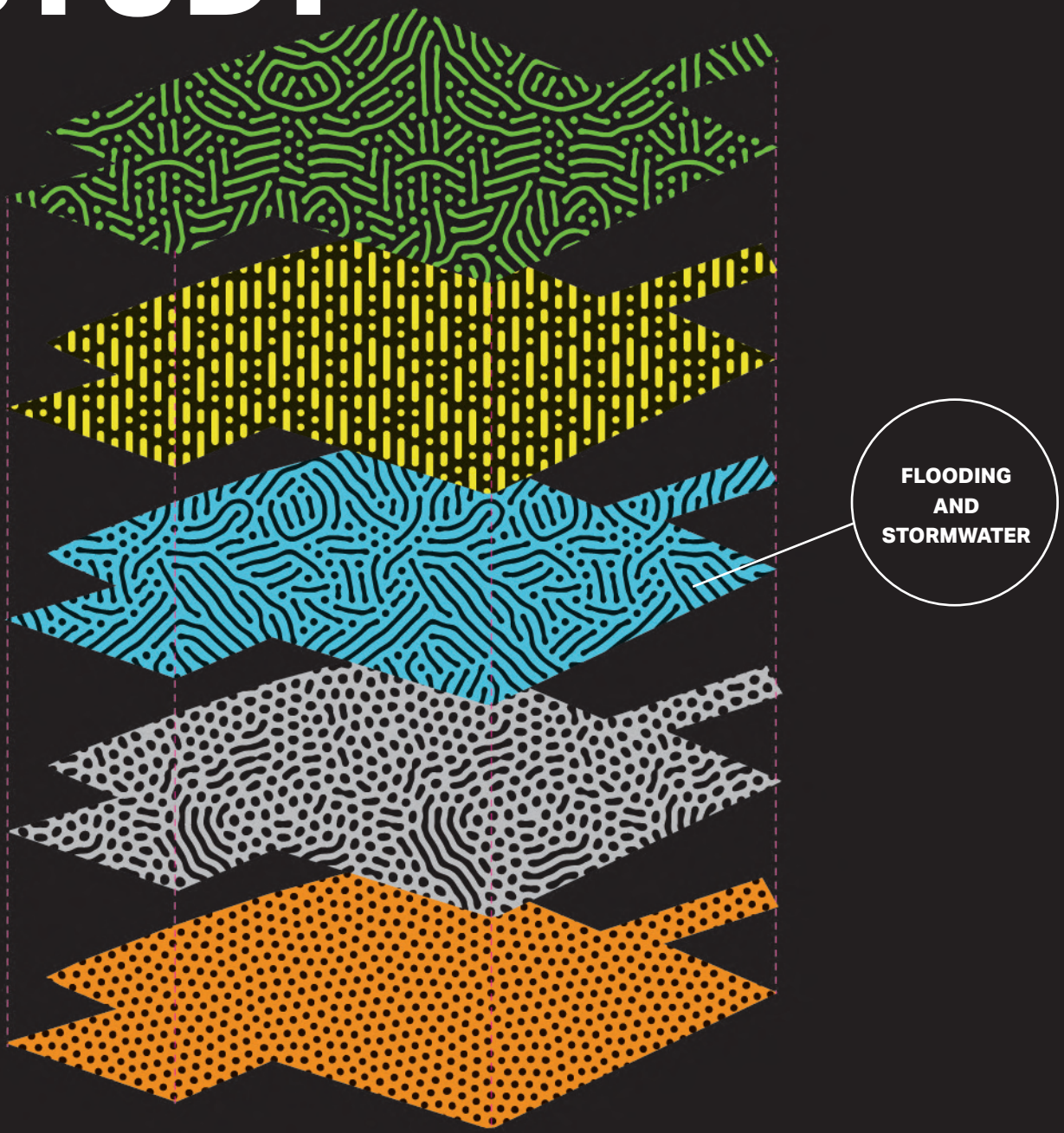
WATERLOO SOUTH

FLOODING AND STORMWATER STUDY



Prepared for

NSW Land and Housing Corporation

19 March 2020

AECOM

Quality information

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Abbreviations

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Annual Recurrence Interval
AR&R	Australian Rainfall & Runoff
BASIX	Building Sustainability Index
BBWQIP	Botany Bay Water Quality Improvement Plan
CGIs	Computer Generated Images
CoS	City of Sydney
DCP	Development Control Plan
ESD	Ecologically Sustainable Development
FPL	Flood Planning Level
FSR	Floor Space Ratio
GFA	Gross Floor Area
HGL	Hydraulic Grade Line
IPCC	Intergovernmental Panel on Climate Change
ISD	Integrated Station Development
LAHC	Land and Housing Corporation
LEP	Local Environment Plan
LGA	Local Government Area
OEH	Office of Environment and Heritage
OSD	Over Station Development
RCP	Representative Concentration Pathway
SMCMA	Sydney Metropolitan Catchment Management Authority
SSP	State Significant Precinct
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UrbanGrowth NSW	UrbanGrowth NSW Development Corporation
WSUD	Water Sensitive Urban Design

Executive Summary

The purpose of this Water Quality, Flooding and Stormwater Report is to address the State Significant Precinct (SSP) study requirements for Waterloo Housing Estate, specifically Waterloo South, and demonstrate the feasibility of proposed development from a flooding and stormwater perspective at a conceptual level. The Planning Proposal will be submitted to the City of Sydney, but for the avoidance of doubt, the historic Study Requirements are referred to within this report as they are still requirements under the Planning Proposal. The report provides preliminary flooding and stormwater analyses for the Waterloo Housing Estate under existing conditions as well as post-development conditions. The associated modelling was undertaken using a modified version of the City of Sydney 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.

This report outlines potential mitigation measures, like on-site detention and appropriate building flood planning levels (FPLs), to offset adverse flood impacts during extreme weather events. Generally, the proposed development does not worsen the flood levels compared to existing conditions. Recommended FPLs for the Estate have been provided in the report where the adopted criterion for setting of FPL was the maximum of Probable Maximum Flood (PMF) level and the 100-year Annual Recurrence Interval (ARI) + 0.5m level. Climate change has also been addressed in this report through conducting a sensitivity analysis. Plans showing the resultant flood depths, flood velocities, flood hazards and flood impacts over current and proposed scenarios have been included in the Indicative Concept Proposal.

For emergency response, the flood hazard is most appropriately managed with a shelter in place strategy, as the duration of inundation is relatively short, and the rate of rise is relatively rapid. A shelter in place strategy for the buildings is also preferred over evacuation, to avoid unnecessary vehicle or pedestrian movements during an extreme storm event. For occupied public open space areas, it is recommended to have a refuge point within a facility that can be accessed easily. Sufficient warning time should be considered, and a flood management plan should be devised to support this.

Water Sensitive Urban Design (WSUD) features have been assessed against pollution reduction targets as outlined in the study requirements. The suggested strategy from MUSIC modelling is to use biofiltration trees, raingardens and proprietary stormwater devices within the public domain. 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, relevant study requirements have been wholly satisfied for the concept level proposal with detailed design development related investigations identified in the report wherever appropriate. Flooding risks at the Estate can be appropriately managed using on-site detention, FPLs, building setbacks, improved drainage and sound emergency response frameworks. WSUD measures can also be readily implemented in the public domain space for water quality enhancement. The proposed development does not worsen the existing flooding conditions, subject to further verification during detailed design, and the site is suitable to be a mixed-use development comprising residential, commercial, open spaces and community facilities.

1.0 Introduction

The Greater Sydney Region Plan and Eastern City District Plan seek to align growth with infrastructure, including transport, social and green infrastructure. With the catalyst of Waterloo Metro Station, there is an opportunity to deliver urban renewal to Waterloo Estate that will create great spaces and places for people to live, work and visit.

The proposed rezoning of Waterloo Estate is to be staged over the next 20 years to enable a coordinated renewal approach that minimises disruption for existing tenants and allows for the up-front delivery of key public domain elements such as public open space. Aligned to this staged approach, Waterloo Estate comprises three separate, but adjoining and inter-related stages:

- Waterloo South;
- Waterloo Central; and
- Waterloo North.

Waterloo South has been identified as the first stage for renewal. The lower number and density social housing dwellings spread over a relatively large area, makes Waterloo South ideal as a first sub-precinct, as new housing can be provided with the least disruption for existing tenants and early delivery of key public domain elements, such as public open space.

A planning proposal for Waterloo South is being led by NSW Land and Housing Corporation (LAHC). This will set out the strategic justification for the proposal and provide an assessment of the relevant strategic plans, state environmental planning policies, ministerial directions and the environmental, social and economic impacts of the proposed amendment. The outcome of this planning proposal will be a revised planning framework that will enable future development applications for the redevelopment of Waterloo South. The proposed planning framework that is subject of this planning proposal, includes:

- **Amendments to the Sydney Local Environmental Plan 2012** – This will include amendments to the zoning and development standards (i.e. maximum building heights and floor space ratio) applied to Waterloo South. Precinct-specific local provisions may also be included.
- **A Development Control Plan (DCP)** – This will be a new part inserted into ‘Section 5: Specific Areas’ of the Sydney DCP 2012 and include detailed controls to inform future development of Waterloo South.
- **An infrastructure framework** – in depth needs analysis of the infrastructure required to service the needs of the future community including open space, community facilities and servicing infrastructure.

This report relates to the Estate. While it provides comprehensive baseline investigations for the entire Precinct, it only assesses the proposed Planning Framework amendments and Indicative Concept Proposal for the Estate.

1.1 Waterloo Estate

Waterloo Estate is located approximately 3.3km south-south-west of the Sydney CBD in the suburb of Waterloo (refer to Figure 1). It is located entirely within the City of Sydney local government area (LGA). Waterloo Estate is situated approximately 0.6km from Redfern train station and 0.5km from Australia Technology Park. The precinct adjoins the new Waterloo Metro Station, scheduled to open in 2024. The Waterloo Metro Quarter adjoins Waterloo Estate and includes the station and over station development and was rezoned in 2019. Waterloo Estate comprises land bounded by Cope, Phillip, Pitt and McEvoy Street, including an additional area bounded by Wellington, Gibson, Kellick and Pitt Streets. It has an approximate gross site area of 18.98 hectares (14.4 hectares excluding roads). Waterloo Estate currently comprises 2,012 social housing dwellings owned by LAHC, 125 private dwellings, a small group of shops and community uses on the corner of Wellington and George Streets, and commercial properties on the south-east corner of Cope and Wellington Streets.

A map of Waterloo Estate and relevant boundaries is illustrated in Figure 2.

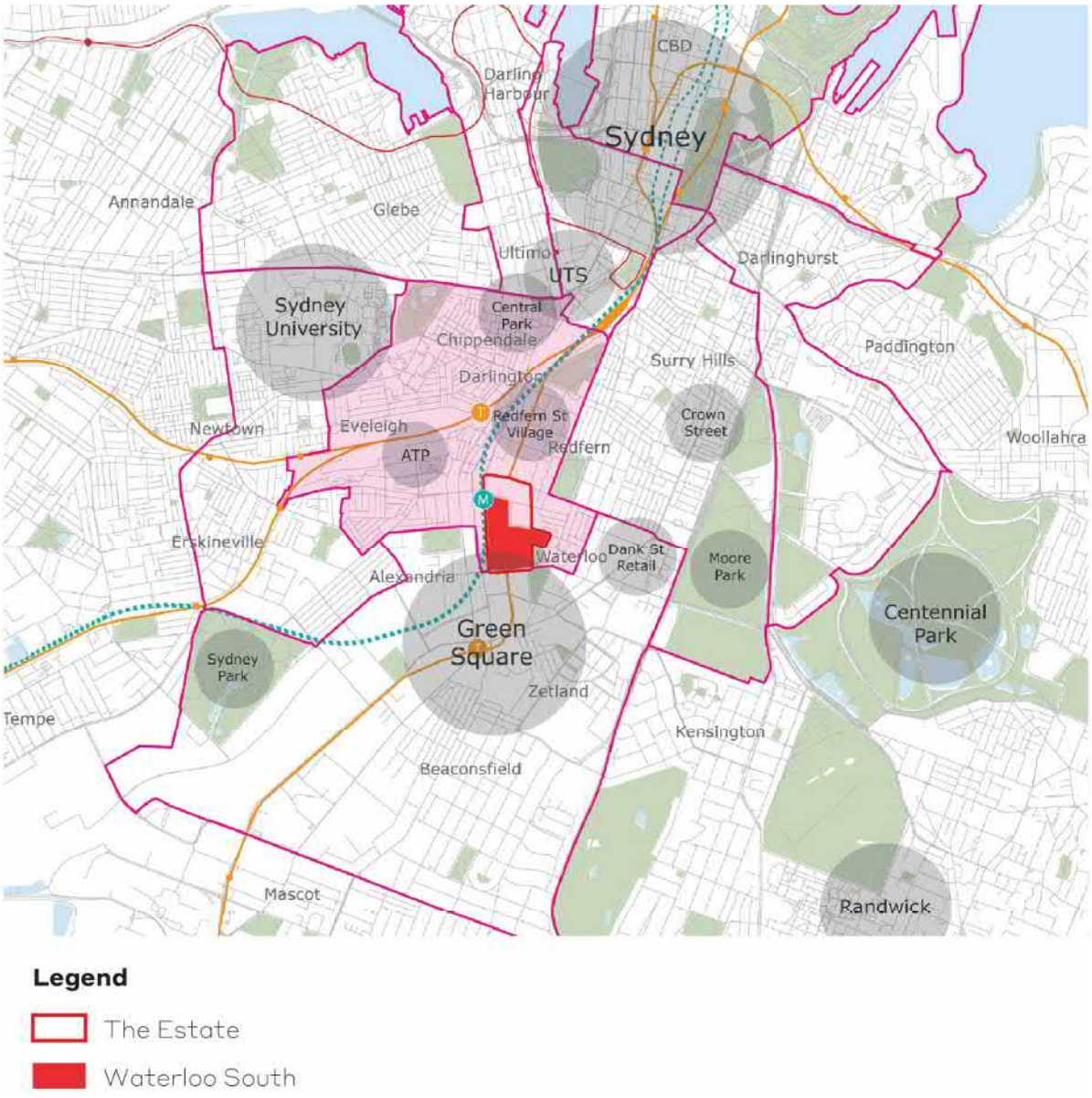


Figure 1: Location plan

Source: Turner Studio

1.2 Waterloo South

Waterloo South includes land bounded by Cope, Raglan, George, Wellington, Gibson, Kellick, Pitt and McEvoy Streets, and has an approximate gross site area of 12.32 hectares (approximately 65% of the total Estate).

Waterloo South currently comprises 749 social housing dwellings owned by LAHC, 125 private dwellings, and commercial properties on the south-east corner of Cope and Wellington Streets. Existing social housing within Waterloo South is predominantly walk up flat buildings constructed in the 1950s and '60s, and mid-rise residential flat buildings (Drysdale, Dobell & 76 Wellington Street) constructed in the 1980s. Listed Heritage Items within Waterloo South include the Duke of Wellington Hotel, Electricity Substation 174 on the corner of George and McEvoy Streets, the terrace houses at 229-231 Cope Street and the Former Waterloo Pre-School at 225-227 Cope Street. The State Heritage listed 'Potts Hill to Waterloo Pressure Tunnel and Shafts' passes underneath the precinct.
A map of Waterloo South and relevant boundaries is illustrated in **Figure 2.**

Figure 2: Aerial photograph of the Precinct

Source: Ethos Urban & Nearmap

1.3 Redevelopment Vision

The transition of Waterloo Estate will occur over a 20-year timeframe, replacing and providing fit for purpose social (affordable rental) housing as well as private housing to create a new integrated and inclusive mixed-tenure community.

This aligns with Future Directions for Social Housing in NSW – the NSW Government's vision for social housing. It also aligns with LAHC's Communities Plus program, which is tasked with achieving three key objectives:

1. Provide more social housing
2. Provide a better social housing experience
3. Provide more opportunities and support for social housing tenants

The following is LAHC's Redevelopment Vision for Waterloo Estate, which was derived from extensive consultation and technical studies:

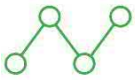
Source: Let's Talk Waterloo: Waterloo Redevelopment (Elton Consulting, 2019)

Culture and Heritage

- Recognise and celebrate the significance of Waterloo's Aboriginal history and heritage across the built and natural environments.
- Make Waterloo an affordable place for more Aboriginal people to live and work.
- Foster connection to culture by supporting authentic storytelling and recognition of artistic, cultural and sporting achievements.

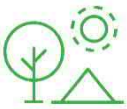
Communal and Open Space

- Create high quality, accessible and safe open spaces that connect people to nature and cater to different needs, purposes and age groups.
- Create open spaces that bring people together and contribute to community cohesion and wellbeing.



Movement and Connectivity

- Make public transport, walking and cycling the preferred choice with accessible, reliable and safe connections and amenities.
- Make Waterloo a desired destination with the new Waterloo Station at the heart of the Precinct's transport network – serving as the gateway to a welcoming, safe and active community.



Character of Waterloo

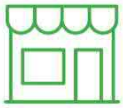
- Strengthen the diversity, inclusiveness and community spirit of Waterloo.
- Reflect the current character of Waterloo in the new built environment by mixing old and new.

Local Employment Opportunities

- Encourage a broad mix of businesses and social enterprise in the area that provides choice for residents and creates local job opportunities.

Community Services, Including Support for Those Who Are Vulnerable

- Ensure that social and human services support an increased population and meet the diverse needs of the community, including the most vulnerable residents.
- Provide flexible communal spaces to support cultural events, festivals and activities that strengthen community spirit.



Accessible Services

- Deliver improved and affordable services that support the everyday needs of the community, such as health and wellbeing, grocery and retail options.

Design Excellence

- Ensure architectural design excellence so that buildings and surrounds reflect community diversity, are environmentally sustainable & people friendly – contributing to lively, attractive and safe neighbourhoods.
- Recognise and celebrate Waterloo's history and culture in the built environment through artistic and creative expression.
- Create an integrated, inclusive community where existing residents and newcomers feel welcome, through a thoughtfully designed mix of private, social (affordable rental) housing.

1.4 Purpose

This report relates to the Waterloo South planning proposal. While it provides comprehensive baseline investigations for Waterloo Estate, it only assesses the proposed planning framework amendments and Indicative Concept Proposal for Waterloo South.

The purpose of this report is to address the relevant Study Requirements detailed below.

2.0 Study Requirements

On 19 May 2017 the Minister issued Study Requirements for the nominated Precinct. Of relevance to this study are the following requirements. While this project is going through a different planning pathway, the overall SSP study requirements are still relevant and addressed below in Table 1 below.

Actions taken in response to these study requirements are outlined in Section 8.

Table 1: Waterloo Nominated State Significant Precinct – Study Requirements

Item	Description	Action	Section in Report
1	Vision, Strategic Context and Justification	*1.5 Consideration of City of Sydney planning documents strategies and policies including, but not limited to:* o The Alexandra Canal Floodplain Risk Management Plan Risk; Management Study and Flood Study 2014 o Interim Floodplain Management Policy 2014	Please refer to Sections 4.2 and 5.1.3,
		1.6 Consideration of other relevant strategies and reports including, but not limited to: o Local Planning for Healthy Waterways using NSW Water Quality Objectives Department of Environment and Conservation June 2006 o Managing Urban Stormwater – Harvesting and Reuse Guidelines Dec 2006 o WSUD Guidelines Landcom 2009 Managing Urban Stormwater: Soils and Construction' series	Please refer to Section 5.6.1.
3	Public Domain: Public Open Space and Streets	*3.11 Provide a (Water Sensitive Urban Design) WSUD strategy that integrates with the flood study, the public domain and private open spaces, show any measures on plans and detail street sections*	Please refer to Section 5.7.3
8	Local Infrastructure and Contributions	*8.11 Outline the proposed ongoing responsibilities and maintenance of any proposed open space/connections, drainage reserves and community facilities*	Please refer to Section 6.4
16	Ecologically Sustainable Development (ESD)	*16.2 Provide an Integrated Waste Water Management Strategy that considers water, waste water and stormwater plus potential alternative water supply, demonstration of water sensitive urban design and any future water conservation measures, including reuse, following appropriate best practice and guidelines. Investigate any opportunities for and include an assessment of the feasibility of a precinct-scale recycled water scheme that includes nearby sites with the capacity to participate.*	Please refer to Section 7.0
17	Water Quality, Flooding and Stormwater	*17.1. Provide an assessment of any potential impacts of the proposal on the hydrology and hydrogeology of the urban renewal precinct and adjoining areas, with particular focus on water quality, and to water quality targets in the City of Sydney DCP 2012:*	Please refer to Section 5.7.

Item	Description	Action	Section in Report
		o *reduce the baseline and annual pollutant load for litter and vegetation larger than 5mm by 90%* o *reduce the baseline annual pollutant load for total suspended solids by 85%* o *reduce the baseline annual pollutant load for total phosphorus by 65%, and* o *reduce the baseline annual pollutant load for total nitrogen by 45%.*	
		17.2. Provide a concept Stormwater Management Plan outlining the general stormwater management measures for the proposal, with particular emphasis on possible WSUD options.	Please refer to Sections 5.5 and 5.7.
		17.3. Consider the effect of climate change and changing rainfall patterns and undertake a sensitivity analysis to address the risks and impacts.	Please refer to Section 5.9.
		17.4. Provide a flood risk assessment developed in consultation with City of Sydney Council identifying flooding behaviours for existing and developed scenarios in order to outline the suitability of the land for proposed uses. Identify flooding characteristics i.e. flow, levels, extent, velocity, rate of rise, hydraulic and hazard categories, for the full range of flooding up to the probable maximum flood (PMF), for both mainstream and overland flow path.	Please refer to Sections 4.4.4 and 4.4.5 for existing flood conditions and Section 5.8 for post-development flood conditions.
		17.5. Consider the future cumulative flood risk impact across the entire Waterloo Precinct and adjoining land areas.	Please refer to Section 5.8.4.
		17.6. Address the impact of flooding on future proposed development including flood risk to people and properties for key flood events including the 1% AEP and the probable maximum flood (PMF) event. The assessment is to address relevant provisions of the NSW Floodplain Development Manual (2005).	Please refer to Sections 5.8 and 5.10
		17.7. Provide an assessment of possible impacts of the proposal on the flood behaviour (i.e. flow levels, extent, velocities and duration of flooding) and any impact of the proposal on adjacent, downstream and upstream areas.	Please refer to Sections 5.8.2 to 5.8.4.
		17.8. Provide concept level information on the impacts of future earthworks and filling of land within the proposal. This assessment is to be based on an understanding of staging and cumulative flood impacts.	Please refer to Section 5.8.4.
		17.9. Provide preliminary assessment on recommended flood management measures including mitigation works and development controls.	Please refer to Sections 5.5, 5.7, 5.8.5 and 5.10.
		17.10. Provide recommendations regarding the most appropriate emergency response strategy to manage risk to life.	Please refer to Section 5.10.
		17.11. Provide concept level details of the drainage associated with the proposal, including stormwater drainage infrastructure and address the impact of stormwater flows on the site from other catchments.	Please refer to Sections 5.5 and 5.7.
		17.12. In addition to securing an acceptable level of personal and property safety from flooding, the proposal is to ensure that measures to address of flooding can achieve high quality urban design outcomes, including ground floor public – private domain engagement i.e. how ground floor retail can be entered at ground at footpath level, and	Please refer to Section 5.8.5 and 5.10.

