WATER QUALITY, FLOODING AND STORMWATER REPORT

APPENDIX T

Sydney Metro City & South West: Waterloo Over Station Development

Water Quality, Flooding and Stormwater Report

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1.0 Introduction

1.1 Purpose of this report

This report accompanies a concept State Significant Development Application (concept SSD Application) submitted to the Department of Planning and Environment (DPE) pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The concept SSD Application is made under Section 4.22 of the EP&A Act.

This report should be read in conjunction with the Nominated State Significant Precinct (SSP) Study – Waterloo, submitted to the Minister for Planning (The Minister) in July 2018. That study proposes new planning controls to facilitate the development proposed.

Sydney Metro is seeking to secure concept approval for over station development (OSD) above and adjacent to Waterloo Station comprising a podium and three taller buildings which include commercial, residential, and community land uses. The concept SSD Application seeks consent for a building envelope and use for residential, retail, commercial, entertainment, community and recreational purposes, maximum building height, maximum gross floor area (GFA), pedestrian and vehicular access, circulation arrangements and associated car parking and the strategies and design parameters for the future detailed design of development.

Sydney Metro proposes to procure the construction of the OSD as part of an integrated station development package, which would result in the combined delivery of the station, OSD and public domain improvements. The station and its public domain elements form part of a separate planning approval for Critical State Significant Infrastructure (CSSI) approved by DPE on 9 January 2017.

As the development is within a rail corridor, is associated with railway infrastructure and is for "commercial premises or residential accommodation" with a Capital Investment Value of more than $30 million, the project is identified as State Significant Development (SSD) pursuant to Schedule 1, 19(2)(a) of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP).

This report has been prepared to outline the Water Quality, Flooding and Stormwater impacts and specifically respond to the Secretary's Environmental Assessment Requirements (SEARs) issued for the concept SSD Application on 29th June 2018 which states that the Environmental Impact Statement (EIS) is to address the following requirements:

Reference	SEARs Requirement	Where Addressed in Report
14. Flooding and Stormwater The EIS shall:		
	• *undertake a concept flood study and flood management plan to inform a detailed flood impact assessment in accordance with the NSW Floodplain Development Manual (2005) and demonstrate consideration of the Alexandra Canal Floodplain Risk Management Study and other existing flood studies for the catchment area.*	Section 3.0; Section 4.1.3; Section 4.6; Section 4.8.5;and Section 4.9.1
	• *identify minimum floor levels for buildings and recommend flood management and/or evacuation plan as relevant to the concept proposal.*	Section 4.7; Section 4.8 Section 4.10; Section 5.0; and Section 5.3
	• *include a stormwater management strategy which must consider the relevant local council stormwater management policy and Water Sensitive Urban Design Principles.*	Section 4.5; Section 4.6; and Section 4.7

1.2 Overview of the Sydney Metro in its context

Sydney Metro is Australia's biggest public transport project. A new standalone metro railway system, this 21st century network will deliver 31 metro stations and 66km of new metro rail for Australia's biggest city — revolutionising the way Sydney travels. Services start in the first half of 2019 on Australia's first fully-automated railway.

Sydney Metro was identified in *Sydney's Rail Future*, as an integral component of the *NSW Long Term Transport Master Plan*, a plan to transform and modernise Sydney's rail network so it can grow with the city's population and meet the future needs of customers. In early 2018, *the Future Transport Strategy 2056* was released as an update to *the NSW Long Term Transport Master Plan* and *Sydney's Rail Future*. Sydney Metro City & Southwest is identified as a committed initiative in the *Future Transport Strategy 2056*.

Sydney Metro is comprised of three projects (refer to Figure 1):

Sydney Metro Northwest — formerly the 36km North West Rail Link. This $8.3 billion project is now under construction and will open in the first half of 2019 with a metro train every four minutes in the peak.

Sydney Metro City & Southwest — a new 30km metro line extending the new metro network from the end of Sydney Metro Northwest at Chatswood, under Sydney Harbour, through the CBD and south west to Bankstown. It is due to open in 2024 with an ultimate capacity to run a metro train every two minutes each way through the centre of Sydney.

Sydney Metro West – a new underground railway connecting the Parramatta and Sydney central business districts. This once-in-a-century infrastructure investment will double the rail capacity of the Parramatta to Sydney CBD corridor and will establish future capacity for Sydney's fast growing west. Sydney Metro West will serve five key precincts at Westmead, Parramatta, Sydney Olympic Park, The Bays and the Sydney CBD. The project will also

provide an interchange with the T1 Northern Line to allow faster connections for customers from the Central Coast and Sydney's north to Parramatta and the Sydney CBD.

Sydney's new metro, together with signalling and infrastructure upgrades across the existing Sydney suburban rail network, will increase the capacity of train services entering the Sydney CBD – from about 120 an hour currently to up to 200 services beyond 2024. That's an increase of up to 60 per cent capacity across the network to meet demand.

Figure 1: Sydney Metro alignment map

Sydney Metro City & Southwest includes the construction and operation of a new metro rail line from Chatswood, under Sydney Harbour through Sydney's CBD to Sydenham and on to Bankstown through the conversion of the existing line to metro standards.

The project also involves the delivery of six (6) new metro stations, including at Waterloo, together with new underground platforms at Central. Once completed, Sydney Metro will have the ultimate capacity for a train every two minutes through the CBD in each direction - a level of service never seen before in Sydney.

On 9 January 2017, the Minister approved the Sydney Metro City & Southwest - Chatswood to Sydenham application lodged by TfNSW as a CSSI project (reference SSI 15_7400).

The CSSI Approval includes all physical work required to construct the CSSI, including the demolition of existing buildings and structures on each site. Importantly, the CSSI Approval

also includes provision for the construction of below and above ground structures and other components of future OSD (including building infrastructure and space for future lift cores, plant rooms, access, parking and building services, as relevant to each site). The rationale for this delivery approach, as identified within the CSSI application is to enable the OSDs to be more efficiently built and appropriately integrated into the metro station structures.

The EIS for the Chatswood to Sydenham alignment of the City & Southwest project identified that the OSD would be subject to a separate assessment process.

Since the CSSI Approval was issued, Sydney Metro has lodged four modification applications to amend the CSSI Approval as outlined below:

- Modification 1 - Victoria Cross and Artarmon Substation which involves relocation of the Victoria Cross northern services building from 194-196A Miller Street to 50 McLaren Street together with inclusion of a new station entrance at this location referred to as Victoria Cross North. The modification also involves the relocation of the substation at Artarmon from Butchers Lane to 98 – 104 Reserve Road. This modification application was approved on 18 October 2017.
- Modification 2 - Central Walk which involves additional works at Central Railway Station including construction of a new eastern concourse, a new eastern entry, and upgrades to suburban platforms. This modification application was approved on 21 December 2017.
- Modification 3 - Martin Place Station which involves changes to the Sydney Metro Martin Place Station to align with the Unsolicited Proposal by Macquarie Group Limited (Macquarie) for the development of the station precinct. The proposed modification involves a larger reconfigured station layout, provision of a new unpaid concourse link and retention of the existing MLC pedestrian link and works to connect into the Sydney Metro Martin Place Station. It is noted that if the Macquarie proposal does not proceed, the original station design remains approved. This modification application was approved on 22 March 2018.
- Modification 4 - Sydenham Station and Sydney Metro Trains Facility South which incorporated Sydenham Station and precinct works, the Sydney Metro Trains Facility South, works to Sydney Water's Sydenham Pit and Drainage Pumping Station and ancillary infrastructure and track and signalling works into the approved project. This modification application was approved on 13 December 2017.

The CSSI Approval as modified allows for all works to deliver Sydney Metro between Chatswood and Sydenham Stations and also includes upgrade of Sydenham Station.

The remainder of the City & Southwest alignment (Sydenham to Bankstown) proposes the conversion of the existing heavy rail line from west of Sydenham Station to Bankstown to metro standards. This part of the project, referred to as the Sydenham to Bankstown upgrade, is the subject of a separate CSSI Application (Application No. SSI 17_8256) for which an EIS was exhibited between September and November 2017. A Response to Submissions and Preferred Infrastructure Report was submitted to DPE in June 2018 for further exhibition and assessment. This application is subject to assessment and

determination by DPE, taking into consideration a further Response to Submissions Report which was submitted to DPE in September 2018.

1.3 Nominated State Significant Precinct - Waterloo

Following the decision to locate a metro station in Waterloo, the Minister determined that parts of Waterloo are of State planning significance which should be investigated for urban renewal through the SSP process. Study requirements for such investigations were issued by the Minister on 19 May 2017.

Investigation of the Precinct is being undertaken by UrbanGrowth NSW Development Corporation (UrbanGrowth NSW), in partnership with Sydney Metro and the Land and Housing Corporation (LAHC). The outcome of the SSP process will be new planning controls that will enable future development applications for renewal of the Precinct.

The Precinct includes two separate but contiguous and inter-related parts:

- The Waterloo Metro Quarter (the Metro Quarter)
- The Waterloo Estate (the Estate)

A separate SSP Study for the Metro Quarter was lodged in July 2018 in advance of the SSP Study for the Estate to provide a planning framework for the construction of OSD within the Metro Quarter. The staged submission of the Metro Quarter SSP Study also facilitates the proposed development to be delivered concurrently with the metro station, as an integrated station development.

As this concept SSD Application relies upon the planning framework proposed in the Metro Quarter SSP Study, it is anticipated that the SSP Study and EIS for the SSD Application will be exhibited concurrently.

1.4 Planning relationship between Waterloo Station and the OSD

While Waterloo Station and the OSD will form an integrated station development, the planning pathways defined under the EP&A Act require separate approval for each component of the development. In this regard, the approved station works (CSSI Approval) are subject to the provisions of Part 5.1 of the EP&A Act (now referred to as Division 5.2) and the OSD component is subject to the provisions of Part 4 of the EP&A Act.

For clarity, the approved station works under the CSSI Approval included the construction of below and above ground structures necessary for delivering the station and also enabling construction of the integrated OSD. This includes but is not limited to:

- demolition of existing development
- excavation
- integrated station and OSD structure (including concourse and platforms)
- lobbies

- retail spaces within the station building
- public domain improvements associated with the station
- access arrangements including vertical transport such as escalators and lifts
- space provisioning and service elements necessary to enable the future development of the OSD, such as lift cores, plant rooms, access, parking, retail, utilities connections and building services.

The vertical extent of the approved station works above ground level is defined by the 'transfer level' level (which for Waterloo is defined by approximately RL 33.1 over the northern station box and RL 35.1 over the southern station box), above which would sit the OSD. An example of this delineation is illustrated in Figure 2.

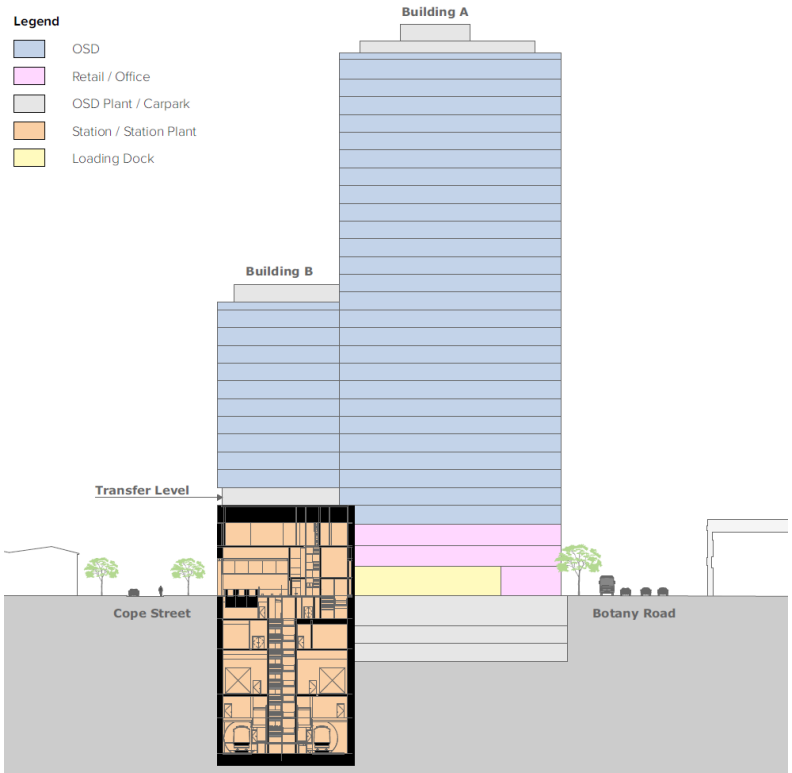

Figure 2: Delineation between the Metro station and OSD

It is noted that the structural and service requirements and space provisioning to support OSD vary from station to station. For example, based on the current level of design, Waterloo Station is not expected to provide for OSD lobbies, end of trip facilities and plant rooms. However, the detailed design may be amended to incorporate these elements as part of the integrated station development.

The CSSI Approval also establishes the general concept for the ground plane of Waterloo Station including access strategies for commuters, pedestrians and workers. In this regard,

the main pedestrian access to the station would be via an entry located at the corner of Raglan and Cope Streets. The station design has continued to be developed having regard to its integration with the Metro Quarter OSD, and as a result, a second entrance to the station is to be provided from a proposed public plaza adjacent to Cope Street. Retail uses (approved under the CSSI Approval) would be located on the ground floor of the station development along the Cope Street frontage of the site.

Since the issue of the CSSI Approval, Sydney Metro has design work to determine the technical requirements for the structural integration of the OSD with the station. This level of design work, together with the planning and design undertaken for the remainder of the Metro Quarter has informed the concept proposal for the OSD. It is noted that ongoing design development of the works to be delivered under the CSSI Approval would continue with a view to developing an Interchange Access Plan (IAP) and Station Design Precinct Plan (SDPP) for Waterloo Station to satisfy Conditions E92 and E101 of the CSSI Approval. The detailed design for the Metro Quarter would continue to evolve having regard to the IAP and SDPP.

Public domain improvement works immediately adjacent to Waterloo Station would be delivered as part of the CSSI Approval to support pedestrian movements between transport modes (including to new and relocated bus stops, bike parking on Cope Street, and taxi and kiss-and-ride bays on Cope Street), while other public domain works within the Metro Quarter are proposed as part of the OSD. Final details of public domain works for the OSD will be provided with the detailed SSD Application(s) following finalisation of the SDPP and IAP for the CSSI Approval.

1.5 The site

1.5.1 Location

The site is located within the City of Sydney (CoS) Local Government Area (LGA).

The Metro Quarter comprises land to the west of Cope Street, east of Botany Road, south of Raglan Street and north of Wellington Street. The heritage listed Waterloo Congregational Church located at 103–105 Botany Road is within this block but is not part of the site.

The site has an approximate area of 1.287 hectares (refer to Figure 3).

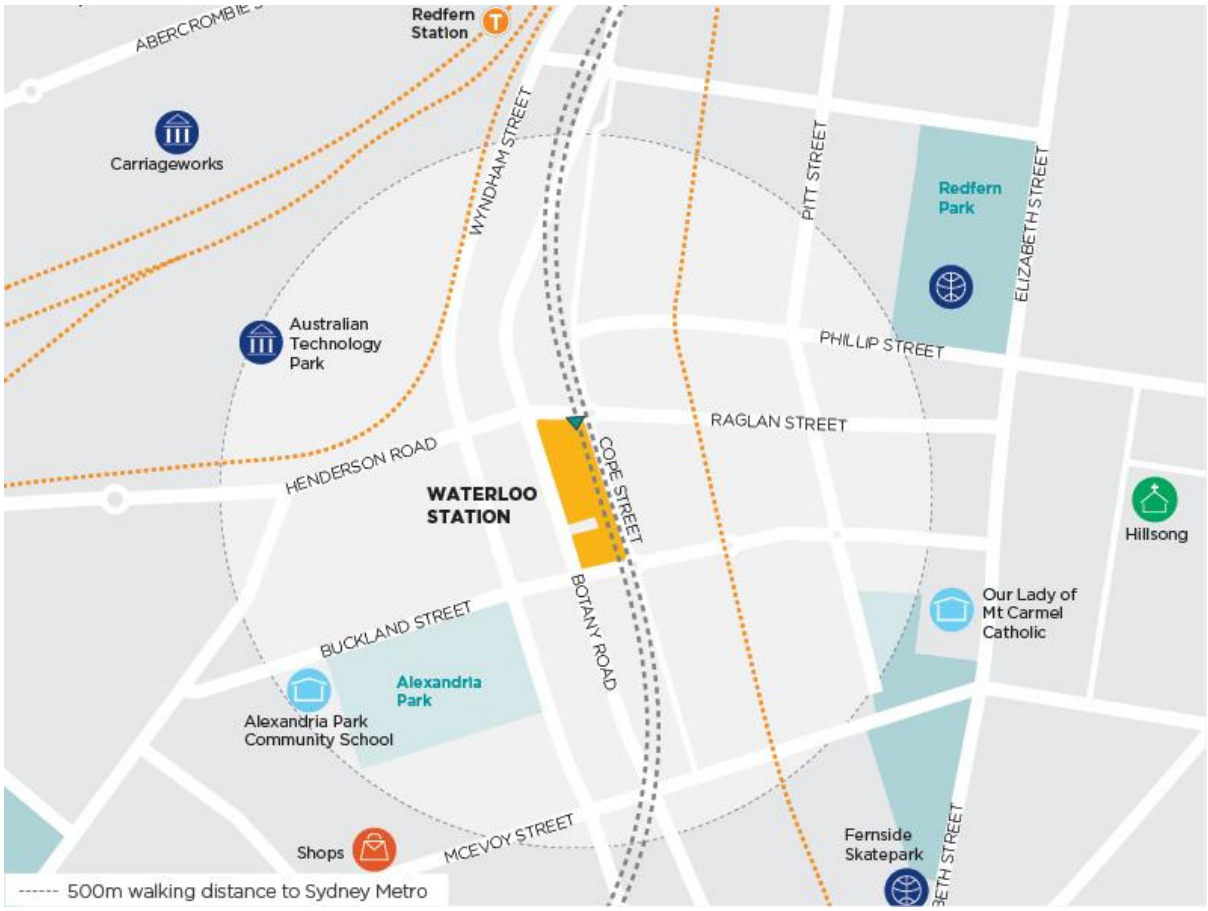

Figure 3: Waterloo Station location plan

1.5.2 Site context

The Metro Quarter is located in Redfern Street Village (see Figure 4) in the City of Sydney LGA approximately 3.3 kilometres south of Sydney CBD, 1 kilometre north of Green Square and less than 1 kilometre south of Redfern Station.

Directly east is the Waterloo Estate (see Figure 5), which is owned by the NSW Government and is under the management of NSW LAHC. The Waterloo Estate comprises 2,012 social housing dwellings and a small number of private dwellings in medium and high density forms, ranging from single storey attached dwellings to apartment buildings of up to thirty storeys.

The Metro Quarter is less than 1 kilometre south-east of the Australian Technology Park (ATP), a technology micro-cluster that currently contains around 3,000 – 3,500 workers with a range of businesses in technology and creative industries; and a start-up/business incubator hub. It is set to grow into a business park that will soon accommodate new

premises currently under construction (i.e. Commonwealth Bank Australia (CBA) has committed to two major office towers).

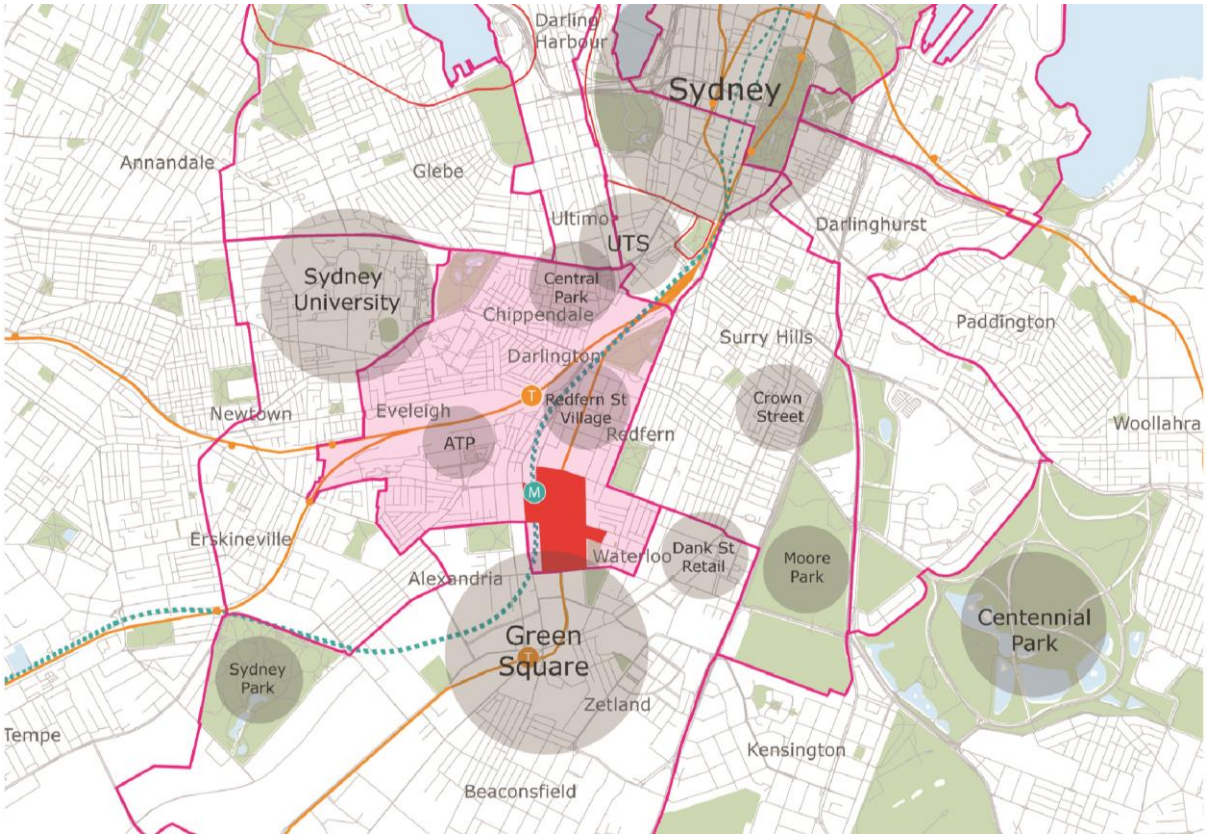

Figure 4: Location and site plan of the Waterloo State Significant Precinct (in red) and Redfern Street Village (in pink)

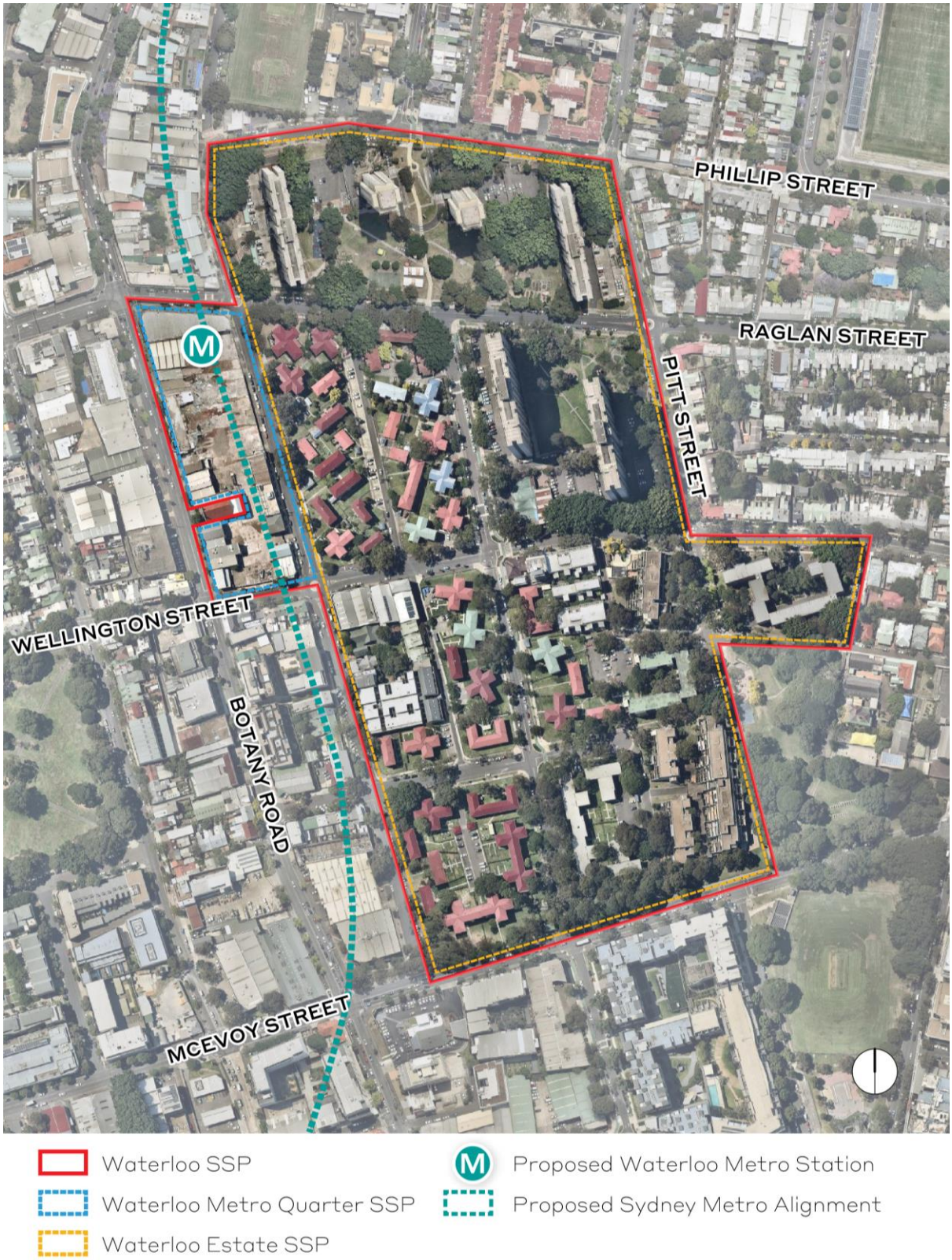

Figure 5 Nominated State Significant Precinct - Waterloo

The site comprises the following properties:

- 136B Raglan Street — Lot 4 DP 215751
- 59 Botany Road — Lot 5 DP 215751
- 65 Botany Road — Lot 1 DP814205
- 67 Botany Road — Lot 1 DP228641
- 124-128 Cope Street — Lot 2 DP228641
- 69-83 Botany Road — SP75492
- 130-134 Cope Street — Lot 12 DP399757
- 136-144 Cope Street — Lots A-E DP108312
- 85 Botany Road — Lot 1 DP27454
- 87 Botany Road — Lot 2 DP27454
- 89-91 Botany Road — Lot 1 DP996765
- 93-101 Botany Road — Lot 1 DP433969 & Lot 1 DP738891
- 156-160 Cope Street — Lot 31 DP805384
- 107-117A Botany Road — Lot 32 DP805384 & Lot A DP408116
- 119-121 Botany Road — Lot 1 DP205942 & Lot 1 DP436831
- 170-174 Cope Street — Lot 2 DP205942

The buildings and structures on the site are now demolished in accordance with the CSSI Approval with the exception of one building which is being used to support construction.

1.6 Overview of the proposed development

This concept SSD Application follows the submission of a SSP Study which supports a proposal to amend existing controls to facilitate the proposed development. The concept SSD Application will in turn comprises the first stage of seeking SSD development consent for the Waterloo OSD project. It will be followed by a future detailed SSD Application(s) for the design and construction of the OSD built form.

This concept SSD Application seeks approval for the planning and development framework and strategies to inform the future detailed design of the OSD. It specifically seeks approval for:

- maximum building envelopes, including maximum building heights, street-wall heights and ground and upper level setbacks
- a maximum gross floor area (GFA) of 68,750 square metres, comprising:
  - approximately 56,200 square metres GFA of residential accommodation, providing for approximately 700 dwellings, including 5 to 10 percent affordable housing and 70 social housing dwellings

  - approximately 3,905 square metres GFA of retail premises and entertainment facilities
  - approximately 8,645 square metres GFA for business and commercial premises and community, health service and recreational facilities (indoor), including at least 2,000 square metres of floor space for community uses
- a three storey podium and a free standing building located within a public plaza, accommodating non-residential land uses
- residential uses above podium level in various building forms including three taller buildings of 23, 25 and 29 storeys (Reduced Level (RL) 96.9, 104.2 and 116.9 metres AHD respectively)
- use of OSD space provisioning within the footprint of the CSSI Approval
- public domain works, including open spaces, through-site links, footpaths, provision for cycle facilities and enhanced pedestrian crossings and roads
- car parking for up to 427 vehicles
- cycle parking to support residential and non-residential land uses and visitors to the Metro Quarter. Approval is also being sought for space within the future basement for a bike hub which would also support future bike parking for Waterloo Station
- loading, vehicular and pedestrian access arrangements
- strategies for utilities and services provision
- strategies for managing stormwater and drainage
- a strategy for the achievement of ecologically sustainable development
- a public art strategy
- provision for future signage zones
- a design excellence framework
- the future subdivision of parts of the OSD footprint (if required).

