NSW GOVERNMENT

Transport for NSW

# Beaches Link and Gore Hill Freeway Connection

## Chapter 18

## Flooding

transport.nsw.gov.au

DECEMBER 2020

# 18 Flooding

This chapter outlines the potential flooding impacts associated with the project and identifies measures to address these impacts. 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.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. The environmental management measures proposed to minimise the potential impacts in relation 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:<br>a. Flood prone land;<br>b. Flood planning areas, the area below the flood planning level;<br>c. Hydraulic categorisation (floodways and flood storage areas);<br>d. Flood Hazard. | Figures containing maps of features relevant to flooding are listed below:<br>a. Flood prone land – Figure 4.4 of **Appendix R** (Technical working paper: Flooding)<br>b. Flood planning areas, the area below the flood planning level – Figure 4.7 of **Appendix R** (Technical working paper: Flooding)<br>c. Hydraulic categorisation (floodways and flood storage areas) – Figure 4.5 of **Appendix R** (Technical working paper: Flooding)<br>d. Flood Hazard – Figure 4.6 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** 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 for construction and operation respectively. |
| a. How the tunnel entries and cut-and-cover sections of the tunnels would be protected from flooding during construction works; | **Section 18.5.1** summarises the findings of the assessed flood risk at the temporary 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. |

| Secretary's requirement | Where addressed in EIS |
|---|---|
| b. Any detrimental increases in the potential flood affectation of the project infrastructure and other properties, assets and infrastructure; | **Sections 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. |
| 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% Annual Exceedance Probability (AEP) flood.<br>**Section 18.5.1** includes discussion on the potential flood hazard at proposed temporary construction support sites, **Section 18.5.2** includes discussion of potential flood risk at temporary 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** 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.<br>**Sections 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<br>**Section 18.6** presents the findings of the assessment of 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 | **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. |

| Secretary's requirement | Where addressed in EIS |
|---|---|
| State Emergency Services and Council; | **Section 18.8** sets out environmental management measures, including consultation with State Emergency Services and relevant councils and incorporation of flood emergency management measures into the relevant project environmental and/or safety documentation.<br><br>**Appendix E** (Community consultation framework) identifies councils and State Emergency Services as key stakeholders, with engagement to continue into the next phases of the project. |
| 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.<br>**Appendix E** (Community consultation framework) identifies councils and State Emergency Services as key stakeholders, with engagement to continue into the next phases of the project. |
| 3. The assessment should take into consideration any flood studies undertaken by local government councils, as available. | **Section 18.3** identifies the flood studies used in the assessment of flooding impacts. |
| 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 | **Section 18.6.5** provides an assessment of the impact the project would have on flood behaviour under future climate change conditions. |

| Secretary's requirement | Where addressed in EIS |
|---|---|
| rainfall intensity of flood producing rainfall events due to climate change. | |

## 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 10 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 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 regard 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 (Institution of Engineers Australia, 1987), with a sensitivity analysis of the recently released ARR 2019 edition (Ball et al., 2019)
  - *Australian Disaster Resilience Handbook 7: Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR) 2017 edition (Australian Institute for Disaster Resilience, 2017)
- State-level:
  - *Floodplain Development Manual* (FDM) 2005 (NSW Government, 2005)
  - *Guideline on Development Controls on Low Risk Flood Areas* 2007 (Department of Planning, 2007)
  - *Environmental Planning and Assessment Act 1979*
  - *Floodplain Risk Management Guidelines: Practical Considerations of Climate Change* 2007 (DECC, 2007)
- Local-level:
  - Warringah Local Environmental Plan (LEP) 2011
  - Manly LEP 2013
  - Willoughby LEP 2012
  - North Sydney LEP 2013
  - Mosman LEP 2012.

## 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 catchment that are crossed by the project, including:
  - Manly Lagoon Floodplain Risk Management Study and Plan (WMA, 2018)
  - *Flat Rock Creek Catchment Flood Study and Overland Flow Mapping Volume 1* (Lyall and Associates, 2018)
  - North Sydney Flood Study (WMA, 2016)
  - Fort Denison Sea Level Rise Vulnerability Study (Watson & Lord, 2008)
- Update of the existing flood models where required to more accurately define flooding and drainage behaviour in the vicinity of the project
- Application of the ARR 1987 methodology (and recently released 2019 ARR sensitivity analysis) for design flood estimation
- Preparation of figures showing flood behaviour under present day conditions for design floods with AEPs of 10%, 1%, 0.5% and 0.2%, as well as the PMF
- Assessment of the potential flood risks during construction and the operational features of the project
- Assessment of the impact future climate change would have on flood behaviour while under construction and during 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
- Development of hydrologic models to assess the impact the upgrade of the Wakehurst Parkway would have on peak flows and hence scour potential in the receiving drainage lines that drain to Bantry Bay and Manly Creek
- Assessment of potential measures which are aimed at mitigating the risk of scour in the aforementioned receiving drainage lines.

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 contribute runoff to the existing drainage systems and waterways that are located within the project footprint (Figure 18-1):

- Willoughby Creek
- Flat Rock Creek
- Pearl Bay (within Middle Harbour)
- Burnt Bridge Creek (a sub-catchment of Manly Lagoon)
- Bantry Bay
- Manly Creek (a sub-catchment of Manly Lagoon)

- Trefoil Creek (a sub-catchment of Narrabeen Lagoon).

The catchments outlined above drain to either Middle Harbour, Manly Lagoon or Narrabeen Lagoon. 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.


**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 areas

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.

### 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 the 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 in the catchment 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 the drainage line 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.

### 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 T1 North Shore and Western Line and T9 Northern 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 T1 North Shore and Western Line and T9 Northern 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 is piped where it runs along the southern side of Gore Hill Freeway from Marsden Street and crosses under the freeway at Hampden Road, via an existing transverse drainage structure. This drainage structure discharges into an open channel that continues along the northern side of the Gore Hill Freeway to a brick arch culvert under the T1 North Shore and Western Line and T9 Northern Line. Two existing transverse drainage structures control runoff from the north of the Gore Hill Freeway discharge into the trunk drainage system along this section. Two existing drainage structures that control runoff from the southern side of Gore Hill Freeway discharge into an open channel between Hampden Road and the T1 North Shore and Western Line (refer to Figure 17-2 of Chapter 17 (Hydrodynamics and water quality) for further details on the characteristics of Flat Rock Creek).

The trunk drainage system downstream of the T1 North Shore and Western Line and T9 Northern Line culvert to Willoughby Road was constructed in the 1930's 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.

As part of the trunk drainage for the Gore Hill Freeway, Artarmon Reserve was converted to a dual purpose playing field/retarding basin. The objective was to reduce the peaks of major stormwater flows which originate from the northern portion of the catchment, to offset the increase in peak flows generated by the freeway. The retarding basin was later modified as part of the Lane Cove Tunnel project to offset the impact that the widening of the Gore Hill Freeway would otherwise have had on peak flows in Flat Rock Creek.

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 Creek 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 150 metres to the east of Flat Rock Drive.

### Pearl Bay

The Pearl Bay catchment drains in a westerly direction, extending from Spit Road in Mosman and has a total catchment area of about 0.27 square kilometres (27 hectares). The catchment is located within the Mosman local government area.

The Spit West Reserve construction support site (BL9) is proposed to be located at the northern end of the catchment within Spit West Reserve.

### Burnt Bridge Creek

The Burnt Bridge Creek catchment drains in an easterly direction from the Wakehurst Parkway and has a total catchment area of about 3.4 square kilometres (340 hectares) at Condamine Street. The catchment covers the Northern Beaches local government area and includes the suburbs of Seaforth, North Balgowlah, Balgowlah, Manly Vale and Fairlight.

Burnt Bridge Creek Deviation runs north-south from Sydney Road to Condamine Street through the middle reaches of the catchment which predominantly comprises low and medium density residential development. Commercial development is mainly located along Condamine Street and Sydney Road. Open space is predominantly located within the middle and lower reaches of the catchment and includes Balgowlah Golf Course, Manly Golf Club, Manly West Park and LM Graham Reserve.

The main arm of Burnt Bridge Creek comprises a vegetated channel that extends from Clontarf Street in the west to Condamine Street in the east and includes culvert crossings at Brook Road, Burnt Bridge Creek Deviation and Kitchener Street. The culvert crossing of Burnt Bridge Creek Deviation comprises twin 3600 millimetre wide by 3600 millimetre high box culverts and twin 2400 millimetre wide by 2400 millimetre high box culverts. East (downstream) of Condamine Street the creek is drained by a box culvert that discharges into a vegetated channel that runs along the northern side of Manly West Park and through the Manly Golf Club before discharging into Manly Lagoon at Pittwater Road (refer to Figure 17-3 of Chapter 17 (Hydrodynamics and water quality) for further details on the characteristics of Burnt Bridge Creek).

A series of piped drainage lines cross Burnt Bridge Creek Deviation between Serpentine Crescent and Abingdon Street. The piped drainage lines control runoff from the catchment to the north of Burnt Bridge Creek Deviation and discharge into Burnt Bridge Creek along its northern bank.

### Bantry Bay

The Bantry Bay catchment drains in a southerly direction from Warringah Road and has a total catchment area of about 4.8 square kilometres (480 hectares). Residential development is located in the upper northern and western portions of the catchment, while the Garigal National Park covers the majority of the middle and lower portions of the catchment.

The section of the project that runs along the Wakehurst Parkway between Grattan Crescent and Kirkwood Street generally follows the catchment divide between Bantry Bay and Manly Creek. Three minor drainage lines presently control runoff from this section of the Wakehurst Parkway which would be upgraded as part of the project.

### Manly Creek

The Manly Creek catchment drains in a south easterly direction, extending from Warringah Road in the north and has a total catchment area of about 18.2 square kilometres (1820 hectares) at Manly Lagoon.

Manly Creek runs in a southerly direction to the east of Wakehurst Parkway. A series of piped crossings along the Wakehurst Parkway control runoff from the residential development and nature reserve to the west of the road. The largest of these piped drainage systems comprises a 2400 millimetre wide by 1800 millimetre high box culvert and a 750 millimetres diameter pipe located about 140 metres south of Warringah Road, and a 1200 millimetre diameter pipe located immediately south of Yarraman Avenue. The piped crossings discharge into receiving drainage lines that feed into Manly Creek.

Manly Dam was originally constructed across Manly Creek in the late 1800’s to supply drinking water to the local area. The dam continued to supply drinking water until 1936, after which time it became an important recreational facility for the local area and beyond. The dam has a capacity of approximately 2000 megalitres and its water body is sheltered and deep (in most parts) with a surface area of approximately 0.3 square kilometres (30 hectares).

### Trefoil Creek

A relatively small section of the project along the Wakehurst Parkway at its connection to Frenchs Forest Road East is located within the headwaters of the Trefoil Creek catchment, runoff from which discharges into Middle Creek. The Trefoil Creek catchment is about 0.97 square kilometres (97 hectares) at its confluence with Middle Creek.

Trefoil Creek is fed by several piped drainage systems which discharge to the steep sided valley to the east of the Wakehurst Parkway and north of Frenchs Forest Road East. These piped drainage systems control runoff from sections of Frenchs Forest Road East, the Wakehurst Parkway and Bantry Bay Road, as well as the north east portion of the Northern Beaches Hospital.

### 18.4.3 Existing flooding and drainage characteristics

A brief description of patterns of both mainstream flooding and major overland flow is provided below with respect to present day (ie pre-project) conditions within areas in the vicinity of construction and/or operational components of the project.

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 above, are defined as follows:

- Annual Exceedance Probability (AEP)
  - 10% AEP – there is a 10 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 upper limiting value of floods that could reasonably be expected to occur (the result of the most severe combination of meteorological conditions) and defines the extent of flood prone land (ie the floodplain).

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 the discussion below considers flooding patterns for the AEP and PMF in catchment areas for which impacts are predicted. As such, the existing AEP and PMF flood impacts are not reported for all catchment areas. A discussion of flooding patterns is provided for those catchments where the AEP and PMF flood impacts are not reported.

Figure 18-2 to Figure 18-8 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 Figures 4.2 to 4.4 in Appendix R (Technical working paper: Flooding)).

#### 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 near 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 persons 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 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 which is 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 is located 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. The flood walls associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project (subject to separate environmental impact assessment and approval) would prevent the ingress of floodwater to the road tunnels for events up to the PMF.

### 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 one 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 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 would travel 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 would collect 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 located between Herbert Street and the T1 North Shore and Western Line and T9 Northern line also contributes to overland flow travelling east along the eastbound carriageway of the Gore Hill Freeway.

#### *PMF*

The main carriageways and various existing 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.

While the majority of flow that discharges from George Place is conveyed in an easterly direction along the eastbound carriageway, a portion of this flow discharges onto the central carriageways where it enters the Lane Cove Tunnel.

Similarly, while the majority of flow that discharges from McLachlan Avenue is conveyed in an easterly direction along the westbound carriageway, a portion of the flow discharges onto the central carriageways where it would enter the Lane Cove Tunnel.

The section of Gore Hill Freeway between Reserve Road and the T1 North Shore and Western Line and T9 Northern 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 T1 North Shore and Western Line and T9 Northern Line are controlled by the rail underpass, which constricts overland flow travelling along the Gore Hill Freeway.

### Pearl Bay

The area of Spit West Reserve where the Spit West Reserve construction support site (BL9) is proposed to be located would be inundated by overland flow that is conveyed along the southbound carriageway of Spit Road and discharges into the reserve via the carpark entry from Spit Road for events up to the PMF.

### Burnt Bridge Creek

#### *Up to 1% AEP*

The existing culvert crossing of Burnt Bridge Creek at Burnt Bridge Creek Deviation has a hydrologic standard in excess of 1% AEP under ideal flow conditions.

While flow would generally be confined to the incised valley through which Burnt Bridge Creek runs between Brook Road and Kitchener Street, residential development located on the southern overbank of the creek in Brook Road, Hope Street and Burnt Bridge Creek Deviation would be inundated by floodwater during a 1% AEP event.

Flow that surcharges existing transverse drainage structures would pond behind the noise wall located along the western side of Burnt Bridge Creek Deviation between Serpentine Crescent and Kitchener Street, with a portion of this flow discharging onto Burnt Bridge Creek Deviation via openings which are present in the noise wall adjacent to Kitchener Street during a 10% AEP event.

Flow would overtop the western bank of Burnt Bridge Creek immediately upstream of Kitchener Street and discharge onto the southbound carriageway of Burnt Bridge Creek Deviation during a 10% AEP event.

#### *PMF*

Flow in excess of the existing transverse drainage structure (culvert crossing of Burnt Bridge Creek at Burnt Bridge Creek Deviation) would overtop Burnt Bridge Creek Deviation to a maximum depth of about one metre. A portion of this flow would re-enter Burnt Bridge Creek to the east of the road corridor, while the remaining flow would travel in a northerly direction along both the northbound and southbound carriageways.

Flow that surcharges the existing transverse drainage structures would pond behind the noise wall that runs along the western side of Burnt Bridge Creek Deviation before discharging onto the road in the vicinity of the Kitchener Street bridge.

Flow would overtop the western bank of Burnt Bridge Creek immediately upstream of Kitchener Street where it discharges onto both the northbound and southbound carriageways of Burnt Bridge Creek Deviation. The depth of flow along Burnt Bridge Creek Deviation would reach a maximum of about two metres near the Kitchener Street bridge.

### Bantry Bay

The section of the Wakehurst Parkway between Grattan Crescent and Kirkwood Street generally follows the catchment divide between Manly Creek and Bantry Bay and is not affected by mainstream flooding or major overland flow.

### Manly Creek

#### *Up to 1% AEP*

During a 1% AEP event, flow that surcharges the piped drainage system in the Wakehurst Parkway at its intersection with Warringah Road would inundate the road to relatively shallow depths that are typically 0.1 metres or less.

Flow that discharges from the drainage system at the northern end of Bantry Bay Road would pond at the inlet of the 1050 millimetre diameter pipe that crosses the Wakehurst Parkway about 140 metres south of Warringah Road. During a 1% AEP event, this ponding would have a maximum depth of over two metres but would not surcharge onto the road.

During a 1% AEP event, flow that surcharges the two pipe crossings of the Wakehurst Parkway between Garner Avenue and Yarraman Avenue would inundate the road to depths typically 0.2 metres or less.

Flow that discharges from the drainage system at the eastern end of Yarraman Avenue would pond at the inlet of the 1200 millimetre diameter pipe that crosses Wakehurst Parkway immediately to its south. During a 1% AEP event, this ponding would have a maximum depth of over two metres but would not surcharge onto the road.