Item	Description	Action	Section in Report
		promote water quality outcomes through measures such as water sensitive urban design (in the public and private domains).	
		17.13. Prepare an implementation plan for the concept Stormwater Management Plan and Flood Risk Assessment.	Please refer to Section 6.0
		17.14. Demonstrate, through assessment against established criteria, how the proposed flooding and stormwater strategy achieves acceptable water quantity and quality outcomes, and in particular, promotes water sensitive urban design.	Please refer to Sections 5.5 and 5.7
18	Noise, Vibration and Pollution	*18.2 Consider and assess potential pollution impacts from the proposed rezoning including, but not limited to, water, air, noise and light pollution.*	Please refer to Sections 5.6 and 5.7.

3.0 Proposal

3.1.1 Waterloo South planning proposal

The planning proposal will establish new land use planning controls for Waterloo South, including zoning and development standards to be included in Sydney LEP 2012, a new section in Part 5 of DCP 2012, and an infrastructure framework. Turner Studio and Turf has prepared an Urban Design and Public Domain Study which establishes an Indicative Concept Proposal presenting an indicative renewal outcome for Waterloo South. The Urban Design and Public Domain Study provides a comprehensive urban design vision and strategy to guide future development of Waterloo South and has informed the proposed planning framework. The Indicative Concept Proposal has also been used as the basis for testing, understanding and communicating the potential development outcomes of the proposed planning framework.

The Indicative Concept Proposal comprises:

- Approximately 2.57 hectares of public open space representing 17.8% of the total Estate (Gross Estate area – existing roads) proposed to be dedicated to the City of Sydney Council, comprising:
  - Village Green – a 2.25-hectare park located next to the Waterloo Metro Station; and
  - Waterloo Common and adjacent – 0.32 hectares located in the heart of the Waterloo South precinct.
  - The 2.57 hectares all fall within the Waterloo South Planning Proposal representing 32.3% of public open space (Gross Waterloo South area – proposed roads)
- Retention of 52% of existing high and moderate value trees (including existing fig trees) and the planting of three trees to replace each high and moderate value tree removed.
- Coverage of 30% of Waterloo South by tree canopy.
- Approximately 257,000 sqm of GFA on the LAHC land, comprising:
  - Approximately 239,100 sqm GFA of residential accommodation, providing for approximately 3,048 dwellings comprising a mix of market and social (affordable rental) housing dwellings;
  - Approximately 11,200 sqm of GFA for commercial premises, including, but not limited to, supermarkets, shops, food & drink premises and health facilities; and
  - Approximately 6,700 sqm of community facilities and early education and child care facilities.

The key features of the Indicative Concept Proposal are:

- It is a design and open space led approach.
- Creation of two large parks of high amenity by ensuring good sunlight access.
- Creation of a pedestrian priority precinct with new open spaces and a network of roads, lanes and pedestrian links.
- Conversion of George Street into a landscaped pedestrian and cycle friendly boulevard and creation of a walkable loop designed to cater to the needs of all ages.
- A new local retail hub located centrally within Waterloo South to serve the needs of the local community.
- A target of 80% of dwellings to have local retail services and open space within 200m of their building entry.
- Achievement of a 6 Star Green Star Communities rating, with minimum 5-star Green Star – Design & As-Built (Design Review certified).
- A range of Water Sensitive Urban Design (WSUD) features.

The proposed land allocation for the Waterloo South precinct is described in Table 2 below.

Table 2 Breakdown of allocation of land within the Waterloo South

Land allocation	Existing	Proposed
Roads	3.12ha / 25.3%	4.38ha / 35.5%
Developed area (Private sites)	0.86ha / 6.98%	0.86ha / 7%
Developed area (LAHC property)	8.28ha / 67.2%	4.26ha / 34.6%
Public open space (proposed to be dedicated to the City of Sydney)	Nil / 0%	2.57ha / 20.9% (32.3% excluding roads)
Other publicly accessible open space (Including former roads and private/LAHC land)	0.06ha / 0.5%	0.25ha / 2%
TOTAL	**12.32ha**	**12.32ha**

The Indicative Concept Proposal for the Waterloo South is illustrated in Figure 3 .

Figure 3: Indicative Concept Proposal

Source: Turner Studio

4.0 Baseline Investigations

This section will address study requirements item 1.5.

4.1 Key Considerations for the Estate

To arrive at a flooding and stormwater solution for the Estate, 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, a tributary of the Cooks River, in line with NSW Water Quality Objectives; and
- Sustainability and climate change adaptation measures, including Water Sensitive Urban Design, for a green and resilient urban development.

4.2 Alexandra Canal Floodplain Risk Management Study

In 2014 the City of Sydney 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).

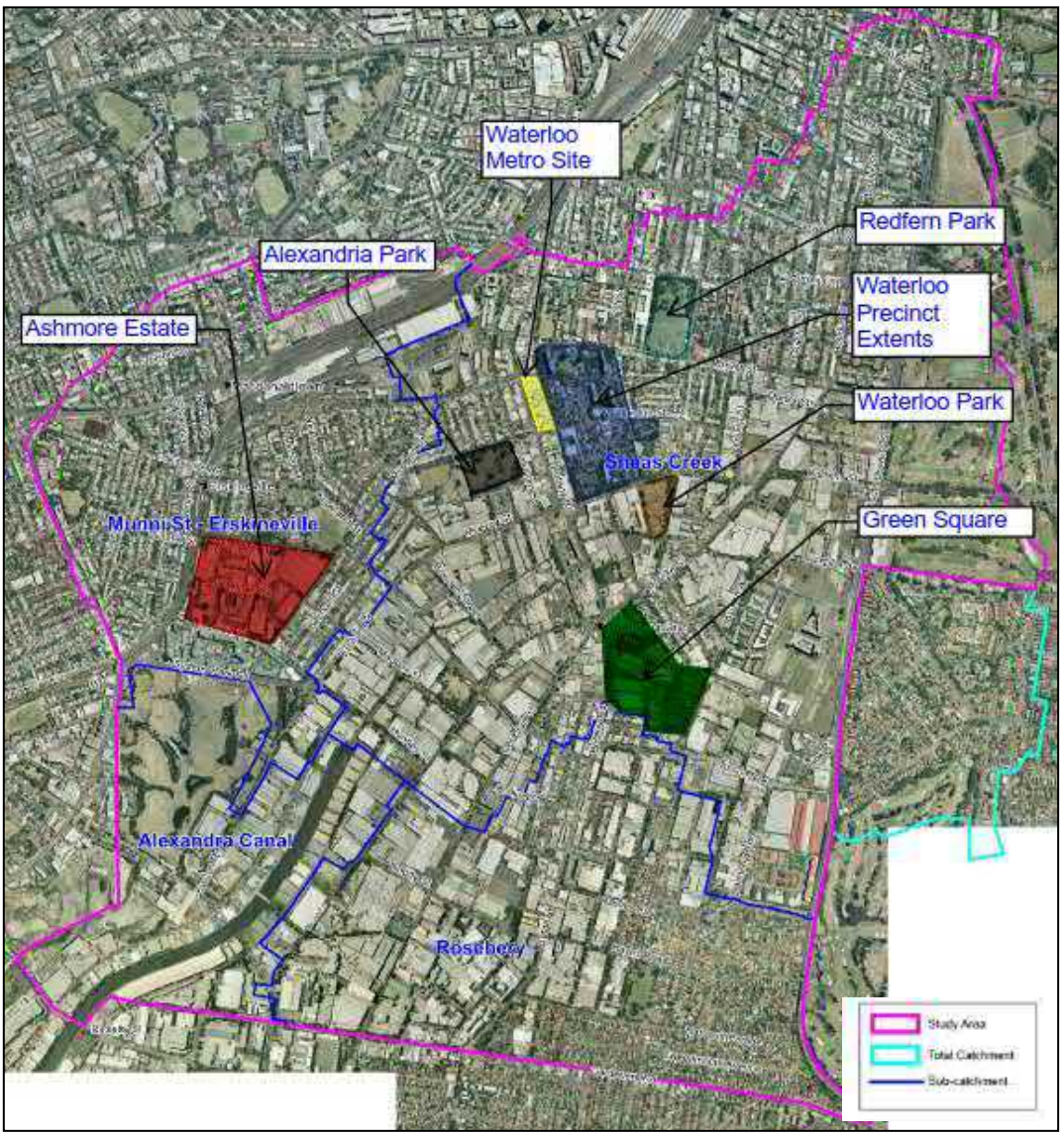


Figure 4: Alexandra Canal Floodplain Risk Management Study extents and catchment delineation

4.3 Flooding Context

4.3.1 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 City of Sydney in 2014.

The images shown in Figure 5 were noted within the study to be of particular relevance to the Estate and surrounding areas. These images demonstrate that the area is known for historical flooding issues and creates constraints for any development works in the area.

Figure 5: 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)

4.4 Hydrological Context

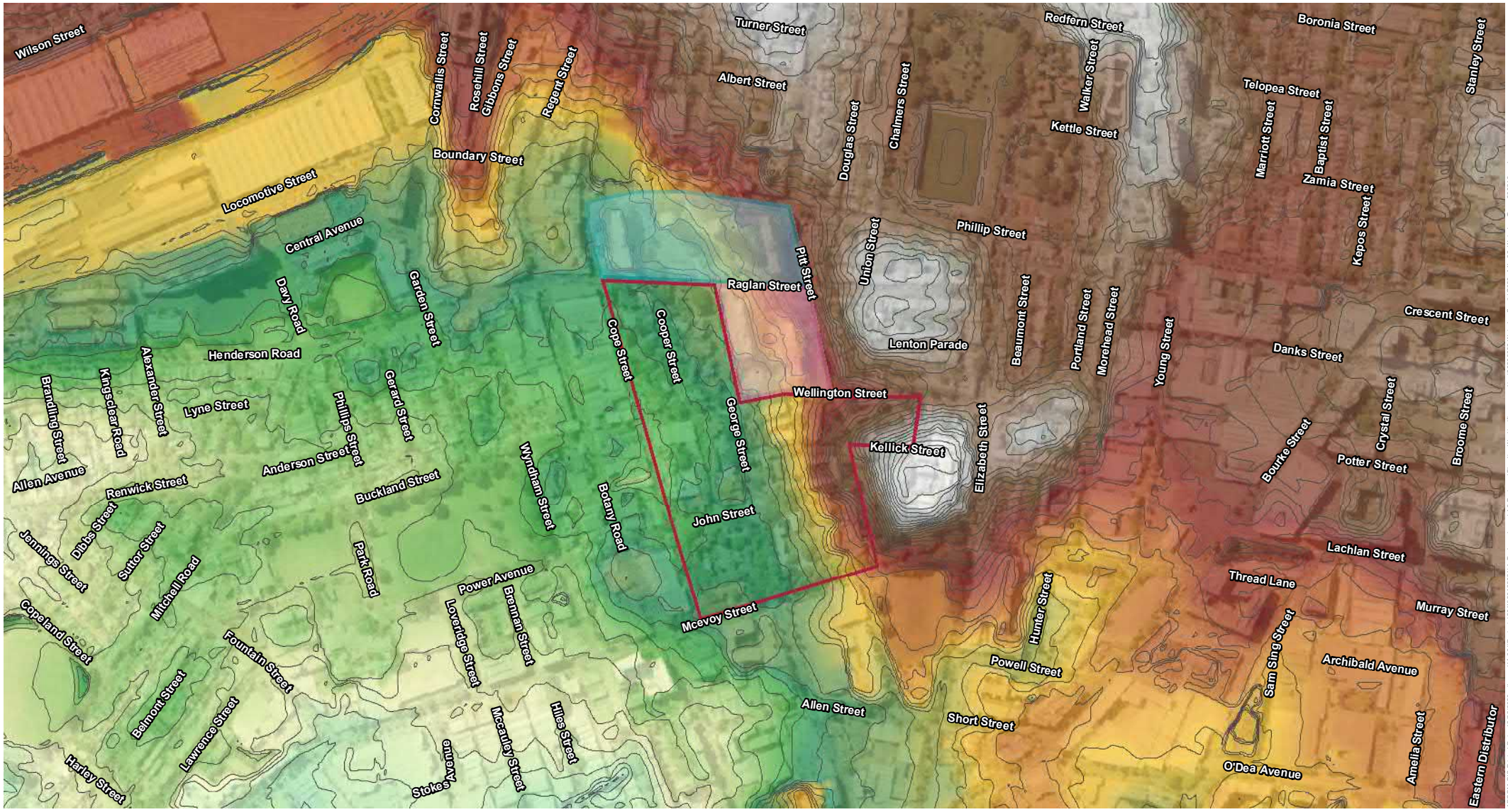
4.4.1 Catchment Characteristics

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 Estate measures approximately 18 Ha and consists of ~2.5% of the overall 775 Ha Shea's Creek sub catchment area. Preliminary analysis suggests that the effective Waterloo SSP catchment and Redfern Park catchment (83.6 Ha in total) are divided along a topographical ridge line extending from the intersection of Redfern and Pitt St to the north and the intersection of McEvoy and Elizabeth St to the south.

A flooding context workshop was held at AECOM's office on 17th May 2017 between UrbanGrowth, LAHC, City of Sydney, TURF, Sydney Metro, Metron and Turner to discuss the existing flooding conditions in the Estate as well as the potential flood modification options including upgrades to trunk drainage, overland flow, OSD and property mitigation strategies.

Further analysis from the workshop on the 17th May 2017 has been undertaken which suggests that the Redfern Park catchment acts independently of the Waterloo SSP Catchment. Based on current 1m LIDAR data and Cardno 2014 flood study it can be demonstrated that there are no overflows from the Redfern Park trapped low point to the Waterloo SSP for events up to the Probable Maximum Flood (PMF). With the Redfern Park catchment isolated from the overall upstream Shea's creek catchment, the effective catchment area contributing to the Estate is estimated to be 47.5 Ha. A site topographic map of the Estate and surrounding region is shown in Figure 6 below.

FIGURE 6



KEY

- Waterloo Central
- Waterloo North
- Waterloo South
- 1m contours

AECOM

0 100 200 m

CONFIDENTIAL GIS MAP

SCALE	1:8,000
SIZE	A4
SHEET	1 of 1
COORDINATE SYSTEM	GDA 1994 MGA Zone 56
TITLE	Site Topography
PROJECT	WATERLOO SOUTH CONCEPT PROPOSAL
CLIENT	NSW LAND AND HOUSING CORPORATION

DRAWN	DATE	MAP #	REV	Project
SC	13/03/2020	G029	01	60548168
CHECK: DF	FIGURE: 3			

AECOM GIS Printed Date: 13/03/2020 \\aeaxyd1fp001\Projects\60\60548168\4. Tech work area\4.6 Drainage\Flooding Working\figures working\20200302 Waterloo South\IG029_A4L_02_Waterloo_Topo_20201 0.mxd

Figure **7** and Figure **8** also provide an indication of existing flood conditions as well as the locations of existing trunk stormwater infrastructure currently servicing the Estate catchment area.

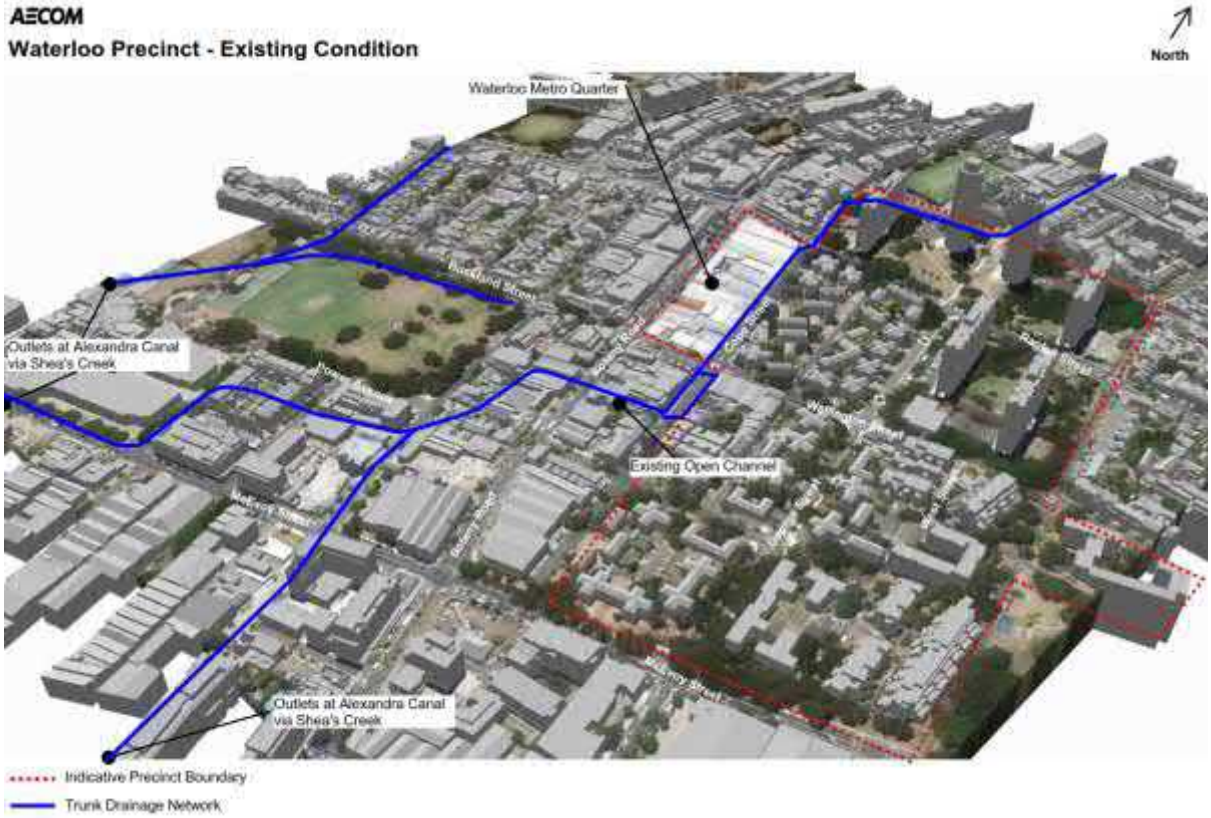


Figure 7: The Estate - Existing Condition

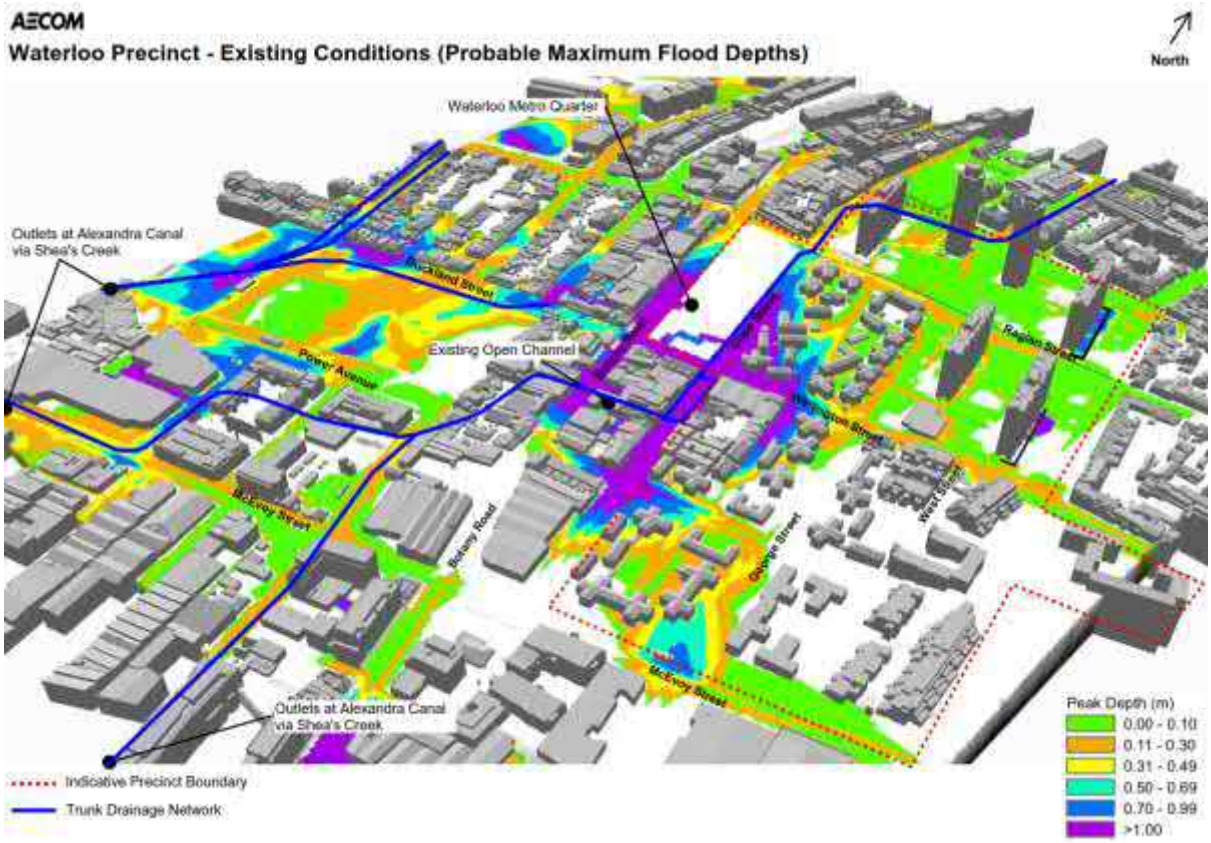


Figure 8: The Estate - Existing Conditions (PMF)

4.4.2 Hydrological Data and Preliminary Results

The results (from WBM data using DRAINS V2017.08) of the DRAINS hydrological analysis for the study area, are shown below. The DRAINS WBM hydrological model, which was utilised in the Flood Plan Risk Management Study commissioned by City of Sydney in 2014, was modified with minor updates to grassed and pervious area to better reflect the study area. The results shown represent the 100yr ARI 2-hour storm.

Table 3: Preliminary hydrological data and peak discharge for the Estate area (Existing)

Location	Effective Catchment Area	Paved Area (average)	Grassed Area (average)	Paved Roughness	Grass Roughness	Q_{peak} 100year 2hr Storm
Waterloo Housing Estate Area	21.0 Ha	67%	33%	0.012	0.027	12.8 m^3/s
Station Area	1.9 Ha	95%	5%	0.012	0.027	1.3 m^3/s
Waterloo SSP Catchment	47.5 Ha	70%	30%	0.012	0.027	27 m^3/s
Redfern Park Catchment	36.07 Ha	70%	30%	0.012	0.027	21 m^3/s
Total Upstream Effective Catchment	83.6 Ha	70%	30%	0.012	0.027	48 m^3/s

4.4.3 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 City of Sydney and a trunk drainage system which discharges to Shea's Creek and eventually the Alexandra Canal and Cooks River. The trunk drainage system is owned by Sydney Water Corporation. The existing drainage network is shown in Figure 9.