It is noted that the Sydney Metro comprises GFA of approximately 8,415 square metres on the site, approved under CSSI Approval. The total GFA for the integrated station development, including the station GFA is approximately 77,165 square metres, which is equivalent to an FSR of approximately 6:1.

Key parameters of the concept proposal based on the current level of design development are indicated at Figure 6 and Figure 7.

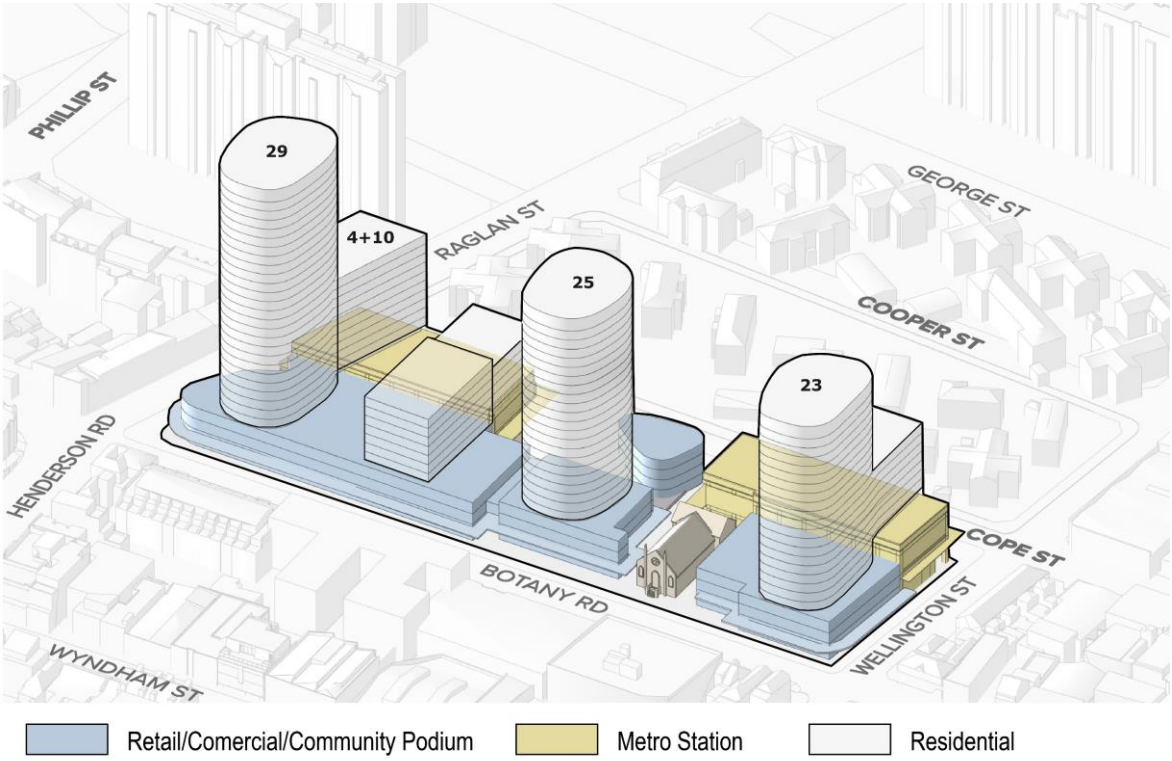

Figure 6 Proposed massing, viewed from the west

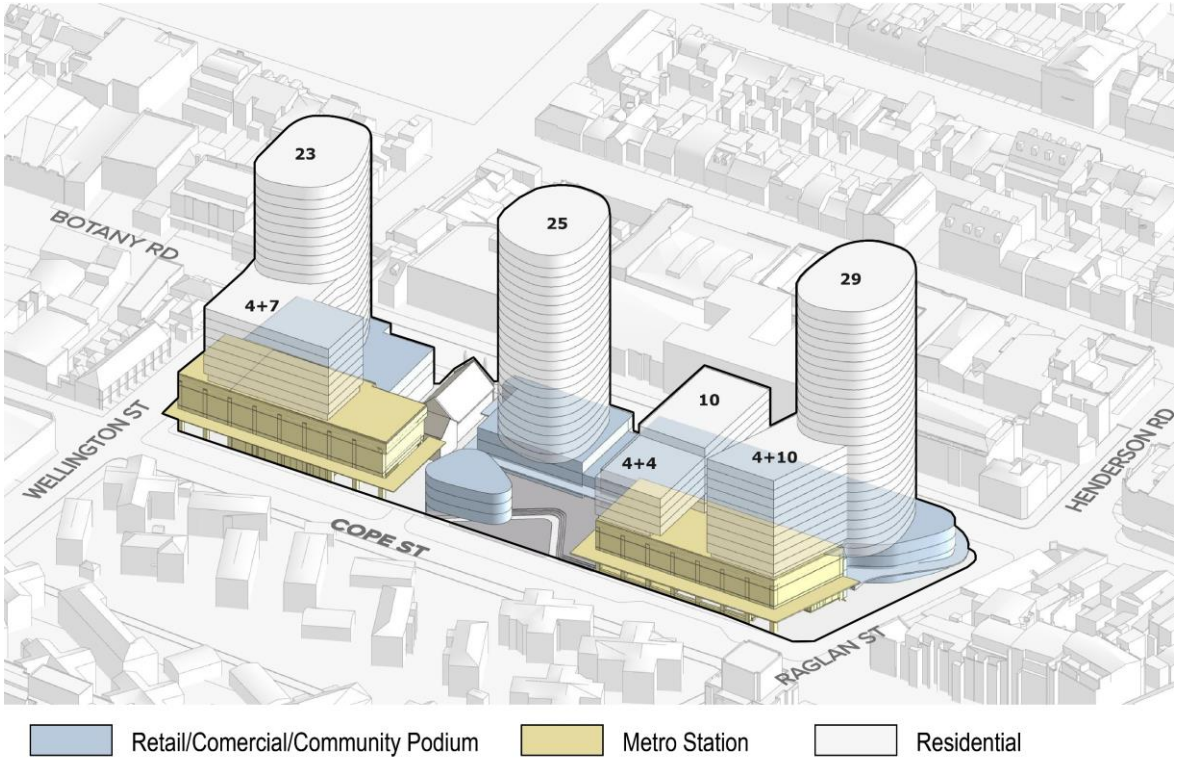

Figure 7 Proposed massing, viewed from the east

The proposal is a significant opportunity to contribute to the urban renewal process for the Waterloo SSP. The objective to deliver the Metro Quarter project as soon as reasonably possible after completion of the Sydney Metro works (earmarked to open 2024) would ensure buildings within the Metro Quarter are occupied to support maximum patronage of the proposed metro station.

The Metro Quarter would contain a mix of uses including residential, commercial, retail, community facilities and services and cultural opportunities sufficient for daily life to be provided for within the wider neighbourhood and to support the activation of the precinct. This would help make Waterloo one of the most connected and attractive inner-city places to live, work and visit.

1.7 Staging and framework for managing environmental impacts

Sydney Metro proposes to procure the delivery of the Waterloo integrated station development in one single package, which would entail the following works:

- station structure fit-out, including mechanical and electrical
- OSD structure fit-out, including mechanical and electrical.

Separate delivery packages are also proposed by Sydney Metro to deliver the excavation of the station boxes/shafts ahead of the integrated station development delivery package, and linewide systems (e.g. track, power, ventilation) and operational readiness works prior to the Sydney Metro City & Southwest metro system being able to operate.

For the purposes of considering construction related impacts, three possible staging scenarios have been identified for delivery of the integrated station development:

1. Scenario 1 – the station and OSD are constructed concurrently by constructing the transfer slab first and then building in both directions. Both the station and OSD would be completed in 2024.
2. Scenario 2 – the station is constructed first and ready for operation in 2024. OSD construction may still be incomplete or soon ready to commence after station construction is completed. This means that some or all OSD construction is likely to still be underway upon opening of the station in 2024.
3. Scenario 3 – the station is constructed first and ready for operation in 2024. The OSD is built at a later stage, with timing yet to be determined. This creates two distinct construction periods for the station and OSD.

The final staging for the delivery of the OSD would be resolved as part of the detailed SSD Application(s).

For the purposes of providing a high level assessment of the potential environmental impacts associated with construction, the following have been considered:

- Impacts directly associated with the OSD, the subject of this SSD Application
- Cumulative impacts of the construction of the OSD at the same time as the station works (subject of the CSSI Approval).

Given the integration of the delivery of the Sydney Metro City & Southwest metro station with an OSD development, Sydney Metro proposes the framework detailed in Figure 8 to manage the design and environmental impacts, in relation to Water Quality, Flooding and Stormwater, consistent with the framework adopted for the CSSI Approval.

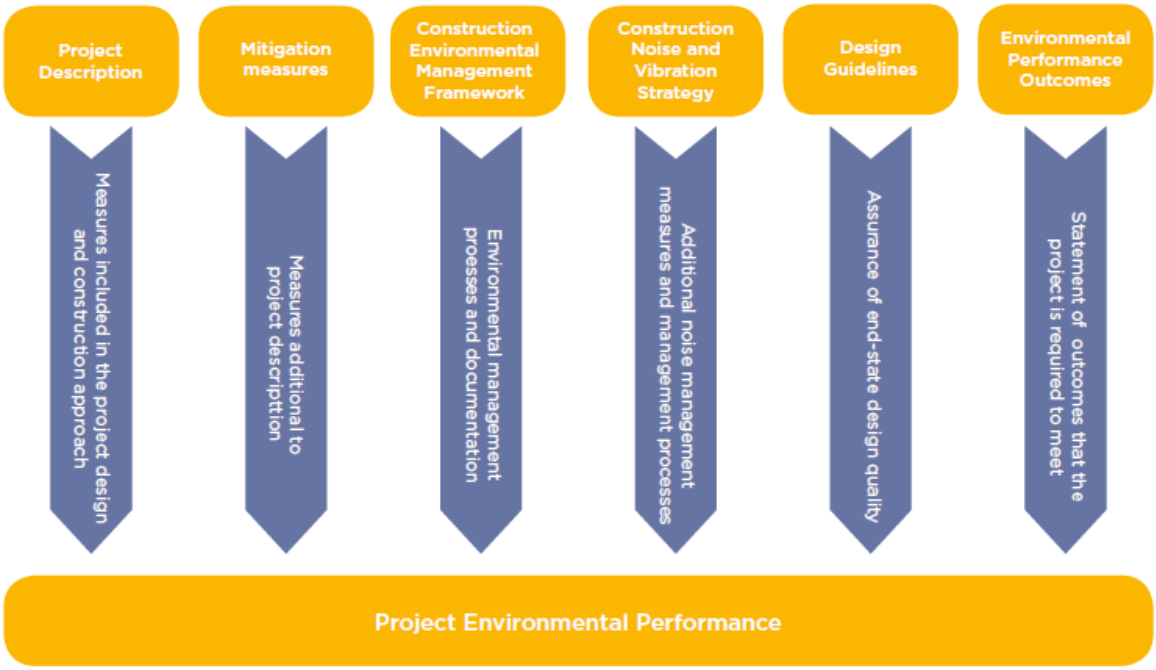

Figure 8 Project approach to environmental mitigation and management

This approach would be implemented until such time as completion of the station works (i.e. works under the CSSI Approval) is achieved. Beyond that point, standard construction environmental management practices would be implemented by the OSD developer in accordance with relevant guidelines and any conditions of approval.

2.0 Scope of assessment

The purpose of this Water Quality, Flooding and Stormwater Report is to address Section 14 of the SEARs for the Metro Quarter OSD concept SSD Application and demonstrate the feasibility of proposed development from a flooding and stormwater perspective at a conceptual level. The report provides preliminary flooding and stormwater analysis for the Metro Quarter site under existing conditions, as well as post-development conditions including a sensitivity analysis for climate change case. The associated modelling was undertaken using a modified version of the CoS TUFLOW model for the Alexandra Canal Flood Study. The results of these initial cases have been presented in parallel with information indicating existing stormwater infrastructure.

Under current flood conditions, a significant area of ponding occurs in Cope Street between the intersection with Wellington Street and extending to the intersection with John Street. This ponding is a result of significant overland flows passing down Cope Street, with contributions from within the Waterloo Precinct. The depth of ponding, more significant in the southern portion of the site, is up to 1m for the 100 year Average Recurrence Interval (ARI) and 1.6m for the Probable Maximum Flood (PMF).

As a consequence of this ponding, the Flood Planning Level (FPL) at the southern end of the Metro Quarter based on existing conditions in this area is approximately 1.5m above street level, while at the north end; it is up to 0.9 metres above the street level. At most locations enveloping the site, the FPL are influenced by the ponding area occurring at Cope Street and Wellington Street. Entrances to underground areas such as carparks are also required to be flood free in the PMF event. Due to these requirements, carpark entrances may need to be ramped up approximately 1.6 metres above street level before ramping down into basement areas. Recommended FPLs for Metro Quarter have been provided where the adopted criterion for setting of flood planning level was maximum of PMF and 100 year ARI +0.5 metres.

This report outlines potential mitigation measures to offset adverse flooding impacts during extreme weather events. These include on-site detention and appropriate building flood planning levels. It is likely that the flood impacts can be addressed but will require additional iterative design development. Climate change has been addressed in this report through conducting a sensitivity analysis by taking an additional 10 percent increase over the 100 year ARI storm event. Plans showing the resultant flood depths, flood velocities, flood hazards and flood impacts over current and proposed scenarios have been included in the report.

The extensive ponding identified during the PMF also presents evacuation considerations. Evacuation from the buildings in this precinct or emergency vehicle access is a possibility; however, as the buildings will be above the PMF level, a shelter in place strategy is preferable to avoid unnecessary vehicle or pedestrian movement during extreme storm events. Sufficient warning time can be provided for the occupied areas including retail levels where the occupants will need to move to the stepped up shelter in place zone within their property.

Water Sensitive Urban Design (WSUD) features have been assessed against pollution reduction targets as outlined in the SEARs. The suggested strategy from MUSIC modelling

is to use stormwater filter cartridges in on-site detention tanks. While the MUSIC modelling results indicate that the nutrient reduction targets can also be met using a mix of gross pollutant traps. Additionally, an integrated water cycle management approach may be adopted for the site in order to maximize stormwater harvesting, reuse and recycle to achieve desirable outcomes for a highly green and sustainable development.

Based on the investigations undertaken, the relevant SEARs have been wholly satisfied for the concept level proposal with detailed design development related investigations identified in the report wherever appropriate. Considering the buildings can be safely occupied, flooding risks at the Metro Quarter can be mitigated using appropriate FPLs, setbacks and emergency response frameworks and WSUD measures can be readily implemented for water quality enhancement. The site is suitable for the proposed mixed-use development comprising residential, commercial, open spaces and community facilities.

3.0 Baseline Investigations

3.1 Key Considerations for Metro Quarter

To arrive at a flooding and stormwater solution for the Metro Quarter, a number of baseline investigations were undertaken and the following key considerations inform the overall strategy for the site –

- Historical flooding issues around the site create development constraints. The site is part of Alexandra Canal catchment and the site has previously been identified as requiring flood management measures.
- Water quality improvement for stormwater discharged into the Alexandra Canal / Sheas Creek, which is a tributary of the Cooks River, in line with NSW Water Quality Objectives.
- Sustainability and climate change adaptation measures, including WSUD, for a green and resilient urban development.

3.2 Alexandra Canal Floodplain Risk Management Study

In 2014 the CoS commissioned a Floodplain Risk Management Study and Plan for the Alexandra Canal Catchment. The overall objective of the Floodplain Risk Management Study and Plan was to devise a strategy that addresses the existing, future and continuing issues in the Alexandra Canal catchment in accordance with the NSW Government's Flood Policy, as detailed in the NSW Floodplain Development Manual (NSW Government, 2005).

As part of this study the Metro Quarter was identified as an area requiring flood management measures to be implemented. Figure 9 below shows the extents of this study and the location of the Metro Quarter site location within the overall Alexandra Canal catchment. The 2014 Report identified that the majority of flooding within the Alexandra Canal catchment is characterised by overland flow with critical storm duration between 1 and 3 hours across the catchment, and the peak of the flood reached approximately 30 minutes to 1 hour after the start of the storm. This is considered short duration "flash" flooding. The short duration until flooding occurs does not allow sufficient time to evacuate residents from their properties. The models from this study were updated with a new survey which served as the pre-development conditions. As part of this work, new modelling was undertaken on the effect of the proposed Metro Quarter and these results and recommendations are found further within the report.

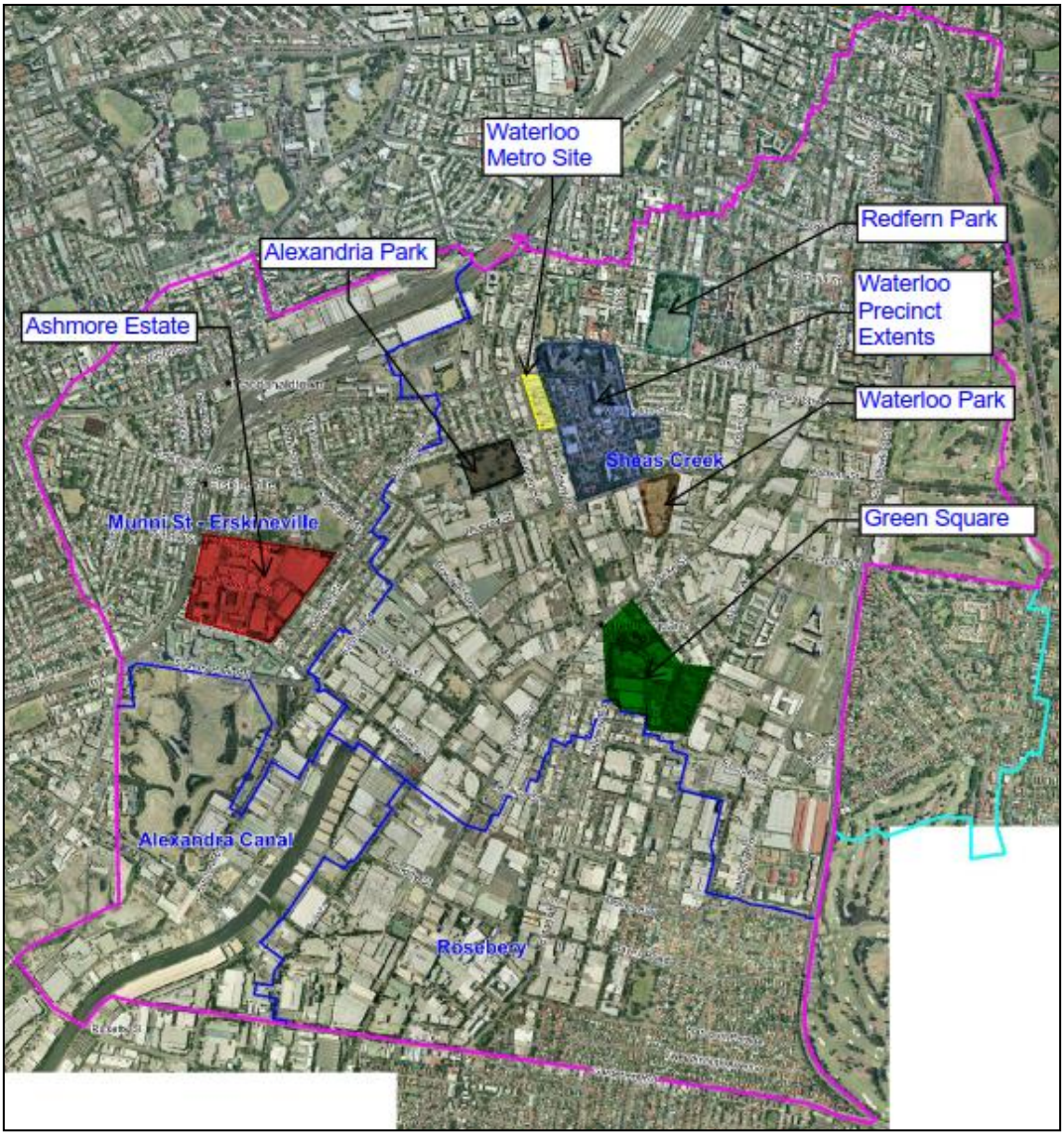

Figure 9: Alexandra Canal Floodplain Risk Management Study extents and catchment delineation

3.3 Flooding Context

3.3.1 Historic Flooding Issues

A local resident and landowner questionnaire was distributed to over 7,000 known flooding areas within the Alexandra Canal Catchment area as part of the Floodplain Risk Management Study commissioned by CoS in 2014.

The images shown in Figure 10 were noted within the study to be of particular relevance to the Metro Quarter and surrounding areas. These images demonstrate that the area has encountered flooding issues which will need to be considered for any development works in the area.

Figure 10: Hunter Street (Left), Botany Road & Buckland Street Intersection (right)

Photo taken May 2011 by J. Chaytor (left), Photo taken February 2010 by J. Gelbart (right)

3.4 Hydrological Context

3.4.1 Catchment Characteristics

The site forms part of the Sheas Creek sub catchment for the Alexandra Canal. The majority of the Sheas Creek sub catchment is fully developed and consists predominantly of medium to high-density housing, commercial and industrial development with some large open spaces and recreational parklands.

The Metro Quarter measures approximately 1.91 hectares and consists of 0.2 percent of the overall 775 hectare Sheas Creek sub catchment area. Preliminary analysis suggests that the catchment contributing overland flow towards the Metro Quarter is delineated by a topographical ridge line extending from the intersection of Redfern and Pitt Streets to the north and the intersection of McEvoy and Elizabeth Street to the south. A site topographic map of the Metro Quarter and surrounding region is shown in Figure 11 below indicating that the Metro Quarter is generally located at a low point.

Figure 12 and Figure 13 also provide an indication of existing flood conditions as well as the locations of existing trunk stormwater infrastructure currently servicing the Metro Quarter catchment area.

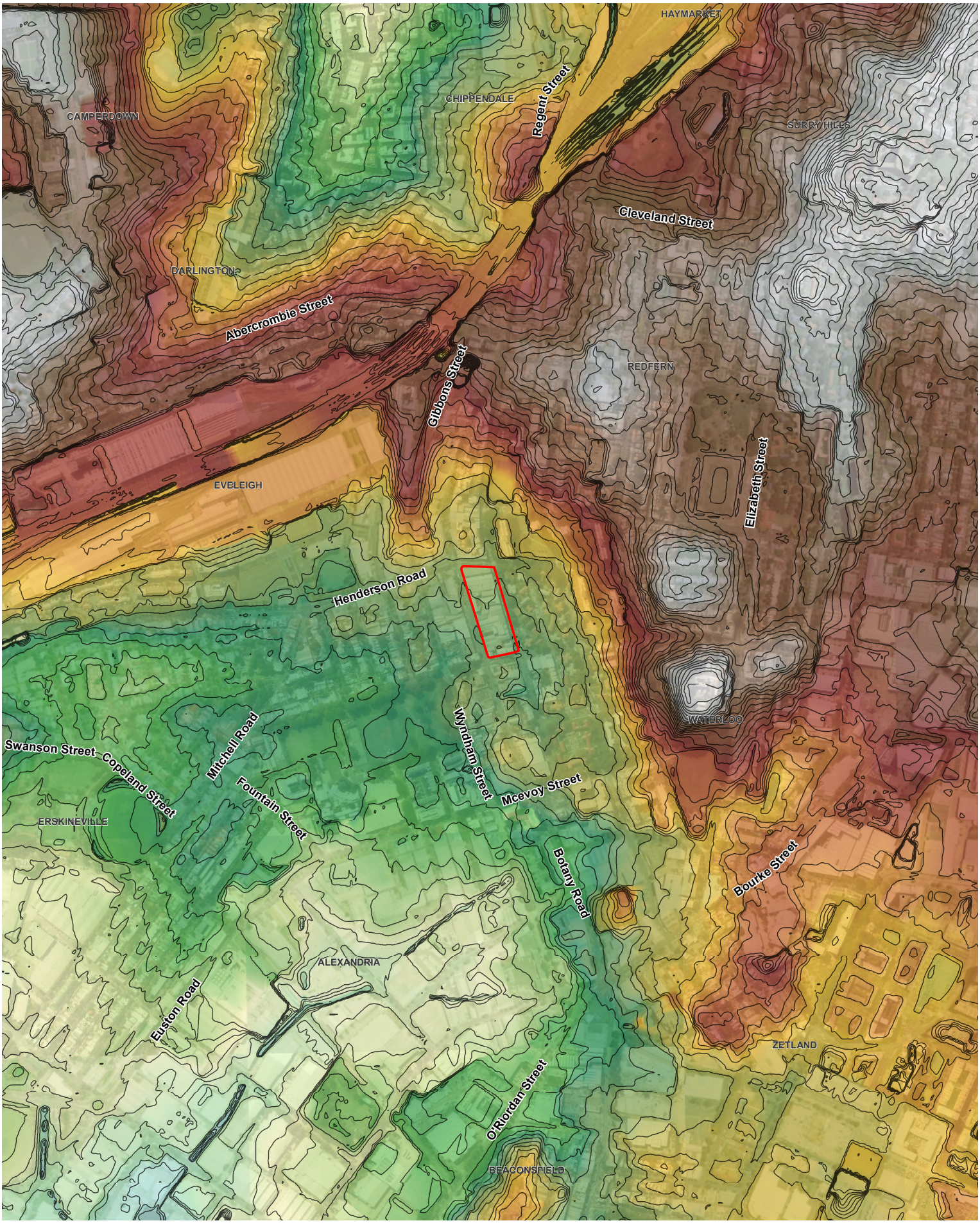

FIGURE 11 - WATERLOO METRO QUARTER
SITE TOPOGRAPHY

AECOM

N 0 125 250 m

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KEY

Site boundary
1m contour

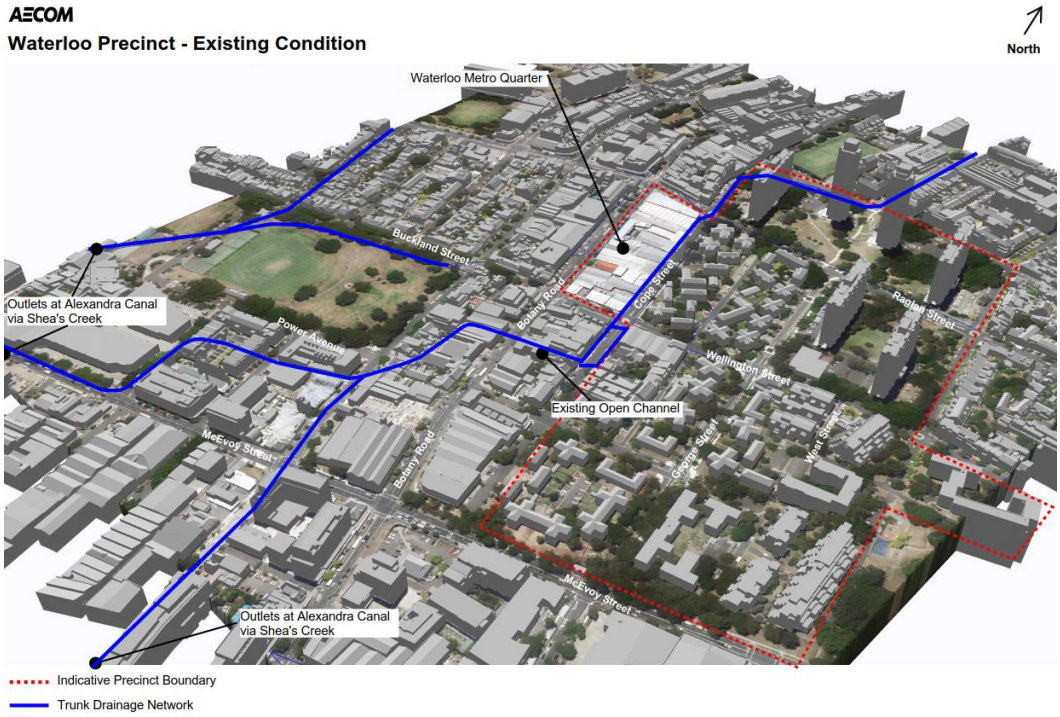

Figure 12: Waterloo Precinct - Existing Condition

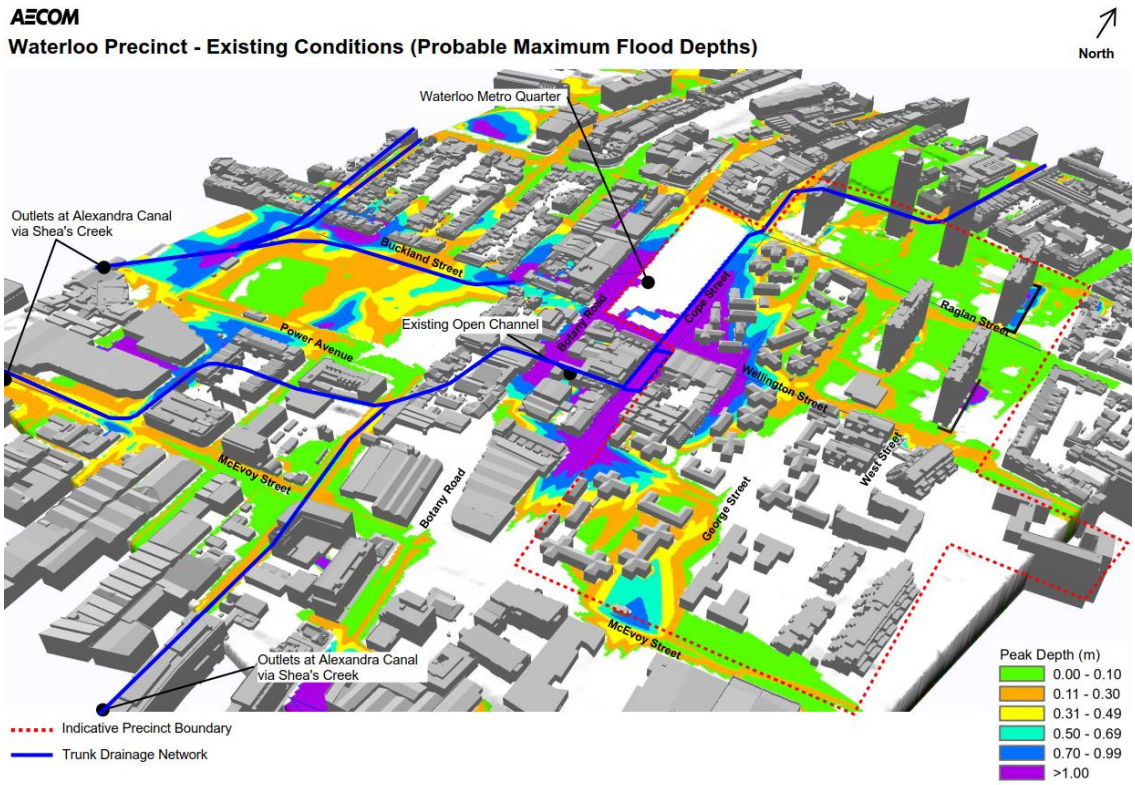

Figure 13: Waterloo Precinct - Existing Conditions (PMF)

3.4.2 Hydrological Data and Preliminary Results

The preliminary results (from WBM data using DRAINS V2017.08) of the hydrological analysis for the site area are shown below in Table 1. It should be noted that the results shown are for existing conditions and represent the 100 year ARI 2hr storm as documented in the WBM Hydrological model as utilised in the Floodplain Risk Management Study commissioned by CoS in 2014. Catchment parameters and analysis of other magnitude storms have relied on original calibrations provided by CoS.