#### *PMF*

The hydraulic model developed as part of the Manly Lagoon Floodplain Risk Management Study and Plan (WMA, 2018) has been configured in a way that applies inflows downstream of Wakehurst Parkway and therefore does not show flooding to the road corridor or any of the areas upstream during a PMF event. Flow would, however, inundate the Wakehurst Parkway at the locations described above to a greater depth during more extreme storm events.

### Trefoil Creek

The section of the project along the Wakehurst Parkway that is located within the Trefoil Creek catchment is not impacted by mainstream flooding or major overland flow.

The Wakehurst Parkway was recently upgraded as part of the Northern Beaches Network Connectivity and Enhancements project. Figure 4.1 of Appendix R (Technical working paper: Flooding) shows the layout of the upgraded drainage system along the Wakehurst Parkway, which has been designed to control runoff from the local catchment during storms up to 10% AEP in magnitude. During a 1% AEP event, overland flow would occur along the kerbside lanes of the Wakehurst Parkway due to surcharge of the drainage system.

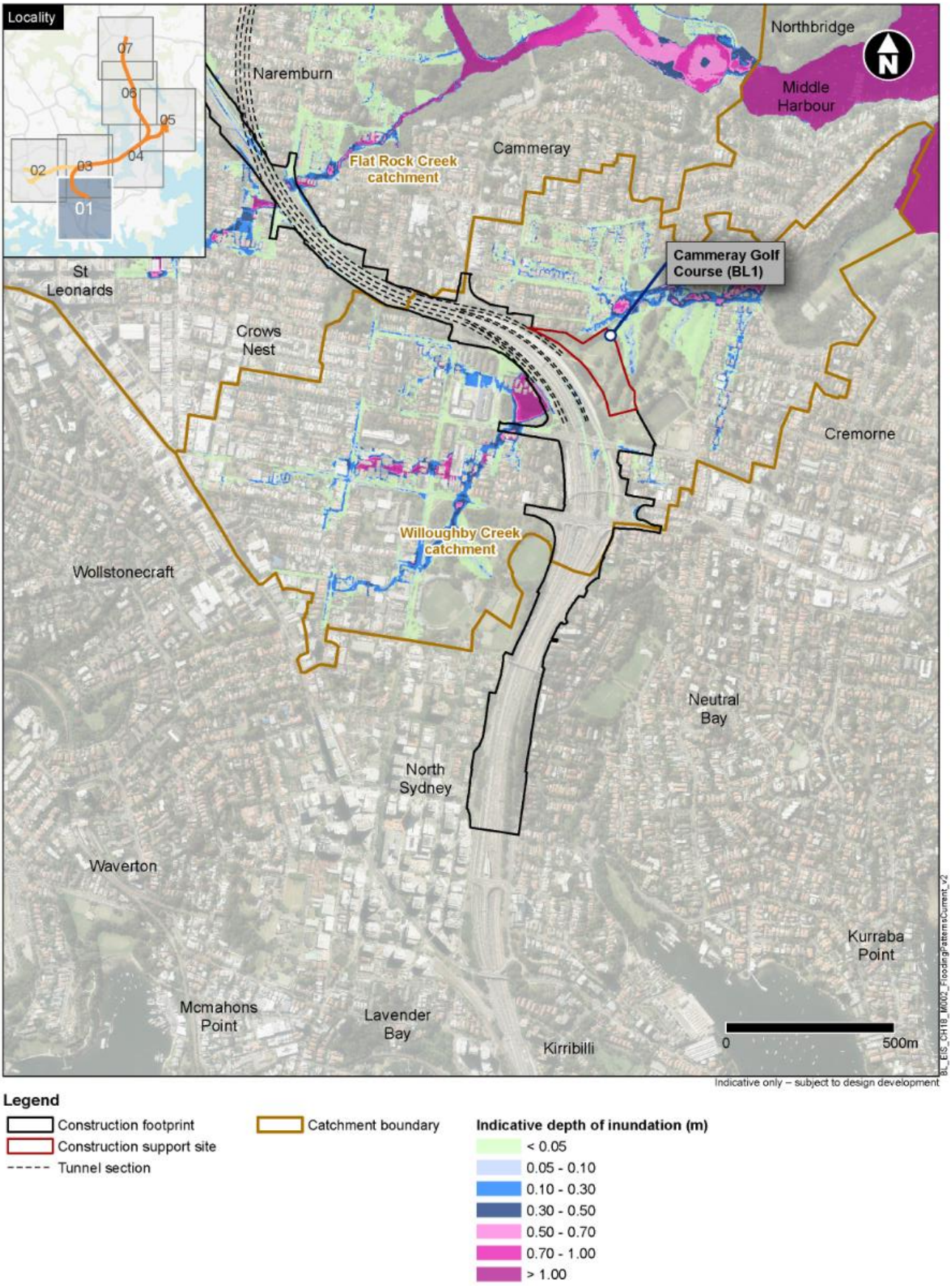


**Figure 18-2 Flood behaviour under present day conditions – 1% AEP event (map 1)**

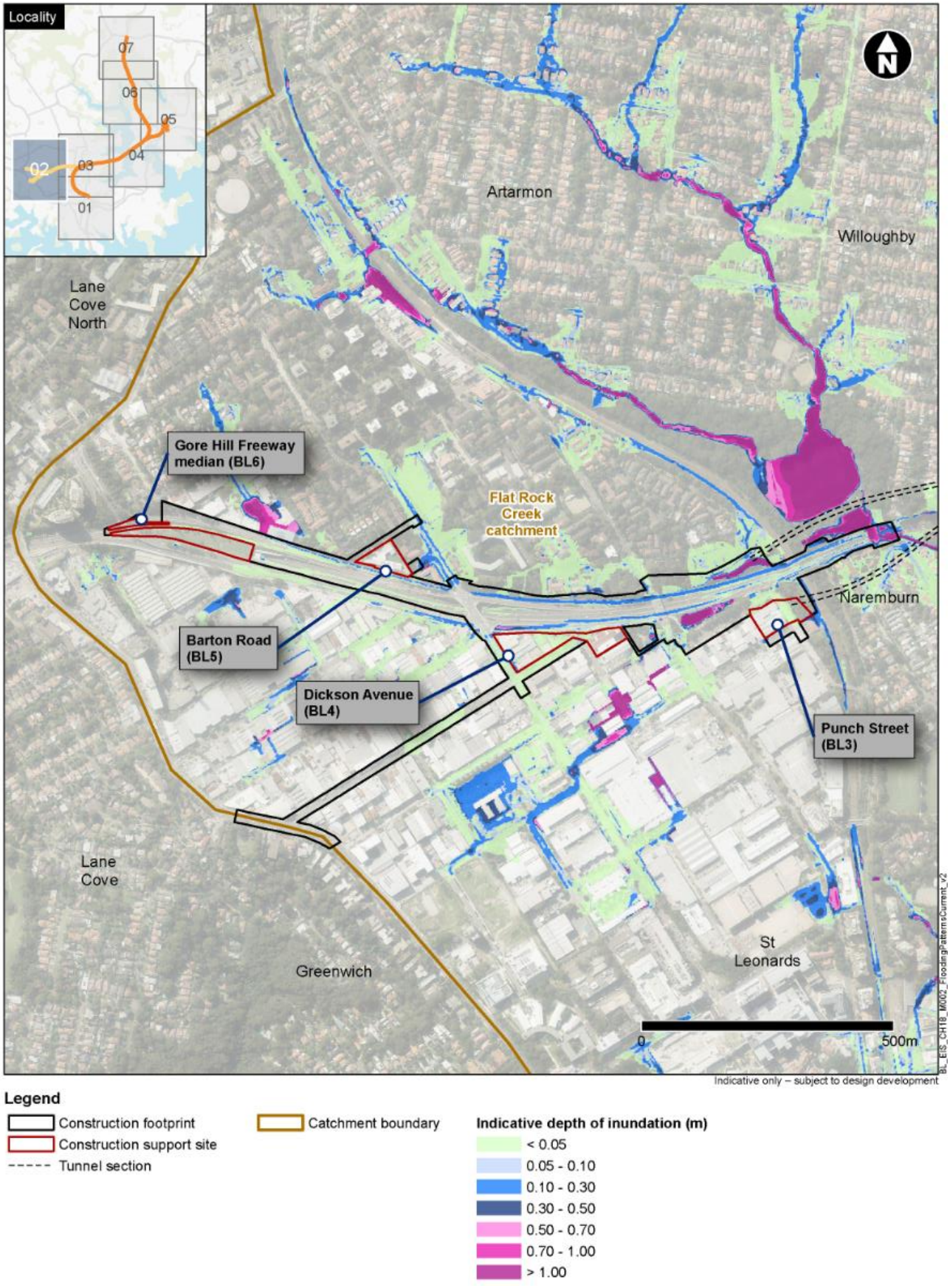


**Figure 18-3 Flood behaviour under present day conditions – 1% AEP event (map 2)**

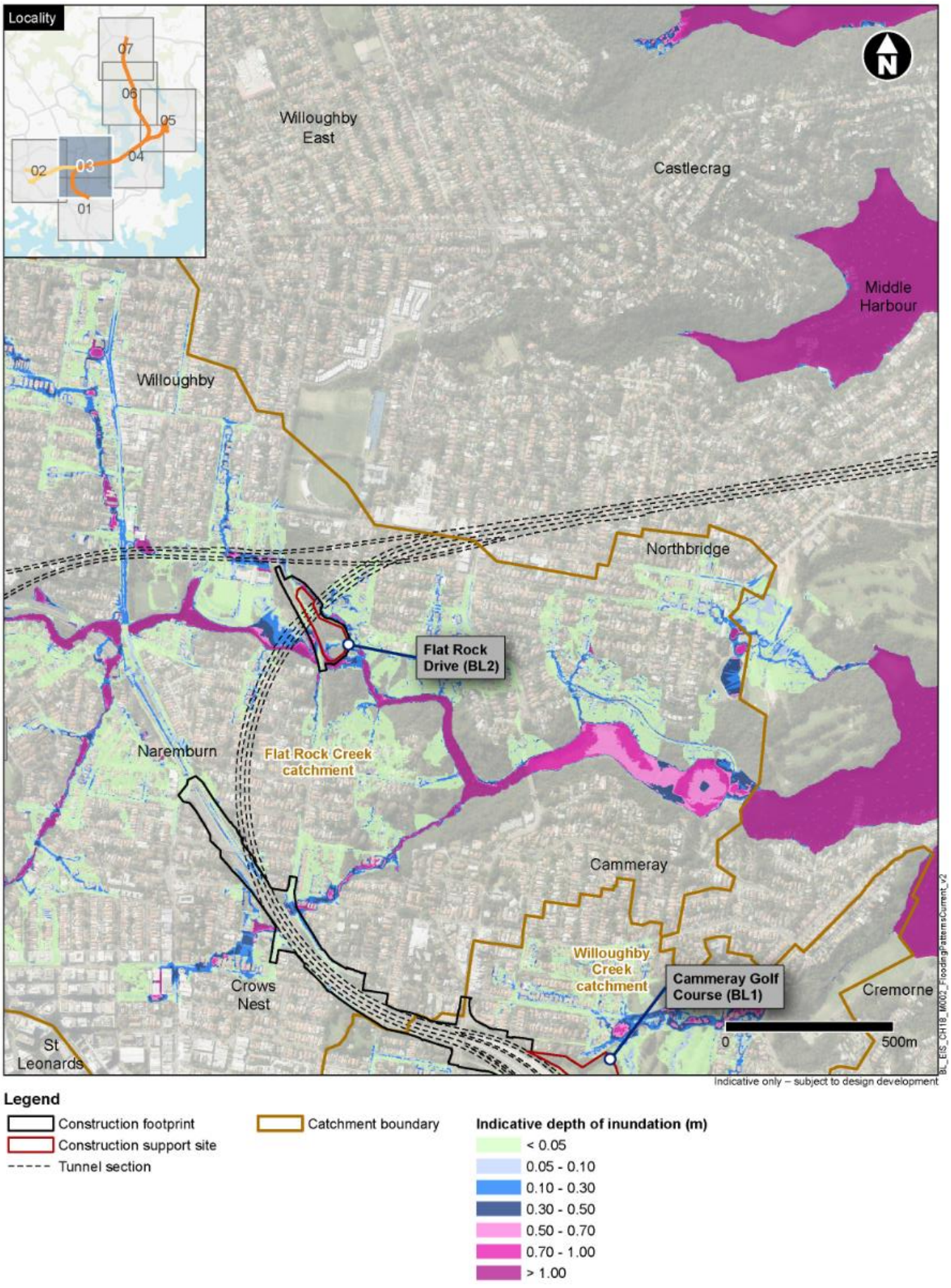


**Figure 18-4 Flood behaviour under present day conditions – 1% AEP event (map 3)**

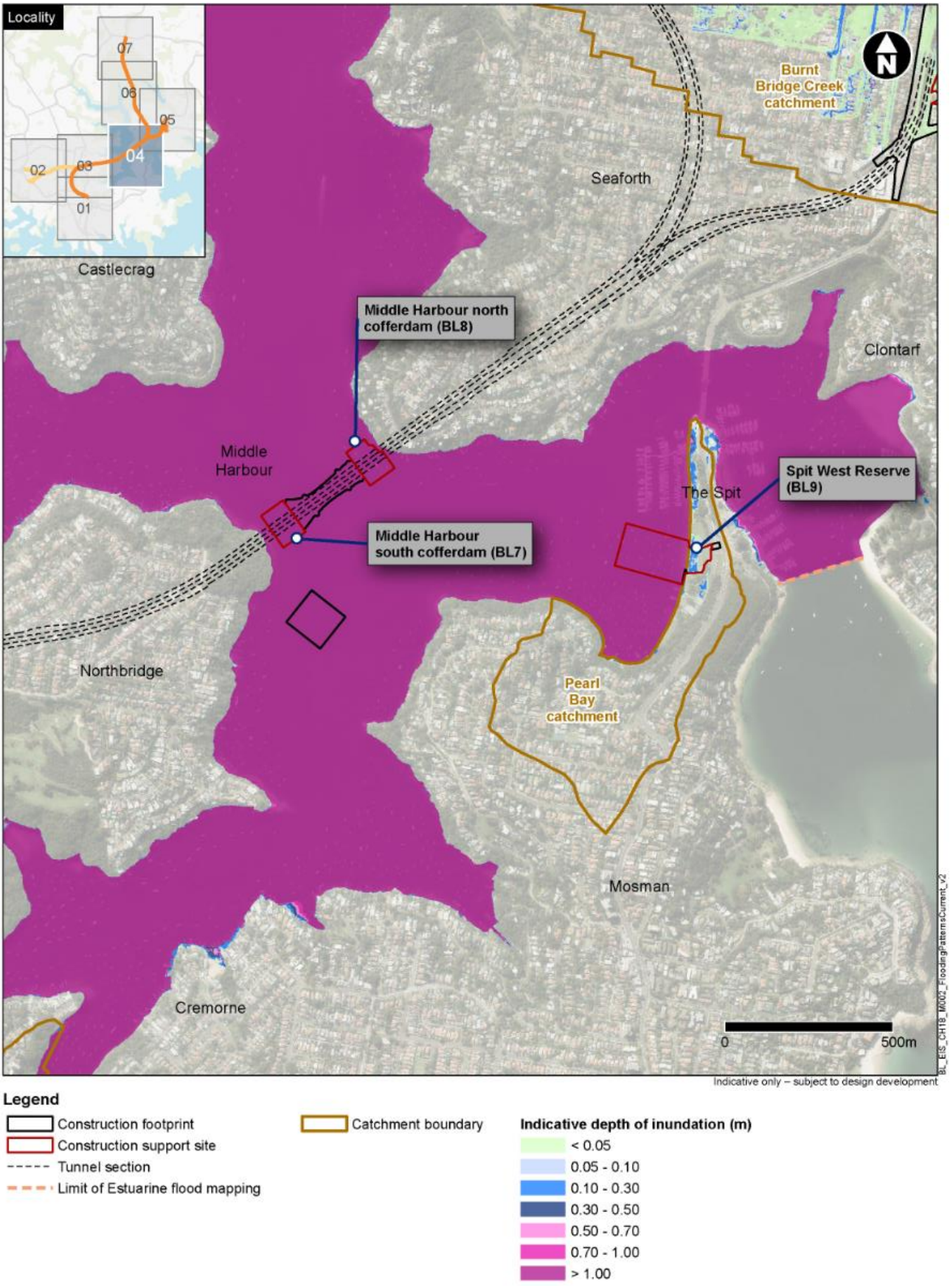


**Figure 18-5 Flood behaviour under present day conditions – 1% AEP event (map 4)**

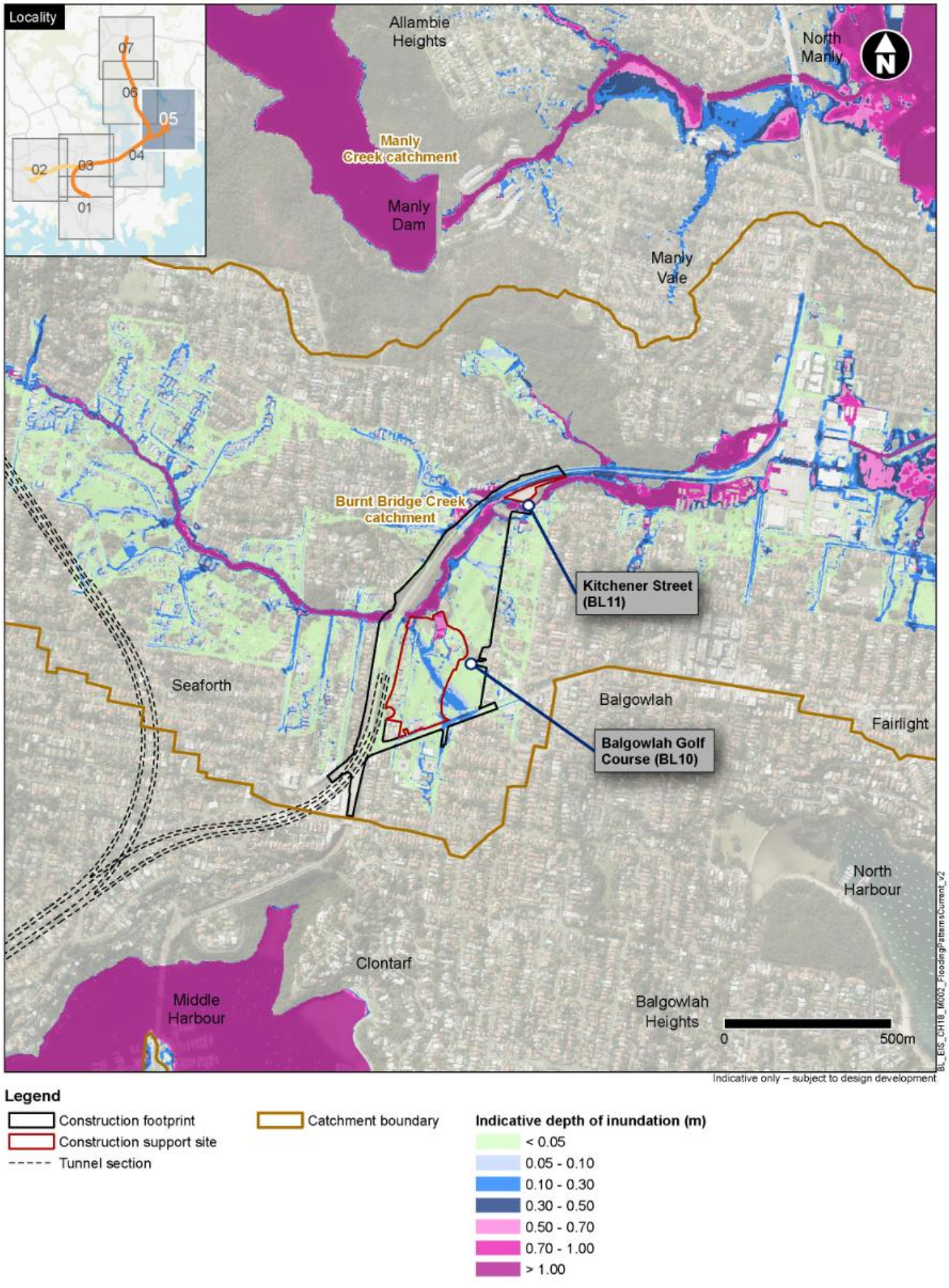


**Figure 18-6 Flood behaviour under present day conditions – 1% AEP event (map 5)**

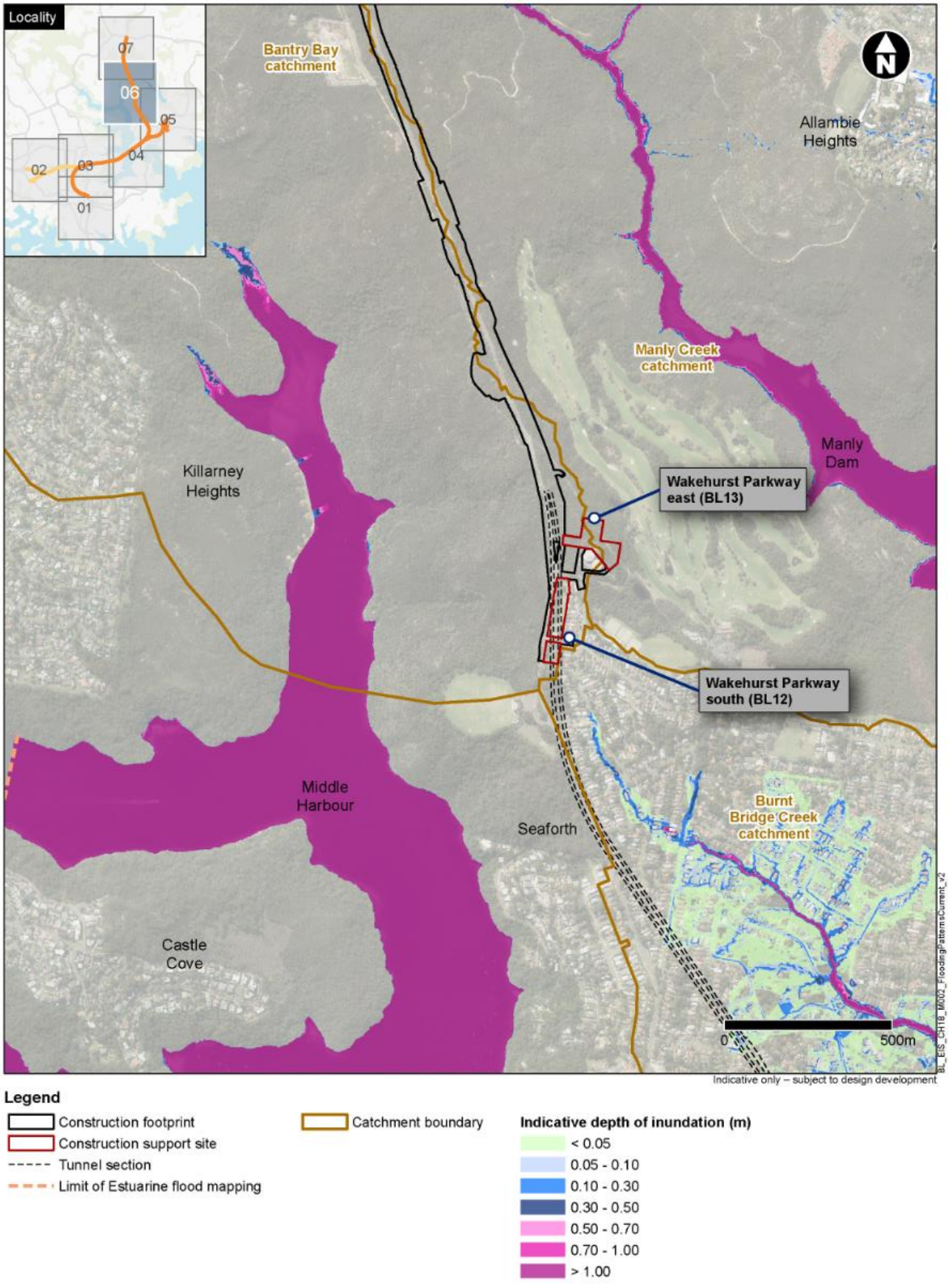


**Figure 18-7 Flood behaviour under present day conditions – 1% AEP event (map 6)**

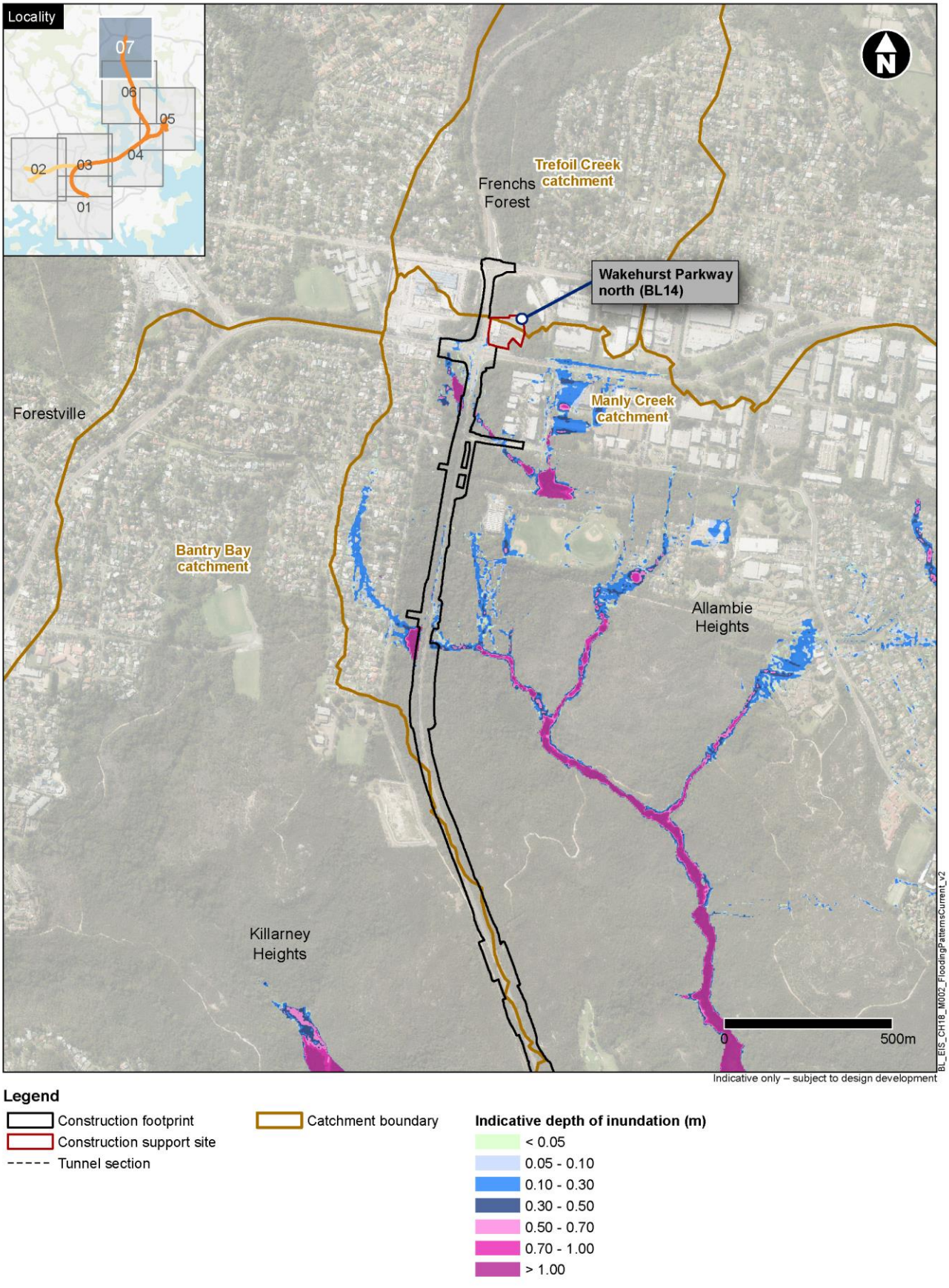


**Figure 18-8 Flood behaviour under present day conditions – 1% AEP event (map 7)**

## 18.5 Assessment of potential construction impacts

This section provides an assessment of the flood risk at the proposed temporary construction support sites which are associated with the construction of the Beaches Link and Gore Hill Freeway project. Details of the proposed temporary 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 exacerbate flooding conditions when compared to both present day and operational conditions. This is because the construction activities typically impose a larger footprint on the floodplain due to the need to provide temporary structures outside the operational project footprint which would be removed following the completion of construction activities.

A qualitative assessment was carried out of the potential impacts construction activities could have on flood behaviour, the key findings of which are summarised in Table 18-2.

While the majority of the temporary 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 Balgowlah Golf Course construction support site (BL10) and the adjacent new and improved public open space and recreation facility works. 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.

Without mitigation the construction of the project has the potential to result in changes in flood behaviour that may result in social and economic cost impacts to the community by exacerbating the impact of flooding to property and infrastructure as well as disruption to the community.

While the findings of the assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would need to be carried out during further design development and construction planning. 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.

#### Temporary construction support site facilities

A range of site facilities including offices, staff amenities, stores and laydown, workshops and parking are proposed at the temporary construction support sites associated with the project, with the exception of Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8) construction support sites located on Middle Harbour.

Most of the locations that have been identified for the proposed construction support sites are affected by flooding, whether as a result of main stream flooding, overland flow or ocean storm tides (refer to Table 18-2), with the exception of Gore Hill Freeway median (BL6), Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.