4.4.4 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. It can be inferred from the mapping that where future development within the Estate reduces the existing flood storage areas, it is likely that an increase in flood depth would occur at another location. As a result, the existing conditions show that flood storage should be a careful consideration for future development to ensure that flood impacts are not significantly increased in other locations.

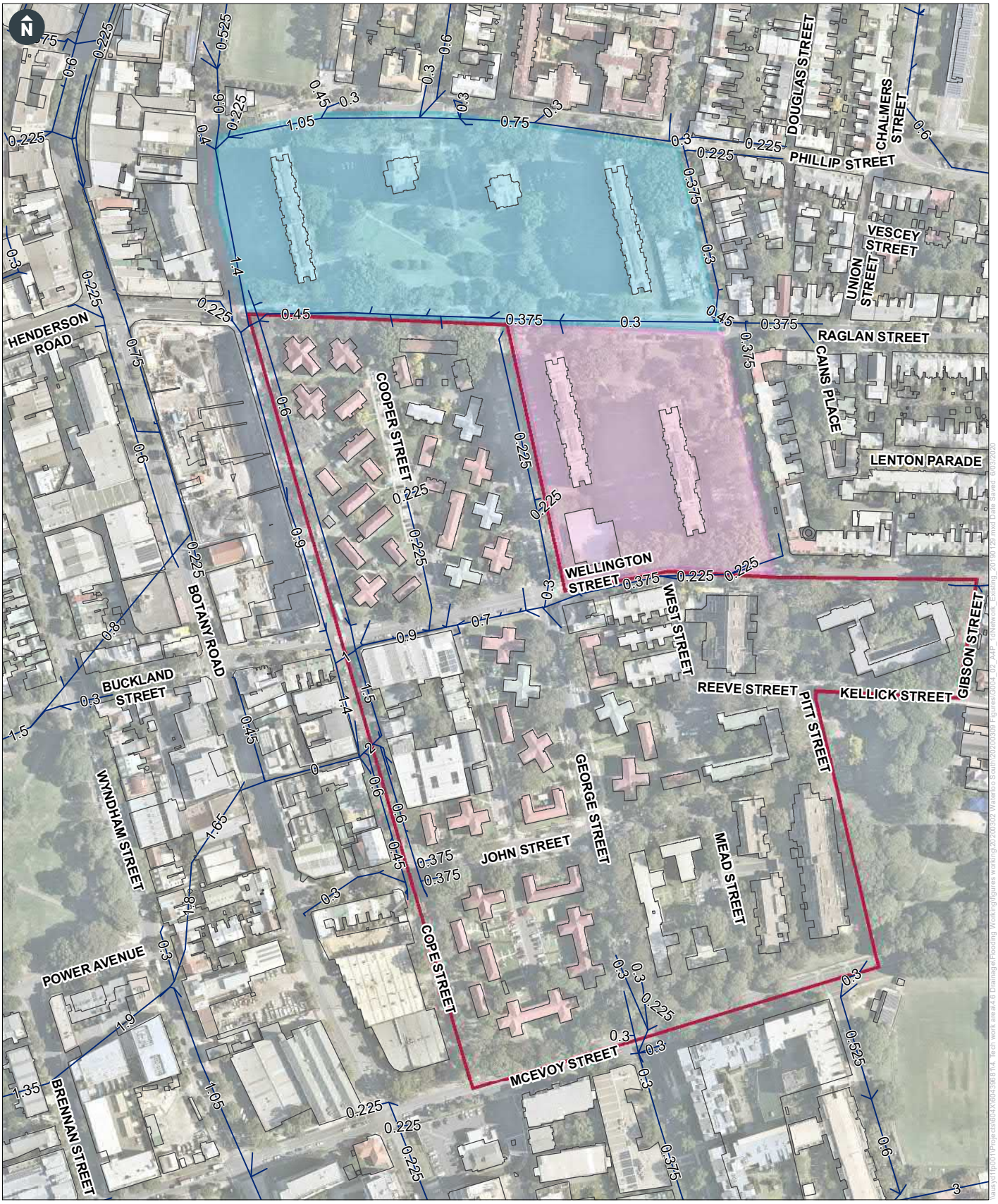
The existing TUFLOW model was provided by City of Sydney and formed the basis to document the preliminary flooding results. Preliminary flood modelling results are shown in Figure 11 to Figure 16.

4.4.5 Preliminary Flood Analysis Conclusions

From the preliminary flooding analysis and hydrology study it appears that the primary source of flooding can be attributed to a number of issues. A notable issue is that the trunk drainage system is outlet constrained at the Cope Street open channel. During the 100yr ARI event it is noted that the Hydraulic Grade Line (HGL) is above the road surface at this location.

With the Hydraulic Grade line above the surface this creates limited opportunity for the upstream overland flow to enter the trunk drainage system until the HGL is lower than the channel inlet. Furthermore, upwelling or surcharging of the system may be occurring as a result of the downstream tailwater effects within the system.

FIGURE 9



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Existing building outlines
- 1d network

AECOM

Source: Imagery © Nearmap, 2019.

SCALE 1:3,500 | SIZE A4

SHEET 1 of 1 | DATE 6/03/2020

TITLE

MODELLED DRAINAGE NETWORK
Existing Case

PROJECT

WATERLOO SOUTH
CONCEPT PROPOSAL

CLIENT

NSW LAND AND HOUSING CORPORATION

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FIGURE 10

Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Existing building outlines
- Peak flood level contours (1m)
- Peak flood level contours (0.2m)

Peak Flood Depth (m) - 20yr ARI

< 0.05	0.25 to 0.5
0.05 to 0.1	0.5 to 1.0
0.1 to 0.15	1.0 to 1.5
0.15 to 0.2	1.5 to 2.0
0.2 to 0.25	> 2.0

AECOM

Source: Imagery © Nearmap, 2019.

SCALE	1:3,500
SIZE	A4
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DATE	9/03/2020

TITLE

FLOODING CONDITIONS
Existing Case - 20yr ARI

PROJECT

WATERLOO SOUTH
CONCEPT PROPOSAL

CLIENT

NSW LAND AND HOUSING CORPORATION

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FIGURE 11

Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Existing building outlines
- Peak flood level contours (1m)
- Peak flood level contours (0.2m)

Peak Flood Depth (m) - 100yr ARI

< 0.05	0.25 to 0.5
0.05 to 0.1	0.5 to 1.0
0.1 to 0.15	1.0 to 1.5
0.15 to 0.2	1.5 to 2.0
0.2 to 0.25	> 2.0

AECOM

Source: Imagery © Nearmap, 2019.

SCALE	1:3,500
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TITLE

FLOODING CONDITIONS
Existing Case - 100yr ARI

PROJECT

WATERLOO SOUTH
CONCEPT PROPOSAL

CLIENT

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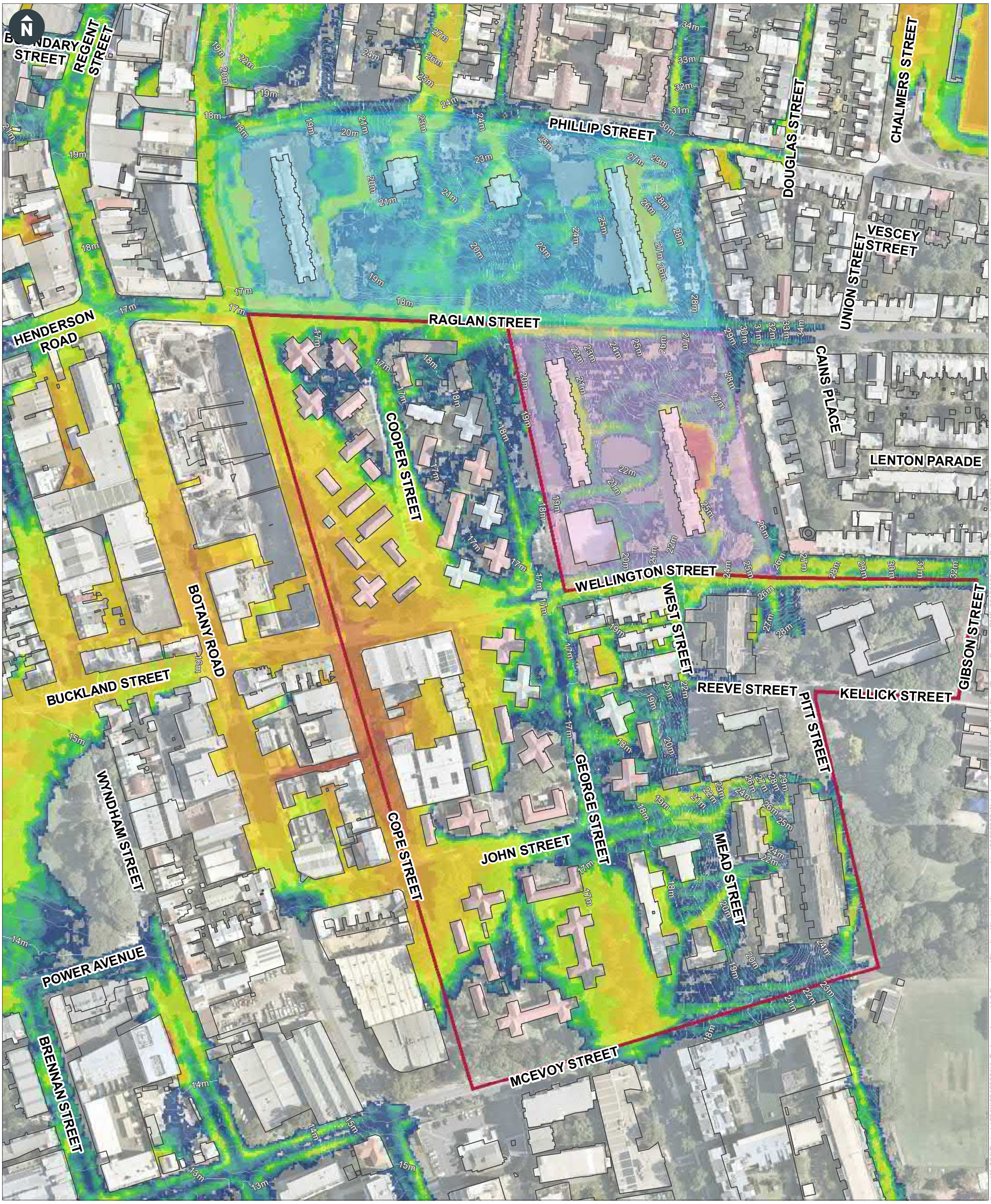
FIGURE 12



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Existing building outlines
- Peak flood level contours (1m)
- Peak flood level contours (0.2m)

Peak Flood Depth (m) - PMF

< 0.05	0.25 to 0.5
0.05 to 0.1	0.5 to 1.0
0.1 to 0.15	1.0 to 1.5
0.15 to 0.2	1.5 to 2.0
0.2 to 0.25	> 2.0

AECOM

SCALE 1:3,500	SIZE A4
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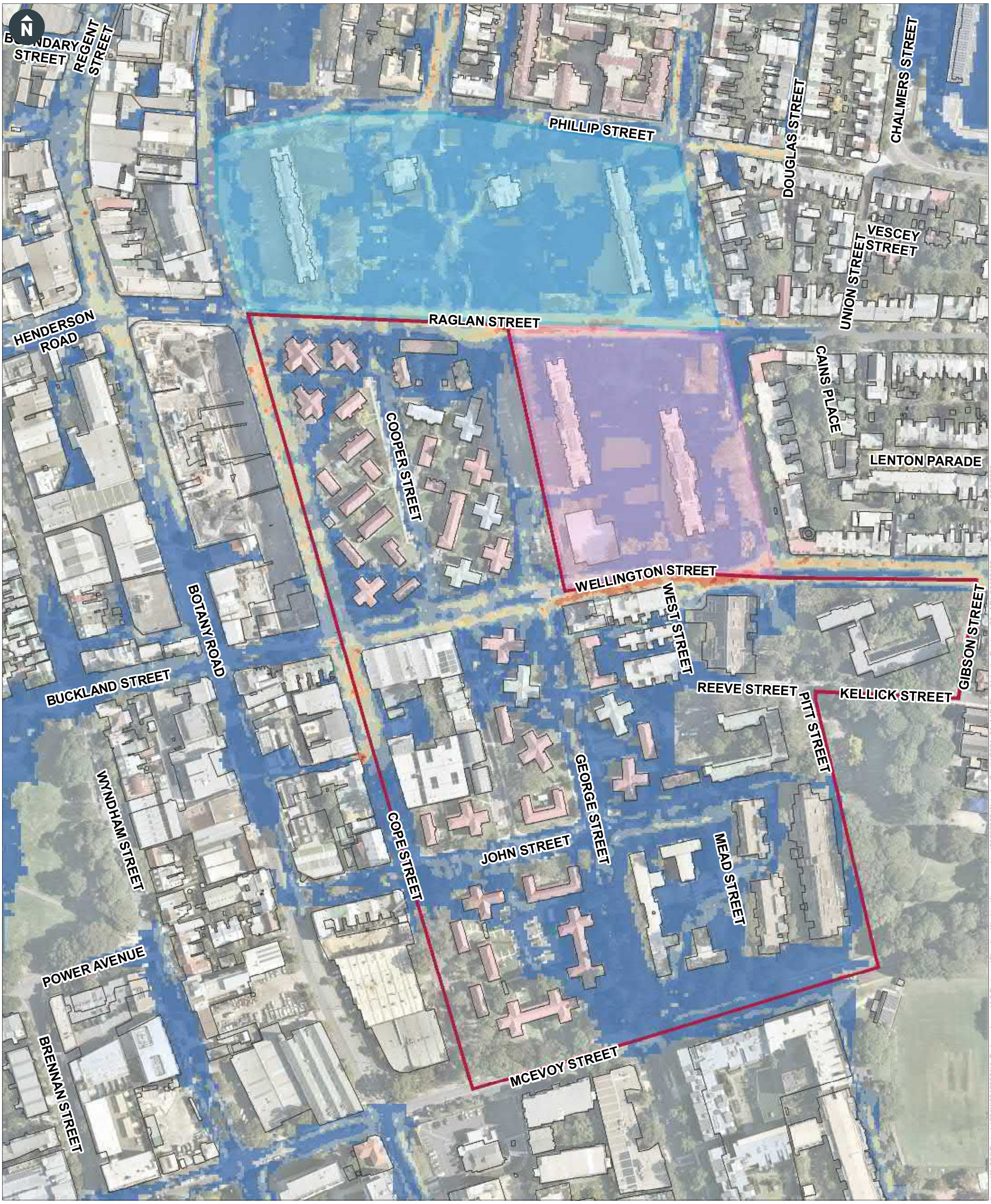
TITLE
FLOODING CONDITIONS
Existing Case - PMF

PROJECT
WATERLOO SOUTH CONCEPT PROPOSAL

CLIENT
NSW LAND AND HOUSING CORPORATION

CONFIDENTIAL GIS MAP

FIGURE 13



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Existing building outlines

Flood Velocity (m/s) - 20yr ARI

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

AECOM

Source: Imagery © Nearmap, 2019.

SCALE	SIZE
1:3,500	A4
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TITLE
FLOOD VELOCITY
Existing Case - 20yr ARI

PROJECT
WATERLOO SOUTH
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NSW LAND AND HOUSING CORPORATION

CONFIDENTIAL GIS MAP

FIGURE 14

Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Existing building outlines

Flood Velocity (m/s) - 100yr ARI

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

AECOM

Source: Imagery © Nearmap, 2019.

SCALE	1:3,500
SIZE	A4
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TITLE

FLOOD VELOCITY
Existing Case - 100yr ARI

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WATERLOO SOUTH
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CLIENT

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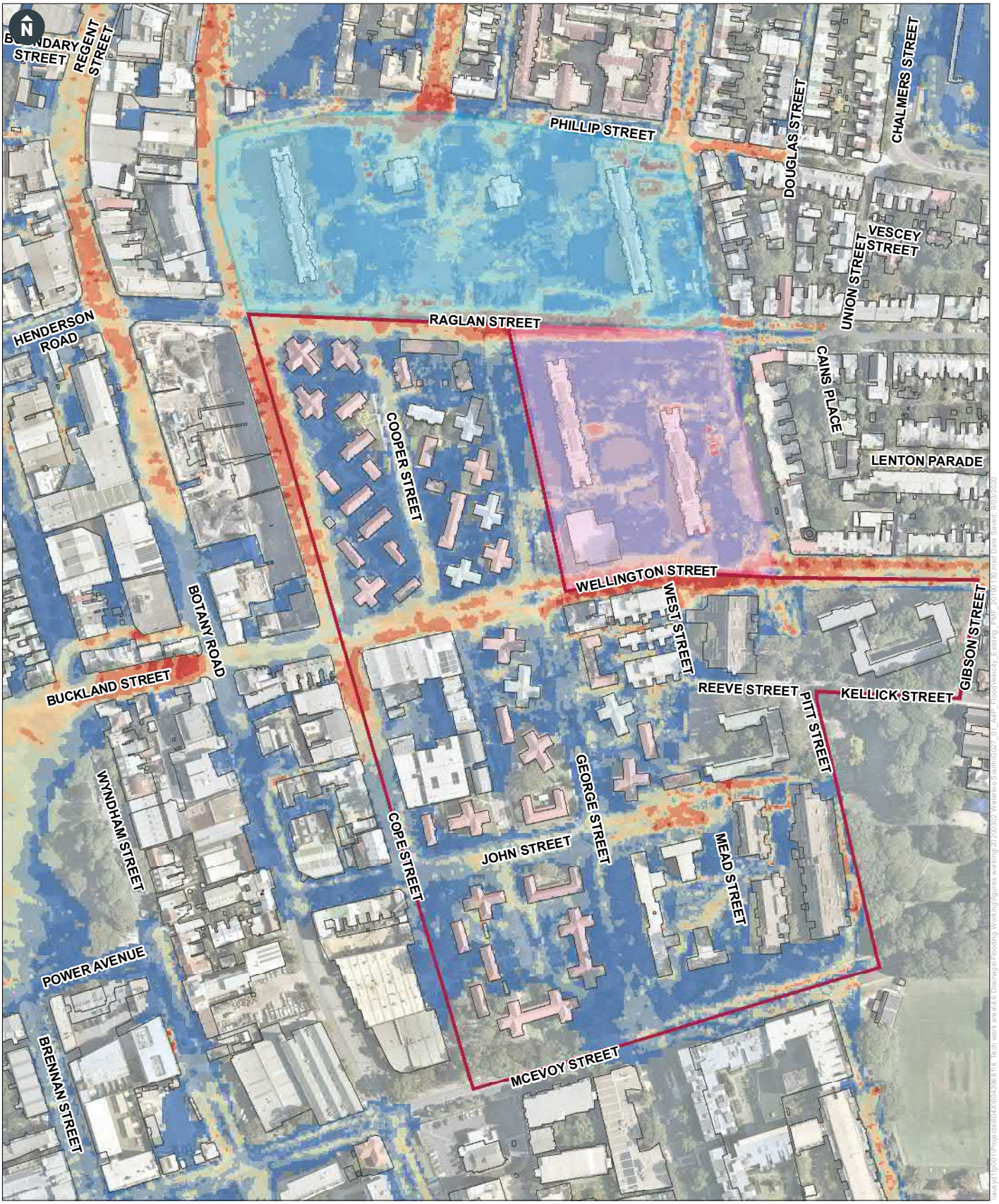
FIGURE 15



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Existing building outlines

Flood Velocity (m/s) - PMF

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

AECOM

Source: Imagery © Nearmap, 2019.

SCALE 1:3,500 | SIZE A4

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TITLE

FLOOD VELOCITY
Existing Case - PMF

PROJECT

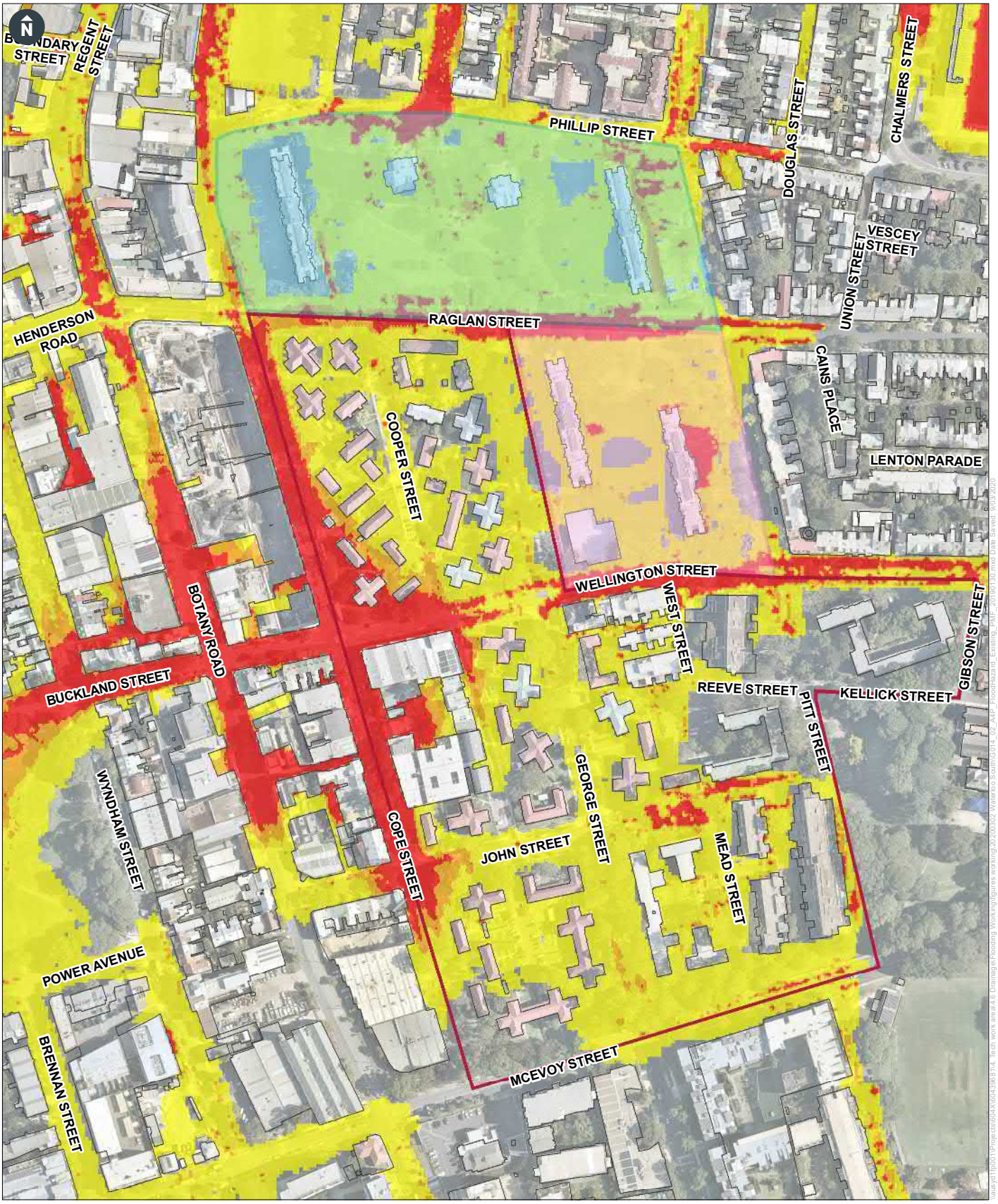
WATERLOO SOUTH
CONCEPT PROPOSAL

CLIENT

NSW LAND AND HOUSING CORPORATION

CONFIDENTIAL GIS MAP

FIGURE 16



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Existing building outlines

Flood Hazard

- Low Hazard
- Transitional Hazard
- High Hazard

AECOM

Source: Imagery © Nearmap, 2019.