Table 1: Preliminary hydrological data and peak discharge for Metro Quarter area (Existing)

Area	Effective Catchment Area	Paved Area (average)	Grassed Area (average)	Paved Roughness	Grass Roughness	Q_{peak} 100year 2hr Storm
Metro Quarter	1.9ha	95%	5%	0.012	0.027	1.3 m^3/s

3.4.3 Existing Drainage Networks

The formal drainage systems around the site area consist of overland flow paths through road kerb and gutter systems, local piped drainage system owned and maintained by the CoS and a trunk drainage system which discharges to Sheas Creek and eventually the Alexandra Canal and Cooks River. The trunk drainage system is owned by Sydney Water Corporation.

3.4.4 Preliminary Flood Analysis

As part of the Alexandra Canal Catchment Flood Study, 2014, a catchment wide flood model was developed by Cardno using the SOBEK hydraulic modelling package. This model included a detailed representation of the underground drainage network. As part of subsequent work, the SOBEK model was converted to a TUFLOW hydraulic model.

Provisional flood hazard mapping from the Floodplain Risk Management Study and Plan for the Alexandra Canal Catchment notes that the Cope St and Wellington St intersection presents a high hazard region with no effective flood access in adjacent areas. Where future development within the Waterloo precinct reduces the existing flood storage areas it is likely that an increase in flood depth would occur at another location. As a result, flood storage should be a careful consideration for future development to ensure that flood impacts are not significantly increased in other locations.

The existing TUFLOW model was provided by CoS and formed the basis to document the preliminary flooding results. Preliminary flood modelling results are shown in Figure 15 to Figure 23, these indicate the flood depths, flood velocities and flood hazard for the area surrounding the Metro Quarter for 20 year ARI, 100 year ARI and the Probable Maximum Flood (PMF) storm events.

These figures identify peak flood depths immediately adjacent to the Metro Quarter for a PMF storm event of up to 1.6 metres at the intersection of Wellington Street and Cope Street and 1.14 metres at the Botany Road and Wellington Street intersection based on the CoS flood results supplied.

There is significant flooding within the site and adjacent streets, additionally the floor levels of a number of the previous buildings did not comply with the CoS Interim Floodplain Management Policy.

3.4.5 Preliminary Flood Analysis Conclusions

From the preliminary flooding analysis and hydrology study it appears that sources of flooding within the vicinity of the Metro Quarter site can be attributed to a number of issues which include:

- An outlet constrained trunk drainage at the Cope Street open channel;
- Poor conveyance of runoff along Botany Road; and
- Local trapped low points at the intersection of Wellington Street and Cope Street.

The Cope Street open channel, shown in Figure 14 consists of a 2030mm(W) x 1750mm(H) brick wall and concrete channel bed which connects to a 1650mm(W) x 1650mm(H) concrete culvert under Botany Road. The Botany Road culvert provides a reduced waterway area for flow conveyance, resulting in hydraulic losses associated with the smaller culvert dimensions consequently providing a constraint on the system. This is further demonstrated during a 100 year ARI event where the Hydraulic Grade Line (HGL) is located above the road surface at this location. This creates limited opportunity for the upstream overland flow to enter the trunk drainage system until the HGL recedes below ground level. Upwelling or surcharging of the system may be occurring as a result of the downstream tailwater effects within the system.

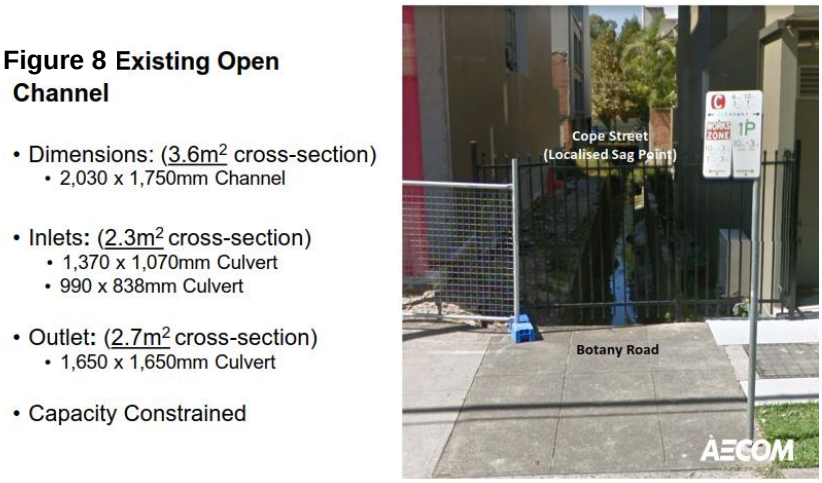

Figure 14: Existing Open Channel

Another source of flooding around the site involves poor conveyance of overland flow through Botany Road as well as trapped low points at the intersection of Cope Street and Wellington Street. This is due primarily to insufficient road grading causing runoff to pond in these locations during major storm events.

FIGURE 15 - EXISTING CASE 20YR ARI FLOOD DEPTHS

WATERLOO METRO QUARTER

AECOM

N 0 25 50 m

KEY

Peak Depth (m)

- 0.00 to 0.10
- 0.11 to 0.30
- 0.31 to 0.49
- 0.50 to 0.69
- 0.70 to 0.99
- >1.00

Site Area

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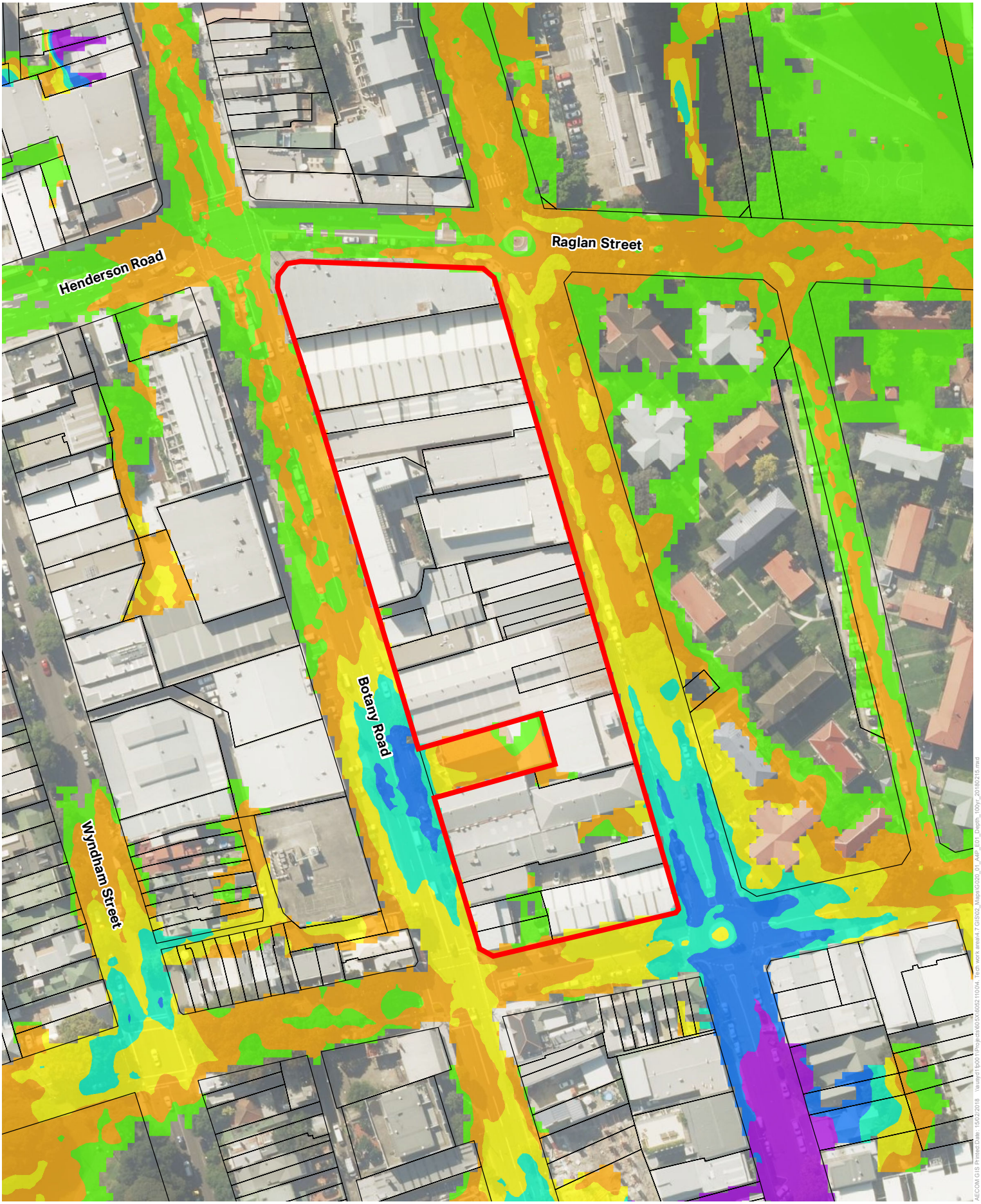

FIGURE 16 - EXISTING CASE 100YR ARI FLOOD DEPTHS

WATERLOO METRO QUARTER

AECOM

0 25 50 m

KEY

Peak Depth (m)

- 0.00 to 0.10
- 0.11 to 0.30
- 0.31 to 0.49
- 0.50 to 0.69
- 0.70 to 0.99
- >1.00

Site Area

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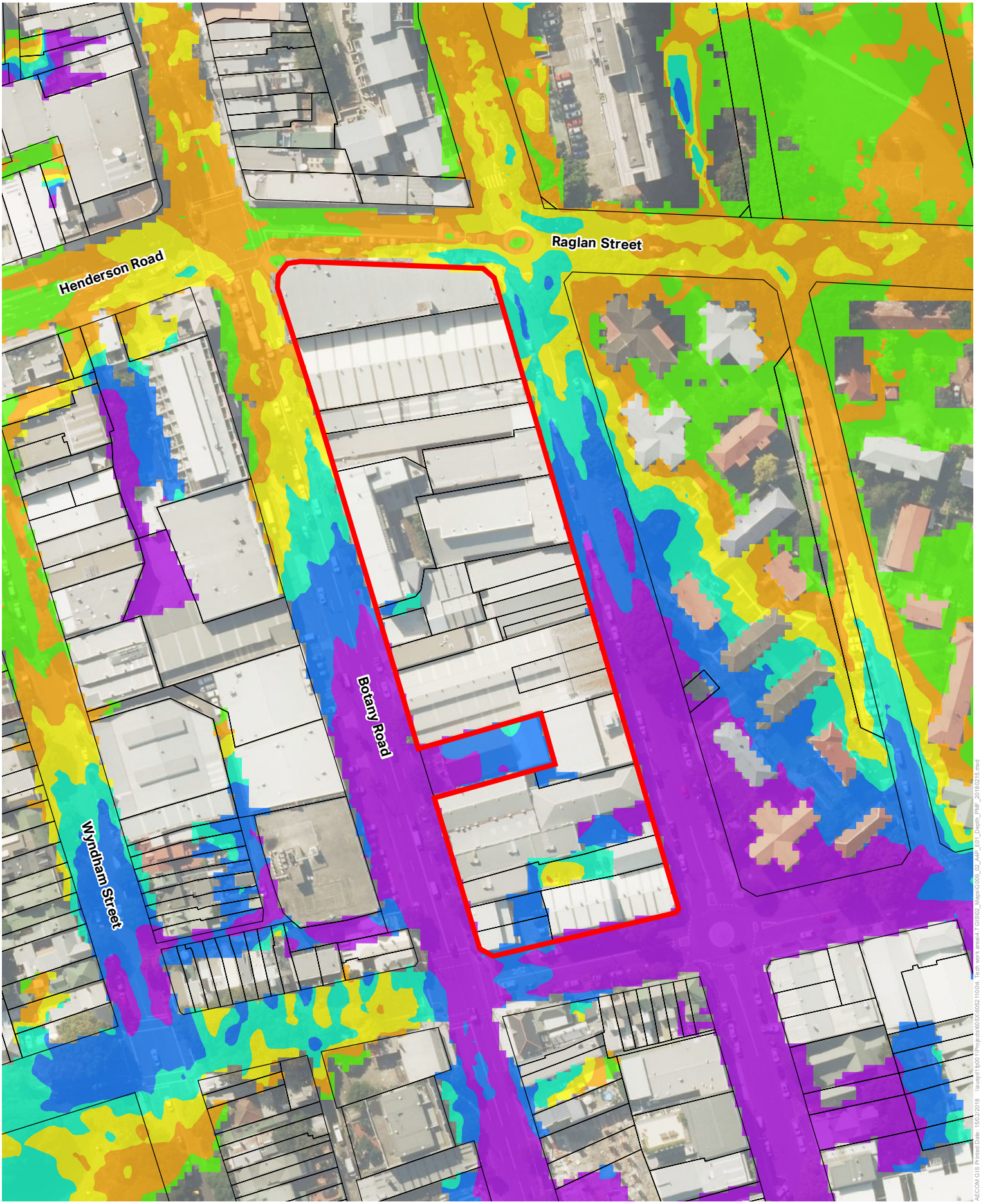

FIGURE 17 - EXISTING CASE PMF FLOOD DEPTHS

WATERLOO METRO QUARTER

AECOM

0 25 50 m

KEY

Peak Depth (m)

- 0.00 to 0.10
- 0.11 to 0.30
- 0.31 to 0.49
- 0.50 to 0.69
- 0.70 to 0.99
- >1.00

Site Area

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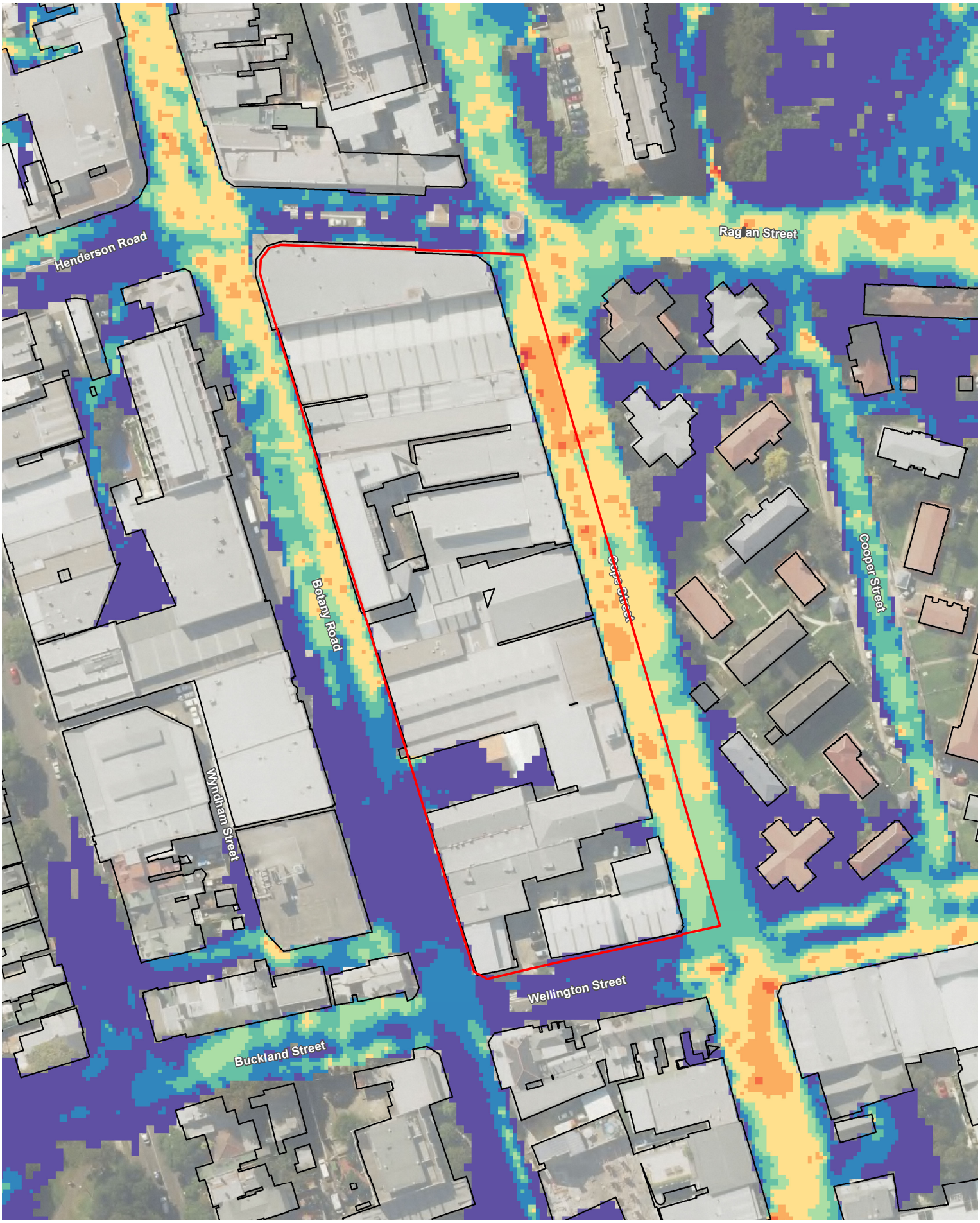

FIGURE 18 - WATERLOO METRO QUARTER - PRE-DEVELOPMENT - 20YR ARI FLOOD VELOCITY

AECOM

0 15 30 m

KEY

Site boundary
Building footprint

Flood Velocity (m/s)

- Less than 0.25
- 0.25 - 0.5
- 0.50 - 0.75
- 0.75 - 1
- 1.0 - 1.5
- 1.5 - 2
- 2.0 - 2.5
- 2.5 - 3
- Greater than 3

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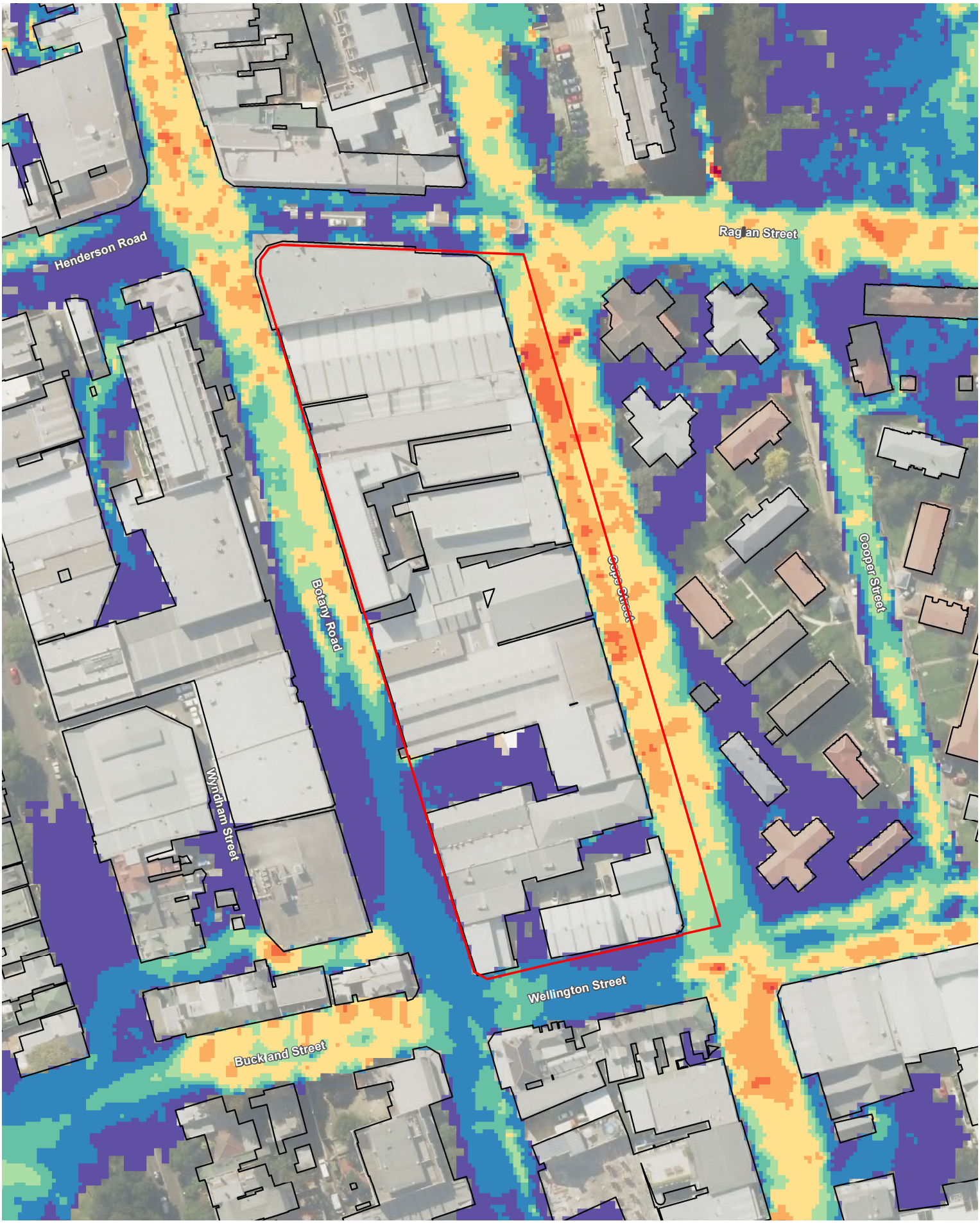

FIGURE 19 - WATERLOO METRO QUARTER - PRE-DEVELOPMENT - 100YR ARI FLOOD VELOCITY

AECOM

N 0 15 30 m

KEY

Site boundary
Building footprint

Flood Velocity (m/s)

- Less than 0.25
- 0.25 - 0.5
- 0.50 - 0.75
- 0.75 - 1
- 1.0 - 1.5
- 1.5 - 2
- 2.0 - 2.5
- 2.5 - 3
- Greater than 3

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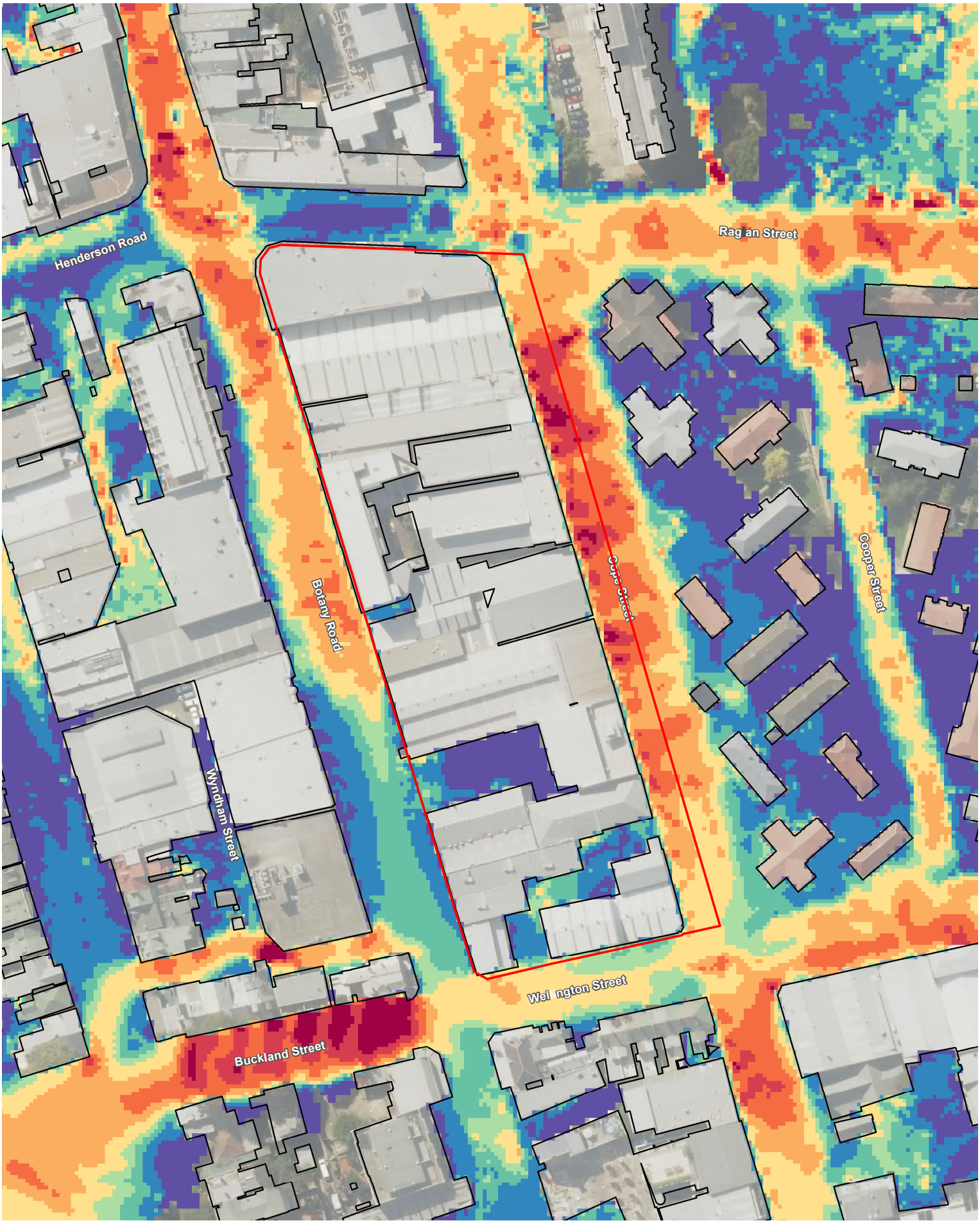

FIGURE 20 - WATERLOO METRO QUARTER - PRE-DEVELOPMENT - PMF FLOOD VELOCITY

AECOM

0 15 30 m

KEY

Site boundary
Building footprint

Flood Velocity (m/s)

- Less than 0.25
- 0.25 - 0.5
- 0.50 - 0.75
- 0.75 - 1
- 1.0 - 1.5
- 1.5 - 2
- 2.0 - 2.5
- 2.5 - 3
- Greater than 3

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FIGURE 21 - WATERLOO METRO QUARTER - PRE-DEVELOPMENT - 20YR ARI FLOOD HAZARD