While the majority of the temporary construction support sites would be subject to flooding during a 10% AEP storm event, depths of inundation are generally shallow and of a short duration nature. The exception is Flat Rock Drive construction support site (BL2), where depths of flow are greater

than 0.5 metres in a 10% AEP flood event. Elevated water levels in Middle Harbour could also result in the partial inundation of Spit West Reserve construction support site (BL9).

Site facilities located on the floodplain, particularly in areas of high hazard, pose a safety risk to construction personnel. It would be necessary to locate site facilities outside high hazard areas with safe evacuation routes. All temporary construction support sites include land located outside areas of high hazard that would be suitable for site facilities.

### Tunnel construction

The key activities associated with tunnel construction carried out from the Beaches Link temporary construction support sites, include:

- Tunnel excavation
- Cut and cover structures.

The tunnel excavation would involve the use of pumps at the tunnel low points, and potentially mobile sumps at the cutting face to collect tunnelling water, groundwater ingress and stormwater runoff from the tunnel openings. While the tunnel excavation arrangement would be designed to accommodate a nominal amount of stormwater runoff, the potential for the ingress of floodwater to the tunnel excavations during their construction poses a significant risk to personal safety and has the potential to cause damage to machinery and delays in the project timetable if not adequately managed. The flood standard adopted at each tunnel opening during construction would be developed during further design development.

Similar to the construction of the driven tunnels, the potential for ingress of floodwater into the open excavations poses a safety risk to construction workers, as well as having the potential to cause damage to machinery and construction delays. Potential impacts to cut and cover structures that are part of the project, include:

- The ability for floodwater which ponds in ANZAC Park in the Willoughby Creek catchment to discharge onto the Warringah Freeway near the proposed cut and cover sections of the tunnel is constrained by the presence of the noise wall which runs along its southern side. Any leakage of floodwater through, or overtopping of, the noise wall (for example in a PMF event), could cause flooding of the freeway in excess of one metre in the vicinity of the cut and cover sections of tunnel
- Stormwater which surcharges the existing drainage system at the Flat Rock Creek and Burnt Bridge Creek catchments has the potential to impact cut and cover operations.

Cut and cover works at the Wakehurst Parkway are not subject to flooding due to the road being located along a natural ridgeline.

The provision of temporary barriers in combination with the permanent solid barriers/flood walls which are proposed around tunnel portals, would be required to prevent floodwater entering the open excavations.

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

### Spoil management and stockpile areas

The construction of the project would generate a significant amount of spoil which, in some situations, may 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.

Some stockpiling of spoil material is proposed at all temporary construction support sites with the exception of Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8) construction support sites. Tunnel spoil is generally stockpiled within an acoustic shed. External stockpiles are generally avoided. While the majority of these sites are affected by flooding to

varying degrees, 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 temporary construction support sites, the main area of surface earthworks is associated with the Gore Hill Freeway Connection component as well as the upgrades of Burnt Bridge Deviation and the Wakehurst Parkway.

Surcharge of the existing drainage along the Gore Hill Freeway occurs during a 1% AEP, when the depth of flow along the northern and southern sides of the freeway exceed about 0.3 metres.