SCALE	SIZE
1:3,500	A4
SHEET	DATE
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TITLE

FLOOD HAZARD
Existing Case - PMF

PROJECT

WATERLOO SOUTH
CONCEPT PROPOSAL

CLIENT

NSW LAND AND HOUSING CORPORATION

CONFIDENTIAL GIS MAP

5.0 Assessment

5.1 Design Criteria

This section will address study requirements item 1.5.

5.1.1 Study Requirements – Nominated SSP – Waterloo 2018

The Department of Planning and Environment working in tandem with the City of Sydney Council and in consultation with State agencies have established a series of Study Requirements for the Waterloo SSP to outline the key planning requirements for the Estate. Those listed in Section 2.0 of this report from the '*Study Requirements, Nominated State Significant Precinct – Waterloo, Revised March 2018'* have been considered in this report. While this project is going through a different planning pathway, the overall SSP study requirements are still relevant and required. Section 8.0 details these specified requirements and provides a summary of how each of these requirements has been addressed in this Water Quality, Flooding and Stormwater Report.

5.1.2 City of Sydney Development Control Plan 2012

The City of Sydney Development Control Plan (DCP) details planning and design guidelines to support the planning controls throughout the City of Sydney Local Government Area (LGA) which include the management of stormwater. The DCP requirements are outlined in Section 3.7 of the *City of Sydney Development Control Plan 2012.*

Specific key requirements in the DCP 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 is not to reduce the capacity of that infrastructure by more than 10%; and
- 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%;
  - Reduce the baseline annual pollutant load for total suspended solids by 85%;
  - Reduce the baseline annual pollutant load for phosphorus by 65%; and
  - Reduce the baseline annual pollutant load for total nitrogen by 45%.

5.1.3 City of Sydney Interim Floodplain Management Policy

The *Interim Floodplain Management Policy* has been developed by the City of Sydney (CoS) which documents the requirements for the management of flood risk for all new developments within the City's 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 4, extracted from the *Interim Floodplain Management Policy* (CoS, 2014) describes the permissible minimum building floor levels and below ground development 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 m (corresponding to mainstream flooding) in Table 4.

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 Estate.

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

Table 4: Flood Planning Level Criteria for the Estate
(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 0.25 m 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 250mmflood 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, lift shaft openings, risers and stairwells

5.2 Design Standards

City of Sydney design standards have generally been adopted for the Estate 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 5. These standards are to be confirmed during later design stages and are included here for reference only.

Table 5: 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

5.3 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 6. These will be used to inform the proposed flood mitigation strategies.

Table 6: 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 Stormwater Drainage (City of Sydney, 2016)	100-year ARI	
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)	

Item	Standard	Adopted	Comment
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 AR&R 2016 document.

5.4 Stormwater Quantity Control Requirements

5.4.1 Permissible Site Discharge (PSD) and OSD Requirements

Sydney Water (the authority responsible for the downstream drainage network) has advised of the required stormwater quantity controls for the site in Table 7 (refer to Appendix A). According to Sydney Water, properties that must have an OSD system include (but are not limited to):

- all commercial, industrial and special use (e.g. community, education, recreational) buildings or structures
- town houses, villas, home units or other strata subdivisions
    - These may use a single OSD system for the total site area as long as it's located on common property and the body corporate is responsible for maintenance.
- dual occupancy lots
    - Each lot within the dual occupancy must have its own OSD system. Each individual lot owner is responsible for maintenance.
- sealed sporting facilities (e.g. tennis, basketball courts, etc)

Table 7: Sydney Water requirements for properties in the Estate

Minimum Sydney Water OSD	Permitted Site Discharge (PSD)
2,900 m^3	5,944 L/s

It should be noted that the above numbers are indicative only and not representative of the actual storage necessary for the entire Estate (covering both private and public domains) to keep any offsite flood impacts within the bounds of the development. The combined detention volume within the Estate may exceed the Sydney Water requirements.

5.5 Proposed Stormwater Quantity Management

This section will address study requirements item 17.14.

5.5.1 Proposed Stormwater Management Approach

The proposed stormwater drainage and runoff system for the Estate development will comply with the design requirements as identified in Section 5.1 with the main design considerations summarised below:

5.5.1.1 Proposed Scenario

The areas and theoretical PSD for each catchment is shown below. The PSD for the site has been provided by Sydney Water which indicates a PSD of 5,944L/s assumed over an area of 18.12Ha. Extrapolating this information provides an approximate PSD rate per metre squared of 328 $Ls^{-1}ha^{-1}$ for the site.

An assumed proposed drainage was included in the model which provides pits and pipes within the Estate and upgrades the sizes of existing drainage on Phillip Street, Cope Street, Raglan Street and Wellington Street. The flood detention basins under the two proposed public open spaces, Village Green and Waterloo Common, were assumed to have an area of 50% of their respective parks and approximately 800 mm cover under the existing terrain. Flows in the existing and proposed drainage network are diverted to the detention basins to provide flood storage and attenuation. The volumes of the storage basins under Village Green and Waterloo Common are 4116 m^3 and 436 m^3 respectively for a total of 4552 m^3 of detention volume in the open public space. Where flowpaths run towards or along proposed building locations, terrain modifications were made where appropriate to reflect an assumed footpath grading away from the buildings. Drainage of adequate size has been included in the model to capture and divert flows approaching the proposed buildings. A representation of continuously grated inlets has been included in the model at some of these locations where approaching flows are relatively large.

To achieve OSD and PSD targets, the total volume of on-site stormwater detention required for the Estate will be provided on each super-lot and within the public open spaces. OSD tanks will be provided within courtyards and within building footprints in accordance with common practice for multi-residential developments. No tanks are proposed within or as part of street scape upgrades. Further detail will be further developed as part of development proposals for each super-lot.

5.6 Stormwater Quality Control Requirements

This section will address study requirements item 1.6.

As the Estate falls within the Alexandra Canal catchment which discharges into Botany Bay, the relevant guidelines that can be used to inform the area's WSUD strategy include the Botany Bay Water Quality Improvement Plan (BBWQIP) and the City of Sydney DCP (2012). The BBWQIP, which was completed by the Sydney Metropolitan Catchment Management Authority (SMCMA), details the stormwater quality requirements which were determined based on a range of scenarios and improvement options to manage water quality within Botany Bay over the 2030 and 2070 timeframes. The relevant BBWQIP stormwater quality criteria for 'large redevelopments' is presented in Table 8. The City of Sydney DCP stormwater quality requirements are discussed in Section 5.1.2 and presented in Table 8. Due to being more stringent, the City of Sydney DCP 2012 stormwater quality targets are adopted for use.

Table 8: Stormwater Quality Targets

Water Quality Parameters	BBWQIP Large Developments (% mean annual pollutant load reduction)	City of Sydney DCP 2012 (% mean annual pollutant load reduction)
Gross Pollutants	90	**90**
Total Suspended Solids (TSS)	85	**85**
Total Phosphorus (TP)	60	**65**
Total Nitrogen (TN)	45	**45**

The stormwater quality management approach will involve integrating WSUD techniques in the proposed stormwater drainage system. This also reflects the obligations noted in the Waterloo SSP – Study Requirements and the approach detailed in the City of Sydney Decentralised Water Master Plan (CoS, 2012).

5.6.1 Other Relevant Guidelines

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

- *Risk based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions*
- *Local Planning for Healthy Waterways Using NSW Water Quality Objectives June 2006*
- *Managing Urban Stormwater – Harvesting and Reuse Guidelines* December 2006

WSUD Guidelines Landcom 2009 was also considered as referenced in the Waterloo SSP Study Requirements Section 1 Item 1.6. However, this document has been out of circulation and no revised version has since been published. Councils have incorporated their WSUD requirements in their respective DCPs. For this study, the City of Sydney DCP 2012 discussed in Section 5.1.2, is applicable.

5.6.1.1 Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions

The Office of Environment and Heritage (OEH) released the 'Risk-based framework for considering waterway health outcomes in strategic land use planning decisions (the Framework)' in 2017 to protect waterways and deliver the objectives of the Marine Estate Management Strategy 2018-2028 (MEM Strategy). The Framework requires that specific and targeted water quality objectives be applied to protect the values of the local receiving waters. In this instance, the specific receiving water body is the Alexandra Canal and Botany Bay and specific water quality targets are specified in the Botany Bay Water Quality Improvement Plan (BBWQIP) as outlined in Section 5.6.

5.6.1.2 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:

- 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 importance in planning decisions.
- Assessing the current condition of waterways – Councils should consider condition of waterways, key pressures on their health and potential risks to water quality during assimilation of information for their LEPs and DCPs.
- Identifying significant risks to water quality – Review of existing and potential activities and use of conceptual and predictive models for decision-making.
- 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.
- 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.
- 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).

5.6.1.3 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 17 and Figure 18 respectively. The treatment adopted for a stormwater reuse project should relate to the stormwater quality criteria.

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 17: 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 18: Stormwater quality criteria

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

5.7 Proposed Stormwater Quality Control

This section will address study requirements items 17.1, 17.2, 17.11 and 17.14.

This section provides detail on how stormwater quality controls will be deployed to manage stormwater runoff from the Waterloo public domain. The public domain stormwater quality strategy is independent of how stormwater is managed on super-lots. It is assumed that the private domain will be able to achieve stormwater quality targets by employing on-lot measures as required, which will be developed in the detailed design stage.

Water Sensitive Urban Design measures, including gross pollutant traps, passive irrigation of landscaping, biofiltration including street trees and rain gardens have been considered as appropriate stormwater treatment measures for the Estate public domain to achieve the stormwater pollutant reduction targets outlined in Table 8.

The following section provides a preliminary WSUD strategy that accommodates the site constraints and identifies opportunities for integration of WSUD into the urban form to provide certainty that the current rezoning provides sufficient allocation of land for WSUD measures to meet the local stormwater quality targets.

Further details on WSUD elements including, drainage connections, media selection, subsoil drainage, structural requirements and exact infrastructure layouts will be required once the proposed site levels and road design become available.

5.7.1 Integration of Stormwater Treatment Measures

Bio-retention is useful in treating stormwater runoff from impervious surroundings through the natural properties of soil to remove pollutants and contaminants. Bio-retention measures include biofiltration tree pits, bioswales and raingardens. For the Estate, raingardens may be incorporated within some open space areas such as the Village Green and Waterloo Common. These would provide treatment to runoff from adjacent pavements able to be drained overland or via shallow pipes and grated drains to the raingarden surface.

The site generally grades to the west and also falls towards Buckland Street.

Stormwater, from external areas, drains through the site via an existing pit and pipe drainage network. New stormwater drainage within the site will ultimately connect to the existing stormwater drainage network along the site's western boundary in Cope St. Stormwater inverts are likely to be 1.0 to 2.0 m below ground surface and will form a key physical constraint to the provision of WSUD.

End of Pipe Biofiltration

Day lighting stormwater from the underground pipe networks is considered to be impracticable due to the depths of those pipes (+1m). The resulting level change between biofiltration surface and surrounding areas would require extensive batter slopes or walls with balustrades which would be a poor urban design outcome for such a high-use urban environment.

Furthermore, the collection pipes within the base of the end of pipe biofiltration basins would be at least 2m below surface level and potentially lower than the surrounding drainage network, in which case, mechanical pumps or pipe drainage at flat grades would be required to collect and discharge treated stormwater to the downstream network. Both outcomes are problematic for long term maintenance.

As such end-of-pipe biofiltration basins have not been considered as part of the strategy.

At Source Biofiltration

Streetscape biofiltration such as biofiltration street tree pits and verge rain gardens have a modest associated land tank and provide much better opportunities for integration into the urban form. These devices will provide the majority of stormwater treatment within public roads, pedestrian zones and streetscape upgrades.

Biofiltration street tree pits are unlikely to be suitable for streets with a width less than 5 m including some pedestrian laneways and pedestrian links.

Stormwater runoff will be collected at-source or via shallow drains to streetscape measures for biofiltration and discharge to the adjacent underground stormwater network. The base of at-source biofiltration devices would be at approximately 1m below surface level and suitable for discharge to the surrounding drainage network under gravity.

Figure 19 Examples of at-source WSUD in highly urban environments

Proprietary Filtration in Underground Chambers

Where paved areas are not able to be drained directly to streetscape biofiltration measures, or where open space outcomes must be maximised (e.g. within narrow laneways), stormwater filtration will be provided through proprietary pollutant control devices situated in pits and underground chambers. There are many proprietary filtration options available which perform a similar function and respond differently to the local specific site constraints.

Stormwater runoff will be diverted to chambers via shallow drains for filtration and will discharge to the adjacent underground stormwater network. The base of chambers devices would be at approximately 1 to 1.5m below surface level and suitable for discharge to the surrounding drainage network under gravity.

Water in the Landscape

WSUD measures provide a means for cooling the microclimate and reducing urban heat island effects.

At-source biofiltration provides a means for passively irrigating the landscape and providing a dual stormwater and landscape function to green infrastructure. When carefully designed and correctly constructed, biofiltration street trees should provide significantly shady canopies without damaging surrounding pavements or causing trip hazards for pedestrians.

Filtered stormwater will be considered for use in ornamental water features and irrigation of public open space on a fit-for-purpose basis. Filtered stormwater from WSUD devices will be collected in underground tanks and treated with further filtration and ultra violet disinfection before being pumped to surface water features.

Discharging stormwater directly into surface water features is subject to the same constraints as end-of-pipe biofiltration described above and is not considered further as part of this strategy.

5.7.2 Compliance with Stormwater Quality Targets

This section presents detail on how the WSUD approach for the Estate public domain will achieve the City of Sydney's stormwater quality targets (refer section 5.6). MUSIC modelling has been used to demonstrate that by applying the approach described below, the stormwater quality targets will be achieved.

Given the public domain is subject to change as the design develops the footprint and specific details of the WSUD measures have not been defined at this stage. The proposed approach enables flexibility to enable appropriate treatment to be provided to achieve the stormwater quality targets as the public domain design develops.

Biofiltration Street Trees

Preliminary calculations based on MUSIC modelling were undertaken to determine the filter area and associated biofiltration tree pit spacing required to achieve the stormwater quality targets. Modelling assumptions are provided in Appendix B.

Modelling indicates that a biofiltration street tree pit filter area equivalent to 2% of the upstream catchment is required to achieve the stormwater quality targets.

A filter area equivalent to 4% of the catchment (including the bypass area) is required where 10% of the catchment bypasses the biofiltration street tree. Equivalent metrics can be applied to raingarden filter area located within road verges.

Table 9: Biofiltration street tree pit requirements to treat 100% of local paved catchment

Assumed Pavement Width (m)	Bio-filter area per 100 m of linear pavement (m^2)	Tree Pit Spacing – single row (m)	Tree Pit Spacing – either side of road (m)
5	10	33	NA
7	14	25	NA
9	18	20	10
11	22	16	32
15	30	12	24
20	40	10	20

Table 10: Biofiltration street tree pit requirements to treat 90% of local paved catchment

Assumed Pavement Width (m)	Bio-filter area per 100 m of linear pavement (m^2)	Tree Pit Spacing – single row (m)	Tree Pit Spacing – either side of road (m)
5	20	16.5	NA
7	28	12.5	NA
9	36	10	5
11	44	8	16
15	60	6	12
20	80	5	10

Pit Inserts and Underground Proprietary Filters

Where greater than 10% of the Precinct bypasses the streetscape biofiltration measures or constraints preclude the use of street tree pits, additional stormwater treatment would be provided underground by way of proprietary stormwater treatment devices.

MUSIC modelling showed that the stormwater quality targets will be achieved by providing 1 x 690 mm Stormfilter cartridge per 750 m^2 of pavement, assuming 1 x Enviropod is installed upstream. Approximately 4 x 690 mm cartridges can be installed per 3 m^2 of chamber.

A 930 mm hydraulic drop is typically required for a standard 690 mm Stormfilter cartridge height. Reduced cartridge heights can be used but these will result in an increase in the number of cartridges and chamber surface area. The number of cartridges can be increased as required to treat the respective catchment draining to the chamber and with consideration to treatment being provided within the streetscape.

5.7.3 WSUD Strategy Plan

An indicative layout plan of the WSUD strategy is presented in Figure 20 which shows the locations of specific WSUD measures described above.

Refinement of WSUD locations and footprints, in accordance with the sizing provided in Section 5.7.2, will be undertaken once site grading, drainage upgrades and road design details become available.

Figure 20: Indicative Stormwater Treatment Strategy

5.8 Post-Development Flood Conditions

5.8.1 Methodology

The DRAINS hydrology model was modified to represent the concept proposal to produce inflow information for the TUFLOW model. This involved updating catchment areas and impervious percentages for the sub-catchments within the Waterloo SSP area. The TUFLOW hydraulic model was modified to include the Indicative Concept Proposal. The modelling considers the cumulative developments of the Metro, Waterloo North and Waterloo Central so to not limit future planning proposals.

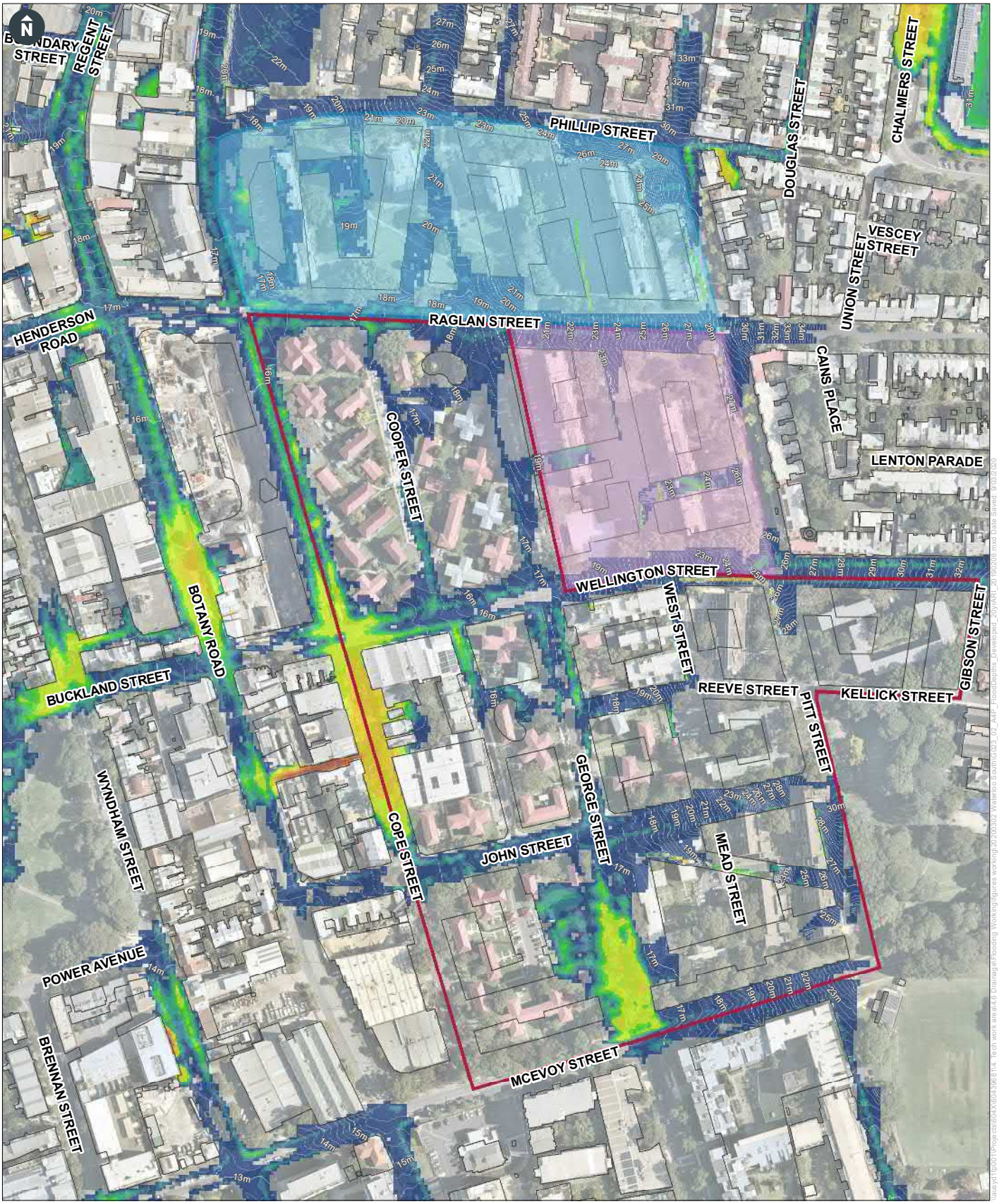
For the TUFLOW model, materials layers and building outlines were updated to reflect the surface roughness and building layout. An assumed drainage network was included in the model which provides pits and pipes within the Estate and upgrades the sizes of existing drainage on Phillip Street, Cope Street, Raglan Street and Wellington Street. The flood detention basins under the two proposed public open spaces, Village Green and Waterloo Common, were assumed to have an area of 50% of their respective parks and approximately 800 mm cover under the existing terrain. Flows in the existing and proposed drainage network are diverted to the detention basins to provide flood storage and attenuation. The volumes of the storage basins under Village Green and Waterloo Common are 4116 m^3 and 436 m^3 respectively. Where flowpaths run towards or along proposed building locations, terrain modifications were made where appropriate to reflect an assumed footpath grading away from the buildings. Drainage of adequate size has been included in the model to capture and divert flows approaching the proposed buildings. A representation of continuously grated inlets has been included in the model at some of these locations where approaching flows are relatively large.

- 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 event, the 60- and 90-minute storm events were identified as being critical, while for the PMF the 30- and 45-minute durations were critical. Flood results 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.