AECOM

N 0 15 30 m

KEY

Site boundary
Building footprint

Flood Hazard
Low Hazard
Transitional Hazard
High Hazard

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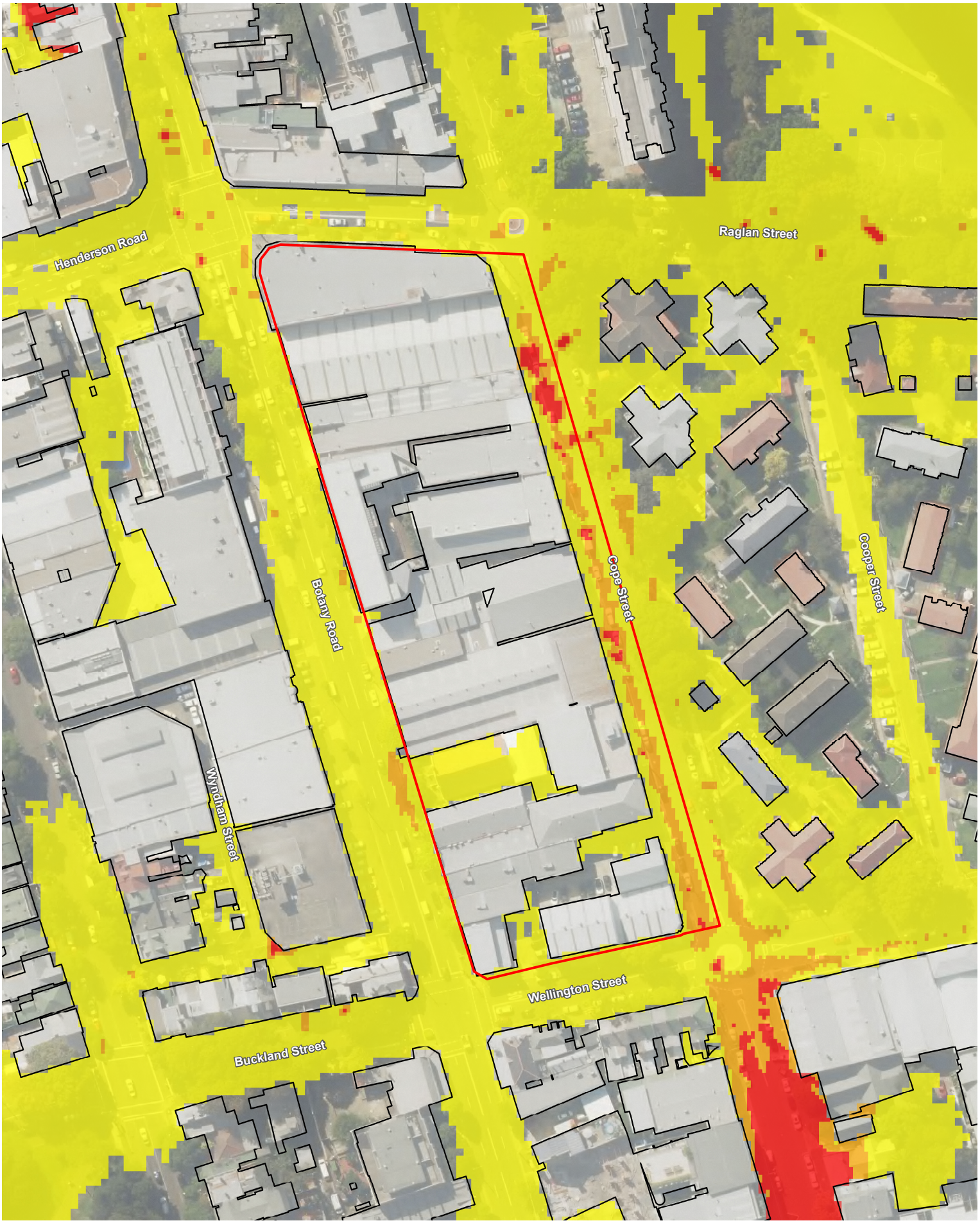

FIGURE 22 - WATERLOO METRO QUARTER - PRE-DEVELOPMENT - 100YR ARI FLOOD HAZARD

AECOM

N 0 15 30 m

KEY

Site boundary
Building footprint

Flood Hazard
Low Hazard
Transitional Hazard
High Hazard

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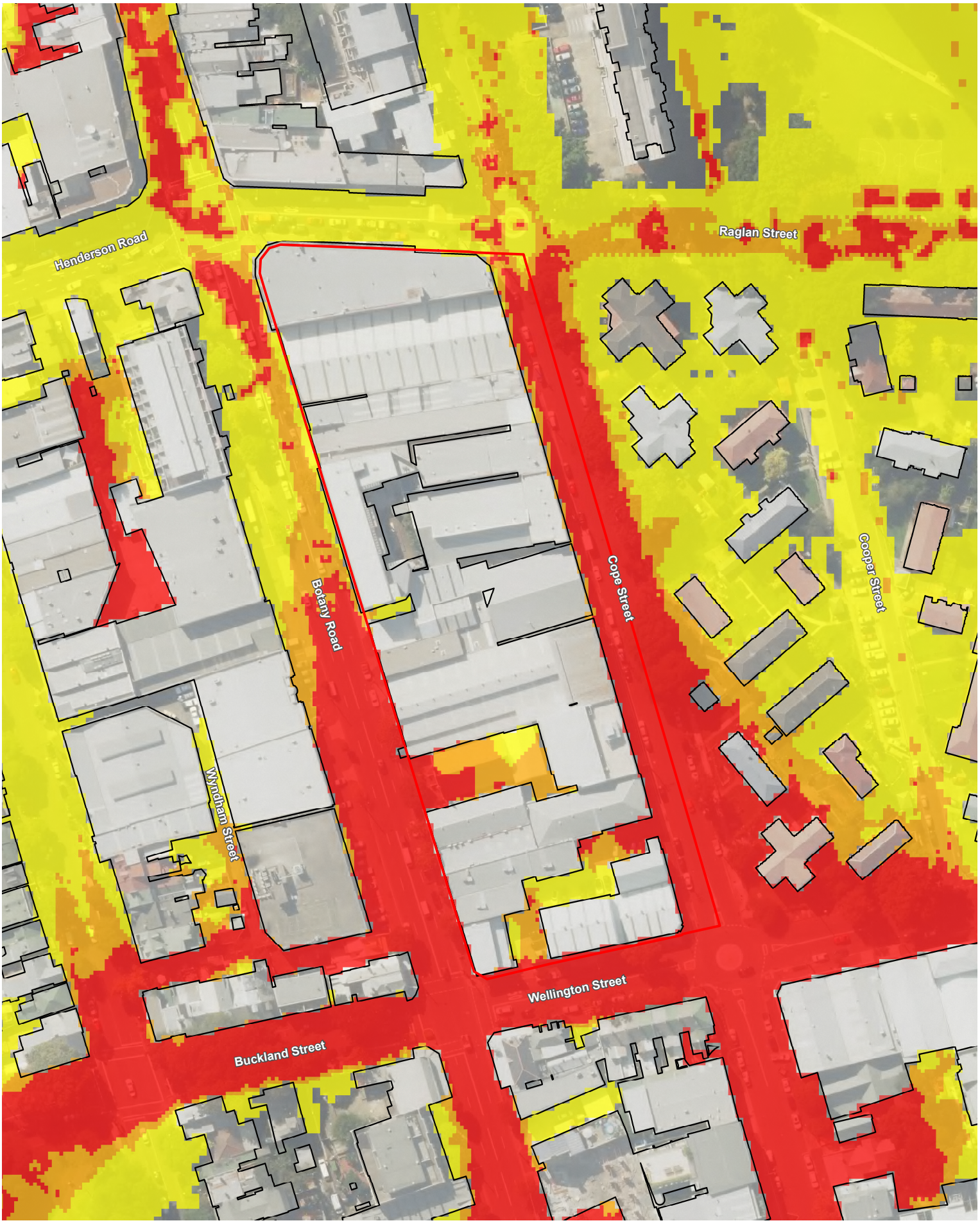

FIGURE 23 - WATERLOO METRO QUARTER - PRE-DEVELOPMENT - PMF FLOOD HAZARD

AECOM

N 0 15 30 m

KEY

Site boundary
Building footprint

Flood Hazard
Low Hazard
Transitional Hazard
High Hazard

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4.0 Assessment

4.1 Design Criteria

4.1.1 City of Sydney Development Control Plan 2012

While the Sydney Development Control Plan 2012 (SDCP2012) does not apply to the proposal, subject to Clause 11 of the SRD SEPP, the flooding requirements under Section 3.7 of the SDCP 2012 have been considered.

Specific key requirements in the SDCP 2012 which relate to stormwater include:

- A site specific flood study should be prepared to support the development of the site
- The connection to the existing stormwater network are not to reduce the capacity of that infrastructure by more than 10 percent
- Post development run-off from impermeable surfaces is to be managed by stormwater source measures that: contain frequent low-magnitude flows; maintain the natural balance between run-off and infiltration; remove some pollutants prior to discharge into receiving waters; prevent nuisance flows from affecting adjacent properties; and enable appropriate use of rainwater and stormwater
- The stormwater quality management approach will involve integrating WSUD techniques in the proposed stormwater drainage system. The water quality requirements are summarised below
  - Reduce the baseline and annual pollutant load for litter and vegetation larger than 5mm by 90 percent
  - Reduce the baseline annual pollutant load for total suspended solids by 85 percent
  - Reduce the baseline annual pollutant load for phosphorous by 65 percent
  - Reduce the baseline annual pollutant load for total nitrogen by 45 percent.

4.1.2 City of Sydney Interim Floodplain Management Policy

The *Interim Floodplain Management Policy* has been developed by the CoS which documents the requirements for the management of flood risk for all new developments within the CoS LGA. CoS has a responsibility to manage floodplains to ensure that any:

- New development will not experience undue flood risk; and
- Existing development will not be adversely flood affected through increased damage or hazard as a result of any new development.

Table 2, extracted from the *Interim Floodplain Management Policy* (CoS, 2014) describes the permissible minimum building floor levels and below ground development Flood Planning Levels (FPLs) for the site development. Considering the existing flood conditions

surrounding the site, the majority of the site would be subject to FPL of the 100 year ARI + 0.5 metres (corresponding to mainstream flooding) in Table 2.

The following key performance criteria extracted from the Interim Floodplain Management Policy govern the permissible minimum building floor levels and below ground development flood planning levels for the Metro Quarter development.

Based on the preliminary flood study results, the majority of the proposed Metro Quarter site is considered to be located within a floodplain.

Table 2: Flood Planning Level Criteria for the Metro Quarter
(Interim Floodplain Management Policy, City of Sydney 2014)

Development Type		Type of Flooding	Flood Planning Level	Comments
Residential	Habitable rooms	Mainstream flooding (flood depth greater than 0.25m 250mm)	1% AEP / 100 year ARI flood level + 0.5 m	Mainstream flooding occurs where the local drainage flooding criteria cannot be satisfied.
		Local drainage flooding (less than 250mm flood depth less than 0.25 m)	1% AEP / 100 year ARI flood level + 0.5 m or Two times the depth of flow with a minimum of 0.3 m above the surrounding surface if the depth of flow in the 1% AEP100 year ARI flood is less than 0.25 m	
	Non-habitable rooms such as a laundry or garage (excluding below-ground car parks)	Mainstream or local drainage flooding	1% AEP / 100 year ARI flood level	Mainstream flooding occurs where the local drainage flooding criteria cannot be satisfied.
Industrial or Commercial	Retail Floor Levels	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of the 1% AEP / 100 year ARI flood. The proposal must demonstrate a reasonable balance between flood protection and urban design outcomes for street level activation.	Mainstream flooding occurs where the local drainage flooding criteria cannot be satisfied.
Below ground garage/ car park	All other below-ground car parks	Mainstream or local drainage flooding	1% AEP / 100 year ARI flood level + 0.5 m or the PMF (whichever is the higher).	The below ground garage/car park level applies to all possible ingress points to the car park such as vehicle entrances and exits, ventilation ducts, windows, light wells,

Development Type		Type of Flooding	Flood Planning Level	Comments
				lift shaft openings, risers and stairwells

4.2 Design Standards

CoS design standards have generally been adopted for the Metro Quarter development, as the stormwater infrastructure external to the buildings will eventually be dedicated to Council. A summary of each standard, code and other additional documents used in the design of stormwater infrastructure for the development is presented in Table 3. These standards are to be confirmed during later design stages and are included here for reference only.

Table 3: Stormwater Drainage Reference Documents and Standards

Reference Number	Title
CoS A4	City of Sydney Design Specification A4 Drainage Design
RMS R11	RMS Specification R11.
CPA	Concrete Pipe Association's "Concrete Pipe Selection and Installation" Guide
AR&R Vol 1	Australian Rainfall and Runoff "A Guide to Flood Estimation" Volume 1, 1987.
AR&R Vol 2	Australian Rainfall and Runoff "A Guide to Flood Estimation" Volume 2, 1987.
AR&R – Project 10	Australian Rainfall and Runoff – Revision Projects "Appropriate Safety Criteria for People"
AR&R – Project 11	Australian Rainfall and Runoff – Revision projects "Blockage of Hydraulic Structures"
AS 3500.3	Australian Standard AS3500.3: Plumbing and Drainage Code – Stormwater Drainage (2003)
AS 3725	Australian Standards AS3725: Design for Installing of Buried Concrete Pipes
BBCW IP	Botany Bay & Catchment Water Quality Improvement Plan. Sydney Metropolitan CMA, 2011
NSW FDM	New South Wales Floodplain Development Manual

4.3 Adopted Design Criteria

Based on the planning commitments and the requirements of the various design standards, the stormwater drainage design criteria assumed for the development are summarised below in Table 4. These will be used to inform the proposed flood mitigation strategies.

Table 4: Stormwater Drainage Design Criteria

Item	Standard	Adopted	Comment
Hydrology			
Hydrological Model	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	DRAINS model	Using the Time Area method – ILSAX
Minor Design Storm	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	20 year ARI	
Major Design Storm	Sydney Streets Technical Specifications: A4	100 year ARI	

Item	Standard	Adopted	Comment
	Stormwater Drainage (City of Sydney, 2016)		
Hydraulics			
Pipe size	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	Min. 150mm diameter Min. 375mm diameter	150 mm pipe diameter is the absolute minimum for pipes located in private property. 375 mm pipe diameter is the minimum for pipes owned by City of Sydney.
Pit spacing	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	Max. 40 m (pipes 375 mm to 750 mm dia.) Max. 60 m (pipes 750 mm to 1500 mm dia.) Max. 100 m (pipes greater than 1500 mm)	
Pit losses	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	Missouri Charts, (Sangster et al, 1958)	
Pit blockage factors	Sydney Streets Technical Specifications: A4 Stormwater Drainage (City of Sydney, 2016)	Grated Inlet Pits: 90% Kerb Inlet Pits <=1.0 m • On-Grade: 50% • Sag: 70% Kerb Inlet Pits > 1.0 m • On-Grade: 20% • Sag: 50%	Applied to proposed infrastructure
Flood Hazard			
Appropriate Safety Criteria for People	AR&R – Project 10	Max. Depth x Velocity = $0.4m^2s^{-1}$	More details provided in ARR 2016 document.

4.4 Stormwater Quantity Control Requirements

4.4.1 Permissible Site Discharge (PSD) and On-Site Detention Requirements

Sydney Water (the authority responsible for the downstream drainage network) has advised of the required stormwater quantity controls for the 13,500 square metre site in Table 5:

Table 5: Sydney Water requirements for the Metro Quarter

On-Site Detention	Permitted Site Discharge (PSD)
$208m^3$	503L/s

Sydney Water has further clarified this requirement with an email received on 25th October 2016. (See Appendix A) It states that:

'Approval for the On Site Detention would only be given as part of the Section 73 application for this development. The On Site Detention is to be designed according to the above values and submitted to Sydney Water for approval with the Section 73 application.'

4.5 Proposed Stormwater Quantity Management

The proposed stormwater drainage and runoff system for the Metro Quarter development will comply with the design requirements as identified in Section 4.3 with the main design considerations summarised below:

- Post development stormwater runoff connections into existing drainage infrastructure will match pre-development case. (i.e. shared building downpipe connection to either Botany Road drainage or Cope Street to reflect existing cadastre boundary)
- Compliance with Sydney Water total Permissible Site Discharge (PSD) requirements of 503L/s (assuming 13,500 square metres area) and On Site Detention of 203 cubic metres for the entire site
- On-site detention is to be situated above the 100 year ARI flood levels to facilitate discharge into potentially fully charged stormwater pipes
- Sizing of on-site detention areas, including bypass areas, to be managed based on relevant stage of construction process
- Management of water quantity to ensure no increase in stormwater discharge rate from the site for the 20 and 100 year ARI storms

A DRAINS model was developed to assess the existing hydrological and hydraulic conditions for the site and revised to estimate the stormwater discharge from the site under the proposed future conditions.

4.5.1.1 Proposed Scenario

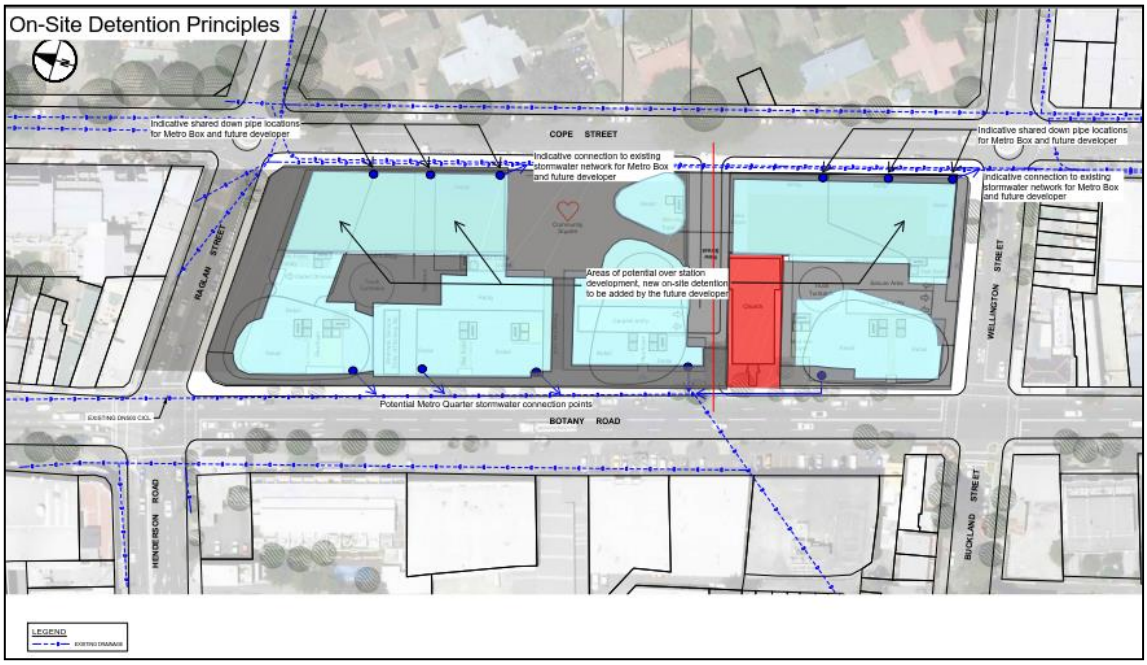

Figure 24: Metro Quarter Overview of Catchment . (Note: Building layouts indicative only)

The proposed drainage scheme considers the site in two sections, divided along the proposed new shared road (as indicated by a red line in Figure 24). There are four catchments identified as the buildings and bypass areas in the north section and buildings and bypass areas in the south section. These catchment areas are shown in Figure 24 above and are each considered to be 100 percent impervious.

The areas and theoretical PSD for each catchment are shown in Table 6 below. The PSD for the site has been provided by Sydney Water which indicates a PSD of 503L/s assumed over an area of 13,500 square metres. Extrapolating this information provides an approximate PSD rate per meter squared of $0.3726Ls^{-1}m^{-2}$ for the site. This unit rate was used to determine the PSD for each sub-catchment.

Table 6: Catchment Area and PSD

Catchment	Area (ha)	Area (m^2)	PSD(L/s)	PSD (m^3/s)	Compliance with Sydney Water Requirements
Buildings (North)	0.5626	5626	209.621	0.210	The total PSD for the site is 0.476 m^3/s which is less than the PSD of 0.503 m^3/s required by
Bypass_North	0.3173	3173	118.224	0.118	
Buildings (South)	0.2581	2581	96.166	0.096	
Bypass_South	0.1383	1383	51.530	0.052	
TOTAL	**1.2763**	**12763**	**475.540**	**0.476**	

					Sydney Water.

A preliminary DRAINS model (See Figure 25) was produced to assess the suitability of the On-Site Detention approach and overall site discharge. On-Site Detention volumes and orifice diameters were sized to achieve a compliant site discharge for each catchment area with allowance for freeboard and additional capacity. Table 7 below shows the On-Site Detention tank sizes required to maintain a compliant site discharge.

This strategy produced a peak site discharge for a **100 year ARI** storm event (1hr storm duration) of **0.425m^3/s** which is lower than Sydney Water's required total site PSD of **0.476m^3/s** as determined in Table 6. The existing site discharge based on pre-development conditions is 1.3m^3/s as shown in Section 3.4.2. These results demonstrate that the On-Site Detention strategy can achieve a lower discharge than the existing case.

Table 7: On-Site Detention Sizing

Building	Detention Orifice Dia. (mm)	Surface Area (m^2)	On-site Detention Volume (m^3)	Sydney Water Minimum Requirement (m^3)
North Building	180	155	320	The total on-site detention volume for the site is 480 m^3 which is more than the 208 m^3 required by Sydney Water.
South Building	130	70	160	
		Total	480	

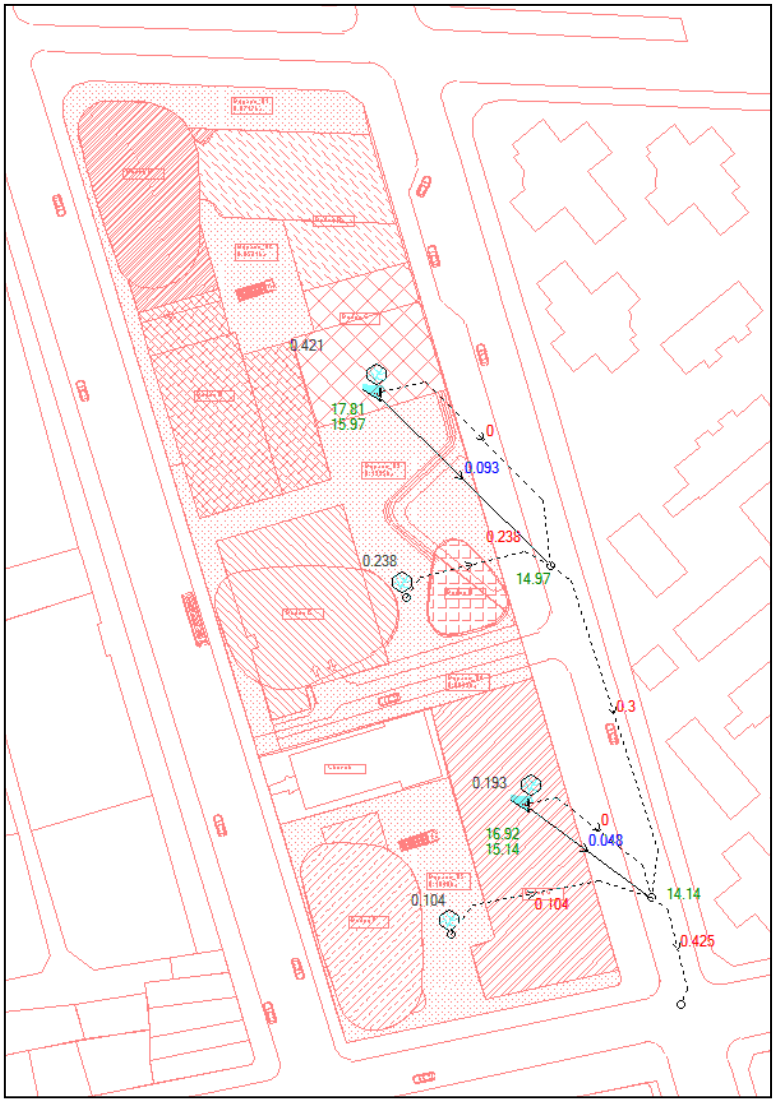

Figure 25: DRAINS Results

4.6 Stormwater Quality Control Requirements

4.6.1 Botany Bay and Catchment Water Quality Improvement Plan

The Metro Quarter which falls within the Alexandra Canal catchment is governed by the Botany Bay and Catchment Water Quality Improvement Plan (BBWQIP). This plan details the water quality requirements for developments within the Botany Bay catchment and outlines the stormwater reduction standards for 'large redevelopments'. These are described in the table below.

Table 8: BBWQIP Stormwater Quality Reduction Targets for Redevelopments

Water Quality Parameters	Large Developments (% reduction)
Gross Pollutants	90
Total Suspended Solids (TSS)	85
Total Phosphorous (TP)	65
Total Nitrogen (TN)	45

These requirements have been determined based on a range of scenarios and improvement options to measure the impact on total nitrogen reduction within Botany Bay over the 2030 and 2070 timeframes. The BBWQIP was completed by the Sydney Metropolitan Catchment Management Authority (SMCMA) and has been adopted in the SDCP 2012 which is discussed in Section 5.1.2. The stormwater quality management approach will involve integrating WSUD techniques in the proposed stormwater drainage system. This also reflects the obligations noted in the SEARs and the approach detailed in the CoS Decentralised Water Master Plan (CoS, 2012).

4.6.2 Other Relevant Guidelines

The following documents relevant to stormwater quality control were also reviewed and considered in the overall assessment.

- *Local Planning for Healthy Waterways using NSW Water Quality Objectives* June 2006
- *Managing Urban Stormwater – Harvesting and Reuse Guidelines* December 2006

Councils have incorporated their WSUD requirements in their respective DCPs. For this study, the SDCP 2012 discussed in Section 4.1.1, is applicable.

4.6.2.1 Local Planning for Healthy Waterways Using NSW Water Quality Objectives June 2006

This document outlines a six-step framework for local councils to establish a water quality strategy and collectively contribute to the health of waterways in NSW:

1. Recognizing the community's values for waterways in LEPs – Water quality objectives should be readily included in LEPs and DCPs as high-level objectives to reflect their important in planning decisions.
2. Assessing the current condition of waterways – Councils should consider condition of waterways, key pressured on their health and potential risks to water quality during assimilation of information for their LEPs and DCPs.
3. Identifying significant risks to water quality – Review of existing and potential activities and use of conceptual and predictive models for decision-making.

4. Identifying zones that protect river corridors, wetlands and sensitive landscapes – Identifying buffer zones of natural vegetation should be a key priority to support water quality objectives and their protection and enhancement should be facilitated through planning controls.
5. Planning for higher risk developments – Identifying sensitive locations that would cause high risk to water quality, establish best land use for designated areas during such assessments.
6. Setting benchmarks for design and best practice – Setting performance benchmarks to minimize impacts on water quality and river health during ongoing activities for development, such as the NSW Building Sustainability Index (BASIX).

4.6.2.2 Managing Urban Stormwater – Harvesting and Reuse Guidelines December 2006

This guideline outlines the following main considerations for stormwater harvesting and reuse projects, based on experience gained from previous projects:

- Planning – Relevance of the project under consideration within the overarching integrated urban water cycle management strategy.
- Project design – Meeting end-use requirements and treatment of Stormwater to address public health and environmental risks.
- Operations, maintenance and monitoring – Assessing the sustainability of the project and monitoring impacts to public health and the environment.

The following key considerations in the design of stormwater storage are specified in the document:

- *Store sufficient water to balance supply and demand, and meet reliability of supply objectives; and*
- *Design above-ground storages to minimise mosquito habitat (virus control), risks to public safety and risks to water quality (e.g. eutrophication), and address dam safety issues.*

The default stormwater quality criteria for managing public health risks for various applications are outlined in Table 4.5 and Table 6.4 of the guideline, extracted below in Figure 26 and Figure 27 respectively. The treatment adopted for a stormwater reuse project should relate to the stormwater quality criteria. Indicative levels of pollution retention for various stormwater treatment measures can be found in Table 6.7 of the document, extracted in Figure 28.

