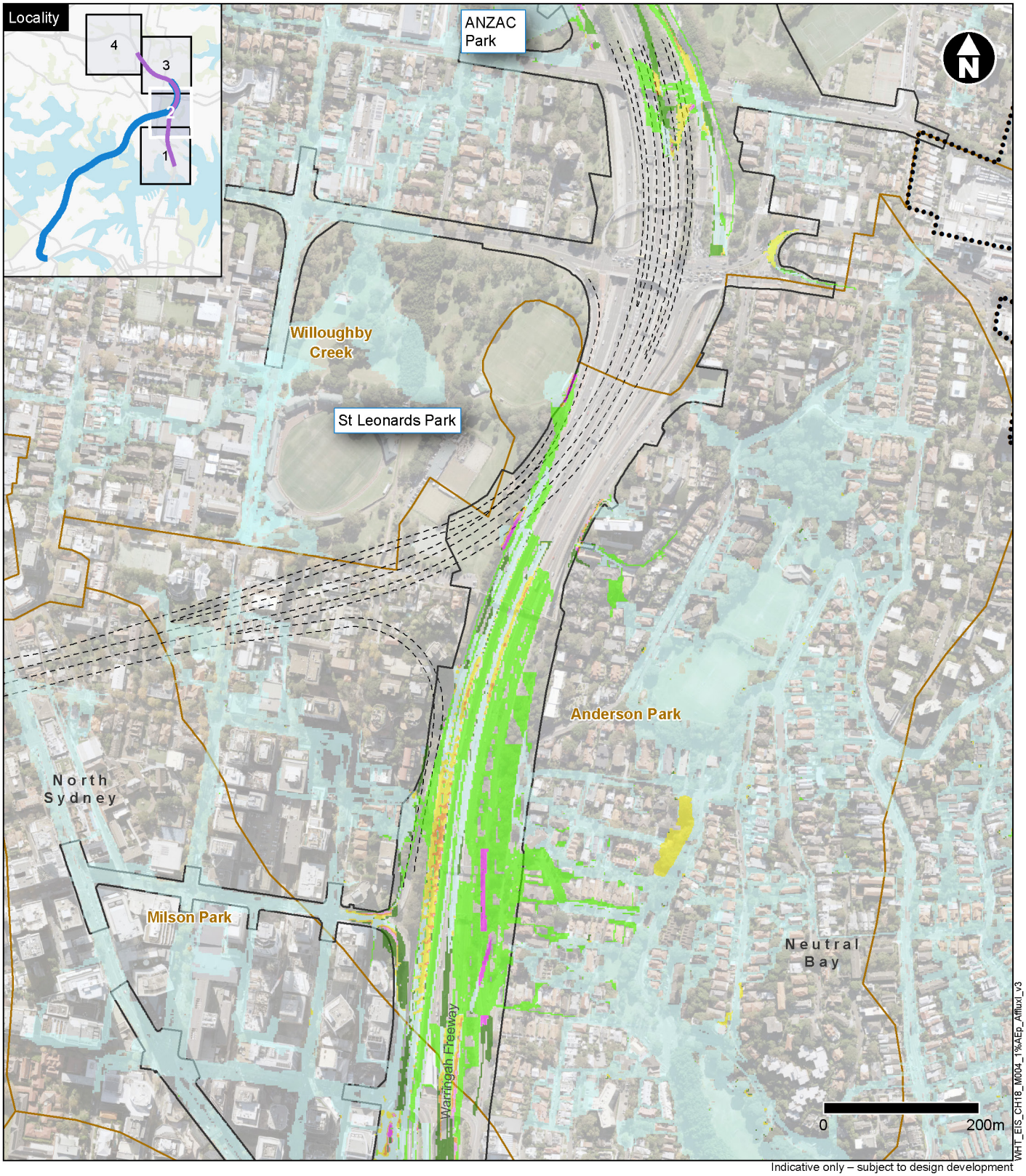


Figure 18-12 Change in flood depth under operational conditions – 1% AEP event (North Sydney, south) (map 1)