5.8.2 Proposed Development Flood Depth, Flood Velocity and Flood Hazard

Flooding characteristics including flood depths and flood velocities for the proposed development are shown in Figure 21 to Figure 26 for the 20 year ARI, 100 year ARI and the PMF events. Flood hazard for the proposed development is shown in Figure 27 for the PMF case.

FIGURE 21



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines
- Peak flood level contours (1m)
- Peak flood level contours (0.2m)

Peak Flood Depth (m) - 20yr ARI

0 - 0.05	0.25 - 0.5
0.05 - 0.1	0.5 - 1
0.1 - 0.15	1 - 1.5
0.15 - 0.2	1.5 - 2
0.2 - 0.25	2 - 3

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FLOODING CONDITIONS
Developed Case - 20yr ARI

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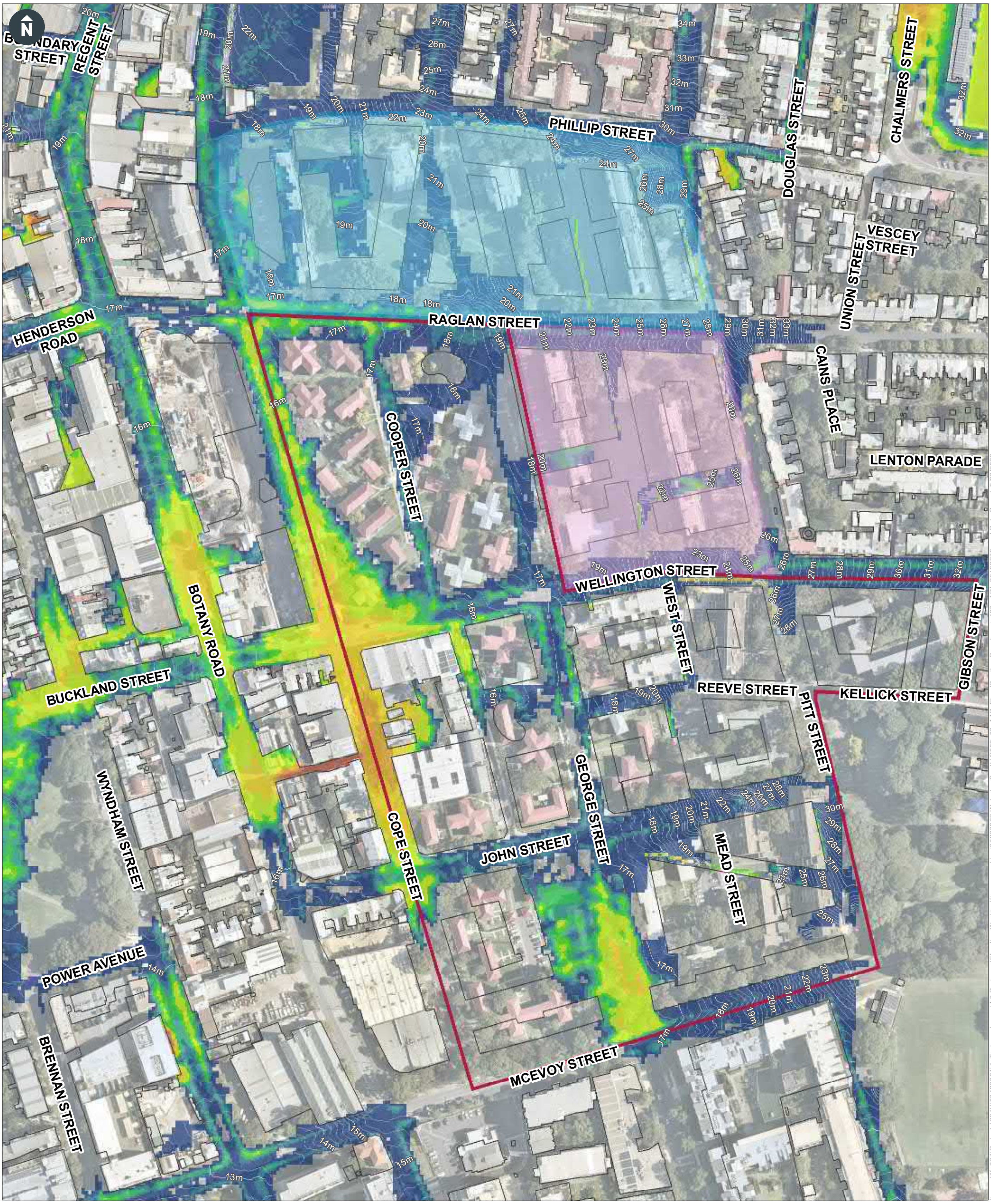
FIGURE 22



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines
- Peak flood level contours (1m)
- Peak flood level contours (0.2m)

Peak Flood Depth (m) - 100yr ARI

< 0.05	0.25 - 0.5
0.05 - 0.1	0.5 - 1
0.1 - 0.15	1 - 1.5
0.15 - 0.2	1.5 - 2
0.2 - 0.25	> 2

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Source: Imagery © Nearmap, 2019.

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FLOODING CONDITIONS
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FIGURE 23

Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines
- Peak flood level contours (1m)
- Peak flood level contours (0.2m)

Peak Flood Depth (m) - PMF

< 0.05	0.25 - 0.5
0.05 - 0.1	0.5 - 1
0.1 - 0.15	1 - 1.5
0.15 - 0.2	1.5 - 2
0.2 - 0.25	> 2

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FLOODING CONDITIONS
Developed Case - PMF

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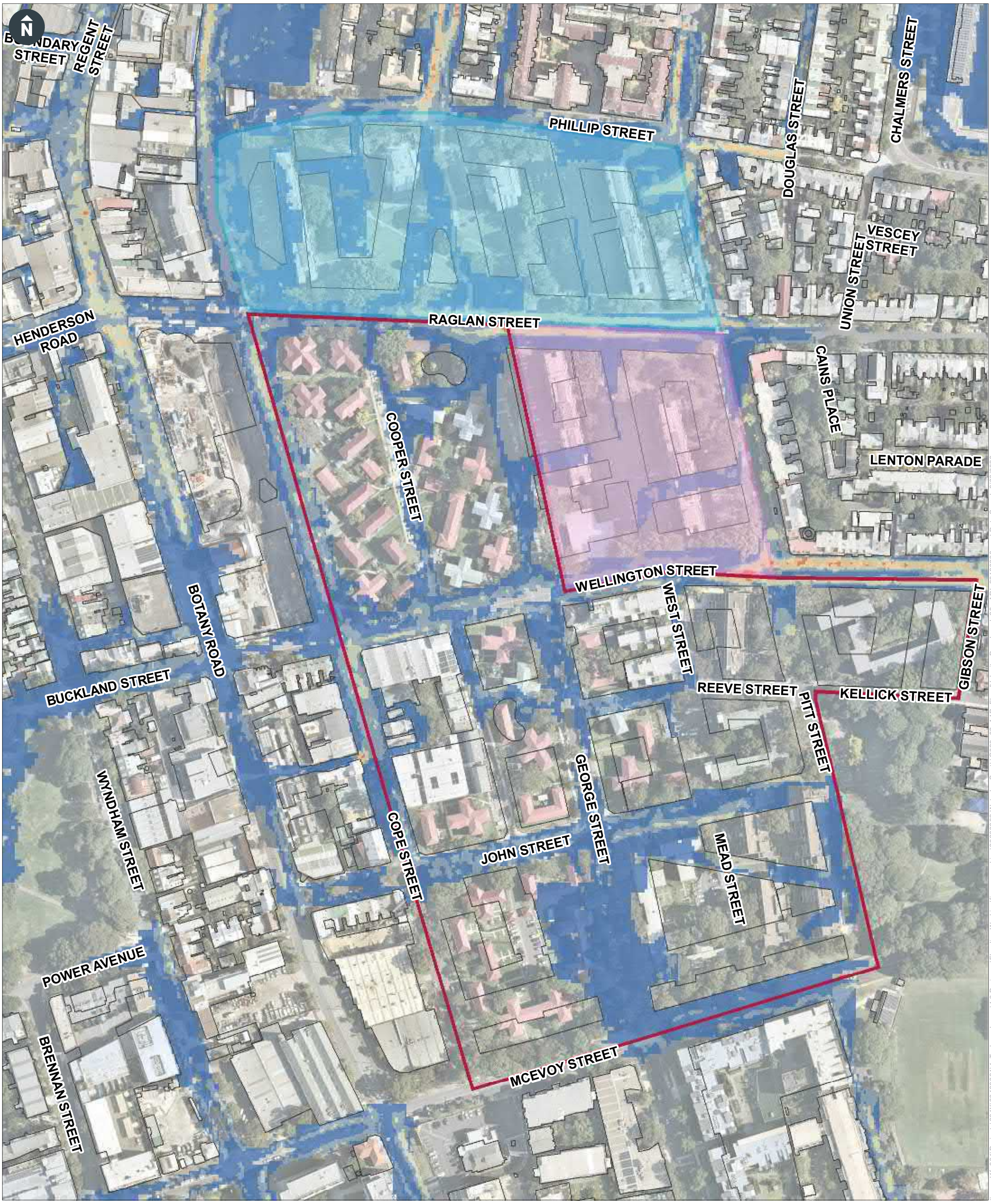
FIGURE 24



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines

Flood Velocity (m/s) - 20yr ARI

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3

Source: Imagery © Nearmap, 2019.

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FLOOD VELOCITY
Developed Case - 20yr ARI

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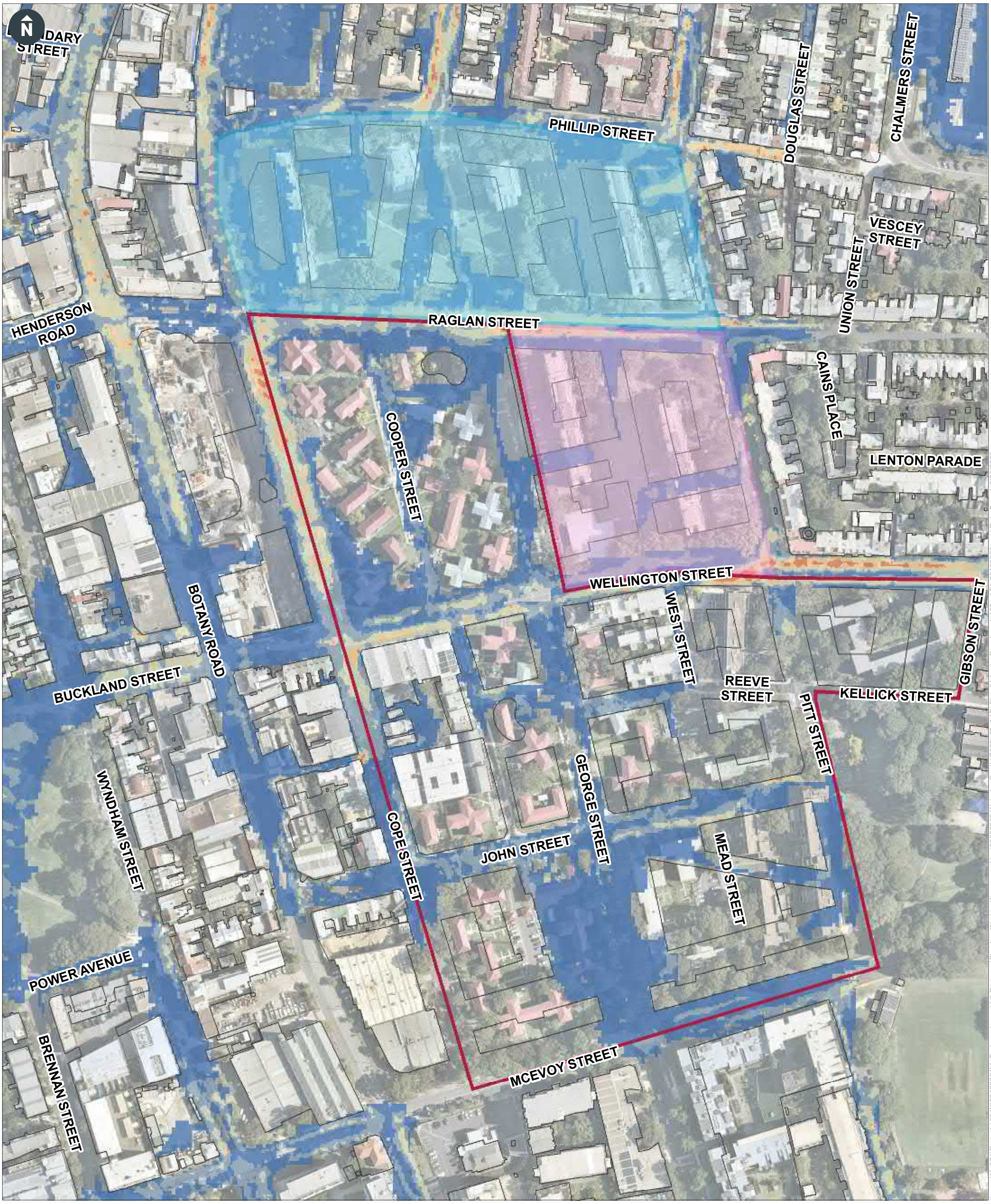
FIGURE 25



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines

Flood Velocity (m/s) - 100yr ARI

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

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FLOOD VELOCITY
Developed Case - 100yr ARI

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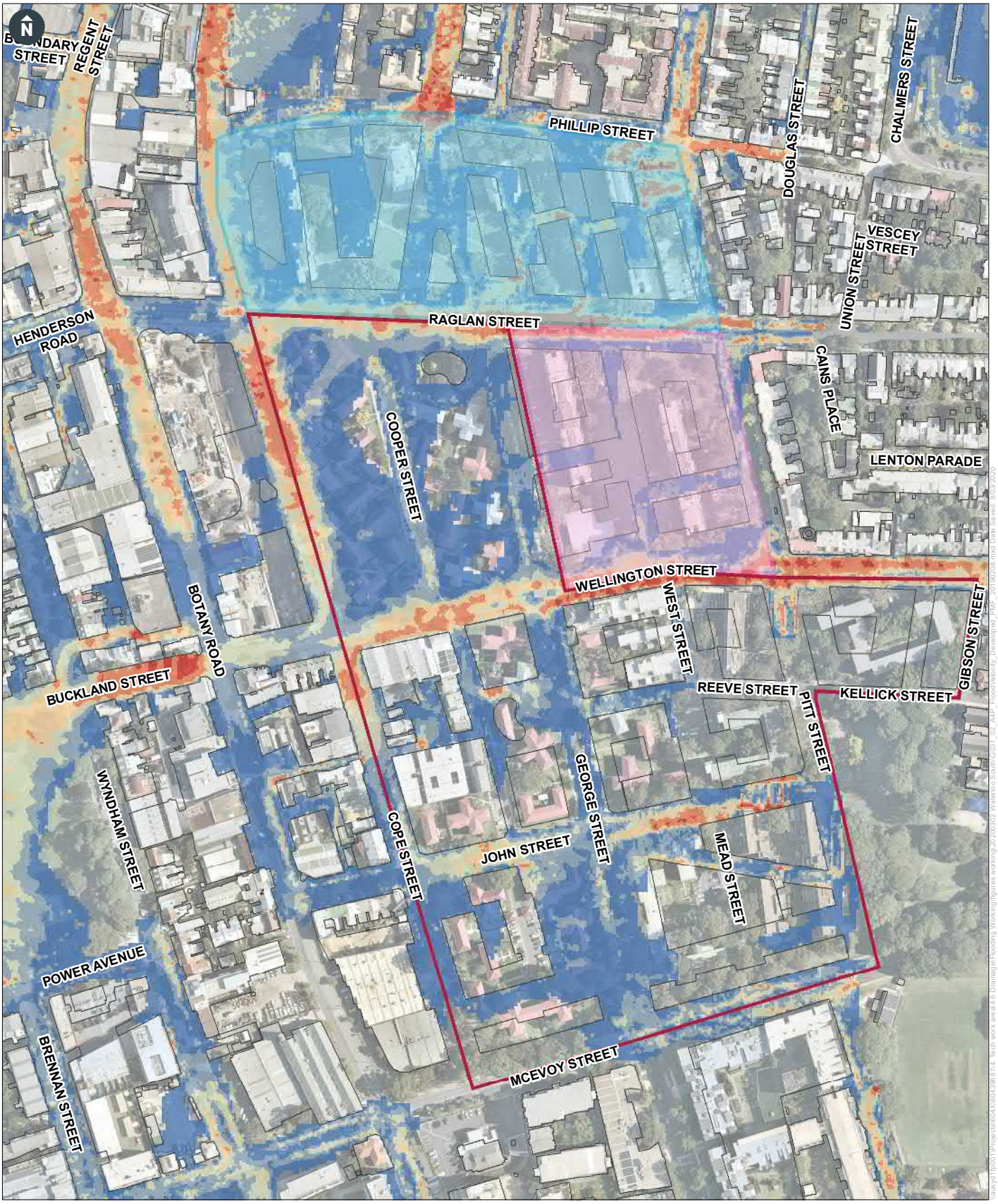
FIGURE 26



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines

Flood Velocity (m/s) - PMF

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

AECOM

Source: Imagery © Nearmap, 2019.

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Developed Case - PMF

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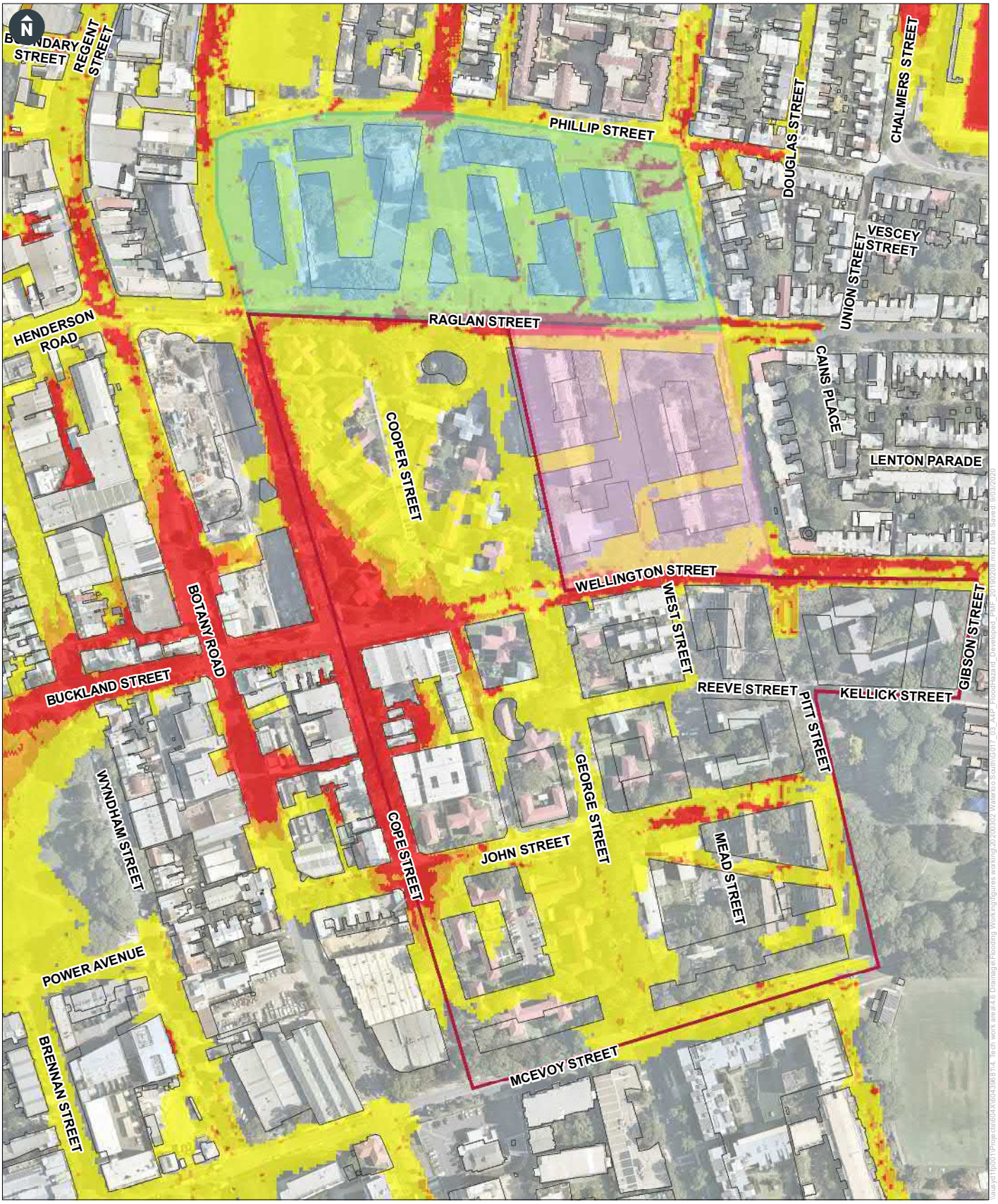
FIGURE 27



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines

Flood Hazard

- Low Hazard
- Transitional Hazard
- High Hazard

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5.8.3 Proposed Development Flood Impacts

Below is a summary of flooding characteristics, the spatial or temporal variability of which are demonstrated through several figures.

Table 11: Summary of Flooding Characteristics

Flooding Characteristic	Pre-Development	Post-Development
Flood Depth	Figure 10 - Figure 12	Figure 21 - Figure 23
Flood Velocity	Figure 13 - Figure 15	Figure 24 - Figure 26
Flood Hazard	Figure 16	Figure 27
Flood Impact	Figure 33 - Figure 36	
Rate of Rise	Figure 29 - Figure 32	

Generally, the proposed development does not worsen the flood levels compared to existing conditions. Decreases in flood levels are also observed in the 100-year ARI at locations along Raglan Street, Wellington Street and Cope Street, primarily because of drainage improvements and provision of flood mitigation storage under public open spaces. For instance, flood levels at the Cope Street and Wellington Street intersection and the Cope Street sag point have decreased by approximately 200 mm.

There are some new areas of inundation due to the diversion and realignment of flowpaths. The increases of flood levels at these new areas are mostly due to the assumed grading and footpath in front of the proposed buildings, which increase terrain levels at such locations.

For the locations shown in Figure 28, the rate of rise and duration of inundation at key building entry ways are generally no worse than existing conditions, as indicated in Figure 33 to Figure 36.