Table 4.5	Specific management measures for default risk management approach		
Application	**Access restrictions**	**Stormwater quality criteria**	**Specific operational practices**
Residential (non-potable)	Nil	Level 1	Above-ground storage design and management Additional plumbing controls
Irrigation of open spaces	Nil	Level 2	Irrigation scheme design and operational controls
	Controlled public access or subsurface irrigation	Level 3	
Industrial	Nil	Level 2	
	Controlled public access	Level 3	
Ornamental waterbodies	Nil	Level 2	
	Controlled public access	Level 3	
Aquifer storage and recovery	Not applicable	Level 3	ASR scheme operational controls

Figure 26: **Specific management measures for various applications**

Source: Managing Urban Stormwater – Harvesting and Reuse Guidelines Dec 2006

Table 6.4 Stormwater quality criteria for public health risk management		
Level	**Criteria[1]**	**Applications**
Level 1	*E. coli* <1 cfu/100 mL Turbidity ≤ 2 NTU[2] pH 6.5–8.5 1 mg/L Cl_2 residual after 30 minutes or equivalent level of pathogen reduction	Reticulated non-potable residential uses (e.g. garden watering, toilet flushing, car washing)
Level 2	*E. coli* <10 cfu/100 mL Turbidity ≤ 2 NTU[2] pH 6.5–8.5 1 mg/L Cl_2 residual after 30 minutes or equivalent level of pathogen reduction	Spray or drip irrigation of open spaces, parks and sportsgrounds (no access controls) Industrial uses – dust suppression, construction site use (human exposure possible) Ornamental waterbodies (no access controls) Fire-fighting
Level 3	*E. coli* <1000 cfu/100 mL pH 6.5–8.5	Spray or drip irrigation (controlled access) or subsurface irrigation of open spaces, parks and sportsgrounds Industrial uses – dust suppression, construction site use, process water (no human exposure) Ornamental waterbodies (access controls)

[1] values are median for *E. coli*, 24-hour median for turbidity and 90th percentile for pH
[2] maximum is 5 NTU
Source: derived from NSW RWCC (1993), DEC (2004), ANZECC & ARMCANZ (2000)

Figure 27: Stormwater quality criteria

Source: Managing Urban Stormwater – Harvesting and Reuse Guidelines Dec 2006

Table 6.7 Indicative levels of pollution retention and outflow concentrations for different stormwater treatment measures					
Stormwater treatment measure	**Suspended solids**	**Total phosphorus**	**Total nitrogen**	**Turbidity**	***E. coli***
Retention					
GPT	0–70%	0–30%	0–15%	0–70%	Negligible
Swale	55–75%	25–35%	5–10%	44–77%	Negligible
Sand filter	60–90%	40–70%	30–50%	55–90%	–25–95% (up to 1.5 log)
Bioretention system	70–90%	50–80%	30–50%	55–90%	–58–90% (up to 1 log)
Pond	50–75%	25–45%	10–20%	35–88%	40–98% (0.5–2 log)
Wetland	50–90%	35–65%	15–30%	10–70%	–5–99% (up to 2 log)

Figure 28: Indicative levels of pollution retention

Source: Managing Urban Stormwater – Harvesting and Reuse Guidelines Dec 2006

4.7 Proposed Stormwater Quality Control

4.7.1 Water Sensitive Urban Design (WSUD) Implementation

WSUD measures, including gross pollutant traps, passive irrigation, bio-retention areas and rainwater harvesting were considered for the development. General layouts have been adopted for the current design, and further details including subsoil drainage and exact infrastructure layouts will be further developed in detailed design. Below provides a preliminary summary of WSUD measures that can be implemented within the site.

4.7.2 On Site Treatment of Stormwater

At-source stormwater pollution control devices provide flexibility to achieve stormwater pollution reduction targets prior to discharge from site. These are placed in tanks beneath podium courtyards and within the upper levels of underground car parks. To remain free from tail-water impacts caused by downstream stormwater networks, tanks will be elevated at or above street level.

4.7.3 Compliance With Stormwater Treatment Targets

This section presents the suggested stormwater quality management approach for the Metro Quarter to achieve the CoS's stormwater quality reduction targets.

The preliminary calculations are based on MUSIC modelling and a commonly available proprietary stormwater treatment device Full Flow ZPG 690mm cartridge. There are a range of other devices available in the markets which perform a similar function such as the Stormfilter™ cartridges and an alternative arrangement employing these may be feasible, subject to demonstration through MUSIC modelling.

The suggested strategy is to locate Full Flow ZPG 690mm cartridge units within 930mm deep chambers at end-of-pipe locations underneath courtyards and within/adjacent to On-Site Detention tanks. Note that each chamber cannot be counted to contribute to the overall On-Site Detention volume required for each building. Chamber surface areas (assumed to be 930mm deep) and required numbers of cartridges are listed in Table 9 and the notional catchments for each chamber are proposed based on the labelling presented in Figure 29 below.

Where several chambers are required for a single building, due to downpipe spacing constraints, then the number of cartridges shall be proportioned based on the catchment area split to each chamber. While the locations of these devices are subject to detailed design, a typical arrangement is provided in Appendix B. Please also refer to the chosen supplier's standard drawings.

It is advised that pits within courtyards draining to chambers also be fitted with gross pollutant traps such as Enviropod® – Gully Pit Inserts to trap silt and litter and prolong the life of the filter units.

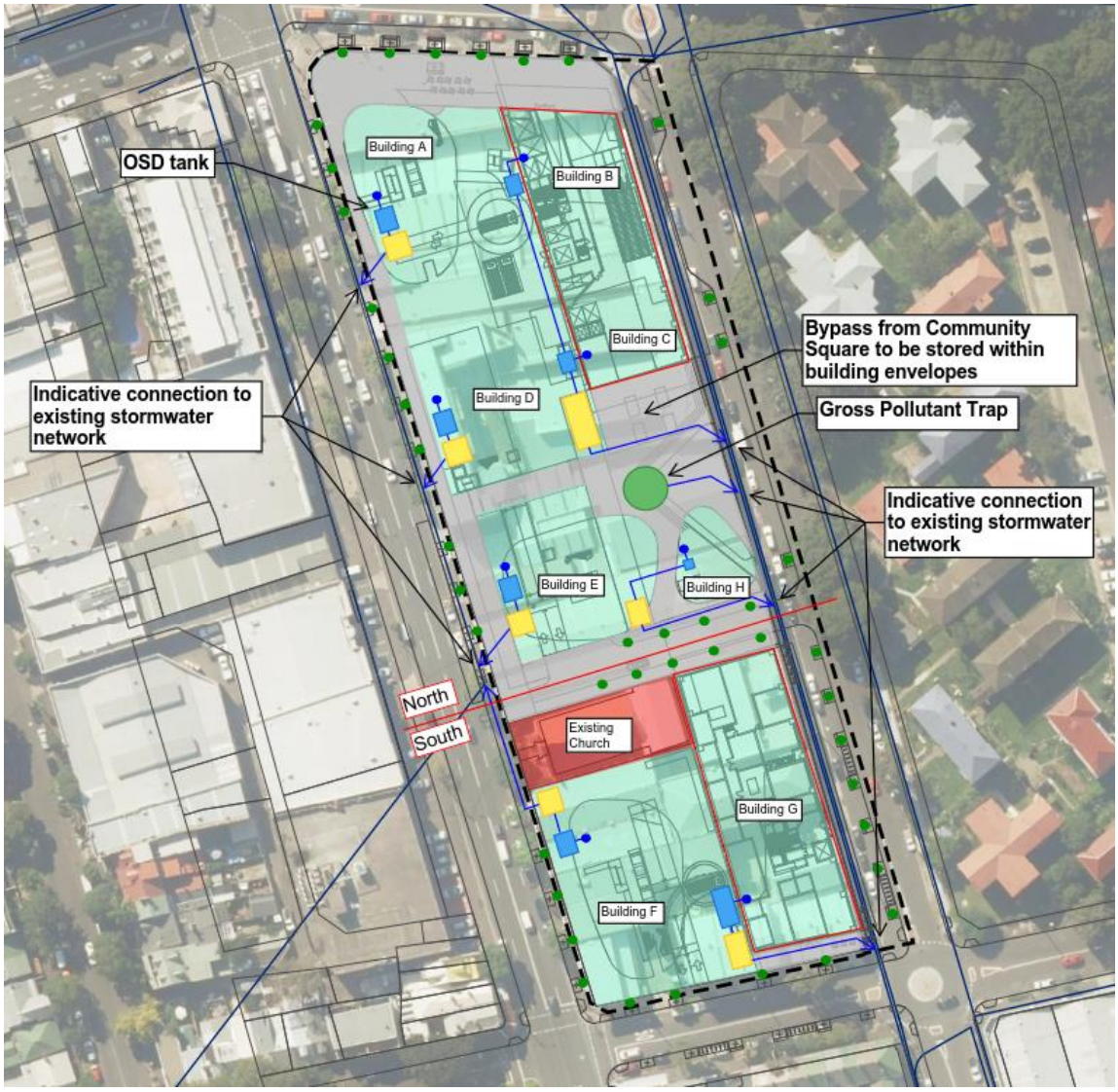

Figure 29: Option 1 On-Site Detention Layout and Stormwater Quality Catchments

Note: Building layouts indicative only.

Table 9: Catchment Area and PSD

Catchment (Refer to Figure 29)	Area (ha)	No. of Full Flow ZPG 690mm Cartridges	Filter Chamber Area (m^2)	Notional Outlet Pipe Dia (mm)	Water Quality Targets Achieved
Building A	0.10	8	3.8	81	• Total Gross Pollutants reduced by 90%; • TSS reduced by 85%; • TP reduced by 65%; and • TN reduced by 45%
Building B	0.11	9	3.7	87	
Building D	0.13	10	3.8	92	
Building C	0.08	7	3.8	75	
Building E	0.12	10	3.8	92	
Building H	0.03	3	1.7	49	
Building F	0.09	8	3.8	81	
Building G	0.17	13	7.5	105	
Bypass_01	0.07	5	3.8	65	
Bypass_02	0.05	4	1.7	58	
Bypass_03	0.19	14	7.5	109	
Bypass_04	0.03	3	1.7	49	
Bypass_05	0.10	8	3.8	81	

4.8 Post-Development Flood Conditions

4.8.1 Methodology

The *Alexandra Canal Catchment Flood Study* was prepared for the CoS by Cardno in 2014. As part of this study, a catchment wide flood model was developed using the SOBEK hydraulic modelling package. This model included a detailed representation of the underground drainage network. As part of subsequent work, the SOBEK model was converted to a TUFLOW hydraulic model.

Accompanying this model, a DRAINS hydrologic model has been prepared to provide inflow information to the hydraulic model. AECOM has adapted these models (as provided by Council on 29 February 2016) to undertake the present flood impact assessment. Modifications that have been made to the existing case models include:

- modifying the existing building outline polygons to represent the current building outlines as shown in recent aerial photographs
- including additional detail for the Waterloo Precinct, such as greater definition regarding street landscaping
- updating the terrain surrounding the Metro Quarter based on recent topographic survey
- refining the catchment inflows to provide a better representation of flow paths on the site and enable the AECOM DRAINS model to be used to represent the drainage on the site
- adding additional pipes and inlet pits to represent the existing drainage from the site
- undertaking a number of other minor adjustments to improve the numerical stability of the TUFLOW model.

For each design flood event, the modified existing case TUFLOW model was then run for a range of durations as outlined in the *Alexandra Canal Catchment Flood Study* (Cardno 2014). For the 100 year ARI events, 60 and 90 minute events were identified as being critical, while for the PMF the 30 and 45 minute durations were critical. Flood levels for each event are taken as the envelope of all the identified critical durations.

To reach a feasible solution for acceptable levels of personal and property safety, an iterative design process was followed and building levels were coordinated with the site architects and urban designers to ensure they are at or higher than the flood planning levels and are responsive to the recommended flood evacuation procedures.

4.8.2 Proposed Development Flood Depth, Flood Velocity and Flood Hazard

Flooding characteristics including flood depths, flood velocities and flood hazard for the proposed development are shown in Figure 30 to Figure 38 for the 20 year ARI, 100 year ARI, and the PMF events respectively. There is a significant area of ponding in Cope Street between the intersection with Wellington Street and extending to the intersection with John Street. This ponding is the result of significant overland flows passing down Cope Street, with contributions from within the Waterloo Estate. The model results indicated that the trunk drainage capacity downstream of Cope Street is insufficient to effectively drain this trapped low point.

Outside of the Metro Quarter and within the Waterloo SSP, there is an area of ponding on George Street between John Street and McEvoy Street. This is a result of a trapped low point that has formed in the terrain with insufficient drainage. Peak ponding depths are approximately in the range of 0.7m to 1.0m adjacent to the site along Cope Street.

4.8.3 Proposed Development Flood Impacts

As there is existing flooding in Cope Street, and the surrounding catchment is already constrained by development, there is little or no ability for any adverse flood impacts resulting from the proposed development on the site to be absorbed. Each building will contain an on-site detention tank, to reduce the peak outflow from the site, and this will assist in offsetting any potential adverse impacts downstream.

Flood impacts during the 20 year, 100 year ARI and PMF design storms, are shown in Figure 30 to Figure 38. In the model, for the 100 year ARI, the station box development in Waterloo results in minimal flood impacts in the surrounding streets and the surrounding properties are unaffected. No impacts on Cope Street north of Raglan Street upstream of the Metro Quarter, or in Wellington Street downstream of the Metro Quarter, are predicted by the flood model. Along Cope Street, where the footpath is to be widened, some localised adjustments are associated with the change in the finished surface level. Increases in flood levels of up to 60 millimetres and decreases of up to 100 millimetres are noted locally. Velocities in the existing and developed cases remain below 0.2 m/s on Raglan Street and reach up to 1.8 m/s on Cope Street. The rate of rise and duration of inundation at key building entry ways are changed by only a few minutes, as indicated in Figure 42 to Figure 44.

Flood depth, velocity, provisional hazard and rate of rise remain considerably unchanged, and no additional properties are impacted as a result of these alterations to the finished surface. Table 10 below is a summary of flooding characteristics, the spatial or temporal variability of which are demonstrated through several figures.

Table 10: Summary of Flooding Characteristics

Flooding Characteristic	Pre-Development	Post-Development
Flood Depth	Figure 15, Figure 16 and Figure 17	Figure 30, Figure 31 and Figure 32
Flood Velocity	Figure 18, Figure 19 and Figure 20	Figure 33, Figure 34 and Figure 35
Flood Hazard	Figure 21, Figure 22 and Figure 23	Figure 36, Figure 37 and Figure 38
Flood Impact	Figure 39, Figure 40 and Figure 41	
Rate of Rise	Figure 42, Figure 43 and Figure 44	

Hence, while flood levels following the development of the Metro Quarter are expected to rise due to widening of kerbs, regrading of road and some landscaping, this will not have an adverse impact on existing development.

4.8.4 Cumulative Flood Impacts

Flood risk assessment for the Metro Quarter has taken into consideration the proposed development for the site. Since the site is expected to be developed before the wider Waterloo Precinct and because the adjacent areas in the catchment are fully developed, any further development will not have an impact on the future cumulative flood risk.

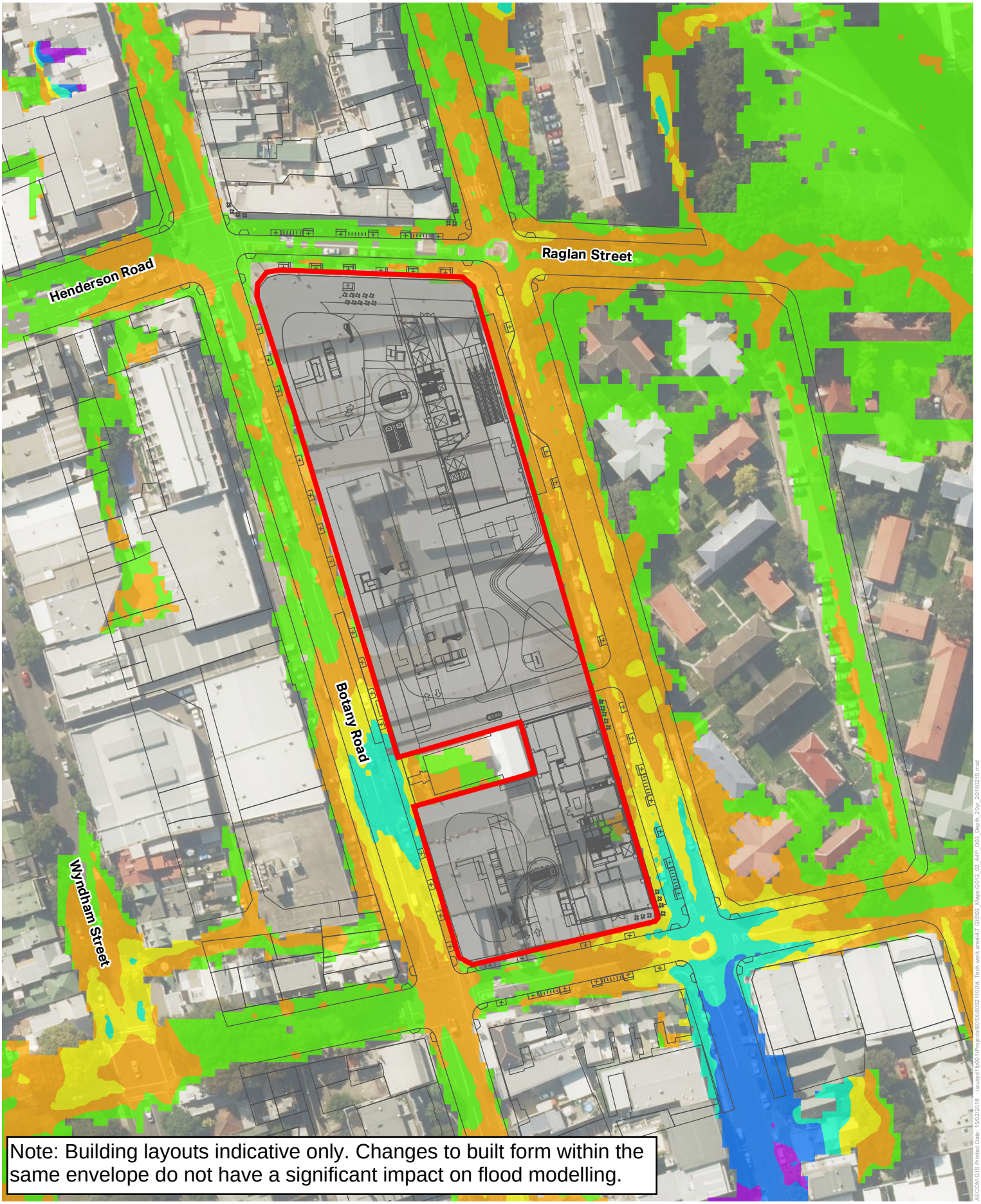

FIGURE 30 - PROPOSED DEVELOPMENT 20YR ARI: FLOOD DEPTHS

WATERLOO METRO QUARTER

AECOM

0 25 50 m

KEY

Peak Depth (m)

- 0.00 to 0.10
- 0.11 to 0.30
- 0.31 to 0.49
- 0.50 to 0.69
- 0.70 to 0.99
- >1.00

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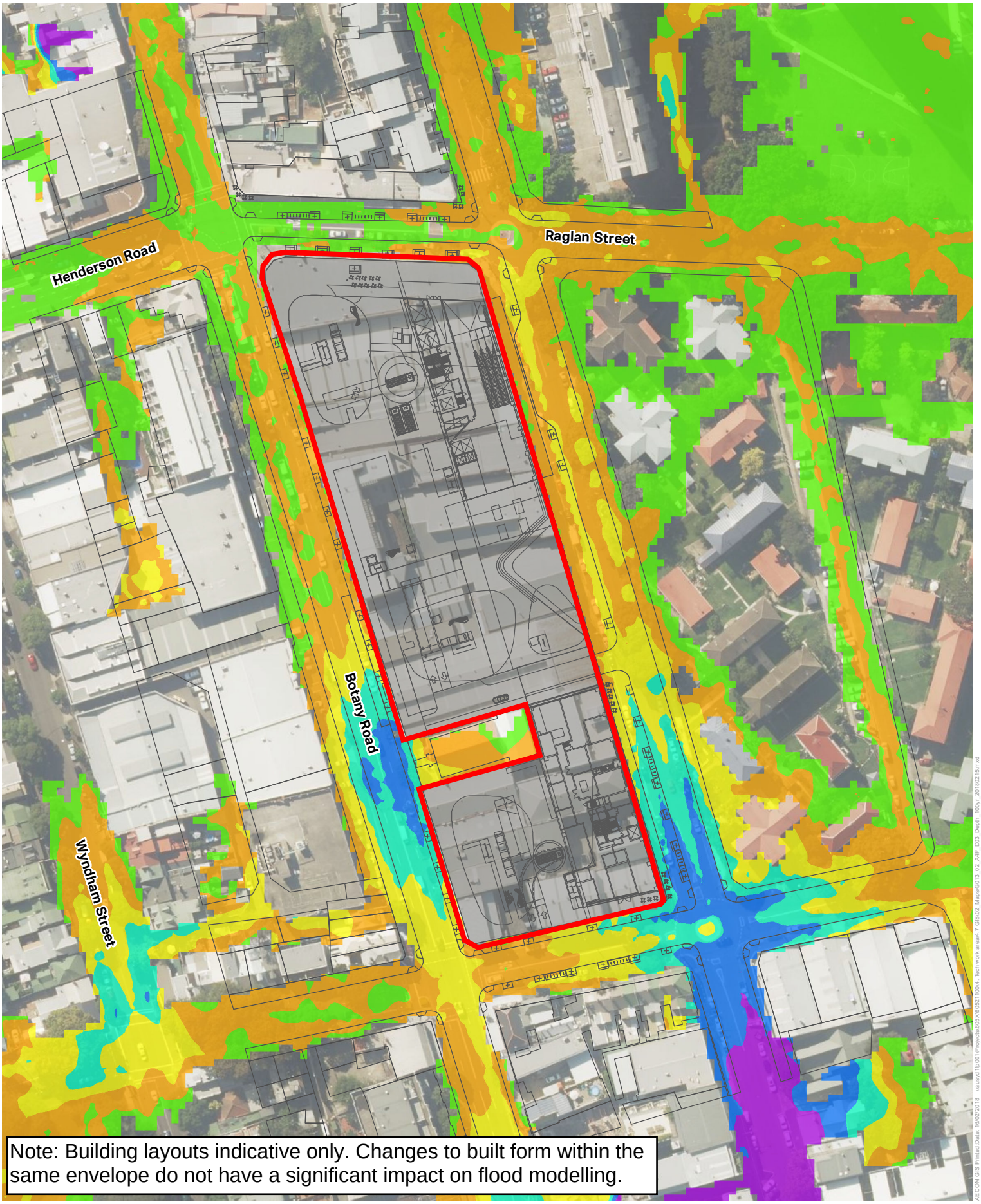

FIGURE 31 - PROPOSED DEVELOPMENT 100YR ARI: FLOOD DEPTHS

WATERLOO METRO QUARTER

AECOM

0 25 50 m

KEY

Peak Depth (m)

- 0.00 to 0.10
- 0.11 to 0.30
- 0.31 to 0.49
- 0.50 to 0.69
- 0.70 to 0.99
- >1.00

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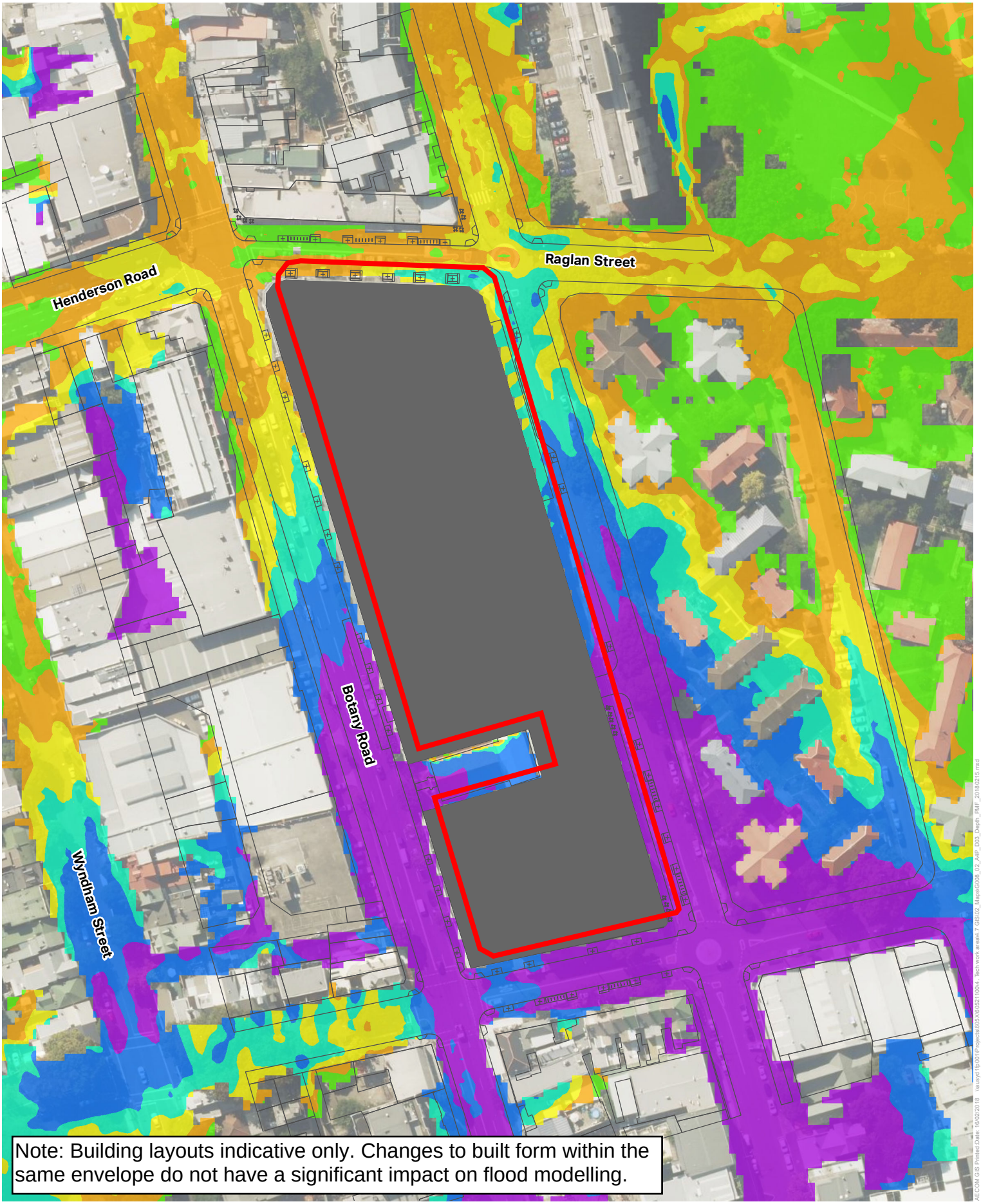

FIGURE 32 - PROPOSED DEVELOPMENT PMF: FLOOD DEPTHS

WATERLOO METRO QUARTER

AECOM

0 25 50 m

KEY

Peak Depth (m)

- 0.00 to 0.10
- 0.11 to 0.30
- 0.31 to 0.49
- 0.50 to 0.69
- 0.70 to 0.99
- >1.00

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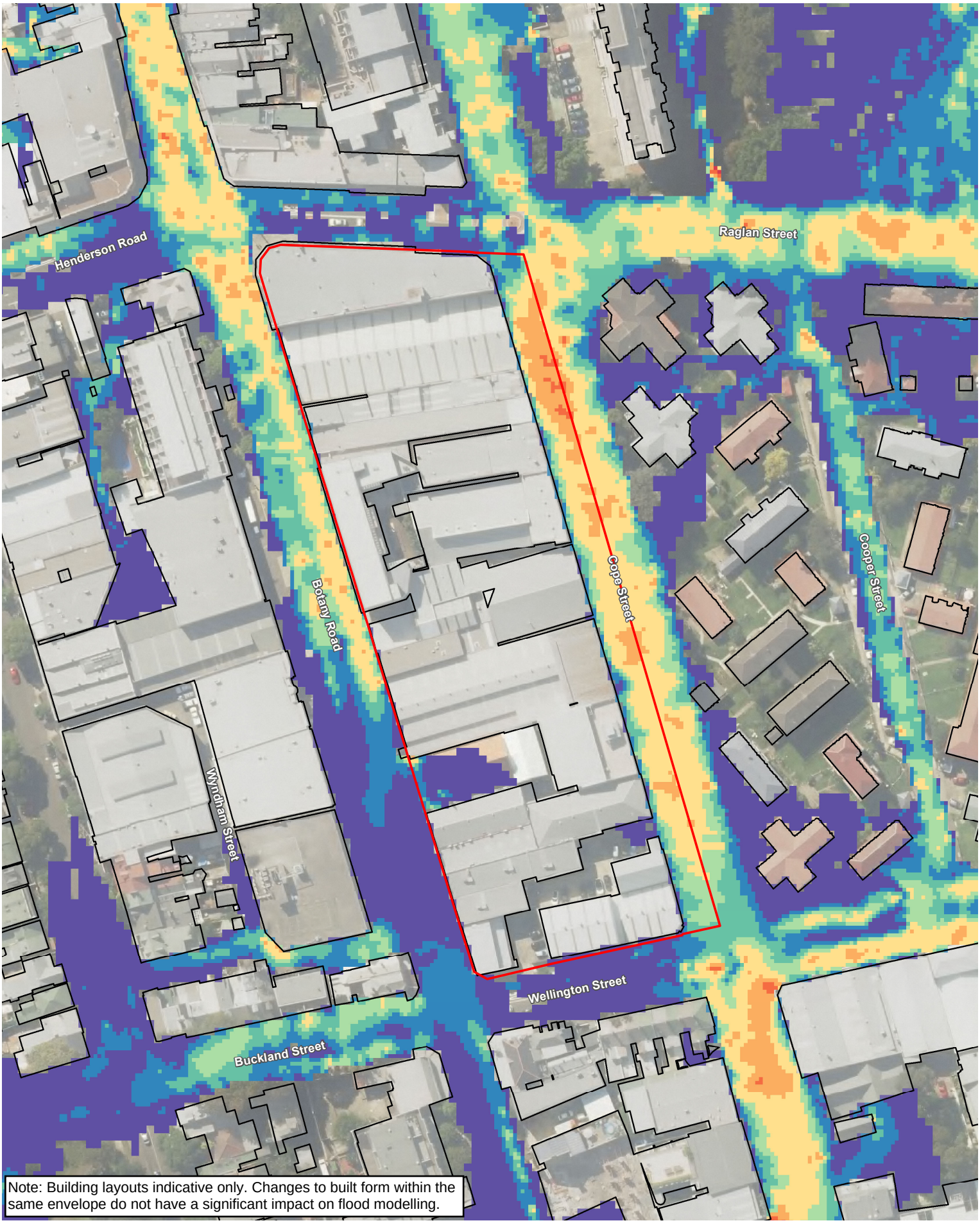