While floodwater is generally confined to the main channel of Burnt Bridge Creek and its immediate overbank area near the project, several major overland flow paths develop during storms which result in the surcharge of the existing stormwater drainage system.

As the Wakehurst Parkway generally runs along the top of a natural ridge line, it is not subject to flooding. Rather, the road corridor is impacted by surface runoff which is generated by a number of relatively small catchments which are located on its eastern and western sides.

The inundation of the surface earthworks by floodwater has the potential to cause scouring of disturbed surfaces and transport sediment and construction materials into the receiving waterways. It would 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 pedestrian and shared user bridge upgrades along the Wakehurst Parkway, the construction of which would be managed from the Wakehurst Parkway north construction support site (BL14).

The proposed pedestrian footbridge works along the Wakehurst Parkway are not at risk of being flooded during construction.

## 18.5.2 Potential flood risk at temporary construction support sites

Without the implementation of appropriate management measures, inundation of the temporary 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 infrastructure such as site sheds, stockpiles, noise walls and flood walls, which in turn, could exacerbate flooding conditions at developments located outside the construction footprint.

Table 18-2 provides a summary of the proposed activities, as well as the assessed flood risk at the temporary construction support sites associated with the construction of the Beaches Link and Gore Hill Freeway Connection project. Figure 5.1 of Appendix R (Technical working paper: Flooding) shows the extent to which floods of varying magnitude affect each temporary construction support site. Figure 5.2 shows the indicative depth and extent of inundation in the vicinity of each temporary construction support site for the 10% AEP and 1% AEP flood events. Figure 5.3 of Appendix R (Technical working paper: Flooding) shows the provisional flood hazard and preliminary hydraulic categorisation of the floodplain near each temporary construction support site for a 1% AEP flood event. Further details of each temporary construction support site and its associated facilities and activities is provided in Chapter 6 (Construction work). 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 proposed temporary construction support sites**

| Temporary construction support site | Catchment | Threshold of flooding[1] | Site facilities [2] | Spoil management [2] | Tunnel launch and support [2] | Cut and cover structures [2] | Surface earthworks [2] | Description of existing flood behaviour | Potential impacts of construction activities on flood behaviour |
|---|---|---|---|---|---|---|---|---|---|
| **Cammeray Golf Course (BL1)** | Willoughby Creek | PMF | ✓ | ✓ | ✓ | ✓ | ✓ | The Cammeray Golf Course construction support site (BL1) would be subject to very shallow sheet flow during heavy rainfall events, principally due to runoff generated from within its extent.<br>Overland flow discharging through the Cammeray Golf Course construction support site (BL1) during storms up to 1% AEP in intensity is classified as low hazard flood fringe.<br>During a PMF event, floodwater would surcharge the Warringah Freeway where it would discharge through the Cammeray Golf Course construction support site (BL1) at depths of up to 0.5 metres.<br>Refer to Figures 5.1 (Sheet 2), 5.2 (Sheet 1) and 5.3 (Sheet 1) of Appendix R (Technical working paper: Flooding). | 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 (BL1) has the potential to exacerbate flooding conditions in existing residential development that is located along Warringa Road, Falls Street, Cammeray Road and Grafton Street.<br>Construction activities within the confines of the Cammeray Golf Course construction support site (BL1) have the potential to obstruct flow which surcharges the Warringah Freeway during a PMF, thereby exacerbating flooding conditions in existing development that is located on the western side of the freeway.<br>Floodwater originating from ANZAC Park, as well as from |

| Temporary construction support site | Catchment | Threshold of flooding[1] | Site facilities [2] | Spoil management [2] | Tunnel launch and support [2] | Cut and cover structures [2] | Surface earthworks [2] | Description of existing flood behaviour | Potential impacts of construction activities on flood behaviour |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | within the Warringah Freeway corridor has the potential to impact tunnel works that are proposed adjacent to Cammeray Golf Course. |
| **Flat Rock Drive (BL2)** | Flat Rock Creek | More frequent than 10% AEP | ✓ | ✓ | ✓ | | ✓ | The Flat Rock Drive construction support site (BL2) would be subject to flooding during storms more frequent than 10% AEP.<br>Flooding occurs in the south-west corner of the Flat Rock Drive construction support site (BL2) during storms which result in the surcharge of the existing transverse drainage of Flat Rock Drive.<br>The Flat Rock Drive construction support site (BL2) also spans an incised natural watercourse which drains from the north.<br>Refer to Figures 5.1 (Sheet 3), 5.2 (Sheet 1) and 5.3 (Sheet 1) of Appendix R (Technical working paper: Flooding). | Changes in natural surface levels within the confines of the Flat Rock Drive construction support site (BL2) have the potential to alter flooding patterns in the area, which in turn could impact on construction activities, as well as the hydrologic standard of Flat Rock Drive.<br>Flooding has the potential to impact the covered section of the decline and the spoil shed, both of which are located across the incised natural watercourse which drains from the north.<br>Construction activities within the Flat Rock Drive construction support site (BL2) would not have an impact on flood behaviour in existing development. |

| Temporary construction support site | Catchment | Threshold of flooding[1] | Site facilities [2] | Spoil management [2] | Tunnel launch and support [2] | Cut and cover structures [2] | Surface earthworks [2] | Description of existing flood behaviour | Potential impacts of construction activities on flood behaviour |
|---|---|---|---|---|---|---|---|---|---|
| **Punch Street (BL3)** | Flat Rock Creek | More frequent than 10% AEP | ✓ | ✓ | ✓ | ✓ | ✓ | Shallow overland flow discharges in a northerly direction along Lambs Road which it is intercepted by a series of kerb inlet pits that are located at the eastern end of Punch Street.<br>Refer to Figures 5.1 (Sheet 4), 5.2 (Sheet 2) and 5.3 (Sheet 2) of Appendix R (Technical working paper: Flooding). | Alterations to existing road levels to facilitate access to the Punch Street construction support site (BL3) has the potential to cause minor flooding within the proposed acoustic shed and access decline.<br>Due to the topography in the area, activities within the Punch Street construction support site (BL3) would not have an impact on flood behaviour in adjacent residential development. |
| **Dickson Avenue (BL4)** | Flat Rock Creek | More frequent than 10% AEP | ✓ | ✓ | ✓ | ✓ | ✓ | Parts of the Dickson Avenue construction support site (BL4) are subject to relatively shallow sheet flow during storms which result in the surcharge of the existing stormwater drainage system.<br>Refer to Figures 5.1 (Sheet 4), 5.2 (Sheet 2) and 5.3 (Sheet 2) of Appendix R (Technical working paper: Flooding). | Due to the relatively shallow nature of the flow, activities within the confines of the Dickson Avenue construction support site (BL4) would not have an impact on flood behaviour in adjacent commercial and industrial development. |

| Temporary construction support site | Catchment | Threshold of flooding[1] | Site facilities [2] | Spoil management [2] | Tunnel launch and support [2] | Cut and cover structures [2] | Surface earthworks [2] | Description of existing flood behaviour | Potential impacts of construction activities on flood behaviour |
|---|---|---|---|---|---|---|---|---|---|
| **Barton Road (BL5)** | Flat Rock Creek | Less frequent than 1% AEP | ✓ | | | | ✓ | The Barton Road construction support site (BL5) is subject to relatively shallow overland flow during very rare and extreme storm events.<br>Refer to Figures 5.1 (sheet 4), 5.2 (sheet 2) and 5.3 (sheet 2) of Appendix R (Technical working paper: Flooding). | Due to the relatively shallow nature of the flow, activities within the Barton Road construction support site (BL5) would not have an impact on flood behaviour in adjacent residential development. |
| **Gore Hill Freeway median (BL6)** | Flat Rock Creek | Not flooded | ✓ | | | | ✓ | Refer to Figures 5.1 (Sheet 4), 5.2 (Sheet 2) and 5.3 (Sheet 2) of Appendix R (Technical working paper: Flooding).<br>The Gore Hill Freeway median construction support site (BL6) is generally flood free. | Activities within the Gore Hill Freeway median construction support site (BL6) would not have an impact on flood behaviour in adjacent residential development. |
| **Middle Harbour south cofferdam (BL7)** | - | Potentially subject to wave action during elevated water levels in Middle Harbour | | | ✓ | | ✓ | Flooding of the Middle Harbour south cofferdam construction support site (BL7) is principally limited to elevated water levels in Middle Harbour.<br>Wave action due to coincident high winds could exacerbate flooding conditions at the Middle Harbour south cofferdam construction support site (BL7) | Activities within the confines of the Middle Harbour south cofferdam construction support site (BL7) would not have an impact on water levels in Middle Harbour. |

| Temporary construction support site | Catchment | Threshold of flooding[1] | Site facilities [2] | Spoil management [2] | Tunnel launch and support [2] | Cut and cover structures [2] | Surface earthworks [2] | Description of existing flood behaviour | Potential impacts of construction activities on flood behaviour |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | during periods of elevated water levels in Middle Harbour.<br>Refer to Figures 5.1 (sheet 5), 5.2 (sheet 3) and 5.3 (sheet 3) of Appendix R (Technical working paper: Flooding). | |
| **Middle Harbour north cofferdam (BL8)** | - | Potentially subject to wave action during elevated water levels in Middle Harbour | | | ✓ | | ✓ | Flooding of the Middle Harbour north cofferdam (BL8) construction support site is principally limited to elevated water levels in Middle Harbour.<br>Wave action due to coincident high winds could exacerbate flooding conditions at the Middle Harbour north cofferdam construction support site (BL8) during periods of elevated water levels in Middle Harbour.<br>Refer to Figures 5.1 (Sheet 5), 5.2 (Sheet 3) and 5.3 (Sheet 3) of Appendix R (Technical working paper: Flooding). | Activities within the confines of the Middle Harbour north cofferdam construction support site (BL8) would not have an impact on water levels in Middle Harbour. |

| Temporary construction support site | Catchment | Threshold of flooding[1] | Site facilities [2] | Spoil management [2] | Tunnel launch and support [2] | Cut and cover structures [2] | Surface earthworks [2] | Description of existing flood behaviour | Potential impacts of construction activities on flood behaviour |
|---|---|---|---|---|---|---|---|---|---|
| **Spit West Reserve (BL9)** | - | Potentially subject to wave action during elevated water levels in Middle Harbour | ✓ | ✓ | ✓ | | | Flooding of the Spit West Reserve construction support site (BL9) is principally limited to elevated water levels in Middle Harbour.<br>Wave action due to coincident high winds could exacerbate flooding conditions at the Spit West Reserve construction support site (BL9) during periods of elevated water levels in Middle Harbour.<br>Refer to Figures 5.1 (Sheet 5), 5.2 (Sheet 4) and 5.3 (Sheet 4) of Appendix R (Technical working paper: Flooding). | Activities within the confines of the Spit West Reserve construction support site (BL9) would not have an impact on water levels in Middle Harbour. |
| **Balgowlah Golf Course (BL10)** | Burnt Bridge Creek | More frequent than 10% AEP | ✓ | ✓ | ✓ | ✓ | ✓ | The Balgowlah Golf Course construction support site (BL10) is also impacted by major overland flow which discharges through Balgowlah Oval from Sydney Road.<br>Flooding is of a low hazard nature along the major overland flow path which forms in Balgowlah Golf Course. | Activities within the extent of the Balgowlah Golf Course construction support site (BL10) have the potential to impact flooding behaviour along Sydney Road and in adjoining parts of the golf course.<br>Activities external to the Balgowlah Golf Course construction support site (BL10) have the potential to impact flood |

| Temporary construction support site | Catchment | Threshold of flooding[1] | Site facilities [2] | Spoil management [2] | Tunnel launch and support [2] | Cut and cover structures [2] | Surface earthworks [2] | Description of existing flood behaviour | Potential impacts of construction activities on flood behaviour |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Refer to Figures 5.1 (Sheet 6), 5.2 (Sheet 5) and 5.3 (Sheet 5) of Appendix R (Technical working paper: Flooding). | behaviour in existing development that is located immediately upstream of the Burnt Bridge Creek Deviation crossing of Burnt Bridge Creek and along the eastern side of the Balgowlah Golf Course. |
| **Kitchener Street (BL11)** | Burnt Bridge Creek | More frequent than 10% AEP | ✓ | ✓ | | | | The Kitchener Street construction support site (BL11) is located on land which generally lies above peak 1% AEP flood levels. It would be subject to shallow inundation during extreme storm events.<br>Refer to Figures 5.1 (Sheet 6), 5.2 (Sheet 5) and 5.3 (Sheet 5) of Appendix R (Technical working paper: Flooding). | Activities within the extent of the Kitchener Street construction support site (BL11) would have a minimal effect on flood behaviour. |

| Temporary construction support site | Catchment | Threshold of flooding[1] | Site facilities [2] | Spoil management [2] | Tunnel launch and support [2] | Cut and cover structures [2] | Surface earthworks [2] | Description of existing flood behaviour | Potential impacts of construction activities on flood behaviour |
|---|---|---|---|---|---|---|---|---|---|
| **Wakehurst Parkway south (BL12)** | Manly Creek and Bantry Bay | Not flooded | ✓ | ✓ | | ✓ | ✓ | The Wakehurst Parkway south construction support site (BL12) is not subject to flooding.<br>Refer to Figures 5.1 (Sheet 7), 5.2 (Sheet 6) and 5.3 (Sheet 6) of Appendix R (Technical working paper: Flooding). | The provision of hard stand areas within the confines of the Wakehurst Parkway south construction support site (BL12) would increase the runoff potential of the area, which in turn would increase the rate at which flow discharges to the adjacent bushland and golf course. |
| **Wakehurst Parkway east (BL13)** | Bantry Bay | Not flooded | ✓ | ✓ | ✓ | | ✓ | The Wakehurst Parkway east construction support site (BL13) is not subject to flooding.<br>Refer to Figures 5.1 (Sheet 8), 5.2 (Sheet 6) and 5.3 (Sheet 6) of Appendix R (Technical working paper: Flooding). | The provision of hard stand areas within the confines of the Wakehurst Parkway east construction support site (BL13) would increase the runoff potential of the area, which in turn would increase the rate at which flow discharges to the adjacent bushland and golf course. |

| Temporary construction support site | Catchment | Threshold of flooding[1] | Site facilities [2] | Spoil management [2] | Tunnel launch and support [2] | Cut and cover structures [2] | Surface earthworks [2] | Description of existing flood behaviour | Potential impacts of construction activities on flood behaviour |
|---|---|---|---|---|---|---|---|---|---|
| **Wakehurst Parkway north (BL14)** | Manly Creek | Not flooded | ✓ | ✓ | | | ✓ | Refer to Figures 5.1 (Sheet 10), 5.2 (Sheet 6) and 5.3 (Sheet 6) of Appendix R (Technical working paper: Flooding).<br>The Wakehurst Parkway north construction support site (BL14) is not subject to flooding.<br>Refer to Figures 5.1 (Sheet 8), 5.2 (Sheet 6) and 5.3 (Sheet 6) of Appendix R (Technical working paper: Flooding). | The provision of hard stand areas within the confines of the Wakehurst Parkway north construction support site (BL14) would increase the runoff potential of the area, which in turn would increase the rate at which flow discharges to the pavement drainage system of Warringah Road. |

Note 1: The assessed threshold of flooding is based on present day conditions
Note 2: 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. 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 an assessment of the 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.

While the project incorporates measures that are aimed at mitigating the impact that it would have on flood behaviour, there are a number of residual impacts that would need to be investigated during further design development. This section identifies and describes the nature of the residual impacts, while a range of potential measures which are aimed at managing the flood risk and further mitigating the residual impacts of the project on flood behaviour are discussed in Section 18.8.

### 18.6.1 Potential flood risk to the project

#### Tunnel portals

While a series of measures have been incorporated into the design of the project in the vicinity of the tunnel portals for all events up to the PMF, a sensitivity analysis identified that there is the potential for floodwater to enter the tunnel system via the Gore Hill Freeway and Burnt Bridge Deviation portals should the stormwater drainage system experience a partial blockage during an extreme storm event. Further details of the sensitivity analysis and studies to be carried out during further design development are set out in Section 18.6.6.

At all other tunnel locations, the ingress of floodwater would be controlled through a combination of grade changes and standard barrier types. Design of the project also includes upgrades to the existing stormwater drainage to divert local catchment runoff around the proposed tunnel portals.

#### Road and pedestrian bridges

The existing road bridges, upgraded as part of the project, are all high level structures that would only be subject to relatively shallow sheet flow during storms which surcharge the pavement drainage system.

The proposed pedestrian and shared user bridges over the Wakehurst Parkway are high level structures that would not be subject to flooding.