Figure 28: Rate of Rise Locations

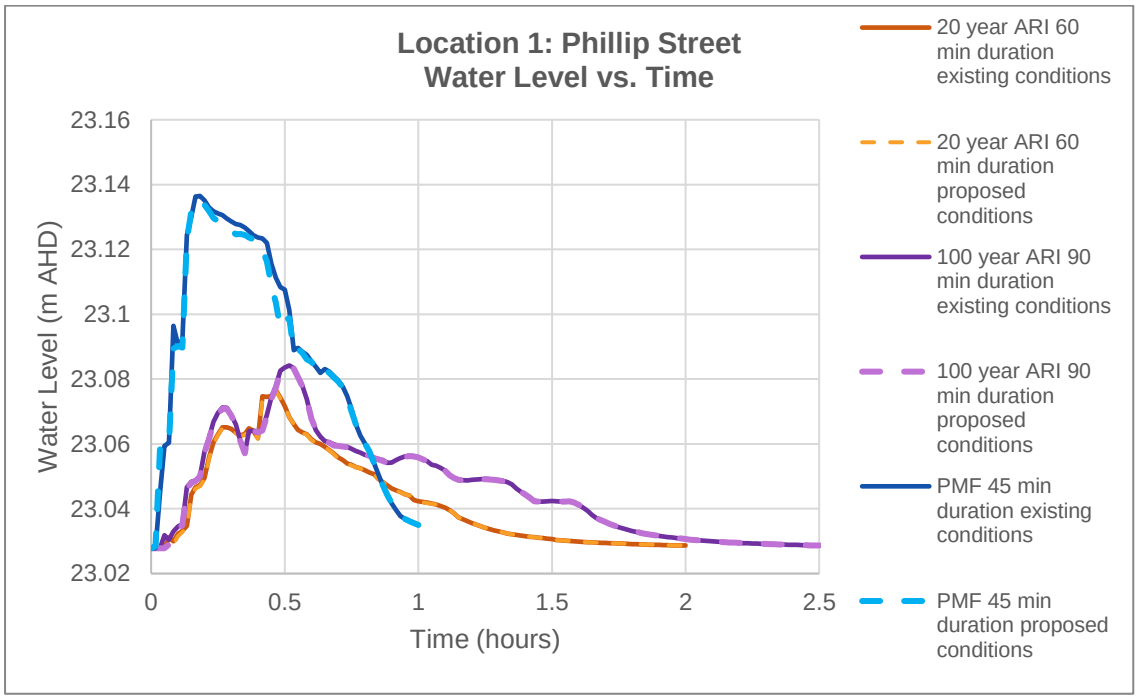

Figure 29: Existing and Proposed Development: Rate of Rise at Location 1 (Phillip Street)

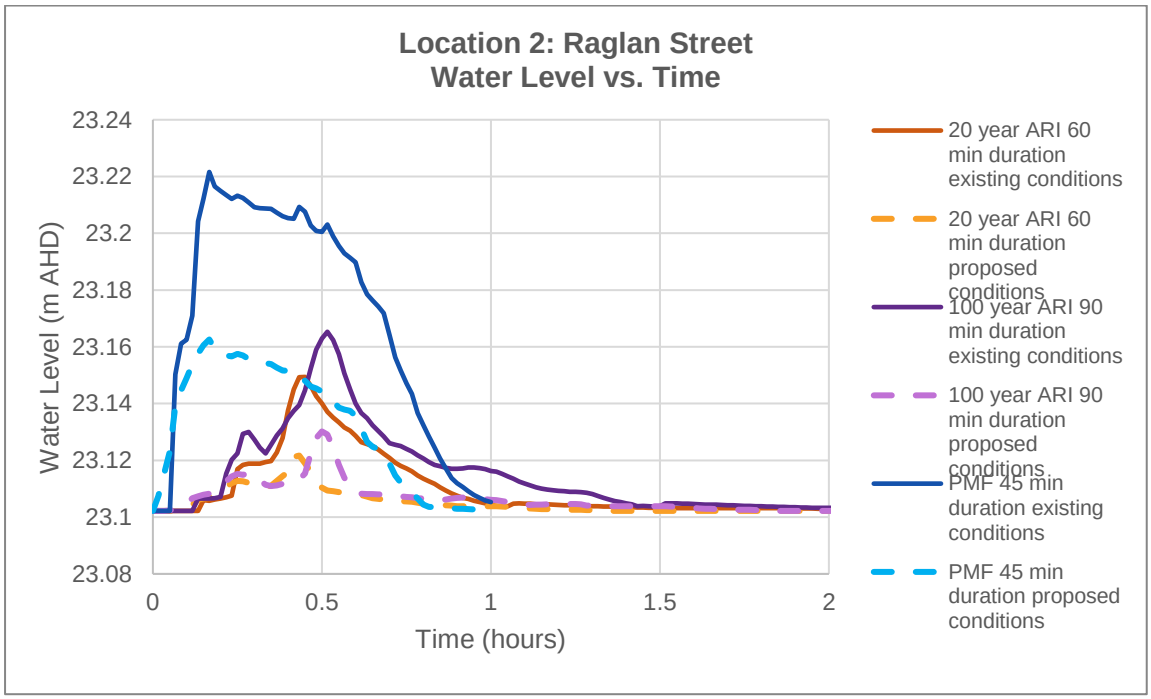

Figure 30: Existing and Proposed Development: Rate of Rise at Location 2 (Raglan Street)

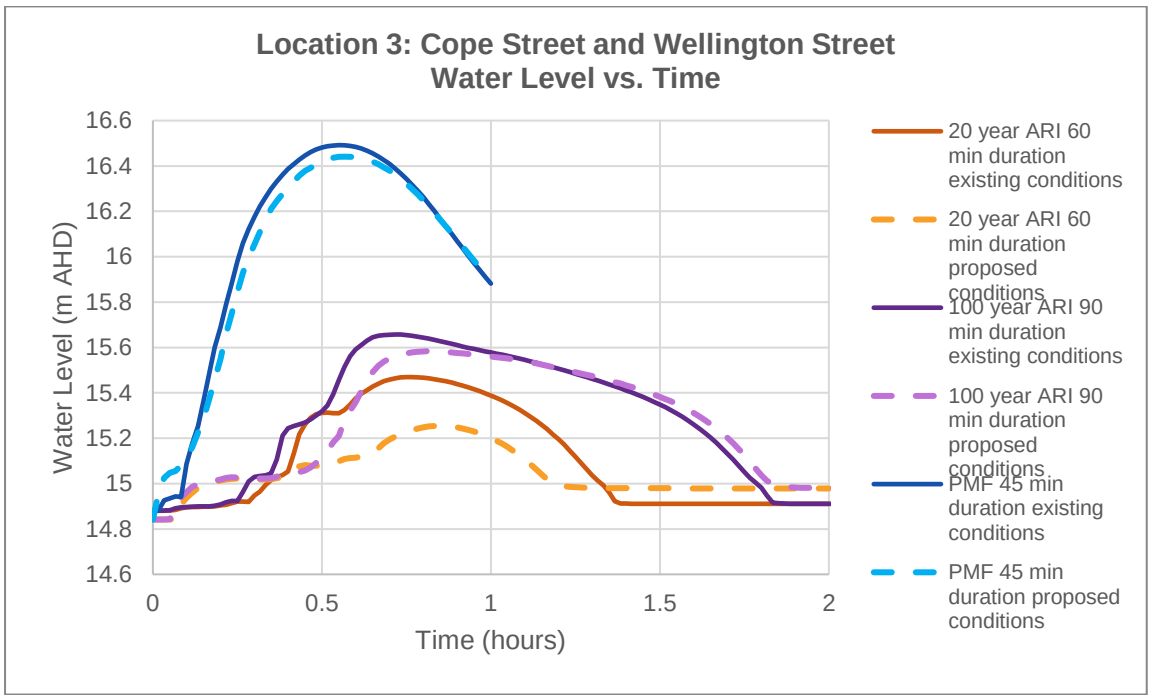

Figure 31: Existing and Proposed Development: Rate of Rise at Location 3 (Cope Street and Wellington Street)

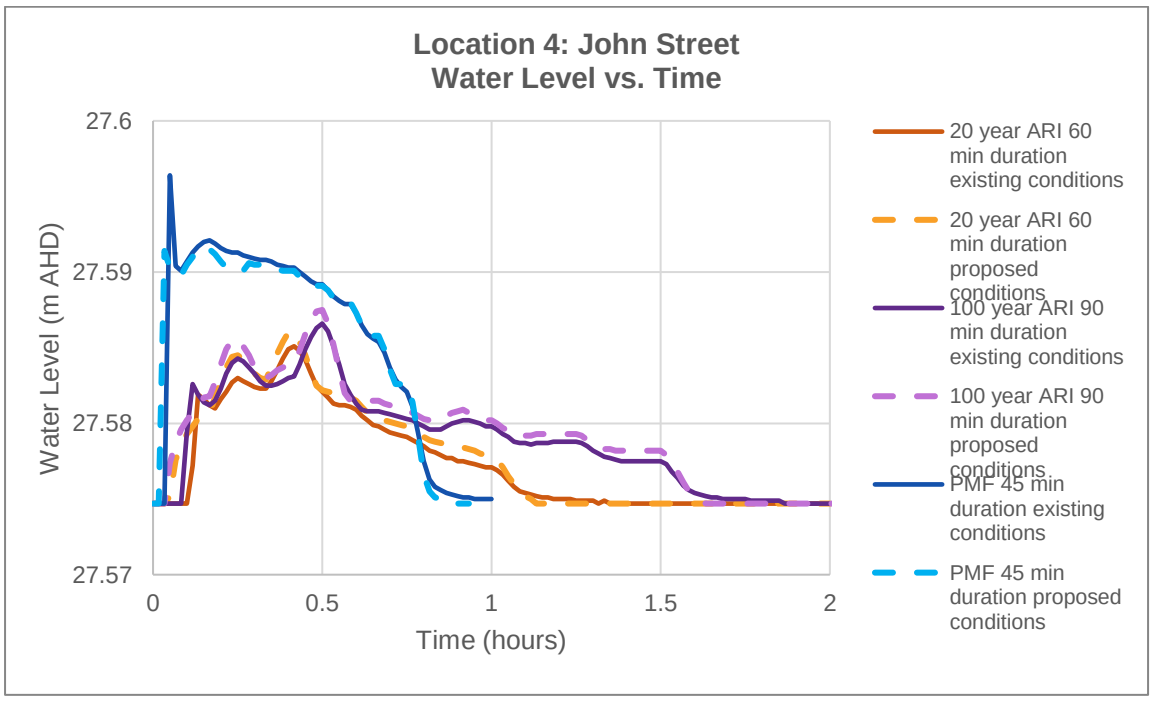

Figure 32: Existing and Proposed Development: Rate of Rise at Location 4 (John Street)

5.8.4 Cumulative Flood Impacts

Flood risk assessment for the Estate has taken into consideration the proposed development for Waterloo North and Waterloo Central within the Estate. Because the adjacent areas in the catchment are fully developed, and the Metro Quarter will be fully developed before the Estate, any further development will not have an impact on the future cumulative flood risk.

FIGURE 33

Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines

Flood Level Impacts

< -0.3	-0.02 - 0.02	Was wet, now dry
-0.3 - -0.15	0.02 - 0.05	Was dry, now wet
-0.15 - -0.05	0.05 - 0.15	
-0.05 - -0.02	0.15 - 0.3	

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FLOOD LEVEL IMPACTS
20 YEAR ARI

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FIGURE 34

Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines

Flood Level Impacts

< -0.3	-0.02 - 0.02	Was wet, now dry
-0.3 - -0.15	0.02 - 0.05	Was dry, now wet
-0.15 - -0.05	0.05 - 0.15	
-0.05 - -0.02	0.15 - 0.3	

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FLOOD LEVEL IMPACTS
100 YEAR ARI

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FIGURE 35

Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines

Flood Depth Impacts

< -0.3	-0.02 - 0.02	Was wet, now dry
-0.3 - -0.15	0.02 - 0.05	Was dry, now wet
-0.15 - -0.05	0.05 - 0.15	
-0.05 - -0.02	0.15 - 0.3	

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FLOOD DEPTH IMPACTS
20 YEAR ARI

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FIGURE 36

Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines

Flood Depth Impacts

< -0.3	-0.02 - 0.02	Was wet, now dry
-0.3 - -0.15	0.02 - 0.05	Was dry, now wet
-0.15 - -0.05	0.05 - 0.15	
-0.05 - -0.02	0.15 - 0.3	

AECOM

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FLOOD DEPTH IMPACTS
100 YEAR ARI

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5.8.5 Flood Planning Levels (FPLs)

FPLs are a key control measure to allow development on land compatible with its flood hazard and to minimize the flood risk to life and property. The Indicative Concept proposal has been designed to account for the flood risks prevalent throughout the Estate and its surroundings. Future development will have flood planning levels that ensure there are no floodwater breeches from significant storm events particularly at building entrances and carparks.

For residential developments the City of Sydney typically requires that normally habitable areas be located 0.5 m above the 100-year ARI flood (City of Sydney, 2014). This level is referred to as the Flood Planning Level (FPL). For underground carparks and similar areas, all access ways to the carpark must be at or above this level and also above the PMF level. The FPL also affects the installation of electrical equipment and air conditioners. For the locations shown in Figure 38 (generally chosen as upstream corner of a building) corresponding to Table 12 below, the peak flood levels for the 100 year ARI, 100 year ARI + 10% (refer to Section 5.9 on Climate Change) and the PMF cases, as well as the FPL, are given below.

Table 12 Peak 100-year ARI and PMF flood levels, and associated FPL

Location ID	100-year ARI flood level (m AHD)	100-year ARI + 10% flood level for climate change (m AHD)	PMF flood level[1] (m AHD)	Freeboard[4] (mm)	Flood planning level[2] (m AHD)
1	20.11	20.11	20.11	300	20.41
2	22.85	22.85	23.01	300	23.15
3	24.53	24.53	24.59	300	24.83
4	25.77	25.77	25.79	300	26.07
5	25.49	25.52	26	500	26.02
6	19.19	19.19	19.24	500	19.69
7	17.2	17.22	17.39	500	17.72
8	28.84	28.87	28.99	500	29.37
9	20.03	20.03	20.09	300	20.33
10	19.4	19.4	19.41	300	19.7
11	18.61	18.62	18.65	500	19.12
12	27.93	27.93	28.01	300	28.23
13	22.92	22.92	23.07	300	23.22
14	24.81	24.81	25.07	300	25.11
15	16.51	16.55	16.82	500	17.05
16	16.73	16.75	16.88	500	17.25
17	23.55	23.56	23.61	300	23.86
18	20.63	20.63	20.68	300	20.93
19	16.35	16.36	16.52	500	16.86
20	27.99	28	28.12	300	28.3
21	17.18	17.2	17.31	500	17.7
22	15.94	15.97	16.44	500	16.47
23	16.53	16.54	16.65	300	16.84
24	20.45	20.46	20.52	500	20.96
25	17.74	17.75	17.79	300	18.05

Location ID	100-year ARI flood level (m AHD)	100-year ARI + 10% flood level for climate change (m AHD)	PMF flood level[1] (m AHD)	Freeboard[4] (mm)	Flood planning level[2] (m AHD)
26	26.26	26.26	26.27	300	26.56
27	25.74	25.74	25.81	300	26.04
28	20.34	20.34	20.5	300	20.64
29	25.17	25.17	25.22	500	25.67
30	20.8	20.82	20.93	300	21.12
31	24.65	24.66	25.06	500	25.16
32	32.39	32.39	32.57	500	32.89
33	30.42	30.42	30.72	500	30.92
34	15.61	15.68	16.44	500	16.44
35	16.38	16.4	16.51	500	16.9
36	15.61	15.68	16.43	500	16.43
37	27.19	27.19	27.41	300	27.49
38	15.57	15.63	16.37	500	16.37
39	15.61	15.68	16.44	500	16.44
40	15.76	15.79	16.45	500	16.45
41	16.31	16.32	16.48	500	16.82
42	19.9	19.9	19.93	300	20.2
43	15.61	15.68	16.45	500	16.45
44	27.24	27.24	27.25	300	27.54
45	29.15	29.15	29.16	300	29.45
46	20.09	20.09	20.27	300	20.39
47	16.76	16.76	16.81	300	17.06
48	16.17	16.18	16.46	500	16.68
49	15.61	15.68	16.44	500	16.44
50	21.28	21.28	21.28	300	21.58
51	26.05	26.05	26.17	300	26.35
52	25.03	25.03	25.03	300	25.33
53	16.77	16.79	16.96	500	17.29
54	22.11	22.11	22.11	500	22.61
55	16.77	16.79	16.96	500	17.29
56	21.66	21.66	21.66	300	21.96
57	16.77	16.79	16.96	500	17.29
58	17.95	17.95	17.97	300	18.25

Notes:

1. If the PMF level is greater than the FPL, the access to underground carparks must be at or above the PMF level.
2. Flood planning level will need to be reviewed during detailed design to consider site drainage and local overland flow paths as outlined in City of Sydney (2014).

3. Lots 11 and 12, are subject to local stormwater flows only. An FPL and access level at each entrance to these buildings should be determined during detailed design in accordance with City of Sydney (2014).
4. The freeboard has been determined in accordance with the City of Sydney Interim Floodplain Management Policy.

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 FPLs 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 to facilitate shelter in place evacuation discussed in Section 5.10. An indicative internal treatment for retail properties is shown in the Figure 37 below which can be developed during the detailed design phase. Treatment options for retail properties affected by flooding should be developed further during the detailed design phase.

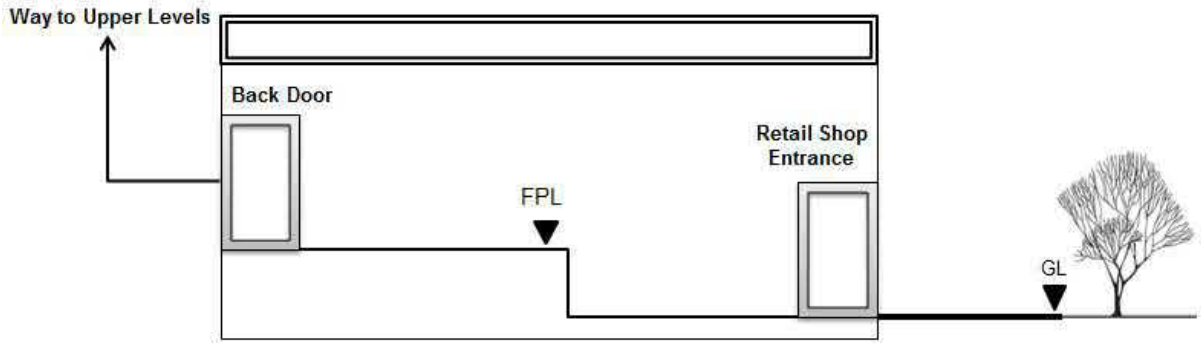
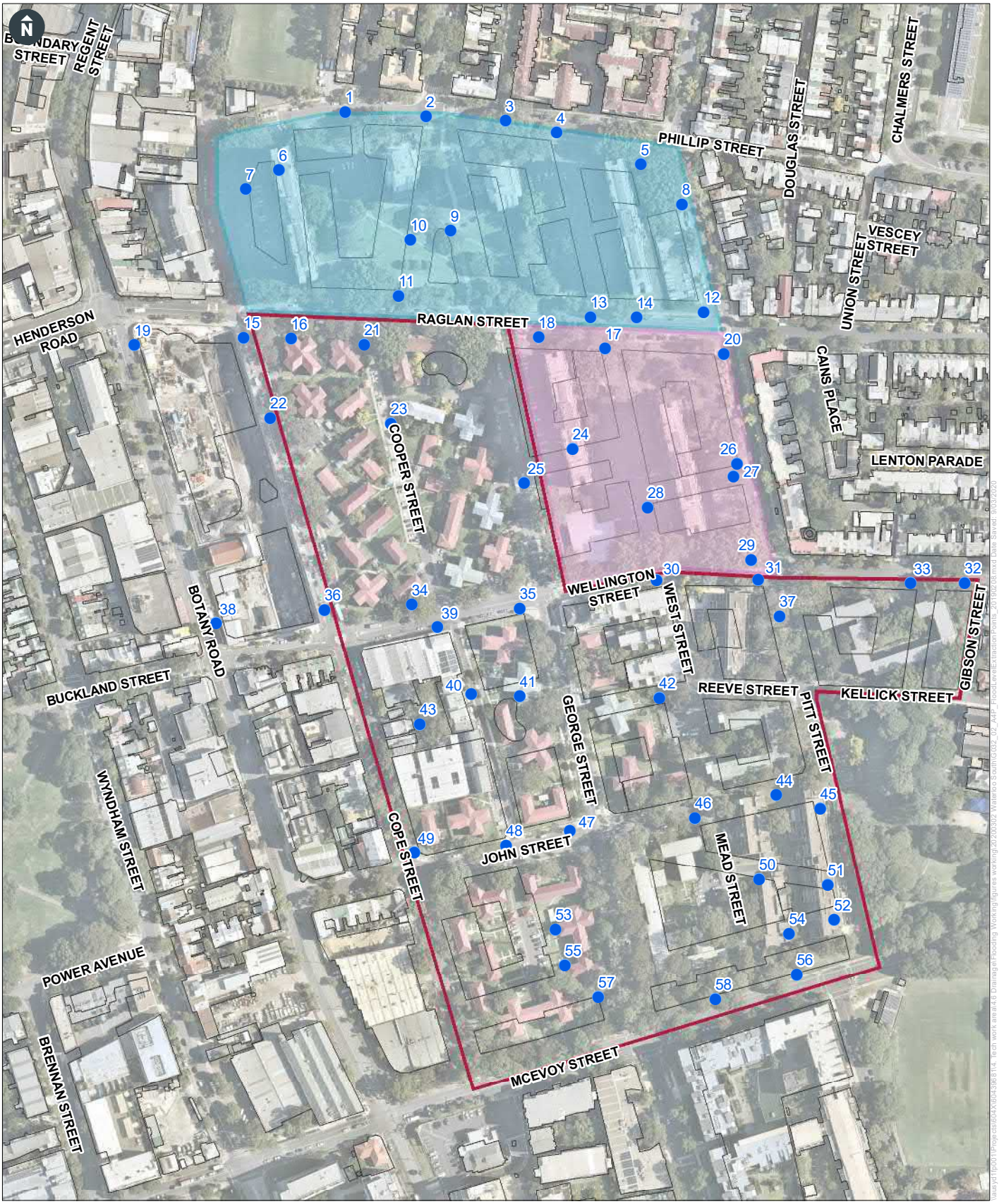


Figure 37: Indicative internal treatment for retail properties

FIGURE 38



Legend

- Flood Level Extraction Point
- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines

AECOM

Source: Imagery © Nearmap, 2019.

SCALE	1:3,500
SIZE	A4
SHEET	1 of 1
DATE	9/03/2020

TITLE

FLOOD LEVEL EXTRACTION POINTS

PROJECT

WATERLOO SOUTH
CONCEPT PROPOSAL

CLIENT

NSW LAND AND HOUSING CORPORATION

CONFIDENTIAL GIS MAP

5.9 Climate Change

This section will address study requirements item 17.3.

5.9.1 Climate Change Sensitivity Analysis

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

Changing rainfall patterns are often associated with climate change. These include extreme heat events, increased temperatures and shorter but more intense summer rainfalls which introduce additional flood risks to the Estate.

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 (AR&R 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% increase in rainfall intensity corresponds to 2090 conditions predicted under the RCP 4.5 emissions scenario (AR&R 2016).

Sensitivity analysis for the Estate was undertaken by increasing the rainfall intensity by 10% for the 100-year ARI, in line with AR&R 2016 and OEH Guidelines. Flood modelling results including flood depths and flood impacts for the existing and proposed cases are shown in Figure 39 and Figure 42.

FIGURE 39

Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Existing building outlines
- Peak flood level contours (1m)
- Peak flood level contours (0.2m)

Peak Flood Depth (m) - 100yr ARI + 10%

< 0.05	0.25 to 0.5
0.05 to 0.1	0.5 to 1.0
0.1 to 0.15	1.0 to 1.5
0.15 to 0.2	1.5 to 2.0
0.2 to 0.25	> 2.0

AECOM

Source: Imagery © Nearmap, 2019.

SCALE	1:3,500
SIZE	A4
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TITLE

FLOODING CONDITIONS
Existing Case - 100yr ARI + 10%

PROJECT

WATERLOO SOUTH
CONCEPT PROPOSAL

CLIENT

NSW LAND AND HOUSING CORPORATION

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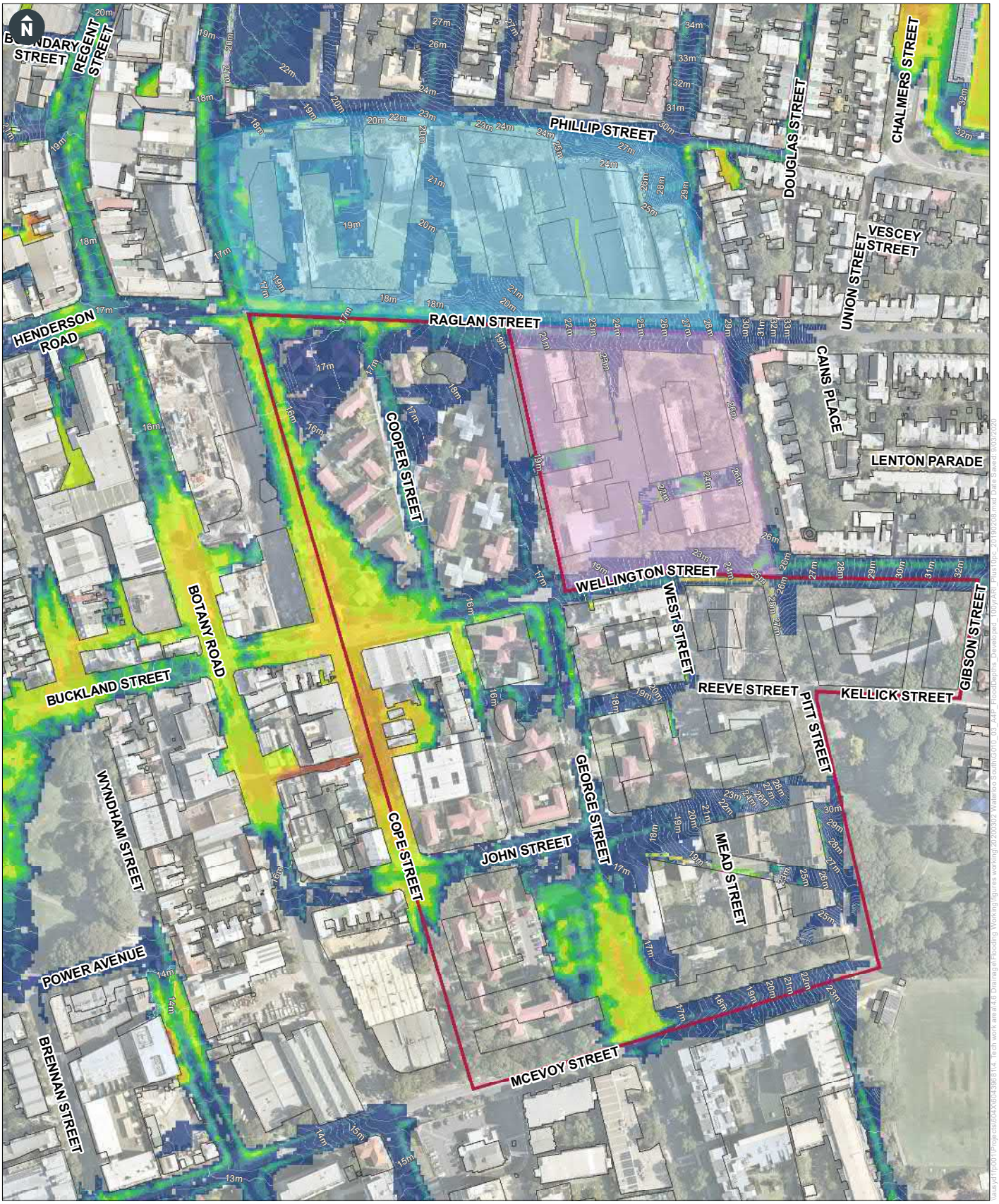
FIGURE 40



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines
- Peak flood level contours (1m)
- Peak flood level contours (0.2m)

Peak Flood Depth (m) - 100yr ARI + 10%

< 0.05	0.25 - 0.5
0.05 - 0.1	0.5 - 1
0.1 - 0.15	1 - 1.5
0.15 - 0.2	1.5 - 2
0.2 - 0.25	> 2

AECOM

Source: Imagery © Nearmap, 2019.

SCALE 1:3,500 | SIZE A4

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TITLE

FLOODING CONDITIONS
Developed Case - 100yr ARI + 10%

PROJECT

WATERLOO SOUTH
CONCEPT PROPOSAL

CLIENT

NSW LAND AND HOUSING CORPORATION

CONFIDENTIAL GIS MAP

FIGURE 41

Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Existing building outlines

Flood Velocity (m/s) - 100yr ARI + 10%

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

AECOM

Source: Imagery © Nearmap, 2019.

SCALE	1:3,500
SIZE	A4
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TITLE

FLOOD VELOCITY
Existing Case - 100yr ARI + 10%

PROJECT

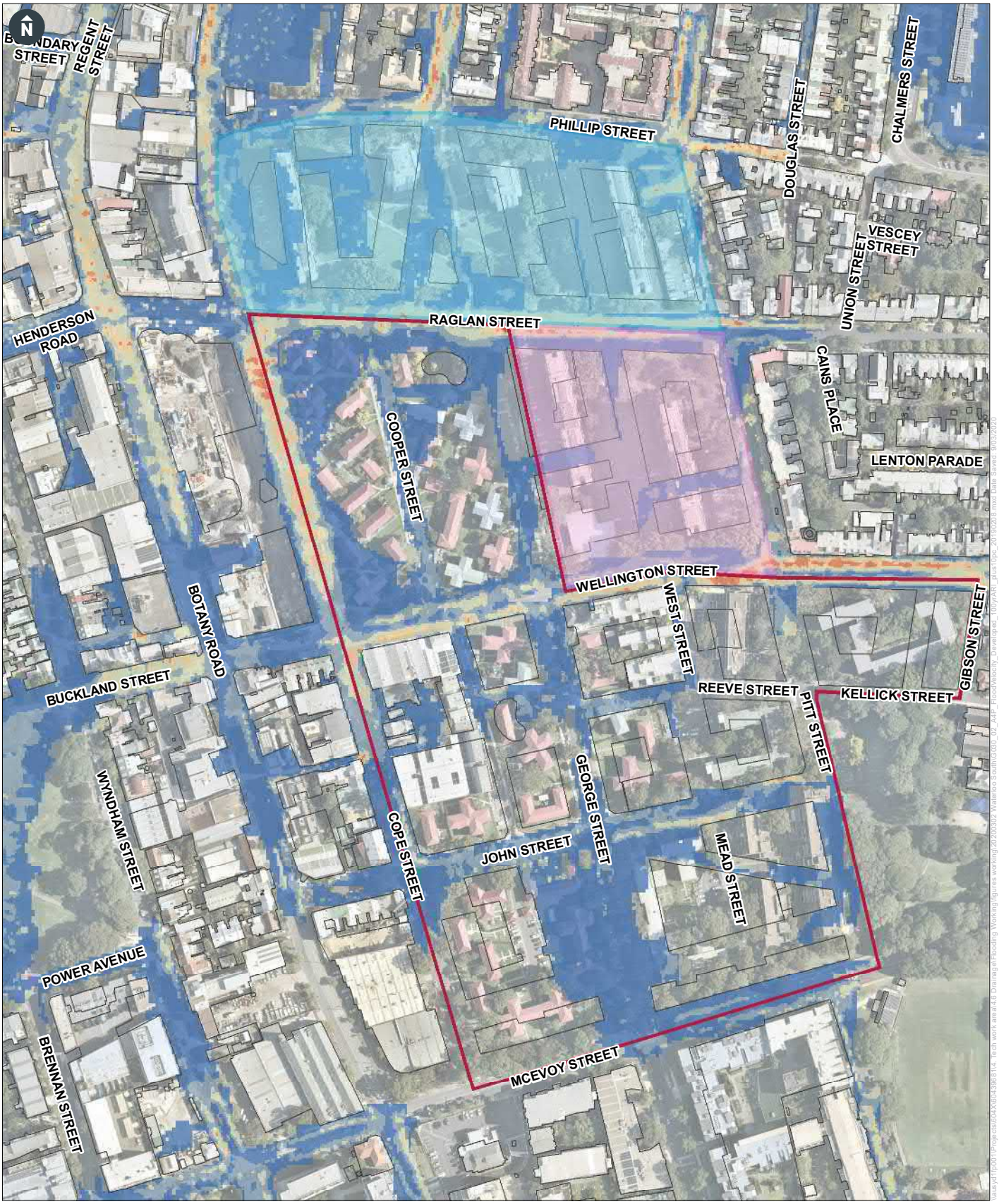
WATERLOO SOUTH
CONCEPT PROPOSAL

CLIENT

NSW LAND AND HOUSING CORPORATION

CONFIDENTIAL GIS MAP

FIGURE 42



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Proposed building outlines

Flood Velocity (m/s) - 100yr ARI + 10%

- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

AECOM

Source: Imagery © Nearmap, 2019.

SCALE 1:3,500 | SIZE A4

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TITLE

FLOOD VELOCITY
Developed Case - 100yr ARI + 10%

PROJECT

WATERLOO SOUTH
CONCEPT PROPOSAL

CLIENT

NSW LAND AND HOUSING CORPORATION

CONFIDENTIAL GIS MAP

5.10 Emergency Response

An emergency response strategy is identified in this section to assist in reducing the consequences of flood risks.

The post-development flood hazard for the site is shown in Figure 27. Examination of the flood results indicate that during the PMF, the depth of flooding on the internal roads, outside of the flow paths and low areas, is typically less than 250 mm. However, the velocity depth product in many locations is typically greater than 0.3 m^2/s. For a small car, the maximum advisable depth for vehicle stability is 300 mm, and maximum velocity depth product is 0.3 m^2/s. For children, the maximum advisable velocity depth product is 0.4 m^2/s (Smith, 2013). Considering this, emergency access to and evacuation from some buildings may be risky. Access to buildings along the flowpaths and low areas, such as Raglan Street, Wellington Street and Cope Street, may be difficult as flood depths exceed 1.0 m, and velocity depth product exceeds 0.5 m^2/s.

Hence, the flood hazard is most appropriately managed with a shelter in place strategy, as the duration of inundation is relatively short, and the rate of rise is relatively rapid. A shelter in place strategy for the buildings is also preferred over evacuation, to avoid unnecessary vehicle or pedestrian movements during an extreme storm event. For occupied public open space areas, it is recommended to have a refuge point within a facility that can be accessed easily. Sufficient warning time should be considered to support this.

Any residual risks to the buildings and public open spaces will require an operational flood emergency response plan. 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; and
- Communicate the plan to residents and other building occupants.

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.

6.0 Implementation Plan & Strategy

6.1 Stormwater and Flooding Management Plan

A combined stormwater and flooding management plan for the Estate site is shown in the Figure 43.

6.2 DCP Provisions

A summary of recommended DCP provisions is provided in the table below.

Table 13: DCP Provisions

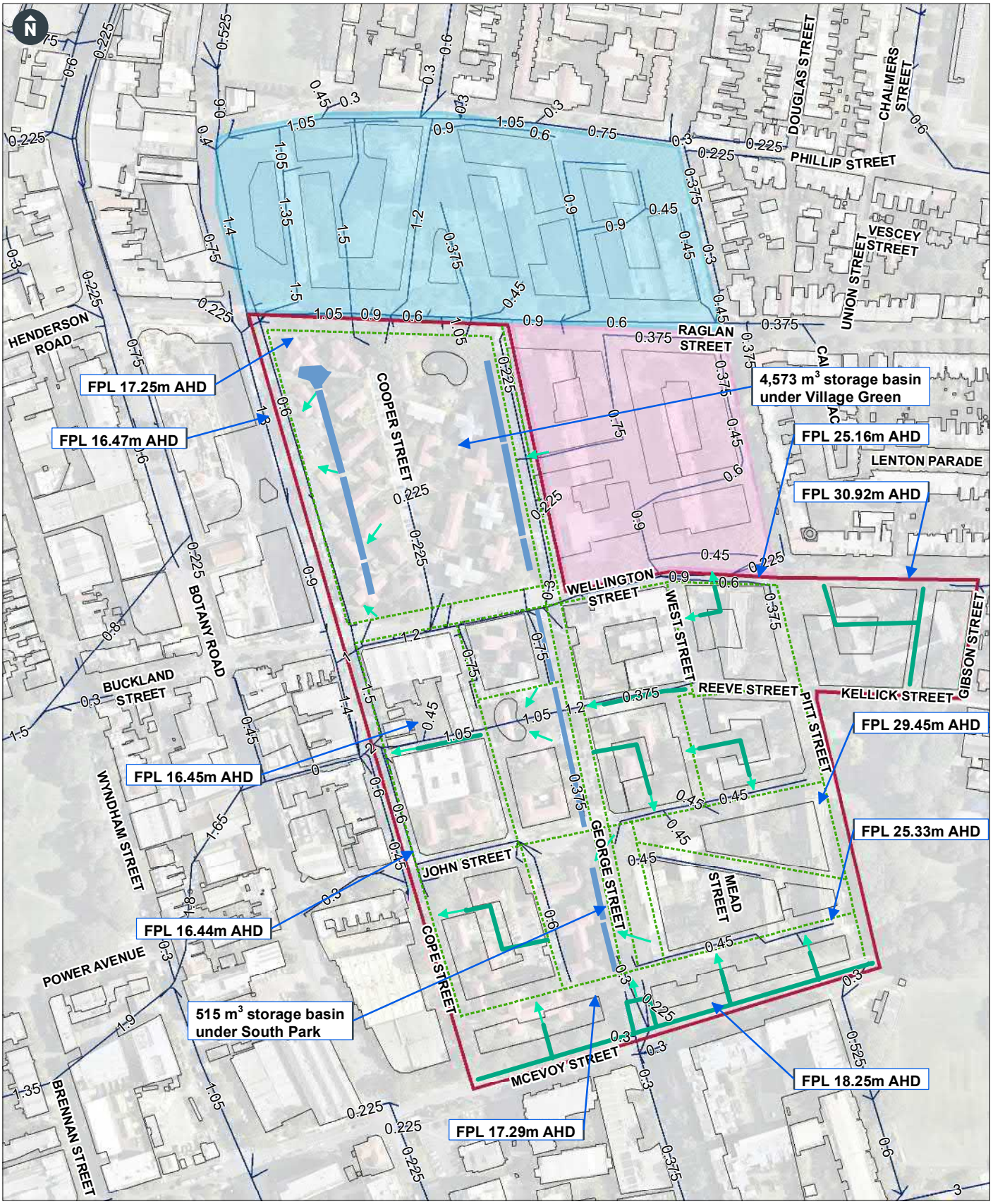
Measure		Recommended Provision
On-Site Detention		Flood detention volume of 4,550 m^3 in the public domain. As per Sydney Water, combined OSD volume of 2,900 m^3 for all properties including (but not limited to): ➢ commercial, industrial and special use (e.g. community, education, recreational) buildings or structures; ➢ town houses, villas, home units or other strata subdivisions; ➢ dual occupancy lots; and ➢ sealed sporting facilities (e.g. tennis, basketball courts)
Water Quality Targets and WSUD		➢ Reduction of baseline annual pollutant load for litter and vegetation larger than 5mm by 90%; ➢ Reduction of baseline annual pollutant load for total suspended solids by 85%; ➢ Reduction of baseline annual pollutant load for total phosphorous by 65%; and ➢ Reduction of baseline annual pollutant load for total nitrogen by 45%.
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).

Note: It is recommended that City of Sydney carry forward other existing provisions pertaining to stormwater and flooding outlined in the City of Sydney DCP 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 Sydney Water OSD volume for properties is approximately 2,900m^3. Refer to Section 5.5. Hydraulic calculations at the detailed design development stage will determine the final detention storage volumes, outlets and interfaces at the properties requiring an OSD system;
3) OSD 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

FIGURE 43



Legend

- Waterloo Central
- Waterloo North
- Waterloo South
- Indicative Bypass
- Raingarden
- Overland Flow Path
- Biofiltration Street Trees
- Proposed building outlines

FPL = Flood Planning Level

AECOM

Source: Imagery © Nearmap, 2019.

SCALE	1:3,500
SIZE	A4
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DATE	10/03/2020

TITLE

PROPOSED STORMWATER MANAGEMENT PLAN

PROJECT

WATERLOO SOUTH
CONCEPT PROPOSAL

CLIENT

NSW LAND AND HOUSING CORPORATION

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6.3 Staging

The development timeframe for the Estate is 15-20 years. Preliminary staging of the proposed stormwater services is shown in Figure 44 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 development.

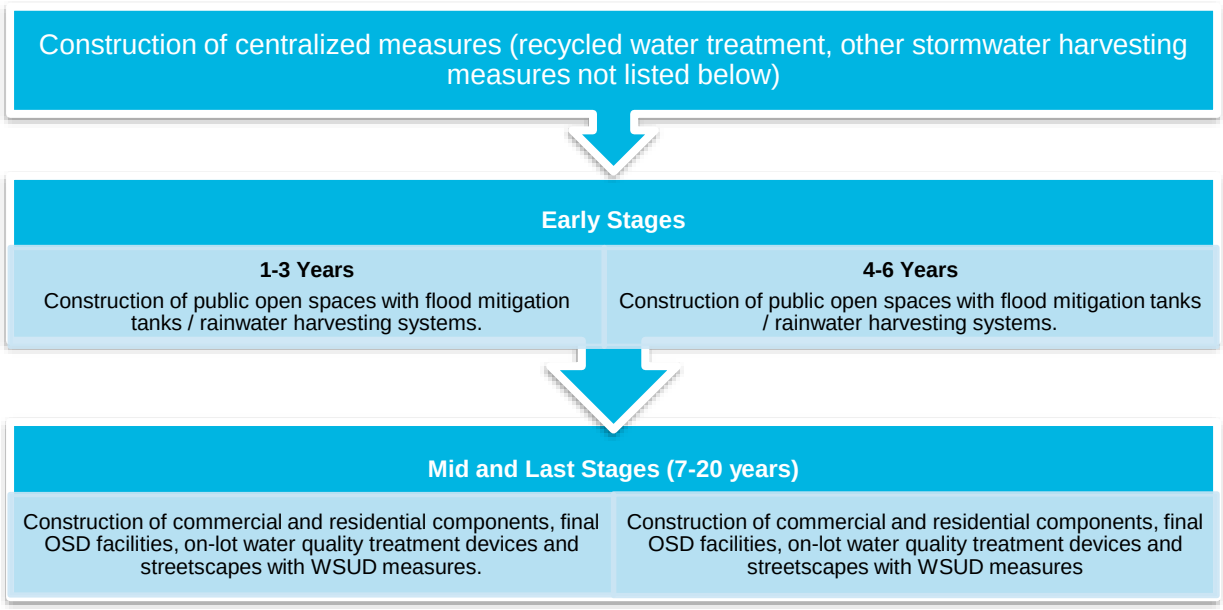

Figure 44: Staging of Stormwater Management

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

1) Sizing of OSD areas, including bypass areas in private domain, to be managed based on relevant stage of construction process; and

- Interim detention storage measures during construction stages could take the form of rainwater harvesting tanks connected to the adjacent stormwater pipes. Trash screens and access to be considered in the detailed design.

6.4 Ongoing Maintenance Responsibilities

The ownership of ongoing maintenance responsibilities for the stormwater infrastructure within the Estate are anticipated as follows. However, the actual allocation of maintenance responsibilities will be determined in the detailed design stage.

Table 14: Maintenance Responsibilities for Stormwater Infrastructure

Land Area	Maintenance Responsibility
- Roads	City of Sydney (minor roads) RMS (major roads)
- Developed area (Private sites)	Lot owners
- Developed area (LAHC property)	LAHC
- Public open space (dedicated to the City of Sydney)	City of Sydney
- Other publicly accessible open space (private land)	Lot owners

7.0 Water Cycle Management

This section evaluates the potential for adoption of an Integrated Water Cycle Management approach at the Estate which includes rainwater harvesting, reuse and recycled water to achieve outcomes for a Green Star accreditation. This section should be read in conjunction with the Estate's *Utilities and Infrastructure Servicing Study* and *Ecologically Sustainable Development Study.*

7.1 Residential Demands

The target dwelling yield within for the Estate as indicated by the proposal is estimated to be around 3,050 dwellings. For residential water demand estimation, an occupancy rate for multi residential developments within the City of Sydney (2 people/apartment occupancy) is adopted. As such, the future population is expected to be 6100 residents within the subject area.

The City of Sydney 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 156 kL/dwelling/year and approximately 42% 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 15 which includes the volume of recycled water that can be substituted for potable waters as an ESD measure.

Table 15: Water usage

Water Uses (kL/dwelling/yr)		Residential Water Split	Adopted Total Demand for Waterloo	Recycled Water Demand for Potable Water Substitution	Residual Potable Water Demand	Waste Water
Non-Potable	Toilet	18%	28.1	28.1	0	28.1
	Washing	15%	23.4	23.4	0	23.4
	Irrigation	4%	6.2	6.2	0	0
	Outdoor	5%	7.8	7.8	0	0
	Total	42%	65.5	65.5	0	51.5
Potable	Basin	5%	7.8	0	7.8	7.8
	Kitchen	5%	7.8	0	7.8	7.8
	Leaks	5%	7.8	0	7.8	7.8
	Shower	37%	57.7	0	57.7	57.7
	Bath	4%	6.2	0	6.2	6.2
	Dishwasher	2%	3.1	0	3.1	3.1
	Total	58%	90.4	0	90.4	90.4
Total Usage / Dwelling (kL/yr)			**155.9**	**65.5**	**90.4**	**141.9**
Total Usage for 3050 dwellings (ML/yr)			**475**	**200**	**276**	**433**

Note:

1. The Basix benchmark for potable water use is 247.5 L/person/day = 181 kL/dwelling/year, assuming an occupancy ratio of 2 people / dwelling. This is 1.26 GL/yr for the Estate.
2. The Basix target for potable water use is 60% x 247.5 L/person/day = 108 kL/dwelling/year, assuming an occupancy ratio of 2 people / dwelling. This is approximately 0.76 GL/yr

Substituting recycled water for all non-potable water uses will achieve a reduction in potable water consumption of 50% when measured against the BASIX benchmark.