FIGURE 33 - WATERLOO METRO QUARTER - PRE-DEVELOPMENT - 20YR ARI FLOOD VELOCITY

AECOM

N 0 15 30 m

KEY

Site boundary
Building footprint

Flood Velocity (m/s)

- Less than 0.25
- 0.25 - 0.5
- 0.50 - 0.75
- 0.75 - 1
- 1.0 - 1.5
- 1.5 - 2
- 2.0 - 2.5
- 2.5 - 3
- Greater than 3

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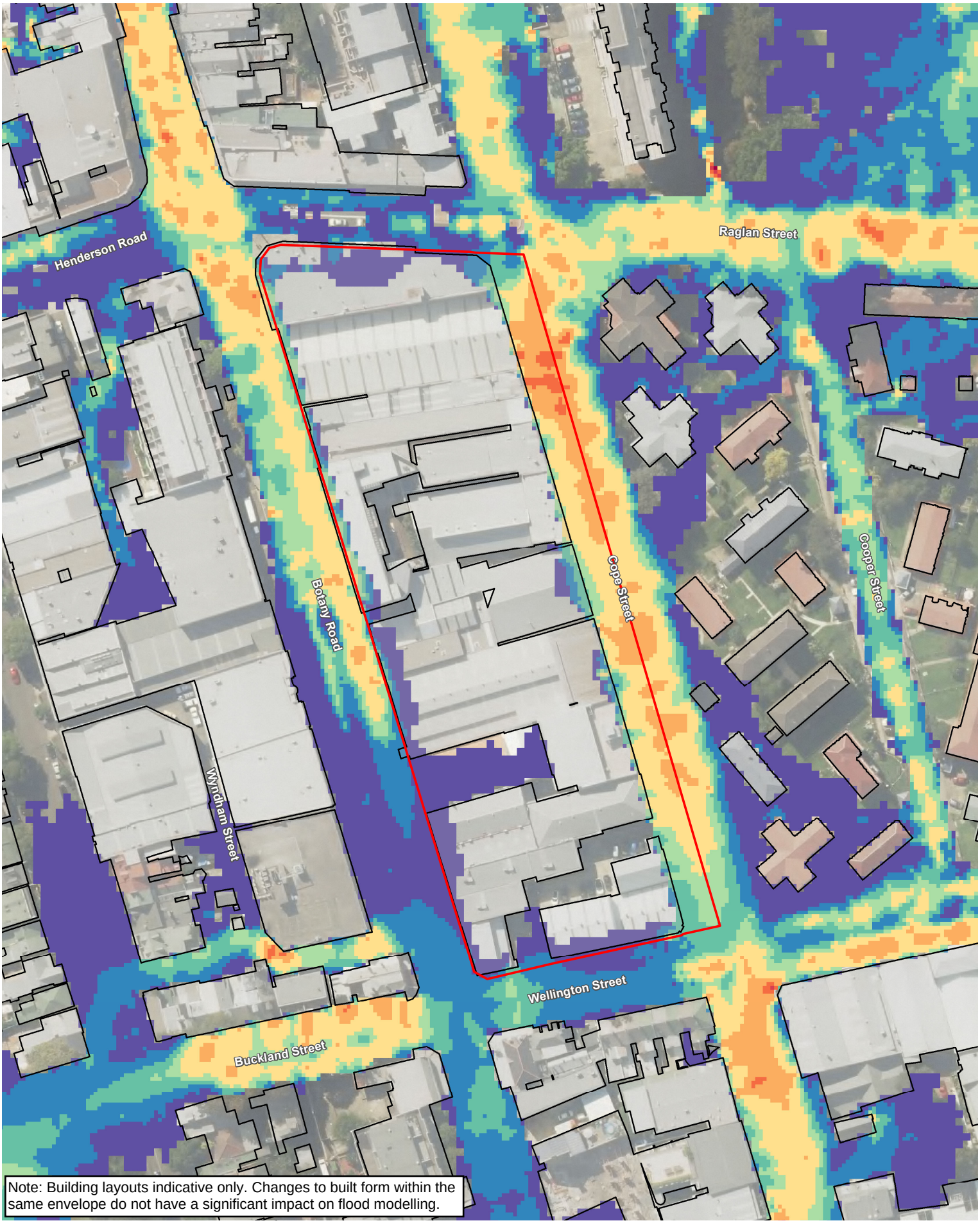

FIGURE 34 - WATERLOO METRO QUARTER - POST-DEVELOPMENT - 100YR ARI FLOOD VELOCITY

AECOM

N 0 15 30 m

KEY

Site boundary
Building footprint

Flood Velocity (m/s)

- Less than 0.25
- 0.25 - 0.5
- 0.50 - 0.75
- 0.75 - 1
- 1.0 - 1.5
- 1.5 - 2
- 2.0 - 2.5
- 2.5 - 3
- Greater than 3

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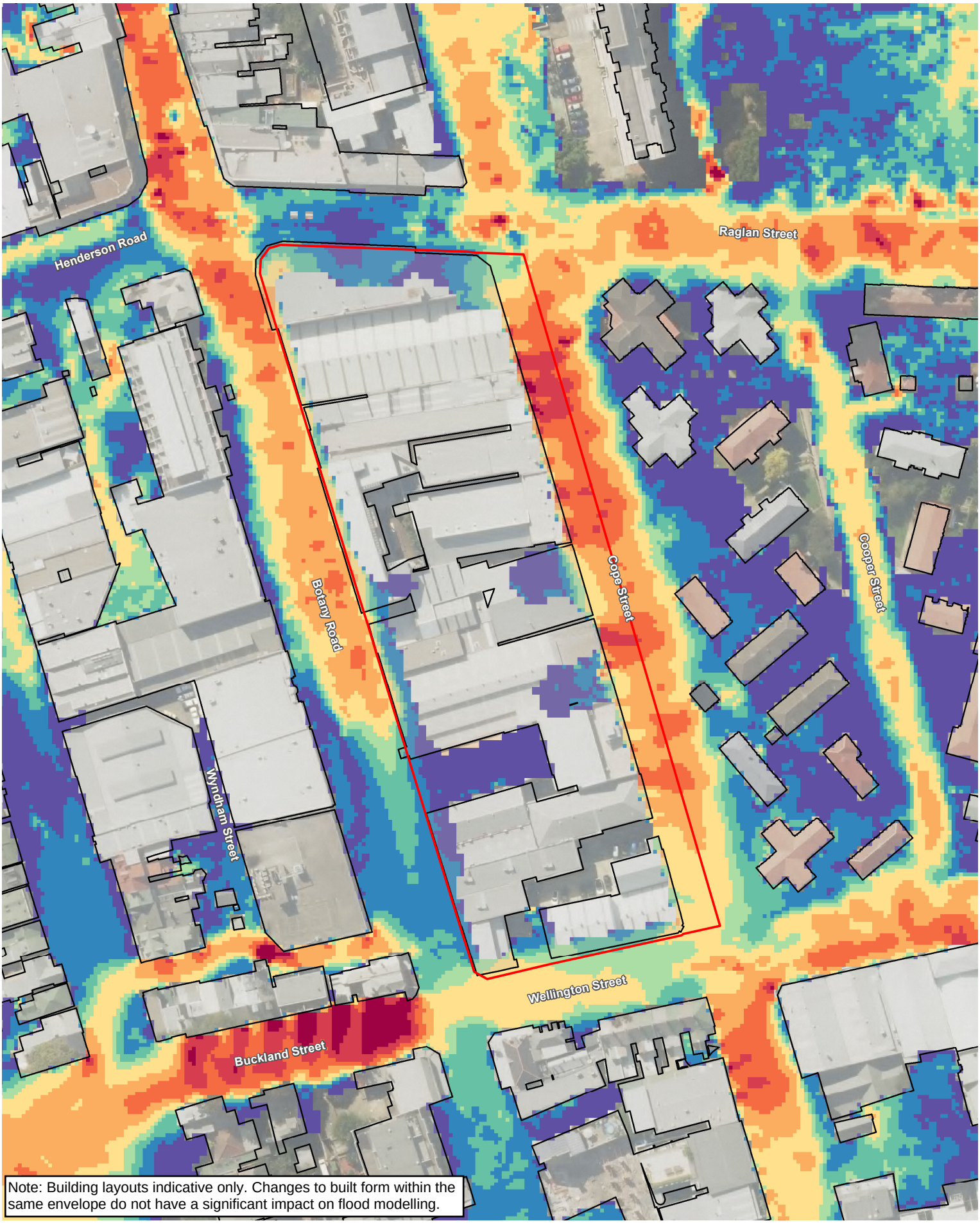

FIGURE 35 - WATERLOO METRO QUARTER - POST-DEVELOPMENT - PMF FLOOD VELOCITY

AECOM

0 15 30 m

KEY

Site boundary
Building footprint

Flood Velocity (m/s)

- Less than 0.25
- 0.25 - 0.5
- 0.50 - 0.75
- 0.75 - 1
- 1.0 - 1.5
- 1.5 - 2
- 2.0 - 2.5
- 2.5 - 3
- Greater than 3

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FIGURE 36 - WATERLOO METRO QUARTER - POST-DEVELOPMENT - 20YR ARI FLOOD HAZARD

AECOM

N 0 15 30 m

KEY

Site boundary
Building footprint

Flood Hazard
Low Hazard
Transitional Hazard
High Hazard

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FIGURE 37 - WATERLOO METRO QUARTER - POST-DEVELOPMENT - 100YR ARI FLOOD HAZARD

AECOM

N 0 15 30 m

KEY

Site boundary
Building footprint

Flood Hazard
Low Hazard
Transitional Hazard
High Hazard

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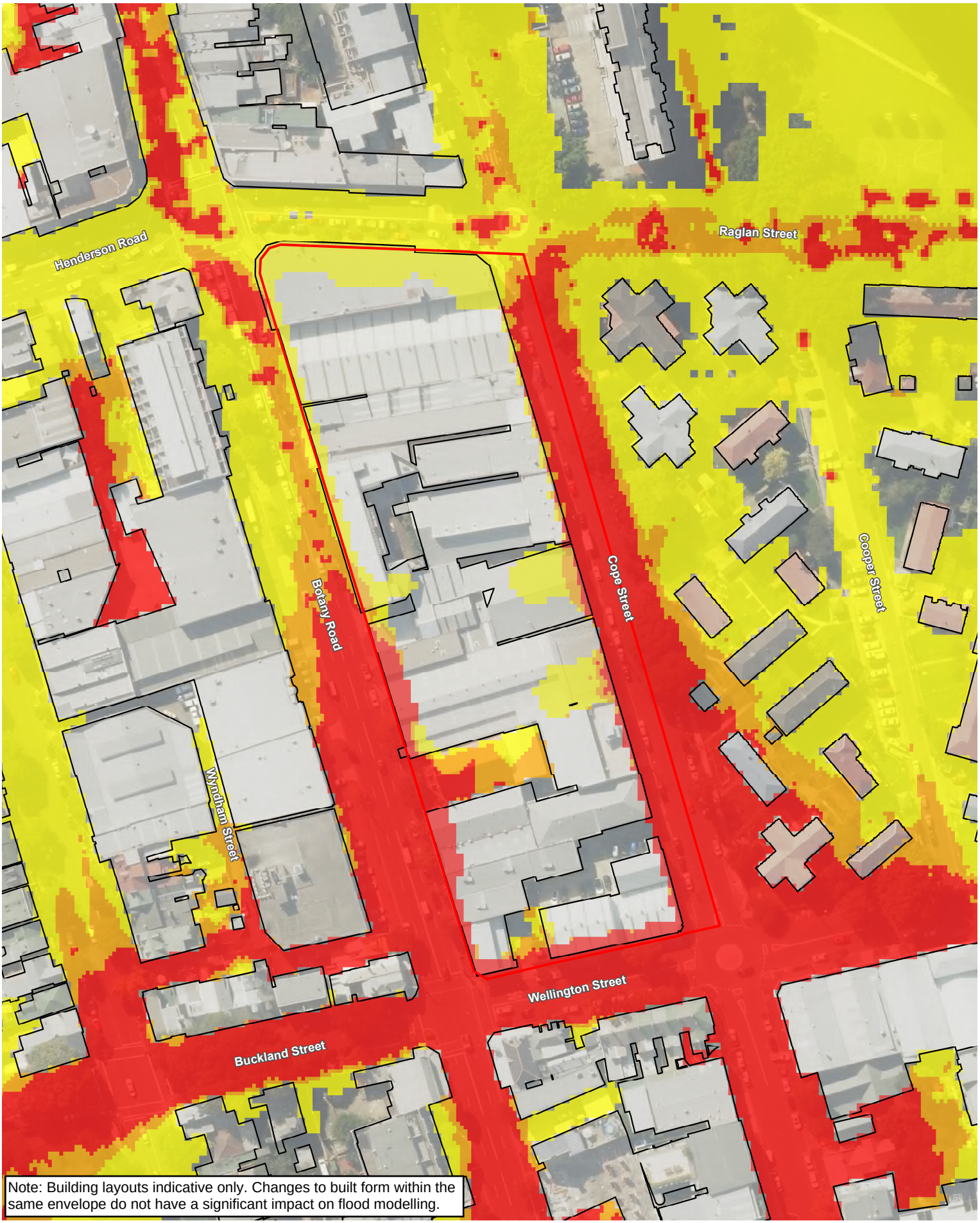

FIGURE 38 - WATERLOO METRO QUARTER - POST-DEVELOPMENT - PMF FLOOD HAZARD

AECOM

N 0 15 30 m

KEY

Site boundary
Building footprint

Flood Hazard
Low Hazard
Transitional Hazard
High Hazard

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FIGURE 39 - PROPOSED DEVELOPMENT 20YR ARI: FLOOD IMPACTS

WATERLOO METRO QUARTER

KEY

- Was wet, now dry
- Was dry, now wet

Relative Flood Level Impact (m)

- Greater than -0.3
- -0.3 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.15
- 0.15 to 0.3
- Greater than 0.3

AECOM

N

0 25 50 m

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FIGURE 40 - PROPOSED DEVELOPMENT 100YR ARI: FLOOD IMPACTS

WATERLOO METRO QUARTER

KEY

- Was wet, now dry
- Was dry, now wet

Relative Flood Level Impact (m)

- Greater than -0.3
- -0.3 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.15
- 0.15 to 0.3
- Greater than 0.3

AECOM

N

0 25 50 m

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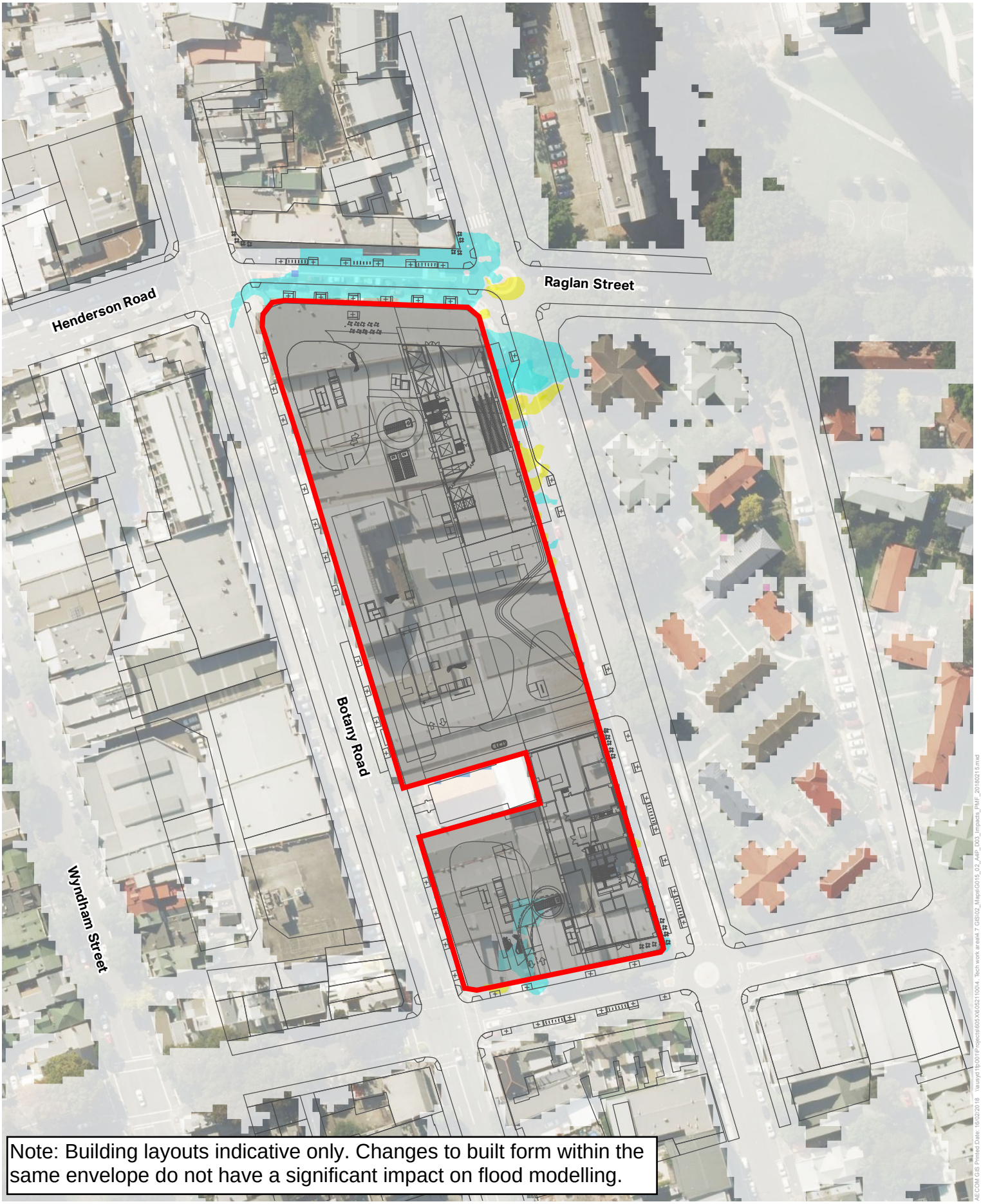

Note: Building layouts indicative only. Changes to built form within the same envelope do not have a significant impact on flood modelling.

FIGURE 41 - PROPOSED DEVELOPMENT PMF: FLOOD IMPACTS

WATERLOO METRO QUARTER

KEY

- Was wet, now dry
- Was dry, now wet

Relative Flood Level Impact (m)

- Greater than -0.3
- -0.3 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.15
- 0.15 to 0.3
- Greater than 0.3

AECOM

N

0 25 50 m

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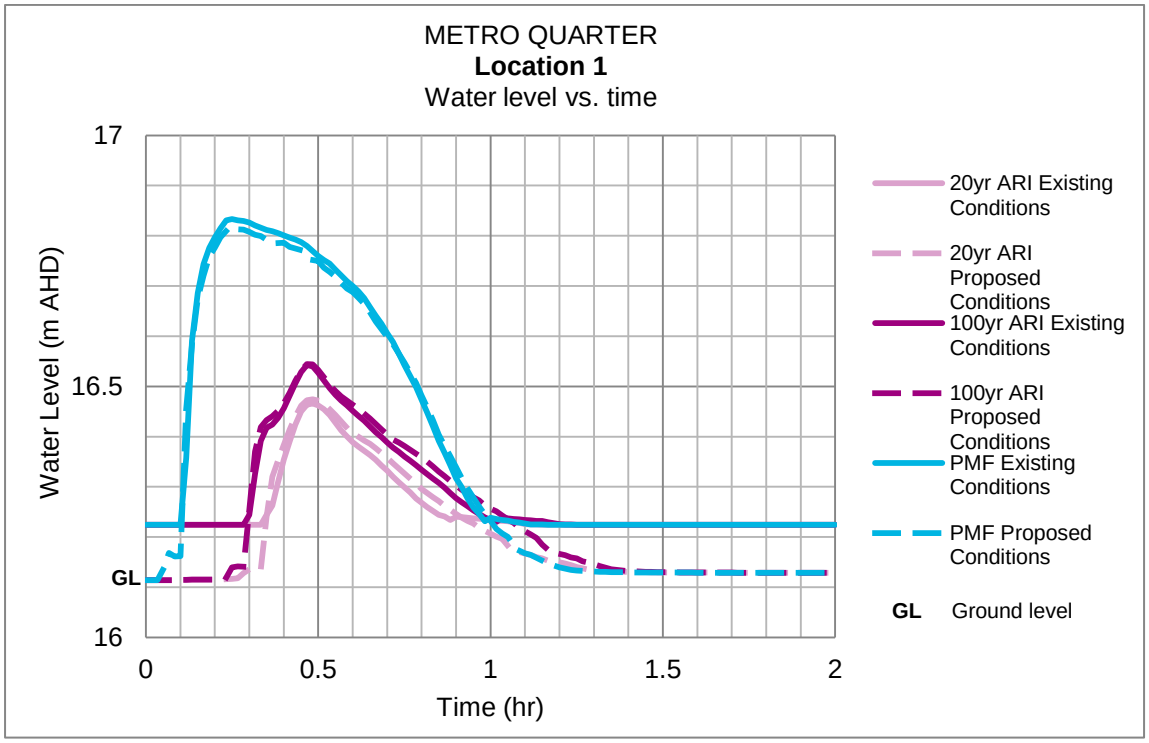


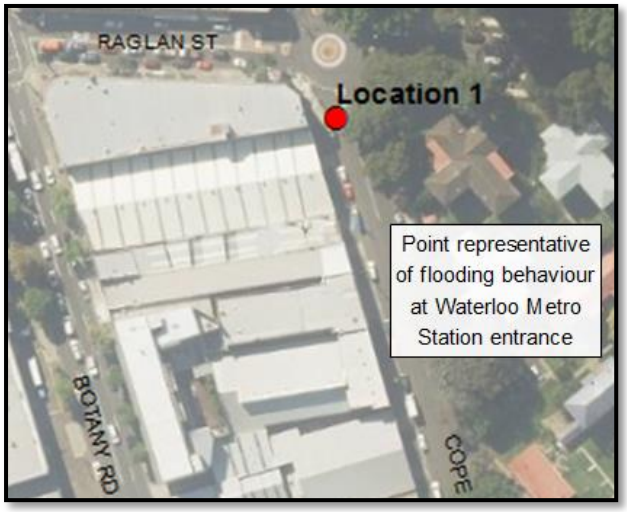
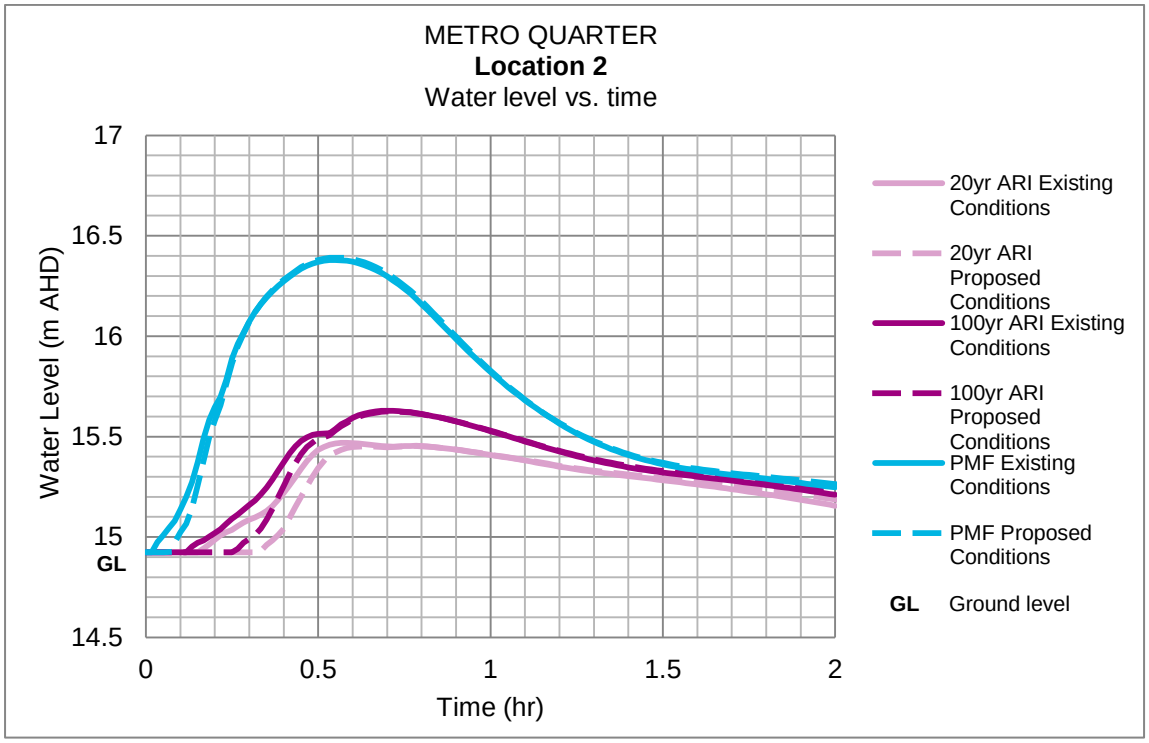


Figure 42: Existing and Proposed Development: Rate of Rise at Location 1 (Metro Quarter North)



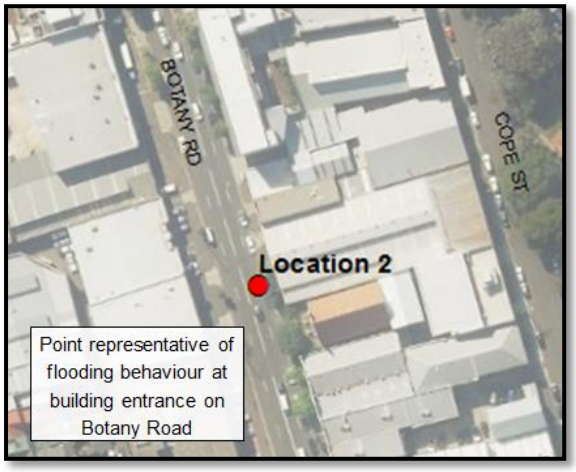


Figure 43: Existing and Proposed Development: Rate of Rise at Location 2 (Metro Quarter West)

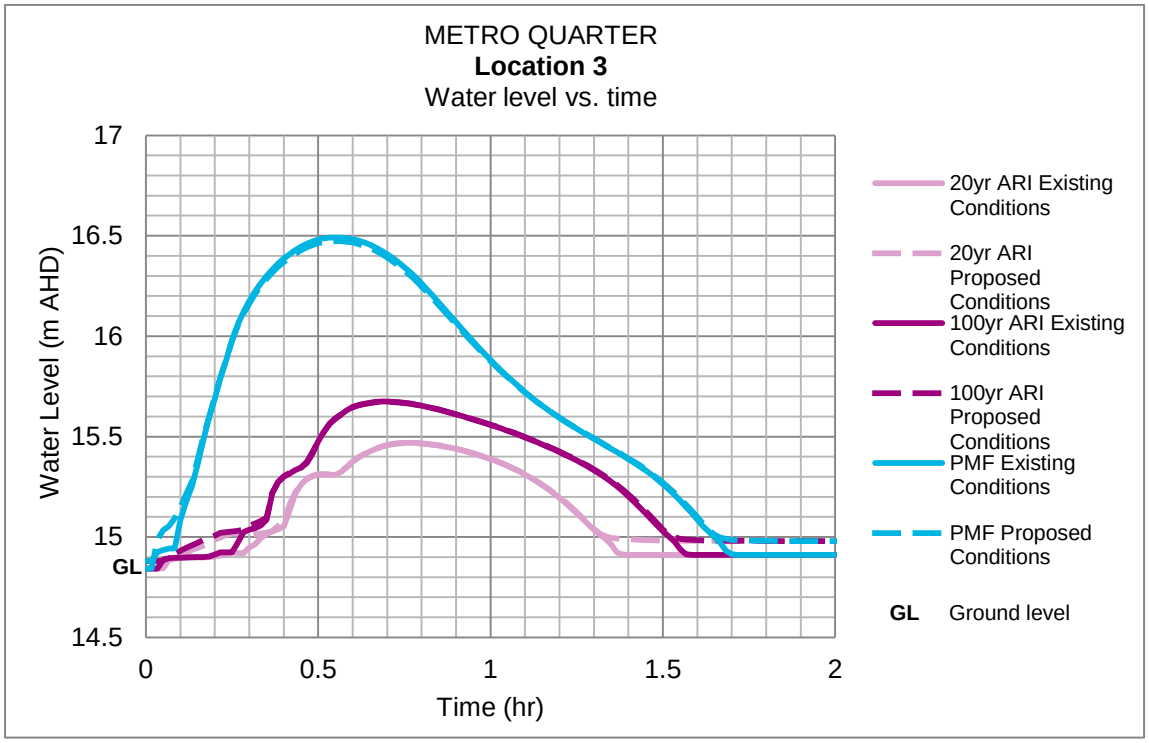


Figure 44: Existing and Proposed Development: Rate of Rise at Location 3 (Metro Quarter South)

4.8.5 Flood Planning Levels (FPLs)

The proposed site has been designed to account for the flood risks prevalent throughout and surrounding the site. Proposed ground levels will be raised to ensure there are no floodwater breeches from significant storm events particularly at Metro and building entrances. Section 4.1.2 reflects the permissible minimum building floor levels and below ground development FPLs in accordance with *Interim Floodplain Management Policy* (CoS, 2014).