#### Surface road works

##### *Willoughby Creek Catchment*

Major 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 (refer to Figure 6.5 (Sheet 2) 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.

##### *Flat Rock Creek Catchment*

Flooding of the surface road works during storms up to 1% AEP in intensity would occur at the location where both the Gore Hill Freeway westbound off ramp to Epping Road and Pacific Highway, and the Gore Hill Freeway eastbound entry ramp to the Beaches Link tunnel runs under Reserve Road. Depths of ponding across the westbound and eastbound lanes of the Gore Hill

Freeway at these two locations would exceed one metre and 0.6 metres, respectively, during a 1% AEP storm event.

Floodwater which ponds across the Gore Hill Freeway eastbound entry ramp to the Beaches Link tunnel would eventually reach a depth where it would commence to flow in a southerly direction beneath the Reserve Road eastbound on ramp to the Gore Hill Freeway via a new bridge structure, where it would discharge onto the eastbound carriageway of the Lane Cove Tunnel. Flow discharging onto the eastbound carriageway of the Lane Cove Tunnel at this location would discharge in an easterly direction, where it would gradually be intercepted by the proposed pavement drainage system.

#### *Burnt Bridge Creek Catchment*

The surface road works would be subject to relatively shallow sheet flow as a result of flow which surcharges the existing pavement drainage system to the south of the crossing of Burnt Bridge Creek. Greater depths of inundation would be experienced further to the north of the tunnel portals as a result of flow which surcharges both the existing and proposed stormwater drainage system. Floodwater would also discharge onto Burnt Bridge Creek Deviation at the location of the Burnt Bridge Creek crossing during storms that are more intense than about 0.2% AEP.

It is noted the Burnt Bridge Creek Deviation is subject to flooding immediately to the north of the project as a result of floodwater which surcharges Burnt Bridge Creek during storms that are more frequent than 1% AEP.

#### *Trefoil Creek, Manly Creek and Bantry Bay Catchments*

Inundation of the Wakehurst Parkway during storms up to 1% AEP would be limited to flow which surcharges the new pavement drainage system given the road generally follows the natural divide between the Manly Creek and Bantry Bay catchments.

### Tunnel support facilities

Tunnel support facilities are to be constructed as part of the project at Waltham Street, Artarmon and the Wakehurst Parkway, Frenchs Forest, with finished ground levels raised above the level of the PMF.

### Motorway control centre

The proposed motorway control centre at the Gore Hill Freeway, Artarmon in the Flat Rock Creek catchment is located on land which generally lies above the level of the PMF. Provision would be 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 discussed in the subsections below, and shown in Figure 18-9 to Figure 18-14. Changes in flood depth as a result of the project, in the 1% AEP event are shown in Figure 18-15 to Figure 18-20. Appendix R (Technical working paper: Flooding) provides discussion regarding the project's effect on flood behaviour for storm events more intense than 1% AEP. 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.

The proposed upgrade of the Wakehurst Parkway is located in the upper reaches of the Trefoil Creek, Manly Creek and Bantry Bay catchments. Due to the minor nature of the receiving drainage lines which control runoff from the road corridor, combined with the available LiDAR survey data, the assessment for these catchments was limited to a comparative peak flow analysis, the results of which were used to identify where the project has the potential to increase the rate of flow and hence scour potential in the affected drainage lines. For this reason, flood mapping is not provided

for these areas. Refer to Appendix R (Technical working paper: Flooding) for further details on assessment methodology.

Given the minor impact that the project would have on flood behaviour under operational conditions, it is not expected that changes in flooding patterns would result in significant change to the social and economic costs of flooding.

### External to the road corridor

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:

- Along the main arm of Burnt Bridge Creek downstream of the Kitchener Street bridge where peak 10% AEP flood levels would be increased at six residential properties in the range 10-50 millimetres
- While peak flows could potentially be increased in a number of the receiving drainage lines which run west toward Bantry Bay, there is no existing development that would be impacted by the change in flow regime
- While peak flows could potentially be increased in a number of the receiving drainage lines which run east toward the main arm of Manly Creek, there is no existing development other than the Wakehurst Golf Course that would be impacted by the change in flow regime. Increases in the rate and volume of runoff discharging to the receiving drainage lines that run through the Wakehurst Golf Course have the potential to cause prolonged inundation of parts of the golf course during periods of heavy rain
- Increases in the rate of runoff has the potential to increase the frequency of surcharge of the existing stormwater drainage system which runs across Aquatic Drive and under Aquatic Reserve, thereby increasing the frequency and depth of overland flow that is experienced across the road and in the reserve during periods of heavy rain.

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 have the following impacts on flow velocities and the duration of inundation external to the road corridor for storms up to 1% AEP:

- Maximum flow velocities would be increased along the main arm of Flat Rock Creek downstream of the T1 North Shore and Western Line and T9 Northern Line crossing, where maximum flow velocities would be increased by a maximum of about 0.1 metres per second
- The extension of the existing transverse drainage structure under Burnt Bridge Creek Deviation in combination with minor works within the main channel of the watercourse immediately downstream of the road crossing has the potential to increase flow velocities by up to one metre per second. The duration of inundation along the main arm of Burnt Bridge Creek Deviation would be reduced slightly when compared to present day conditions. It is noted that changes in landform in this area would also alter the nature of flows
- The concentration of flow at discrete locations along the widened section of the Wakehurst Parkway has the potential to increase peak flows, and hence flow velocities and the duration of inundation, in a number of receiving drainage lines which run to the east of the road corridor. Conversely, in a number of different receiving drainage lines which run to the east of the road corridor, the upgrade of the Wakehurst Parkway also has the potential to decrease peak flows.