7.2 External Water Use and Irrigation

The public open space area will total around 2.57 ha 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 at 2.5 ML/ha or 250 mm/year.

Passive irrigation is proposed for all street trees and no further water usage is anticipated with the streetscape. However, if passive irrigation is not pursued as a strategy for irrigating street trees, there will be an increase in stormwater pollution requiring treatment in parks and open space areas.

7.3 Water Balance

Based on Table 15, potable water supply will generally be used for potable demands (58% of residential water split) while harvested rainwater and recycled water may be used for non-potable water uses (42% of residential water split) such as toilet flushing, laundry, irrigation of lawns, green walls and green roofs.

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 the development.

7.4 District Scale Waste Water Treatment

Sydney Water does not provide recycled water to the study area, although the adjacent Green Square Town Centre does include a privately-operated recycled water scheme Green Square Water. Additionally, the water recycling facility at Australian Technology Park (ATP) is currently under construction, for completion in 2020.

The Estate is currently of a scale that could suit a stand-alone district recycling and reticulation system. It is recommended that dual reticulation of water / recycled water pipes be considered to service the district as one of the key options to meet the sustainability target of being water positive. This approach would need to be market led and considered at the DA stage. It is important to note that the option of considering Waterloo South in isolation to the wider Estate would potentially be less viable.

Alternative options to service the Estate include extending the existing Green Square and/or planned ATP recycled water network. Due to the large concentration of services within the site and Cope Street, it is further recommended that future proofing pipe connections across Cope Street be considered, including the consideration of laying capped recycled water pipes.

8.0 Response to Study Requirements

This Water Quality, Flooding and Stormwater Report presents the proposed stormwater management approach for the Estate site. This proposed management approach will ensure that the development complies with planning commitments from the Estate study requirements established by the Department of Planning and Environment, addresses City of Sydney requirements and adheres to the Sydney Water quantity control standards. The following table provides a summary of how the Waterloo SSP study requirements have been met in this report.

Table 16: Response to Waterloo SSP Requirements

Waterloo SSP Study Requirements	Response to Study Requirements
Section 1. Vision, Strategic Context and Justification	
1.5 Consideration of City of Sydney planning documents strategies and policies including, but not limited to: • *The Alexandra Canal Floodplain Risk Management Plan Risk; Management Study and Flood Study 2014* • *Interim Floodplain Management Policy 2014*	This report considers all of the documents discussed in Sections 4.2 and 5.1.3.
1.6 Consideration of other relevant strategies and reports including, but not limited to: • *Local Planning for Healthy Waterways using NSW Water Quality Objectives Department of Environment and Conservation June 2006* • *Managing Urban Stormwater – Harvesting and Reuse Guidelines Dec 2006* • *WSUD Guidelines Landcom 2009* • *Managing Urban Stormwater: Soils and Construction series*	This report considers these strategies and reports as discussed in Section 5.6.1. The document *WSUD Guidelines Landcom 2009* is out of circulation and no revision has been published for the same. City of Sydney has incorporated its WSUD requirements in the City of Sydney DCP 2012 which have been taken into consideration for this study. The document *Managing Urban Stormwater: Soils and Construction series* is a construction document which is not applicable at this stage of assessment.
Section 3. Public Domain: Public Open Space and Streets	
3.11 Provide a (Water Sensitive Urban Design) WSUD strategy that integrates with the flood study, the public domain and private open spaces, show any measures on plans and detail street sections	Please refer to Sections 5.7.3.
Section 8. Local Infrastructure and Contributions	
8.11 Outline the proposed ongoing responsibilities and maintenance of any proposed open space/connections, drainage reserves and community facilities.	Please refer to Section 6.4.
Section 16. Ecologically Sustainable Development (ESD)	
16.2 Provide an Integrated Waste Water Management Strategy that considers water, waste water and stormwater plus potential alternative water supply, demonstration of water sensitive urban design and any future water conservation measures, including reuse, following appropriate best practice and guidelines. Investigate any opportunities for and include an assessment of the feasibility of a precinct-scale recycled water scheme that includes nearby sites with the capacity to participate.	This report discusses an integrated water cycle management strategy in Section 7.
Section 17. Water Quality, Flooding and Stormwater	
17.1 Provide an assessment of any potential impacts of the proposal on the hydrology and hydrogeology of the urban renewal precinct and adjoining areas, with particular focus on water quality, and to water quality targets in the City of Sydney DCP 2012: • *reduce the baseline and annual pollutant load for litter and vegetation larger than 5mm by 90%* • *reduce the baseline annual pollutant load for total suspended solids by 85%* • *reduce the baseline annual pollutant load for total phosphorus by 65%, and* • *reduce the baseline annual pollutant load for total nitrogen by 45%.*	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 5.7. The assessment for the concept design satisfies the study requirement for this application. Further assessment will be required site wide during the detailed design phase.

Waterloo SSP Study Requirements	Response to Study Requirements
17.2 Provide a concept Stormwater Management Plan outlining the general stormwater management measures for the proposal, with particular emphasis on possible WSUD options.	This Flooding and Stormwater Report outlines the proposed general stormwater management measures including WSUD options and requirements. Please refer to Sections 5.5 and 5.7. Current recommendations are suitable for the concept level proposal. Further assessment for stormwater and integrated water cycle management will be required during the detailed design phase.
17.3 Consider the effect of climate change and changing rainfall patterns and undertake a sensitivity analysis to address the risks and impacts.	Please refer to Section 5.9. A climate change sensitivity test considering changing rainfall patterns has been conducted and potential flood depths and impact areas have been modelled. The design of the proposed development considers these scenarios and adopts measures to reduce the impact of these flood risks. Current analysis satisfies the study requirement for this application. Further analysis may be required during the detailed design phase.
17.4 Provide a flood risk assessment developed in consultation with City of Sydney Council identifying flooding behaviours for existing and developed scenarios in order to outline the suitability of the land for proposed uses. Identify flooding characteristics i.e. flow, levels, extent, velocity, rate of rise, hydraulic and hazard categories, for the full range of flooding up to the probable maximum flood (PMF), for both mainstream and overland flow path.	Please refer to Sections 4.4.4 and 4.4.5 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 City of Sydney Council. Flooding characteristics and their spatial / temporal variation across the site are demonstrated through several figures. Please refer to for the summary. Current flood modelling for the concept design satisfies the study requirement for this application. Further modelling will be required site wide during the detailed design phase.
17.5 Consider the future cumulative flood risk impact across the entire Waterloo Precinct and adjoining land areas.	Please refer to Section 5.8.4. Current analysis satisfies the study requirement for this application. Further analysis may be required during the detailed design phase.
17.6 Address the impact of flooding on future proposed development including flood risk to people and properties for key flood events including the 1% AEP and the probable maximum flood (PMF) event. The assessment is to address relevant provisions of the NSW Floodplain Development Manual (2005).	Please refer to Sections 5.8 and 5.10. A flood model showing depths and flood impact for existing and proposed scenarios has been included in this study. The assessment addresses relevant provisions of the NSW Floodplain Development Manual (2005). Current flood modelling for the concept design satisfies the study requirement for this application. Further modelling will be required site wide during the detailed design phase.
17.7 Provide an assessment of possible impacts of the proposal on the flood behaviour (i.e. flow levels, extent, velocities and duration of flooding) and any impact of the proposal on adjacent, downstream and upstream areas.	Please refer to Sections 5.8.2 to 5.8.4. Flood models for post-development scenarios have been prepared, indicating impacts of the development on the flooding behaviour. These are shown in the post development flood models. Current flood modelling for the concept design satisfies the study requirement for this application. Further modelling will be required site wide during the detailed design phase.
17.8 Provide concept level information on the impacts of future earthworks and filling of land within the proposal. This assessment is to be based on an understanding of staging and cumulative flood impacts.	As a part of this report flood depth plans have been created, these have allowed the architects to confirm building and public domain levels. As such, the current modelling considers these future earthworks and filling of land. Flood Impact plans include these levels and the cumulative flood impacts due to different staging scenarios are neutral or less than the developed case. Please refer to Section 5.8.4.
17.9 Provide preliminary assessment on recommended flood management measures including mitigation works and development controls.	Please refer to Sections 5.5, 5.7, 5.8.5 and 5.10. All building developments are to comply with the Sydney Water PSD and OSD 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. Current recommendations are suitable for the concept level proposal. Further assessment will be required during the detailed design phase.
17.10 Provide recommendations regarding the most appropriate emergency response strategy to manage risk to life.	Please refer to Section 5.10. Recommendations regarding appropriate emergency responses have been included in this report. Current evaluation satisfies the study requirement for this application. Further evaluation will be required during the detailed design phase.
17.11 Provide concept level details of the drainage associated with the proposal, including stormwater drainage infrastructure and address the impact of stormwater flows on the site from other catchments.	Please refer to Sections 5.5 and 5.7. Current analysis for the concept design satisfies the study requirement for this application. Further analysis will be required site wide during the detailed design phase.
17.12 In addition to securing an acceptable level of personal and property safety from flooding, the proposal is to ensure that measures to address of flooding can achieve high	Please refer to Section 5.8.5 and 5.10. Building levels have been coordinated with the site architect to ensure that acceptable levels of personal and property safety are achieved. In conjunction with

Waterloo SSP Study Requirements	Response to Study Requirements
quality urban design outcomes, including ground floor public – private domain engagement i.e. how ground floor retail can be entered at ground at footpath level, and promote water quality outcomes through measures such as water sensitive urban design (in the public and private domains).	this, measures were provided to achieve the intended urban design outcomes and given advice on achieving water quality objectives for the concept level design. For public private domain engagement, this has required setting of appropriate Flood Planning Level (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 for shelter in place evacuation. An indicative internal treatment is shown in Section 5.8.5 which should be developed in the detailed design phase.
17.13 Prepare an implementation plan for the concept Stormwater Management Plan and Flood Risk Assessment.	This report includes an implementation plan and strategy under Section 6.0 sufficient for the concept stage. Further evaluation will be required during the detailed design phase.
17.14 Demonstrate, through assessment against established criteria, how the proposed flooding and stormwater strategy achieves acceptable water quantity and quality outcomes, and in particular, promotes water sensitive urban design.	DRAINS and TUFLOW modelling were undertaken to reach acceptable flooding and stormwater quantity outcomes, MUSIC model was configured to demonstrate the effectiveness of recommended WSUD measures against the specific water quality targets outlined in the study requirements. Sections 5.5 and 5.7 of this report outline the proposed stormwater quantity and quality management approaches in line with the criteria established for stormwater quantity and quality in Sections 5.4 and 5.6 respectively.
Section 18. Noise, Vibration and Pollution	
18.2 Consider and assess potential pollution impacts from the proposed rezoning including, but not limited to, water, air, noise and light pollution.	Please refer to Sections 5.6 and 5.7.

9.0 Conclusion

Preliminary flood modelling of the Estate under existing conditions as well as for the post-development case has been undertaken using a modified version of the City of Sydney 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.

Generally, the proposed development does not worsen the flood levels compared to existing conditions. Decreases in flood levels are also observed in the 100-year ARI at locations along Raglan Street, Wellington Street and Cope Street, primarily because of drainage improvements and provision of flood mitigation storage under public open spaces. For instance, flood levels at the Cope Street and Wellington Street intersection and the Cope Street sag point have decreased by approximately 200 mm. There are some new areas of inundation due to the diversion and realignment of flowpaths. The increases of flood levels at these new areas are due to the assumed grading and footpath in front of the proposed buildings, which raise the terrain levels at these locations. Flood mitigation in these areas can be addressed through local drainage refinements.

Entrances to buildings and underground areas such as carparks are required to be flood free in the PMF event. Recommended FPLs for the Estate have been provided where the adopted criterion for setting of flood planning level was the maximum of PMF level and the 100-year ARI +0.5m level.

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. Initial investigation shows that the flood impacts can be addressed but this 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% 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 in the Indicative Concept Proposal.

For emergency response, the flood hazard is most appropriately managed with a shelter in place strategy, as the duration of inundation is relatively short, and the rate of rise is relatively rapid. A shelter in place strategy for the buildings is also preferred over evacuation, to avoid unnecessary vehicle or pedestrian movements during an extreme storm event. For occupied public open space areas, it is recommended to have a refuge point within a facility that can be accessed easily. Sufficient warning time should be considered, and a flood management plan should be devised to support this.

WSUD features have been assessed against pollution reduction targets as outlined in the study requirements. The suggested strategy from MUSIC modelling is to use biofiltration trees, raingardens and proprietary stormwater devices in the public domain space. 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.

It is concluded that the flooding risks at the Estate can be mitigated using appropriate on-site detention, flood planning levels, building setbacks, improved drainage and sound emergency response frameworks. 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.

10.0 References

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Appendix A

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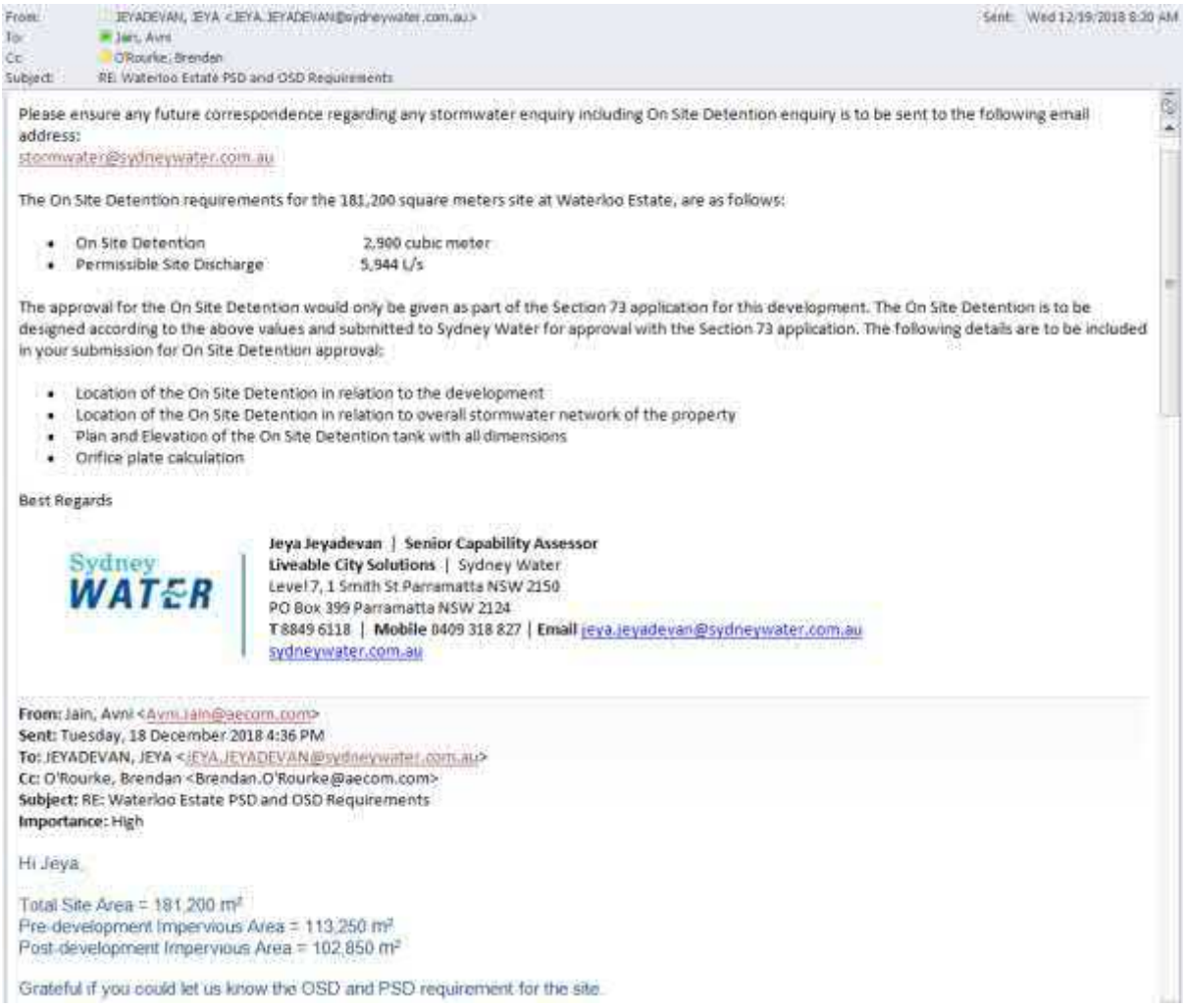
Sydney Water Correspondence



From: JEYADEVAN, JEYA <JEYA.JEYADEVAN@sydneywater.com.au> Sent: Wed 12/19/2018 8:30 AM
To: Jain, Avni
Cc: O'Rourke, Brendan
Subject: RE: Waterloo Estate PSD and OSD Requirements

Please ensure any future correspondence regarding any stormwater enquiry including On Site Detention enquiry is to be sent to the following email address:
stormwater@sydneywater.com.au

The On Site Detention requirements for the 181,200 square meters site at Waterloo Estate, are as follows:

- On Site Detention 2,900 cubic meter
- Permissible Site Discharge 5,944 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

Sydney WATER

Jeya Jeyadevan | Senior Capability Assessor
Liveable City Solutions | Sydney Water
Level 7, 1 Smith St Parramatta NSW 2150
PO Box 399 Parramatta NSW 2124
T 8849 6118 | **Mobile** 0409 318 827 | **Email** jeya.jeyadevan@sydneywater.com.au
sydneywater.com.au

From: Jain, Avni <Avni.Jain@aecom.com>
Sent: Tuesday, 18 December 2018 4:36 PM
To: JEYADEVAN, JEYA <JEYA.JEYADEVAN@sydneywater.com.au>
Cc: O'Rourke, Brendan <Brendan.O'Rourke@aecom.com>
Subject: RE: Waterloo Estate PSD and OSD Requirements
Importance: High

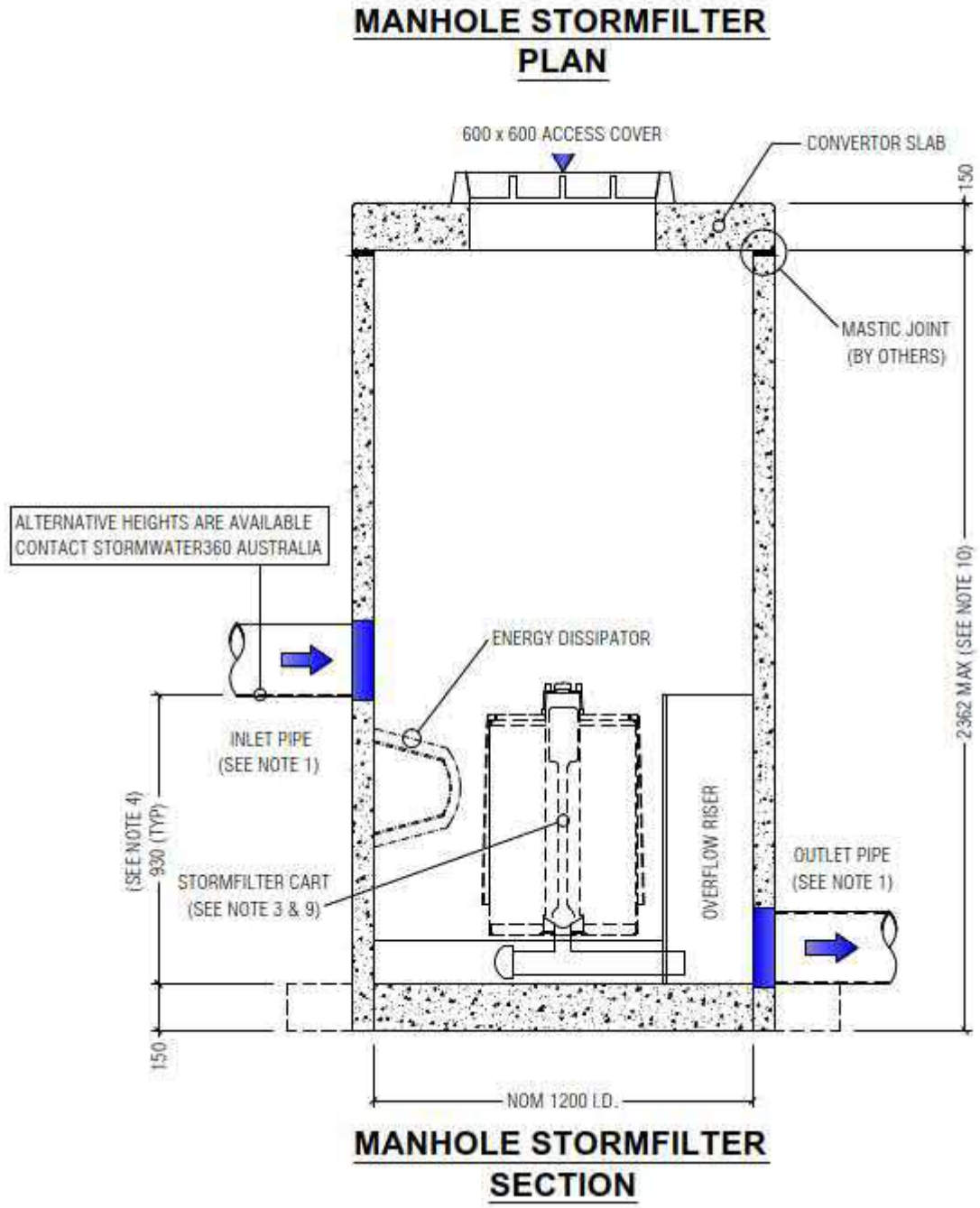
Hi Jeya

Total Site Area = 181,200 m²
Pre-development Impervious Area = 113,250 m²
Post-development Impervious Area = 102,850 m²

Grateful if you could let us know the OSD and PSD requirement for the site.

Appendix B

Typical Arrangement – Combined Chamber & Filter Cartridges



Source: Stormwater 360 (2013)

Appendix C

MUSIC Modelling Assumptions

Pollutant Generation Parameters

Pollutant concentrations for all streets were based on NSW MUSIC Modelling Guidelines (WBM BMT, 2015) for sealed roads.

Biofiltration Street Trees

Street Tree Properties	Quantity	Unit
Filter Area per Tree	4	m^2
Extended Detention	0.1	m
Filter Depth	0.8	m
TN Content of Filter Media	800	mg/kg
Orthophosphate Content of Filter Media	50	mg/kg
Exfiltration Rate	0	mm/hr

Stormfilter and Enviropod

Stormfilter and Enviropod modelling assumptions were based on information provided by Stormwater 360.

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