Legend

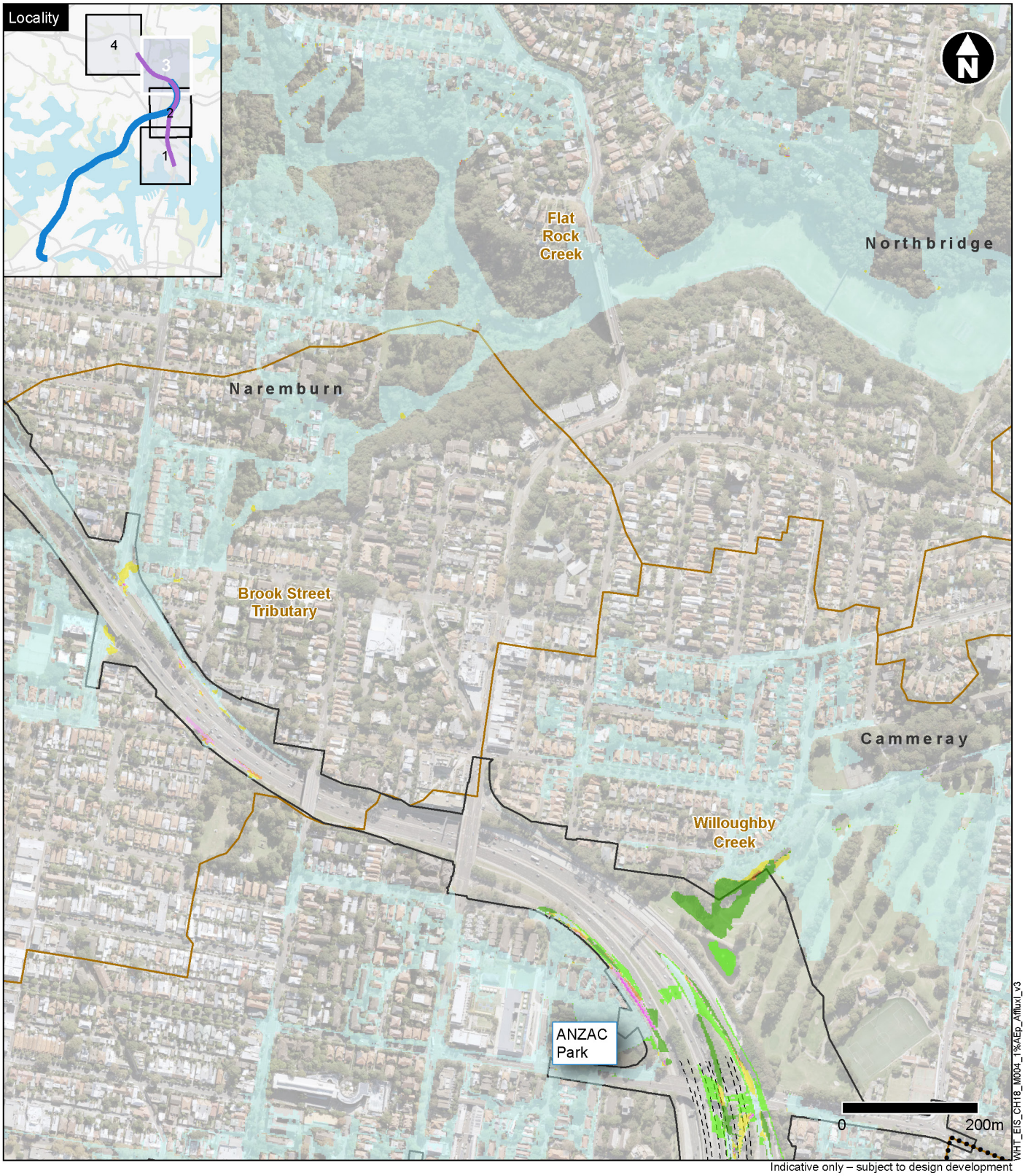
- Limit of main stream flooding and major overland flow mapping
- Tunnel section
- Construction footprint
- Catchment boundary

Change in flood depth (m)

- <0
- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.50

- Land rendered flood free as a result of change
- Additional area of land flooded as a result of change

Figure 18-13 Change in flood depth under operational conditions – 1% AEP event (North Sydney, north) (map 2)



Legend

- Limit of main stream flooding and major overland flow mapping
- Tunnel section
- Construction footprint
- Catchment boundary

Change in flood depth (m)

- <0
- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.50

- Land rendered flood free as a result of change
- Additional area of land flooded as a result of change

Figure 18-14 Change in flood depth under operational conditions – 1% AEP event (Cammeray) (map 3)

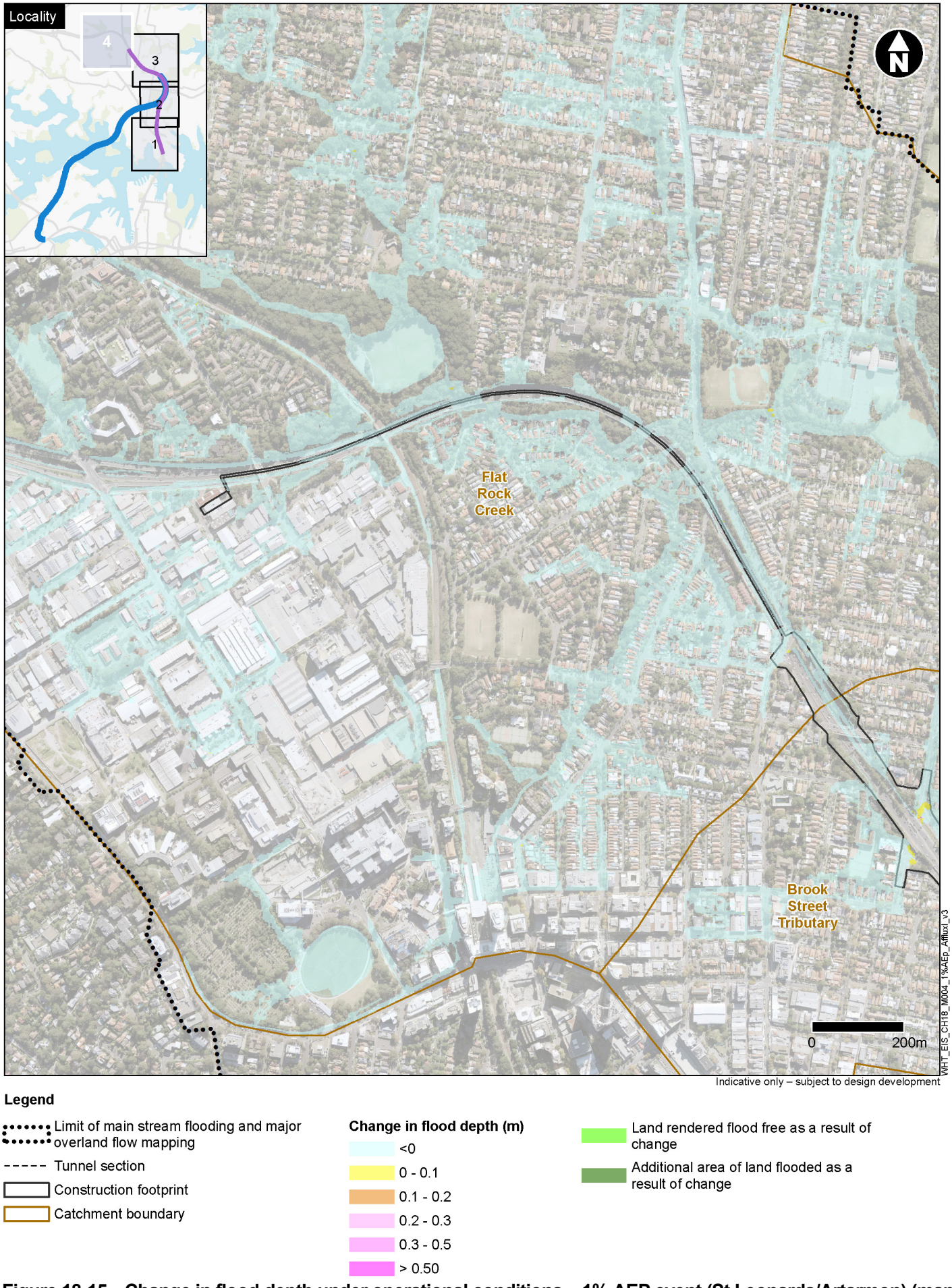


Figure 18-15 Change in flood depth under operational conditions – 1% AEP event (St Leonards/Artarmon) (map 4)

Internal to the road corridor

Internal to the road corridor the project would increase flooding in several of the northbound and southbound lanes of the Warringah Freeway south of the Ridge Street pedestrian bridge principally due to the channelising effect of the proposed Type-F safety barriers along the alignment. While depths of ponding at the location of the southern Warringah Freeway sag would generally be increased by the project, the project would not increase the rate at which overland flow discharges to the Sydney Harbour Tunnel portals for storm events up to 1% AEP in intensity. While floodwater currently enters the Sydney Harbour Tunnel via its portals during a PMF event, the increased depth of ponding at the location of the southern Warringah Freeway would result in an increase in the rate and volume of floodwater discharging to the tunnel system during an extreme flood event.

Flow velocities would be increased by up to one and two m/s along the Pacific Highway and Warringah Freeway, respectively, as a result of changes in road levels and the provision of Type-F safety barriers along the alignment which have the effect of channelising the flow.

18.6.3 Consistency with state government and local council flood plans and policies

While clause 6.3 of Willoughby Local Environmental Plan 2012 titled 'Flood planning' outlines Willoughby Council's objectives in regards to development of land that lies at or below the flood planning level, the North Sydney Local Environmental Plan 2013 does not contain a similar clause.

In accordance with the Secretary's environmental assessment requirements, a flood planning area has 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 4.7 of Appendix R (Technical working paper: Flooding) is based on mainstream flooding along the major 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 carried out 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 18.6.2, show that, subject to the provision of appropriate mitigation measures, the project would have only a minor impact on peak 1% AEP flood levels. As a result, the project would have no significant impact on the extent of the flood planning area and therefore the area of land to which clause 6.3 of Willoughby Local Environmental Plan 2012 would apply.

While no floodplain risk management studies or plans have been prepared for the catchments through which the project runs, the findings of the assessment presented in Section 18.6.2 show that the project would have only a small change on peak flood levels and flow velocities external to the Warringah Freeway corridor.

NSW State Emergency Service maintains local units that are located on Balls Head Drive, Waverton and Station Street, Naremburn, both of which are located remote from the project and its flood related impacts.

Provided the flood mitigation measures as set out in Section 18.8 are incorporated into the design of the project, then it would not increase the flood hazard in existing development for all events up to the PMF. It would also not have an adverse impact on NSW State Emergency Service's emergency response arrangements.

18.6.4 Impact of future climate change on flood behaviour

Impact of future climate change on flooding to the project

Annexure B of Appendix R (Technical working paper: Flooding) contains a series of figures which show flood behaviour under present day and project operation conditions for design storms with AEPs of 0.5% and 0.2%. Also included are a series of figures which show the impact that an increase in the intensity of a 1% AEP storm event would have on flooding patterns under project operation conditions. The 0.5% AEP and 0.2% AEP storms have been used as proxies to assess the impact that a 10 per cent and 30 per cent increase in 1% AEP rainfall intensities would have on flood behaviour in the vicinity of the project.

Impacts on flood behaviour associated with a potential increase in the rainfall intensities associated with future climate change are principally limited to the southern Warringah Freeway sag. For example, depths of ponding at the southern Warringah Freeway sag would be increased by 280 millimetres and 260 millimetres for the scenarios where the intensity of a 1% AEP storm event are increased by 10 per cent and 30 per cent, respectively.

During a 1% AEP flood event, flood levels would be increased by up to 0.9 metres along the western side of the entry ramp to the Western Harbour Tunnel and the Berry Street on ramp to the Warringah Freeway, however, peak flood levels would not overtop the proposed flood wall at this location. Similarly, while peak 1% AEP flood levels would be increased by up to 0.9 metres in ANZAC Park, they would not be high enough to overtop the proposed flood walls which would border the proposed tunnel portals.

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

The project would generally have a similar impact on flood behaviour to that described in Section 18.6.2 for a 1% AEP storm event under present day conditions for the two assessed climate change scenarios.

18.6.5 Impact of a partial blockage of the local stormwater drainage system on flood behaviour

The mechanism and geometric characteristics of blockages in the piped system are difficult to quantify and would be different for each storm event. Realistic scenarios would be limited to one or two pipes becoming partially blocked during a storm event. However, for the purposes of this assessment, analyses were carried out with the cross-sectional areas of all pipes and conduits reduced by 50 per cent for the 1% AEP storm event. This represents a case which is well beyond a blockage scenario which could reasonably be expected to occur and is presented for illustrative purposes.

Annexure C (Figure C1) of Appendix R (Technical working paper: Flooding) shows the impact a partial blockage of the local stormwater drainage system would have on peak 1% AEP flood levels in the vicinity of the proposed tunnel portals, bridges and surface road works. The assessment showed that a partial blockage of the local stormwater drainage system has the potential to increase flooding conditions at the location of the southern Warringah Freeway sag. For example, depths of ponding at the southern Warringah Freeway sag would be increased by up to 40 millimetres in a 1% AEP storm event.

While peak 1% AEP flood levels would be increased by about 1.2 metres along the western side of the on ramp from Berry Street to the Western Harbour Tunnel and Warringah Freeway, they would not be high enough to overtop the flood wall that is proposed at this location. Similarly, while peak 1% AEP flood levels would be increased by about 1.4 metres in ANZAC Park, they would not be high enough to overtop the proposed flood walls which would border the proposed tunnel portals.