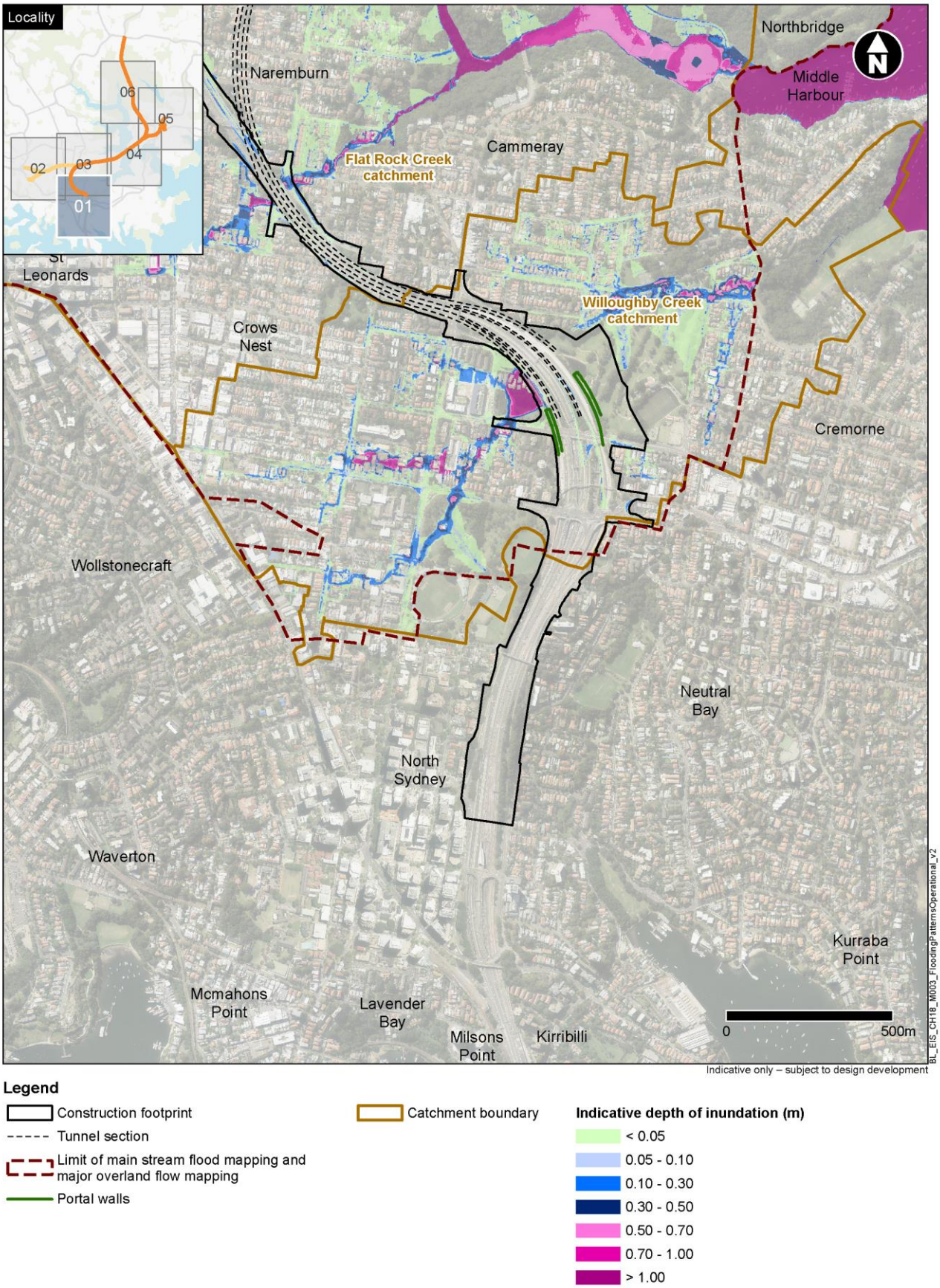


**Figure 18-9 Flood behaviour under operational conditions – 1% AEP event (map 1)**

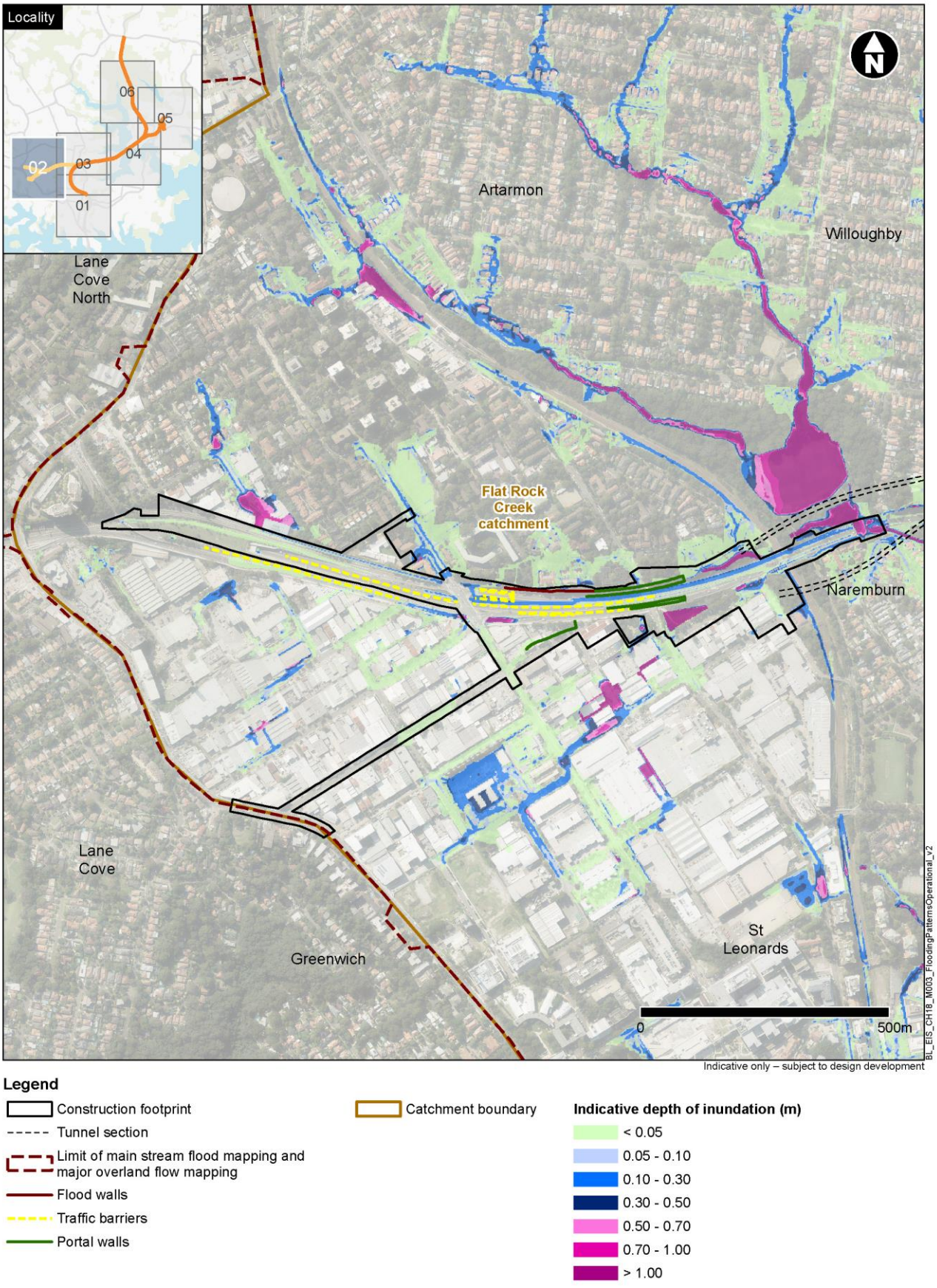


**Figure 18-10 Flood behaviour under operational conditions – 1% AEP event (map 2)**

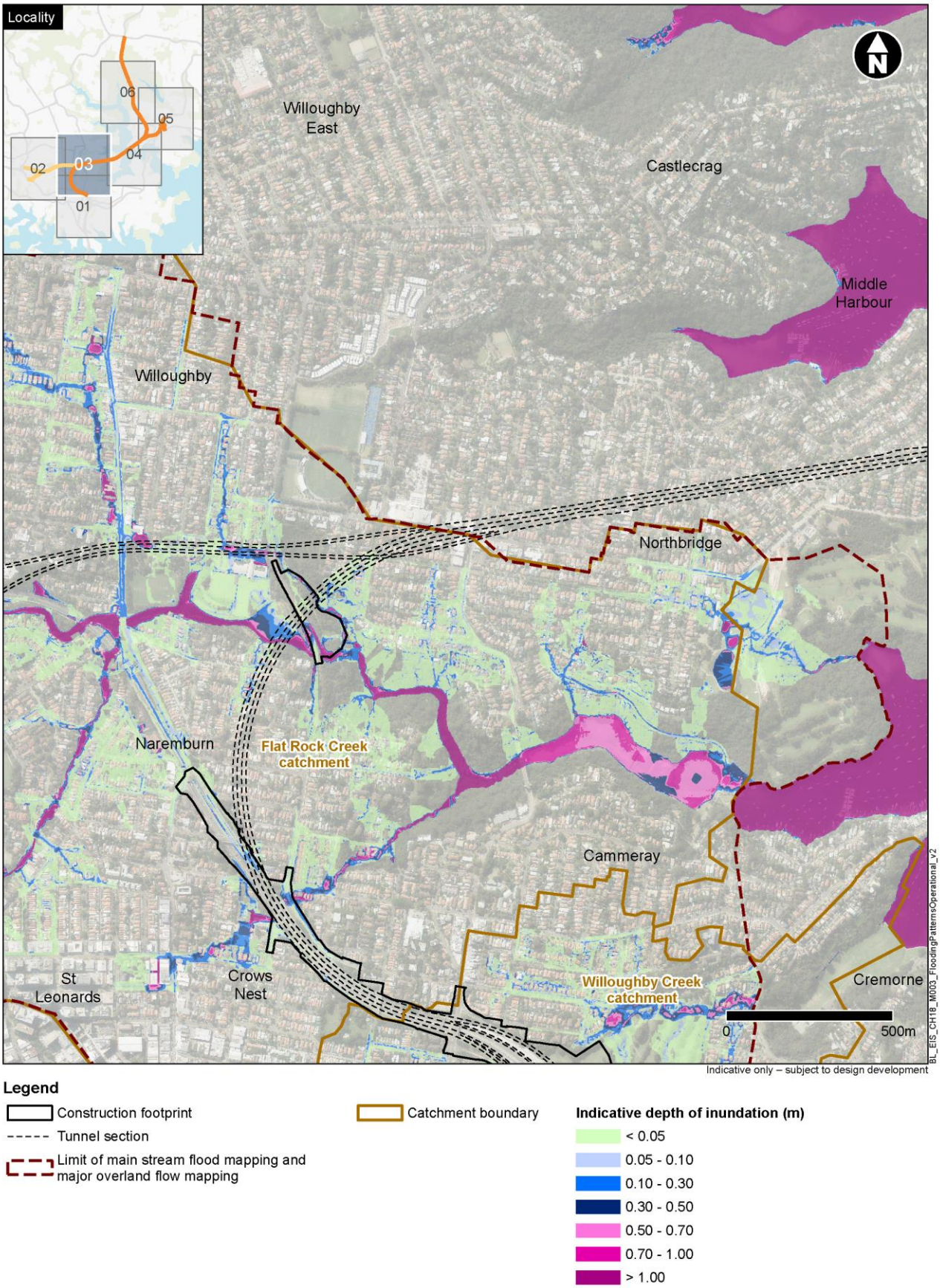


**Figure 18-11 Flood behaviour under operational conditions – 1% AEP event (map 3)**

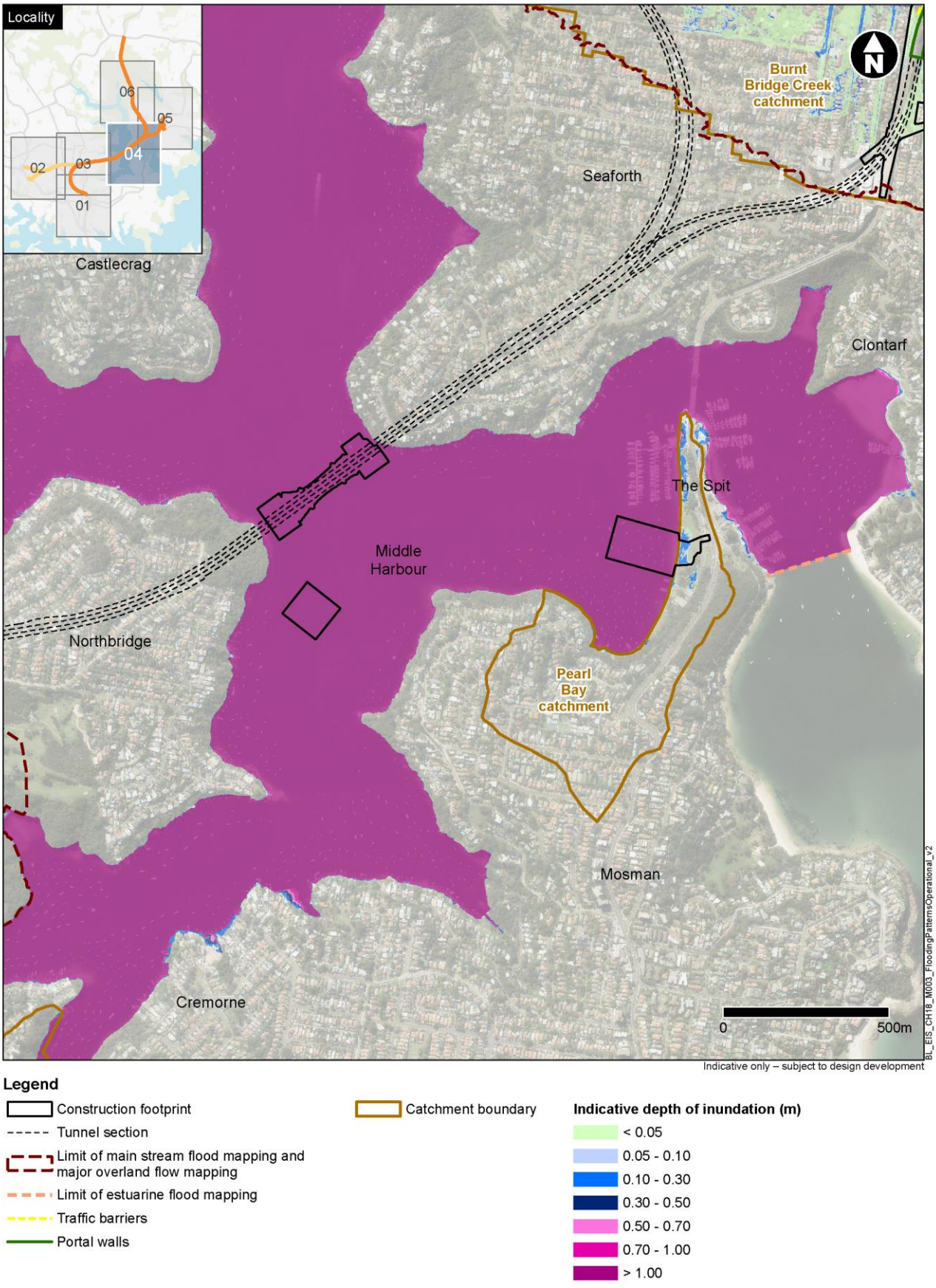


**Figure 18-12 Flood behaviour under operational conditions – 1% AEP event (map 4)**

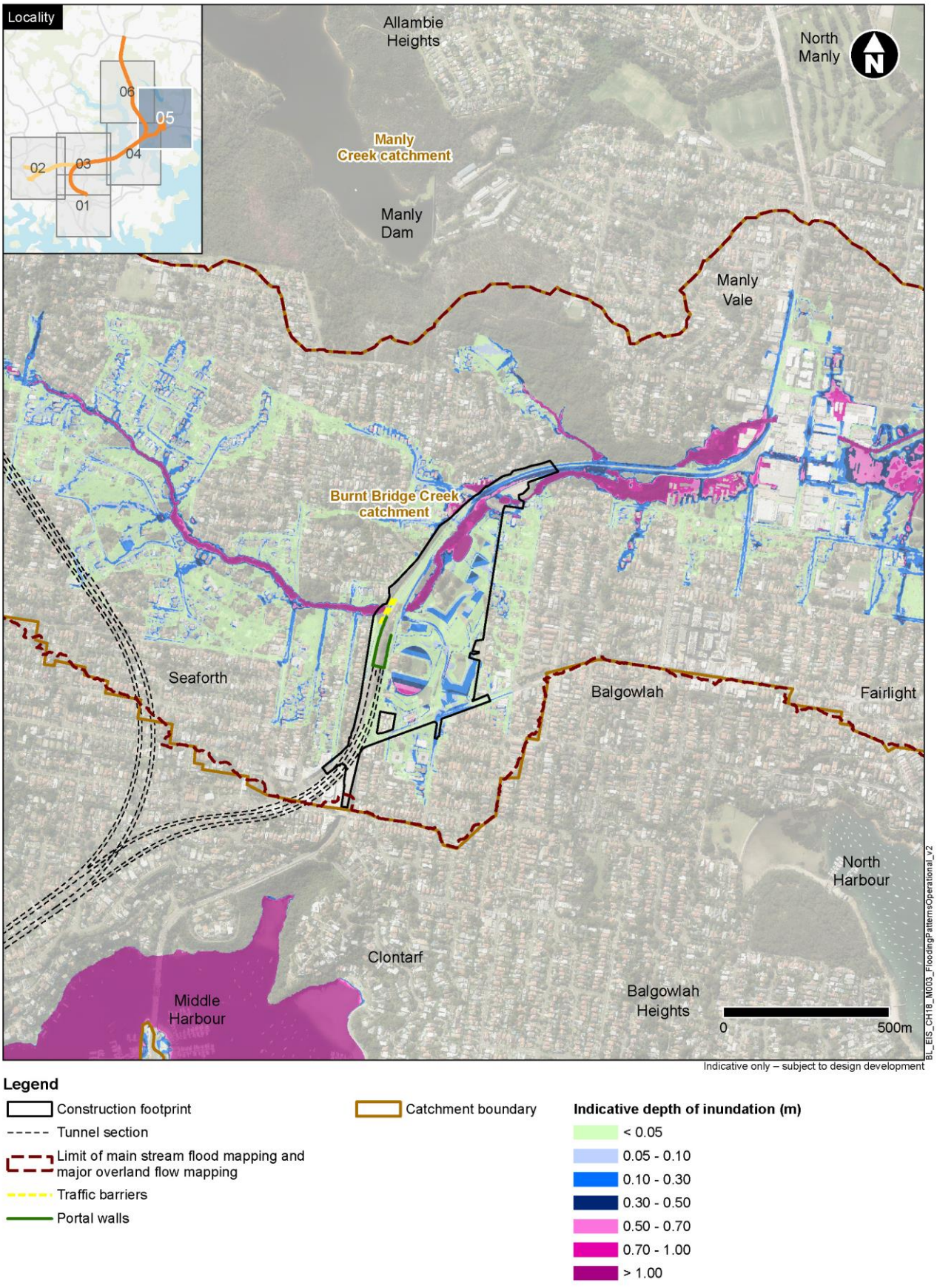


**Figure 18-13 Flood behaviour under operational conditions – 1% AEP event (map 5)**

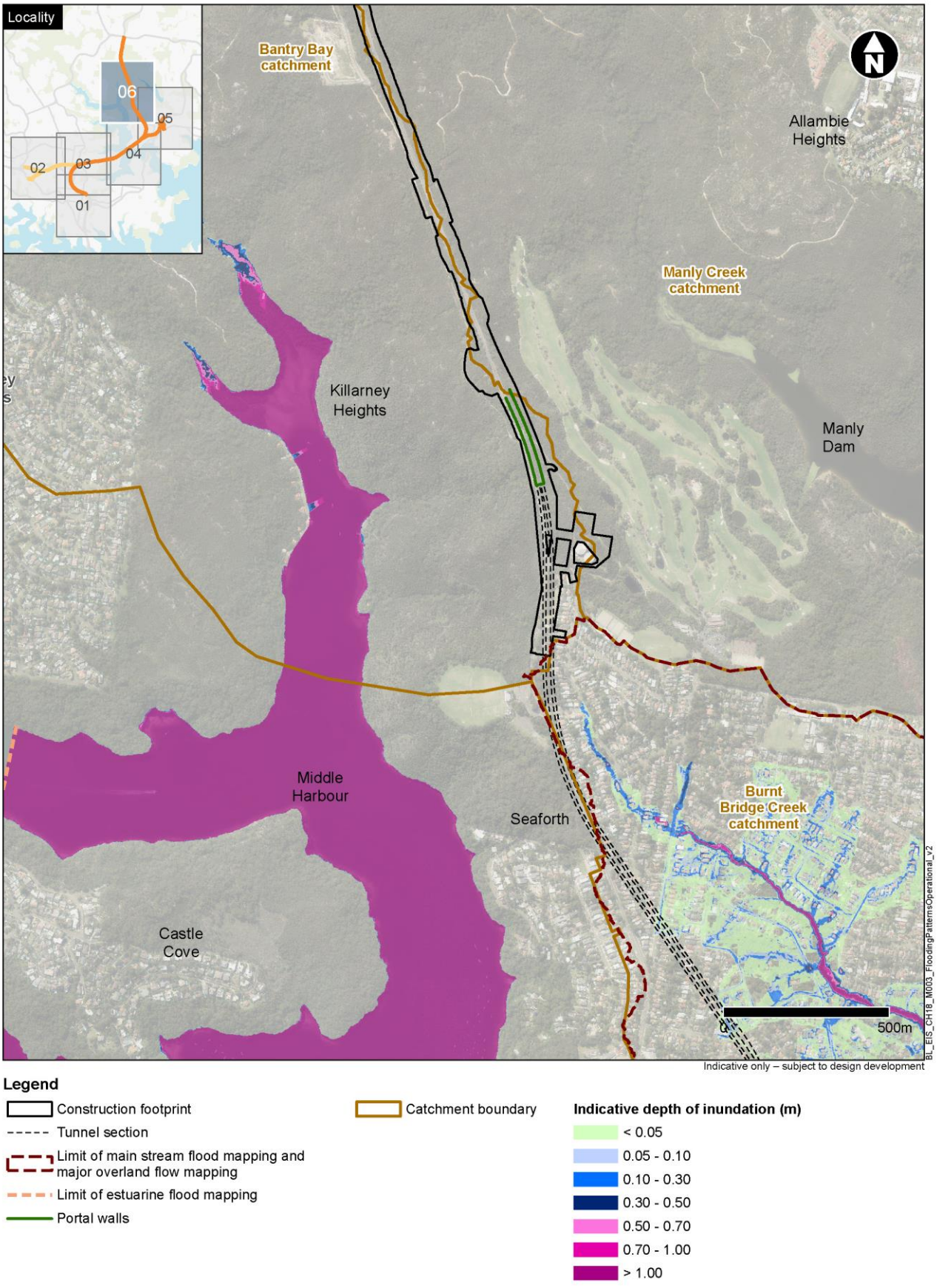


**Figure 18-14 Flood behaviour under operational conditions – 1% AEP event (map 6)**

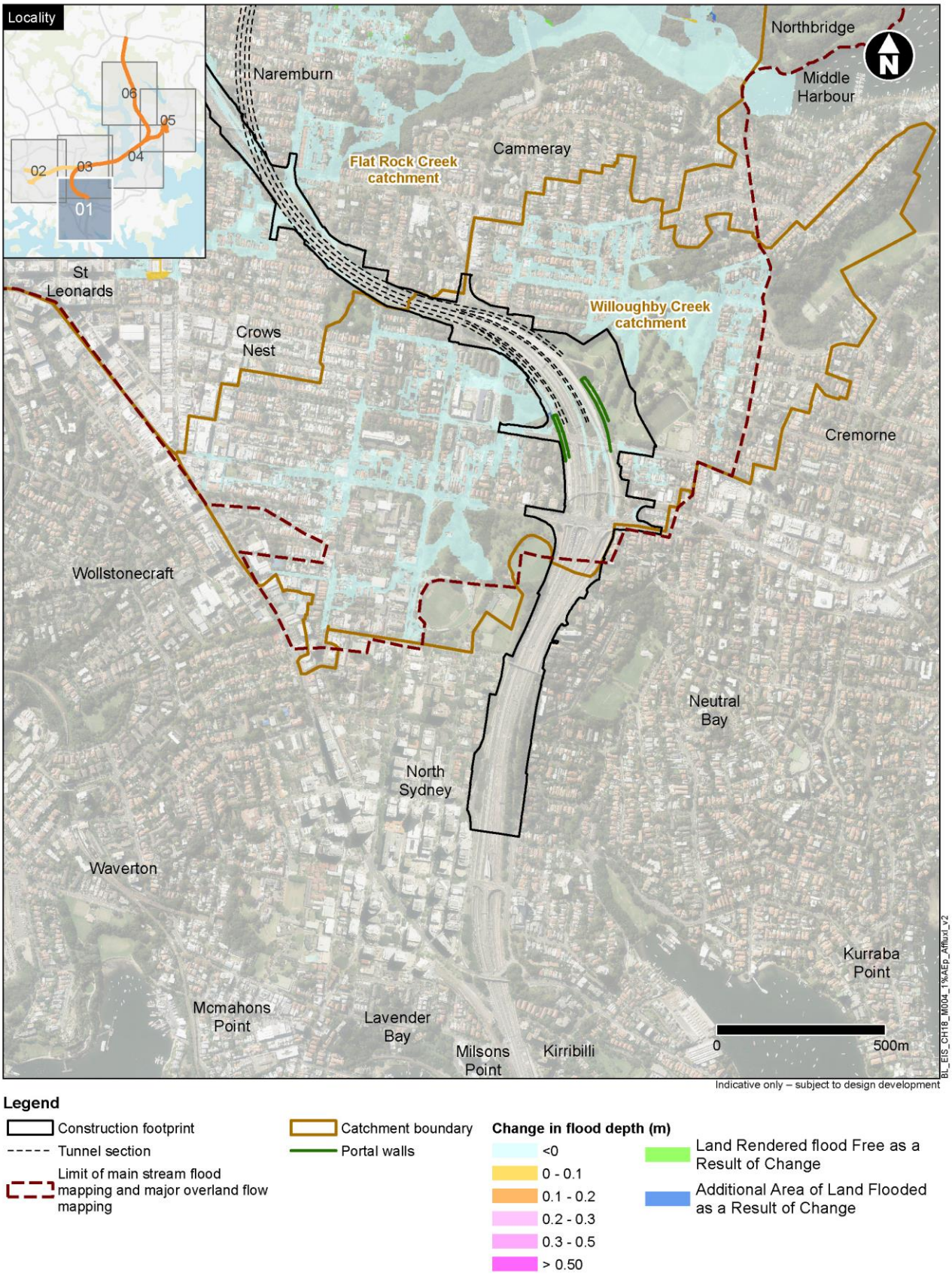


**Figure 18-15 Change in flood depth under operational conditions – 1% AEP event (map 1)**

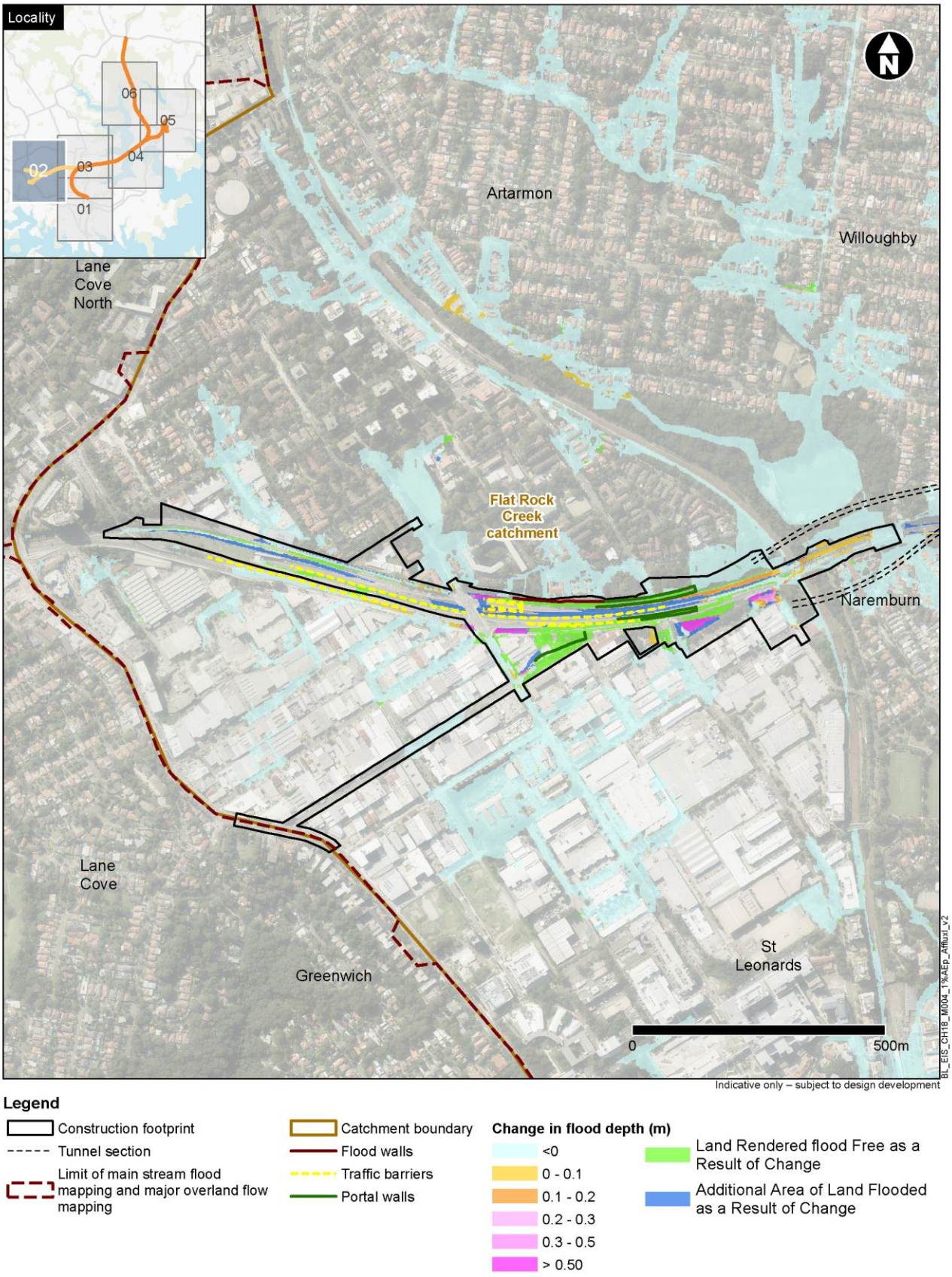


**Figure 18-16 Change in flood depth under operational conditions – 1% AEP event (map 2)**

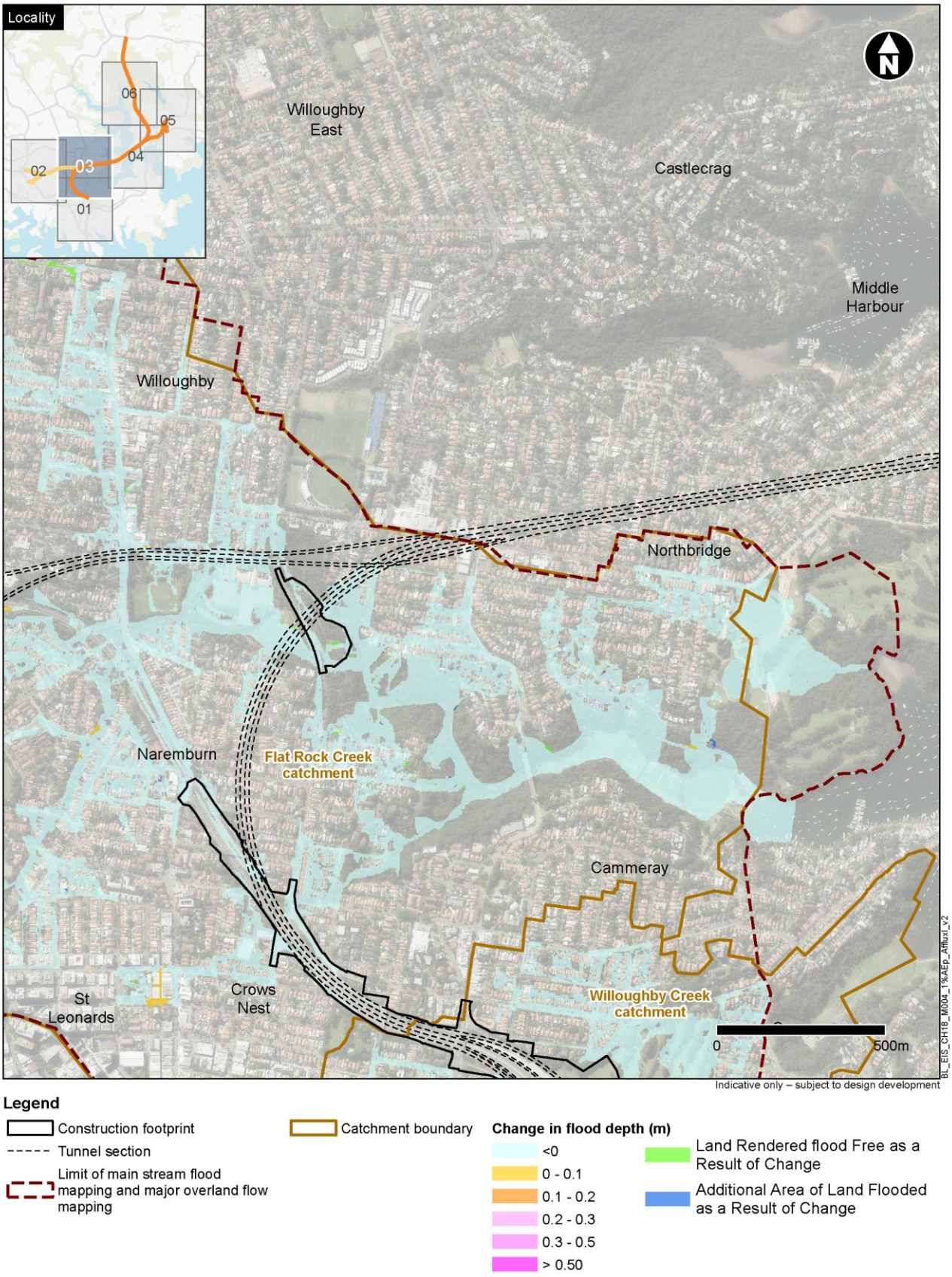


**Figure 18-17 Change in flood depth under operational conditions – 1% AEP event (map 3)**

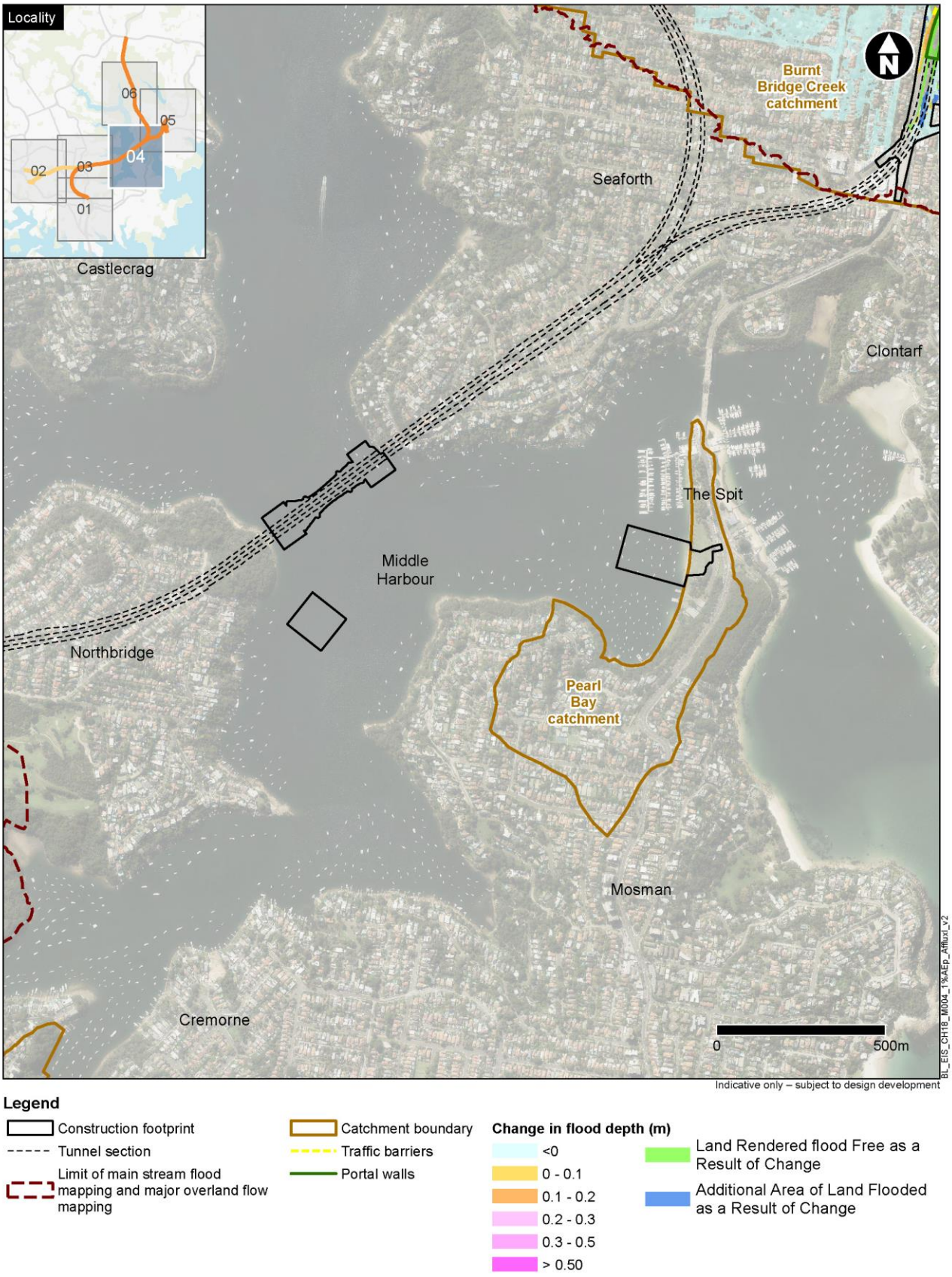


**Figure 18-18 Change in flood depth under operational conditions – 1% AEP event (map 4)**

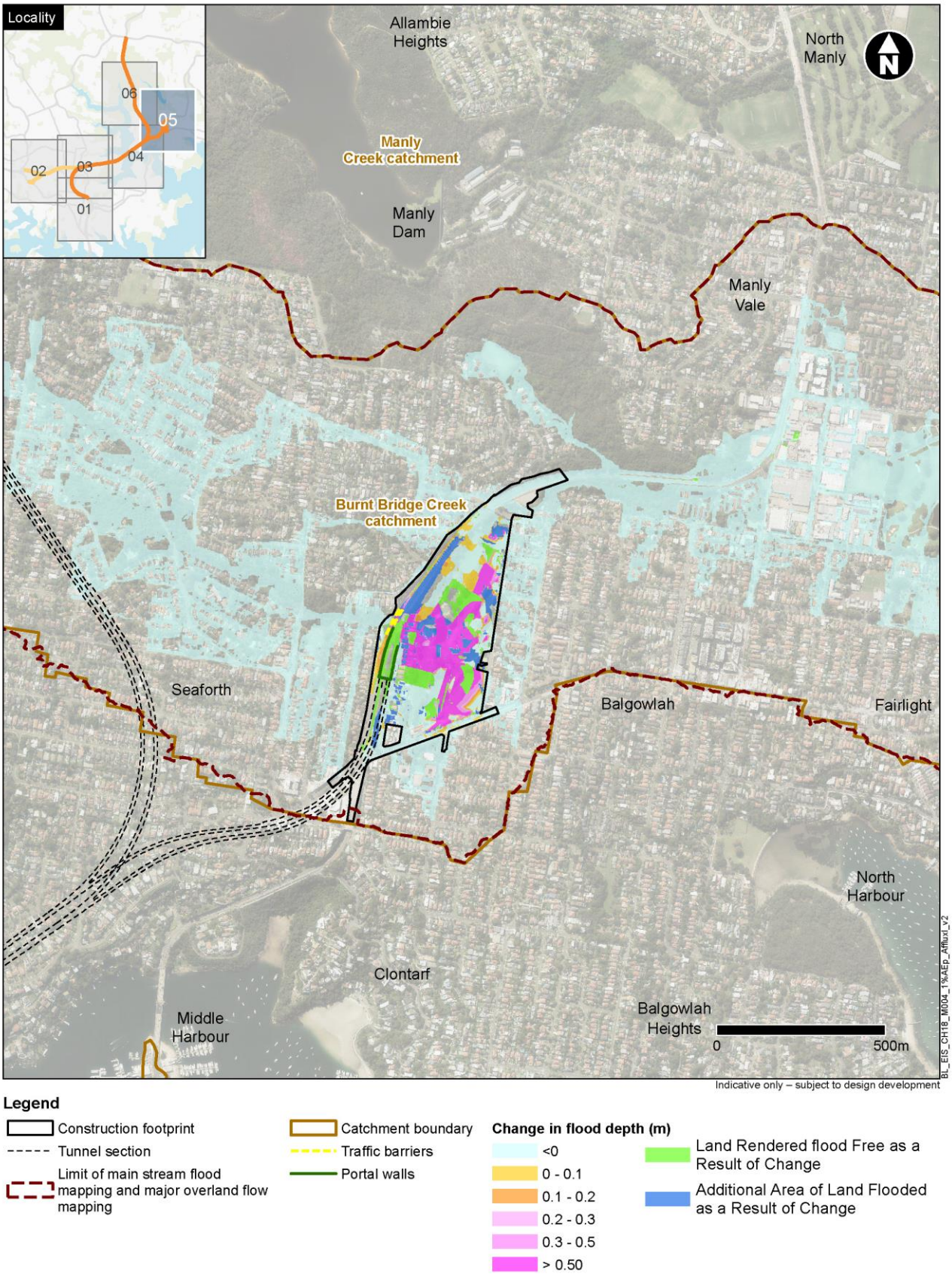


**Figure 18-19 Change in flood depth under operational conditions – 1% AEP event (map 5)**

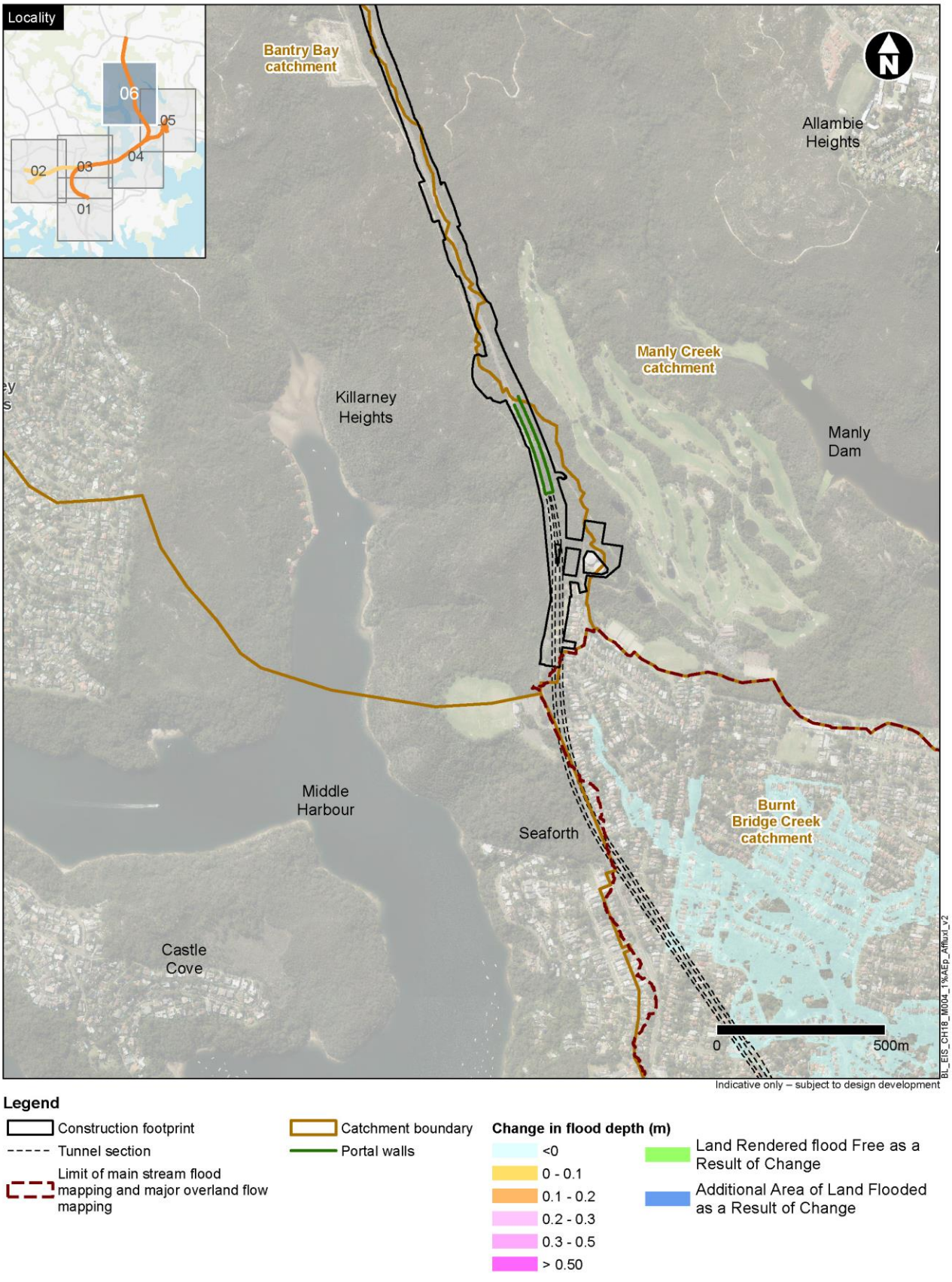


**Figure 18-20 Change in flood depth under operational conditions – 1% AEP event (map 6)**

### Internal to the road corridor

Internal to the road corridor, the project would exacerbate flooding conditions during storms up to 1% AEP in intensity at the following locations:

- Flat Rock Creek Catchment:
  - At the location of a newly formed sag which would be located beneath the Reserve Road overpass on the Gore Hill Freeway westbound off ramp to Epping Road and the Pacific Highway. During a 1% AEP storm event, floodwater would pond across the two lane carriageway to a maximum depth of about 1.6 metres
  - At the location of a newly formed sag which would be located beneath the Reserve Road overpass on the Gore Hill Freeway eastbound on ramp to the Beaches Link tunnel. During a 1% AEP storm event, floodwater would pond across the two lane carriageway to a maximum depth of about 0.6 metres
  - Along the eastbound lanes of the Lane Cove Tunnel and Gore Hill Freeway carriageways extending from the Reserve Road interchange to a location east of the T1 North Shore and Western Line and T9 Northern Line overpass. Depths of flow along the two carriageways would be a maximum of about 300 millimetres in a 1% AEP storm event
- Burnt Bridge Creek Catchment:
  - While the flood modelling carried out as part of this study indicates that the depth of flow in the road corridor would be increased as part of the project, improvements to the existing pavement drainage system, the features of which were not incorporated in the flood models, would be aimed at controlling runoff under post-upgrade conditions.

Internal to the road corridor flow velocities and durations of inundation would generally be increased in the areas where increases in the depth and extent of inundation would be increased.

## 18.6.3 Potential impacts of the project on scour potential

The project has the potential to cause scouring in Burnt Bridge Creek, as well as the receiving drainage lines that are located along the Wakehurst Parkway due to the following:

- Increases in the rate of flow (and hence the depth and velocity of flow) associated with:
  - The enlargement of transverse drainage structures
  - The discharge of runoff from the widened carriageway
  - Changes in the distribution of flow along the project corridor
- Increases in the velocity of flow where it discharges from pipe outlets or newly lined sections of channel
- The concentration of flow resulting from the formalisation of the drainage system within the project corridor.

Increases in the rate of flow in the receiving drainage lines could result in a lowering of the stream bed through a process of headwater erosion, as well as a possible widening of the watercourse through a process of bank erosion. The lining of channels and the concentration of flow could also result in localised scour in the receiving drainage lines at the downstream limit of the drainage works.

Scour of Burnt Bridge Creek and the receiving drainage lines that are located along the Wakehurst Parkway has the potential to increase the turbidity of flow discharging to Bantry Bay and Manly Dam and to a lesser extent, Manly Lagoon.

### 18.6.4 Consistency with state government and local council flood plans and policies

The Warringah Local Environmental Plan 2011, the Manly Local Environmental Plan 2013 and the Willoughby Local Environmental Plan 2012 each contain flood planning clauses that apply to land at or below the Flood Planning Level, which is defined in all documents as equal to the peak 1% AEP flood level plus 0.5 metres. It is noted that both the North Sydney Local Environmental Plan 2013 and the Mosman Local Environmental Plan 2012 do not include a definition of the Flood Planning Level.

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 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 Manly Local Environmental Plan 2013, Warringah Local Environmental Plan 2011 and Willoughby Local Environmental Plan 2012 would apply. While North Sydney Local Environmental Plan 2013 and Mosman Local Environmental Plan 2012 do not contain a definition of the flood planning level, the project would have no significant impact on the extent of the flood planning area were the two councils to adopt the same definition as set out in clause 6.3 of Manly Local Environmental Plan 2013, Warringah Local Environmental Plan 2013 and Willoughby Local Environmental Plan 2012.

While a floodplain risk management study and plan has only been prepared for the Manly Creek catchment, the findings of the assessment (Section 18.6.2) show that the project would have only a minor impact on peak flood levels external to the road corridor.

NSW State Emergency Service maintains two local units located on Station Street, Naremburn and Quirk Road, Balgowlah, both of which are located outside the project footprint and would not be affected by the project related flood impacts. Provided the flood mitigation measures set out in Section 18.8 are incorporated into the design of the project, the project would not increase the flood hazard in existing development for all events up to the 1% AEP event. The project would not have an adverse impact on NSW State Emergency Service's emergency response arrangements.