Recommended FPLs for Metro Quarter are shown in Figure 46 where the adopted criterion for setting of flood planning level was maximum of PMF and 100 year ARI +0.5m. The FPLs for areas contiguous with the Waterloo Metro station including station entrances are subject to the CSSI Approval and confirmation by TfNSW / Sydney Metro.

Building levels have been coordinated with the site architect to ensure that acceptable levels of personal and property safety are achieved. For public private domain engagement, this has required setting of appropriate FPL for retail establishments. While their entrances can be at street level, a stepped up zone inside ground level retail properties above the FPL will need to be considered by site architects, where possible, to facilitate shelter in place evacuation discussed in Section 4.10. An indicative internal treatment for retail properties is shown in the Figure 45 below which could be developed during the detailed design phase. Treatment options for retail properties affected by flooding should be developed further during the detailed design phase.

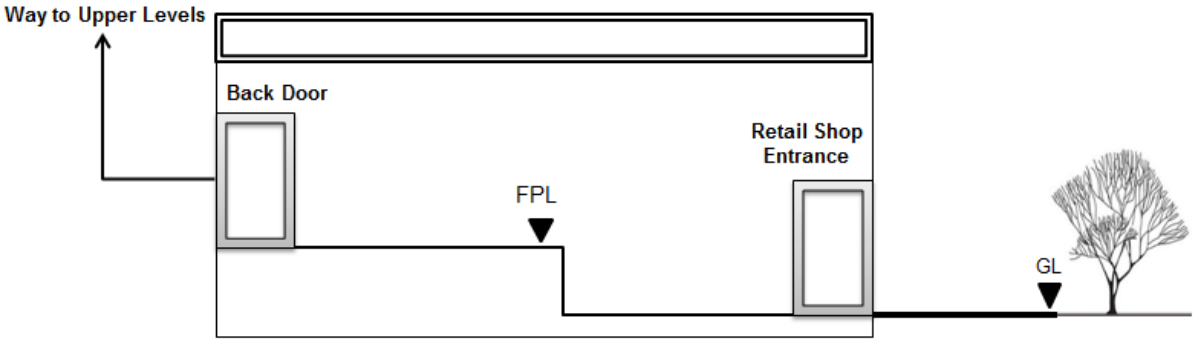
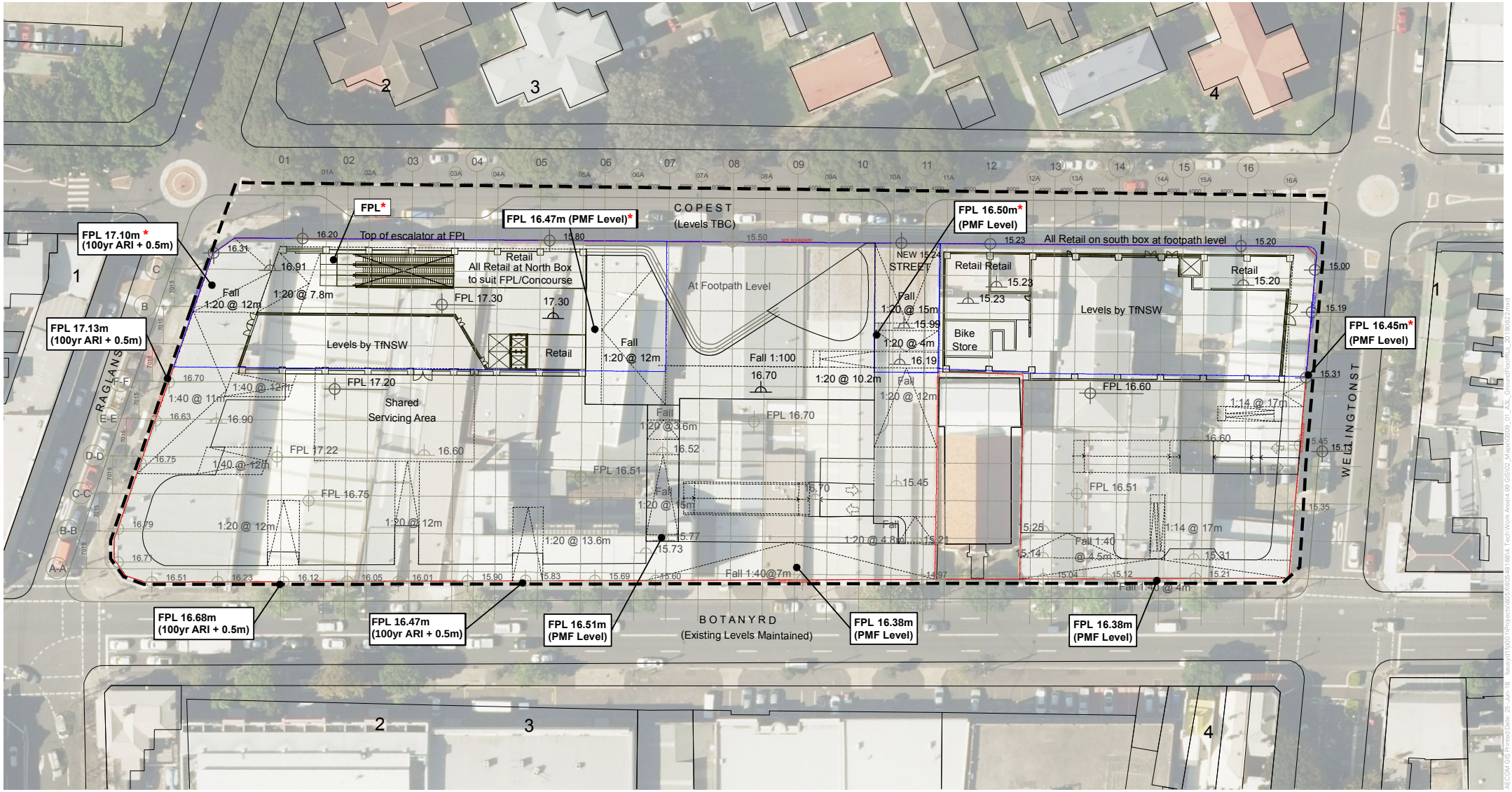


Figure 45: Indicative internal treatment for retail properties


FPL*
FPL 17.10m * (100yr ARI + 0.5m)
FPL 17.13m (100yr ARI + 0.5m)
FPL 16.47m (PMF Level)*
FPL 16.50m* (PMF Level)
FPL 16.45m* (PMF Level)
FPL 16.68m (100yr ARI + 0.5m)
FPL 16.47m (100yr ARI + 0.5m)
FPL 16.51m (PMF Level)
FPL 16.38m (PMF Level)
FPL 16.38m (PMF Level)
Top of escalator at FPL
Retail
All Retail at North Box to suit FPL/Concourse
COPEST
(Levels TBC)
At Footpath Level
All Retail on south box at footpath level
Retail Retail
Retail
Bike Store
Levels by TfNSW
Levels by TfNSW
Shared Servicing Area
Retail
NEW STREET
RAGLAN ST
WELLINGTON ST
BOTANY RD
(Existing Levels Maintained)
FPL 17.30
FPL 17.20
FPL 17.22
FPL 16.75
FPL 16.51
FPL 16.70
FPL 16.60
FPL 16.51
Fall 1:20 @ 12m
Fall 1:20 @ 7.8m
Fall 1:40 @ 11m
Fall 1:40 @ 12m
Fall 1:20 @ 3.6m
Fall 1:20 @ 15m
Fall 1:20 @ 13.6m
Fall 1:100
Fall 1:20 @ 10.2m
Fall 1:20 @ 4m
Fall 1:20 @ 4.8m
Fall 1:40@7m
Fall 1:40 @ 4.5m
Fall 1:14 @ 17m
Fall 1:20 @ 12m
Fall 1:20 @ 15m
Fall 1:20 @ 12m
Fall 1:40 @ 4m
1:14 @ 17m
1:14 @ 17m
1:20 @ 12m
1:20 @ 12m
1:20 @ 12m
1:40 @ 12m
1:40 @ 12m
1:20 @ 12m
1:20 @ 12m
1:20

4.9 Climate Change

4.9.1 Climate Change Sensitivity Analysis

This section should be read in conjunction with the *Climate Change Adaptation Report Waterloo - Metro Quarter* (AECOM, 2018).

Changing rainfall patterns are often associated with climate change. These include increased average temperatures and shorter but more intense summer rainfalls which introduce additional flood risks to the Metro Quarter site.

A sensitivity analysis for climate change has been performed for both the existing and proposed development cases. The current climate change guidelines in Australia are based on the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5). The recent draft revision of Australian Rainfall and Runoff (ARR 2016) provides guidelines for assessing climate change impacts on flood behaviour and is based on IPCC AR5 projections. It recommends a risk-based approach that considers:

- Regional climate change projections
- Service life of asset/planning horizon
- Design standard
- Purpose and nature of the asset
- Consequence of failure of the asset

Current climate change projections as documented in IPCC AR5 are based on four climate change futures, which are classified based on likely predictions of greenhouse gases emitted in the years to come. These are called Representative Concentration Pathways (RCPs). A 10 percent increase in rainfall intensity corresponds to 2090 conditions predicted under the RCP 4.5 emissions scenario (ARR 2016).

The sensitivity analysis for Metro Quarter was undertaken by increasing the rainfall intensity by 10 percent for the 100 year ARI, in line with the requirement adopted for Sydney Metro which has been derived from ARR 2016 and OEH Guidelines. Flood modelling results including flood depths and flood impacts for the existing and proposed cases are shown in Figure 47, Figure 48 and Figure 49.

Increasing the 100 year ARI rainfall intensity by 10 percent to account for potential future climate change increased flood level around the Metro Quarter by up to 60 mm. As such, the FPL at locations where it is less than the PMF level will increase by up to 60 mm in the northern portion of the site.

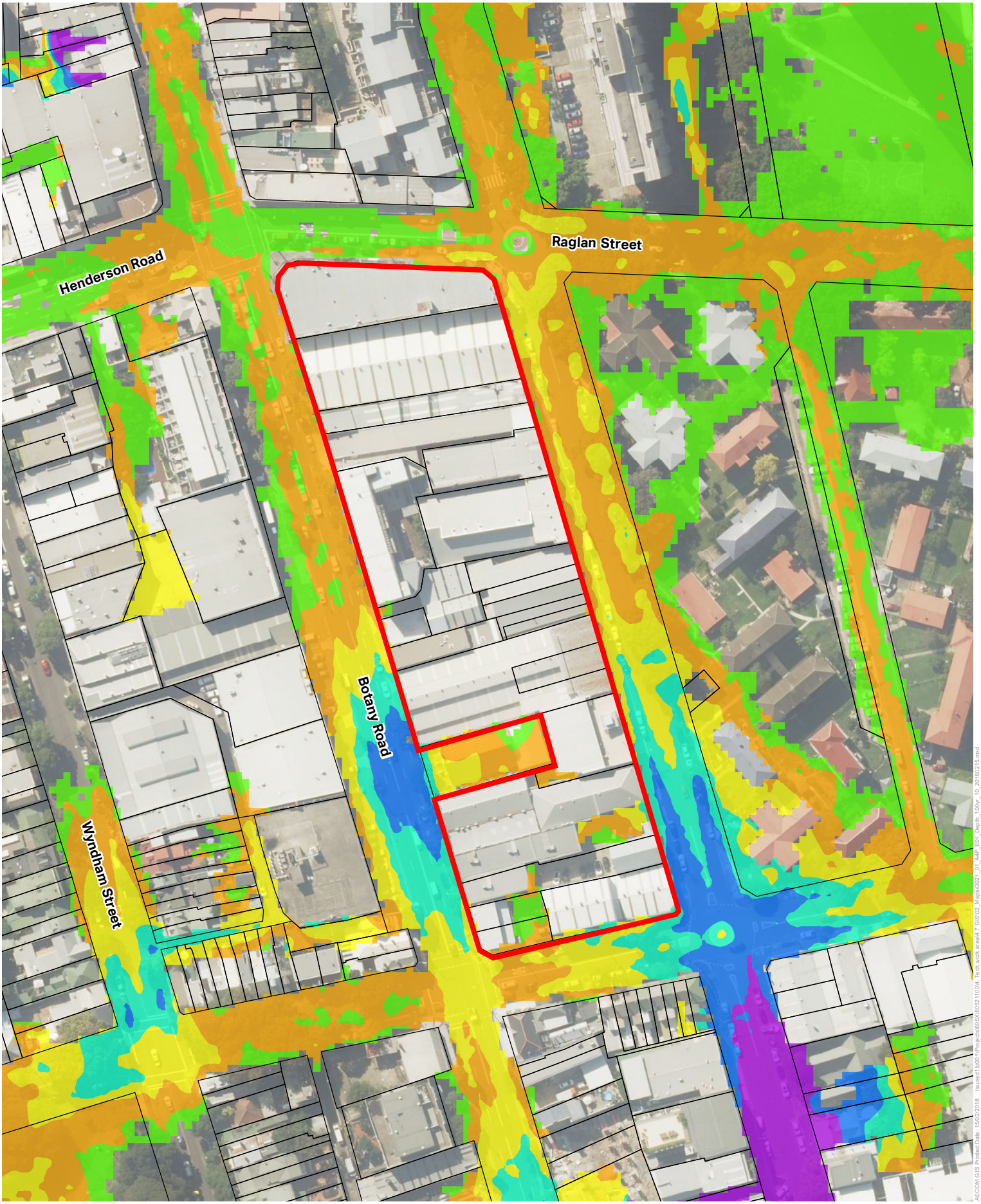


FIGURE 47 - EXISTING CASE 100YR ARI FLOOD DEPTHS (INC CLIMATE CHANGE) (+10% ARI INCREASE TESTED)

WATERLOO METRO QUARTER

KEY

Peak Depth (m)

- 0.00 to 0.10
- 0.11 to 0.30
- 0.31 to 0.49
- 0.50 to 0.69
- 0.70 to 0.99
- >1.00

AECOM

N

0 25 50 m

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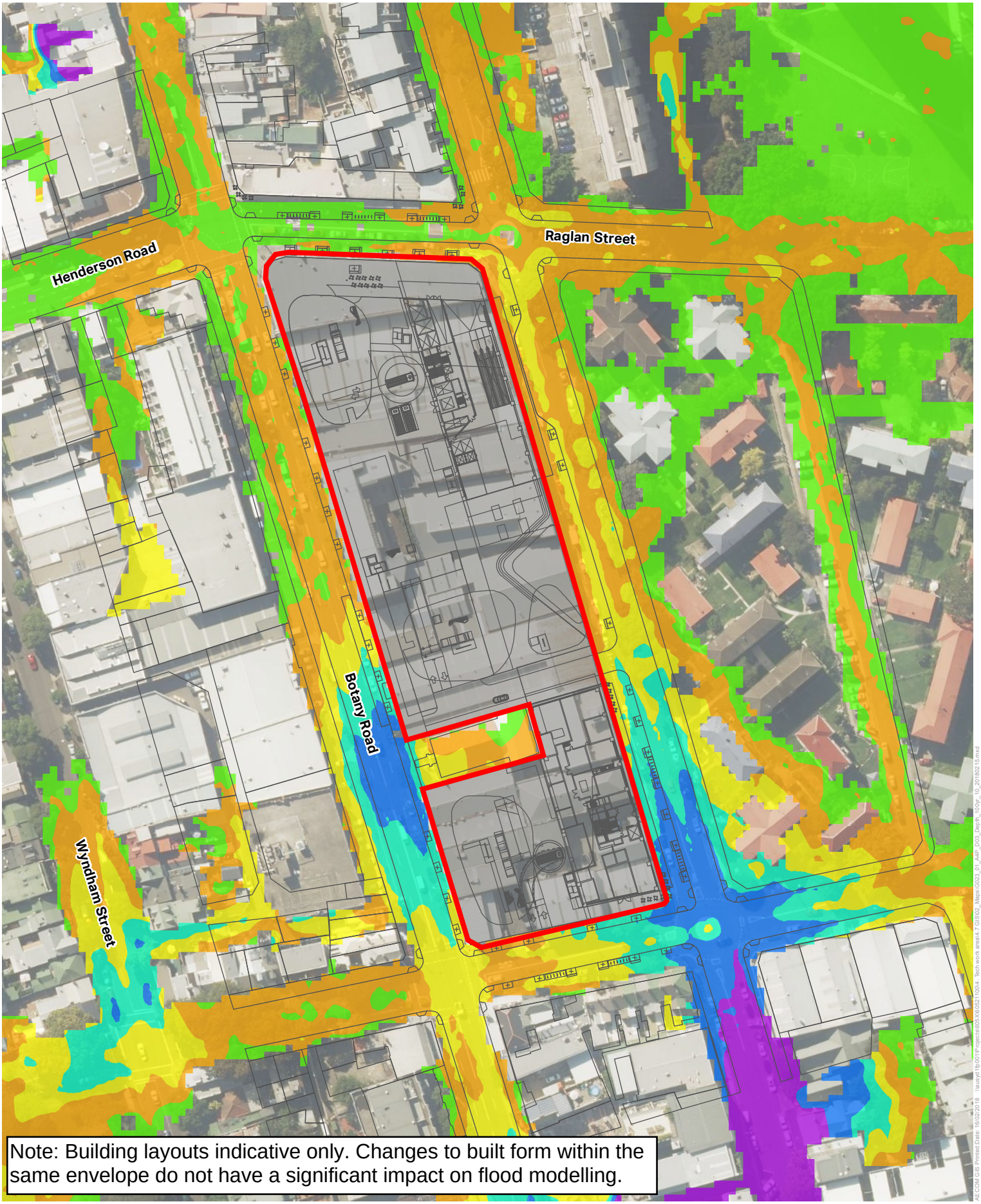

FIGURE 48 - PROPOSED DEVELOPMENT 100YR ARI FLOOD DEPTHS (INC CLIMATE CHANGE) (+10% ARI INCREASE TESTED)

WATERLOO METRO QUARTER

KEY

Peak Depth (m)

- 0.00 to 0.10
- 0.11 to 0.30
- 0.31 to 0.49
- 0.50 to 0.69
- 0.70 to 0.99
- >1.00

AECOM

N

0 25 50 m

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FIGURE 49 - PROPOSED DEVELOPMENT 100YR ARI FLOOD IMPACTS (INC CLIMATE CHANGE) (+10% ARI INCREASE TESTED)

AECOM

N

0 25 50 m

KEY

- Was wet, now dry
- Was dry, now wet

Relative Flood Level Impact (m)

- Greater than -0.3
- -0.3 to -0.15
- -0.15 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.15
- 0.15 to 0.3
- Greater than 0.3

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4.10 Emergency Response

Potential emergency response measures have been identified to assist in reducing the consequences of flood risks. For the Metro Quarter, this will primarily rely on adopting an appropriate FPL, and ensuring that developments are sufficiently raised to enable a shelter in place strategy to be effective.

Evacuation of the metro station, including retail tenancies within the two above ground structures, is subject to the CSSI Approval and will be managed through the detailed design phase of that application.

Sufficient warning time can be provided for the occupied areas including retail levels where the occupants will need to move to the stepped up shelter in place zone within their property (refer to Figure 50) to get to the muster point such as the loading dock.

During infrequent and rare flood events, potentially hazardous flood conditions may temporarily impede emergency vehicles from accessing the Metro Quarter, as flood depths exceed 1 metre on the southern side. It may be possible for emergency vehicles to access the Metro Quarter from Raglan Street; however this will be dependent on the flood conditions in the surrounding streets, as well as the judgment of the vehicle operator. The expected duration of flooding is anticipated to be relatively short, with the flooding along Cope Street and Botany Road responding quickly to local rainfall. As a consequence, flood levels will recede relatively quickly (approximately 1 hour following storm commencement) which will eventually allow vehicle access to the Metro Quarter following the rainfall event. Isolated ponding areas may remain throughout the catchment that take longer to recede, and these may contribute to traffic issues.

The flood hazard is most appropriately managed for residents with a shelter in place strategy, as the duration of inundation is relatively short and the rate of rise is relatively rapid. Any residual risks to the residential areas, and the risks to the retail spaces, will require an operational flood emergency response plan. This plan can be supported with appropriate design features as identified in the report (refer to Section 4.8.5). Future work should be undertaken to:

- Develop an operational flood emergency response plan. The plan will, at a minimum, confirm the most appropriate response strategy, nominate shelter locations or muster points, plot the recommended evacuation routes, consider the timeline to execute the plan, identify trigger conditions for initiating the plan, and assign specific responsibilities;
- Provide appropriate facilities and shelter spaces to support the response strategy;
- Consult the local State Emergency Service (SES) and other emergency services;
- Communicate the plan to residents and other building occupants; and
- Develop an appropriate operational response for the station (under separate approval) to manage the number of people who may be exiting the station during a flood event. Station box retail spaces are also considered under a separate approval which will undergo their own detailed design (including flooding emergency).

It should be noted that the detailed design of site may necessitate formulation of improved emergency response frameworks in which additional studies will be required in the detailed design phase.

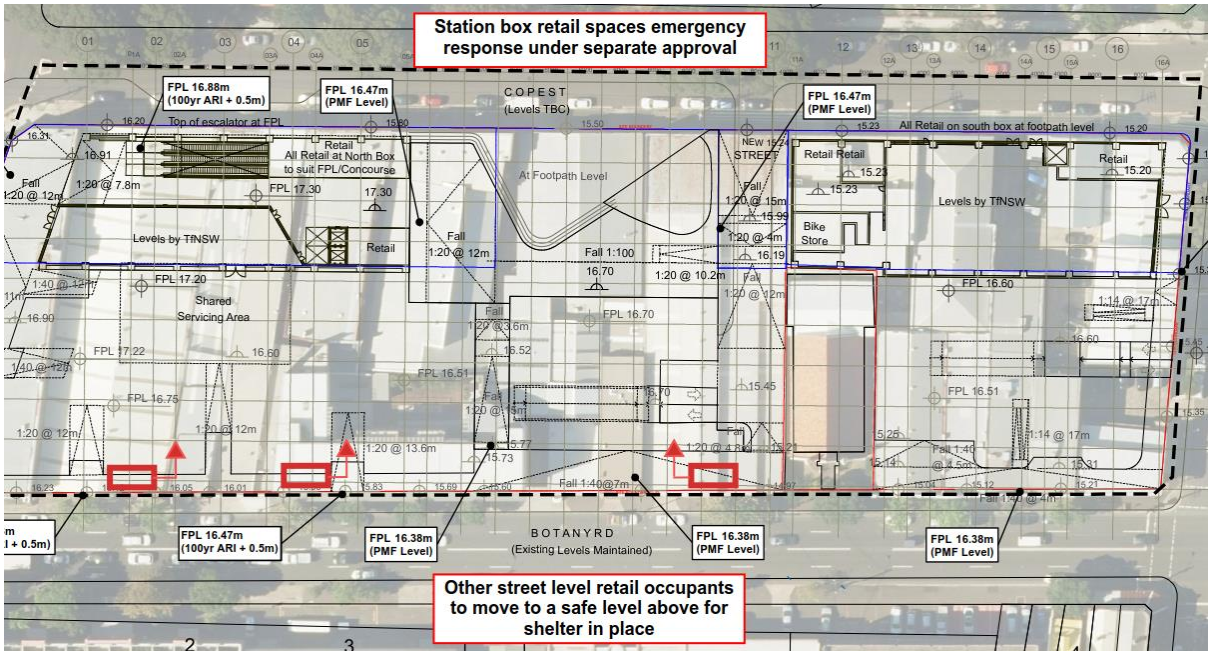

Figure 50: Emergency Response

5.0 Implementation Plan & Strategy

5.1 Stormwater and Flooding Management Plan

A combined stormwater and flooding management plan for the Metro Quarter site is shown in the Figure 51.

5.2 Draft Waterloo Metro Quarter DCP Provisions

A summary of the proposed provisions in the draft Waterloo Metro Quarter DCP, which is submitted as part of the SSP Study, is provided in the table below.

Table 11: DCP Provisions

Measure		Recommended Provision
On-Site Detention		Combined on-site detention tank volume of 480 m^3
Water Quality Targets and WSUD		• Reduction of baseline annual pollutant load for litter and vegetation larger than 5mm by 90 percent; • Reduction of baseline annual pollutant load for total suspended solids by 85 percent; • Reduction of baseline annual pollutant load for total phosphorous by 65 percent; and • Reduction of baseline annual pollutant load for total nitrogen by 45 percent.
Flood Planning Levels		
Residential	Habitable rooms	100 year ARI flood level + 0.5 m or the PMF (whichever is the higher).
	Non-habitable rooms such as a laundry or garage (excluding below-ground car parks)	100 year ARI flood level.
Industrial or Commercial	Retail Floor Levels	100 year ARI flood level. Stepped up zone inside property for shelter in place evacuation for emergency response.
Below ground garage/ car park	All other below-ground car parks	100 year ARI flood level + 0.5 m or the PMF (whichever is the higher).
Areas contiguous with Waterloo Metro Station (including station entrances)	To be compliant with the *Critical State Significant Infrastructure Sydney Metro City & Southwest Chatswood to Sydenham Conditions of Approval* dated 9 January 2017.	

Note: It is recommended that CoS carry forward other existing provisions pertaining to stormwater and flooding outlined in the SDCP 2012.

The key factors that need to be taken into consideration at the implementation stage are:

1) Each developer is responsible for managing rainfall run-off from their respective development sites;
2) The total required On-Site Detention volume is approximately 480m^3 split through a number of different catchment zones. Refer to Section 4.5. Hydraulic calculations at the detailed design development stage will determine the final detention storage volumes, outlets and interfaces;
3) On-Site Detention should be situated above the 100 year ARI Flood Level to facilitate discharge into potentially fully charged stormwater pipes;
4) Building floor levels to be assessed against proposed flood depths to mitigate future flood risks; and
5) Flood protection and on-site detention is required prior to any construction or occupancy certificate.

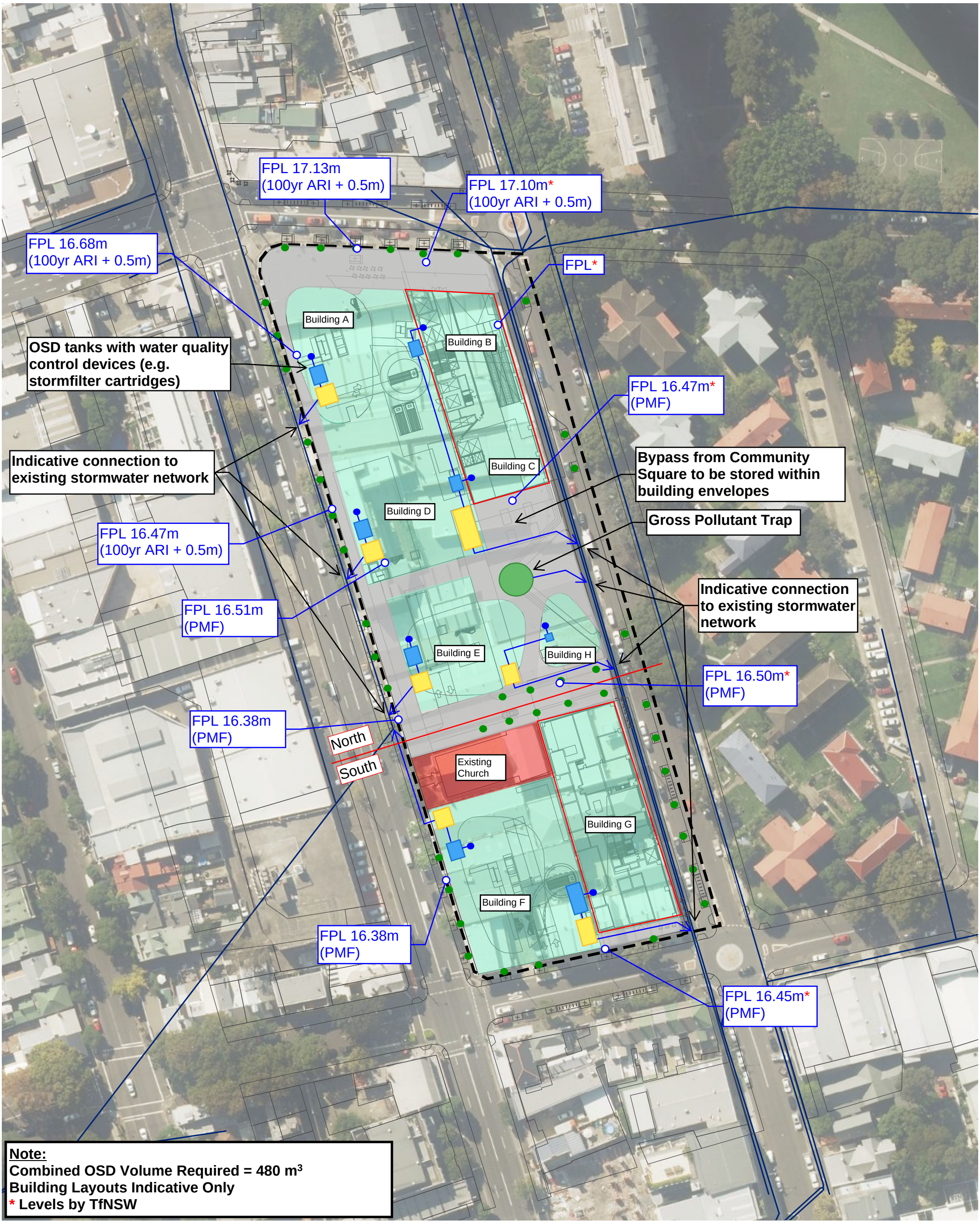

FIGURE 51 - WATERLOO METRO QUARTER

STORMWATER AND FLOODING MANAGEMENT PLAN

AECOM

N 0 15 30 m

KEY

- Site boundary
- **Sydney Water** Stormwater
- Building Roof Catchment
- Bypass Catchment
- Stormfilter Cartridge
- On Site Detention Tank
- Sydney Metro Station Box
- Indicative shared downpipe locations
- Indicative street tree location

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5.3 Staging

The development timeframe for the Metro Quarter is between 2 years (lower scenario) to 10 years (upper scenario). Preliminary staging of the proposed stormwater services is shown in Figure 52 below while the exact staging is subject to detailed design development in parallel with any utility diversion requirements and road upgrades for the delivery of the proposed station.

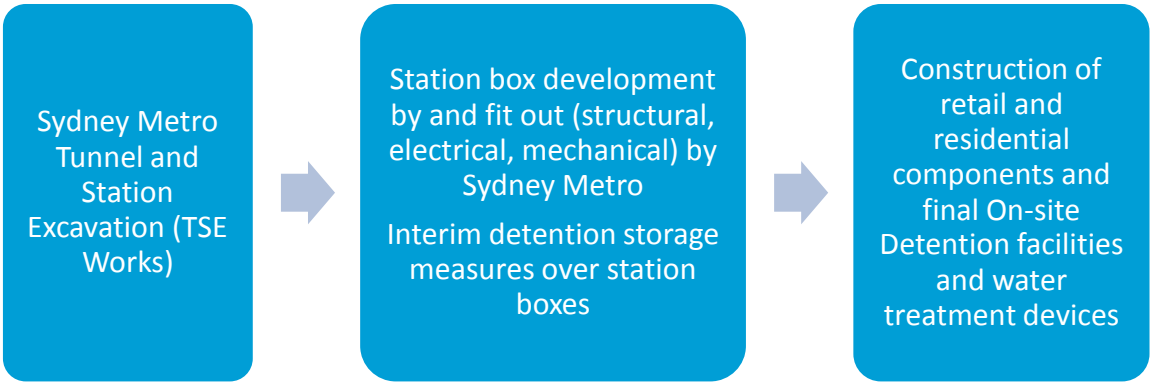

Figure 52: Staging of Metro Quarter Stormwater Services

The key factors that need to be taken into consideration at the implementation stage are:

1) Sizing on On-Site Detention areas, including bypass areas, to be managed based on relevant stage of construction process;
2) Flood mitigation is required for both the metro box and subsequent development of the metro quarter;
3) Interim detention storage measures could take the form of parapets, with a slope towards downpipes connected via risers in the station to the adjacent stormwater pipes. Trash screens and access to be considered in the detailed design; and
4) Staging of Metro Quarter over-station development is independent of the developments in the wider Waterloo Precinct. However, the commencement will depend upon tunnels, station and excavation (TSE) and subsequent station box works by Sydney Metro. The responsibility related to interim detention storage during interfacing periods is of consideration during the detailed design phase.

6.0 Water Cycle Management

This section evaluates the potential for adoption of an Integrated Water Cycle Management approach at Metro Quarter which includes rainwater harvesting, reuse and recycled water to achieve the best possible outcomes for a Green Star accreditation. This section can be read in conjunction with the accompanying *Waterloo Metro Precinct Utilities and Infrastructure Servicing Study* and *Waterloo Metro Precinct ESD Report.*

The proposed development comprises a mix of retail and commercial uses with open public space and residential towers. For potable water supply, the area is within the Potts Hill Trunk Delivery System incorporating the Potts Hill Reservoir and Crown Street Reservoir. Although Sydney Water does not provide recycled water to the study area, the adjacent Green Square Town Centre does include a privately operated recycled water scheme wherein there may be opportunities to extend this system to the Metro Quarter study area.

6.1 Population

The target dwelling yield within for the Metro Quarter site is 700 apartments. Based on approximate occupancy rates for multi residential developments within the CoS (2 people/apartment occupancy) the future population is expected to be 1,400 residents within the subject area.

6.2 Residential Demands

The CoS Decentralised Water Masterplan provides a basis for determining the split of potable and non-potable water use in multi dwelling apartments. This study found that multi-unit dwellings consume approximately 156kL/dwelling/year and approximately 42 percent of these demands could be supplied by non-potable water. Applying this water usage rate to the proposed dwelling yield gives an indicative water usage volume for the proposed development. A breakdown of typical potable and non-potable water demands is provided in Table 12.

Table 12: Water usage

Water Uses (kL/dwelling/yr)		Residential Water Split	BASIX Bench-mark for Potable Water Use	Adopted Water Demand	Recycled Water	Potable Water	Waste Water
Non Potable	Toilet	18%	24.0	28.1	28.1	0.0	25.3
	Washing	15%	20.0	23.4	23.4	0.0	21.1
	Irrigation	4%	5.3	6.2	6.2	0.0	5.6
	Outdoor	5%	6.7	7.8	7.8	0.0	7.0
	Total	42%	**56.0**	**65.5**	**65.5**	**0.0**	**59.0**
Potable	Basin	5%	6.7	7.8	0.0	6.7	6.0
	Kitchen	5%	6.7	7.8	0.0	6.7	6.0
	Leaks	5%	6.7	7.8	0.0	6.7	6.0
	Shower	37%	49.4	57.7	0.0	37.0*	33.3
	Bath	4%	5.3	6.2	0.0	5.3	4.8
	Dishwasher	2%	2.7	3.1	0.0	2.7	2.4
	Total	**58%**	**77.4**	**90.5**	**0.0**	**65.0**	**58.5**
Total Usage / Dwelling (kL/yr)			**133.4**	**156.0**	**65.5**	**65.0**	**117.5**

The water usage figures show that the use of recycled water for all non-potable water demands and use of efficient shower heads could provide a reduction in potable water use of 51 percent against the BASIX benchmark.

6.3 External Water Use and Irrigation

The public plaza area will total 1,400 square metres which is intended to have high amenity with some paved and open grassed areas with planted trees. The irrigation rate for the grassed area is expected to be moderate (2.5ML/ha or 250mm/year).

The proposed community square is intended to provide high amenity to local residents. Due to the relatively low proportion of public open space provided within the development, it is expected that the open space will be well patronised and will demand a high rate of irrigation of approximately (4ML/ha or 400mm/year).

Passive irrigation is proposed for street trees and no further water usage is associated with this landscape. However, if passive irrigation is not pursued as a strategy for irrigating street trees, there will be slight reductions in stormwater pollution removals and other options for rainwater tanks on buildings can be explored.

6.4 Water Balance

Based on Table 10, potable water supply will generally be used for potable demands (58 percent of residential water split) while harvested rainwater and recycled water may be used for non-potable water uses (42 percent of residential water split).

It should be noted that if recycled water is used, the addition of rainwater tanks may not be cost-effective due to the duplication of water supply infrastructure.

The annual water balance for the proposed development will depend upon the final approach adopted and should be clarified during the detailed design phase as well as subsequent detailed development applications for built form.

7.0 Response to SEARs

This Water Quality, Flooding and Stormwater Report presents the proposed stormwater management approach for the Metro Quarter site. This proposed management approach satisfies the SEARs issued by the DPE, addresses CoS requirements and adheres to the Sydney Water quantity control standards. The following table provides a summary of how the relevant SEARs have been met in this report.

Table 13: Response to Waterloo SSP Requirements

Metro Quarter OSD SEARs	Stormwater Management Response
14.0 Flooding and Stormwater	
• undertake a concept flood study and flood management plan to inform a detailed flood impact assessment in accordance with the NSW Floodplain Development Manual (2005) and demonstrate consideration of the Alexandra Canal Floodplain Risk Management Study and other existing flood studies for the catchment area.	This report considers all of the documents discussed in Sections 3.2and 4.1.2. This report considers strategies listed and previous reports as discussed in Section 4.6.2. The document *WSUD Guidelines Landcom 2009* is out of circulation and no revision has been published for the same. CoS has incorporated its WSUD requirements in the SDCP 2012 which have been taken into consideration for this study.
• identify minimum floor levels for buildings and recommend flood management and/or evacuation plan as relevant to the concept proposal.	Please refer to Sections 3.4.4 and 3.4.5 for existing flood conditions and Section 5.8 for post-development flood conditions. As a part of this report a flood risk assessment has been developed in consultation with the Cos. Flooding characteristics and their spatial / temporal variation across the site are demonstrated through several figures. Please refer to Table 10 for the summary. Current flood modelling for the concept design satisfies the SEARs for this application. Further modelling will be required site wide during the detailed design phase. Please refer to Section 4.10. Recommendations regarding appropriate emergency responses have been included in this report. This report includes an implementation plan and strategy under Section 5.0 sufficient for the concept stage. Further evaluation will be required during the detailed design phase with a particular focus on any interfacing works with Sydney Metro.
• include a stormwater management strategy which must consider the relevant local council stormwater management policy and Water Sensitive Urban Design Principles.	Please refer to Sections 4.5, 4.7, 4.8.5 and 4.10. All building developments are to comply with the Sydney Water PSD and on-site detention requirements. Provision has been considered in the hydraulic modelling as part of this report. Sydney Water approval will be sought as part of each construction package. This report provides an assessment of the potential impacts on the hydrology and hydrogeology and details how the water quality targets can be achieved. Please refer to Section 4.7. The assessment for the concept design satisfies the SEARs for this application. Further assessment will be required site wide during the detailed design phase.

8.0 Conclusion

Preliminary flood modelling of the Metro Quarter site under existing conditions as well as for the post-development case has been undertaken using a modified version of the CoS TUFLOW model for the Alexandra Canal Flood Study. The results of these initial cases have been presented in parallel with information indicating existing stormwater infrastructure.

Under current flood conditions, ponding occurs in Cope Street between the intersection with Wellington Street and extending to the intersection with John Street. This ponding is the result of overland flows coming down Cope Street, with contributions from within the Waterloo Estate. The depth of ponding in the southern portion of the site is up to 1 metre for the 100 year ARI and 1.6 metres for the PMF.

As a consequence of this ponding, the FPL at the southern end of the Metro Quarter based on existing conditions in this area is approximately 1.5 metres above street level, while at the north end; it is up to 0.9 metres above the street level. At most locations enveloping the site, the FPL are influenced by the ponding area occurring at Cope Street and Wellington Street. Entrances to underground areas such as carparks are also required to be flood free in the PMF event. Due to these requirements, carpark entrances may need to be ramped up approximately 1.6 metres above street level before ramping down into basement areas. Recommended FPLs for Metro Quarter have been provided where the adopted criterion for setting of flood planning level was maximum of PMF and 100 year ARI +0.5m. The FPLs for metro station elements will be established as part of the CSSI Approval and coordinated with Sydney Metro in the detailed design of the metro station and OSD elements.

This report outlines potential mitigation measures to offset adverse flooding impacts during extreme weather events. These include on-site detention and appropriate building flood planning levels. It is likely that the flood impacts can be addressed but will require additional iterative design development. Climate change has also been addressed in this report through conducting a sensitivity analysis by taking an additional 10 percent increase on top of the 100 year ARI storm event. Figures showing the resultant flood depths, flood velocities, flood hazards and flood impacts over current and proposed scenarios have been included.

The extensive ponding identified during the PMF also presents evacuation considerations. Evacuation from the buildings in this precinct or emergency vehicle access is a possibility; however, as the buildings will be above the PMF level, a shelter in place strategy is preferable to avoid unnecessary vehicle or pedestrian movement during extreme storm events. Sufficient warning time can be provided for the occupied areas including retail levels where the occupants will need to move to the stepped up shelter in place zone within their property. Suitable facilities and a flood management plan will be required to support this.

WSUD features have been assessed against pollution reduction targets as outlined in the SEARs. The suggested strategy from MUSIC modelling is to use stormwater filter cartridges in on-site detention tanks. While the MUSIC modelling results indicate that the nutrient reduction targets can also be met using a mix of gross pollutant traps. Additionally, an integrated water cycle management approach may be adopted for the site in order to maximize stormwater harvesting, reuse and recycle to achieve desirable outcomes for a highly green and sustainable development.

Based on the investigations undertaken, the relevant SEARs have been wholly satisfied for the concept level proposal with further investigations for detailed design applications identified in Section 8 of this report. Considering the buildings can be safely occupied, flooding risks at Metro Quarter can be mitigated using appropriate FPLs, setbacks and emergency response frameworks and WSUD measures can be readily implemented for water quality enhancement, the site is suitable to be a mixed-use development comprising residential, commercial, open spaces and community facilities.

9.0 References

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Appendix A

Sydney Water Correspondence

Fettell, Daniel

From: JEYADEVAN, JEYA <JEYA.JEYADEVAN@sydneywater.com.au>
Sent: Tuesday, 25 October 2016 3:34 PM
To: Lewis, Patrick
Cc: Fettell, Daniel
Subject: RE: Waterloo Over Station Development - PSD Requirements

Patrick,

The On Site Detention requirements for the 13,500 square meters site at Waterloo Over Station (59 – 121 Botany Road, Waterloo), are as follows:

- On Site Detention 208 cubic meter
- Permissible Site Discharge 503 L/s

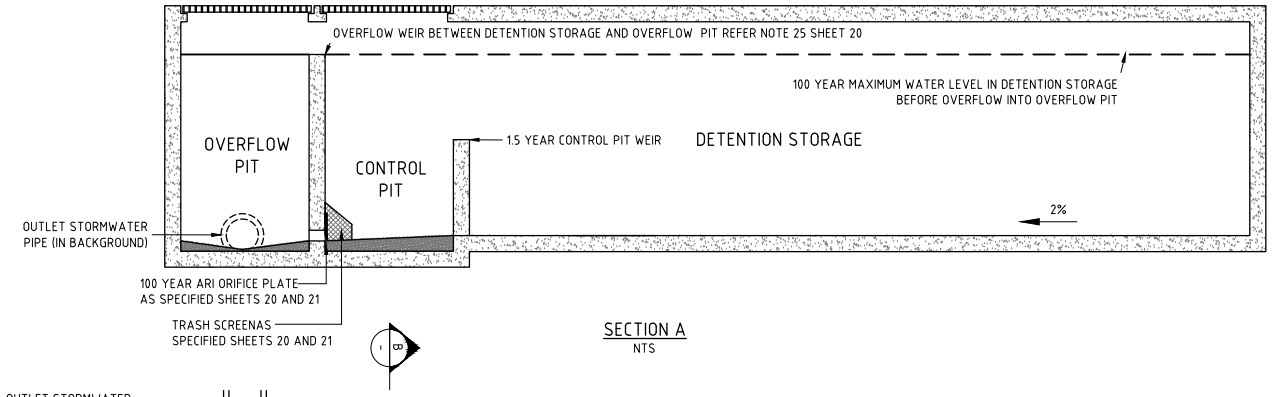
The approval for the On Site Detention would only be given as part of the Section 73 application for this development. The On Site Detention is to be designed according to the above values and submitted to Sydney Water for approval with the Section 73 application. The following details are to be included in your submission for On Site Detention approval:

- Location of the On Site Detention in relation to the development
- Location of the On Site Detention in relation to overall stormwater network of the property
- Plan and Elevation of the On Site Detention tank with all dimensions
- Orifice plate calculation

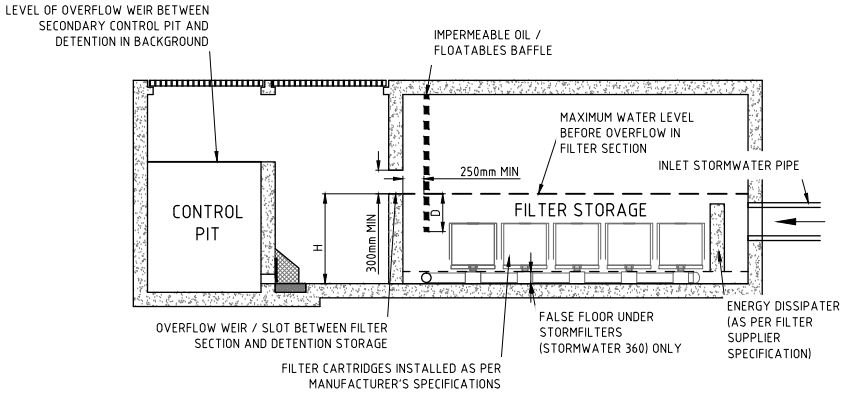
Best regards,
Jeya Jeyadevan | **Senior Capability Assessor**
Customer Delivery | Sydney Water
Level 7, 1 Smith St Parramatta NSW 2150
PO Box 399 Parramatta NSW 2124
T 8849 6118 | **M** 0409 318 827
E jeya.jeyadevan@sydneywater.com.au
sydneywater.com.au

Appendix B

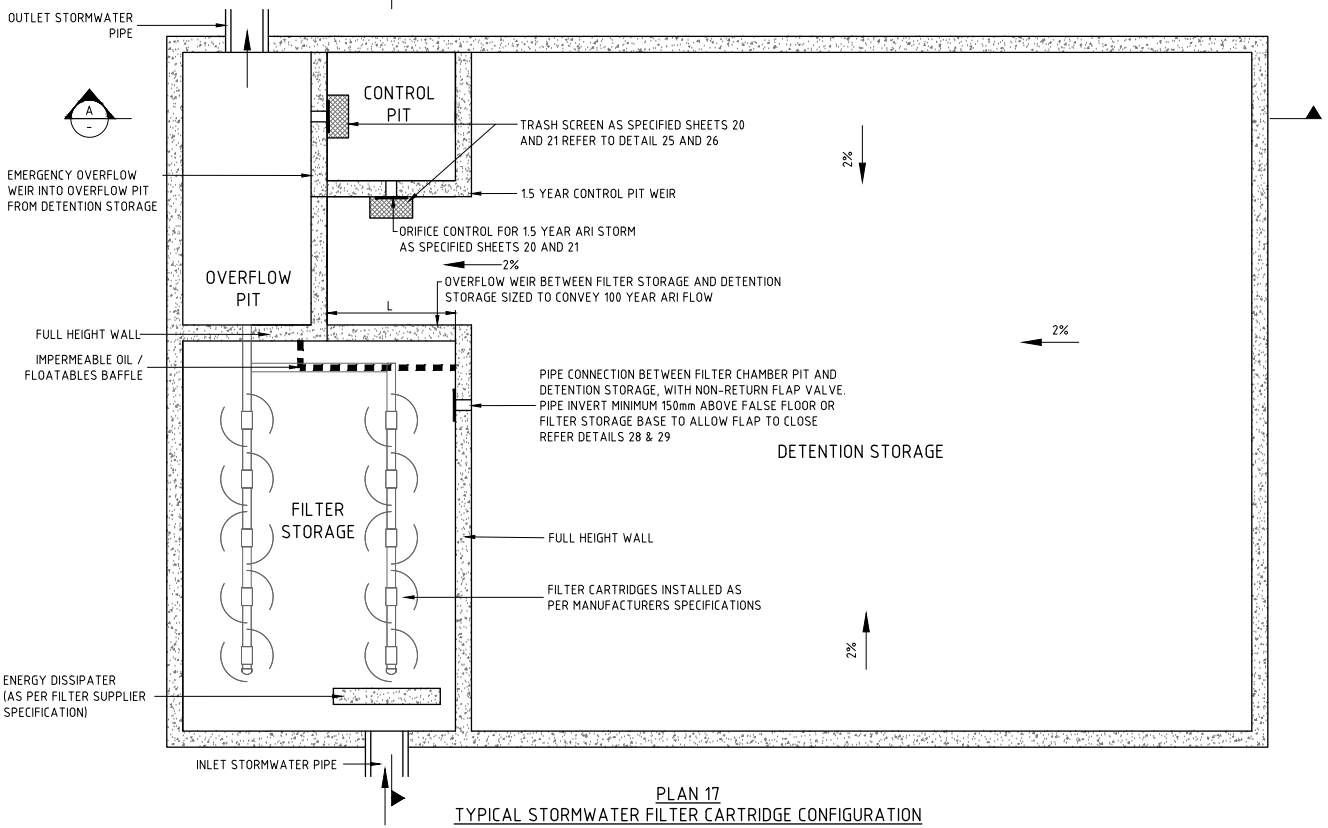
Typical Arrangement – Combined On-Site Detention & Filter Cartridges



SECTION A
NTS



SECTION B
NTS



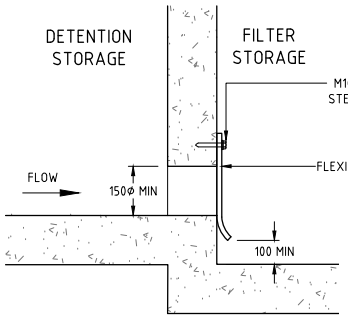
PLAN 17
TYPICAL STORMWATER FILTER CARTRIDGE CONFIGURATION
UPSTREAM OF DISCHARGE CONTROL PIT
NTS

DESIGN NOTES:

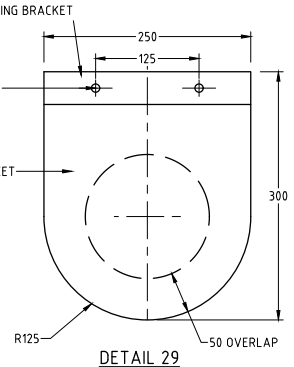
1. THE FILTER TANK STORAGE IS CONSIDERED AS PART OF THE 1.5 YEAR ARI DETENTION STORAGE.
2. COMBINED OSD & FILTER CARTRIDGE SYSTEMS SHALL COMPLY WITH THE STORAGE VOLUME AND DISCHARGE REQUIREMENTS DOCUMENTED ON SHEET 20. THIS REQUIRES THAT ORIFICES BE ADJUSTED TO ACCOUNT FOR THE COMBINED FLOW FROM THE CARTRIDGES AND THE ORIFICES.
3. THE SIZING OF THE 1.5 YEAR ARI ORIFICES NEEDS TO TAKE INTO ACCOUNT THE BYPASS OF WATER THROUGH THE UNDERDRAIN FROM THE FILTER STORAGE USING THE MANUFACTURERS NOMINAL DESIGN FLOW RATES (REFER MANUFACTURER'S SPECIFICATIONS). IF THE MINIMUM ORIFICE SIZE NEEDS TO BE LESS THAN 15mm.
4. IN THE EVENT THAT THE NOMINAL DISCHARGE FROM THE FILTER STORAGE EXCEEDS THE 1.5 YEAR ARI FLOW THEN OMIT THE 1.5 YEAR ARI ORIFICE CONTROL AND GRADE FLOOR OF OSD TANK TO NON-RETURN FLAP.
5. THE SIZING OF THE 100 YEAR ARI ORIFICE NEEDS TO TAKE INTO ACCOUNT THE BYPASS OF WATER FROM THE FILTER CARTRIDGES, THE CARTRIDGE FLOW WILL EXCEED THE NOMINAL DESIGN FLOW RATES DURING EVENTS LARGER THAN A 1.5 YEAR ARI STORM DUE TO ADDITIONAL HEAD ON EACH CARTRIDGE. CONTACT THE MANUFACTURER FOR THE REVISED CARTRIDGE FLOW AT THE 100 YEAR TOP WATER LEVEL.
6. THE ADJUSTED ORIFICE SIZES WILL BE MANUALLY CALCULATED USING THE DIFFERENCE BETWEEN THE FLOW RATES FROM SHEET 20 AND THE CARTRIDGE FLOW RATE.
7. DETAILED DESIGN OF THE DETENTION AND FILTER CARTRIDGE SYSTEM IS TO BE DONE IN ACCORDANCE WITH SPECIFICATIONS FOR ONSITE DETENTION AND THE DETAILED DESIGN SPECIFICATIONS FROM THE CARTRIDGE MANUFACTURER.
8. DIMENSIONS D, H AND WEIR LENGTH (L) IN METRES FOR FLOW ($Q=m^3/s$) (REFER SECTION B ABOVE). FOR DETENTION TANKS Q IS 100 YEAR ARI HOWEVER FOR OFF LINE TREATMENT MINIMUM Q IS 0.75 x 1 YEAR ARI.

FILTER CARTRIDGE	D	H	L
STORMFILTER (690)	400mm	770mm + FALSE FLOOR THICKNESS	10.0 x Q
STANDARD STORMFILTER (460)	300mm	540mm + FALSE FLOOR THICKNESS	13.2 x Q
SMALL STORMFILTER (310)	200mm	390mm + FALSE FLOOR THICKNESS	17.8 x Q
SPEL FILTER EMC - 45N (STANDARD)	450mm	850mm	10.0 x Q
SPEL FILTER EMC - 45L (LOW)	250mm	530mm	13.2 x Q

9. ALL SECTIONS OF THE OSD SYSTEM SHALL HAVE GRATED ACCESS POINTS. MINIMUM 900mm x 900mm AS PER AS3500



DETAIL 28
NON-RETURN FLAP MOUNTING
NTS



DETAIL 29
NON-RETURN FLAP MIN DIMENSIONS
NTS

PREPARED BY:

REV	DATE	DESCRIPTION	CHECKED	APPROVED	DATE
C	FEB '17	PEER REVIEWED FOR ADOPTION	GJH	TN	FEB '17
B	DEC '16	FINAL DRAFT	M.L	TN	DEC '16
A	MAY '16	ISSUED FOR CONSULTATION	M.L	TN	MAY '16

PUBLIC UTILITIES LEGEND

WATER MAINS	W	GAS	G	TELSTRA	T
HYDRANT		GAS VALVE		TELSTRA PIT	
STOP VALVE		ELECTRICITY	E	TELSTRA PILLAR	
WATER METER		ELECTRICITY PIT		TELSTRA POLE	
WATER TAP		POWER POLE		STORMWATER PIT	
SEWER	S	POWER LIGHT POLE			
SEWER LAMPHOLE		LIGHT POLE			
SEWER MANHOLE		STAY POLE			

DATUM: AHD
GRID: MGA
SHEET SIZE: A1
TITLE BLOCK VERSION: A

SURVEYED: -
DESIGNED: -
CADD: AJ
VERIFIED: ML
DATE: FEB '17

APPROVED
MANAGER ASSET DESIGN
DATE: FEB '17

CLIENT
DATE:

Blacktown City Council

COUNCIL CHAMBERS 62 FLUSHCOMBE ROAD,BLACKTOWN
ALL MAIL: GENERAL MANAGER PO BOX 63, BLACKTOWN NSW 2148
TELEPHONE: (02) 9839 6000 FAX: (02) 9831 1961
DX : 8117 BLACKTOWN

PLAN 1:1000 @ A1
LONG SECTION:HORIZ
VERT
CROSS SECTIONS

PROJECT TITLE: WSUD STANDARD DRAWINGS
SHEET TITLE: OSD - COMBINED OSD & FILTER CARTRIDGES
CAD FILE: A(BS)175M.dwg
FILE No: N/A
PLAN No: A(BS)175M

ISO 9001 International Standards Certification
Lic No:QAC/R61/0183
ASSET DESIGN

REV C

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