18.6.6 Application of ARR 2019 to Design Flood Estimation

The ARR (Australian Rainfall and Runoff) 2019 was released during the preparation of the environmental impact statement. As a result, the procedures set out in ARR 1987 have been used as the basis of carrying out the flooding investigation for the project, noting the approach is consistent with the flood studies that have been carried out to date in the catchments through which it runs.

As the procedures set out in ARR 2019 would be used by councils to carry out new flood studies and to also update previous studies, a sensitivity study was carried out as part of the present investigation to assess the likely changes that would occur in predicted flood behaviour in the vicinity of the project where it runs through the Willoughby Creek catchment.

The procedures set out in ARR 2019 were applied to the hydrologic model and both it and the hydraulic model run for the 1% AEP storm event. The investigation found that there would be a reduction in the rate of runoff which would be generated by the catchment which in turn would result in a reduction in peak flood levels. This finding would apply to the adjacent catchments through which the project runs given the similar level of development in each.

Based on the above finding, the adoption of the procedures set out in ARR 1987 represents a worse-case scenario in terms of assessing flood behaviour in the vicinity of the project.

18.7 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.

18.7.1 Other motorway projects

M4-M5 Link project

Flood behaviour under post WestConnex M4-M5 Link conditions has been used as the basis for assessing the flood risk during the construction of the project. Operationally, any impacts south of Sydney Harbour have not been considered in this assessment.

Beaches Link and Gore Hill Freeway Connection

The proposed Beaches Link and Gore Hill Freeway Connection project would involve the construction of the following:

- Tunnel, trough and cut-and-cover structures within the Warringah Freeway at Cammeray
- Motorway facilities on the northern side of the freeway adjacent to Cammeray Park
- Tunnel, trough, cut-and-cover and bridge structures, as well as surface road works within the road reserve of the Gore Hill Freeway at Artarmon.

The construction of the tunnel, trough and cut-and-cover structures within the Warringah Freeway at Cammeray would not impact flood behaviour for storm events up to 1% AEP in intensity (ie because the construction area is not impacted by flooding during storms up to this intensity).

Construction of the Beaches Link and Gore Hill Freeway Connection project would not impact flood behaviour in the immediate vicinity of the Western Harbour Tunnel motorway control centre that is located on Waltham Street.

Other projects

There are no other proposed projects that are of a scale that would influence flood behaviour in the vicinity of the project.

18.8 Environmental management measures

The project has aimed to limit its impact in respect to flooding, both in terms of impacts on the project itself and the areas surrounding it. Project elements have been designed with consideration of the surrounding areas and management measures are proposed in order to further reduce the impacts of flooding brought on by the project. Environmental management measures relating to flooding impacts are outlined in Table 18-3.

Table 18-3 Environmental management measures

Ref	Phase	Impact	Environmental management measure	Location
F1	Design	Impact of the project on flood behaviour	Impact of the project on flood behaviour during construction and operation will be confirmed during further project development. This will include the consideration of future climate change and a partial blockage of the local stormwater drainage system. A floor level survey will be carried out in affected areas to determine whether the project would increase flood damage in adjacent development (i.e. in properties where there is a potential for increases in peak flood levels for storms of up to 1% AEP in intensity). The design of the project will incorporate measures that are aimed at mitigating the impact of the project 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.	WHT/WFU
F2	Design	Flooding on the Warringah Freeway	Where feasible and reasonable, the hydraulic capacity of the existing transverse drainage of the Warringah Freeway will be designed to comply with relevant guidelines and standards.	WFU
F3	Construction	Flooding impacts to tunnel excavation	Entries to tunnel excavations, including cut and cover sections of tunnel, will be protected against frequent flooding by locating openings outside flood prone areas, and/or the provision of local bunding and flood protection barriers	WHT
F4	Construction		The flood standard adopted at each tunnel entry during construction will be developed taking into consideration the duration of construction, the magnitude of inflows and the potential risks to personal safety and	WHT

Ref	Phase	Impact	Environmental management measure	Location
			the project works.	
F5	Construction	Flood impacts to construction sites	Spoil stockpiles will be located in areas which are not subject to frequent inundation by floodwater, 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.	WHT/WFU
F6	Construction	Flood impacts to construction sites	Site facilities will be located outside high flood hazard areas based on a 1% AEP flood.	WHT/WFU
F7	Construction and operation	Impact of flooding on the project	Flood emergency management measures for construction and operation of the project will be incorporated into relevant environmental and/or safety management documentation.	WHT/WFU

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