### 18.6.5 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 are summarised below.

### *Willoughby Creek Catchment*

- While depth of ponding would be increased in ANZAC Park, it would not be deep enough to overtop the continuous concrete noise wall which runs along its northern side
- As a series of measures have been incorporated into the design of the project to prevent the ingress of floodwater to the tunnel portals for events up to the PMF, increases in peak flood levels associated with future climate change would not increase the flood risk to the project
- As the motorway facilities and ventilation outlet at the Warringah Freeway would be designed to prevent the ingress of floodwater to the tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

### *Flat Rock Creek Catchment*

- The rate at which flow approaches the Gore Hill Freeway from the urbanised catchments which lie to its north and south would increase, resulting in an increase in the depth of flow along several of its lanes
- As the operational facilities and ancillary infrastructure at the Gore Hill Freeway would be designed to prevent the ingress of floodwater to the building during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project
- As a series of measures have been incorporated into the design of the project that would prevent the ingress of floodwater to the tunnel portals for events up to the PMF, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

### *Burnt Bridge Creek Catchment*

- Floodwater would surcharge the existing transverse drainage structure on Burnt Bridge Creek during storms that are more intense than about 0.2% AEP
- As a series of measures have been incorporated into the design of the project that would prevent the ingress of floodwater to the tunnel portals for events up to the PMF, increases in peak flood levels associated with future climate change would not increase the flood risk to the project
- As the motorway facilities and ventilation outlet at the Burnt Bridge Creek Deviation would be designed to prevent the ingress of floodwater to the tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

### *Bantry Bay Catchment*

- As a series of measures have been incorporated into the design of the project that would prevent the ingress of floodwater to the tunnel portals for events up to the PMF, increases in peak flood levels associated with future climate change would not increase the flood risk to the project
- As the motorway facilities and ventilation outlet at the Wakehurst Parkway would be designed to prevent the ingress of floodwater to the tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

### *Manly Creek Catchment*

- Surcharge of the new pavement and transverse drainage could occur as a result of an increase in rainfall intensities. As the project generally runs along the catchment divide, surcharge of the proposed drainage is unlikely to result in an increase in the flood risk to road users
- As the operational facilities and ancillary infrastructure at Frenchs Forest and Killarney Heights at the Wakehurst Parkway would be designed to prevent the ingress of floodwater to the

tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

#### *Trefoil Creek Catchment*

- Surcharge of the new pavement drainage could occur as a result of an increase in rainfall intensities. As the project is located on the catchment divide, surcharge of the proposed drainage is unlikely to result in an increase in the flood risk to road users.

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

While 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 assessed climate change scenarios, it would increase peak post-climate change 1% AEP flood levels, as described below.

Increases in sea level were not included in the assessment of climate change impacts on the basis that the surface works associated with the project operation are located above Reduced Level (RL) 10 metres Australian Height Datum (AHD) and are therefore well above areas that would be impacted by an increase in sea level due to climate change.

#### *Burnt Bridge Creek Catchment*

- Immediately upstream of the Burnt Bridge Creek Deviation crossing of Burnt Bridge Creek, peak post-climate change 1% AEP flood levels could be increased by up to 250 millimetres, with the impacts extending into eleven residential properties located on either side of the watercourse
- Immediately downstream of the Burnt Bridge Creek Deviation crossing of Burnt Bridge Creek, peak post-climate change 1% AEP flood levels could be increased by up to 200 millimetres, noting that no existing or future development would be impacted as a result of these changes.

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

The mechanism and geometrical 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 the flooding impact 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 C.1) of Appendix R (Technical working paper: Flooding) shows the impact a partial blockage of the local stormwater drainage system and the extended culverts under the Burnt Bridge Creek Deviation would have on peak 1% AEP flood levels in the vicinity of the proposed tunnel portals, bridges and surface road works. The key findings of the assessment are outlined below.

While the tunnel system would not be impacted by flooding should the existing stormwater drainage system experience a partial blockage during storms up to 1% AEP in intensity, there is the potential for floodwater to enter the tunnels should a partial blockage occur during more extreme storm events. For example, a partial blockage of the stormwater drainage system during a PMF event would result in flow discharging to the tunnel system at the location of the Gore Hill Freeway connection, while floodwater would commence to enter the tunnels via the Burnt Bridge Creek Deviation tunnel portals. During further design development, a risk assessment would be carried out to assess the flood risk in the tunnel system should the stormwater drainage system experience a partial blockage during storms that are more intense than 1% AEP.

### Willoughby Creek Catchment

- While peak 1% AEP flood levels would be increased by about 1.5 metres in ANZAC Park, they would not be high enough to overtop the proposed flood walls which would border the proposed tunnel portals.

### Flat Rock Creek Catchment

- While peak 1% AEP flood levels would be increased in the road corridor, they would not be high enough to cause floodwater to enter the proposed tunnel portals.

### Burnt Bridge Creek Catchment

- Flow would surcharge the existing Burnt Bridge Creek transverse drainage structure on Burnt Bridge Creek Deviation, where it would discharge across both the northbound and southbound lanes before re-entering the creek on the eastern (downstream) side of the road corridor
- There would be a minor increase in the depth of overland flow discharging north along the access road.

### Bantry Bay Catchment

- A partial blockage of the new pavement drainage system would result in the minor inundation of the Wakehurst Parkway at the major sag in the road which is located a short distance to the north of the tunnel portals. For example, flow would pond across the road until it reached the height of the adjacent footpath before discharging into the adjacent bushland.

### Manly Creek Catchment

- A partial blockage of the new pavement drainage system would result in the minor inundation of the Wakehurst Parkway at the location of the two major sags in the road. For example, flow would pond across the road at these two locations until it reached the height of the adjacent footpath before discharging into the adjacent bushland
- A partial blockage of the transverse drainage may result in floodwater discharging onto the surface of the Wakehurst Parkway where it would pond at the location of the two major sags in the road. In this instance, flow would pond across the road until it reached the height of the adjacent footpath before discharging into the adjacent bushland.

Refer to Table 6.1 and 6.2 of Appendix R (Technical working paper: Flooding) for further details on the assessment findings outlined above.

## 18.6.7 Application of Australian Rainfall and Runoff 2019 to design flood estimation

The ARR 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 that relate to the Willoughby Creek, Bantry Bay and Manly Creek (upper reaches only) catchments, and both them and the hydraulic model in the case of the Willoughby Creek catchment 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 the area.

Based on the above finding, it was concluded that 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 nearby projects. 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

#### Western Harbour Tunnel and Warringah Freeway Upgrade

The flood impact assessment set out in this technical working paper assumes that the Western Harbour Tunnel and Warringah Freeway Upgrade project forms part of baseline (ie pre-project) flooding conditions (ie it assumes that construction of the Western Harbour Tunnel and Warringah Freeway Upgrade project precedes that of the project).

While the present investigation found that the project would not exacerbate flooding conditions in existing development located in the Willoughby Creek catchment, a similar investigation found that the Western Harbour Tunnel and Warringah Freeway Upgrade project would increase peak 1% AEP flood levels by up to 16 millimetres in nine residential properties located along Cammeray Road, Park Avenue, Fall Street and Grafton Street in Cammeray.

### 18.7.2 Other projects

There are no other proposed non-motorway 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 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 - flooding**

| Reference | Phase | Impact | Environmental management measure | Location |
|---|---|---|---|---|
| **F1** | Design | Impact of the project on flood behaviour | Where flood levels in the 1% AEP event are predicted to increase at any residential, commercial and/or industrial buildings as a result of operation of the project, a floor level survey will be carried out.<br>If the survey indicates existing buildings would experience above floor inundation during a 1% AEP event as a result of the project, further refinements will be made (as required) to the design of permanent project components to minimise the potential for impacts. | BL/GHF |
| **F2** | Design | Operational flooding impacts | Impact of the project on flood behaviour during 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. | BL/GHF |
| **F3** | Design | Impact of flooding on the project | Flood emergency management measures for construction and operation of the project will be prepared in consultation with State Emergency Services and relevant councils and incorporated into relevant environmental and/or safety management documentation. | BL/GHF |
| **F4** | Design | Impact of the project on scour potential | Measures will be assessed during further design development which are aimed at reducing as far as is practical the risk of increased scour in the receiving drainage lines that are located along the Wakehurst Parkway. Scour countermeasures will also be provided at the outlet of new or upgraded transverse and longitudinal drainage lines. | BL/GHF |

| Reference | Phase | Impact | Environmental management measure | Location |
|---|---|---|---|---|
| **F5** | Design and construction | Impacts of construction sites on flood behaviour | Detailed construction planning will consider flood risk at construction sites and construction support sites. This will include:<br>• A review of site layout and staging of construction activities to avoid or minimise obstruction of overland flow paths and limit the extent of flow diversion required<br>• Identification of measures to not worsen flood impacts on the community and on other property and infrastructure during construction up to and including the 1% AEP flood event where reasonable and feasible<br>• Measures to mitigate alterations to local runoff conditions due to construction activities. | BL/GHF |
| **F6** | 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. | BL/GHF |
| **F7** | Construction | Flooding impacts to tunnel excavation | 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 the project works. | BL/GHF |
| **F8** | 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 10% 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 it would impact flooding conditions in adjacent development. | BL/GHF |
| **F9** | Operation | Flood impacts to construction sites | Site facilities will be located outside high flood hazard areas based on a 1% AEP flood. | BL/GHF |

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection