WESTMEAD SOUTH – FLOODING, WATER QUALITY & STORMWATER STUDY

Final Report

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CUMBERLAND CITY COUNCIL WESTMEAD SOUTH

Flooding, Water Quality & Stormwater Study

Final Report

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REVISIONS

Revision	Date	Description	Prepared by	Approved by
A	9/02/2024	Draft to Client for Review	YL	MC
B	4/03/2024	Revised to Client	YL	MC
C	06/05/2024	Updated to Reflect Masterplan Issue G – Final Status	MG	MC

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1 INTRODUCTION

1.1 Project Background

In July 2020, Council endorsed the strategic planning work program for Cumberland City's key centres and strategic corridors, including Westmead South. The works program involves the preparation of a planning proposal for each of the key centres and strategic corridors identified in the work program, with the following activities to be undertaken prior to any additional reports being considered by Council:

- Completion of background analysis
- Early community consultation on the planning proposal
- Preparation of draft planning proposal
- Preparation of draft planning controls associated with the planning proposal
- Consideration of draft planning proposal by the Cumberland Local Planning Panel
- Councillor briefings prior to early community consultation and prior to consideration by the Cumberland Local Planning Panel

As part of the works program, this project is to prepare a Flooding, Water Quality and Stormwater Study for Westmead South Precinct to support the preparation of a planning proposal to amend the Cumberland Local Environmental Plan 2021 and the Cumberland Development Control Plan 2021.

The following report summarises the findings of the flood modelling, stormwater assessment, and integrated water cycle management (IWCM) assessment. The assessment has been carried out based on the existing catchment / precinct conditions (base case) and the proposed masterplan (developed case).

1.2 Vision

1.2.1 Westmead Vision

Westmead, including Westmead South, is a place for connection, inspiration and collaboration. Celebrating the unique qualities and sensitive history of Dharug Country, Westmead seeks to become a place of truth-telling and healing. Westmead will attract specialists, researchers, health customers, students, entrepreneurs and residents to journey through Country under the cooling shade of trees, at the edge of restored waterways, and among the flora and fauna of a restored 'West Meadow'.

The overarching vision for the Westmead is that of a '**District in Nature**', as described in Westmead Public Domain Strategy (Greater Cities Commission, 2022). This vision is realised through an understanding of the historic natural context of Westmead and the natural systems that have shaped its development.

The 'District in Nature' is reflected through three contexts:

- River Setting – the defining natural system of Westmead
- Re-imagining the 'Western Meadow'
- A Managed Landscape

1.2.2 Vision for Water

Westmead is geographically divided into two north/ south ridgelines that were heavily forested prior to colonisation and overlooking valley areas with substantial waterways.

The waterways in the Westmead PDS area are significant as this is where fresh water meets salt water, with an abundance of varied resources that were used and sustained by Dharug people and other visitors to the area.

Waterways and the land around them have been places of significance for First Nations people for millennia. Depending on the location and available resources, waterways have been used as camping places for clans or smaller family groups, providing a source of water, food and other resources.

Natural waterway system conservation and design to support water systems is the key vision for water cycle management in Westmead, which is reflected in below aspects:

- consider holistic Catchment and sub catchment systems
- restore waterways and associated salt marsh Country
- revive/maintain habitat + ecosystems through caring for Country
- retrofitting existing streets and spaces and creating new public infrastructure that embeds Country into the public domain
- prioritise a naturalised response to water on Country
- recommended 40% target canopy cover
- WSUD interventions – to promote water collection and re-use, to slow water movement, to hold, cleanse and allow infiltration, and to mitigate urban heat island effects.
- responsive, site-specific interventions; for example, streets parallel to low ground used for street-based swale systems, removing concrete channels, mini “wetlands” at base of sloping streets
- District permeability – slowing the movement of water, allowing it to infiltrate, re-establishing nature’s functions.

1.3 Objectives

1.3.1 Westmead South Master Planning Objectives

The overall objectives for the Westmead South Master Planning include the following aspects:

Urban Design

- To undertake a place-based response to precinct planning, that acknowledges the current and future desired character of the area including heritage conservation, the community fabric and natural environment.
- To maintain and enhance the cultural heritage of the precinct through retention.
- To design for growth and an increased diverse housing supply, including affordable housing, by integrating land use and transport infrastructure.
- To design and promote high quality, sustainably designed buildings with good amenity and accessibility.
- To create active and accessible public domains that encourages safe, social interactions. Hawkesbury Road, the Metro interchange and the Oakes Centre will be key transformational areas within the precinct.
- To enhance vehicle and active transport linkages within the sub-precinct, to the Westmead public transport interchange, and to the adjoining precincts of Westmead North, Wentworthville, and Parramatta CBD.
- To ensure that the future community’s needs and aspirations are considered through appropriate urban design and built form outcomes.

Environmental

- To promote sustainable design and built forms that reduce the ‘urban heat island’ impact, storm water runoff, and flooding impacts, and which allow for the regeneration of Westmead’s natural assets including the Parramatta River, Toongabbie, and Darling Mills Creeks.
- To provide adequate open space and recreational opportunities to meet the anticipated population growth for the whole Westmead Precinct.
- To design for natural environments that retain mature vegetation, protects and or enhances significant flora and fauna, where possible.
- To identify areas of contamination to ensure an appropriate land use response.

Social

- To ensure that adequate community infrastructure and support services are provided for the future population.

- To incorporate social and affordable housing needs through implementation of an affordable housing contribution scheme (where appropriate) and collaboration with the Land and Housing Corporation (LAHC).

Economic

- To ensure that any proposed development is financially viable and that the proposed mix of uses adequately reflects current and projected market requirements.
- To capitalise on infrastructure investment in the Parramatta light rail and future Sydney Metro.
- To protect existing industry within the precinct whilst also encouraging new emerging industries and technologies.

1.3.2 Flooding, Water Quality and Stormwater Objectives

The aim of the Flooding, Water Quality and Stormwater Study is to inform and support the development of the Westmead South Master Plan and subsequent Planning Proposal. The objectives of the Study include:

- Collaborate with the suite of consultants engaged by Council for the Master Plan.
- Understand the existing water quality, flooding, and stormwater management context in the study area.
- Test and assess the existing (base case) and proposed (development) scenarios proposed to advise on the potential impacts on flooding, water quality and stormwater management, with the consideration of the climate change and impacts within and external to the study area.
- Provide recommendations for the Westmead South Master Plan that will enable compliance with Local Planning Direction 4.1: Flooding (section 9.1 Ministerial Directions).
- Provide a flood risk assessment and implementation plan, including flood mitigation strategies, a stormwater management plan, a water quantity and quality assessment, and an integrated water cycle management strategy, that provides strategies and recommendations for the growth scenario.
- Prepare the required provisions, in collaboration with Council, which can be integrated into the Cumberland Local Environmental Plan 2021 and/or Cumberland Development Control Plan 2021.

2 STUDY AREA

The Cumberland Local Government Area (LGA), proclaimed in May 2016, is situated 20 km west of Sydney and covers 72 km^2, with a population of 240,000 residents.

The study area (site) is the southern portion of Westmead Precinct, located at the central north part of the Cumberland LGA, as shown in Diagram 1. It plays an important role as a Gateway and residential community hub to the Westmead health and education facilities at the precinct's core.

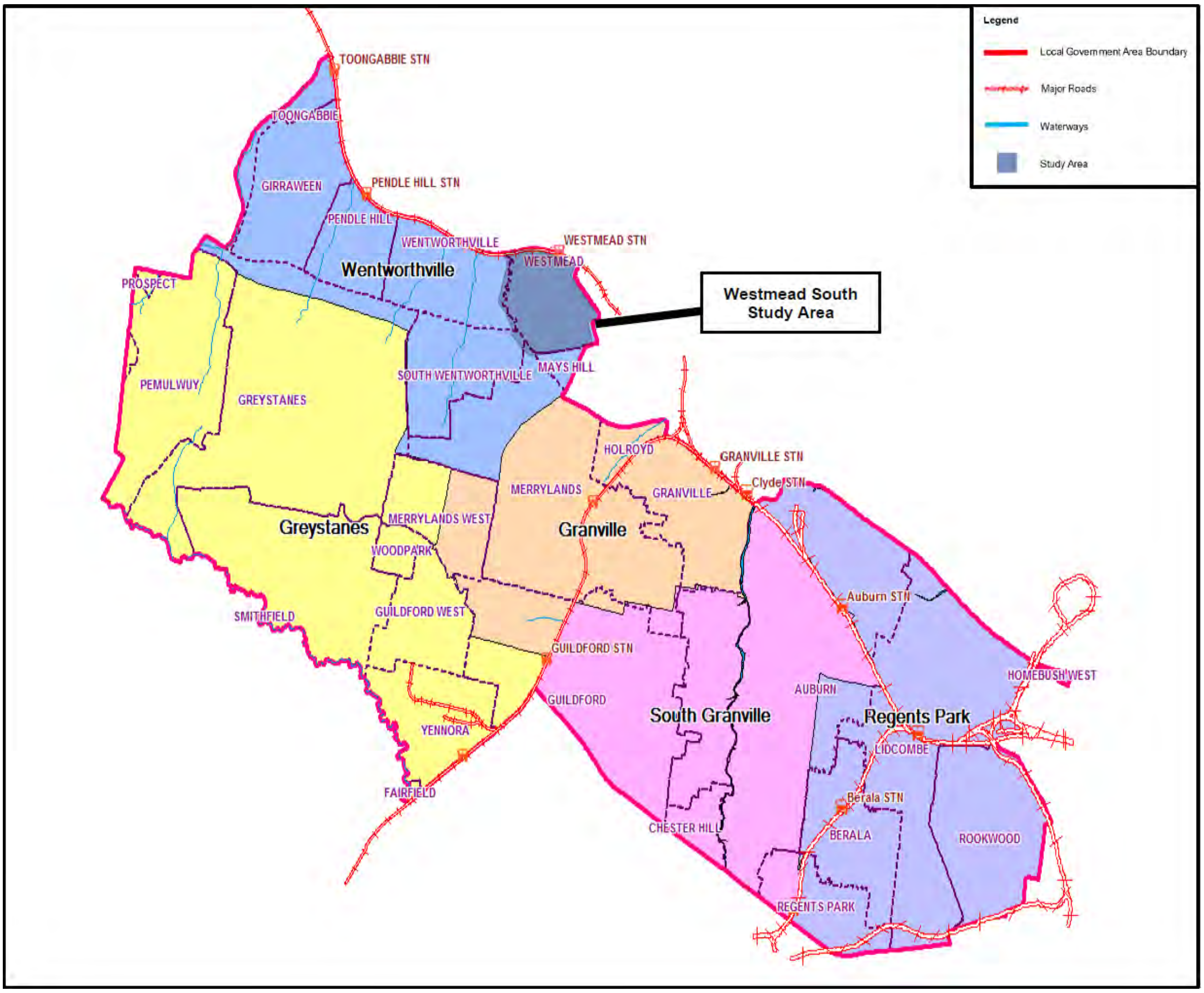


Diagram 1 - Site Location

2.1 Existing Site

The study area is bound by a railway line to the north, the Great Western Highway to the south, Mays Hill Precinct (Parramatta Park) to the east and Bridge Road to the west. It covers two local catchments - Domain Creek and Westmead Creek catchments; draining northwards towards the railway line. The area is fully urbanised with an existing residential land use, as illustrated in Diagram 2.

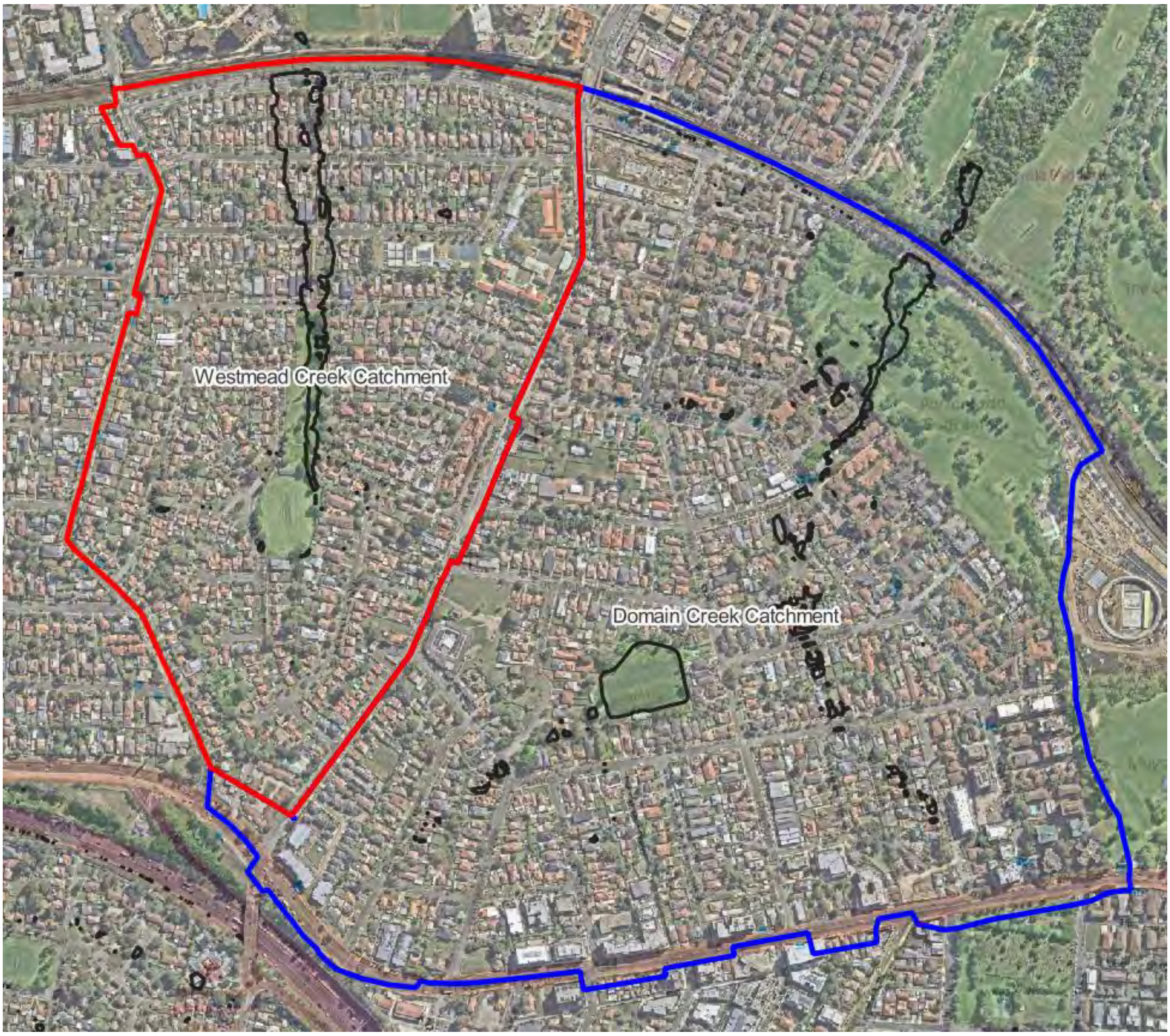


Diagram 2 - Study Catchments with Council Adopted 1% AEP Flow Path (Lyall & Associates, 2017)

2.2 Master Planning

Strategic planning work program has been taking place for Cumberland City's key centres and strategic corridors, including Westmead South, since 2020. As part of the program, Westmead South is being planned to provide diverse and affordable housing with associated specialised retail, commercial and community facilities to support existing and future residents who likely work in central Westmead and Parramatta CBD.

The urban design masterplan, the post exhibition version - dated 10 April 2024, is shown in Diagram 3. The master plan allows future Westmead South to accommodate over 25,000 residents, compared to approximately a population of 8,000 under existing conditions, by rezoning the general residential into high/median density residential apartments. The proposed masterplan will result in a significant increase of potable water demand and could also potentially impact the stormwater quality and quantity, as well as the flood risk within and external to the area, which are the issues this Study aiming to address.

It should be noted that the hydrological and hydraulic modelling exercises (DRAINS and TUFLOW) presented in this report were undertaken based on the publicly exhibited version (31 October – 8 December 2023), rather than the post exhibition version shown in Diagram 3. The two versions are generally close in built form and total yield, therefore, the post-exhibition changes will be unlikely to have material impact on the conclusions and recommendations of this report. However, this needs to be confirmed at the next stage by updating the modelling to the revised masterplan. The proposed WSUD measures and modelling assessment (MUSIC) has been updated with the post exhibition masterplan as shown in Diagram 3.

Summary of master plan outcomes

The adjacent map summarises the built form approach for Westmead South including proposed land uses, building height in storeys and floor space ratio, which have been iteratively tested and refined through collaboration with the Council and consultant team. This will inform potential amendments to the planning controls within the Cumberland Local Environmental Plan.

Legend - Development areas

Area	FSR (of which retail)	Storeys	Land use / description
A0	5.9:1 (0.7:1)	25	Mixed use - Adjacent Station Development site (+ affordable housing)
A1	0.5:1 (Metro station)	1-2	Metro site - station entrance and supporting services
A2	4.5:1 (0.6:1)	20	Mixed use (+ community facility and affordable housing)
A3	4.2:1 (0.6:1)	20	Mixed use (+ affordable housing)
A4	2.8:1 (0.6:1)	15	Mixed use
B1	3.6:1	25	High density residential (+ new open space and through site link)
B2	3.6:1	15	Residential apartments (+ affordable housing and through-site link)
B3	3.6:1	20	Residential apartments (+ commuter car park)
B4	3.2:1	15	Residential apartments (+ affordable housing)
C	2.9:1	12	Residential apartments
D1	2.5:1	8	Residential apartments (+ through site link)
D2	2.5:1	8	Residential apartments
D3	2.5:1	8	Residential apartments
E0	1.2:1	4	Residential apartments
E1	1.6:1	6	Residential apartments
E2	1.6:1	6	Residential apartments
E3	1.6:1	6	Residential apartments
E4	1.6:1	6	Residential apartments
E5	1.6:1	6	Residential apartments
E6	1.6:1	6	Residential apartments
E7	1.6:1	6	Residential apartments
E8	1.6:1	6	Residential apartments
F0	3.2:1 (0.6:1)	8	Mixed use (Hawkesbury Road high street)
F1	3.2:1 (0.6:1)	8	Mixed use (Hawkesbury Road high street)
F2	3.2:1 (0.6:1)	8	Mixed use (Hawkesbury Road high street)
G0	2.5:1 (0.6:1)	8	Mixed use (Great Western Highway E3 zone)
G1-1	2.2:1 (0.6:1)	8	Mixed use (Great Western Highway E3 zone)
G1-2	2.2:1 (0.6:1)	8	Mixed use (Great Western Highway E3 zone)
G1-3	2.2:1 (0.6:1)	8	Mixed use (Great Western Highway E3 zone)
G1-4	2.2:1 (0.6:1)	8	Mixed use (Great western highway extension)
G2-1	1.8:1 (0.6:1)	6	Mixed use (Great western highway extension)
G2-2	1.8:1 (0.6:1)	6	Mixed use (Great western highway extension)
G3	3:1 (0.4:1)	12	Hawkesbury Place site (+ open space and community facility)
H	1.2:1 [no change]	4	Residential apartments (existing blocks)
I	0.7:1	2	Medium density residential (1-2 storeys)
J0	0.7:1	2	Low to medium density residential (1-2 storeys)
J1	0.7:1	2	Low to medium density residential (1-2 storeys)
J2	0.7:1	2	Low to medium density residential (1-2 storeys)
J3	0.7:1	2	Low to medium density residential (1-2 storeys)
K	-	1	Potential Special Character Area or Heritage Conservation Area

Land use, FSR and height approach map

Legend - other items

- Westmead South boundary
- SP1 zone - school
- Potential Heritage Conservation Area
- Potential Special Character Area or Heritage Conservation Area
- Potential heritage item
- Existing Heritage Conservation Area
- Unlikely to change (existing heritage item)
- Unlikely to change (school, church, strata title)
- Hawkesbury Road - movement spine
- Key pedestrian streets
- Existing open spaces
- New public plaza - Oakes Centre and Metro plaza
- Potential new open space (dedication or other)
- Existing pocket parks to be zoned RE1
- Hawkesbury Road high street - active frontages
- Great Western Highway frontage - ground floor non-residential uses
- Laneway (dedication or other)
- Proposed laneway (dedication or other)
- Widened link - Dedication through development - 4.5m of 6m setback

Diagram 3 – Study Area Proposed Conditions – Masterplan Issue G (Final Issue) - dated 10 April 2024

3 PREVIOUS STUDIES

Relevant policies, strategies, and previous studies obtained for this Study are summarised in Table 1. Those studies were reviewed with a focus on flooding, stormwater, IWCM and WSUD.

Table 1 - Relevant policies, strategies, and studies

Title	Source
Greater Sydney Region Plan – "A Metropolis of Three Cities"	Greater Sydney Commission
Central City District Plan	Department of Planning and Environment
Future Transport Strategy 2056	Transport for NSW
Westmead 2036 Place Strategy	Department of Planning and Environment
Westmead Place-based Transport Strategy	Transport for NSW
Westmead Health and Innovation District Public Domain Strategy	Greater Cities Commission
Westmead South Land Use Capability Study, dated 13 September 2021	SGS Economics and Planning
Westmead South Centre Traffic and Transport Study, dated 8 February 2022	SCT Consulting
Westmead South Community Needs and Social Infrastructure Assessment Report dated 21 October 2022	GHD Pty Ltd
NSW BASIX	Department of Planning and Environment
Cumberland Community Strategic Plan 2017-2027	Cumberland City Council
Cumberland 2030: Our Local Strategic Planning Statement	Cumberland City Council
Cumberland Local Housing Strategy 2020	Cumberland City Council
Cumberland Cultural Plan 2019 – 2029	Cumberland City Council
Cumberland Local Infrastructure Contributions Plan 2020	Cumberland City Council
Cumberland Affordable Housing Strategy 2020	Cumberland City Council
Cumberland Open Space and Recreation Strategy 2019 – 2029	Cumberland City Council
Cumberland Urban Tree Strategy 2020	Cumberland City Council
Cumberland Community Facilities Strategy 2019 – 2029	Cumberland City Council
Cumberland Employment and Innovation Lands Strategy 2019	Cumberland City Council
Cumberland Local Environmental Plan 2021	Cumberland City Council
Cumberland Development Control Plan 2021	Cumberland City Council
Holroyd City LGA Overland Flood Study 2017	Lyall and Associates

3.1 Flood Study

An overland food study for the Holroyd City LGA, the majority of which has been merged into Cumberland City Council, was conducted by Lyall and Associates in 2017. The study covers Westmead and Domain Creek catchments, i.e., the Westmead South master planning area.

The DRAINS and TUFLOW models for Westmead and Domain Creek catchments from the 2017 study were supplied by Council. The models were established in accordance with the processes defined in Australian Rainfall Runoff (ARR) guidelines 1987. The sub-catchment rainfall-runoff processes were modelled through DRAINS, producing inflow hydrographs for TUFLOW. No 1D hydraulic routing was modelled in DRAINS. The hydraulic models (TUFLOW) cover the main overland flow paths and the inflow hydrographs, generated by hydrologic models, were implemented directly into pits through 1d_bc. The underground drainage, i.e., pits and pipes, and key culverts were represented through 1D elements.

The 2017 models were used as a base for this study and were updated to current best practice guideline, i.e., ARR 2019, and existing catchment conditions. The model updates are summarised in Section 4.

3.2 Stormwater and IWCM requirements

The stormwater and Integrated Water Cycle Management (IWCM) requirements for are mainly defined in:

- NSW BASIX;
- Cumberland Local Environmental Plan 2021; and
- Cumberland Development Control Plan 2021.

Relevant information has also been obtained from background studies relevant to Westmead South master planning, including:

- Westmead 2036 Place Strategy;
- Westmead Health and Innovation District Public Domain Strategy;
- Westmead South Land Use Capability Study;
- Cumberland Open Space and Recreation Strategy 2019 – 2029; and
- Cumberland Urban Tree Strategy 2020.

Detailed analysis of stormwater and IWCM requirements and targets is discussed in Section 6.2.

4 FLOOD RISK AND IMPACT ASSESSMENT

4.1 Overview

The following updates were performed:

- Updated rainfall data from ARR Datahub (including compliance to NSW specific advice):
  - Rainfall depths from 2016 Bureau of Meteorology data
  - 10 temporal patterns
  - Transformational pre-burst depths (accounting for varying probability neutral burst initial loss)
- Adopted ARR 2019 IL-CL method in the updated DRAINS model instead of the ILSAX method in the original model. The adopted loss parameters include:
  - Probability neutral burst initial loss (PNBIL), represented through transformational pre-burst
  - ARR Data hub continuing loss (CL) adjusted by 0.4 multiplier based on NSW specific advice.
- Updated impervious fractions, including further break down into ARR2019 surface types.
- Modelled ensemble of 10 storms and extracted envelope of maximum values according to ARR2019 methodology.

The sub-catchment layout was reviewed and considered to be reasonable. As such, no changes to the sub-catchment boundaries were performed. The sub-catchments are identified in Diagram 4.

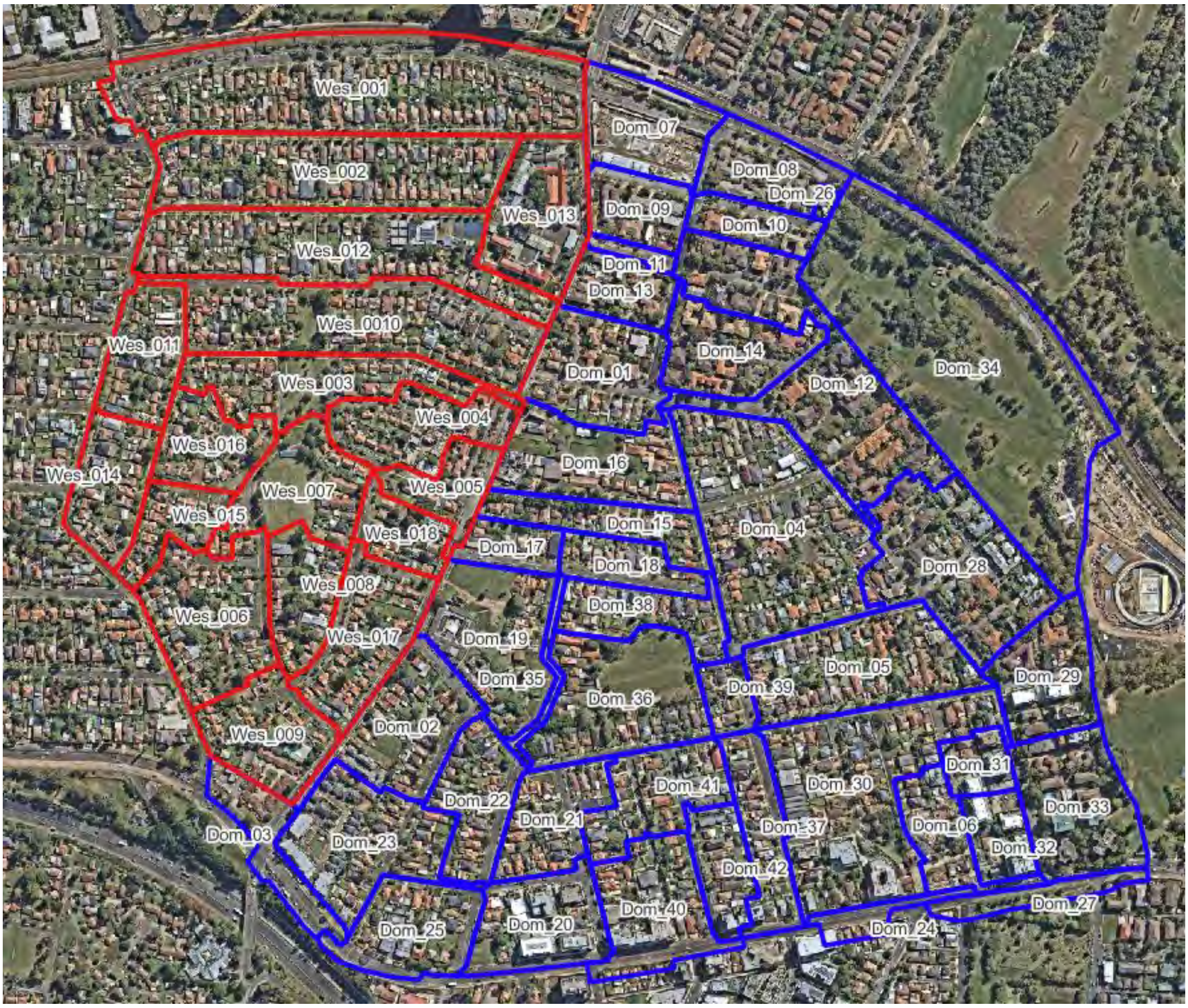


Diagram 4 - Sub-catchment layout (Westmead Creek sub-catchments in red, Domain Creek sub-catchments in blue)

4.2 Hydrological Model Updating

Runoff hydrographs were generated in DRAINS. DRAINS is common software that is conventionally used as both a hydrologic and 1D hydraulic model. However, for this project, it has only been used for the hydrologic component of the project.

4.2.1 Impervious Fractions

The impervious fractions of the sub-catchments were updated as follows:

1. Derivation of impervious fractions to match the latest aerial imagery and land use.
2. Further break down of the derived impervious fractions into ARR2019 surface types.

The ARR2019 approach involves breaking down urban catchments into three surface types, identified in Table 2.

Table 2 - ARR2019 urban catchment surface types

Surface Type	Description
Effective Impervious Area (EIA)	Impervious areas directly connected to drainage systems.
Indirectly Connected Area (ICA)	Impervious areas not directly connected to drainage systems. Pervious areas directly connected to drainage systems.
Pervious Area (PA)	Large pervious areas that do not interact with impervious areas or drainage systems.

However, DRAINS applies the ARR2019 approach differently. It has a slightly different definition of the surface types. These are described in Table 3.

Table 3 - DRAINS surface types for the ARR2019 approach

Surface Type	**Description**
Effective Impervious Area (EIA)	No change from ARR2019 definitions.
Remaining Impervious Area (RIA)	Impervious areas not directly connected to drainage systems. Impervious areas not directly connected to drainage systems.
Pervious Area (PA)	Any pervious areas, regardless of connectivity to impervious areas or drainage systems.

The different surface type definitions correspond to different loss values. From a planning and flood-risk perspective, this change is not significant. However, any practitioner performing updates to the DRAINS model must take note of this subtle difference to avoid mixing the DRAINS ARR2019 methodology with the unmodified ARR2019 methodology.

Impervious fractions were updated according to the latest aerial imagery. The average total impervious area (TIA) fraction as well as the other surface types is shown in Table 4.

Table 4 – Average of Impervious Fractions used in 2017 and 2023 models

Model	Average TIA Fraction	Average Paved/EIA Fraction	Average Supplementary/RIA Fraction	Average Grassed/PA Fraction
2017 Model	0.37	0.37	-	0.63
2023 Model	0.56	0.35	0.21	0.44

The TIA fraction has increased, as shown in Table 4. A review of aerial imagery from 2017 to 2023 revealed that the increase in TIA is partially attributed to developments within the catchments. However, the majority of TIA increase is attributed to the low impervious fractions assigned to the sub-catchments in the 2017 model.

For example, an impervious fraction of 0.4 was assigned to the high-density areas towards the northeast of Domain catchment. These areas already existed when the 2017 model was built. In addition, these sub-catchments include the road, which should further increase the impervious fraction. Arcadis concluded that the adopted impervious fractions of the 2017 model were lower than expected range.

The increase in TIA resulted in an increase in runoff volumes. The net effect of the hydrological updates is discussed in Section 4.2.8. A table identifying the impervious fractions for each sub-catchment is included in Appendix A.

4.2.2 Loss Model and Routing Model

The 2017 model utilised the Horton/ILSAX hydrological model with parameters shown in Table 5. This was replaced with the ARR2019 Initial Loss-Continuing Loss (IL-CL) hydrological model with parameters shown in Table 6. This is due to the lack of calibration data to identify ILSAX parameters, noting that the 2017 report was for a much larger region (i.e., LGA) and the validation was carried out in other catchments. Therefore, according to NSW specific advice by ARR 2019, IL-CL method (i.e., PNBIL and CL adjusted by 0.4 factor) was adopted.

Table 5 - ILSAX hydrological model parameters

Parameter	Value
Paved (impervious) area depression storage	1 mm
Supplementary area depression storage	1 mm (not used)
Grassed (pervious) area depression storage	5 mm
Soil Type	3
Antecedent Moisture Condition	3
Initial Infiltration Rate	33.7 mm/h
Final Infiltration Rate	6 mm/h

Table 6 - ARR2019 IL-CL hydrological model parameters

Parameter	Value
Impervious Area Initial Loss	1 mm
Impervious Area Continuing Loss	0 mm/h
Pervious Area Initial Loss	28 mm
Pervious Area Continuing Loss	0.76 mm/hr

It should be noted that the ARR Datahub includes NSW-specific advice regarding the appropriate initial losses for pervious areas. These loss values are called the Probability Neutral Burst Initial Loss and vary depending on the duration and frequency of the storm. These are shown in Table 7.

Table 7 - Probability Neutral Burst Initial Loss in mm

Duration (min)	50%	20%	10%	5%	2%	1%
60	17.5	9	8.8	9.6	9.4	8.3
90	18.9	9.9	9.4	9.5	8.2	6.2
120	14.6	8.4	8.7	9	8.3	6.4
180	16.9	9.3	9	8.4	7.7	6

DRAINS is unable to nominate varying loss values, therefore this step has been accounted for by modifying the pre-burst rainfall, discussed in Section 4.2.3.

4.2.3 Pre-burst Rainfall

The rainfall depths provided by the Bureau of Meteorology represent the burst depth. Pre-burst rainfall, however, is the rainfall that occurs before the burst of the storm. This rainfall has the effect of reducing the initial loss of the catchment. The pre-burst rainfall depths identified in Table 8 have been updated to account for the varying Probability Neutral Burst Initial Loss as described in Section 4.2.2.

Table 8 - Transformational Pre-Burst Rainfall in mm

Duration (min)	50%	20%	10%	5%	2%	1%
60	10.3	18.8	19	18.2	18.4	19.5
90	8.9	17.9	18.4	18.3	19.6	21.6
120	13.2	19.4	19.1	18.8	19.5	21.4
180	10.9	18.5	18.8	19.4	20.1	21.8

4.2.4 Rainfall Depths

Rainfall depths from the 2016 Bureau of Meteorology database were used as part of the update. The 2016 database is based on significantly more rainfall observations than the 1987 database. The difference between the two sources is shown in Table 9 and Table 10.

Table 9 - Difference in Rainfall Depths in mm (2016 Data minus 1987 Data)

	Frequency						
Duration (min)	**1 / 63.2%**	**2 / 0.5EY**	**5 / 20%**	**10 / 10%**	**20 / 5%**	**50 / 2%**	**100 / 1%**
5	0.45	0.12	-0.81	-0.56	-0.77	-0.93	-1.01
10	1.03	0.76	-0.2	0.43	0.34	0.23	0.17
15	1.23	0.91	-0.35	0.56	0.38	0.27	0.16
20	1.27	0.75	-0.83	0.06	-0.17	-0.49	-0.64
25	1.05	0.52	-1.46	-0.63	-1.02	-1.44	-1.74
30	0.98	0.11	-2.21	-1.39	-1.99	-2.55	-3.04
45	0.4	-0.94	-4.3	-3.74	-4.85	-5.94	-6.65
60	-0.12	-1.89	-6.14	-5.91	-7.35	-8.82	-9.85
90	-0.98	-3.37	-8.99	-9.08	-11.17	-13.31	-14.71
120	-1.54	-4.36	-10.93	-11.28	-13.79	-16.39	-18.03
180	-2.1	-5.58	-13.53	-13.98	-16.95	-20.09	-21.9

Table 10 - Difference in Rainfall Depths as a percentage of 1987 Data

Duration (min)	1 / 63.2%	2 / 0.5EY	5 / 20%	10 / 10%	20 / 5%	50 / 2%	100 / 1%
5	6%	1%	-7%	-4%	-5%	-6%	-5%
10	10%	6%	-1%	2%	2%	1%	1%
15	9%	5%	-2%	2%	1%	1%	0%
20	8%	4%	-3%	0%	-1%	-1%	-2%
25	6%	2%	-5%	-2%	-3%	-3%	-4%
30	5%	0%	-7%	-4%	-5%	-6%	-6%
45	2%	-3%	-12%	-9%	-10%	-11%	-11%
60	0%	-6%	-15%	-13%	-14%	-14%	-14%
90	-3%	-9%	-18%	-16%	-18%	-18%	-18%
120	-5%	-10%	-20%	-18%	-19%	-20%	-20%
180	-5%	-11%	-21%	-19%	-20%	-20%	-20%

As shown in the tables above, the 2016 rainfall depths are generally less than the 1987 rainfall depths for rarer events. The reduction in rainfall depths resulted in lower runoff volumes. The net effect of the hydrological updates is discussed in Section 4.2.8.

No changes to the rainfall depths were made for PMF events.

4.2.5 Rainfall Temporal Patterns and Storm Selection

Rainfall temporal patterns describe how rainfall is distributed across time. Storm selection is the process of selecting the storm that causes the highest peak flow and/or flood level at a specific location.

The ARR1987 approach includes one temporal pattern per duration and the duration yielding the highest peak flow and/or flood level is selected.

The ARR2019 approach involves modelling an ensemble of 10 temporal patterns per duration. For each duration, the temporal pattern corresponding to the median peak flow and/or flood level is selected. This is then followed by selecting the duration yielding the highest peak flow and/or flood level.

Storm selection was performed fully in the hydraulic model and supersedes the hydrological model. Diagram 5 illustrates the difference in temporal patterns between the ARR1987 and ARR2019 approaches.

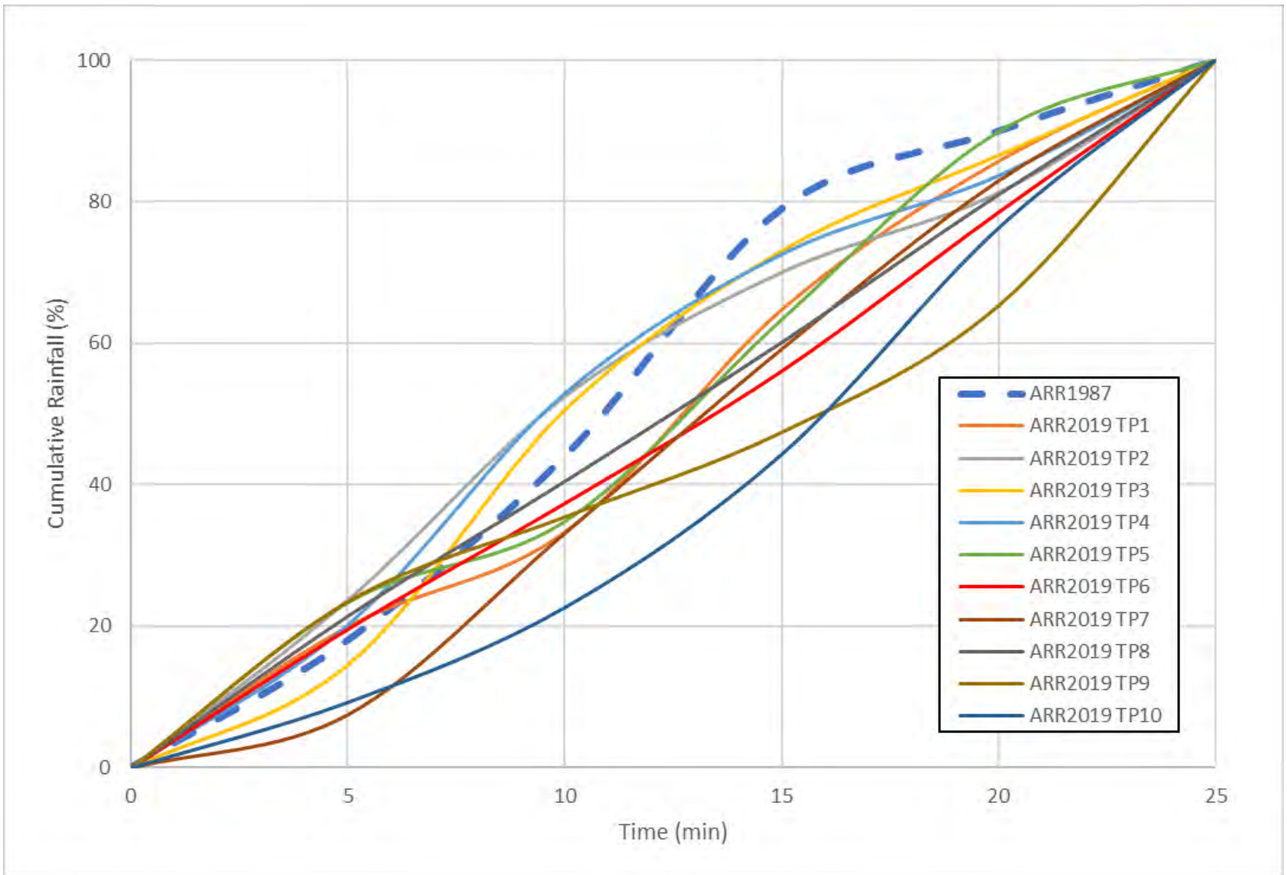


Diagram 5 - 1% AEP 25-minute storm temporal patterns (shown as cumulative % of rainfall)

As shown in Diagram 5, ARR2019 temporal patterns are generally more rear-loaded than ARR1987 for the 25-minute storm. Assessments of temporal patterns for other storm durations were not performed. This assessment was purely to identify the individual factors affecting the runoff hydrograph to ensure that the behaviour of the hydrograph is expected and reasonable.

No changes to the rainfall temporal patterns were made for PMF events.

4.2.6 Time of Concentration

The time of concentration is the time required for water to flow from the furthest point on a catchment to its outlet. This parameter greatly affects the runoff hydrograph from each sub-catchment due to its interaction with the storm durations and temporal patterns. Generally, a longer time of concentration yields a flatter hydrograph, corresponding to a lower peak and a longer base.

The Kinematic Wave Equation was used to determine the time of concentration for each sub-catchment. There is an option to increase the time of concentration through the "Additional Time" parameter, which "adds on" time to the time of concentration calculated by the Kinematic Wave Equation. The parameters used are identified in Table 11.

Table 11 - Sub-catchment Parameters for Time of Concentration

Surface Type	Parameter	2017 model	2023 model
Paved / Effective Impervious Area	Additional time	5 minutes	Unchanged
	Flow path length	Calculated from DEM	Unchanged
	Flow path slope	Calculated from DEM	Unchanged
	Retardance coefficient n*	0.02	Unchanged
Supplementary / Remaining Impervious Area	Additional time	Not used	0
	Flow path length	Not used	0
	Flow path slope	Not used	Redundant due to 0 flow path length
	Retardance coefficient n*	Not used	Redundant due to 0 flow path length
Grassed / Pervious Area	Additional time	0	6
	Flow path length	30 m	Same as EIA
	Flow path slope	Same as Paved	Unchanged
	Retardance coefficient n*	0.04	0.02
	Lag time	Proportional to Paved flow path length	Removed – no longer available as a parameter

The hydrograph is especially sensitive to the time of concentration which, in turn, is sensitive to additional time and other flow path parameters. Particular care must be taken when selecting appropriate values for these parameters.

A review of the 2017 model found that the grassed area parameters were excessively conservative. The lag time parameter of the 2017 model assumed a 2.0 m/s flow velocity, thus returning a time of concentration significantly shorter than the paved area. Arcadis believes the time of concentration for the grassed areas should not be shorter than the paved areas, and hence, the hydrographs from the 2017 model should be flatter.

As part of the ARR2019 update, additional times of Pervious Areas have been increased to 6 minutes and flow path parameters are now matching EIA. These steps result in a generally higher time of concentration and hence, a flatter hydrograph.

4.2.7 Climate Change Effects

There are two climate change effects that are relevant to flooding – sea level rise and increased rainfall. Sea level rise has been excluded from the assessment due to the location and elevation of the study area relative to sea level. With regards to increased rainfall, a rainfall multiplier has been applied for the 1% AEP storms.

The ARR Datahub provides interim climate change factors up to the year 2090 and nominates a 19.7% increase in rainfall assuming a Representative Concentration Pathway (RCP) of 8.5 for the year 2090. The RCP is a projection of the carbon dioxide emissions, with 8.5 corresponding to the worst-case of the three RCPs provided.

4.2.8 Net Effect

The following image identifies 11 hydrographs from one of the sub-catchments. A single hydrograph applied the ARR1987 approach whereas the remaining ten used the ARR2019 approach.

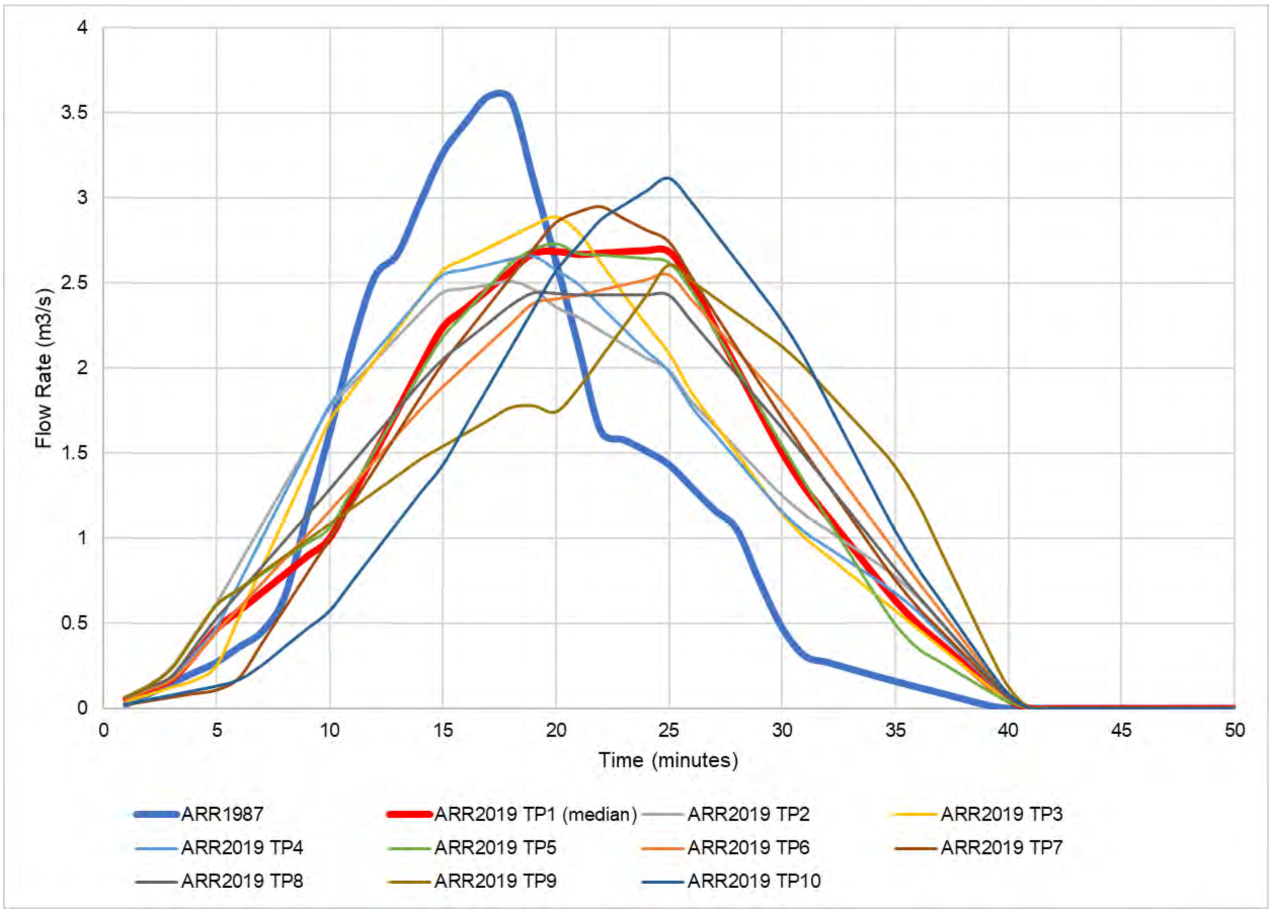


Diagram 6 - 1% AEP 25-minute storm Hydrographs for Wes_001 sub-catchment

As shown in Diagram 6, the ARR2019 approach produces a significantly lower peak flow, from 3.6 (using ARR1987 approach) to 2.7 m^3/s. This represents a reduction in peak flow of about 25%.

Whilst the peak flow has reduced, there is also an increase in overall volume by about 10%. Whilst Table 9 identifies a 4% reduction in rainfall depths, the impervious fraction increases by 40%, as shown in Appendix A.

Arcadis believes that this behaviour is expected and is reasonable considering the different loss models, loss values, temporal patterns, rainfall data, and critical storm methodology.

4.3 Hydraulic Model Updating

4.3.1 DEM Comparison

The digital elevation model (DEM) used in the 2017 flood model was based off LiDAR captured in 2013. LiDAR captured in 2019 was also obtained. The metadata for the LiDAR sources is shown in Table 12.

Table 12 - LiDAR metadata

Source	2017 Model DEM	2019 ELVIS / Spatial Services NSW
Acquisition Date	April 2013	July 2019
Vertical Accuracy (mm)	150	300
Horizontal Accuracy (mm)	400	800
Confidence Interval	95%	95%
Flight Altitude (m)	1530	3500
DEM resolution (m)	1	1

The metadata shows that the LiDAR captured in 2013 has a higher accuracy. A comparison of the LiDAR sources against aerial imagery revealed that the 2013 LiDAR had a better horizontal alignment (and hence, accuracy) with the aerial image. This is shown in Diagram 7, where the 2013 LiDAR has a closer alignment to the road kerb compared to the 2019 LiDAR.

Diagram 7 – Ground Surface Elevation with cursor location corresponding to kerb & channel location (Black – 2013 LiDAR; Red – 2019 LiDAR)

There were no data sources available to compare the vertical accuracy of the LiDAR sources. However, when compared to each other, 2013 LiDAR was generally at a higher elevation than 2019 LiDAR. The differences are shown from Diagram 8 to Diagram 13.

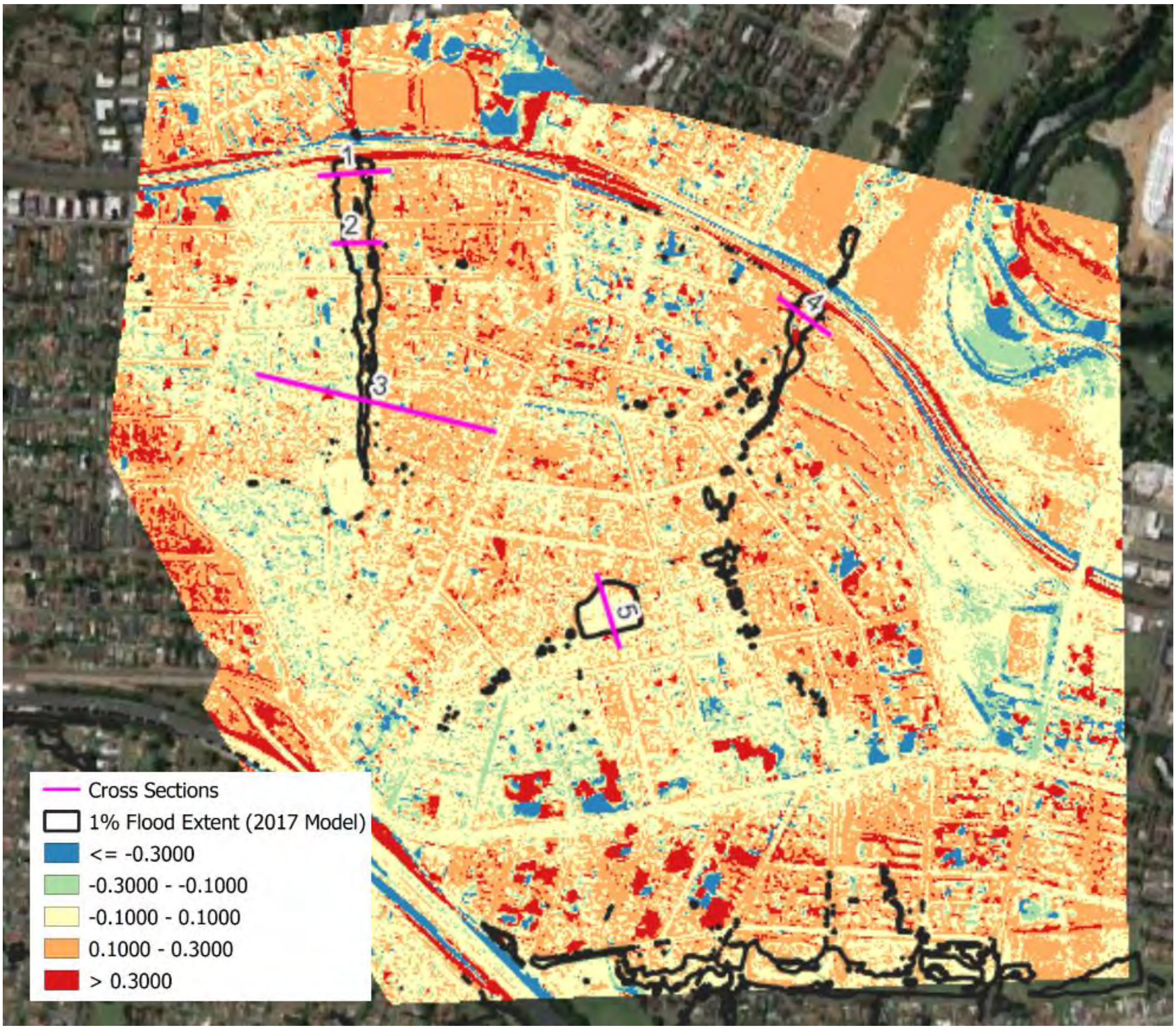


Diagram 8 - Difference between LiDAR elevation in metres (2013 LiDAR minus 2019 LiDAR)

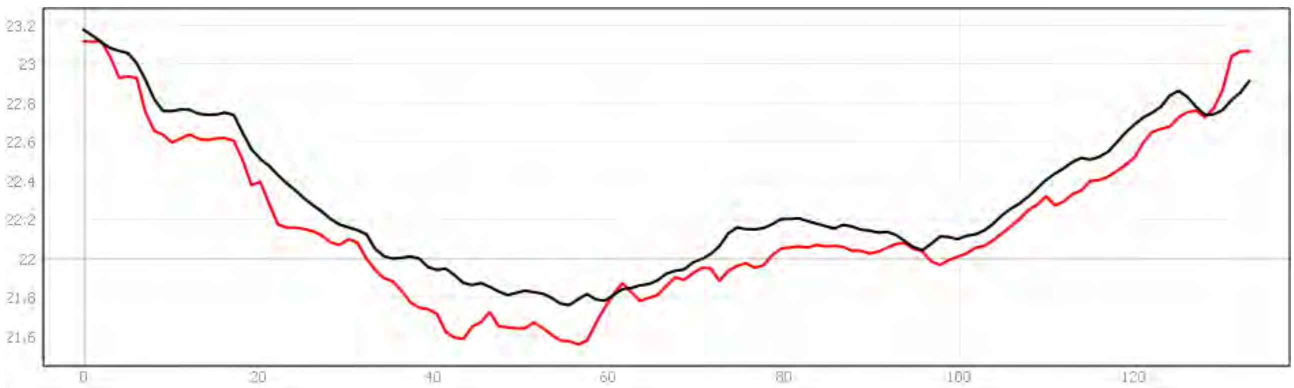


Diagram 9 – Ground Surface Elevation at Cross Section 1 (Black – 2013 LiDAR; Red – 2019 LiDAR)

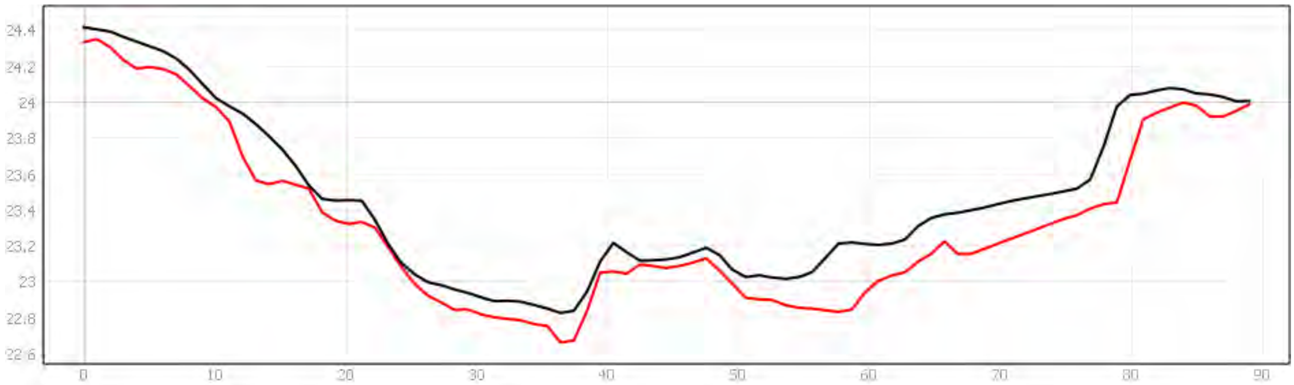


Diagram 10 – Ground Surface Elevation at Cross Section 2 (Black – 2013 LiDAR; Red – 2019 LiDAR)

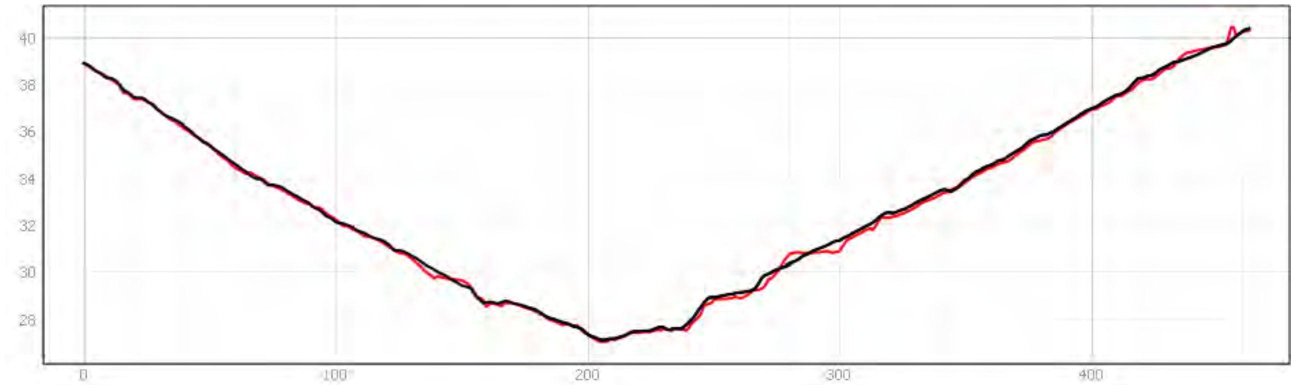


Diagram 11 – Ground Surface Elevation at Cross Section 3 (Black – 2013 LiDAR; Red – 2019 LiDAR)

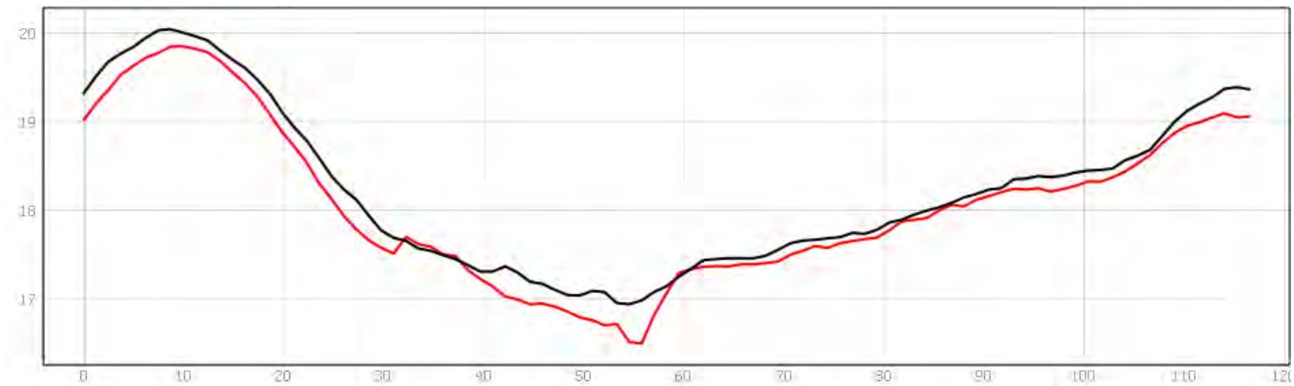


Diagram 12 – Ground Surface Elevation at Cross Section 4 (Black – 2013 LiDAR; Red – 2019 LiDAR)

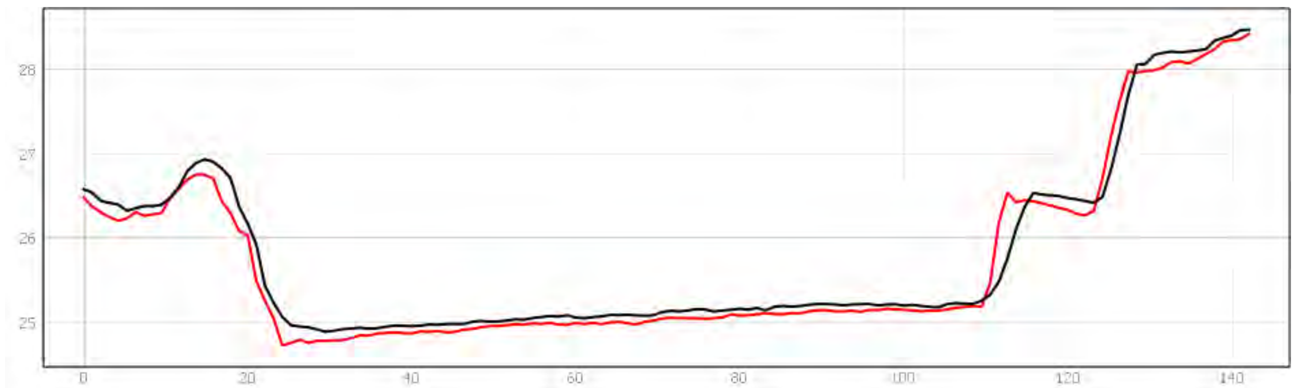


Diagram 13 – Ground Surface Elevation at Cross Section 5 (Black – 2013 LiDAR; Red – 2019 LiDAR)

Based on the cross-sections, there are no significant differences in levels between the 2013 and 2019 LiDAR within the predominant flow paths. In the absence of further information to verify the LiDAR levels (e.g., feature survey), the 2013 LiDAR was retained as it had better accuracy. To account for developments in the catchment, updated building polygons were used and checked against the latest aerial imagery.

It is worth noting that the 2013 LiDAR used by the 2017 Westmead Creek model does not match the 2013 LiDAR used by the 2017 Domain Creek model where both models overlap. While these differences are minor (+- 25 mm), these differences will contribute to small discrepancies if the models are merged or when the models are updated.

4.3.2 Building Footprints

The 2017 model accounted for building footprints by applying a high roughness value on these areas. This allowed water to flow across the footprints, thus assuming the buildings provided a level of flow conveyance and storage. Inundation extents were then trimmed from within the building footprints through post-processing for the adopted flood mapping outputs. The potential risk of this approach is that it could underestimate the flood distribution, affecting flood extents and levels. Therefore, two updates were performed with respect to building footprints which were:

- Digitising building footprints that have been newly built.
- Removing buildings footprints from code 2D Domain.

4.3.3 Existing Stormwater Pipes

Council has provided a GIS layer identifying existing stormwater pipes, including information on the alignment and size. This was cross checked against the stormwater pipe drainage network integrated in the 2017 model.

It was found that the stormwater pipes modelled in the 2017 model were generally consistent with the GIS layer provided by council. However, the 2017 model contained additional pipes that were not found in the GIS layer provided by council. This was primarily around the southern and northeast boundaries of the catchment, and likely due to incomplete data or different asset ownership.

The drainage network was updated according to GIS information from council as well as photos taken from a site visit. The changes included:

- Changing the size of the pipe upstream of Church Avenue from 2x900DIA to 1x1050DIA
- Increasing the inflow pipe for the Sydney Smith Park basin from 1x2400Wx700H to 2x2400Wx700H

4.3.4 Other Model Features and Parameters

The TUFLOW solver was upgraded to the latest version (at time of writing), from 2013-12-AC to 2023-03-AB. The Classic solver with double precision was used, which was deemed to be fit-for-purpose for this assessment after consultation with Council. The opportunity to upgrade to the Heavily Parallelised Compute (HPC) solver with Sub-Grid Sampling (SGS) enabled for future application, was presented to Council. Adoption of the HPC solver with SGS can provide a higher definition of the terrain, potentially high grid resolutions, and smaller timesteps. However, TUFOW Classic was deemed suitable. Grid size and timesteps were maintained from the previous model. These are shown in Table 13.

Table 13 - Model grid size and timesteps

Parameter	Domain Creek Model	Westmead Creek Model
2D grid size (m)	2	2
2D timestep (seconds)	1	0.5
1D timestep (seconds)	1	0.5

Arcadis considers the grid size and timestep selected were a reasonable balance between model accuracy and simulation times. However, the hydrologic and hydraulic model updates caused instabilities in 5 of the 6 Domain Creek PMF runs. Interrogation the model could identify no clear source of the instability, therefore, no other changes to the model were made. The 2D timestep for the Domain Creek model was reduced from 1 to 0.5 seconds for the PMF runs. This appeared to resolve the instability issues.

4.4 Model Validation

The 2017 model compared its peak flows with a MIKE 11 model by the Upper Parramatta River Catchment Trust (UPRCT). It was identified that the 2017 Westmead Creek model peak flows closely matched the UPRCT model peak flows. However, the 2017 Domain Creek model peak flows were significantly different from the UPRCT model peak flows. The reason for this is explained in Section 6.2.1 of the Holroyd City LGA Overland Flood Study report.

4.4.1 Comparison between Updated and Original Models

The net effect of all the changes to the hydrology and hydraulics is shown in Diagram 14.

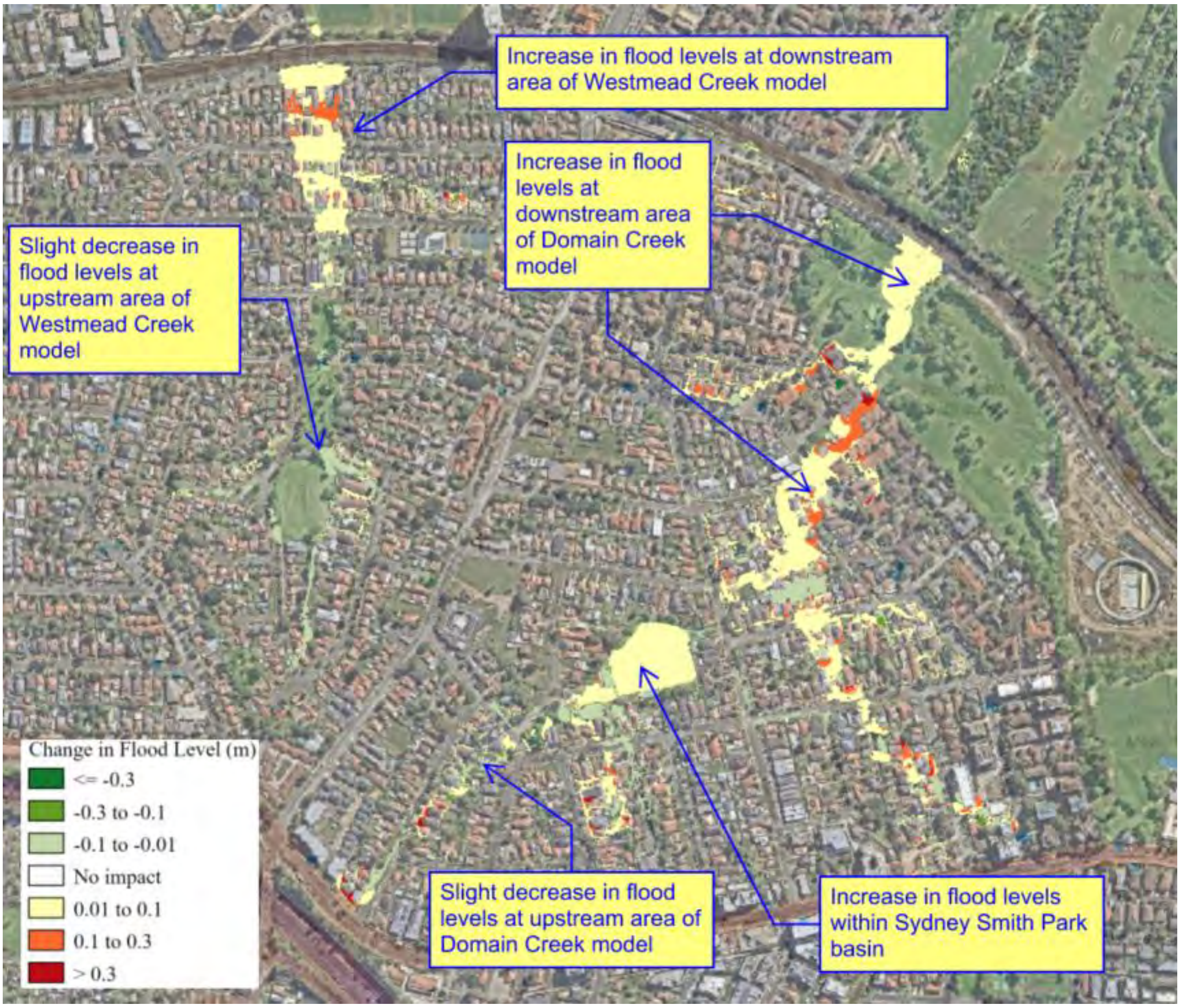


Diagram 14 – Change in 1% AEP flood level (2023 model minus 2017 model)

The increase in flood levels towards the downstream areas of the Domain Creek and Westmead Creek models is due to the reduction in flow area and storage caused by the “blocking out” of buildings from the model. This was not included in the previous model which assumed flow could be conveyed through and stored in buildings. Refer to Section 4.3.2

The increase in flood levels within the Sydney Smith Park basin is due to the increase in inlet pipe size, thus allowing more flow to enter the basin than previously modelled. Refer to Section 4.3.3.

The slight decrease in flood levels at the upstream areas of the Domain Creek and Westmead Creek models is due to the changes made to the hydrology. As discussed in Section 4.2.8, there is a general increase in runoff volume but a reduction in peak flows. A flood map identifying the change in flood level is included in Appendix C.

4.5 Existing Conditions Modelling

Hydrographs for the 10-minute to 3-hour storms for the 5%, 1%, 1% with Climate Change, 0.5% and the 0.2% AEP events were generated in the hydrological model and applied in the hydraulic model. Each storm duration had 10 temporal patterns. In addition, the PMF event was also modelled, consisting of 6 storm durations with 1 temporal pattern each. This totalled 506 storms modelled.

4.5.1 Flood Mapping

Flood envelopes to select the peak values of flood depth, flood level, velocity, flood hazard, and flood function were generated. The process of selecting peak values is discussed in Section 4.2.5. Diagram 16 shows the 1% AEP with Climate Change flood depths. Detailed flood maps are included in Appendix B. The flood depth is not shown where depth < 50mm. Runoff depths < 50 mm is classified as shallow sheet flow.

4.5.1.1 Flood Hazard

The Australian Disaster Resilience Handbook Collection deals with floods in Handbook 7 (Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia). The supporting guideline 7-3 contains information relating to the categorisation of flood hazard. A summary of this categorisation is provided in Diagram 15.

This classification provides a more detailed distinction and practical application of hazard categories, identifying the following 6 classes of hazard:

- H1 – No constraints, generally safe for vehicles, people and buildings;
- H2 – Unsafe for small vehicles;
- H3 – Unsafe for all vehicles, children and the elderly;
- H4 – Unsafe for all people and all vehicles;
- H5 – Unsafe for all people and all vehicles. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure. Buildings require special engineering design and construction; and
- H6 – Unsafe for all people and all vehicles. All building types considered vulnerable to failure.

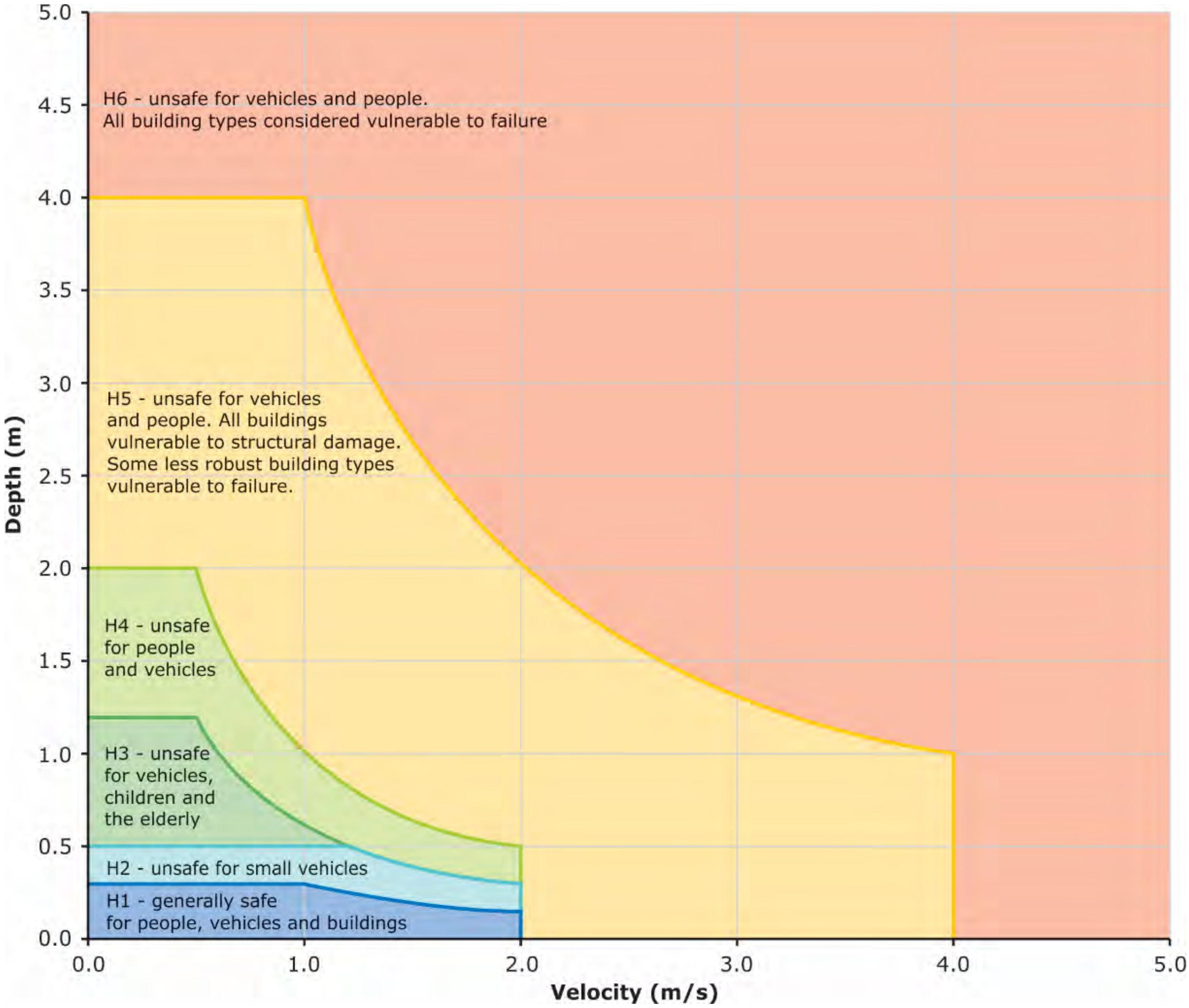


Diagram 15 – Flood Hazard Categorisation (ADR Handbook 7)

4.5.1.2 Flood Function

With regards to flood function, additional steps were taken to classify the flood extent into the following categories:

- Floodway
- Flood storage
- Flood fringe

There is no quantitative definition of these three categories or accepted approach to differentiate between the various classifications. The delineation of these areas is somewhat subjective based on knowledge of an area and flood behaviour, hydraulic modelling and previous experience in categorising flood function. A number of approaches are available, such as the method defined by Howells et al (2003).

For this study, hydraulic categories were defined by the following criteria, based on the method by Howells et al (2003). Different thresholds were tested to understand the sensitivity of the classification to those parameters and below adopted values are considered to be a reasonable representation of the flood function of this catchment.

- Floodway is defined as areas where **either** of the conditions are met:
  - Peak value of Z0 (velocity x depth) > 0.25m^2/s **AND** peak velocity > 0.25m/s
  - Peak velocity > 1.0m/s **AND** peak depth > 0.1m

The remainder of the flood extent is either flood storage or flood fringe:

- Flood storage comprises of areas outside the floodway where peak depth > 0.2m
- Flood fringe comprises of areas outside the floodway where peak depth ≤ 0.2m

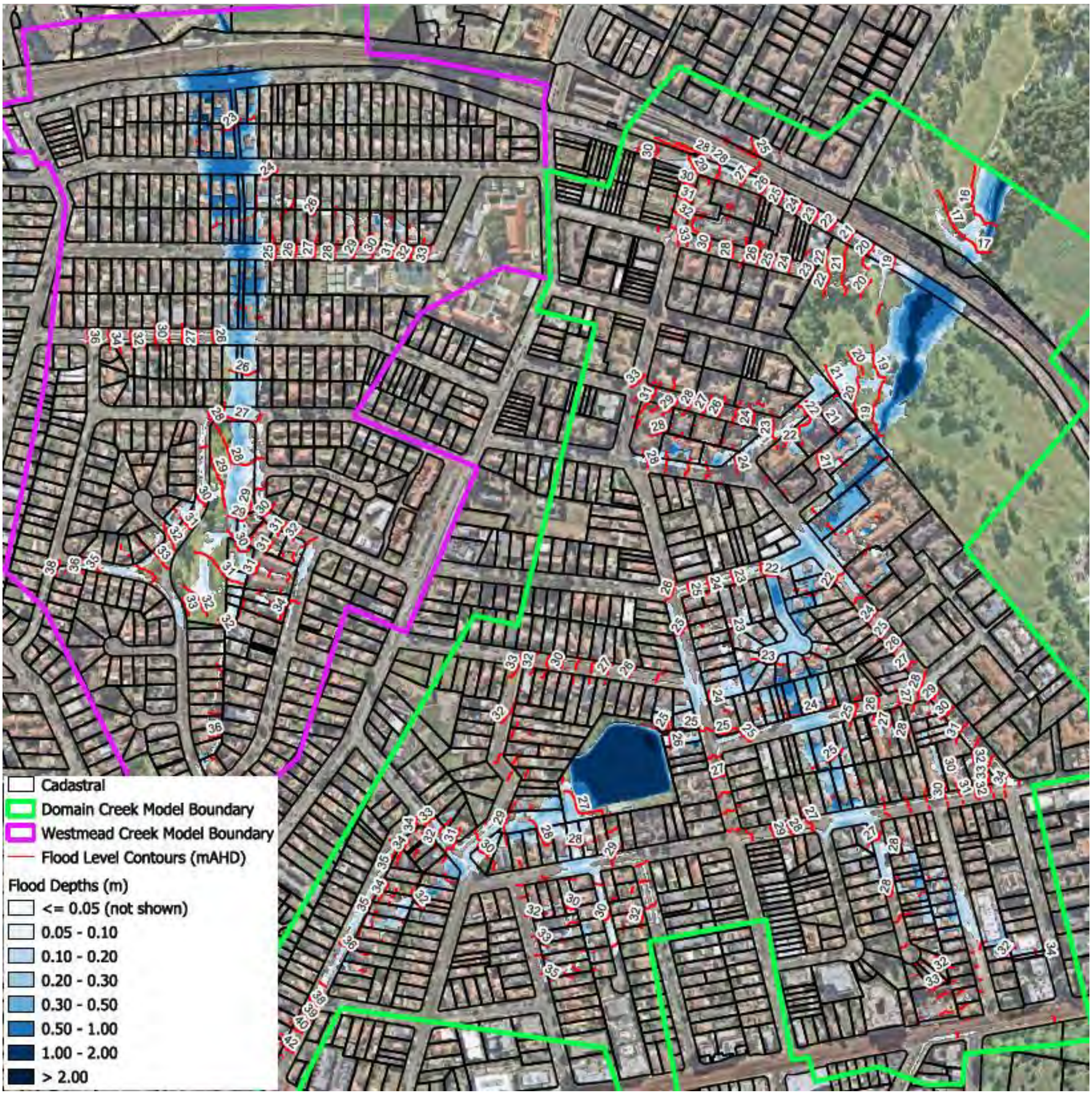


Diagram 16 - 1% AEP with Climate Change Flood Depths – Existing Conditions

4.5.2 Flood Risk Assessment

The proposed buildings were overlayed on the 1% AEP with climate change flood depths to assess flood risk. These are shown from Diagram 17 to Diagram 21. The flood risk assessment is undertaken with reference to the existing conditions flood depth mapping and the proposed buildings shown are for reference only. The inclusion of these buildings in the flood model, i.e., the proposed conditions modelling, will result in impacts on flood extents and levels, which is discussed in Section 4.6.

The flood depths and levels shown in the callouts (1% AEP and 1% AEP with Climate Change) are intended as a preliminary estimate of the required finished floor levels for the proposed buildings as well as an approximate guide of areas prone to flooding.

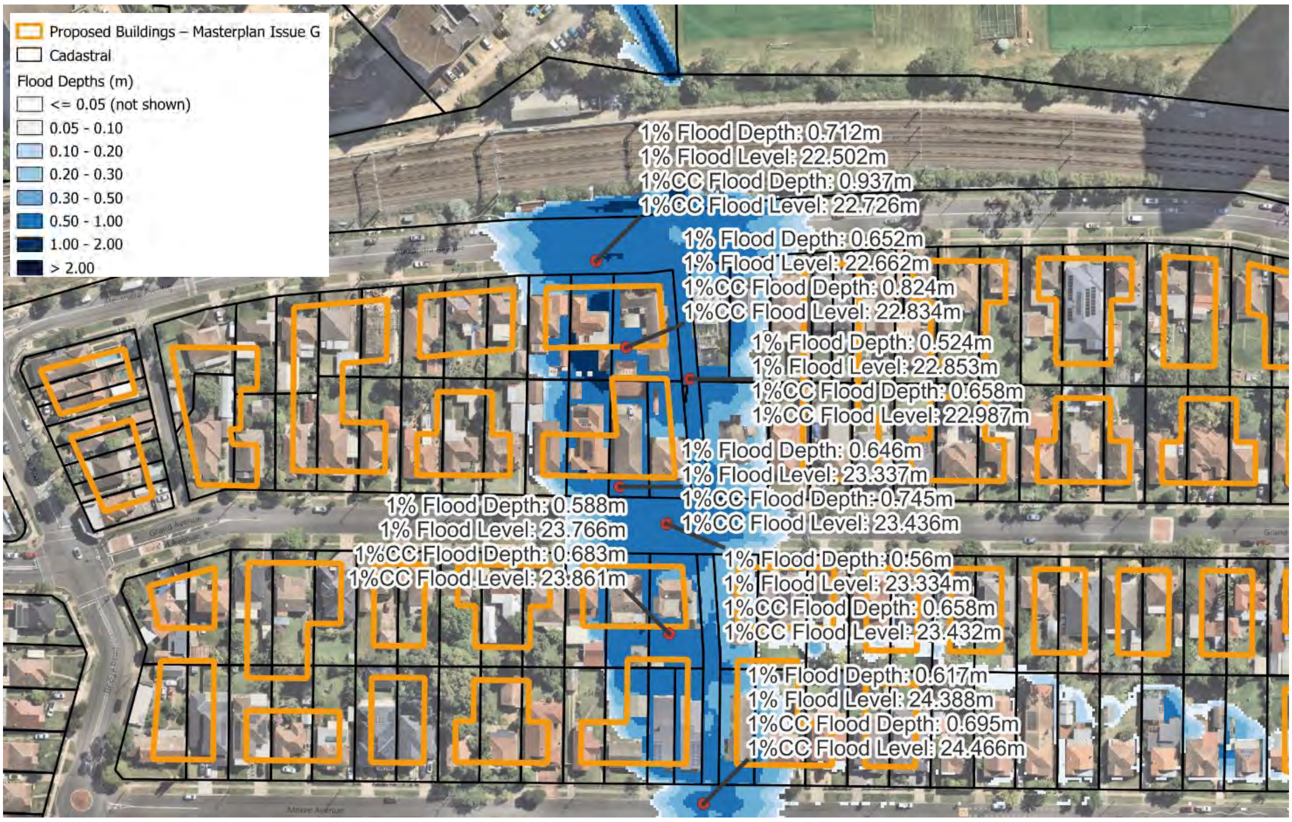


Diagram 17 – Existing 1% AEP with Climate Change Flood Depths with Scenario 2 Buildings (Orange) Overlayed at Grand Avenue, Westmead Creek

Diagram 18 – Existing 1% AEP with Climate Change Flood Depths with Scenario 2 Buildings (Orange) Overlayed at Austral Avenue, Westmead Creek

According to the requirements from the Flood Risk Management Manual 2023, Council's DCP 2021, as well as the recommendation by Council's flooding and stormwater team, the finished floor levels of those residential buildings are recommended to be set above the 1% AEP flood level with 0.5 m freeboard where flood depth is higher than 0.1 m. Due to the topography, the proposed buildings are unlikely to change the general flood behaviour but will cause localised changes to flood levels.

The connection from Austral Avenue through to Alexandra Avenue is frequently inundated even in the 20% AEP event. Therefore, measures such as signage and warning systems must be included along the connection to ensure pedestrians and vehicles are safe and are well informed to take action during storm events.

The connection is also an ideal location for centralised WSUD assets because the catchment drains towards this area. However, further consideration in the placement and design of WSUD assets in this area is required to avoid damage of WSUD assets due to high flows. Inundation of WSUD assets is likely to scour the delicate plants and/or displace filter material or captured pollutants.

Diagram 19 shows the flood depths within Parramatta Park. The development is not likely to change the flood behaviour within Parramatta Park but will result in minor changes in flood levels.

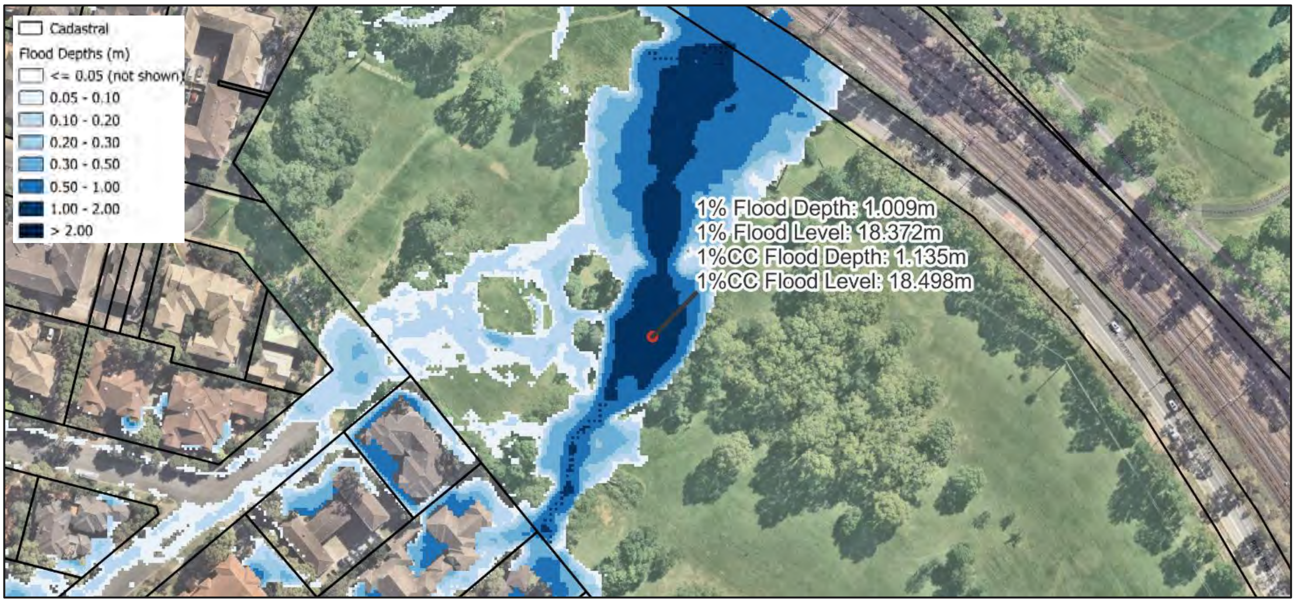


Diagram 19 – Existing 1% AEP with Climate Change Flood Depths at Parramatta Park, Domain Creek

As mentioned above, the finished floor levels of the residential buildings indicated in Diagram 20 are to be set 0.5 m (freeboard) above the 1% AEP flood level. The flow behaviour in this area is generally more complex than other areas of the catchment. This is because the flow paths do not have an easement and pass directly through properties.

The changes due to the proposed buildings will likely result in significant change in the flow paths as the flow paths under existing conditions are not clearly defined or concentrated at any low point. This area will have a greater level of uncertainty with regards to the preliminary estimate of finished floor levels.

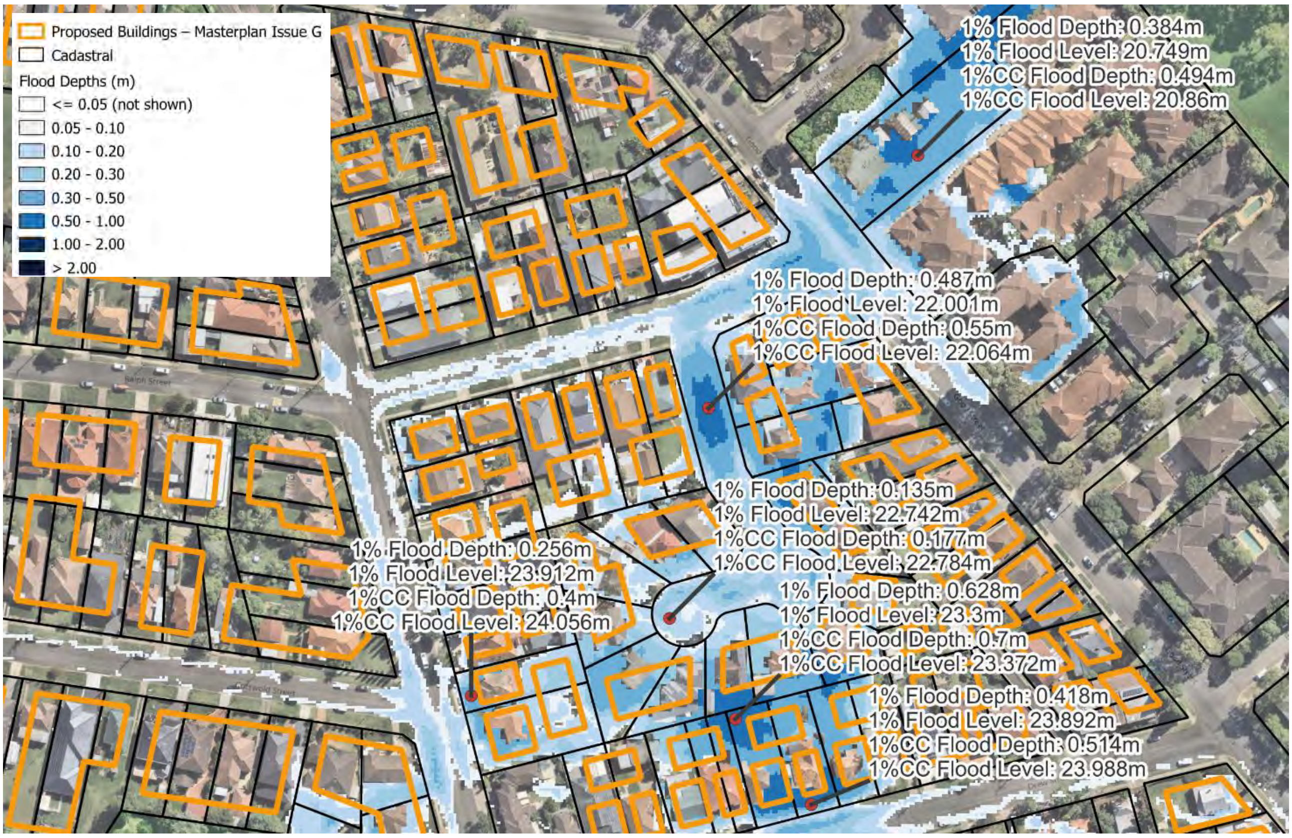


Diagram 20 – Existing 1% AEP with Climate Change Flood Depths with Scenario 2 Buildings (Orange) Overlayed at Thomas Clarke Street, Domain Creek

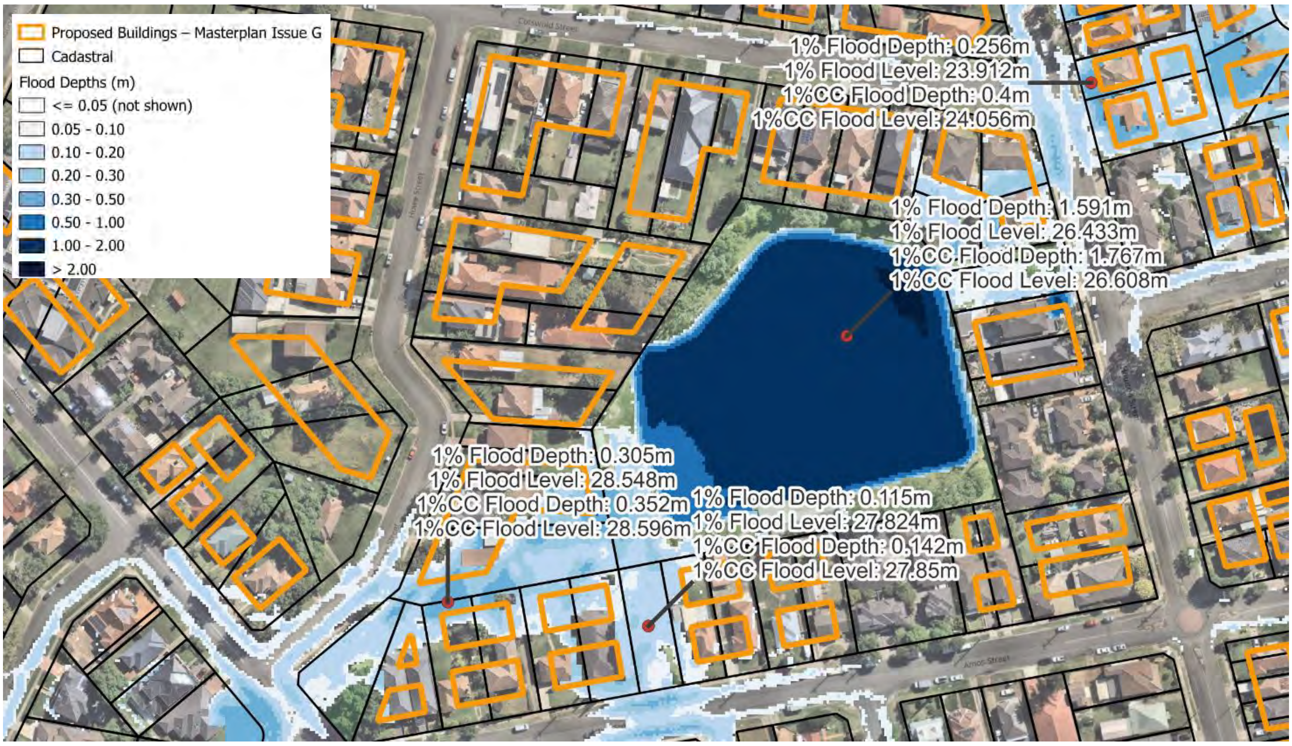


Diagram 21 – Existing 1% AEP with Climate Change Flood Depths with Scenario 2 Buildings (Orange) Overlayed at Sydney Smith Park, Domain Creek

Diagram 21 identifies the flood depths around Sydney Smith Park in the 1% AEP with climate change event. While flood depths are in excess of 1.5 m within the park, this is an existing basin and therefore, is not an introduced flood risk. However, the basin was designed to contain the 1% AEP flows. Any changes to the flood behaviour that causes the basin to overflow in a more frequent event will constitute an increase in flood risk on the downstream (northeast) areas.

Similar to Diagram 20, the flow path from the southwest is not concentrated at any low point and flows through properties. Therefore, any changes due to the proposed building is likely to result in significant change to the flow paths and the preliminary estimate of finished floor levels has a greater level of uncertainty.

4.6 Proposed Conditions Modelling

The existing hydrologic and hydraulic models were updated to reflect the proposed development as per the masterplan (publicly exhibited version). The updates include two aspects:

- The impervious fractions were updated in the hydrologic model (DRAINS) to reflect the proposed zones.
- The proposed building layout, including new buildings and retained existing buildings, was incorporated into the hydraulic model (TUFLOW).

The impervious fractions calculated for each sub-catchment under proposed conditions are listed in Appendix A.

4.6.1 Flood Mapping

Flood depth, flood level, velocity, flood hazard, and flood function maps were generated for the proposed conditions for the same AEPs as per the existing conditions mapping. The change of flood level maps (proposed vs existing) were also produced to facilitate the flood impact assessment. Diagram 22 shows the 1% AEP with Climate Change flood depths for the proposed conditions. Detailed flood maps are included in Appendix B. The flood depth is not shown where depth < 50mm.

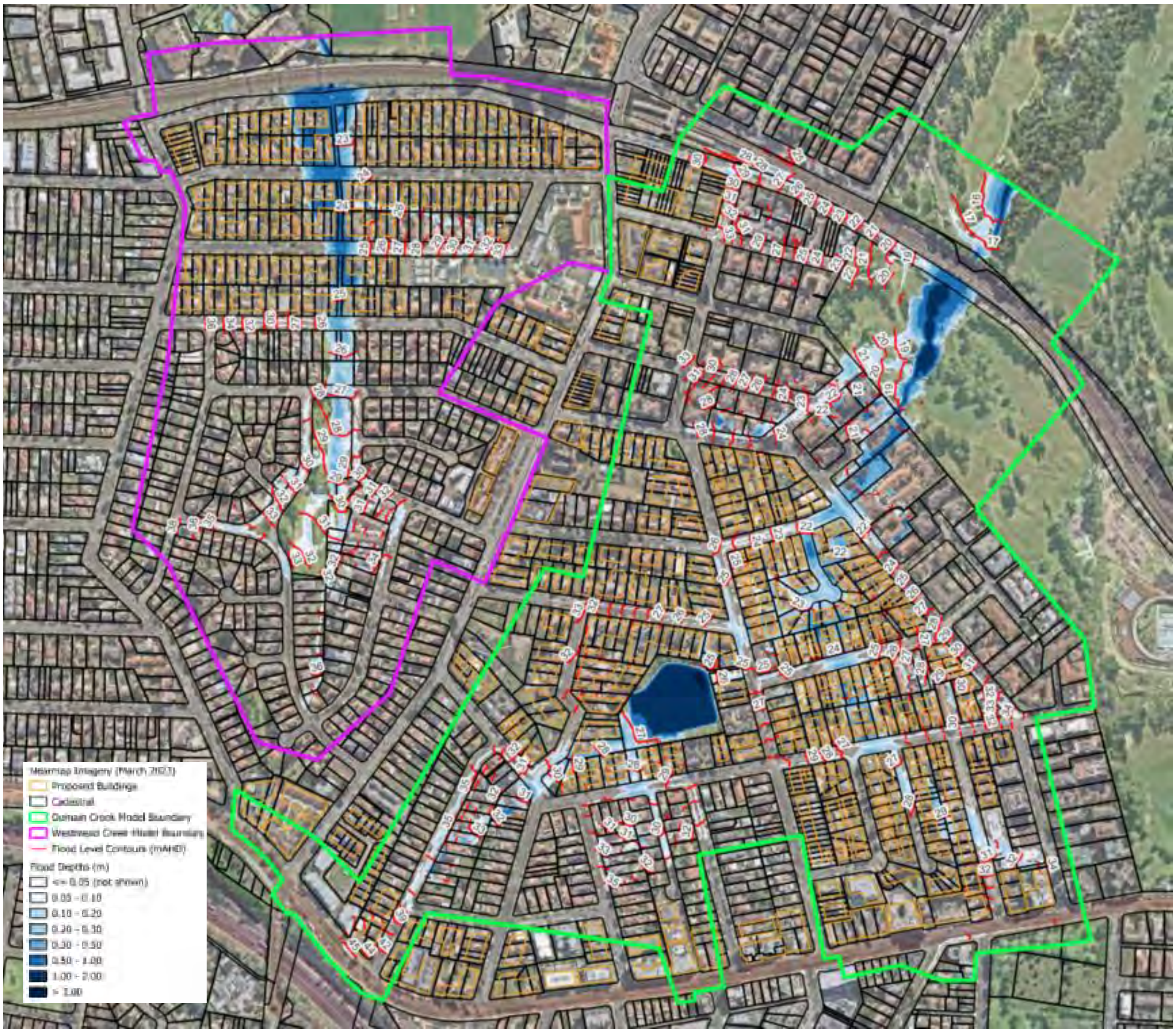


Diagram 22 - 1% AEP with Climate Change Flood Depths – Proposed Conditions

4.6.2 Flood Impact Assessment

The change in flood level map for the 1% AEP with Climate Change event is shown in Diagram 23. A full set of change in flood level maps for modelled AEPs are shown in Appendix B. Any change less than ±10 mm is not shown and is considered to not have any impact.

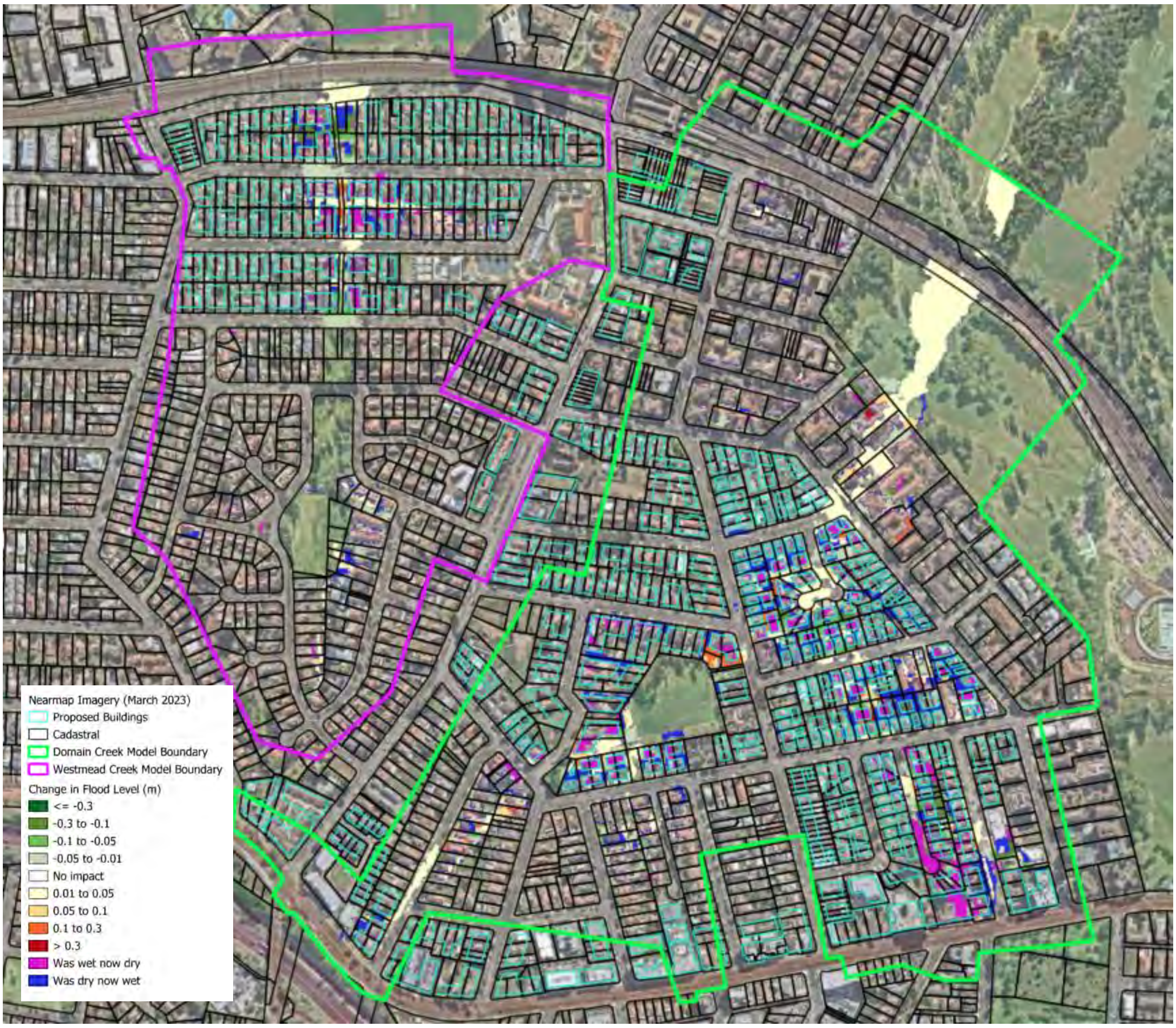


Diagram 23 - 1% AEP with Climate Change – Change in Flood Level

As shown in Diagram 23, in Westmead Creek catchment, the impact occurs mostly in the downstream area, which is mainly because that the majority of the upstream areas are retained as their existing conditions, e.g., Zones K and J (Diagram 3). The impact in the Domain Creek exhibits different patterns from upstream to downstream. The flood area upstream of Good Street is subject to change of flood extent (spatial distribution) with localised change of flood level. The flood area downstream of Good Street is subject to a general increase of flood level around 20 mm to 40 mm within the waterway.

There are two driven factors for the flood impact:

- Hydrologic impact (increase of runoff) due to the increase of impervious fractions
- Hydraulic impact (flood storage and conveyance) due to the change of building layout

4.6.2.1 Hydrologic Impact

The proposed development will in general result in an increase of residential density, e.g., change from detached houses (general residential) into multi-dwellings or middle to high rise departments, which however will not result in the same level of increase in the impervious fraction as the floor area increase goes vertically (i.e., multi-storey). Based on a high-level analysis of the masterplan, the impervious fractions were assumed for each planned zone type, as summarised in . At the precinct scale, the proposed development was estimated to cause approximately 7% of increase of the TIA.

To better understand the contribution by the impervious fraction to the flood impact, a sensitivity testing for the 1% AEP and 1% AEP with Climate Change events was carried out to represent the hydraulic change only scenario, i.e., using the proposed building layout (as per public exhibition Masterplan 31 Oct – 8 Dec) with existing conditions hydrology. The flood impact maps (sensitivity test vs existing conditions) are shown in Appendix B – Figure B55 to B56, which indicates that the increase of the impervious fraction is only responsible for a small portion of the flood impact. Specifically, the change of flood extent upstream of Good Street does not vary much when the exiting conditions hydrology is used. The flood level increase in Domain Creek downstream of Good Street only reduces from 40 mm to 30 mm when the existing conditions hydrology is used.

4.6.2.2 Hydraulic Impact

The change of the building layout can cause flood impact from two aspects:

- changing the flood storage; and
- altering the flow path, which results local impacts on flood extent.

In Domain Creek, the flood area upstream of Good Street is subject to change of flood extent (spatial distribution) with localised change of flood level. This is mainly because the proposed buildings in the area (i.e., Zones D, E, I) altered the flow path and caused local change of inundation areas.

In Domain Creek, the total building footprint under proposed conditions is 12.4% bigger than the footprint under existing conditions. As those buildings are impermissible and were blocked out from 2d Code, the increase of building footprint means less active flood storage along the flow path, which is partially responsible for the flood level increase in Domain Creek downstream of Good Street.

In Westmead Creek, the total building footprint area under proposed conditions is only 3.3% higher than the area under existing conditions, which is mainly in downstream area. A large portion of the catchment is retained as its existing conditions, e.g., Zones K and J (Diagram 3). Therefore, the impact of buildings is shown in the downstream area.

4.7 Flood Risk and Impact Management

It should be noted that the precinct development is still at master planning stage, which will be used to guide future development through amendments to the Cumberland LEP and the DCP. Therefore, the proposed building layout at this stage is preliminary and indicative, which should be further assessed and refined in the design stages of each individual development within the precinct.

This section summarises the recommendations on flood risk management based on the flood risk and impact assessment of the current masterplan, to ensure master planning proposal comply with the Ministerial Local Planning Directions on Flooding and the latest NSW Flood Risk Management Manual (2023).

The flood function mapping categories the flood prone area into the floodway, flood storage, and flood fringe extents, as detailed in Section 4.5.1.2. The existing conditions flood function map for 1% AEP with Climate Change is shown in Diagram 24, which is used as a reference to define the food risk management measures.

Floodway areas –

- In general, development should not be permitted in floodway areas.
- As shown in Diagram 24, the floodway within Westmead Creek catchment originates from the southern end of M J Bennett Reserve and is mainly along the open space from the Reserve to the railway line north of Alexandra Avenue. The proposed green link in the masterplan retains the reserve for the floodway. The section of the green link between Austral Avenue and Alexandra Avenue is proposed to be widened in the masterplan. Therefore, the proposed developments (buildings) are generally outside the existing floodway in Westmead Creek catchment.
- Domain Creek catchment is more complicated. There is no obvious defined drainage easement upstream of Thomas Clarke Street. There are isolated paddles upstream of Thomas Clarke Street classified as floodway, which are mostly flood water passing directly through existing properties. Arcadis believe developments within those areas should be managed through flood impact and floor level controls, as detailed below. There is a more defined floodway from Thomas Clarke Street

towards the railway line downstream of Park Parade, which does not interact with the developments proposed in the masterplan.

Development in flood prone area –

- Floor level – The finished floor level of proposed buildings should be designed to above the 1% AEP flood level with appropriate freeboard, e.g., 0.5 m. Freeboard is used to account for various uncertainties in flood modelling (e.g., input data, model inaccuracy, and climate change) and safety considerations.
- Flood impact – There are a number of proposed developments within or interacting with the flood prone area (based on flood extent for 1% AEP with Climate Change). The proposed buildings are shown to cause different levels of impacts. It should be noted that no detailed topographic design has been undertaken during this master planning stage, which should be considered during design stages of individual developments within the precinct. It is recommended that the site-based flood assessment to be undertaken for each development application if the site is within the flood-prone area to ensure the design provides sufficient flood storage and conveyance so that it does not increase the flood risk to surrounding properties and structures.
- Site-specific flood studies shall comply with Council's standard requirements and the most up-to-date best practice guidelines, including Australia Rainfall Runoff 2019 and NSW Flood Risk Management Manual 2023.
- Post-development site discharge should comply with the site stormwater management requirements, which are discussed in Section 5.

Development outside flood prone area –

- Development outside the flood prone area should comply with the site stormwater management requirements, which are discussed in Section 5.

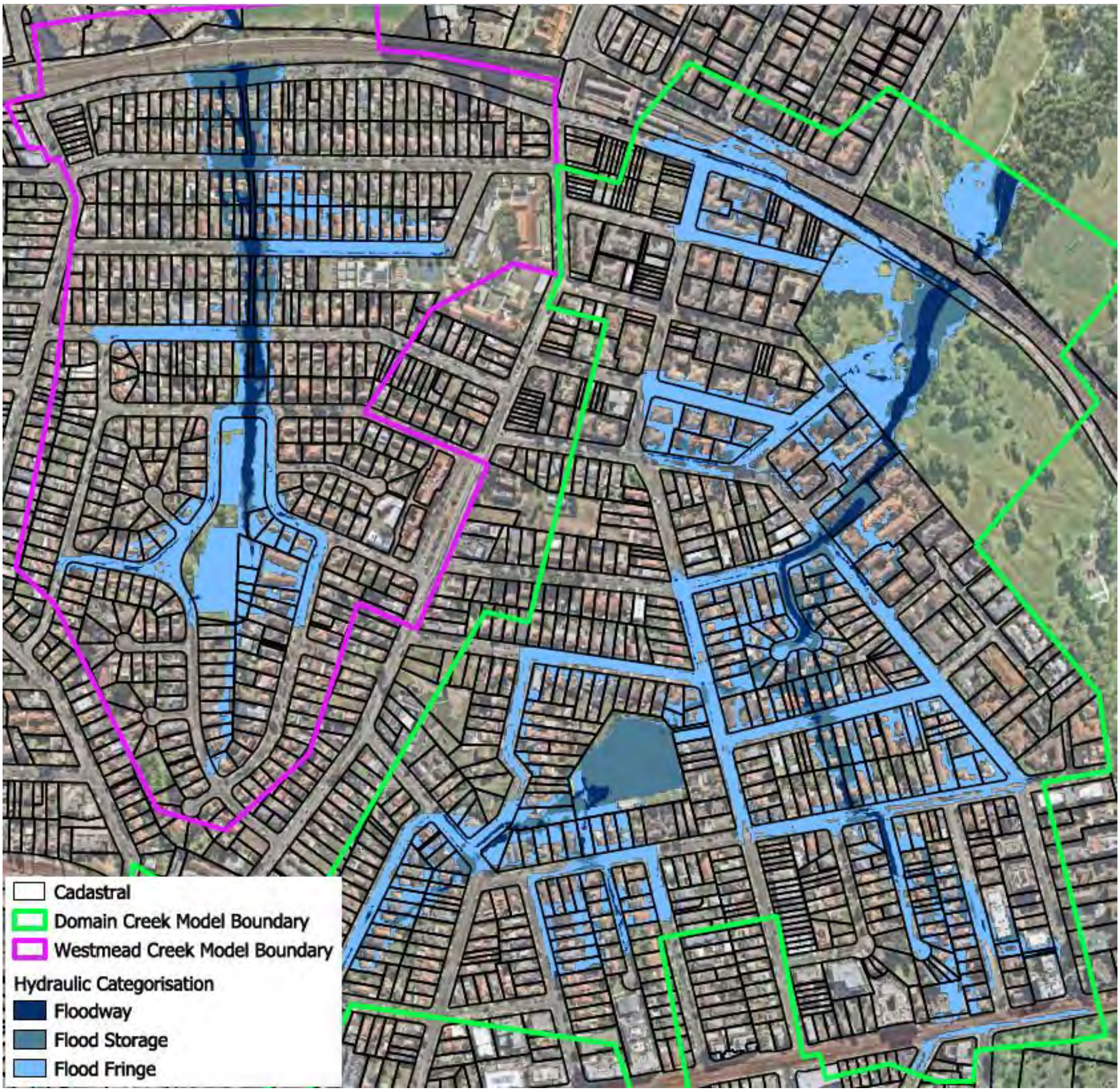


Diagram 24 - 1% AEP with Climate Change – Flood Function under Existing Conditions

5 STORMWATER ASSESSMENT AND PLAN

5.1.1 Underground Network

An assessment of the underground network indicates that most of them are full in the 20% AEP event as shown in Diagram 25. This means that the network is already at capacity and is unable to receive additional flows due to new impervious areas. Therefore, new developments need to maintain the existing impervious fraction or maintain the site discharge at existing flow rates.

Diagram 25 – Percentage full of existing stormwater pipes in the 20% AEP event

As expected, the pipes are also mostly full in the 1% AEP event Diagram 26. It should be noted that the presence of pipes that are 0 to 20% full in both the 20% AEP and 1% AEP events is due to the modelling methodology, which "injects" flow directly into some pipes.

This is a reasonable approach which assumes the capacity of the network is limited by the pipes rather than the pits. This approach also concentrates the flow path along the drainage network which is more realistic. However, the result is that some modelled pipes will not receive any flows and will seem as though additional capacity is available. It must be noted that these pipes are also likely to be at capacity and do not indicate that additional flow can be received by the network.

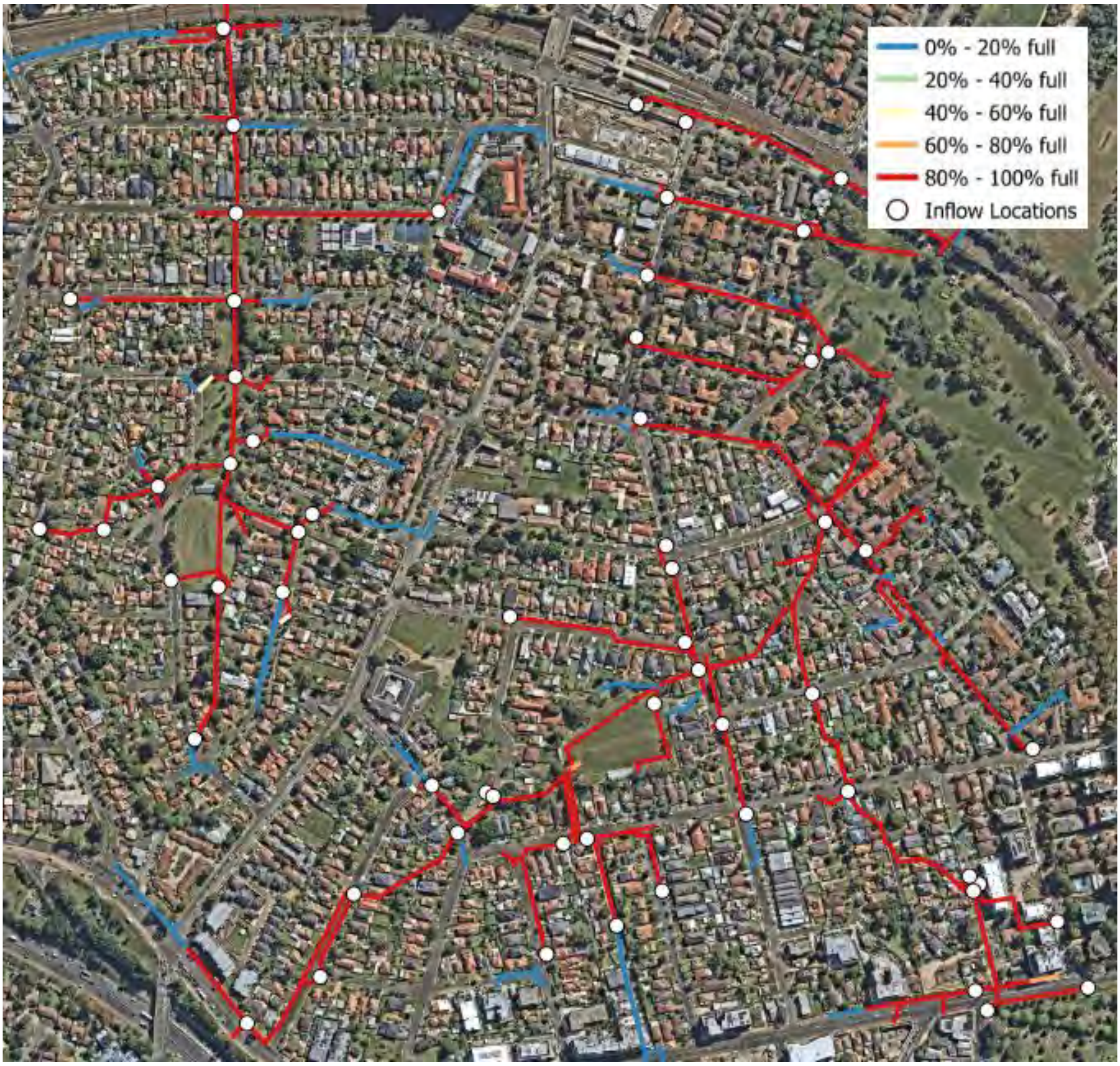


Diagram 26 - Percentage full of existing stormwater pipes in the 1% AEP event

5.1.2 Sydney Smith Park Basin

There is an existing basin within the Domain Creek catchment. The layout is shown in Diagram 27. It was designed to contain 1% AEP flows as well as capture flows during smaller events in an underground tank for irrigation purposes. For the purpose of flood assessments, the underground tank has been excluded and assumed to be full.

Diagram 27 - Layout of Sydney Smith Park Basin

Diagram 28 shows that most of the pipes are full in the 1% AEP event. The inlet pipe is activated when the downstream network is full. While the inlet pipe is not full and still has additional capacity to discharge flows into the basin, any additional flows discharged into the basin would cause higher flood levels and may engage the spillway in an event more frequent than 1% AEP.

Diagram 28 - Percentage full of existing stormwater pipes in the 1% AEP event

5.1.3 Stormwater Management

Although the underground stormwater drainage network appears to be at capacity during 20% AEP events, it is not recommended to upsize the drainage system in this precinct for the following reasons:

- The proposed masterplan is built upon a fully urbanised existing precinct and there is no space reserved in the masterplan to fit end-of-line detention basins. Without detention, the upsizing of existing drainage network will convey flood water more efficiently and can cause impact to the downstream properties, structure, and environment.
- The overall vision for future Westmead, 'District in Nature', promotes WSUD principles within the precinct, which are more decentralised and source controls.

As mentioned in Section 4.6.2, the overall estimated increase of the impervious fraction is relatively small, i.e., approximately 7% catchment-wide, which is due to the existing catchment being generally impervious. The small potential increase can potentially be avoided through incorporating more pervious area within each development, e.g., increase grassland percentage and/or incorporating permeable surfaces (carparks, driveways), which is more in line with the vision for future Westmead. Therefore, the following management measures are recommended for stormwater management:

- For future developments, the post-development site permeability should be maintained where possible to the pre-development (existing) level, i.e., the fractions of the effective and total impervious areas are no more than those under the pre-development conditions.

- Where there is an increase of impervious surfaces under the developed conditions, on-site detention (OSD) shall be required to ensure the site peak discharge is maintained to the permissible site discharge (PSD), except the scenarios excluded in Part G4 Section 2.4 of Cumberland DCP 2021. The PSD should be calculated based on existing condition discharge rates using appropriate computer modelling, or comply with the Upper Parramatta River Catchment Trust requirements, as per DCP 2021.

The existing conditions peak discharge for each sub-catchment within the precinct was determined through DRAINS modelling for modelled AEPs. The 20% and 1% AEP discharge rates are shown in Table 14. It should be noted that the modelled discharge for each sub-catchment can be treated as PSD for that sub-catchment, which can be different from the developable site coverage under future development applications. Therefore, the discharges here are for reference only, and the PSD for future development should be determined for the actual site coverage.

Table 14 – Permissible Site Discharge (PSD) based on existing conditions peak discharge

Sub-catchment	20% AEP Peak Discharge (m^3/s)	20% AEP Critical Storm	1% AEP Peak Discharge (m^3/s)	1% AEP Critical Storm
Dom_01	0.608	10 min, Storm 8	1.151	10 min, Storm 7
Dom_02	0.568	20 min, Storm 10	1.073	15 min, Storm 8
Dom_03	0.297	15 min, Storm 4	0.564	15 min, Storm 8
Dom_04	1.182	20 min, Storm 6	2.283	15 min, Storm 8
Dom_05	0.764	20 min, Storm 10	1.463	15 min, Storm 8
Dom_06	0.305	15 min, Storm 4	0.57	15 min, Storm 8
Dom_07	0.557	10 min, Storm 8	1.006	10 min, Storm 7
Dom_08	0.411	10 min, Storm 8	0.775	10 min, Storm 7
Dom_09	0.341	10 min, Storm 8	0.623	10 min, Storm 7
Dom_10	0.256	10 min, Storm 8	0.473	10 min, Storm 7
Dom_11	0.073	10 min, Storm 8	0.134	10 min, Storm 7
Dom_12	1.018	20 min, Storm 6	1.917	15 min, Storm 8
Dom_13	0.318	10 min, Storm 8	0.582	10 min, Storm 7
Dom_14	0.506	15 min, Storm 4	0.935	10 min, Storm 7
Dom_15	0.334	15 min, Storm 4	0.631	15 min, Storm 8
Dom_16	0.603	15 min, Storm 4	1.138	15 min, Storm 8
Dom_17	0.203	10 min, Storm 8	0.392	10 min, Storm 7

Sub-catchment	20% AEP Peak Discharge (m^3/s)	20% AEP Critical Storm	1% AEP Peak Discharge (m^3/s)	1% AEP Critical Storm
Dom_18	0.27	15 min, Storm 4	0.493	10 min, Storm 7
Dom_19	0.695	15 min, Storm 4	1.279	10 min, Storm 7
Dom_20	0.539	15 min, Storm 4	1.003	10 min, Storm 7
Dom_21	0.39	15 min, Storm 4	0.742	15 min, Storm 8
Dom_22	0.411	15 min, Storm 4	0.777	15 min, Storm 8
Dom_23	0.665	20 min, Storm 10	1.265	15 min, Storm 8
Dom_24	0.132	15 min, Storm 4	0.239	10 min, Storm 3
Dom_25	0.485	15 min, Storm 4	0.894	10 min, Storm 7
Dom_26	0.034	10 min, Storm 8	0.057	10 min, Storm 7
Dom_27	0.17	20 min, Storm 6	0.324	15 min, Storm 8
Dom_28	0.936	15 min, Storm 4	1.705	15 min, Storm 8
Dom_29	0.495	15 min, Storm 4	0.921	10 min, Storm 7
Dom_30	1.142	20 min, Storm 6	2.177	15 min, Storm 8
Dom_31	0.198	10 min, Storm 8	0.365	10 min, Storm 7
Dom_32	0.263	10 min, Storm 8	0.476	10 min, Storm 7
Dom_33	0.658	15 min, Storm 4	1.248	10 min, Storm 7
Dom_34	1.953	25 min, Storm 4	4.02	20 min, Storm 2
Dom_35	0.069	15 min, Storm 4	0.125	15 min, Storm 8
Dom_36	0.711	20 min, Storm 5	1.408	15 min, Storm 8
Dom_37	0.353	15 min, Storm 4	0.674	15 min, Storm 8
Dom_38	0.34	20 min, Storm 5	0.651	15 min, Storm 8
Dom_39	0.155	15 min, Storm 4	0.292	10 min, Storm 7
Dom_40	0.569	15 min, Storm 4	1.06	10 min, Storm 3

Sub-catchment	20% AEP Peak Discharge (m³/s)	20% AEP Critical Storm	1% AEP Peak Discharge (m³/s)	1% AEP Critical Storm
Dom_41	0.444	20 min, Storm 10	0.839	15 min, Storm 8
Dom_42	0.281	15 min, Storm 4	0.524	10 min, Storm 7
Wes_001	1.541	20 min, Storm 6	2.992	15 min, Storm 8
Wes_002	0.976	20 min, Storm 6	1.897	15 min, Storm 8
Wes_003	0.53	20 min, Storm 6	1.035	15 min, Storm 8
Wes_004	0.454	15 min, Storm 4	0.861	15 min, Storm 8
Wes_005	0.28	15 min, Storm 4	0.516	10 min, Storm 7
Wes_006	0.695	20 min, Storm 4	1.295	15 min, Storm 8
Wes_007	0.474	20 min, Storm 5	0.937	15 min, Storm 8
Wes_008	0.354	15 min, Storm 4	0.678	15 min, Storm 8
Wes_009	0.498	15 min, Storm 4	0.912	10 min, Storm 7
Wes_0010	0.978	20 min, Storm 6	1.897	15 min, Storm 8
Wes_011	0.417	15 min, Storm 4	0.762	10 min, Storm 7
Wes_012	0.962	20 min, Storm 6	1.877	15 min, Storm 8
Wes_013	0.606	15 min, Storm 4	1.13	10 min, Storm 7
Wes_014	0.424	15 min, Storm 4	0.775	10 min, Storm 7
Wes_015	0.266	15 min, Storm 4	0.495	15 min, Storm 8
Wes_016	0.364	15 min, Storm 4	0.679	15 min, Storm 8
Wes_017	0.545	20 min, Storm 10	1.03	15 min, Storm 8
Wes_018	0.246	15 min, Storm 4	0.452	15 min, Storm 8

6 INTEGRATED WATER CYCLE MANAGEMENT ASSESSMENT AND PLAN

Water is a key driver of economic and social development while it also has a basic function in maintaining the integrity of the natural environment. However, water is only one of a number of vital natural resources and it is imperative that water issues are not considered in isolation.

Managers have to make difficult decisions on water allocation. More and more they have to apportion diminishing supplies between ever-increasing demands. Drivers such as demographic and climatic changes further increase the stress on water resources. In addition, there is variability of supply through time as a result both of seasonal variation and inter-annual variation.

All too often the magnitude of variability and the timing and duration of periods of high and low supply are not predictable; this equates to unreliability of the resource which poses great challenges to water managers in particular and to societies as a whole. The natural variability can be overcome by supply-side infrastructure to assure reliable supply and reduce risks, albeit at high cost and often with negative impacts on the environment and sometimes on human health and livelihoods.

However, we are now finding that supply-side solutions alone are not adequate to address the ever-increasing demands from demographic, economic and climatic pressures. Waste-water treatment, water recycling and demand management measures are being introduced to counter the challenges of inadequate supply.

In addition to problems of water quantity there are also problems of water quality. Pollution of water sources is posing major problems for water users as well as for maintaining natural ecosystems.

In many regions the availability of water in both quantity and quality is being severely affected by climate variability and climate change, with more or less precipitation in different regions and more extreme weather events. In many regions, too, demand is increasing as a result of population growth and other demographic changes and agricultural and industrial expansion following changes in consumption and production patterns. As a result, some regions are now in a perpetual state of demand outstripping supply and in many more regions that is the case at critical times of the year or in years of low water availability.

The traditional fragmented approach is no longer viable and a more holistic approach to water management is essential. This is the rationale for the Integrated Water Cycle Management (IWCM) approach that has now been accepted internationally as the way forward for efficient, equitable and sustainable development and management of the world's limited water resources and for coping with conflicting demands.

Westmead South is geographically divided into two catchments, i.e., Westmead Creek and Domain Creek catchments. The two catchments and waterways contribute to Parramatta River, which is a significant waterway affecting the Greater Sydney area. An IWCM promoting water sensitive urban design (WSUD) principles will have a great significance on local water cycle health and beneficial impact on downstream built environment and natural ecosystems.

This Section summarises the IWCM and WSUD targets based on the understanding of the precinct vision and review of existing policies and guidelines and identify potential opportunities for integration into Westmead South master plan.

6.1 Urban Water Cycle

The water cycle system in a natural catchment typically involves below processes:

- Rainfall and canopy inception
- Infiltration, evapotranspiration, and runoff generation
- Flow concentration and channel routing
- Sub-surface flow and groundwater propagation

In an urbanised area, such as Westmead South, water use and wastewater generation are integrated as additional processes into the urban water cycle system. A conceptual comparison of natural and urban water cycle systems is shown in Diagram 29. Due to the increased impervious area and intensified human activities, the urbanisation alters the natural water cycle from different aspects, including:

- Reducing infiltration and evapotranspiration
- Increasing stormwater runoff volume
- Increasing peak flow and flood risks during storm events
- Deteriorating water quality

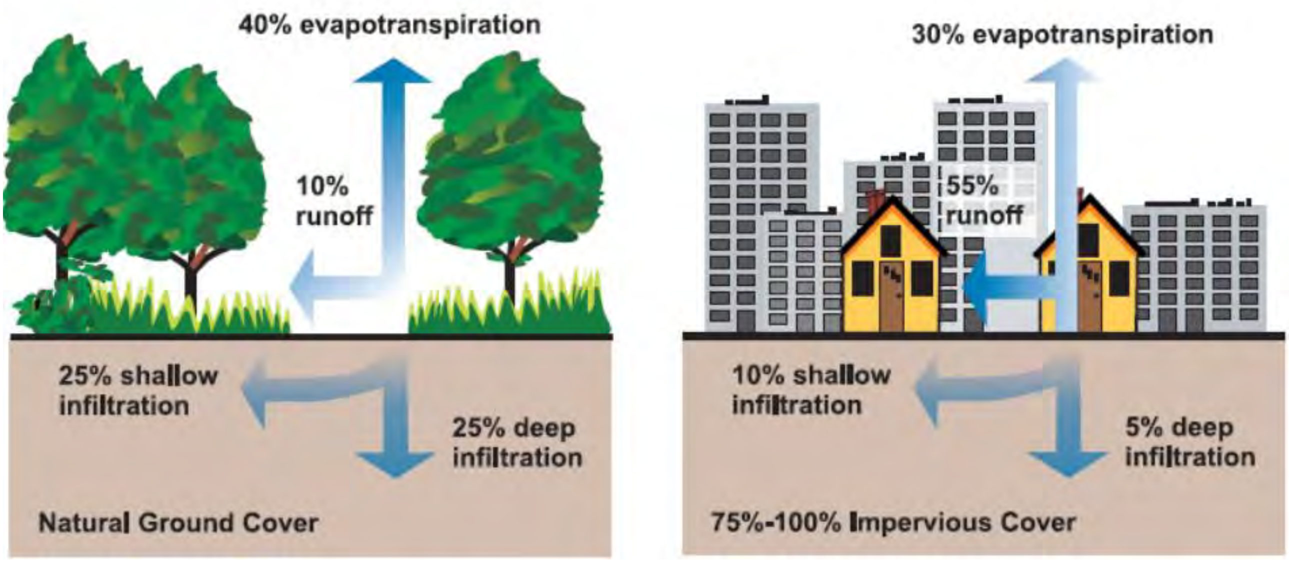


Diagram 29 - Natural and urban water cycle systems

To understand the water cycle and associated water quality and quantity budget of an urban environment, water balance analysis/modelling is typically required. A water balance analyses the input (source), output (demand) and storage changes of water within a designated system. A schematic of the type of data inputs for a water balance model is shown in Diagram 30.

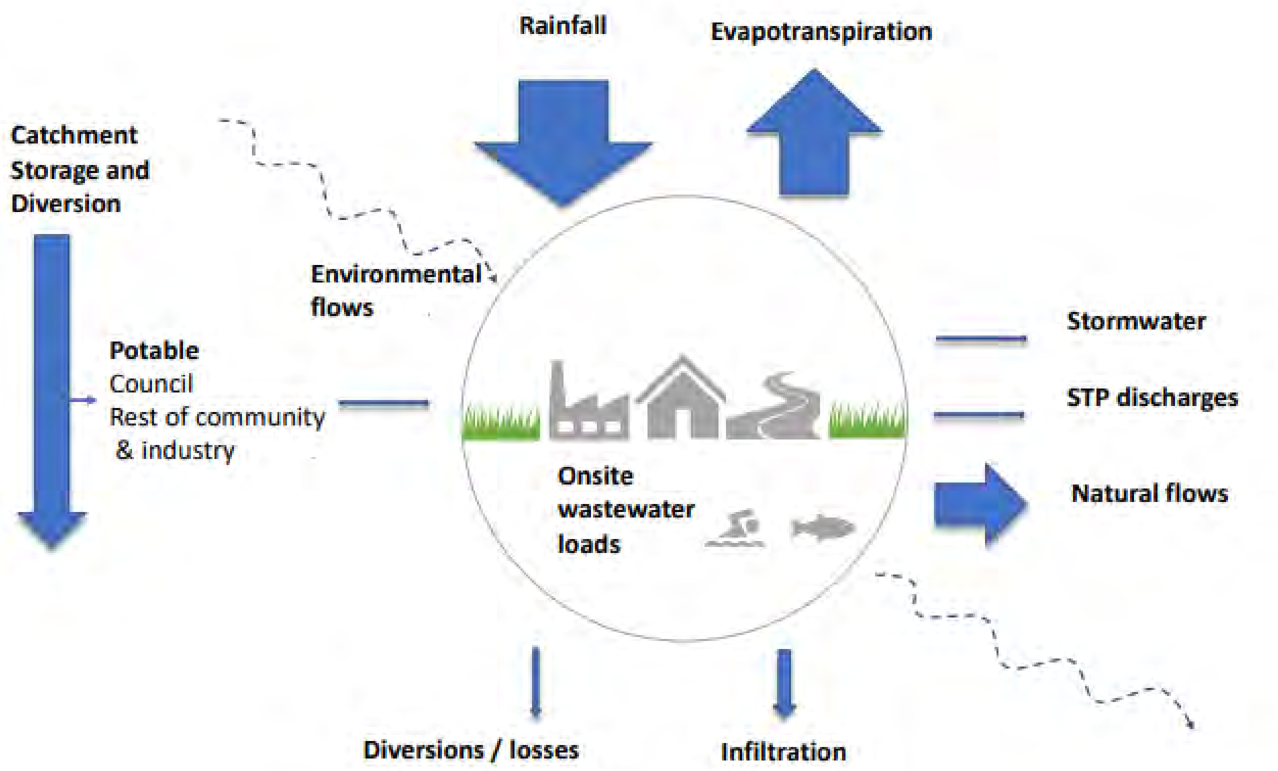


Diagram 30 – Schematics of a typical water balance analysis

6.2 Water Demand Analysis

This section summarises a potable water demand analysis and demand parameters and reduction target adopted for the IWCM assessment.

6.2.1 Regional Water Demand Background

The Westmead South Precinct is located within the Sydney Water Prospect Hill Water Supply Zone (Diagram 31), is part of the Prospect North Water Delivery Network. The Prospect North Water Delivery Network Capacity Report (Sydney Water, 2023) summarised the projected potable water demand for each zone, as shown in Table 15. However, no specific demand data for Westmead South has been provided.

An Existing Utilities Infrastructure Audit report (IDC, 2023) was prepared as part of the Westmead South Master Plan program. As noted in the report, a series of trunk mains extend from the closest reservoirs (Mt Dorothy Reservoir and Holroyd Reservoir) to the Precinct.

A series of smaller reticulation mains extend along existing roads within the precinct from the trunk mains in Bridge Road and the Great Western Highway to supply the development. The existing potable water infrastructure within the vicinity of the precinct is shown in Diagram 32.

Sydney Water's 2022 Growth Servicing Plan (GSP) has assessed the Greater Parramatta to Olympic Peninsula (GPOP) growth area, which includes the Precinct. For the Westmead South Precinct, Sydney Water anticipate that there is adequate existing trunk capacity in the potable water network to support the planned growth.

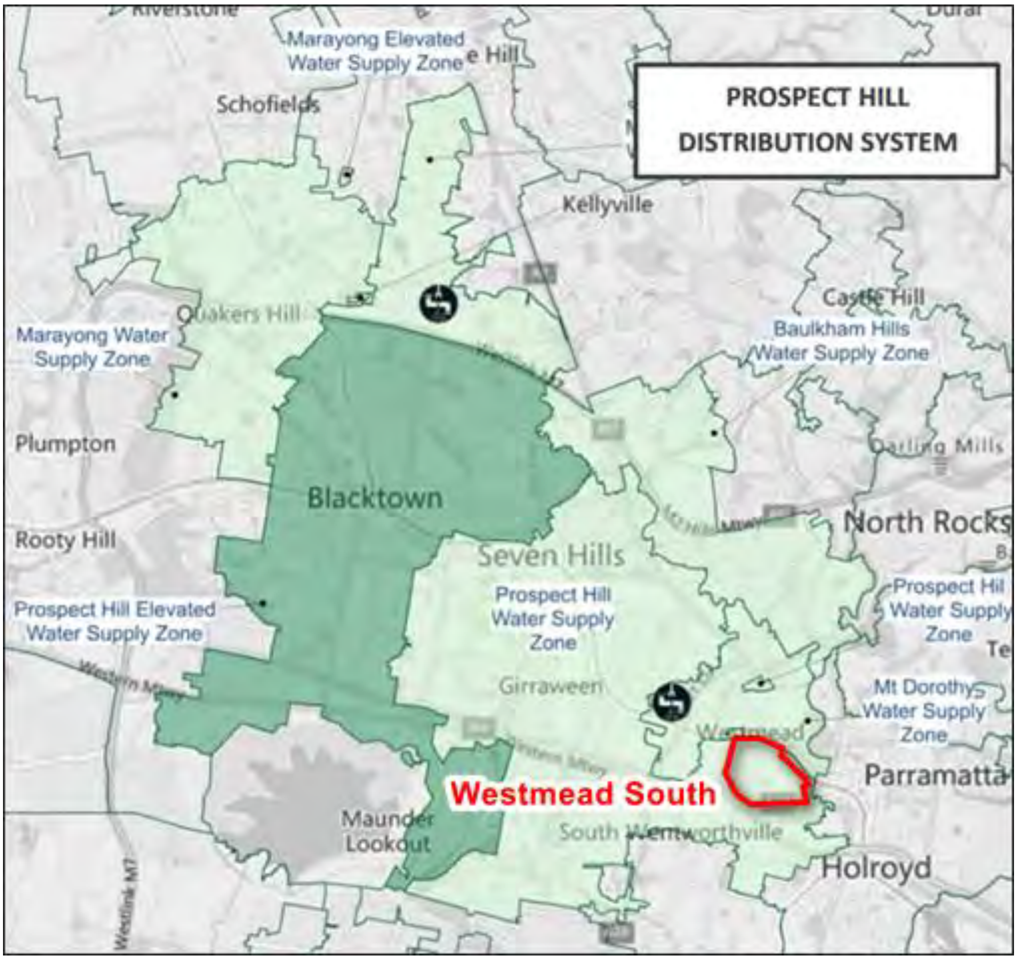


Diagram 31 – Sydney Water Prospect Hill Water Supply Zone

Table 15 - Projected Potable Water Demand within Prospect North Water Delivery Network

System Summary	Projected			
	2026	2031	2041	2051
Demand MDD (ML/d)				
Dural South and Dural Elevated	61.3	64.4	68.0	70.1
Kellyville Elevated	7.2	7.2	7.3	7.3
Rogans Hill, Parklea, Rouse Hill, Castle Hill and Oakville Elevated	122.6	140.1	156.2	163.5
West Pennant Hills	28.2	31.6	35.0	37.5
Beecroft	15.4	16.0	16.2	16.3
Berowra Elevated	10.4	10.8	11.4	12.0
Cowan North	1.7	1.8	2.0	2.1
Hornsby Heights	4.0	4.2	4.5	4.8
Wahroonga and Wahroonga Elevated	67.1	70.1	73.9	75.3
Baulkham Hills	14.5	14.8	15.3	15.8
Marayong, Marayong Elevated Water Network	45.8	52.9	59.3	62.1
Prospect Hill and Mt Dorothy Water Network	61.6	66.8	74.0	79.2
Prospect Hill Elevated Water Network	36.6	38.8	42.7	45.2

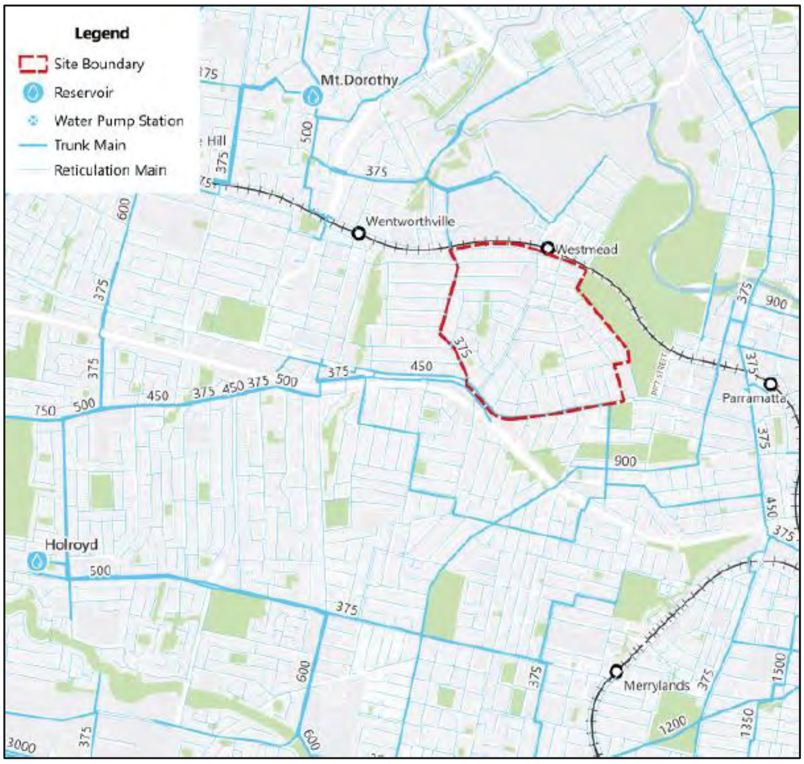


Diagram 32 – Existing Potable Water Infrastructure (IDC, 2023)

6.2.2 Water Demand and Reduction for Westmead South

6.2.2.1 Water demand reduction target

Minimising the demand for potable water supply is an important objective of a IWCM strategy. Different strategy may propose different targets for water demand reduction.

The current general requirement for water demand reduction of the new development in NSW is defined through Building Sustainability Index (BASIX), which is a part of NSW planning system.

The benchmark water demand is the average potable water consumption of a pre-BASIX home. This has been identified as 247 litres per person per day (90,340 litres per person per year). The BASIX water target requires up to a 40% reduction in mains-supplied potable water consumption, compared to the average 'pre-BASIX' home benchmark.

6.2.2.2 Water demand parameters for assessment

As noted above, the benchmark demand per person will be adopted as 247 L/day. The average population per dwelling for the master planning scenario (future) is assumed to be 2.59, which was adopted for the Urban Design Yield Assessment assuming the same as the existing population per dwelling. Therefore, the benchmark demand per dwelling will be 639 L/day, which is close to the 623 L/day as reported in Sydney Water Average Daily Water Use report.

The IWCM strategy will aim to reduce the residential potable water demand to 98.8 L/person/day (i.e., 40% reduction). The reduction will be achieved through:

- Water-efficient fixtures and habits – implementing Water Efficiency Labelling and Standards (WELS) for water fixtures and fittings and promoting water-efficient water use habit.
- Rainwater / stormwater harvesting and reuse.

Sydney Water has set up daily water use targets for water-efficient household based on a range of water appliance and water use requirements/recommendations, including toilet flushing, laundry, bathing and showering, water taps, dishwashing, gardening, car washing, pools, etc. With water-efficient household requirements, the water use targets are set for each quarter based on size and number of people of dwellings. The seasonal water use targets for small properties (< 500 m^2) are shown in Table 16, which will be most of the cases within the future Westmead South Precinct. For medium and large properties, refer to Sydney Water website[1].

There is a 5% to 10% seasonal variation of the water use targets due to the irrigation requirements, which is not proposed to be characterised in this study for the following reasons:

- A large portion of the Precinct is designed to be vertical apartment living, which will have shared open spaces utilised by a larger population compared to traditional homes, i.e., less irrigation required;
- Planting that has low water requirements will be promoted, as per Westmead South ESD Options Paper;
- Seasonal varying water use targets are not directly comparable with the pre-BASIX benchmark, i.e., no seasonal variation represented.

Table 16 - Sydney Water Daily Water Use Targets for Small Properties

People in the home	November–January	February–April	May–July	August–October
1 person	194 L/day	197 L/day	181 L/day	189 L/day
2 people	351 L/day	356 L/day	327 L/day	340 L/day
3 people	449 L/day	456 L/day	419 L/day	436 L/day
4 people	516 L/day	524 L/day	482 L/day	501 L/day
5 people	542 L/day	551 L/day	506 L/day	527 L/day

Without the consideration of the seasonal variation, it is likely that the water-efficient fixtures and water use habit will achieve 106 to 190 L/day/person, pending on the number of people per dwelling. Considering the likely property size and number of people in future Westmead South Precinct, it is assumed that with the

[1] https://www.sydneywater.com.au/your-home/saving-water-at-home/water-efficiency-targets.html

water-efficient fixtures and habits, demand can be reduced to 171 L/day, based on 2 people small properties of Table 16, i.e., a conservative assumption avoiding overestimation of reduction by water-efficient fixtures and habits.

Based on above assumptions, the potable water demand and reduction targets are set as per Table 17.

Table 17 - Potable water demand and reduction targets (per person per day) for Westmead South Master Plan

Benchmark	Water-efficient fixtures and habits		Rainwater/stormwater harvesting		Target
	Reduction	Post-reduction demand	Harvested water demand*	Demand Reduction required by harvesting	
247 L	76 L	171 L	137 L	22.8 L	98.8 L (40%)

* Water demand which can be met by harvested rainwater/stormwater, i.e., toilet flushing, laundry, hot water, outdoor use, assumed to be 80% of the total demand in a water-efficient house. The other 20% of total demand is assumed to be met by main-supplied potable water, i.e., drinking, cooking, dishwashing, etc.

The harvested water demand, i.e., 137 L/day/person, represents the maximum volume which can be potentially supplied by harvested rainwater/stormwater under an ideal scenario, i.e., always sufficient water in the harvesting system. The actual volume supplied by the harvesting system is restricted by multiple factors, e.g., the annual rainfall and temporal variation, the connected roof/surface area to harvest water, and the tank size. As long as the proposed rainwater/stormwater harvesting systems can supply 22.8 L/day/person on average, the 40% reduction to the benchmarking consumption will be achieved.

The 137 L/day/person will be adopted as the demand parameter for rainwater tanks in MUSIC modelling. The daily harvested water demand of each residential zone/block will be calculated based on the daily harvested water demand per person and the population forecast for each zone/block as per the Yield Scenario report.

6.3 WSUD Targets

Generally, WSUD aims create urban environments that allow the water cycle to function as it would naturally. As Westmead South is a fully urbanised area under existing conditions, the objective of the IWCM is defined to ensure the water cycle to perform similarly or better as it would be under pre-masterplan conditions.

Several quantitative targets need to be set up to enable that the main object is achieved. Traditionally, quantitative targets would be set for stormwater quality and stormwater peak discharge controls. With the advancement in IWCM and WSUD understanding and practices, the focus has been extended to include potable water usage/demand reduction and stormwater volume reduction.

As the findings of the IWCM strategy will be used to inform the preparation of a planning proposal to amend the Cumberland Local Environmental Plan (LEP) 2021 and the Cumberland Development Control Plan (DCP) 2021, it is critical to consider the stormwater and WSUD requirements in the current LEP and DCP. Based on the understanding of the precinct vision and review of existing policies and guidelines, including the current LEP and DCP, the WSUD targets are set out in Table 18 and Table 19.

Table 18 – WSUD Targets

	Traditional	WSUD (adopted for this Study)
Stormwater quality	% reduction	% reduction
Stormwater peak	No-worsening	No-worsening (discussed in Section 5.1.3)
Stormwater volume	-	Reduction (to existing conditions)
Potable water consumption	-	40% reduction (BASIX)

6.3.1 Stormwater Quality

The minimum targets for stormwater quality for Westmead South masterplan are defined in accordance with the requirements as in Cumberland DCP 2021, as summarised in Table 19.

Table 19 – Stormwater Quality Targets

Pollutant	Description	Reduction in Load
Litter e.g., cans, bottles, wrapping materials, food scraps	All anthropogenic materials with a minimum dimension >5 mm i.e. Gross Pollutants (GP)	90%
Coarse sediment	Coarse sand and soil particles (<0.5 mm diameter) i.e. Total Suspended Solids (TSS)	85%
Nutrients	Total phosphorous (TP) and total nitrogen (TP)	60%
Fine particles	Coarse sand and soil particles (<0.05 mm diameter)	85%
Cooking oil and grease	Free floating oils that do not emulsify aqueous solutions	90%
Hydrocarbons inc. motor fuels, oils and greases	Anthropogenic hydrocarbons that can be emulsified	90%

6.3.2 Stormwater Volume

There are no explicit quantitative targets defined in Cumberland LEP 2021 and DCP 2021. However, the requirements of rainwater tanks, as promoted for water reuse target (see below section), will contribute to stormwater runoff volume reductions.

In accordance with the Westmead Precinct strategic vision, i.e., 'District in Nature', and the vision for water, the preliminary target to stormwater volume is defined as:

- Stormwater volume to be maintained to existing/pre-masterplan conditions.

6.3.3 Potable Water Consumption

As outlined in Section 6.2.2.1, the mains-supplied potable water consumption will be reduced by 40% compared to the average 'pre-BASIX' home benchmark. The rainwater/stormwater harvesting tanks / reuse devices will be assessed together with the effect of using water efficient appliances against the 40% potable water consumption reduction target.

6.4 WSUD Opportunities for Future Westmead South

There are a range of water management measures that can be used to promote IWCM and WSUD principles. The range of water management options and scale of implementation can be summarised as in Table 20.

Table 20 – Water Management Options

Management Technique	Scale			
	Regional	Precinct (PSP)	Development / Local	Domestic / Household
Aquifer recharge and rural reuse	■			
Retarding basins	■	■	■	
Purple pipe	■			
Potable water	■			
Wetlands	■	■	■	
Sewerage treatment & recycled water plants	■	■		
Dams	■			
Rivers & creeks	■	■	■	
Sewer mining	■			
Stormwater capture and reuse	■	■	■	
Pricing	■			
Aquifer Recharge and Urban Reuse	■	■		
Land use layout & green space		■	■	
Sediment traps		■	■	
Bio-retention systems		■	■	
Swales		■	■	
Local run off treatments			■	■
Litter traps			■	
Infiltration trenches			■	
Porous paving			■	■
Rain gardens			■	
Greywater reuse			■	■
Rainwater Capture and reuse			■	■
Inspection and monitoring			■	■
Rooftop greening				■
Onsite domestic sewerage treatment and reuse				■
Education				■

A high-level screening of management options was undertaken against the draft Master Plan (Diagram 3). As the IWCM strategy to be developed as part of this Study will be used to inform the precinct planning and development control, i.e., amending DCP, the options suitable for precinct, development, and household scales were considered. With the consideration of existing waterways, masterplan, and local guidelines, the following measures have been preliminarily identified for assessment in next stage:

- Water efficient appliances
- Rainwater / Underground tanks
- Green roofs
- Porous pavement
- Tree pits
- Infiltration trenches or swales
- Raingardens

6.4.1 Water Efficient Appliances

Water efficiency within new developments should be implemented in line with BASIX and green star rating requirements. Water efficient appliances and fixtures, e.g., hot water systems, shower heads, washing machines, and toilets, will save water, energy, and associated cost. Solar heated hot water systems are also encouraged. It is recommended to achieve 4 stars or above as rated through Water Efficiency Labelling and Standards (WELS) Scheme for non-residential developments and high-rise residential developments. For low- and mid-rise residential developments, a minimum of 3 stars WELS rated water conserving devices and fitting shall be installed and water-efficient habit shall be promoted to achieve Sydney Water's water use targets for water-efficient household.

6.4.2 Rainwater / Stormwater Tanks

The use of rainwater/stormwater tanks can reduce potable water demand, reduce stormwater runoff volumes, and improve stormwater quality. Rainwater tanks are recommended to be plumbed to all non-potable internal uses such as toilets, laundry and hot water units as well as used for garden/lawn irrigation. The reduction in stormwater volume will help to reduce the pressure on the precinct drainage system and the impact on receiving waterways.

Rainwater tanks are specifically required for new development as defined in Cumberland DCP 2021. This should be carried on for Westmead South master planning. Above ground rainwater tanks are considered to be suitable for single dwelling houses, town houses, or low-rise apartments, e.g., Zones I, J. For the mid- and high- rise apartments, e.g., Zones A, B, C, D, E, F, the potable water demand will be relatively high and there will be limited space to accommodate above-ground tanks, therefore, bigger size underground tanks are recommended for rainwater and stormwater harvesting.

6.4.3 Green Roofs

A green roof enables a building rooftop to be partially or completely covered with vegetation and a growing medium. It can also include additional layers such as a root barrier and drainage and irrigation systems. Diagram 33 shows an example of typical green roof of a high-rise building.

A green roof can cool the roof, increase the 'permeability' of a building, absorb and retain rainwater, and thus reduce stormwater runoff in urban environments. It can be used together with or as an alternative to rainwater/stormwater tanks to reduce the stormwater volume. However, it should be used with caution if there is a high potable water demand, as a green roof also reduces the rainwater volume which can be harvested by rainwater tanks for reuse applications. The modelling assessment conducted during the following stage (Section 6.6) suggested that the potable water demand reduction is a restriction factor (target) for WSUD in future Westmead South, therefore, green roofing is not adopted as a preferred WSUD measure as part of the IWCM strategy for Westmead South masterplan.

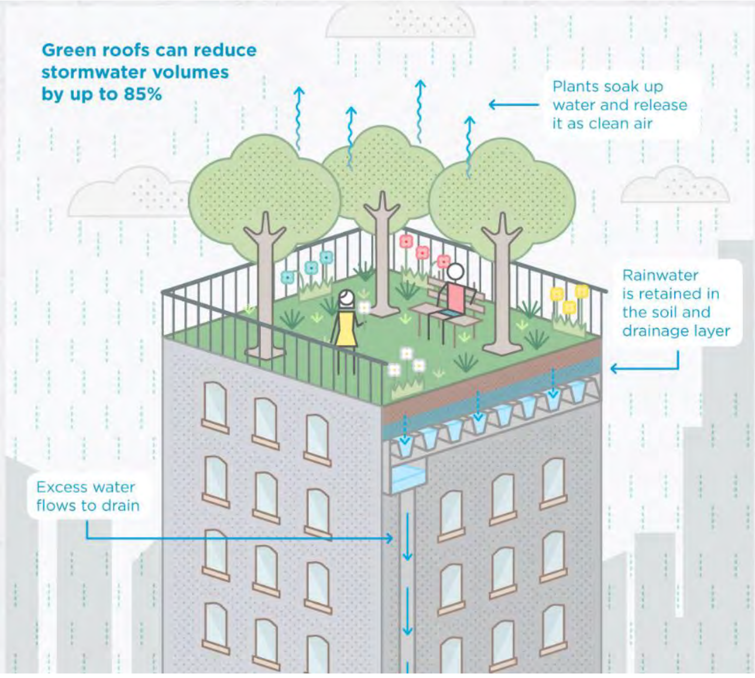


Diagram 33 – Schematics of green roof

6.4.4 Porous Pavement

Porous pavement (permeable pavement) enables rainfall to infiltrate through the permeable media (layer) into the soil below. The infiltrated water recharges soil moisture and ground water. By directing stormwater away from the drainage system, porous pavement reduces the discharge volume, delay the peak, and mitigate associated flood risk. Diagram 34 shows the schematic of a typical porous pavement and an example of a constructed permeable carpark.

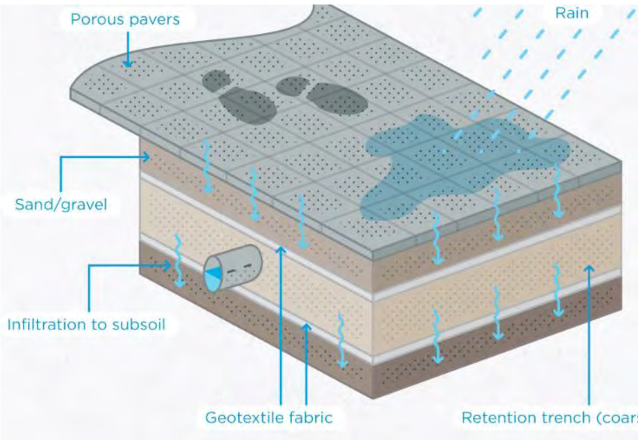


Diagram 34 – Schematics of porous pavement (left) and example of constructed permeable carpark (right)

6.4.5 Tree Pits

Tree pits are suitable for water sensitive road design in urban areas. The street tree is lowered, typically below the invert of the kerb, to allow stormwater runoff from kerb and channel to enter the tree pit through inlet structure and filter through the vegetated media.

As noted in Cumberland Tree Strategy (Cumberland City Council, 2020), a raingarden tree pit system removes pollution from stormwater before entering waterways, reduces the amount of water required to support the tree in a compact small design suitable for urban areas. A raingarden tree pit has a temporary ponding, i.e., extended detention, above the filter media providing additional treatment within a small space. The specific tree inlet takes advantage of kerbside stormwater runoff. It captures stormwater through grate and/or permeable paving and use the water to passively irrigate the street trees.

Diagram 35 shows the schematic of a typical tree pit and an example of an inlet structure to capture water.

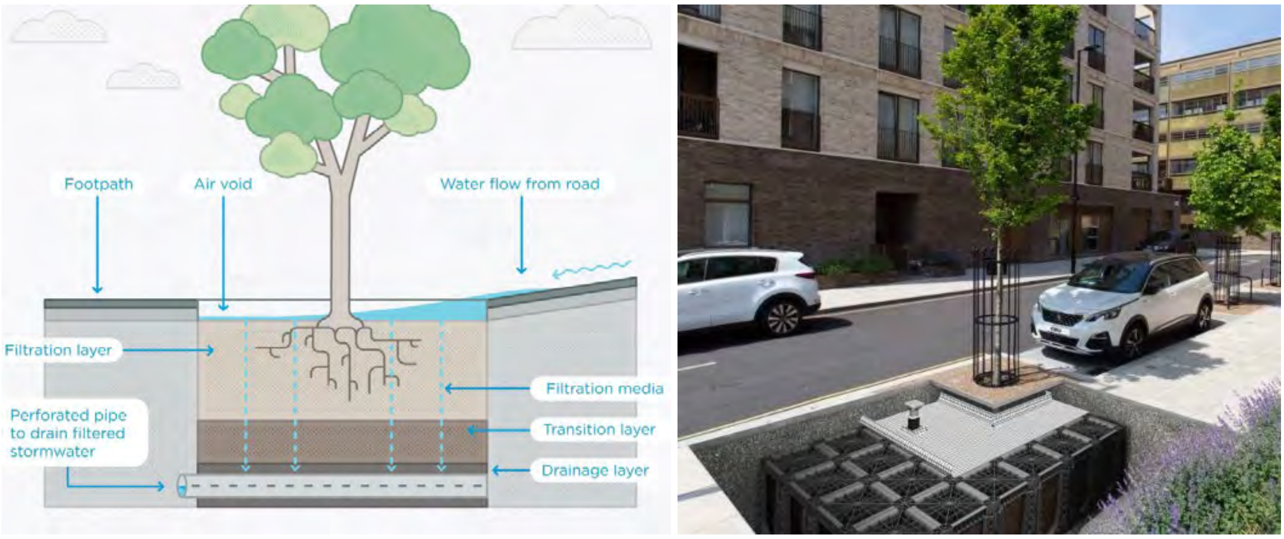


Diagram 35 – Schematics of tree pit (left) and example of the inlet structure (right)

6.4.6 Infiltration Trenches/Swales

An infiltration trench is an excavation filled with porous material, e.g., rock screenings. An infiltration swale is a swale with infiltration trench at the bottom of the swale, which allows longer extended detention than a normal trench to improve the infiltration and pollution removal.

Stormwater is directed into the infiltration trench/swale through a primary filter that retains sediment, litter and organic matter. The collected stormwater is utilised by vegetation grown in or around the trench and infiltrates into the surrounding soil. Similar to tree pits, Infiltration trenches/swales are suitable for passive irrigation of streetscape trees and vegetation. Diagram 36 shows a typical schematic of an infiltration swale. Infiltration trenches/swales are recommended along the green links along the main waterways.

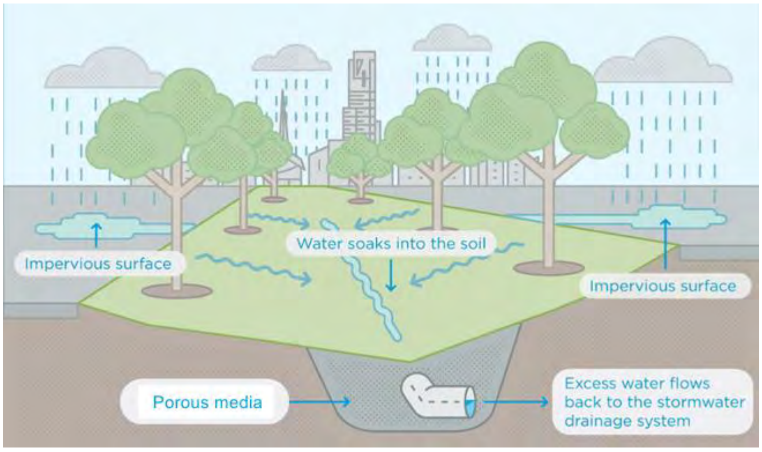


Diagram 36 – Schematics of an infiltration swale

6.4.7 Bioretention System

A bioretention system, or raingarden, is a garden bed that uses plants and soils to capture, filter and clean stormwater. It is typically filled with vegetated sandy soil media, which improve the stormwater quality by allowing it to pond on the vegetated surface, then slowly infiltrate through the sandy soil media. Treated water is captured at the base of the system, which can be partially recharged into the soil and groundwater and partially discharged into underground drainage systems. Diagram 37 shows a typical schematic of a bioretention system.

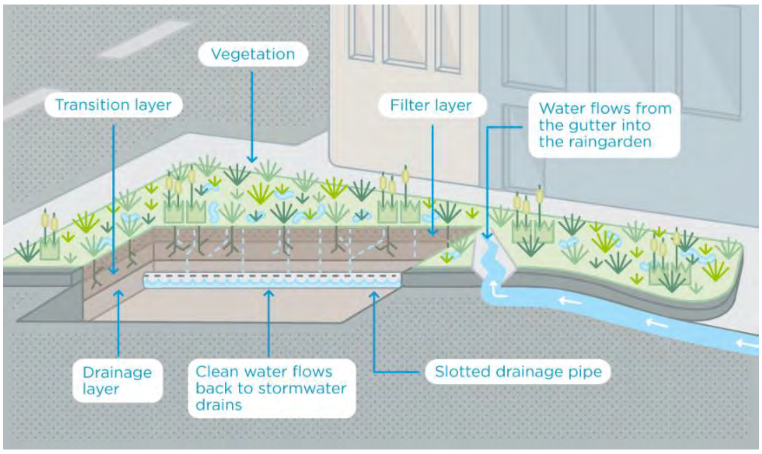


Diagram 37 – Schematics of a bioretention system

**Schematics courtesy of City of Melbourne*

6.5 Soil Permeability

The WSUD options with infiltration function, e.g., porous pavement, tree pits, infiltration systems, etc., can be designed with high hydraulic conductivity fillings, allowing water traveling through. However, the effectiveness and efficiency of those facilities are restricted by the permeability of the receiving soil. Therefore, it is critical to understand the soil type and permeability of the study area. The hydraulic conductivity of typical Australian soil types is detailed in Table 21**.**

Table 21 – Typical soil types and associated hydraulic conductivity

Soil Type	Saturated Hydraulic Conductivity (mm/hr)
Coarse Sand	> 360
Sand	180 to 360
Sandy Loam	36 to 180
Sandy Clay	3.6 to 36
Medium Clay	0.36 to 3.6
Heavy Clay	0.0036 to 0.36

The soil texture grids (for soil depth 100-200cm) for the study area were obtained from Soil and Landscape Grid of Australia[2]. The average percentages of soil particles for the area are approximately:

- sand – 50%
- clay – 35%
- silt – 15%

Based on the soil texture data, the soil type of the area can be classified into Sandy Clay, indicating the saturated hydraulic conductivity is 3.6 to 36 mm/hr. A conservative value of 3.6 mm/hr was used for

[2] https://esoil.io/TERNLandscapes/Public/Pages/SLGA/

modelling assessment to ensure that the effectiveness of infiltration based WSUD opportunities is suitably represented.

6.6 Proposed WSUD Measures and Modelling Assessment

Due to the shape of the catchment topography, available space, and layout of the existing drainage network, Arcadis believes the most appropriate WSUD strategy is decentralised treatment devices.

Areas with minimum/no changes, such as schools and Areas H and K, have been excluded from the assessment. Only areas where new developments are planned or areas where treatment devices are introduced have been considered. It should be noted that the modelling was based on the publicly exhibited masterplan, although the area references adopted in this section (in tables and diagrams) are consistent with the post exhibition version as shown in Diagram 3.

6.6.1 At-source Treatment within Lot Boundary

This section describes the required treatment devices within the lot boundary. Treatment devices identified in this section only consider flows, and hence, pollutants, generated from areas within the lot boundary. Flows from areas outside the lot boundary such as roads or parks have been considered in Section 6.6.2. It is anticipated that installation and maintenance of treatment devices within the lot boundary will be the responsibility of the developer or landowner.

A combination of rainwater/stormwater tanks and/or bioretention is proposed for each area type. The layout of the treatments within the lot boundary is shown in Diagram 38.

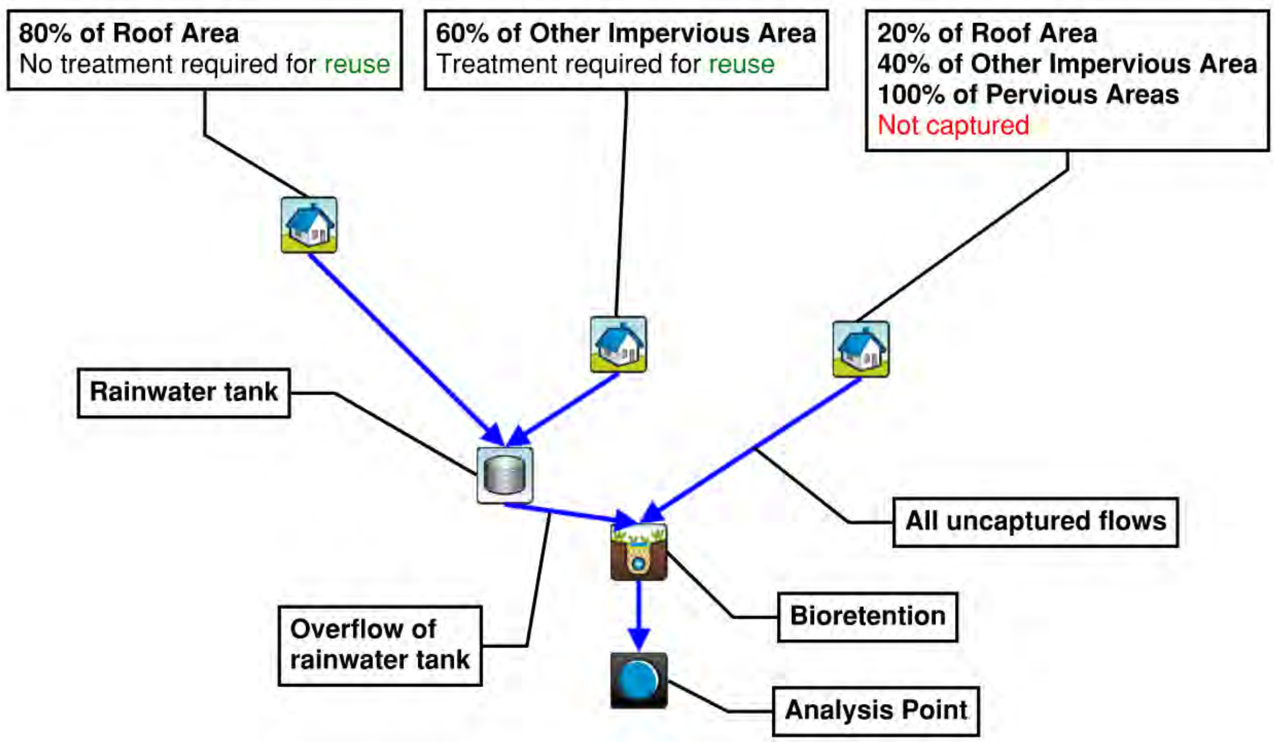


Diagram 38 – Layout of treatment devices within the lot boundary

These devices have been sized based on preliminary calculations. The sizes (volume and areas) shown in Table 22 are the sum of all the treatment devices in each area that future detailed designs must aim to achieve as a minimum.

Table 22 – Approximate size of rainwater/stormwater tanks and bioretention

Area	Reference	Rainwater/stormwater Tank Volume (m^3)	Bioretention Area (m^2)
Mixed use – Hawkesbury Road north	A0*	2 x 1100	20
	A1	-	30
	A2	400	10
	A3	300	10
	A4	300	10
Residential apartments	B1	400	30
	B2	1600	100
	B3	400	20
	B4	500	30
	C	800	50
	D1	900	70
	D2	1100	70
	D3	1700	110
	E0	1100	120
	E1	300	20
	E2	300	20
	E3	800	70
	E4	1400	130
	E5	600	120
	E6	1700	140
	E7	800	60
	E8	1000	80
Mixed use – Hawkesbury / Oakes Centre / Great Western Highway	F0	300	10
	F1	800	70
	F2	300	20
	G0	500	20

Area	Reference	Rainwater/stormwater Tank Volume (m^3)	Bioretention Area (m^2)
	G1-1	1100	40
	G1-2	700	30
	G1-3	1100	40
	G1-4	1000	60
	G2-1	1000	70
	G2-2	800	50
	G3	500	40
Medium density	I	465	150
Low-medium density	J0	1760	960
	J1	1400	720
	J2	260	110
	J3	1445	690
No Change	H	No rainwater tank	No bioretention
	K	No rainwater tank	No bioretention

*As area A1 does not have any dwellings, it is assumed that the harvested rainwater is used to supply the dwellings in area A0. Therefore, the rainwater tanks from A0 and A1 are combined.

Although the sizing of the rainwater/stormwater tanks was determined by water reuse requirements rather than water quality requirements, the rainwater tanks are still contributing to water quality treatment performance. A discussion of rainwater/stormwater tank sizing is included in Section 6.6.4.

Bioretention refers to treatment devices such as bioretention basins, tree pits, or raingardens. Therefore, any or a combination of these treatment devices could be used within the lot to achieve the required area provided that the parameters in Table 23 are used.

Table 23 – Bioretention parameters

Parameter	Value
Filter Area (m^2)	As identified in Table 22
Filter Depth (m)	0.5
Extended Detention Depth (m)	0.2
Exfiltration Rate (mm/h)	3.6

6.6.2 Decentralised Treatment within Road Boundary

This section describes the required treatment devices outside the lot boundary. Treatment devices identified in this section only consider flows, and hence, pollutants, generated from areas outside the lot boundary. Areas such as these include parks, roads, nature strips, and foot paths. Flows from areas within the lot boundary have been considered in Section 6.6.1. It is anticipated that installation and maintenance of treatment devices outside the lot boundary will be the responsibility of Council.

A combination of tree pits and swales is proposed throughout the precinct. These treatment devices have been sized based on preliminary calculations. The sizes shown in Diagram 39 are the sum of all the treatment devices in each area that future detailed design must aim to achieve as a minimum.

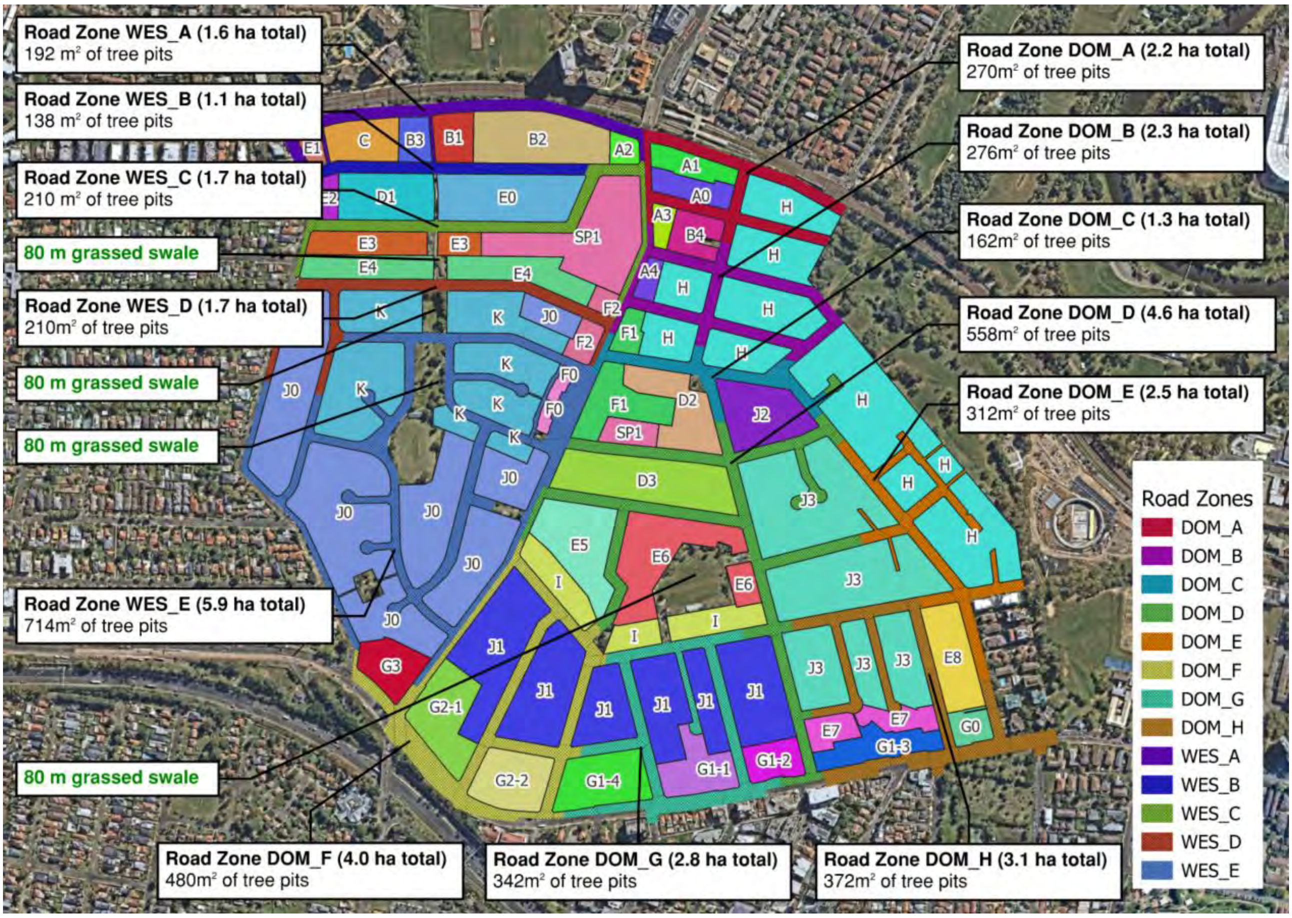


Diagram 39 – Layout of proposed tree pits and swales across the precinct (treatment devices within lot boundaries not shown)

Roads across the precinct were divided into several catchments to allow for spatial variation of tree pit density. An average spacing of 25 m was assumed to estimate the required number of tree pits and filter area. It was identified that this configuration was able to meet the required reduction targets at the outfalls. Thus, spatial variation of tree pit density was not required.

The results are shown in Table 24. Table 25 identifies the parameters used by the tree pits.

Table 24 – Proposed Tree Pits for Road Catchments

Road Catchment	Total catchment area (ha)	Total road length (m)*	Target spacing (m)	No. of Tree Pits*	Total Filter Area (m^2)
Dom_A	2.215	1108	25	90	270
Dom_B	2.252	1126	25	92	276

Road Catchment	Total catchment area (ha)	Total road length (m)*	Target spacing (m)	No. of Tree Pits*	Total Filter Area (m^2)
Dom_C	1.32	660	25	54	162
Dom_D	4.611	2306	25	186	558
Dom_E	2.564	1282	25	104	312
Dom_F	3.963	1982	25	160	480
Dom_G	2.839	1420	25	114	342
Dom_H	3.082	1541	25	124	372
Wes_A	1.589	795	25	64	192
Wes_B	1.102	551	25	46	138
Wes_C	1.725	863	25	70	210
Wes_D	1.735	868	25	70	210
Wes_E	5.93	2965	25	238	714

** Based on average road catchment width of 20 m.*

*** One tree pit on either side of road (two tree pits per location).*

**** Based on 3 m^2 filter area per tree pit.*

Table 25 – Tree pit parameters

Parameter	Value
Total Filter Area (m^2)	As identified in Table 24
Filter Area per Tree Pit (m^2)	3
Filter Depth (m)	0.5
Extended Detention Depth (m)	0.2
Exfiltration Rate (mm/h)	3.6

Swales are proposed to treat flows generated from the open spaces. The parameters used are shown in Table 26.

Table 26 – Swale parameters

Parameter	Value
Top Width (m)	3
Bottom Width (m)	0
Depth (m)	0.5
Longitudinal Grade	2%
Vegetation Height (m)	0.25
Exfiltration Rate (mm/h)	3.6

It should be noted that the tree pits and swales are intercepting flows before they enter the underground network. Flows that have entered the underground network are not treated by any treatment device identified in this report.

6.6.3 Stormwater Quality and Volume Results

The following section discusses the reduction in total suspended solids (TSS), total phosphorus (TP), total nitrogen (TN), and gross pollutants (GP), as well as the flow volume. Table 27 identifies the treatment performance for each treatment device. Table 28 identifies the overall treatment performance.

Table 27 – Load reduction in percentage for each treatment node

Area	Reference	Treatments	Flow	TSS	TN	TP	GP
Mixed use – Hawkesbury Road north	A0	RWT and Bioretention	87	98	93	94	100
	A1	Bioretention	14	86	57	63	100
	A2	RWT and Bioretention	78	96	89	91	100
	A3	RWT and Bioretention	78	97	89	91	100
	A4	RWT and Bioretention	77	96	88	90	100
Residential apartments	B1	RWT and Bioretention	69	94	84	87	100
	B2	RWT and Bioretention	73	96	87	89	100
	B3	RWT and Bioretention	73	95	86	89	100
	B4	RWT and Bioretention	73	95	87	89	100
	C	RWT and Bioretention	74	97	88	90	100
	D1	RWT and Bioretention	73	96	87	89	100

Area	Reference	Treatments	Flow	TSS	TN	TP	GP
	D2	RWT and Bioretention	72	96	87	89	100
	D3	RWT and Bioretention	73	96	87	88	100
	E0	RWT and Bioretention	73	96	88	89	100
	E1	RWT and Bioretention	78	98	91	92	100
	E2	RWT and Bioretention	76	98	90	91	100
	E3	RWT and Bioretention	75	97	89	90	100
	E4	RWT and Bioretention	75	97	89	90	100
	E5	RWT and Bioretention	64	95	83	85	100
	E6	RWT and Bioretention	77	97	90	91	100
	E7	RWT and Bioretention	76	97	90	91	100
	E8	RWT and Bioretention	72	96	88	89	100
Mixed use – Hawkesbury / Oakes Centre / Great Western Highway	F0	RWT and Bioretention	80	96	90	92	100
	F1	RWT and Bioretention	65	92	80	85	100
	F2	RWT and Bioretention	73	95	85	88	100
	G0	RWT and Bioretention	76	97	89	90	100
	G1-1	RWT and Bioretention	74	94	85	88	100
	G1-2	RWT and Bioretention	76	96	88	90	100
	G1-3	RWT and Bioretention	77	96	88	90	100
	G1-4	RWT and Bioretention	71	95	84	87	100
	G2-1	RWT and Bioretention	63	93	81	84	100
	G2-2	RWT and Bioretention	67	93	82	85	100
	G3	RWT and Bioretention	72	95	85	88	100
Medium density	I	RWT and Bioretention	89	99	93	96	100
Low-medium density	J0	RWT and Bioretention	34	85	63	70	100
	J1	RWT and Bioretention	36	85	63	70	100
	J2	RWT and Bioretention	17	84	58	63	100

Area	Reference	Treatments	Flow	TSS	TN	TP	GP
	J3	RWT and Bioretention	74	97	83	90	100
Open Spaces	Austral Avenue Reserve (Existing)	Swale	3	87	21	62	100
	M J Bennett Reserve (Existing)	Swale	1	71	11	50	100
	Moree Avenue Reserve (Potential New)	Swale	4	89	23	65	100
	Sydney Smith Park (Existing)	Swale	1	71	11	50	100
Road Catchments	Dom_A	Tree Pit	8	81	47	58	100
	Dom_B	Tree Pit	8	79	48	58	100
	Dom_C	Tree Pit	8	79	47	58	100
	Dom_D	Tree Pit	8	81	47	58	100
	Dom_E	Tree Pit	8	80	48	58	100
	Dom_F	Tree Pit	8	80	48	59	100
	Dom_G	Tree Pit	8	81	48	59	100
	Dom_H	Tree Pit	8	82	47	59	100
	Wes_A	Tree Pit	8	80	46	57	100
	Wes_B	Tree Pit	8	81	48	58	100
	Wes_C	Tree Pit	8	81	47	58	100
	Wes_D	Tree Pit	8	80	47	58	100
	Wes_E	Tree Pit	8	81	48	58	100
Receiving Waters	Domain Creek Post Development	-	39	87	66	72	100
	Westmead Creek Post Development	-	38	87	65	72	100

Table 28 – Overall treatment performance

Area	Pollutant	Pre-treatment	Post-treatment	Reduction (%)	Target (%)
Overall	Flow (ML / year)	739	456	38	N/A
	TSS (kg / year)	148933	19295	87	85
	TP (kg / year)	304	85	72	60
	TN (kg / year)	2122	730	66	60
	GP (kg / year)	19074	0	100	90

The pollutant reduction targets were achieved through the proposed treatment devices. It is worth noting that the TP reduction is significantly higher than the targets. However, the TSS reduction is only 2% higher than the target and therefore, no further reduction in treatment devices is possible.

6.6.4 Potable Water Consumption Reduction

The following assumptions and rules were made when sizing rainwater/stormwater tanks:

- Reuse demand, the maximum rate at which water in the tank is used, was 137 L per person per day. Refer to Section 6.2.2.2 for a discussion on how the reuse demand was determined.
- 80% of the roof area and 60% of the remaining impervious area is capturable.
- Rainwater/stormwater tanks are 2m tall with no minimum water level requirement.
- Rainwater/stormwater tanks are 50% full at the start of the simulation.

Zones A0 to G3 have a higher density of dwellings, corresponding to higher reuse demands. It was found that the area contributing to rainwater capture is not large enough relative to the population. Therefore, the limiting factor was the volume of rain that could be captured rather than the tank size. Hence, rainwater/stormwater tanks for Zones A0 to G3 were estimated based on feasible configurations.

Zone I and zones J0 to J3 have a lower density of dwellings, corresponding to lower reuse demands. It was found that the area contributing to rainwater capture was large enough relative to the population. Therefore, the limiting factor was tank size. With the consideration of the feasibility for the tanks to be fitted, rainwater tanks for Zones I to J3 were based on a volume of 5 kL per dwelling.

It was assumed that there were no tanks for Zones H, K, open spaces, or existing school buildings.

The potable water consumption reduction results are identified in Table 29.

Table 29 – Potable Water Consumption Reduction

Area	Reference	Storeys	Population	Daily Demand (L/person/day)	Reuse Supplied (ML/year)	Reuse Reduction (L/person/day)	Appliance Reduction (L/person/day)	Total Reduction (%)	40% Reduction Target Met?
Mixed use – Hawkesbury Road north	A0/A1	25/2	818	247	7.5	25	76	41%	YES
	A2	20	308	247	1.7	15	76	37%	NO
	A3	20	272	247	1.6	16	76	37%	NO
	A4	15	163	247	1.6	26	76	41%	YES
Residential apartments	B1	25	658	247	3.0	13	76	36%	NO
	B2	15	2181	247	10.7	13	76	36%	NO
	B3	20	477	247	2.4	14	76	36%	NO
	B4	15	591	247	3.2	15	76	37%	NO
	C	12	793	247	4.9	17	76	38%	NO
	D1	8	1039	247	7.3	19	76	39%	NO
	D2	8	715	247	7.1	27	76	42%	YES
	D3	8	1790	247	12.5	19	76	39%	NO
	E0	4	567	247	8.1	39	76	47%	YES
	E1	6	117	247	1.0	25	76	41%	YES
	E2	6	130	247	1.2	24	76	41%	YES
	E3	6	570	247	4.9	24	76	40%	YES
	E4	6	891	247	8.8	27	76	42%	YES
	E5	6	417	247	5.9	39	76	46%	YES

Area	Reference	Storeys	Population	Daily Demand (L/person/day)	Reuse Supplied (ML/year)	Reuse Reduction (L/person/day)	Appliance Reduction (L/person/day)	Total Reduction (%)	40% Reduction Target Met?
	E6	6	1041	247	9.8	26	76	41%	YES
	E7	6	433	247	4.0	25	76	41%	YES
	E8	6	671	247	5.2	21	76	39%	NO
Mixed use – Hawkesbury / Oakes Centre / Great Western Highway	F0	8	205	247	1.7	23	76	40%	YES
	F1	8	523	247	7.9	41	76	48%	YES
	F2	8	417	247	3.2	21	76	39%	NO
	G0	8	300	247	2.6	24	76	40%	YES
	G1-1	8	585	247	6.3	30	76	43%	YES
	G1-2	8	383	247	4.1	29	76	43%	YES
	G1-3	8	567	247	6.7	32	76	44%	YES
	G1-4	6	756	247	8.0	29	76	42%	YES
	G2-1	6	290	247	7.6	72	76	60%	YES
	G2-2	6	381	247	6.7	48	76	50%	YES
	G3	12	689	247	5.1	20	76	39%	NO
Medium density	I	2	241	247	4.5	51	76	51%	YES
Low-medium density	J0	2	912	247	20.2	61	76	55%	YES
	J1	2	725	247	16.4	62	76	56%	YES
	J2	2	135	247	3.0	61	76	55%	YES
	J3	2	749	247	17.7	65	76	57%	YES

Area	Reference	Storeys	Population	Daily Demand (L/person/day)	Reuse Supplied (ML/year)	Reuse Reduction (L/person/day)	Appliance Reduction (L/person/day)	Total Reduction (%)	40% Reduction Target Met?
No Change	H	4	2774	247	-	-	-	-	-
	K	2	438	247	-	-	-	-	-
		Total	25193				Average Reduction (%)	43%	YES

At a catchment level, the average potable water consumption reduction achieved through water-efficient appliances and rainwater reuse was 43%. This was based off a weighted average of population and potable water consumption reduction. This meets the 40% reduction requirement set out by BASIX. It should be noted, however, that at the zone level, some zones do not meet the 40% reduction requirement. This is most prevalent in zones with buildings that are over 6 storeys.

In addition, the 50% reduction in potable water consumption proposed by the ESD Options Paper was not met. Arcadis believes that the current rainwater tank configurations and capturable area assumptions are generally aggressive. Therefore, any intention to meet the proposed 50% potable water reduction (as well as meeting the 40% BASIX requirements across all zones) will require a highly detailed assessment with local data.

This is because the current assessment is based off several assumptions of which could greatly affect the outcome. For instance, the reuse demand is based off Sydney's average potable water usage of 247 L per person per day. Refer to Section 6.2.2.2 for further discussion on the reuse demand. This could vary depending on the locality, season, demographics, and other factors. Furthermore, a key factor potable water usage is dwelling type. For example, a low-density house would have more water requirements for irrigation of gardens and lawns compared to a high-rise apartment.

Due to the lack of local water usage data, level of detail required to refine the assessment, and the need for detailed building configurations, the detailed assessment is considered beyond the scope of this study.

6.7 Integrated Water Cycle Management

The proposed WSUD measures and the modelling/sizing are based on a number of assumptions, e.g., water demand, soil permeability, impervious fractions, etc. and the most suitable combination of measures was selected for modelling assessment.

Alternative options and arrangements, as discussed in Section 6.4, are available which may achieve similar or even better targets/outcomes. For example, infiltration trench might be used as an alternative to bioretention system as a source control, pending on which type of facility is more feasible to be fitted within each development within the precinct. Therefore, we recommend that the WSUD measures proposed within the public domain (Council assets) should be adopted as part of the planning process.

However, for individual developments, it is more important to set up targets through the precinct specific DCP and the measures and their sizes modelled in this assessment should be referred as an example to guide site-specific assessment for future development applications under the master planning framework.

The recommendations for IWCM are summarised as follow:

Public domain –

- The existing streets in the precinct exhibit a low tree canopy coverage of 0% to 20%. Tree canopy coverage is proposed to be increased to 40% in streets. New trees are recommended to be fitted with tree pits, allowing passive irrigation, stormwater quality treatment, and stormwater volume reduction. The number and size of tree pits should generally match or exceed that proposed in this assessment (Section 6.6.2).
- 3-metre-wide and over 80 m long swales should be incorporated within each public reserve, i.e., the Northern section of MJ Bennet Reserve (Greenlink), the Greenlink between Church Avenue and Austral Avenue, the Greenlink between Austral Avenue and Moree Avenue, and the Sydney Smith Park.

Development control for Individual development –

- For low- and mid-rise residential developments, a minimum of 3 stars Water Efficiency Labelling and Standards (WELS) rated water conserving devices and fitting shall be installed and water-efficient habit shall be promoted to achieve Sydney Water's water use targets for water-efficient household.
- For non-residential developments (commercial, industrial, and mixed use) and high-rise residential developments, a minimum of 4 stars WELS rated water conserving devices and fitting shall be installed.

- All developments shall incorporate rainwater and/or stormwater harvesting and reuse devices (above- or under-ground) into the stormwater drainage system for non-potable uses, e.g., toilet flushing, laundry, hot water, garden watering, and external cleaning, car washing.
- For all low-rise multi-dwelling developments and single-dwelling development exceeding 65% impervious area, a minimum of 5 kL per dwelling rainwater harvesting storage shall be incorporated.
- For all mid- and high-rise developments, stormwater harvesting system shall be designed to capture rainwater and stormwater for reuse application to supplement potable water demand. Stormwater harvesting and reuse applications should be designed with consideration of the 40% reduction in potable water consumption target.
- All developments shall aim to achieve the stormwater quality targets set out in Part G4 Section 2.4 of Cumberland DCP 2021 (i.e., Table 19 of this report). Rainwater/stormwater tanks and bioretention systems as demonstrated in this report (Section 6.4.1), or alternative measures which can achieve similar water quality outcomes, should be included as part of the design for individual developments.
- The stormwater peak should be management as summarised in Section 5.1.3 of this report.

7 CONCLUSION

This report summarises the findings of the flood modelling, stormwater assessment, and integrated water cycle management assessment to support Westmead South Precinct Master Planning.

Council adopted hydrologic and hydraulic models (Lyall and Associates, 2017) were updated to ARR 2019 and current existing conditions. Flood level contours, depth, velocity, hazards, and function categories were mapped for 5%, 1%, 0.5%, 0.2%, 1% with climate change, and PMF for existing conditions. Flood risk and impact assessment were conducted for the preferred master plan. Localised impact on flood extent and cumulative impact on downstream flood level were identified due to the increase of the impervious fraction and change of building layout. It is recommended that site-specific flood assessment to be conducted for development in the flood prone area, to ensure that site discharge is controlled, and the design provides sufficient flood storage and flood conveyance to avoid the impact on neighbouring and downstream properties.

The capacity of the existing underground drainage network was assessed for minor (20% AEP) and major (1% AEP) events, indicating most of the drainage pipes are full or nearly full during minor events. It is recommended that future development promotes to maintain the site permeability or manage peak discharge through on-site detention facilities.

The IWCM and WSUD opportunities were nominated and sized through modelling assessment. At-source and decentralised treatment facilities were promoted. It was demonstrated that through the use of rainwater/stormwater harvesting systems, bioretention systems, tree pits and swales, the potable water consumption reduction target, stormwater quality targets, and stormwater volume target can be achieved at precinct scale. Public domain treatment measures and development control measures for individual developments were recommended to facilitate the master planning proposal and precinct specific DCP development.

The detailed recommendations and plan for flood risk management, stormwater management, and integrated water cycle management are summarised at the end of Sections 4-6 of this report.

The modelling exercises presented in this report were undertaken based on the publicly exhibited version, rather than the post exhibition version. Although the changes will be unlikely to have material impact on the conclusions and recommendations of this report, it is recommended that the revised/final masterplan is remodelled at a future stage.

REFERENCES

1. Australian Institute for Disaster Resilience, *Australian Disaster Resilience Guideline 7-3 Flood Hazard – Supporting document for the implementation of Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia*, 2017
2. Cumberland City Council, *Development Control Plan*, 2021
3. Cumberland City Council, *Cumberland Local Environmental Plan*, 2021
4. Cumberland City Council, *Cumberland Open Space and Recreation Strategy 2019–2029*, 2019
5. Cumberland City Council, *Cumberland Urban Tree Strategy*, 2020
6. Greater Cities Commission, *Westmead Health and Innovation District Public Domain Strategy*, 2022
7. Howells, L., McLuckie, D., Collings, G. and Lawson, N., *Defining the Floodway – Can One Size Fit All?* Floodplain Management Authorities of NSW 43rd Annual Conference, Forbes, 2003
8. Lyall & Associates, *Holroyd City LGA Overland Flood Study*, 2017

APPENDIX A IMPERVIOUS FRACTIONS FOR SUB-CATCHMENTS

Table A 1 - Fractions used in DRAINS (2017 Model)

Name	Paved	Supplementary	Grassed
Dom_01	0.4	0	0.6
Dom_02	0.4	0	0.6
Dom_03	0.8	0	0.2
Dom_04	0.4	0	0.6
Dom_05	0.4	0	0.6
Dom_06	0.4	0	0.6
Dom_07	0.4	0	0.6
Dom_08	0.4	0	0.6
Dom_09	0.4	0	0.6
Dom_10	0.4	0	0.6
Dom_11	0.4	0	0.6
Dom_12	0.4	0	0.6
Dom_13	0.4	0	0.6
Dom_14	0.4	0	0.6
Dom_15	0.4	0	0.6
Dom_16	0.35	0	0.65
Dom_17	0.4	0	0.6
Dom_18	0.4	0	0.6
Dom_19	0.2	0	0.8
Dom_20	0.4	0	0.6
Dom_21	0.4	0	0.6
Dom_22	0.4	0	0.6
Dom_23	0.7	0	0.3
Dom_24	0.8	0	0.2
Dom_25	0.6	0	0.4
Dom_26	0.4	0	0.6
Dom_27	0.3	0	0.7
Dom_28	0.4	0	0.6
Dom_29	0.3	0	0.7

Name	Paved	Supplementary	Grassed
Dom_30	0.4	0	0.6
Dom_31	0.4	0	0.6
Dom_32	0.4	0	0.6
Dom_33	0.3	0	0.7
Dom_34	0	0	1
Dom_35	0.75	0	0.25
Dom_36	0.25	0	0.75
Dom_37	0.4	0	0.6
Dom_38	0.4	0	0.6
Dom_39	0.4	0	0.6
Dom_40	0.4	0	0.6
Dom_41	0.4	0	0.6
Dom_42	0.4	0	0.6
Wes_001	0.4	0	0.6
Wes_0010	0.4	0	0.6
Wes_002	0.4	0	0.6
Wes_003	0.35	0	0.65
Wes_004	0.4	0	0.6
Wes_005	0.55	0	0.45
Wes_006	0.4	0	0.6
Wes_007	0.2	0	0.8
Wes_008	0.4	0	0.6
Wes_009	0.4	0	0.6
Wes_011	0.4	0	0.6
Wes_012	0.4	0	0.6
Wes_013	0.65	0	0.35
Wes_014	0.4	0	0.6
Wes_015	0.4	0	0.6
Wes_016	0.4	0	0.6
Wes_017	0.4	0	0.6
Wes_018	0.4	0	0.6

Table A 2 - Fractions of ARR2019 Surface Types. Existing Conditions shown in Blue, Proposed Conditions shown in Red (as per public exhibition Masterplan 31 Oct – 8 Dec).

Name	TIA		EIA		ICA		PA	
Dom_01	0.732	0.8	0.437	0.51	0.541	0.47	0.022	0.02
Dom_02	0.529	0.6	0.317	0.36	0.683	0.64	0	0
Dom_03	0.724	0.83	0.434	0.55	0.566	0.45	0	0
Dom_04	0.542	0.72	0.325	0.43	0.675	0.57	0	0
Dom_05	0.466	0.72	0.280	0.43	0.720	0.57	0	0
Dom_06	0.664	0.74	0.431	0.48	0.569	0.52	0	0
Dom_07	0.844	0.84	0.619	0.62	0.381	0.38	0	0
Dom_08	0.785	0.79	0.471	0.47	0.529	0.53	0	0
Dom_09	0.82	0.82	0.528	0.53	0.472	0.47	0	0
Dom_10	0.8	0.8	0.480	0.48	0.520	0.52	0	0
Dom_11	0.8	0.8	0.480	0.48	0.520	0.52	0	0
Dom_12	0.799	0.79	0.480	0.47	0.520	0.52	0	0.01
Dom_13	0.82	0.82	0.529	0.53	0.471	0.47	0	0
Dom_14	0.8	0.8	0.480	0.48	0.520	0.52	0	0
Dom_15	0.651	0.8	0.390	0.48	0.610	0.52	0	0
Dom_16	0.608	0.82	0.377	0.56	0.586	0.44	0.037	0
Dom_17	0.669	0.8	0.402	0.48	0.598	0.52	0	0
Dom_18	0.673	0.8	0.404	0.48	0.596	0.52	0	0
Dom_19	0.628	0.65	0.377	0.39	0.623	0.61	0	0
Dom_20	0.822	0.86	0.534	0.63	0.466	0.37	0	0
Dom_21	0.479	0.56	0.288	0.34	0.712	0.66	0	0
Dom_22	0.493	0.57	0.296	0.34	0.704	0.66	0	0
Dom_23	0.538	0.76	0.323	0.55	0.677	0.45	0	0
Dom_24	0.829	0.83	0.549	0.55	0.451	0.45	0	0
Dom_25	0.622	0.85	0.373	0.62	0.618	0.38	0.009	0
Dom_26	0.8	0.8	0.480	0.48	0.520	0.52	0	0
Dom_27	0.587	0.59	0.351	0.35	0.362	0.36	0.287	0.29
Dom_28	0.767	0.79	0.460	0.47	0.533	0.53	0.007	0
Dom_29	0.701	0.7	0.481	0.48	0.354	0.36	0.165	0.16
Dom_30	0.635	0.73	0.406	0.46	0.594	0.54	0	0
Dom_31	0.8	0.64	0.480	0.39	0.520	0.61	0	0

Name	TIA		EIA		ICA		PA	
Dom_32	0.843	0.76	0.583	0.53	0.417	0.47	0	0
Dom_33	0.73	0.73	0.553	0.55	0.278	0.28	0.169	0.17
Dom_34	0.177	0.18	0.106	0.11	0.125	0.12	0.769	0.77
Dom_35	0.8	0.8	0.480	0.48	0.520	0.52	0	0
Dom_36	0.309	0.44	0.161	0.24	0.472	0.39	0.367	0.37
Dom_37	0.642	0.69	0.422	0.45	0.578	0.55	0	0
Dom_38	0.406	0.55	0.240	0.32	0.707	0.56	0.053	0.12
Dom_39	0.548	0.7	0.329	0.42	0.671	0.58	0	0
Dom_40	0.738	0.77	0.527	0.54	0.473	0.46	0	0
Dom_41	0.485	0.56	0.291	0.34	0.709	0.66	0	0
Dom_42	0.628	0.68	0.424	0.45	0.576	0.55	0	0
Wes_001	0.56	0.78	0.341	0.48	0.659	0.52	0	0
Wes_0010	0.501	0.51	0.297	0.3	0.645	0.64	0.058	0.06
Wes_002	0.489	0.78	0.293	0.47	0.698	0.52	0.009	0.01
Wes_003	0.448	0.45	0.259	0.26	0.595	0.59	0.146	0.15
Wes_004	0.575	0.58	0.360	0.36	0.640	0.64	0	0
Wes_005	0.674	0.68	0.420	0.42	0.555	0.56	0.025	0.02
Wes_006	0.472	0.54	0.282	0.32	0.663	0.62	0.055	0.06
Wes_007	0.296	0.32	0.150	0.17	0.431	0.41	0.419	0.42
Wes_008	0.379	0.48	0.224	0.28	0.714	0.67	0.062	0.05
Wes_009	0.518	0.66	0.311	0.44	0.689	0.56	0	0
Wes_011	0.492	0.53	0.295	0.32	0.705	0.68	0	0
Wes_012	0.489	0.54	0.293	0.32	0.698	0.63	0.009	0.05
Wes_013	0.717	0.72	0.430	0.43	0.570	0.57	0	0
Wes_014	0.492	0.55	0.295	0.33	0.705	0.67	0	0
Wes_015	0.481	0.53	0.288	0.32	0.712	0.68	0	0
Wes_016	0.489	0.49	0.294	0.29	0.706	0.71	0	0
Wes_017	0.538	0.57	0.323	0.34	0.677	0.62	0	0.04
Wes_018	0.477	0.56	0.286	0.33	0.714	0.67	0	0

Table A 3 – Impervious Fractions used in DRAINS (2023 Model). Existing Conditions shown in Blue, Proposed Conditions shown in Red (as per public exhibition Masterplan 31 Oct – 8 Dec).

Name	Area (ha)	TIA		EIA		RIA		PA	
Dom_01	2.62	0.732	0.8	0.437	0.51	0.294	0.29	0.269	0.2
Dom_02	2.69	0.529	0.6	0.317	0.36	0.211	0.24	0.472	0.4
Dom_03	1.43	0.724	0.83	0.434	0.55	0.289	0.28	0.277	0.17
Dom_04	6.19	0.542	0.72	0.325	0.43	0.217	0.29	0.458	0.28
Dom_05	3.71	0.466	0.72	0.28	0.43	0.186	0.29	0.534	0.28
Dom_06	1.42	0.664	0.74	0.431	0.48	0.233	0.26	0.336	0.26
Dom_07	2.22	0.844	0.84	0.619	0.62	0.224	0.22	0.157	0.16
Dom_08	1.76	0.785	0.79	0.471	0.47	0.314	0.32	0.215	0.21
Dom_09	1.33	0.82	0.82	0.528	0.53	0.292	0.29	0.18	0.18
Dom_10	1.03	0.8	0.8	0.48	0.48	0.32	0.32	0.2	0.2
Dom_11	0.28	0.8	0.8	0.48	0.48	0.32	0.32	0.2	0.2
Dom_12	5.41	0.799	0.79	0.48	0.47	0.32	0.32	0.2	0.21
Dom_13	1.25	0.82	0.82	0.529	0.53	0.291	0.29	0.18	0.18
Dom_14	2.16	0.8	0.8	0.48	0.48	0.32	0.32	0.2	0.2
Dom_15	1.58	0.651	0.8	0.39	0.48	0.26	0.32	0.35	0.2
Dom_16	2.83	0.608	0.82	0.377	0.56	0.231	0.26	0.392	0.18
Dom_17	0.88	0.669	0.8	0.402	0.48	0.268	0.32	0.33	0.2
Dom_18	1.16	0.673	0.8	0.404	0.48	0.269	0.32	0.327	0.2
Dom_19	3.12	0.628	0.65	0.377	0.39	0.251	0.26	0.372	0.35
Dom_20	2.3	0.822	0.86	0.534	0.63	0.288	0.23	0.178	0.14
Dom_21	1.83	0.479	0.56	0.288	0.34	0.192	0.22	0.52	0.44
Dom_22	1.91	0.493	0.57	0.296	0.34	0.197	0.23	0.507	0.43
Dom_23	3.18	0.538	0.76	0.323	0.55	0.215	0.21	0.462	0.24
Dom_24	0.58	0.829	0.83	0.549	0.55	0.28	0.28	0.171	0.17
Dom_25	2.2	0.622	0.85	0.373	0.62	0.249	0.24	0.378	0.14
Dom_26	0.12	0.8	0.8	0.48	0.48	0.32	0.32	0.2	0.2
Dom_27	0.82	0.587	0.59	0.351	0.35	0.236	0.24	0.413	0.41
Dom_28	4.24	0.767	0.79	0.46	0.47	0.307	0.32	0.233	0.21
Dom_29	2.13	0.701	0.7	0.481	0.48	0.22	0.22	0.299	0.3
Dom_30	5.79	0.635	0.73	0.406	0.46	0.229	0.27	0.365	0.27
Dom_31	0.77	0.8	0.64	0.48	0.39	0.32	0.25	0.2	0.36

Name	Area (ha)	TIA		EIA		RIA		PA	
Dom_32	1.01	0.843	0.76	0.583	0.53	0.26	0.23	0.157	0.24
Dom_33	2.9	0.73	0.73	0.553	0.55	0.176	0.18	0.271	0.27
Dom_34	11.38	0.177	0.18	0.106	0.11	0.071	0.07	0.823	0.82
Dom_35	0.31	0.8	0.8	0.48	0.48	0.32	0.32	0.2	0.2
Dom_36	3.6	0.309	0.44	0.161	0.24	0.148	0.2	0.691	0.56
Dom_37	1.7	0.642	0.69	0.422	0.45	0.22	0.24	0.358	0.31
Dom_38	1.65	0.406	0.55	0.24	0.32	0.166	0.23	0.594	0.45
Dom_39	0.66	0.548	0.7	0.329	0.42	0.219	0.28	0.452	0.3
Dom_40	2.57	0.738	0.77	0.527	0.54	0.211	0.23	0.262	0.23
Dom_41	2.11	0.485	0.56	0.291	0.34	0.194	0.22	0.515	0.44
Dom_42	1.26	0.628	0.68	0.424	0.45	0.204	0.23	0.372	0.32
Wes_001	8.33	0.56	0.78	0.341	0.48	0.219	0.3	0.44	0.22
Wes_0010	5.15	0.501	0.51	0.297	0.3	0.204	0.21	0.499	0.49
Wes_002	5.05	0.489	0.78	0.293	0.47	0.196	0.31	0.511	0.22
Wes_003	2.79	0.448	0.45	0.259	0.26	0.189	0.19	0.552	0.55
Wes_004	2.14	0.575	0.58	0.36	0.36	0.216	0.22	0.424	0.42
Wes_005	1.24	0.674	0.68	0.42	0.42	0.254	0.26	0.326	0.32
Wes_006	3.22	0.472	0.54	0.282	0.32	0.19	0.22	0.528	0.46
Wes_007	2.39	0.296	0.32	0.15	0.17	0.147	0.15	0.703	0.68
Wes_008	1.66	0.379	0.48	0.224	0.28	0.156	0.2	0.62	0.52
Wes_009	2.2	0.518	0.66	0.311	0.44	0.207	0.22	0.482	0.34
Wes_011	1.84	0.492	0.53	0.295	0.32	0.197	0.21	0.508	0.47
Wes_012	5.18	0.489	0.54	0.293	0.32	0.196	0.22	0.511	0.46
Wes_013	2.59	0.717	0.72	0.43	0.43	0.287	0.29	0.283	0.28
Wes_014	1.87	0.492	0.55	0.295	0.33	0.197	0.22	0.508	0.45
Wes_015	1.21	0.481	0.53	0.288	0.32	0.192	0.21	0.52	0.47
Wes_016	1.66	0.489	0.49	0.294	0.29	0.196	0.2	0.51	0.51
Wes_017	2.58	0.538	0.57	0.323	0.34	0.215	0.23	0.462	0.43
Wes_018	1.1	0.477	0.56	0.286	0.33	0.191	0.23	0.523	0.44

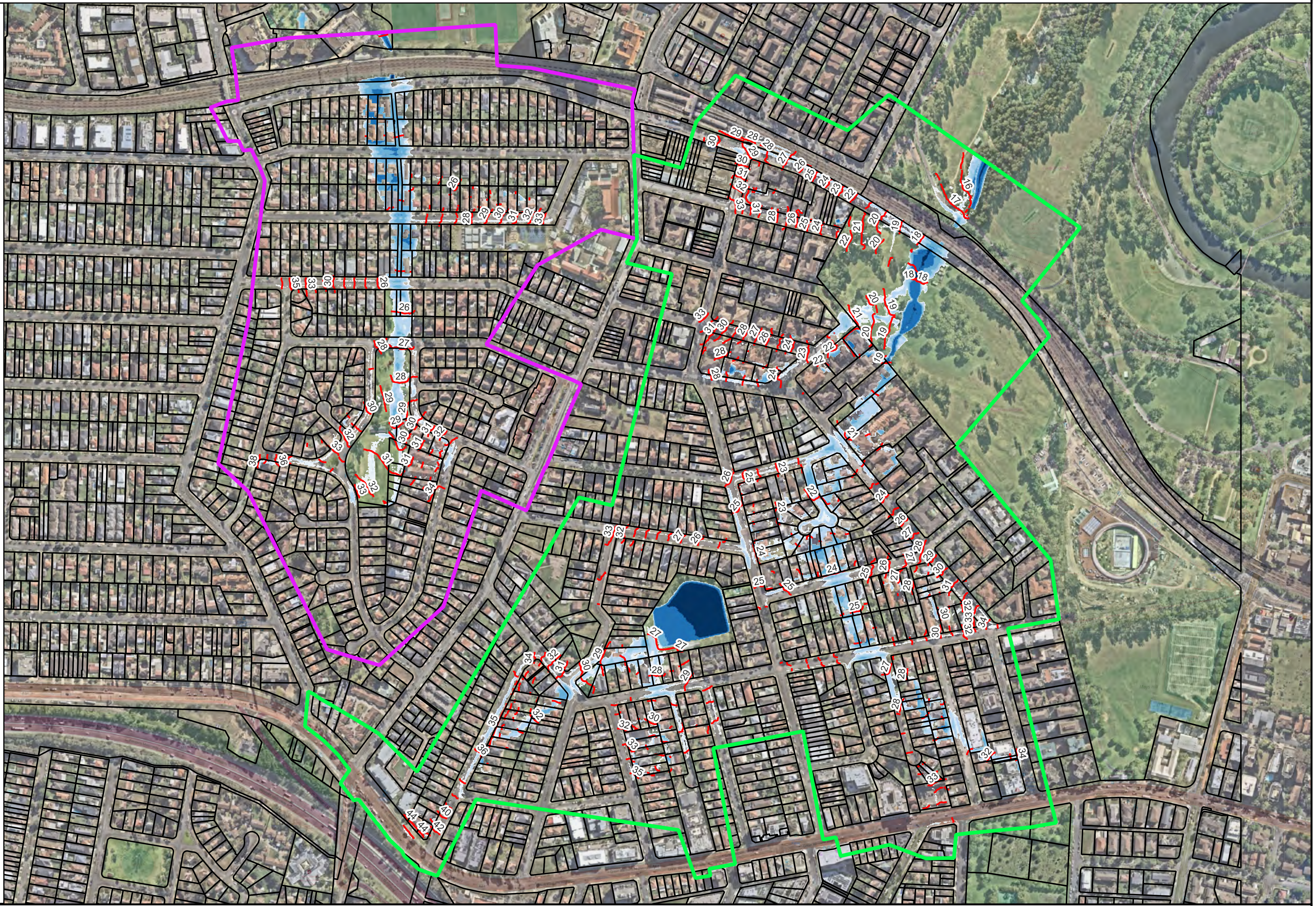
APPENDIX B FLOOD MAPS

Figure B-1 - 5% AEP Flood Depths with Flood Level Contours
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary
- Flood Level Contours (mAHD)

Flood Depths (m)
- <= 0.05 (not shown)
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- > 2.00



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0 200 400 600 800 m

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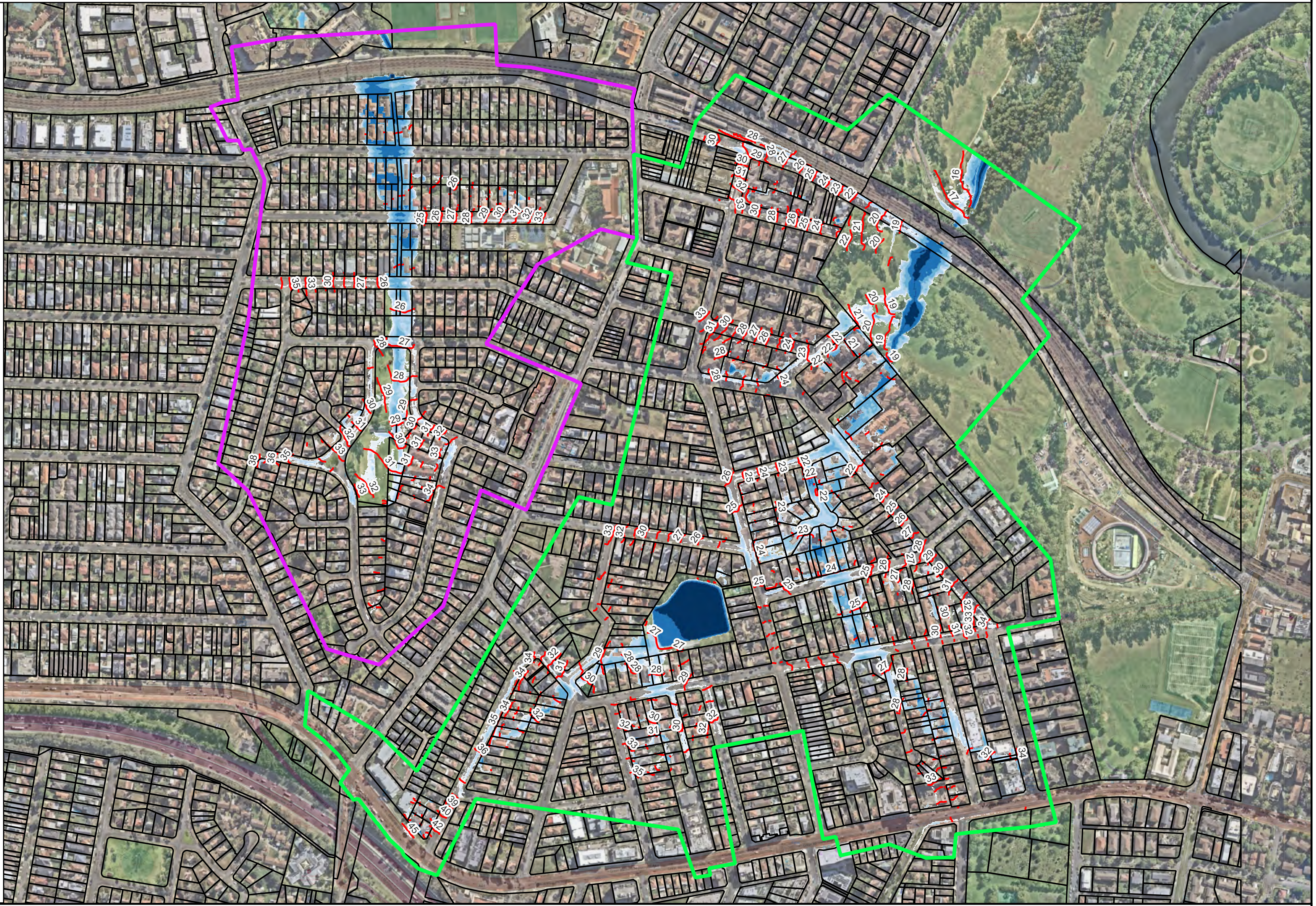
Figure B-2 - 1% AEP Flood Depths with Flood Level Contours
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary
- Flood Level Contours (mAHD)

Flood Depths (m)
- <= 0.05 (not shown)
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- > 2.00



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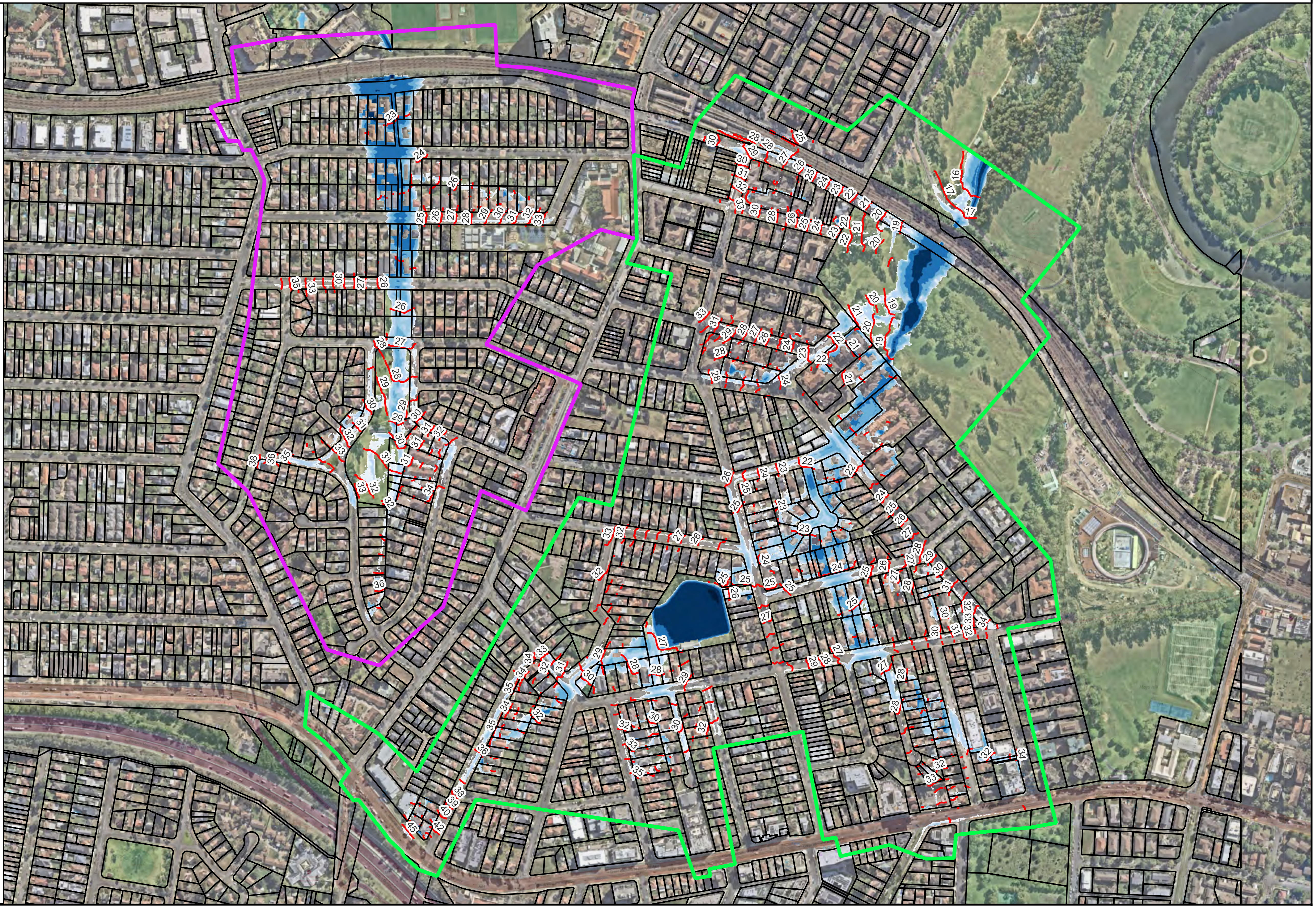
ARCADIS

Figure B-3 - 1% AEP with CC Flood Depths with Flood Level Contours
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary
- Flood Level Contours (mAHD)

Flood Depths (m)
- <= 0.05 (not shown)
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- > 2.00



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0 200 400 600 800 m

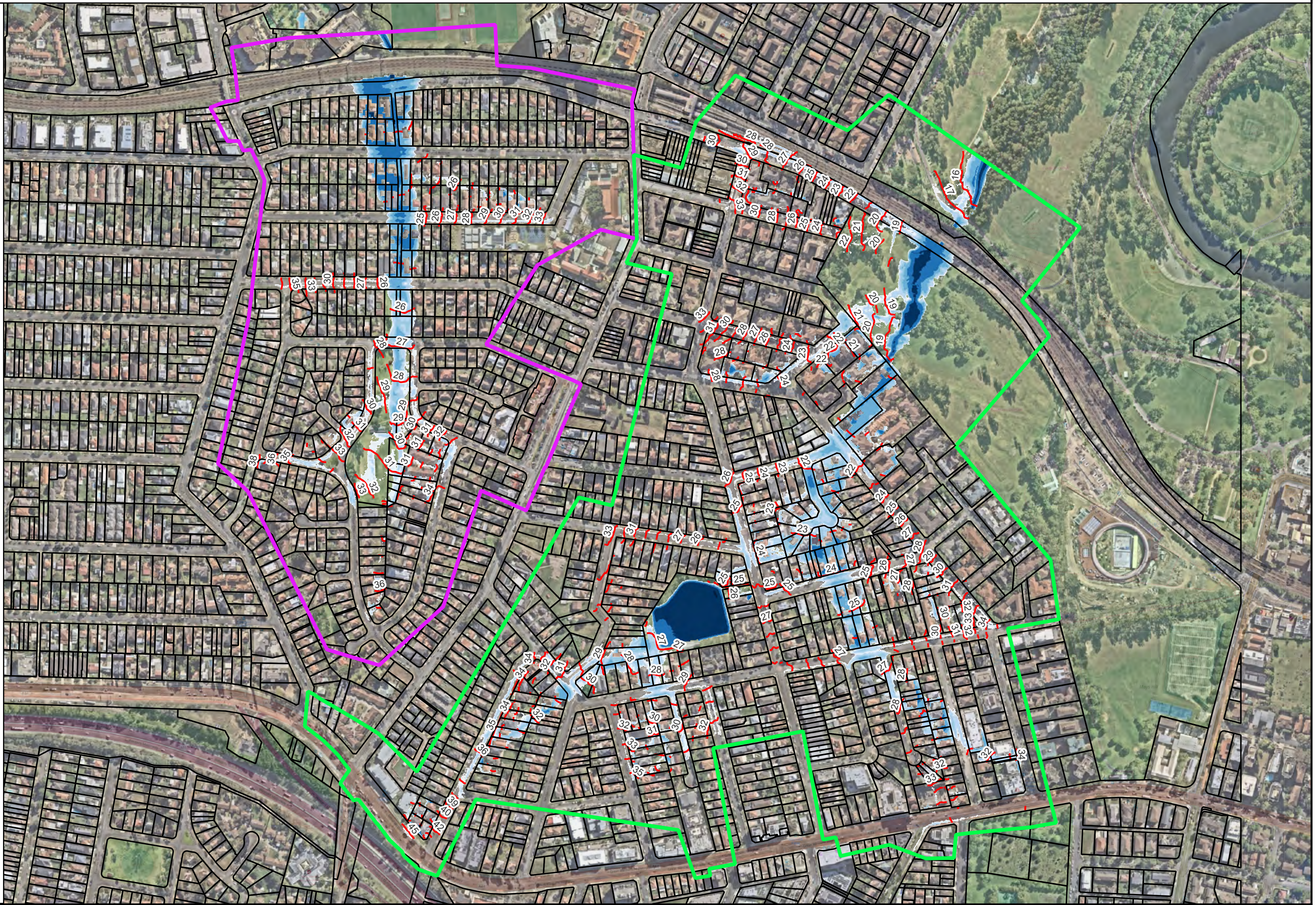
ARCADIS

Figure B-4 - 0.5% AEP Flood Depths with Flood Level Contours
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary
- Flood Level Contours (mAHD)

Flood Depths (m)
- <= 0.05 (not shown)
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- > 2.00



N

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0 200 400 600 800 m

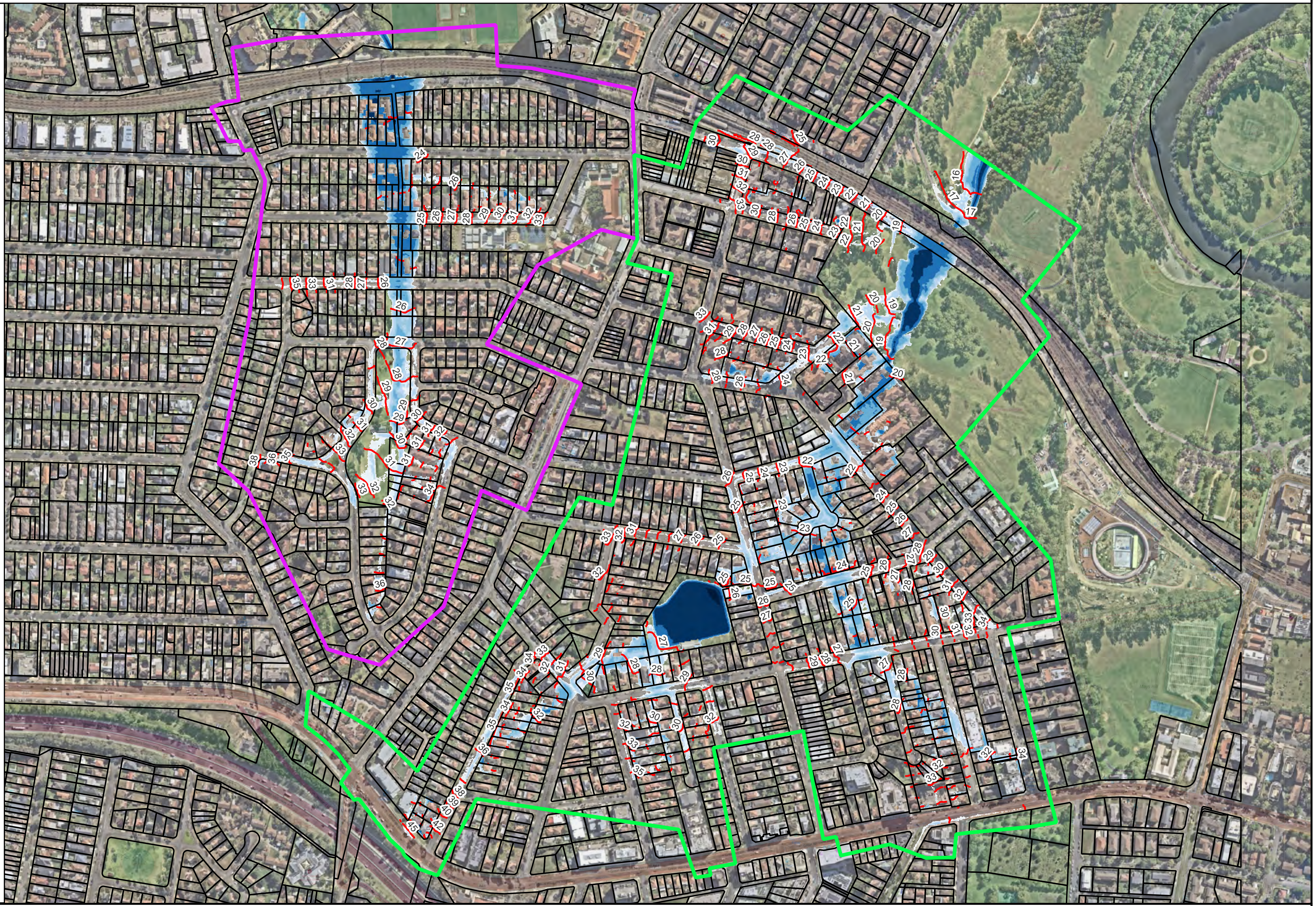
ARCADIS

Figure B-5 - 0.2% AEP Flood Depths with Flood Level Contours
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary
- Flood Level Contours (mAHD)

Flood Depths (m)
- <= 0.05 (not shown)
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- > 2.00



N

0 200 400 600 800 m

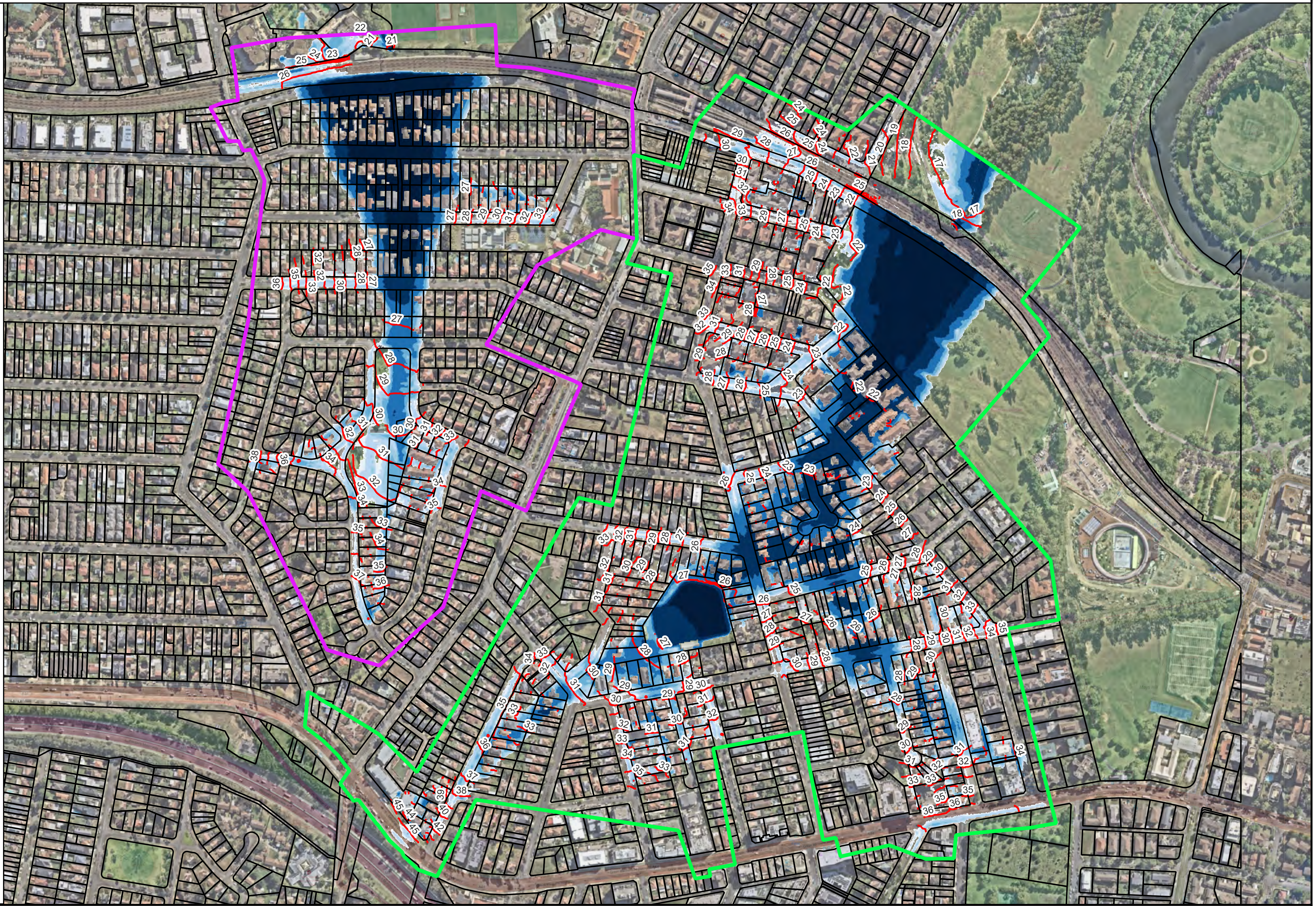
ARCADIS

Figure B-6 - PMF Flood Depths with Flood Level Contours
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary
- Flood Level Contours (mAHD)

Flood Depths (m)
- <= 0.05 (not shown)
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- > 2.00



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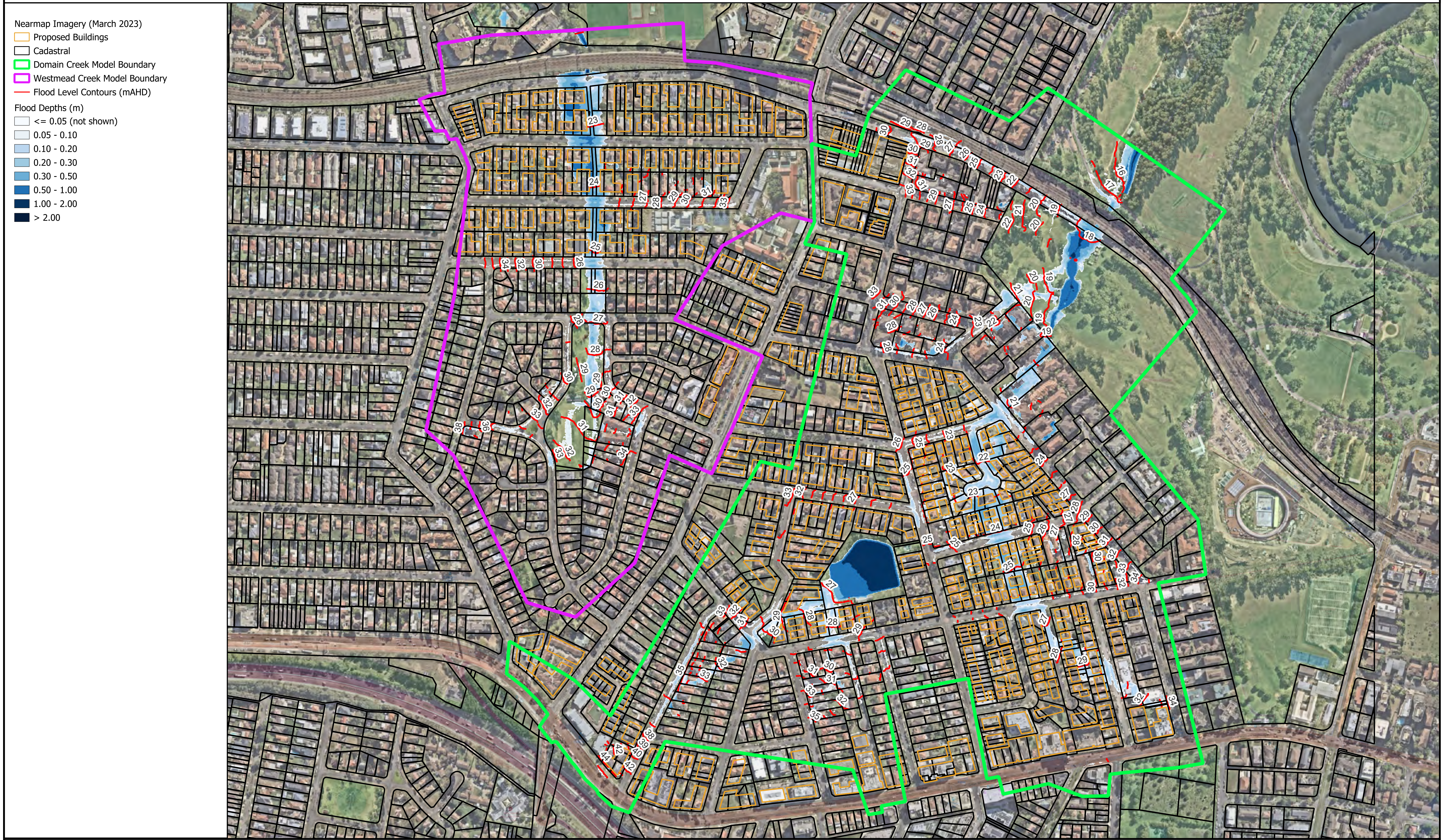
0 200 400 600 800 m

ARCADIS

Figure B-7 - 5% AEP Flood Depths with Flood Level Contours
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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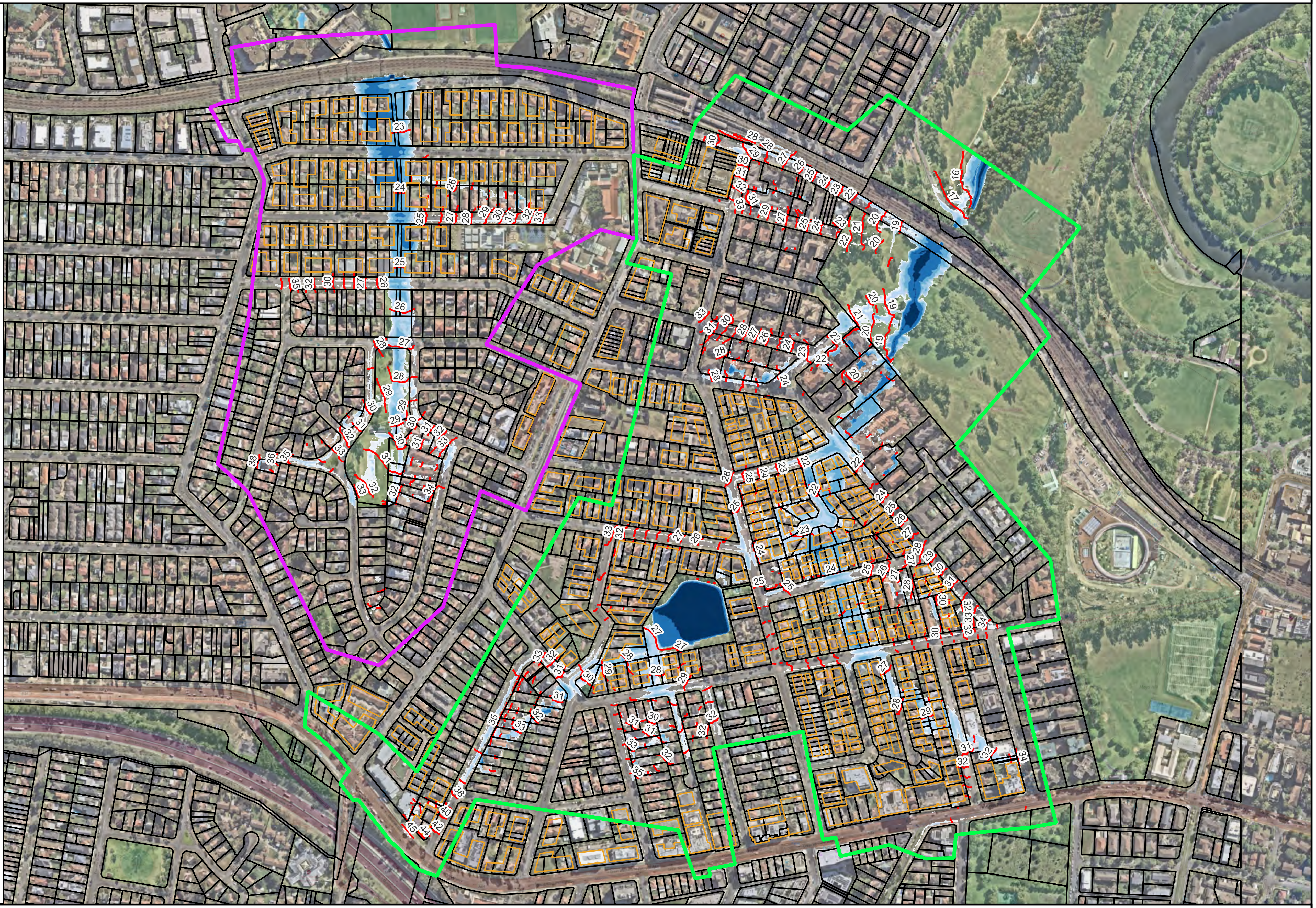
ARCADIS

Figure B-8 - 1% AEP Flood Depths with Flood Level Contours
Proposed Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Proposed Buildings
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary
- Flood Level Contours (mAHD)

Flood Depths (m)
- <= 0.05 (not shown)
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- > 2.00



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0 200 400 600 800 m

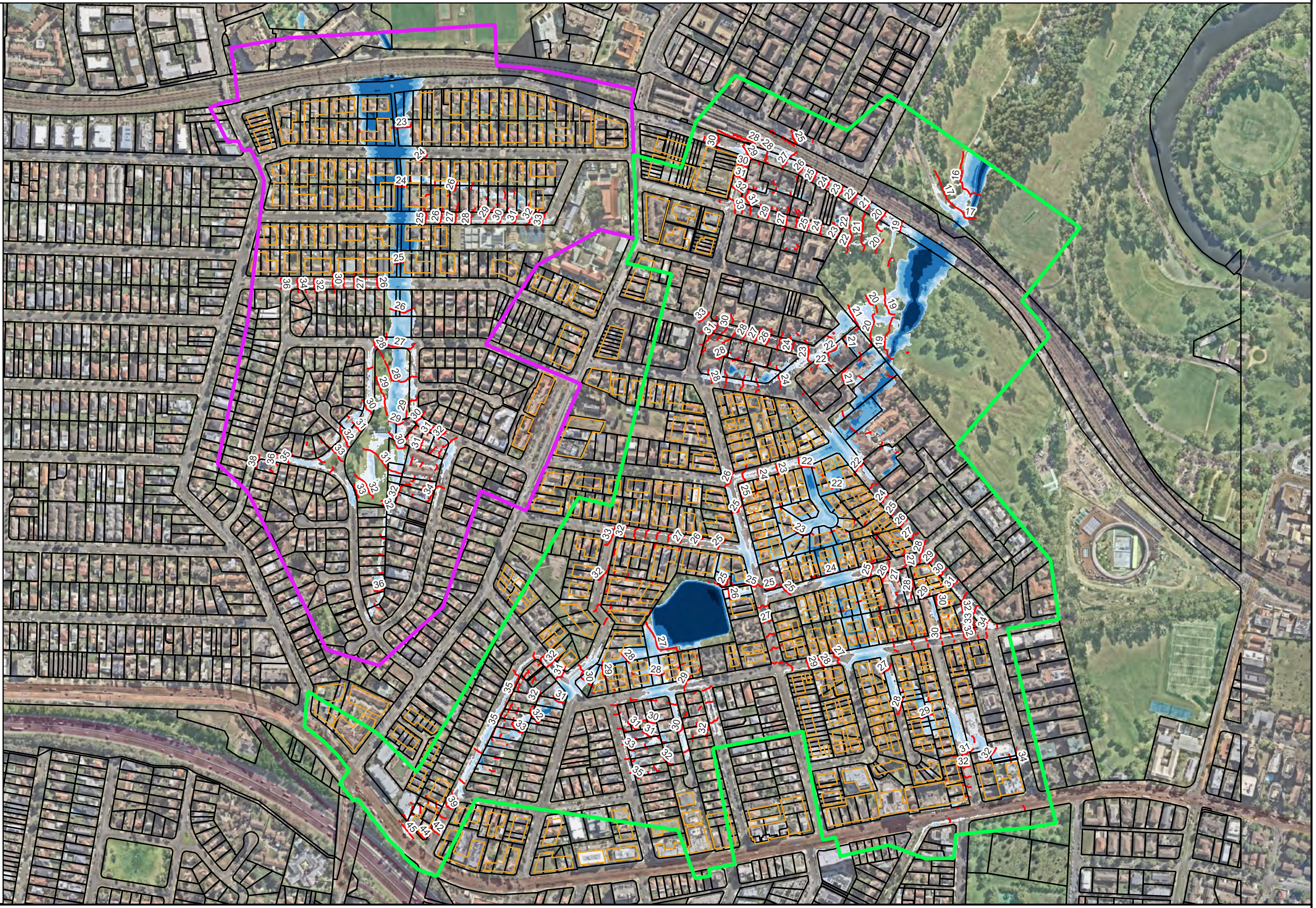
ARCADIS

Figure B-9 - 1% AEP with CC Flood Depths with Flood Level Contours
Proposed Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Proposed Buildings
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary
- Flood Level Contours (mAHD)

Flood Depths (m)
- <= 0.05 (not shown)
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- > 2.00



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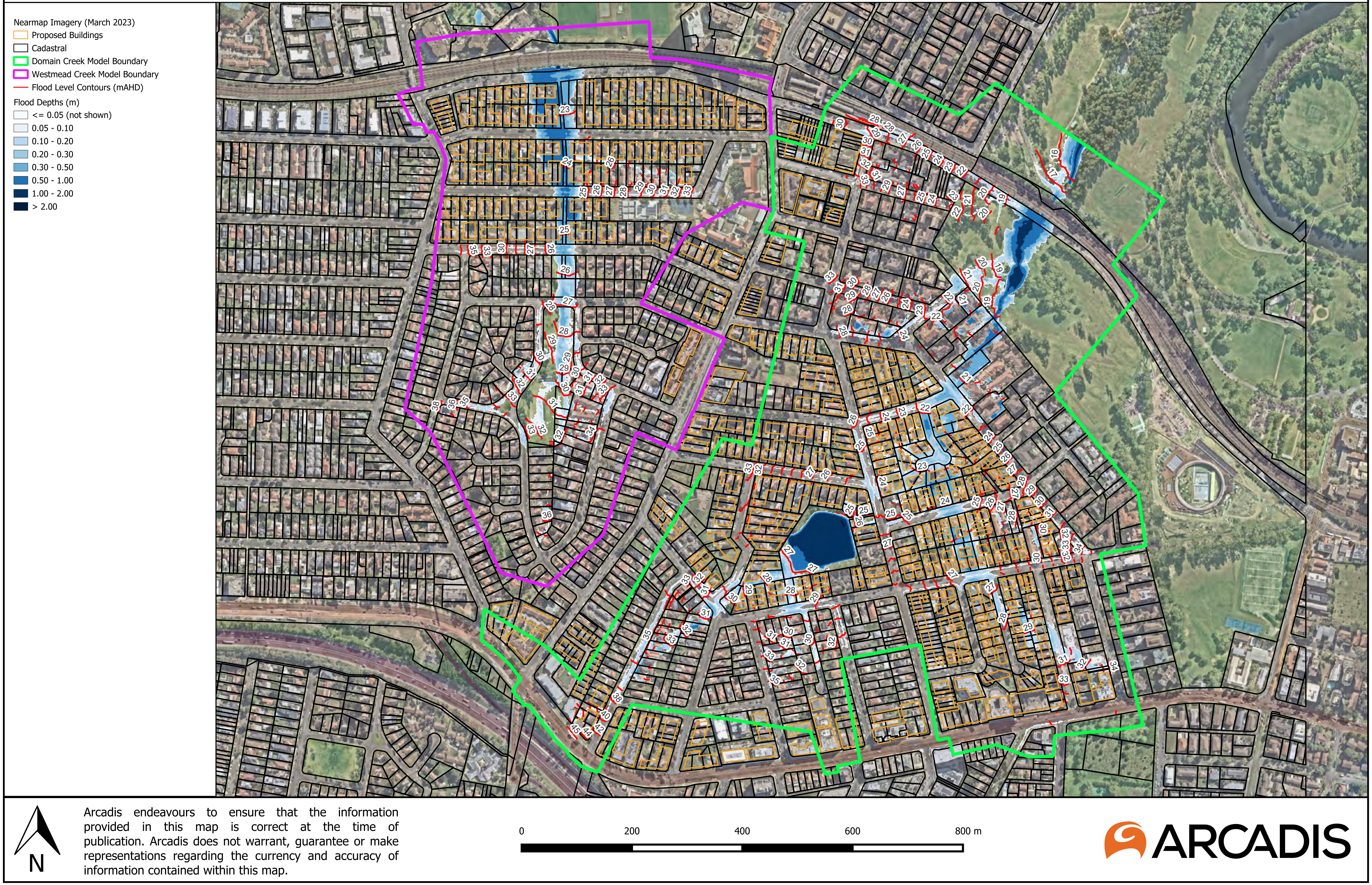
0 200 400 600 800 m

ARCADIS

Figure B-10 - 0.5% AEP Flood Depths with Flood Level Contours
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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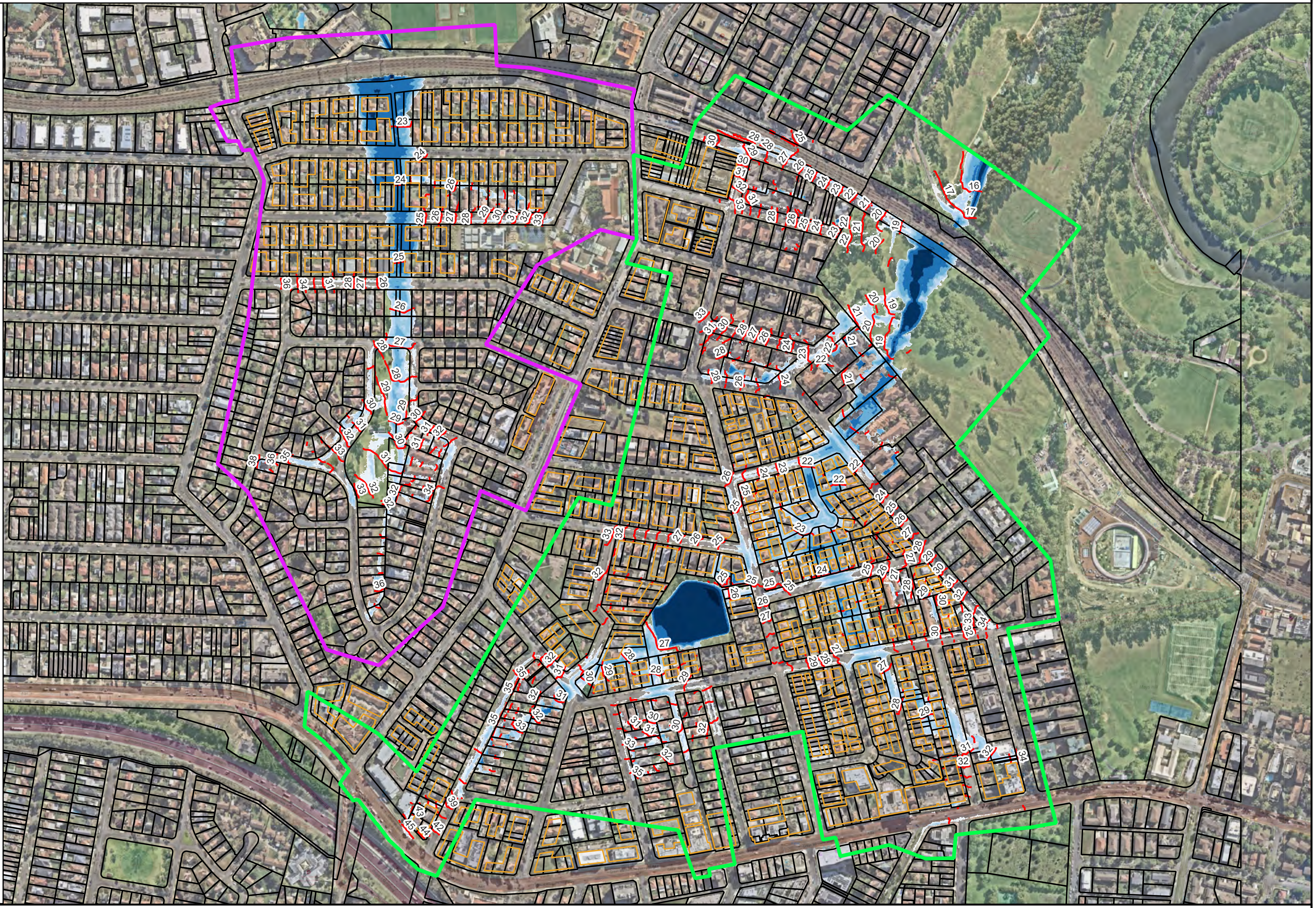
ARCADIS

Figure B-11 - 0.2% AEP Flood Depths with Flood Level Contours
Proposed Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Proposed Buildings
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary
- Flood Level Contours (mAHD)

Flood Depths (m)
- <= 0.05 (not shown)
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- > 2.00



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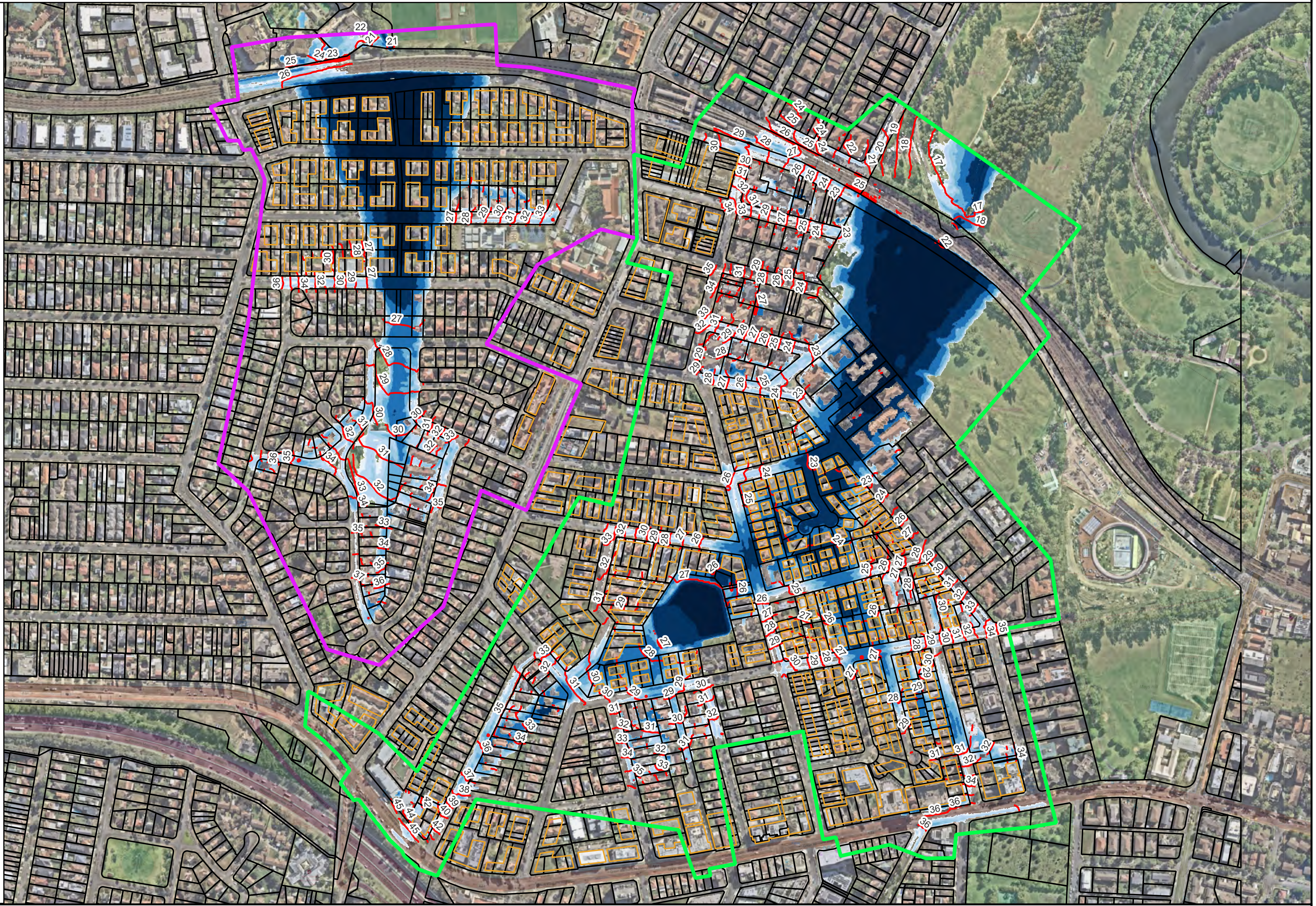
0 200 400 600 800 m

ARCADIS

Figure B-12 - PMF Flood Depths with Flood Level Contours
Proposed Conditions

Westmead South
30181752
Cumberland City Council



Nearmap Imagery (March 2023)
- Proposed Buildings
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary
- Flood Level Contours (mAHD)

Flood Depths (m)
- <= 0.05 (not shown)
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- > 2.00

N

0 200 400 600 800 m

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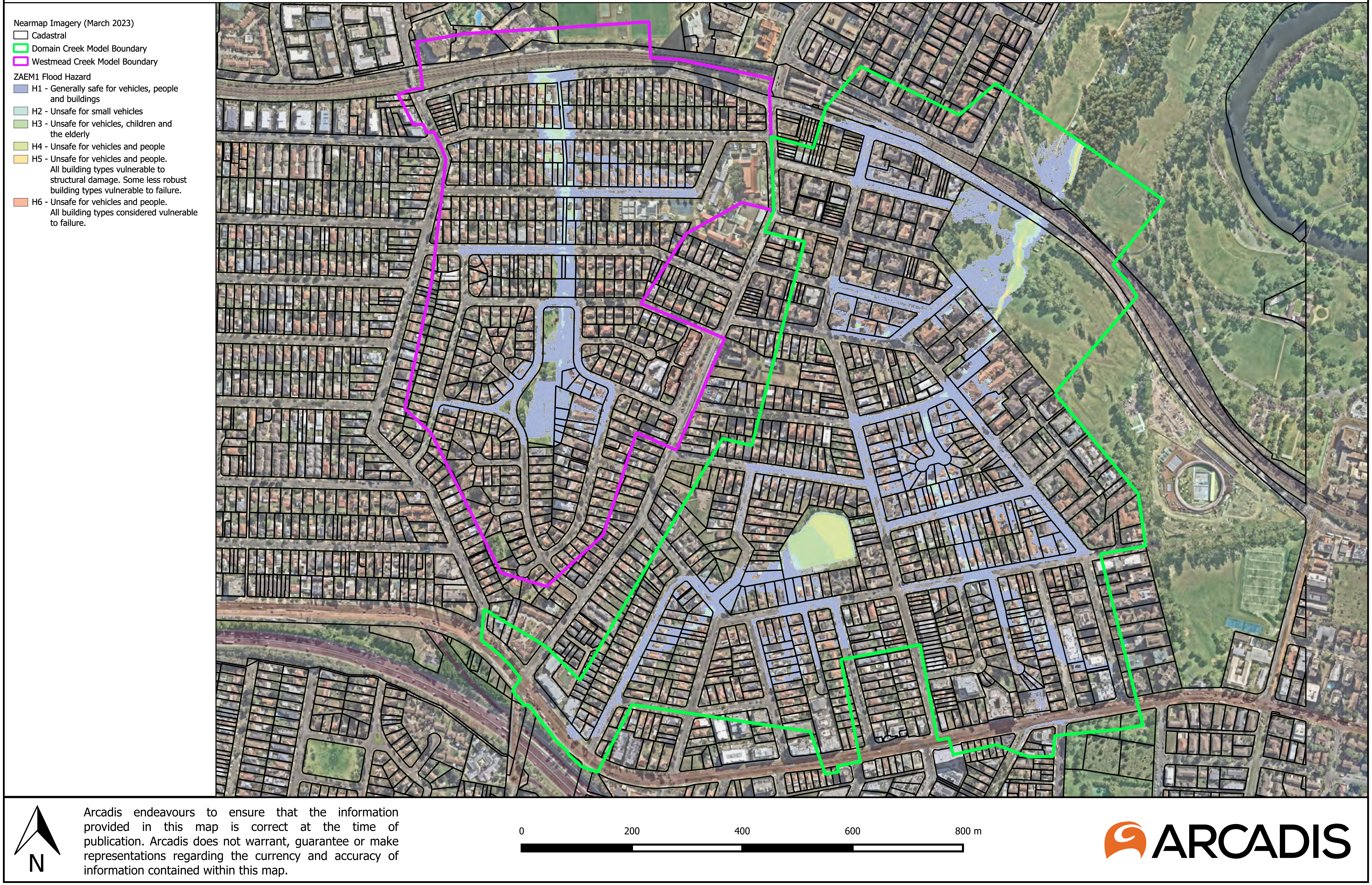
ARCADIS

Figure B-13 - 5% AEP Flood Hazard Categories
Existing Conditions

Westmead South
30181752
Cumberland City Council



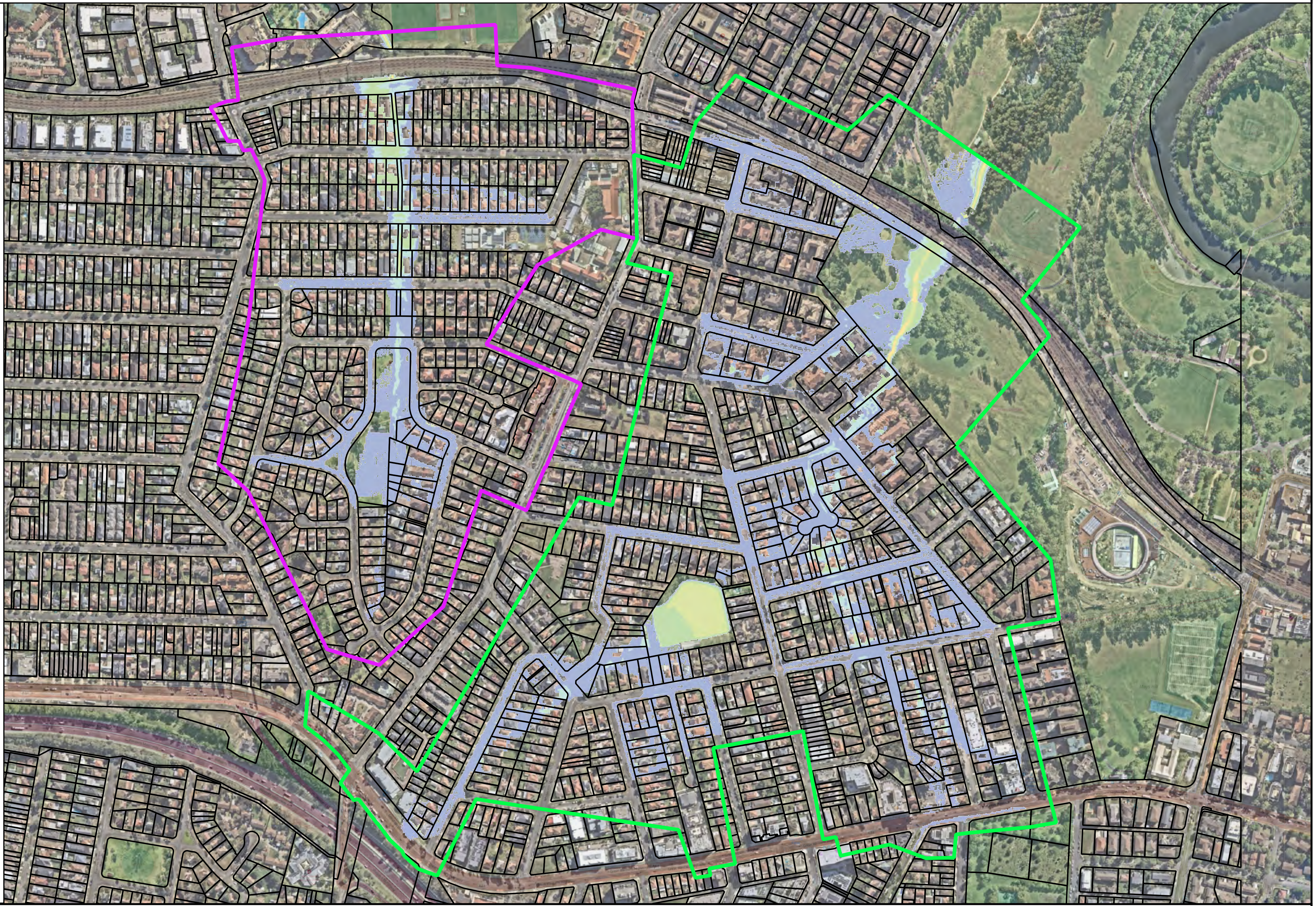
ARCADIS

Figure B-14 - 1% AEP Flood Hazard Categories
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary

ZAEM1 Flood Hazard
- H1 - Generally safe for vehicles, people and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for vehicles and people
- H5 - Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.



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0 200 400 600 800 m

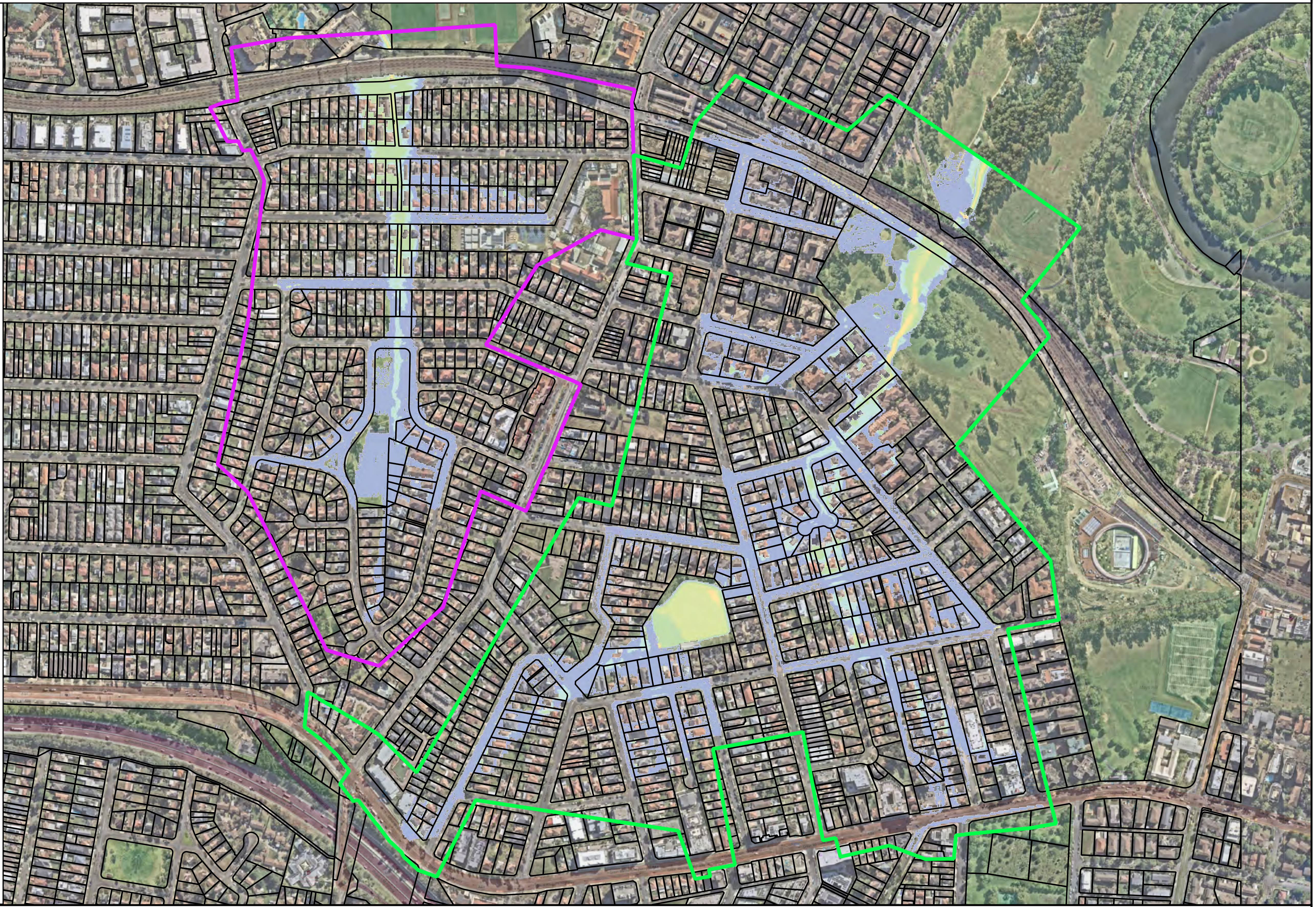
ARCADIS

Figure B-15 - 1% AEP with CC Flood Hazard Categories
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary

ZAEM1 Flood Hazard
- H1 - Generally safe for vehicles, people and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for vehicles and people
- H5 - Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.



N

0 200 400 600 800 m

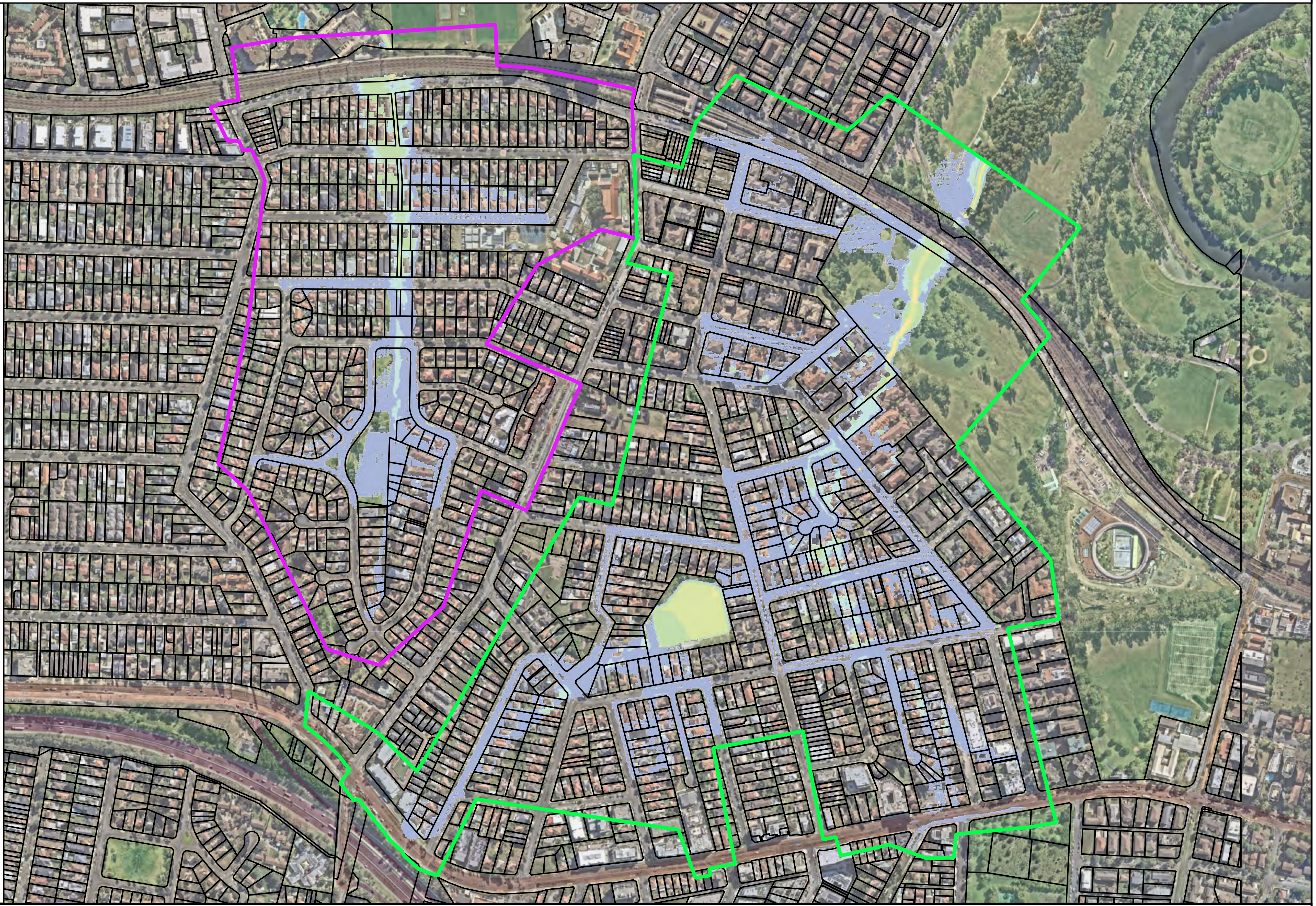
ARCADIS

Figure B-16 - 0.5% AEP Flood Hazard Categories
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary

ZAEM1 Flood Hazard
- H1 - Generally safe for vehicles, people and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for vehicles and people
- H5 - Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.



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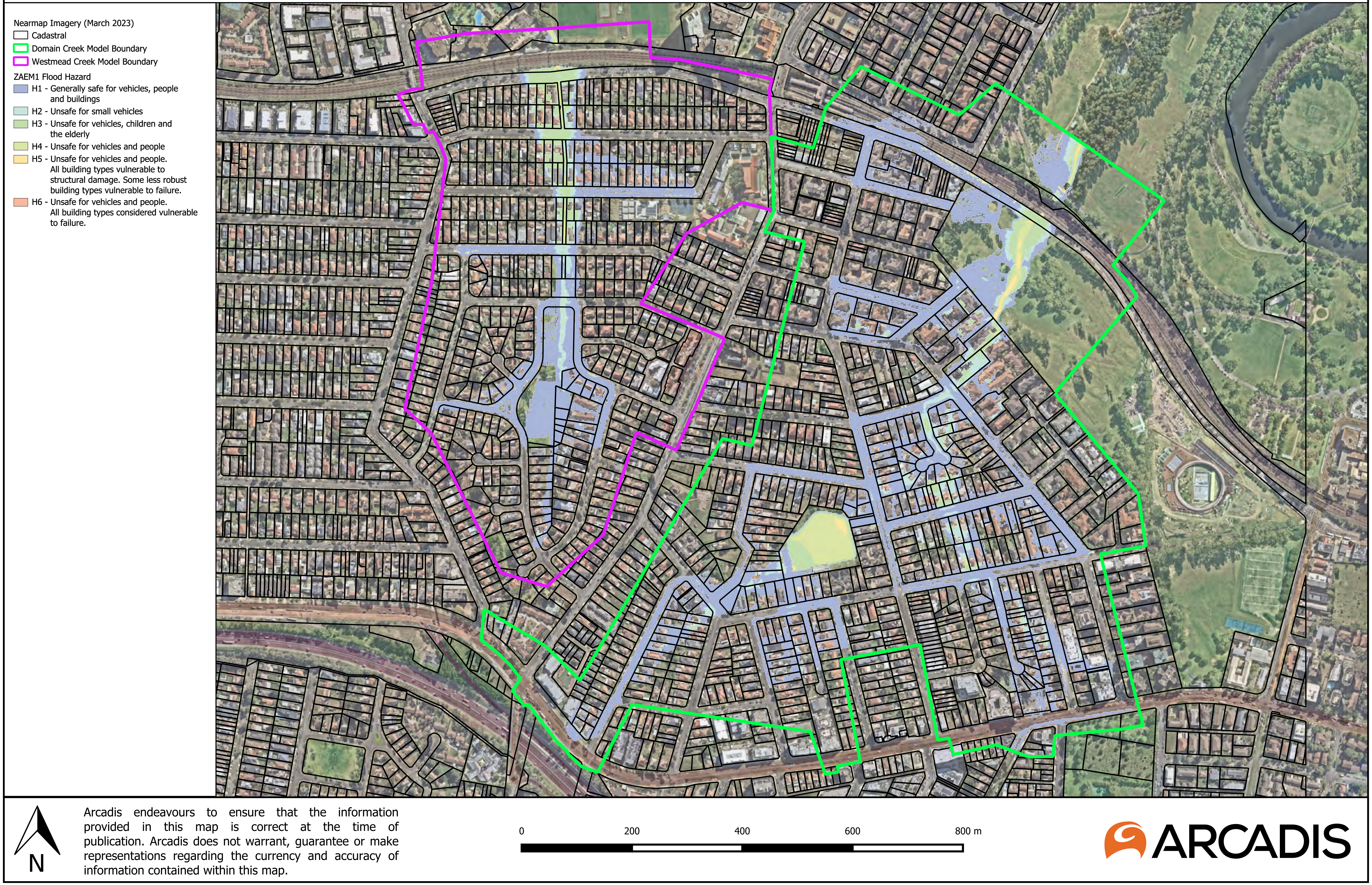
0 200 400 600 800 m

ARCADIS

Figure B-17 - 0.2% AEP Flood Hazard Categories
Existing Conditions

Westmead South
30181752
Cumberland City Council



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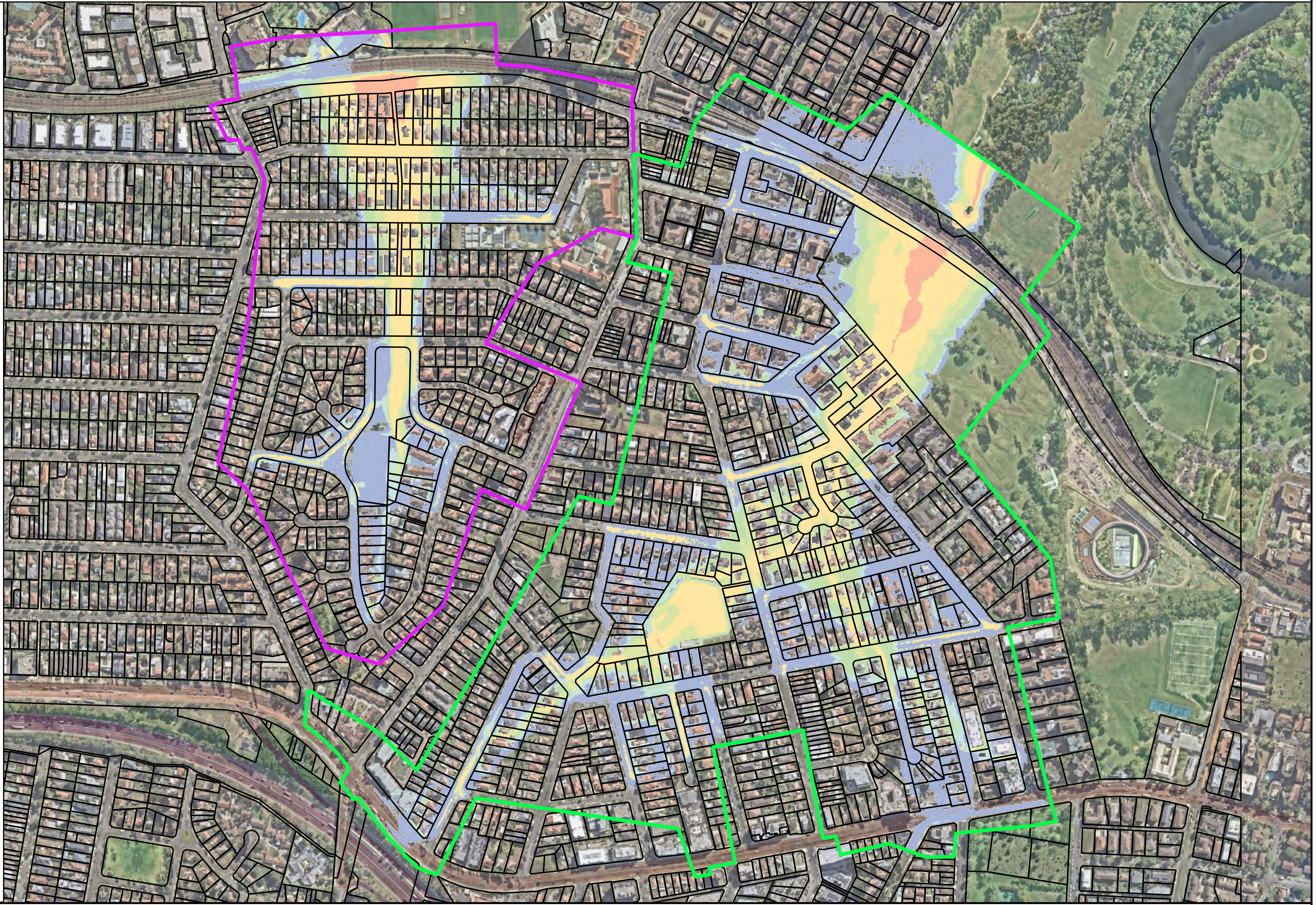
ARCADIS

Figure B-18 - PMF Flood Hazard Categories
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
Cadastral
Domain Creek Model Boundary
Westmead Creek Model Boundary
ZAEM1 Flood Hazard
H1 - Generally safe for vehicles, people and buildings
H2 - Unsafe for small vehicles
H3 - Unsafe for vehicles, children and the elderly
H4 - Unsafe for vehicles and people
H5 - Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.



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0 200 400 600 800 m

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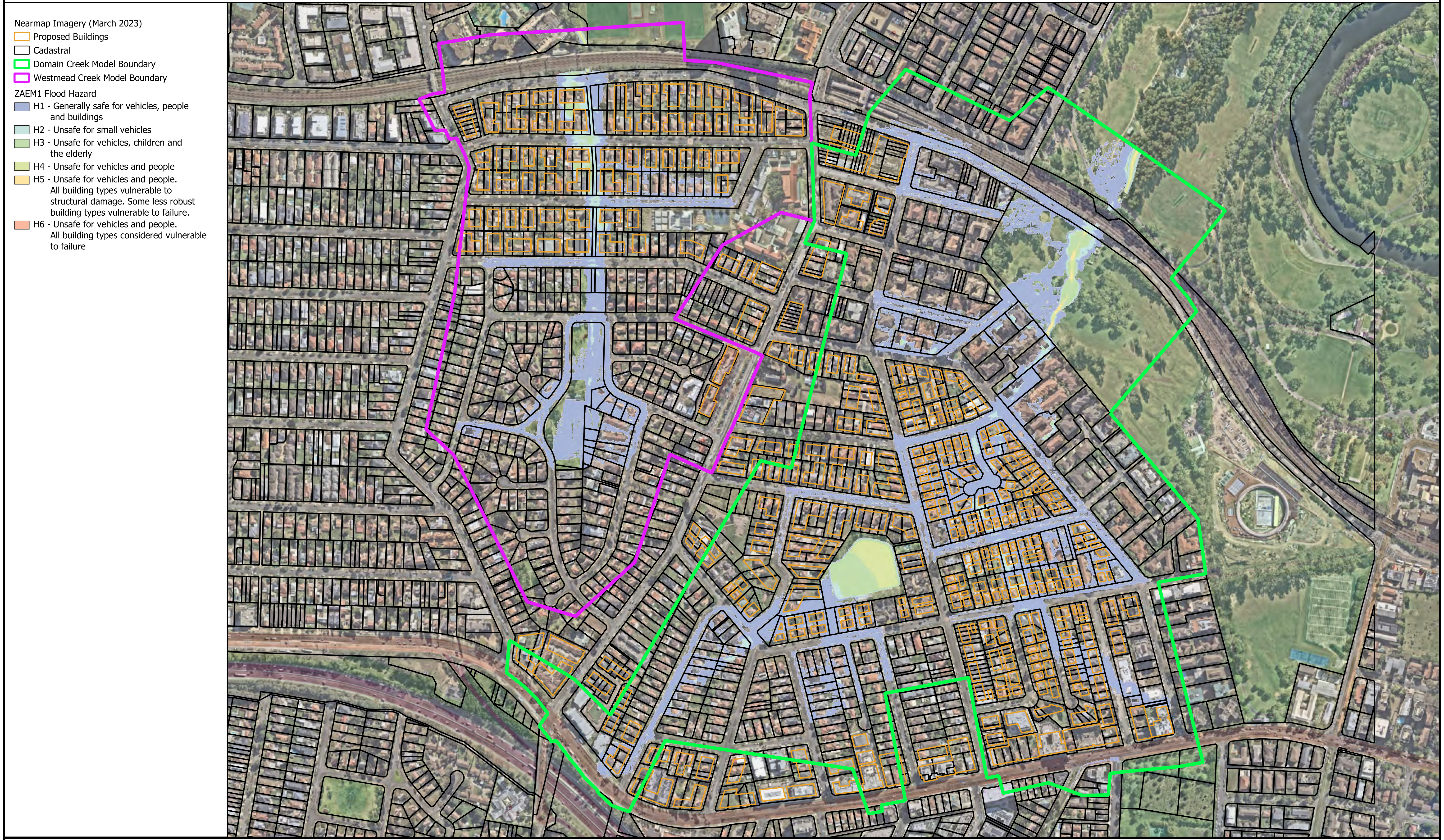
Figure B-19 - 5% AEP Flood Hazard Categories
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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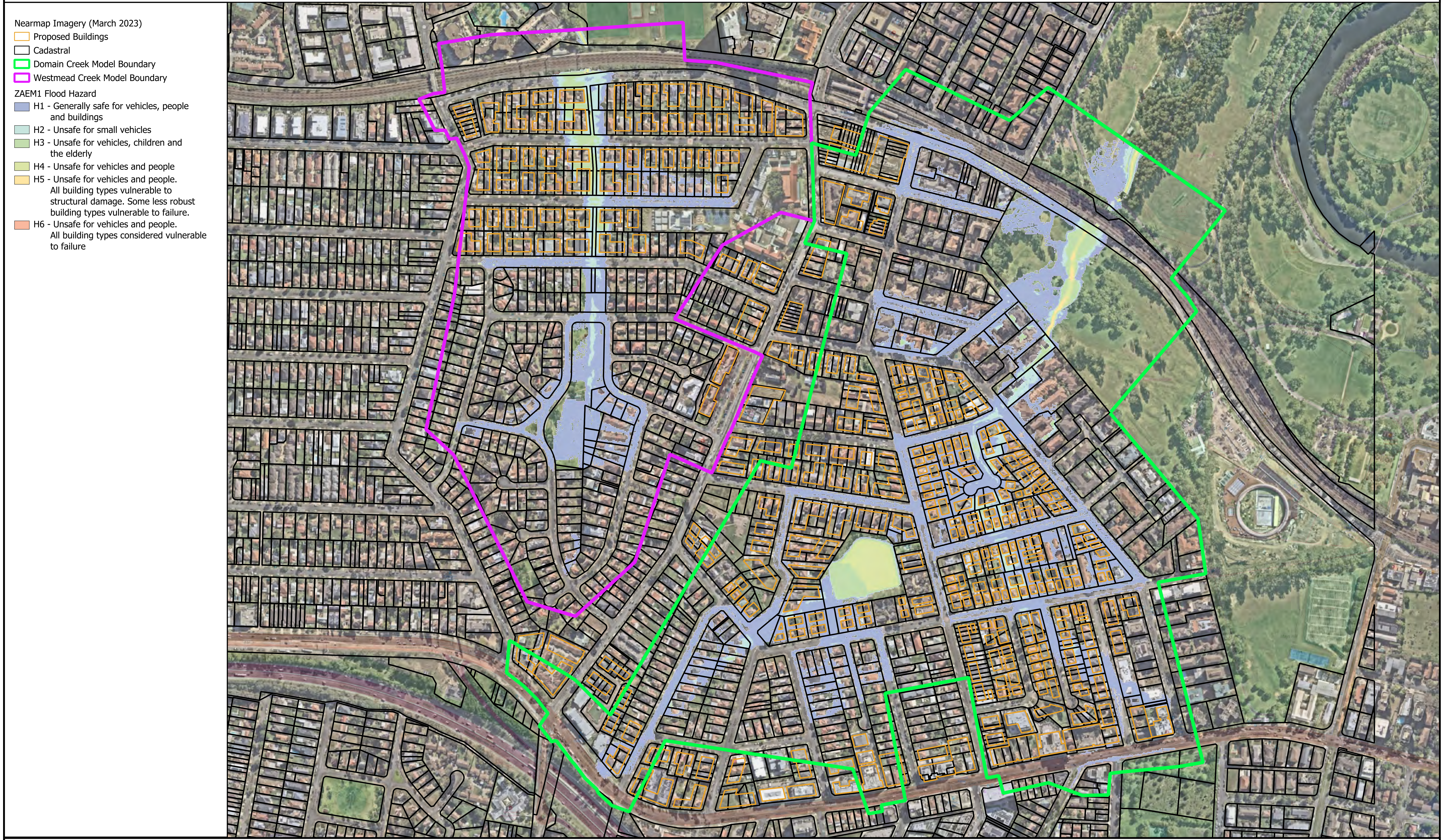
ARCADIS

Figure B-20 - 1% AEP Flood Hazard Categories
Proposed Conditions

Westmead South
30181752
Cumberland City Council

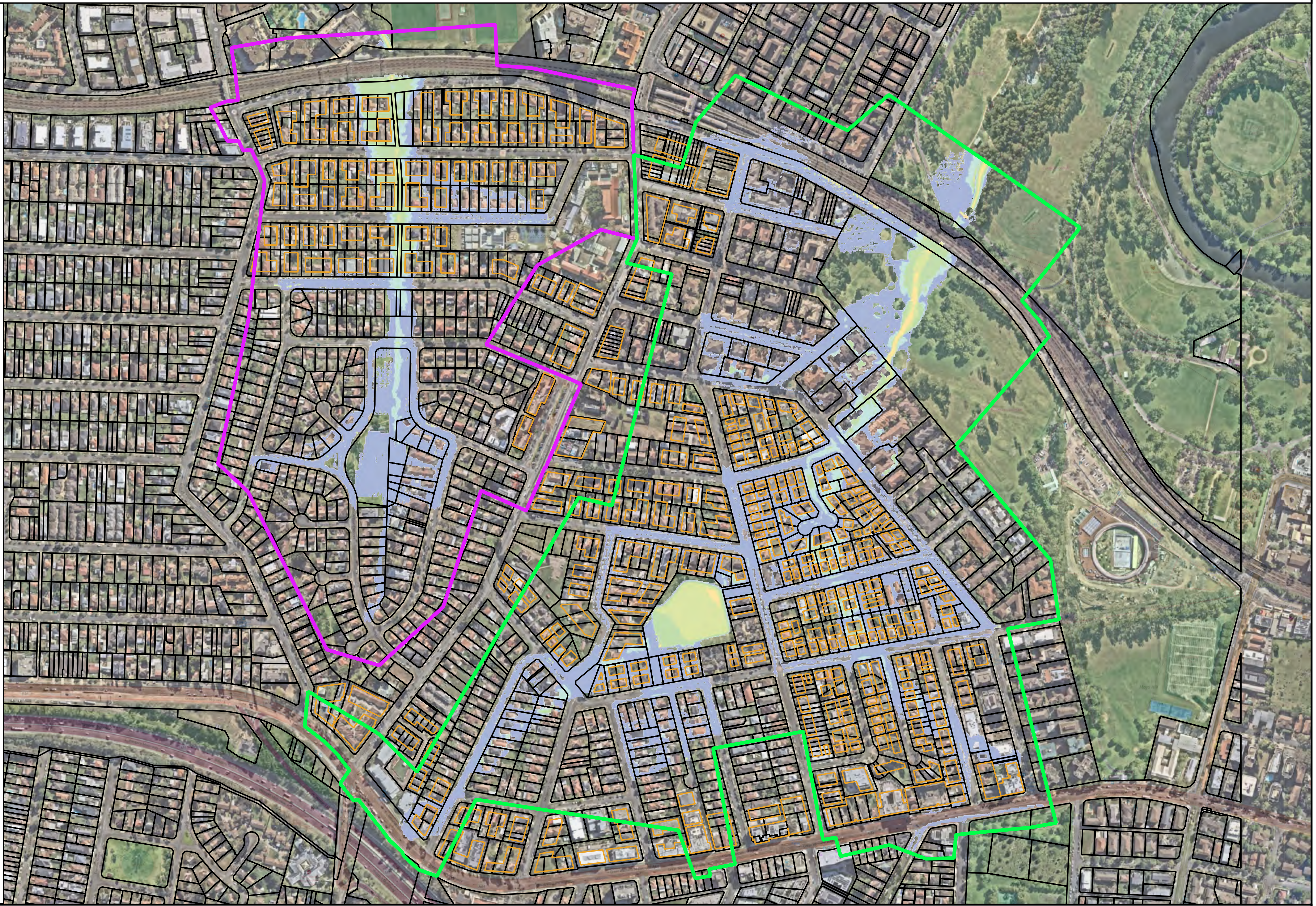


ARCADIS

Figure B-21 - 1% AEP with CC Flood Hazard Categories
Proposed Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
Proposed Buildings
Cadastral
Domain Creek Model Boundary
Westmead Creek Model Boundary
ZAEM1 Flood Hazard
H1 - Generally safe for vehicles, people and buildings
H2 - Unsafe for small vehicles
H3 - Unsafe for vehicles, children and the elderly
H4 - Unsafe for vehicles and people
H5 - Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure



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0 200 400 600 800 m

ARCADIS

Figure B-22 - 0.5% AEP Flood Hazard Categories
Proposed Conditions

Westmead South
30181752
Cumberland City Council

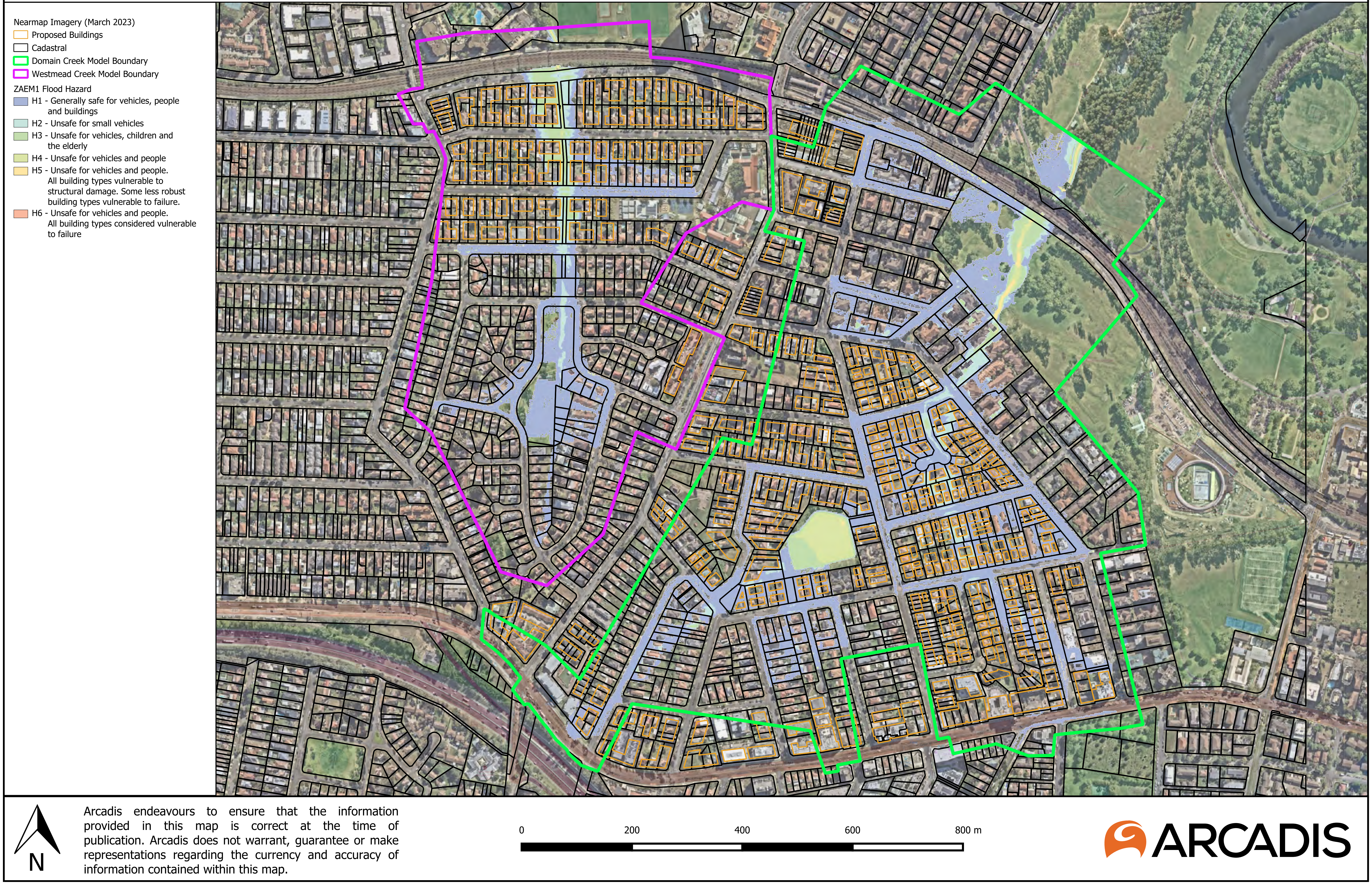

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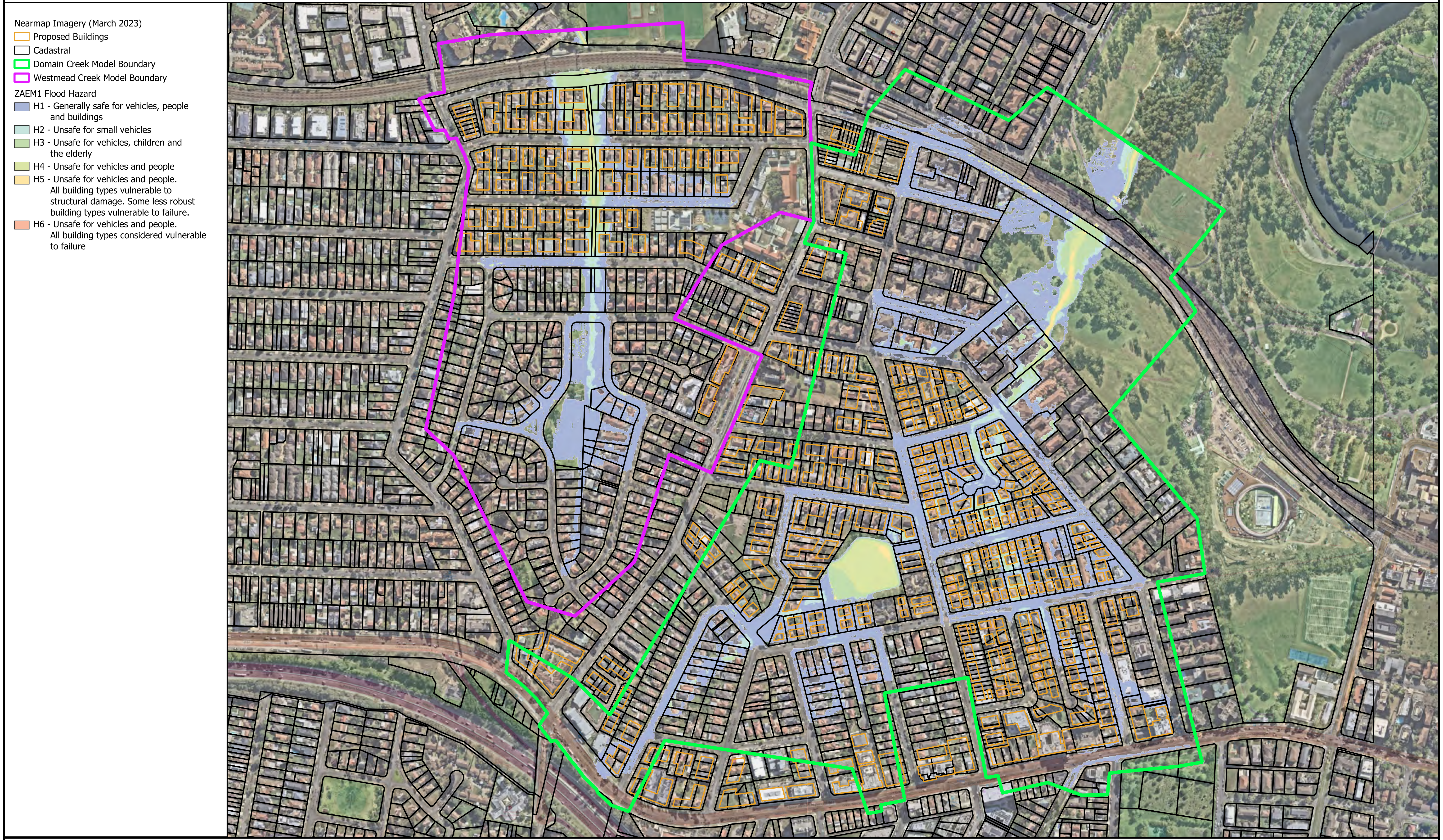
Figure B-23 - 0.2% AEP Flood Hazard Categories
Proposed Conditions

Westmead South
30181752
Cumberland City Council



N

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0 200 400 600 800 m

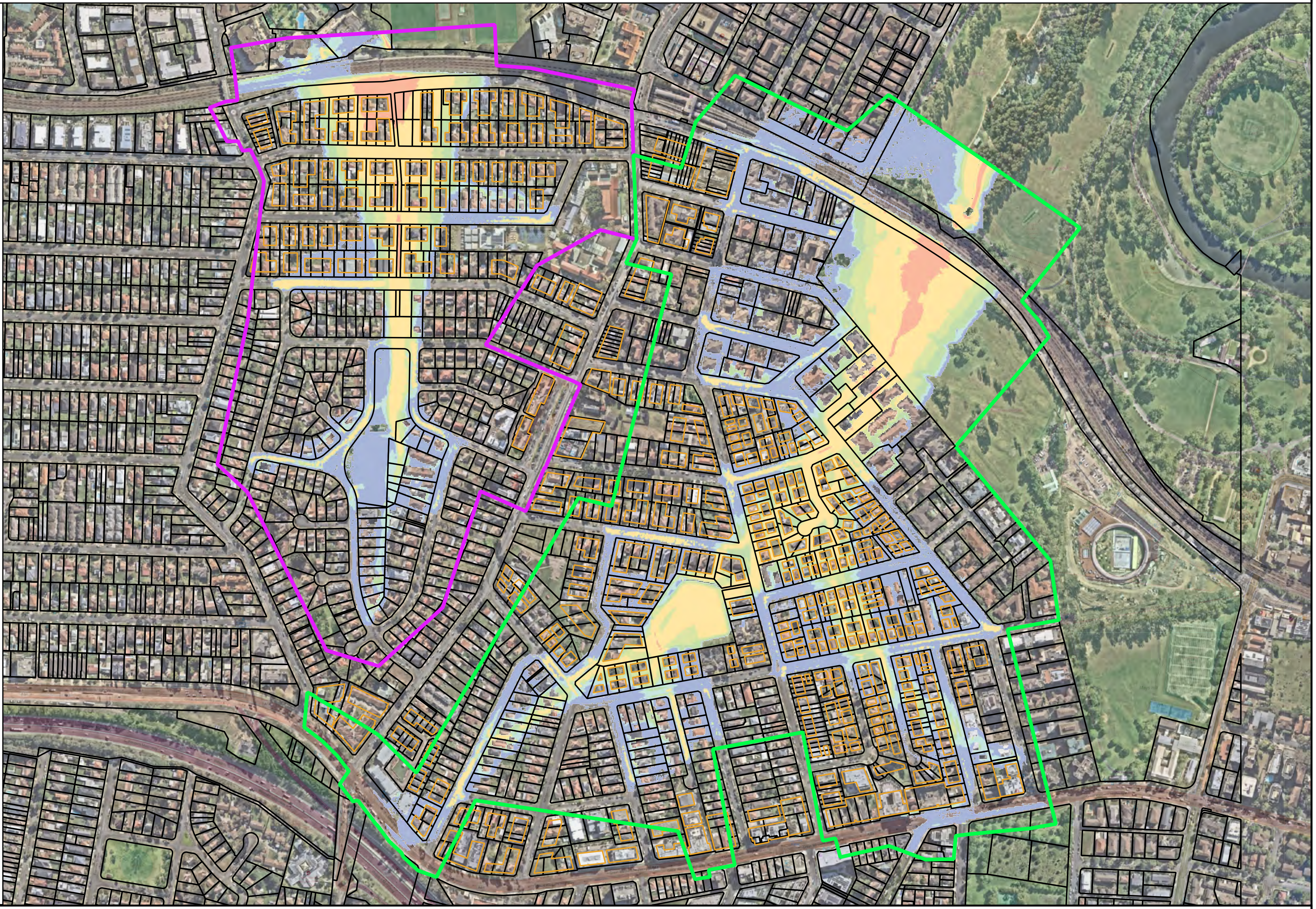
ARCADIS

Figure B-24 - PMF Flood Hazard Categories
Proposed Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Proposed Buildings
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary

ZAEM1 Flood Hazard
- H1 - Generally safe for vehicles, people and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for vehicles and people
- H5 - Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure



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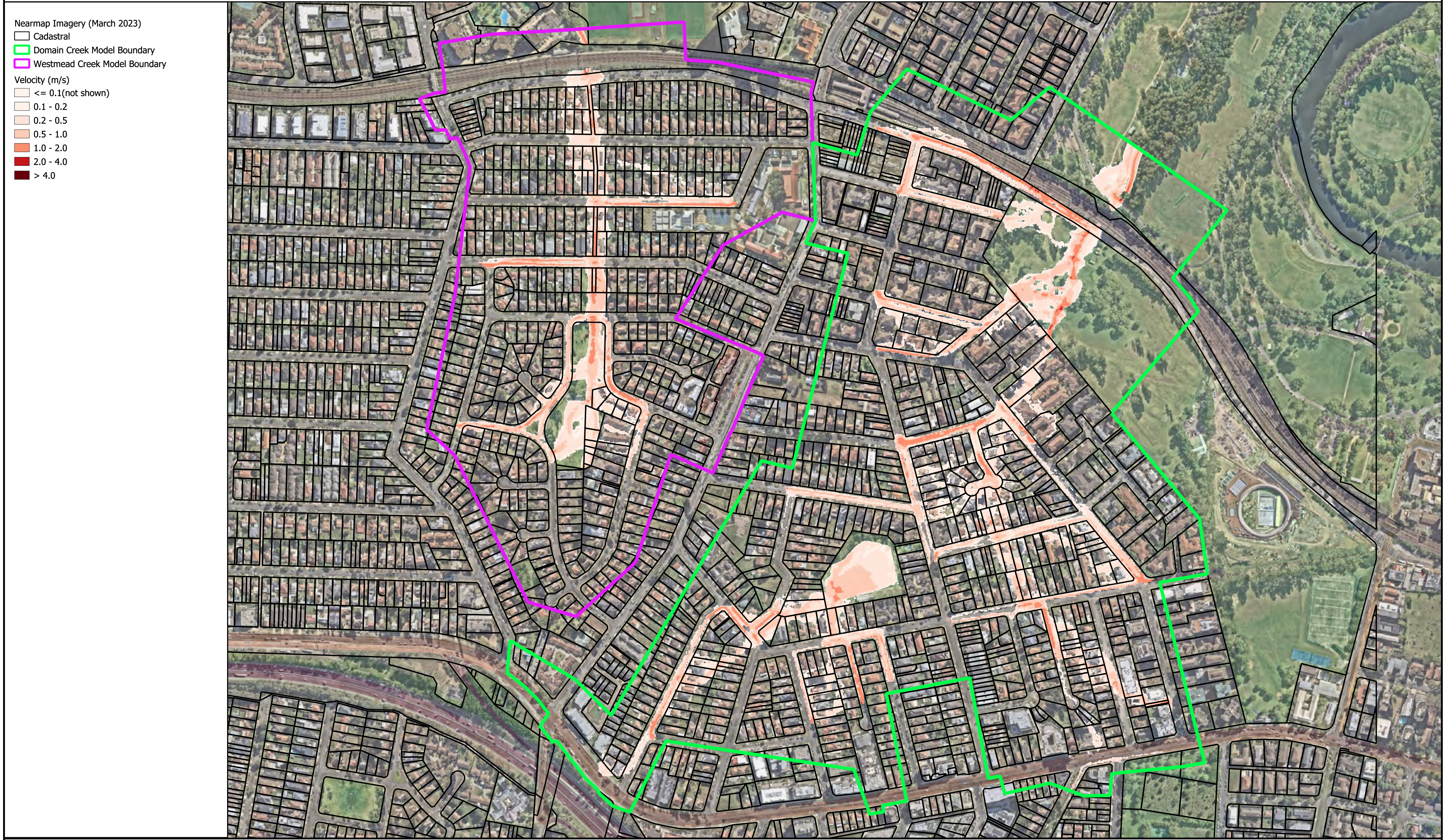
0 200 400 600 800 m

ARCADIS

Figure B-25 - 5% AEP Flow Velocities
Existing Conditions

Westmead South
30181752
Cumberland City Council

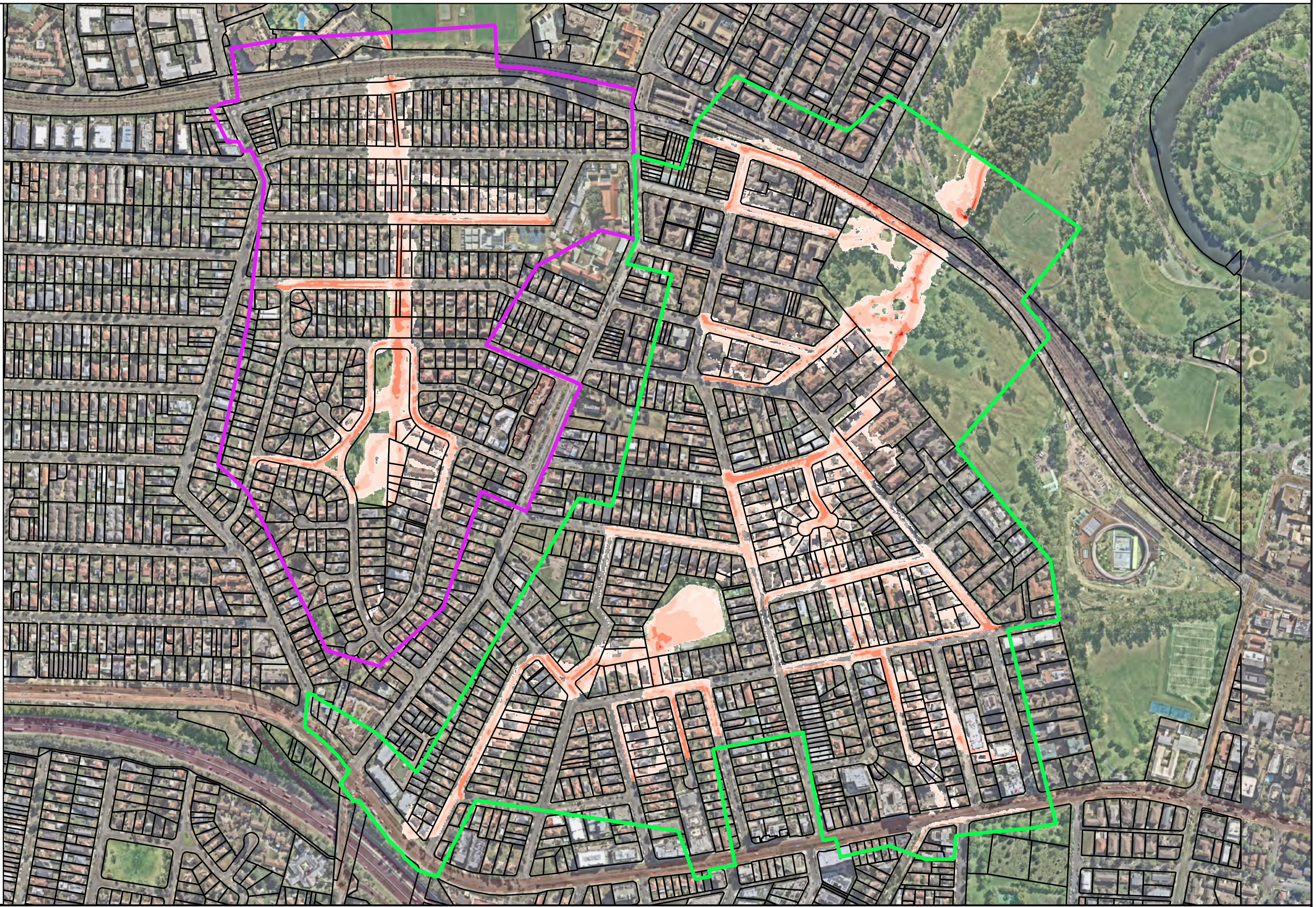


ARCADIS

Figure B-26 - 1% AEP Flow Velocities
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
Cadastral
Domain Creek Model Boundary
Westmead Creek Model Boundary
Velocity (m/s)
<= 0.1(not shown)
0.1 - 0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 4.0
> 4.0



N

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0 200 400 600 800 m

ARCADIS

Figure B-27 - 1% AEP with CC Flow Velocities
Existing Conditions

Westmead South
30181752
Cumberland City Council

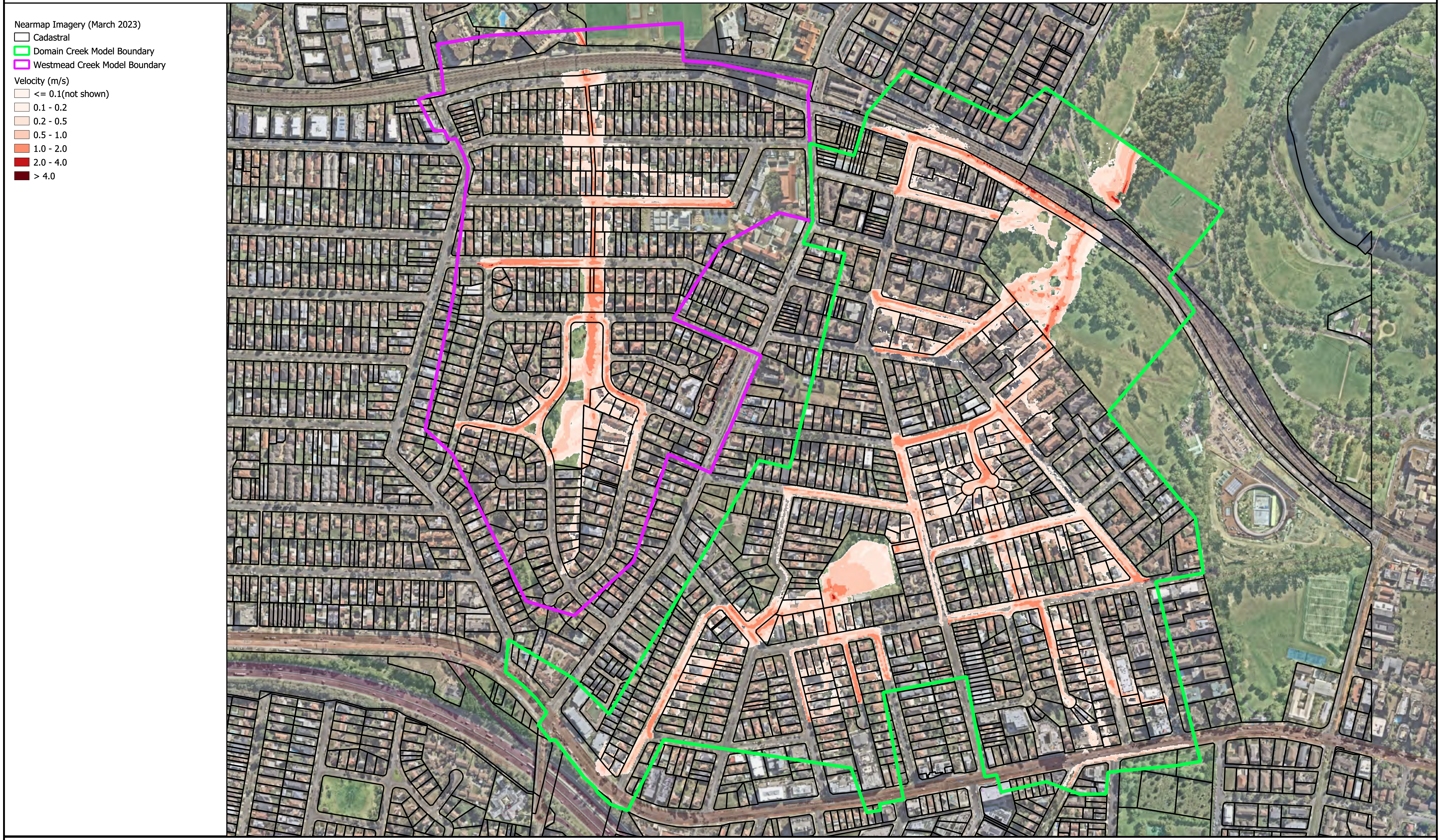
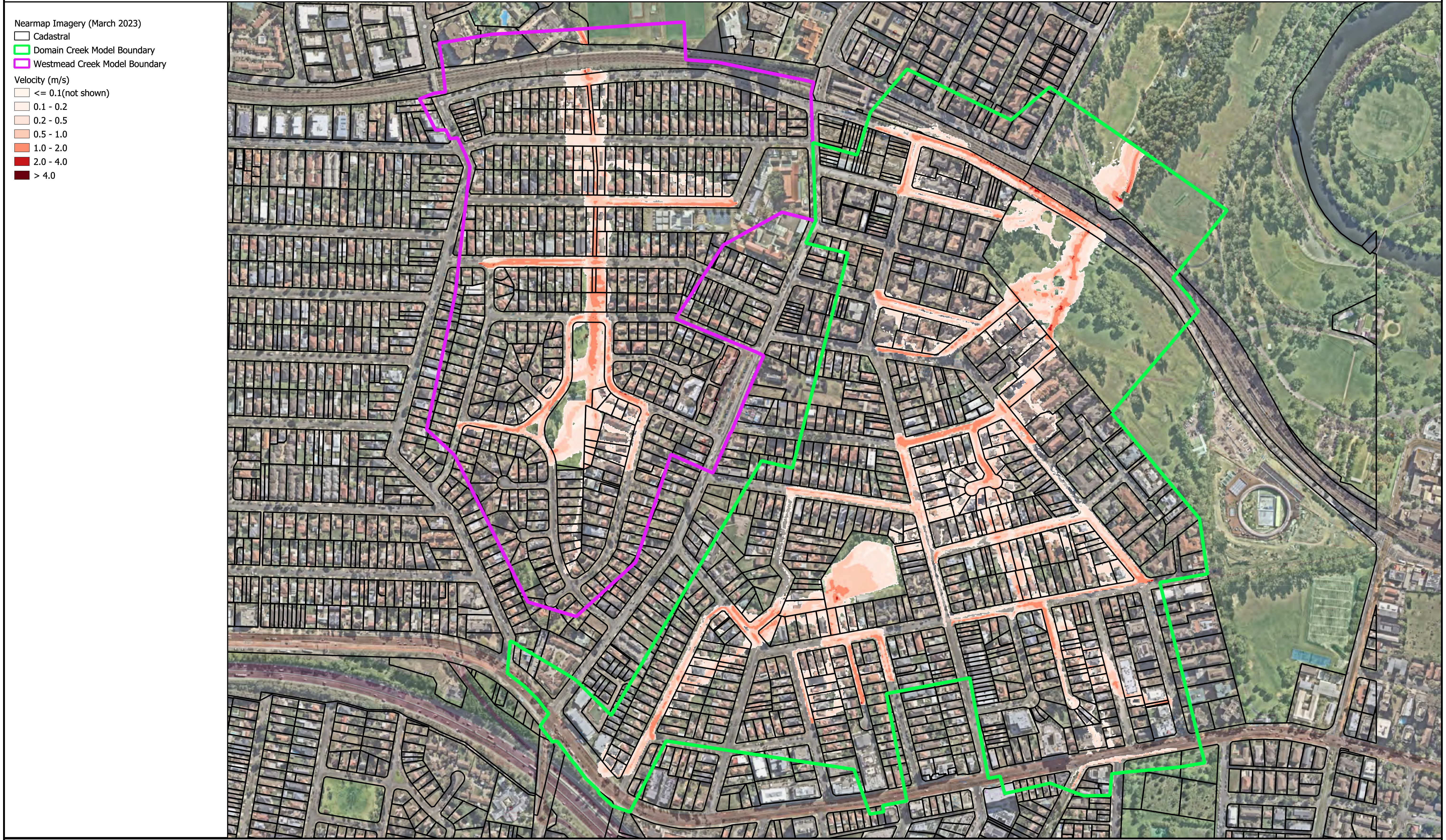


Figure B-28 - 0.5% AEP Flow Velocities
Existing Conditions

Westmead South
30181752
Cumberland City Council



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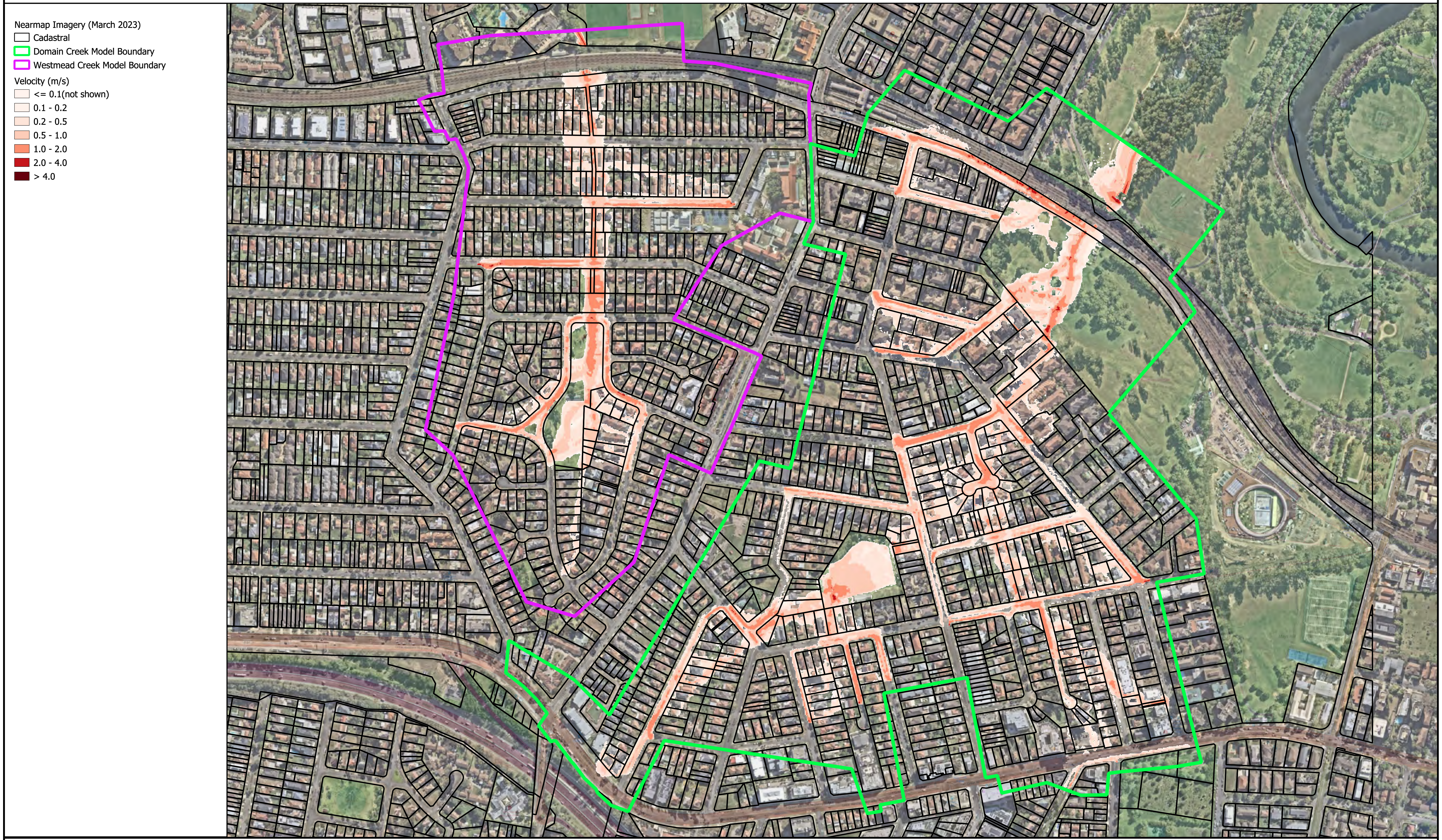
ARCADIS

Figure B-29 - 0.2% AEP Flow Velocities
Existing Conditions

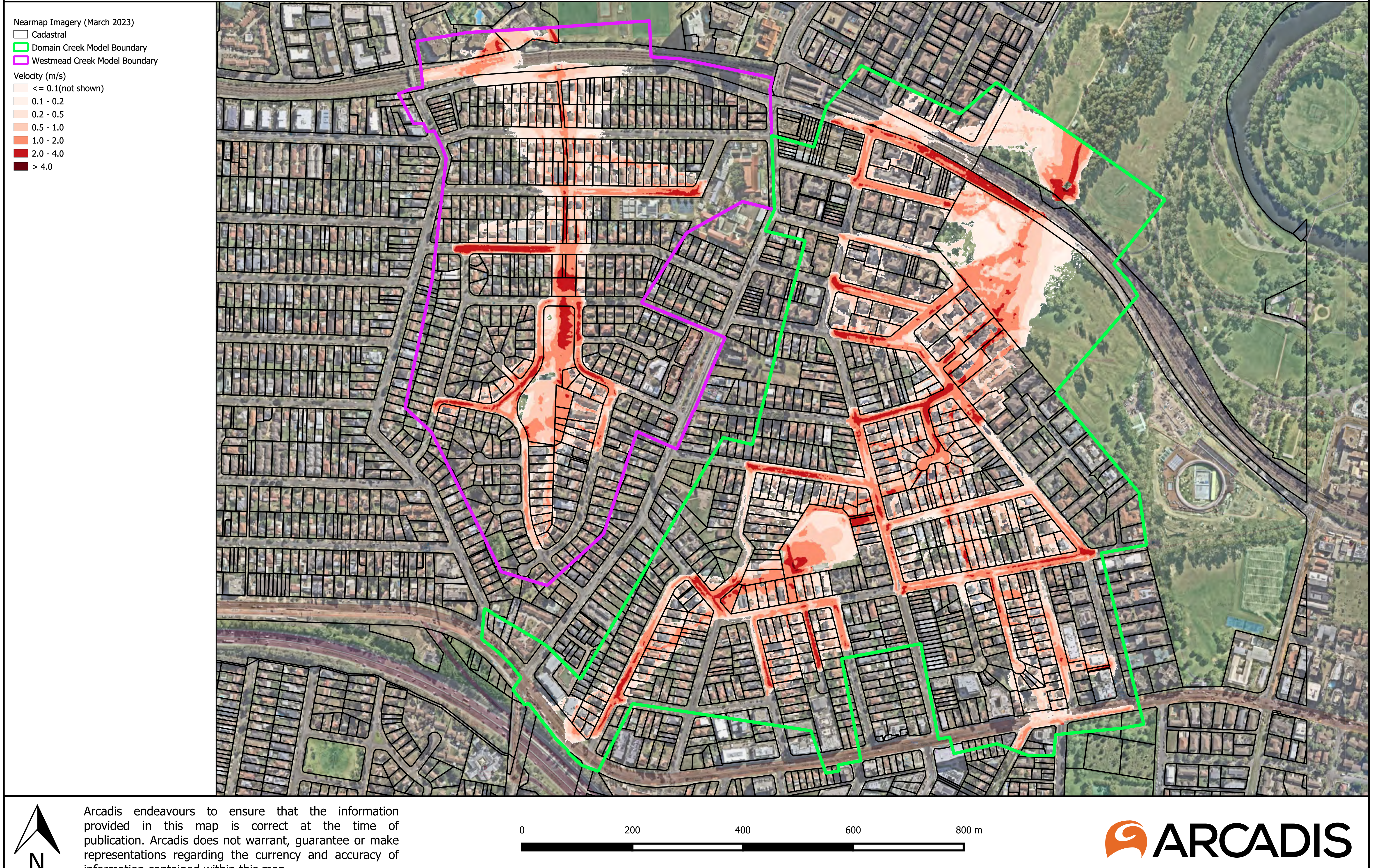
Westmead South
30181752
Cumberland City Council



ARCADIS

Figure B-30 - PMF Flow Velocities
Existing Conditions

Westmead South
30181752
Cumberland City Council



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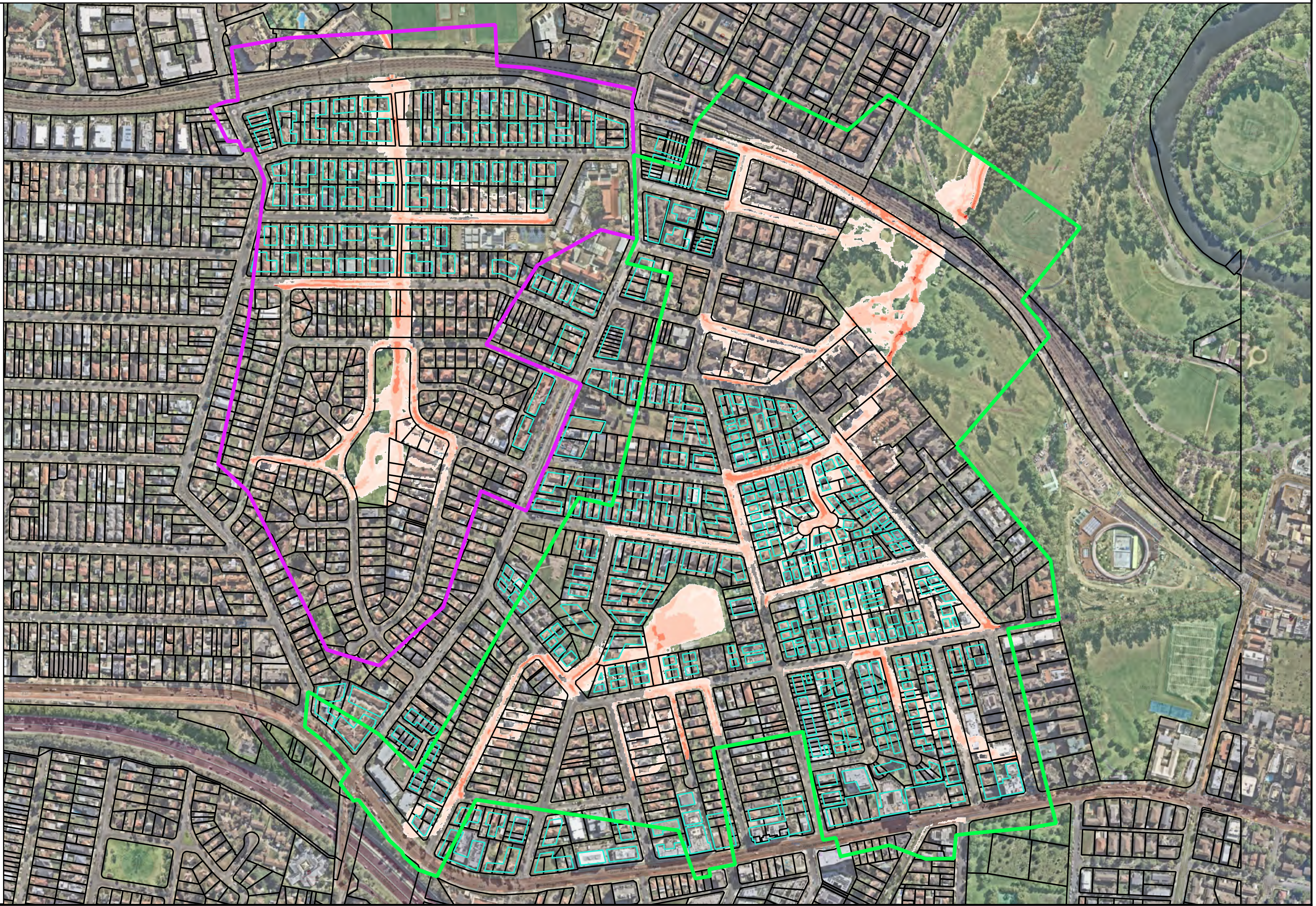
ARCADIS

Figure B-31 - 5% AEP Flow Velocities
Proposed Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Proposed Buildings
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary

Velocity (m/s)
- <= 0.1(not shown)
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 4.0
- > 4.0



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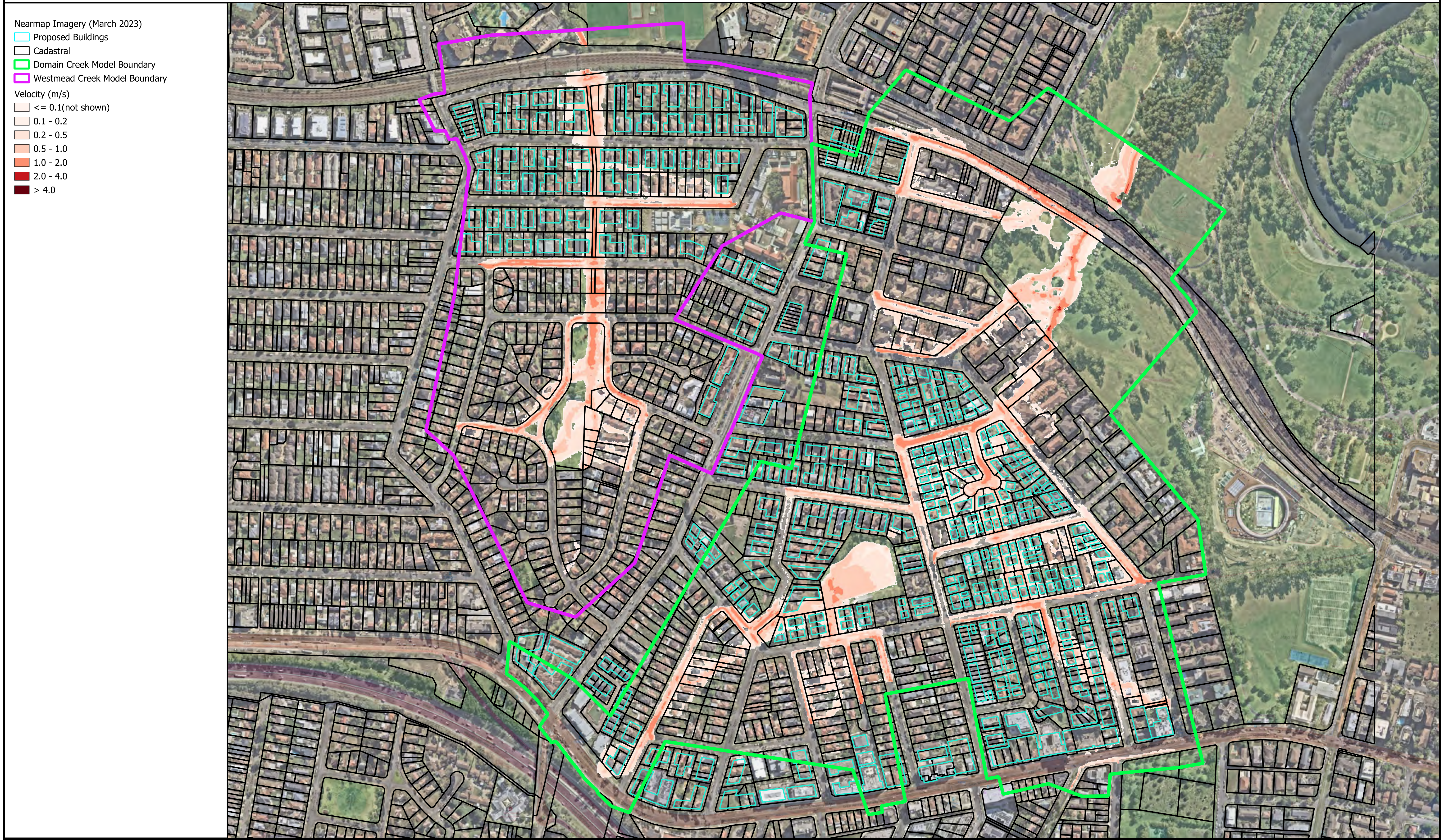
0 200 400 600 800 m

ARCADIS

Figure B-32 - 1% AEP Flow Velocities
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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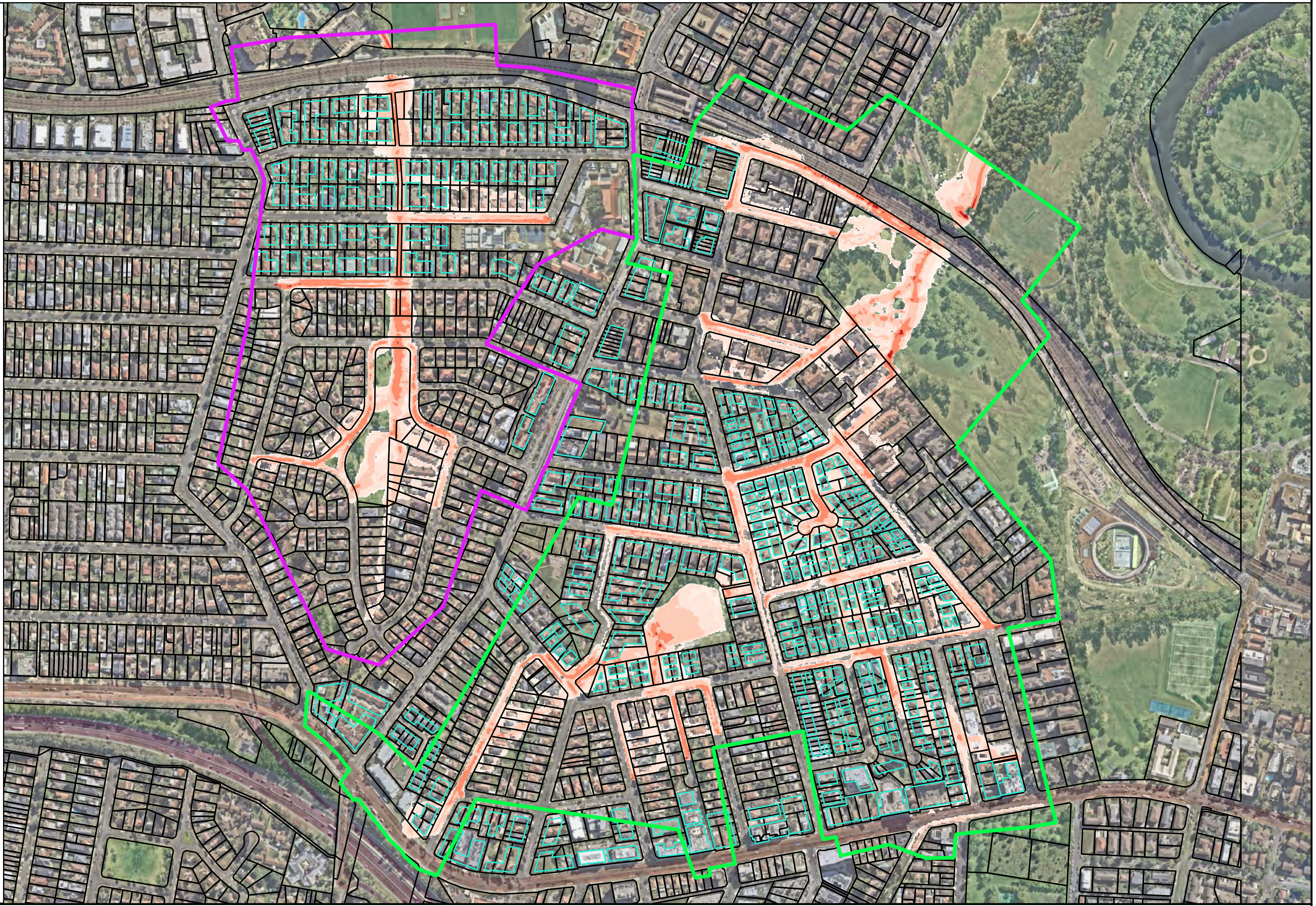
ARCADIS

Figure B-33 - 1% AEP with CC Flow Velocities
Proposed Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Proposed Buildings
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary

Velocity (m/s)
- <= 0.1(not shown)
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 4.0
- > 4.0



N

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0 200 400 600 800 m

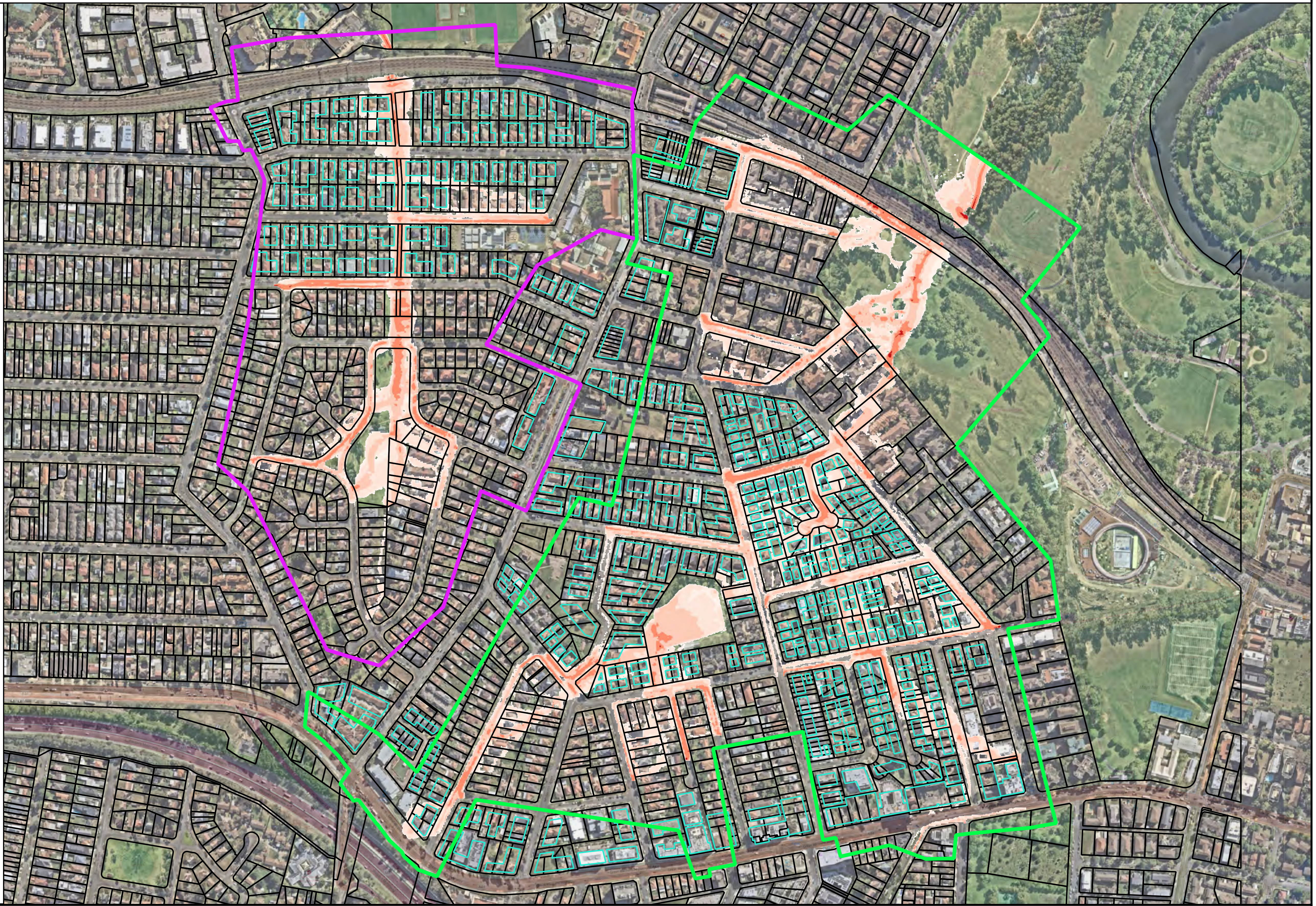
ARCADIS

Figure B-34 - 0.5% AEP Flow Velocities
Proposed Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Proposed Buildings
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary

Velocity (m/s)
- <= 0.1(not shown)
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 4.0
- > 4.0



N

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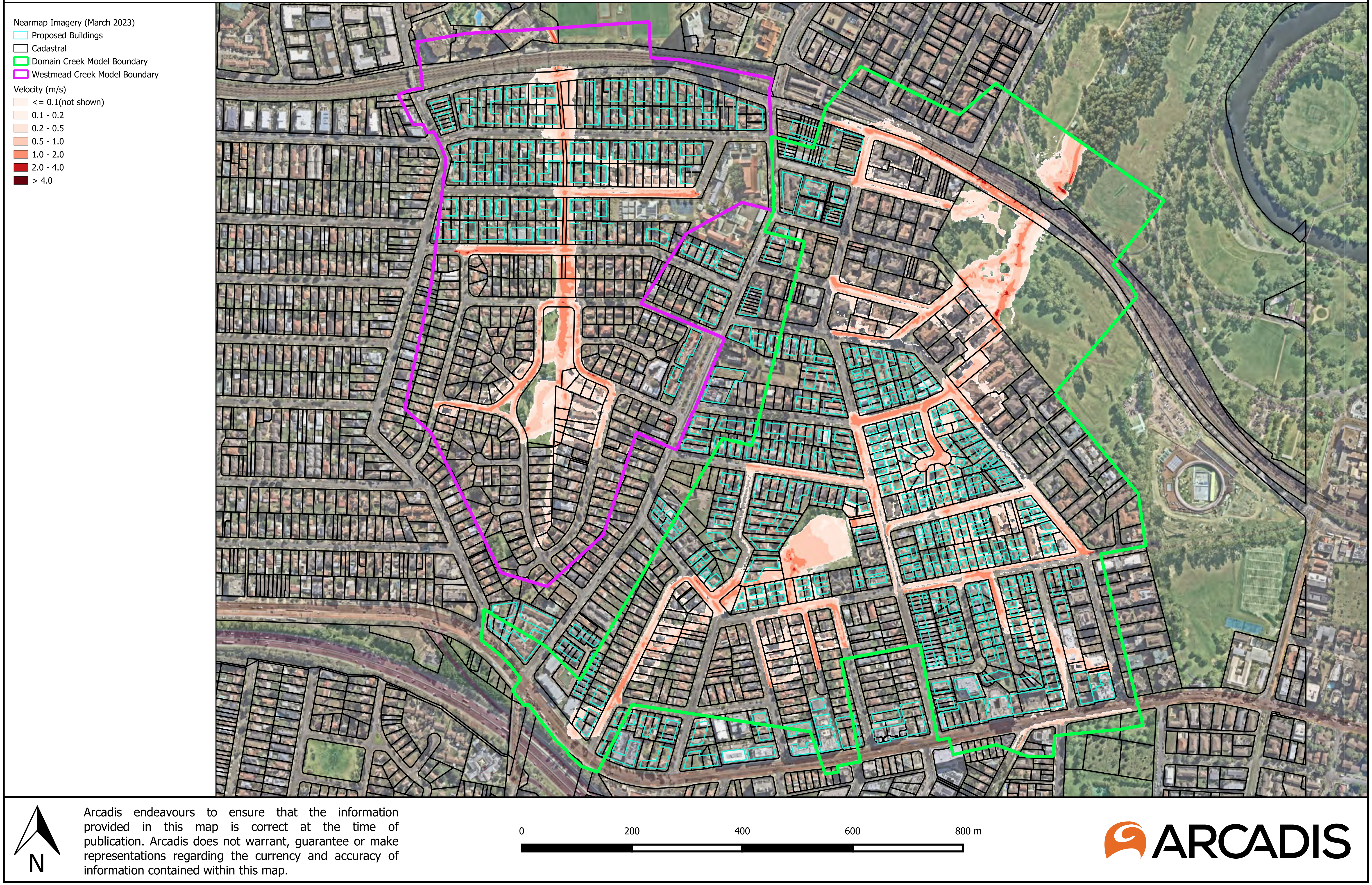
0 200 400 600 800 m

ARCADIS

Figure B-35 - 0.2% AEP Flow Velocities
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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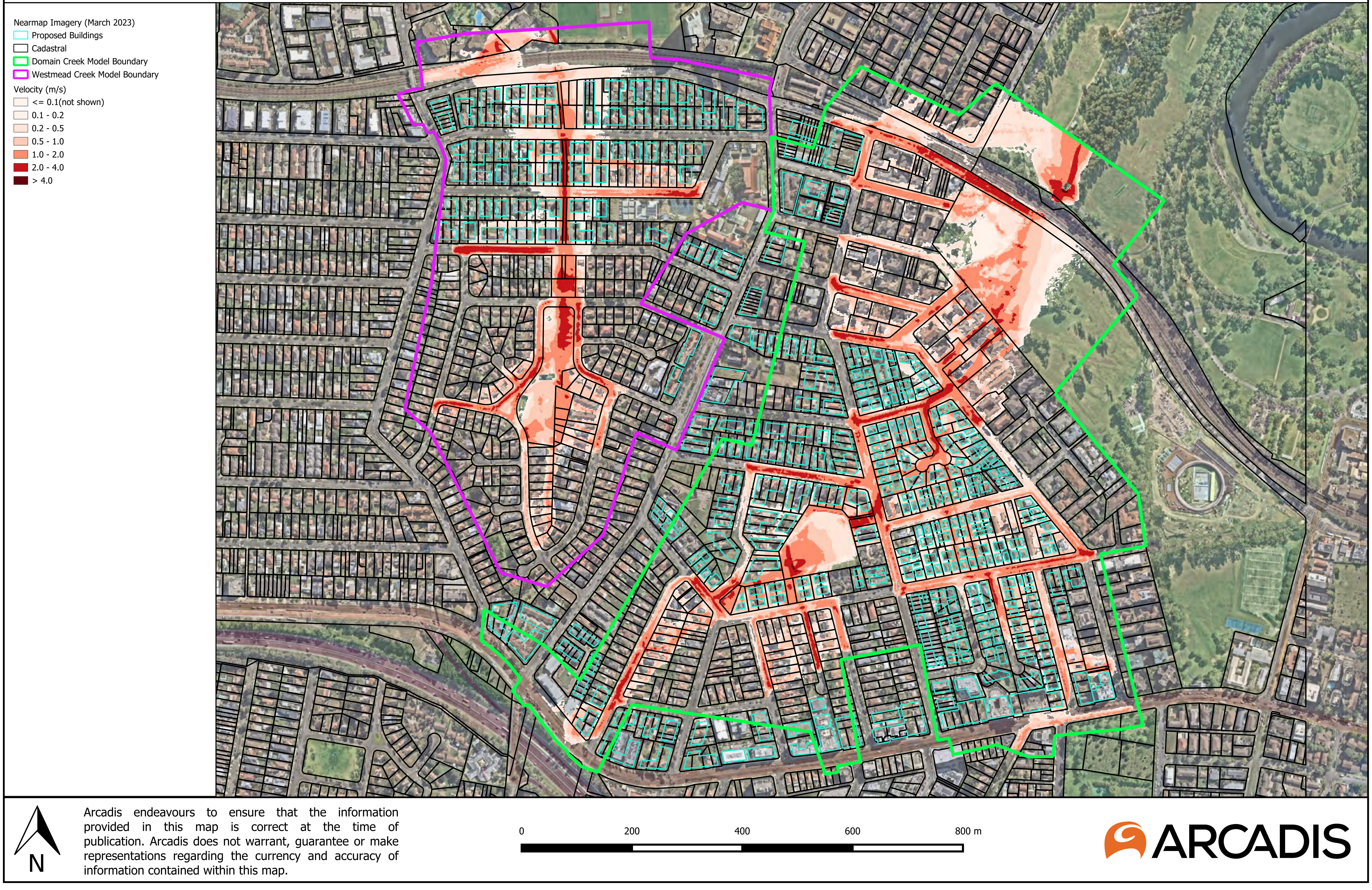
ARCADIS

Figure B-36 - PMF Flow Velocities
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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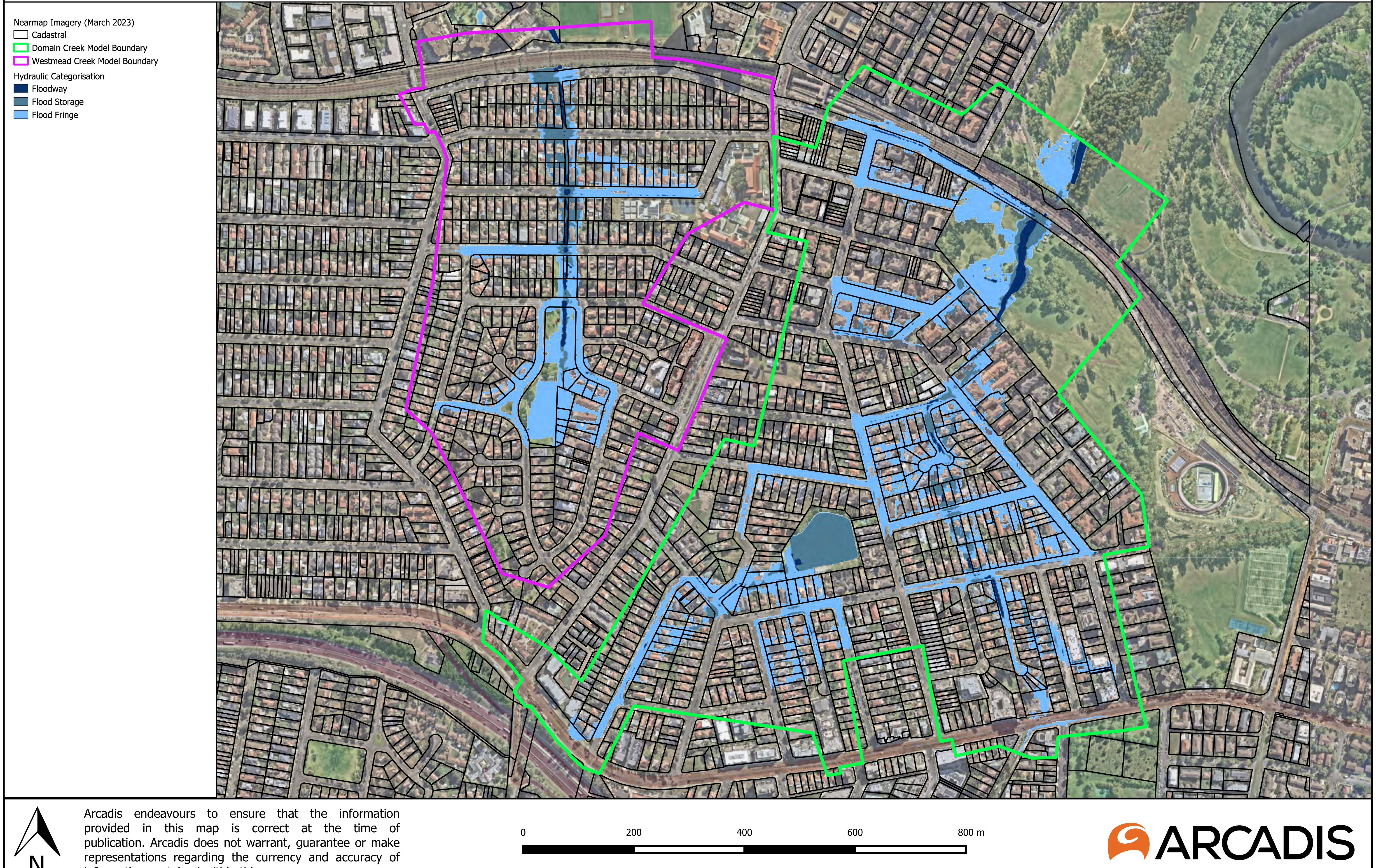
ARCADIS

Figure B-37 - 5% AEP Flood Function
Existing Conditions

Westmead South
30181752
Cumberland City Council



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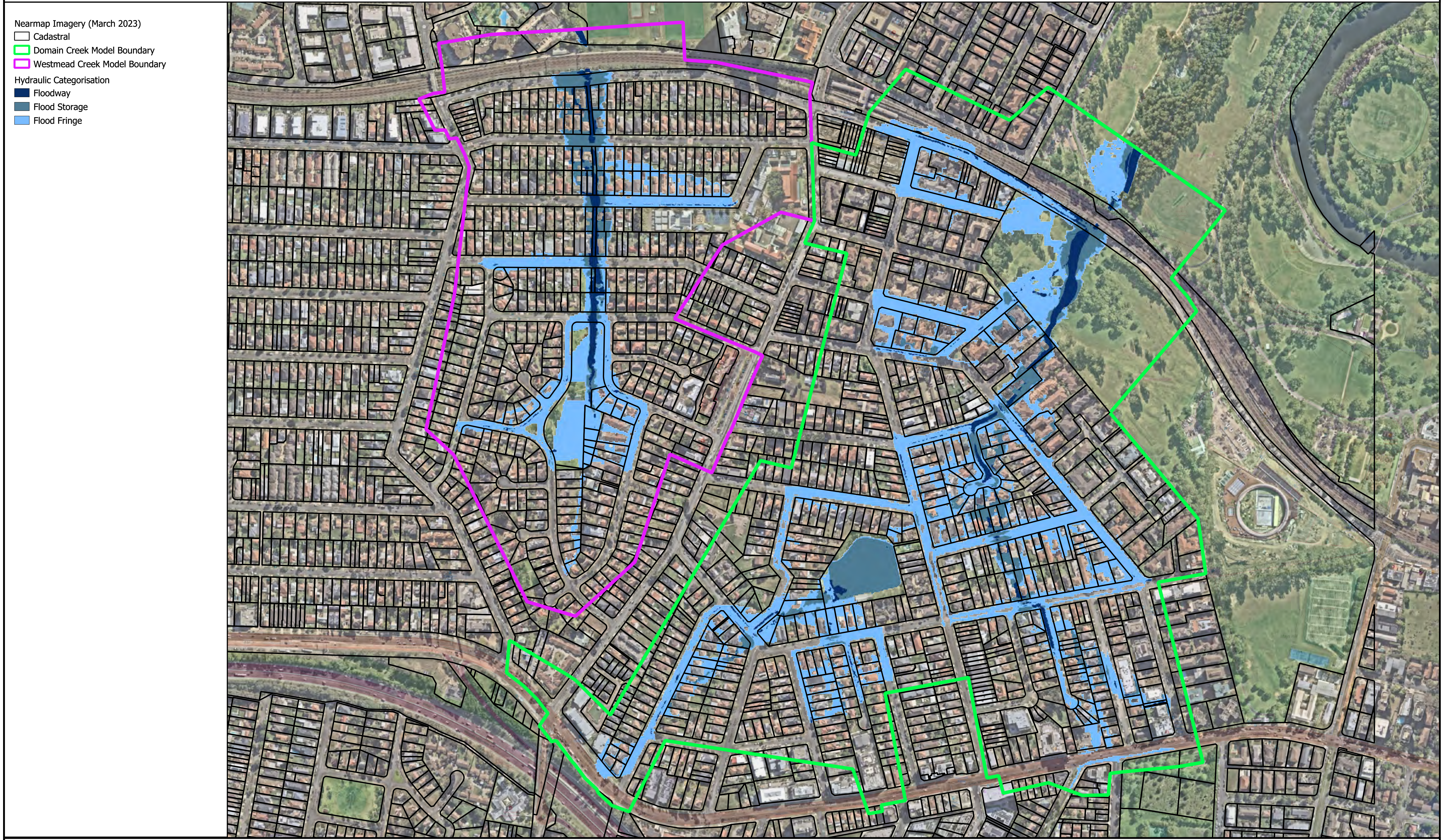
ARCADIS

Figure B-38 - 1% AEP Flood Function
Existing Conditions

Westmead South
30181752
Cumberland City Council



N

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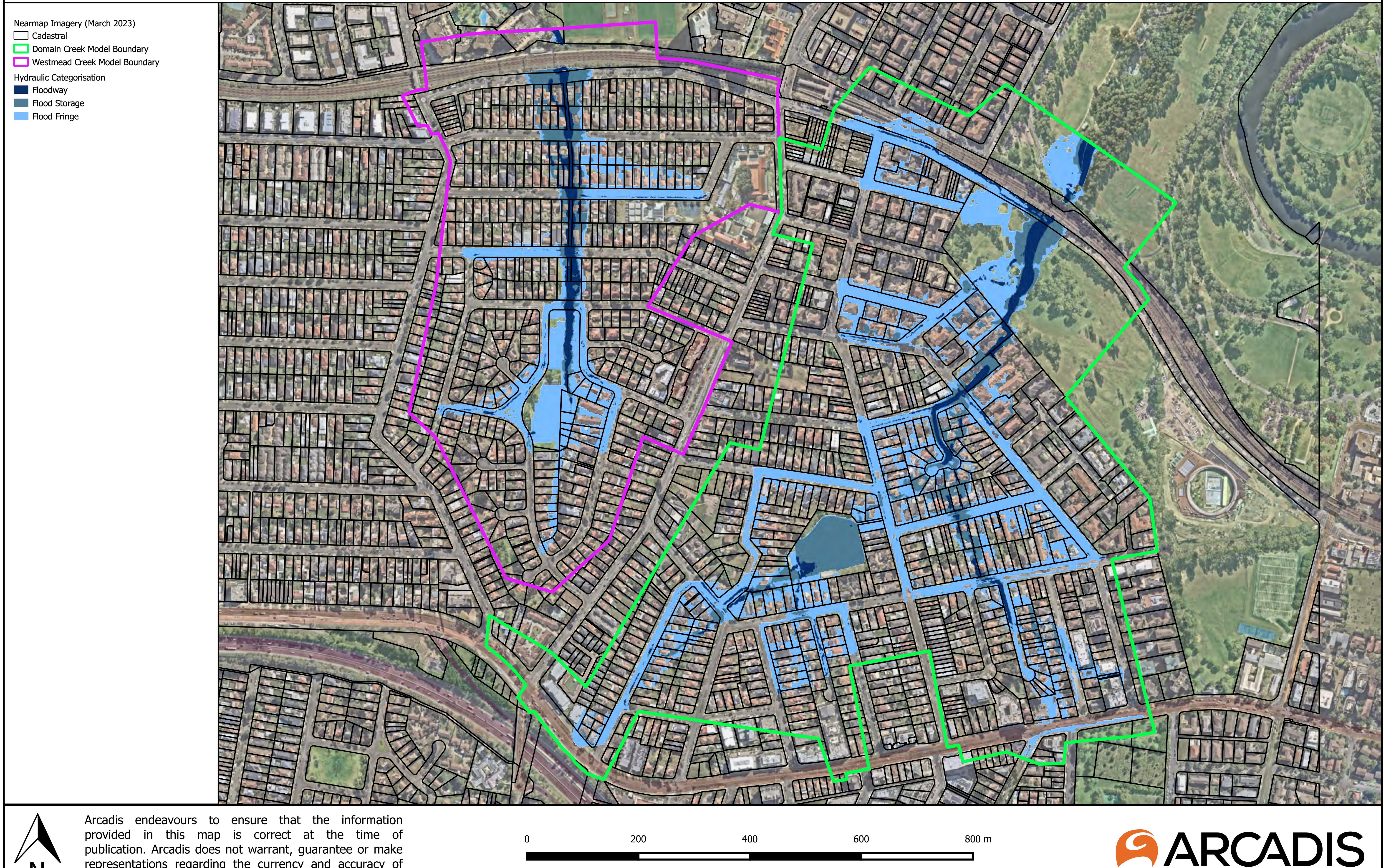
0 200 400 600 800 m

ARCADIS

Figure B-39 - 1% AEP with CC Flood Function
Existing Conditions

Westmead South
30181752
Cumberland City Council



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ARCADIS

Figure B-40 - 0.5% AEP Flood Function
Existing Conditions

Westmead South
30181752
Cumberland City Council

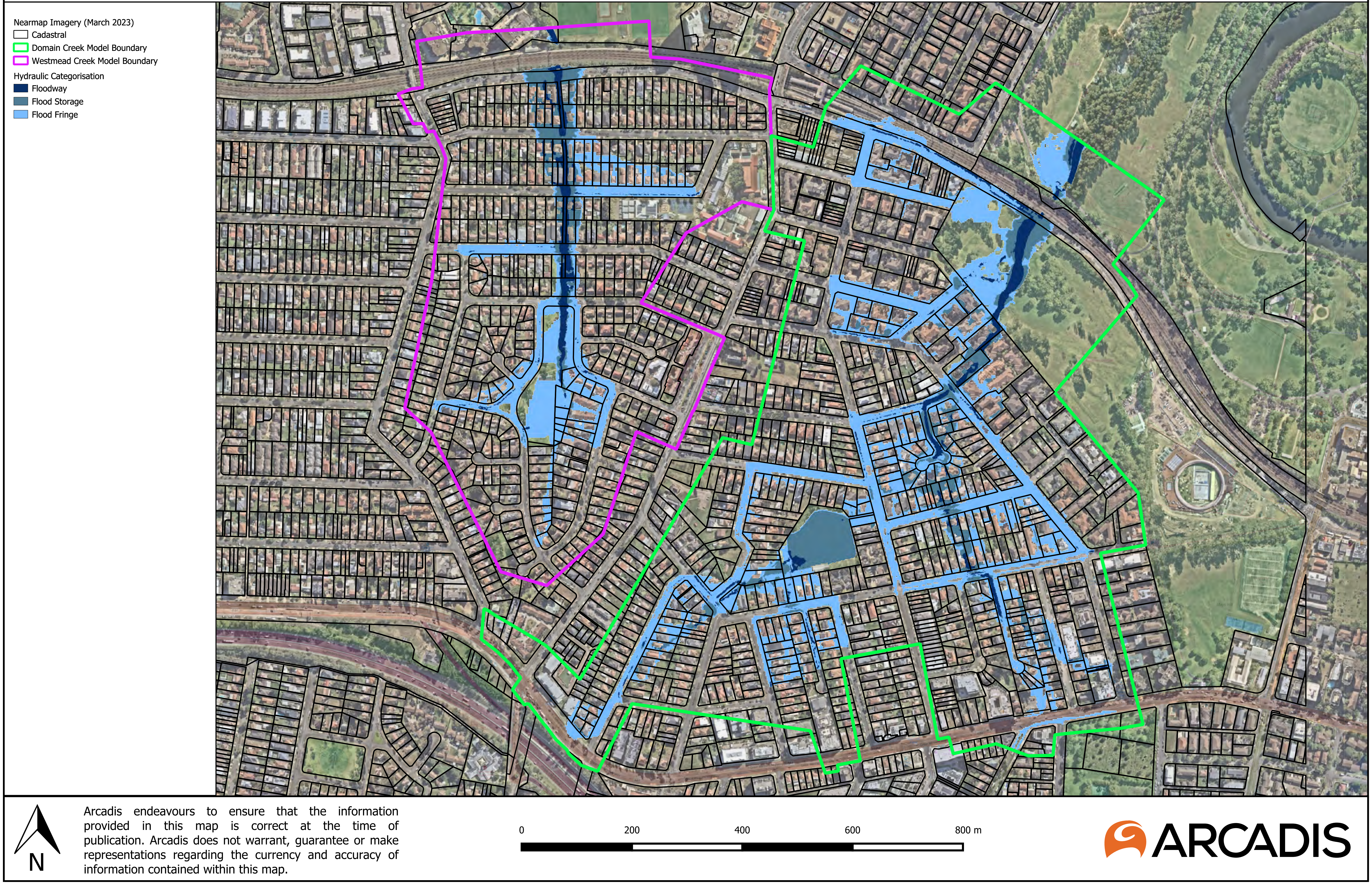

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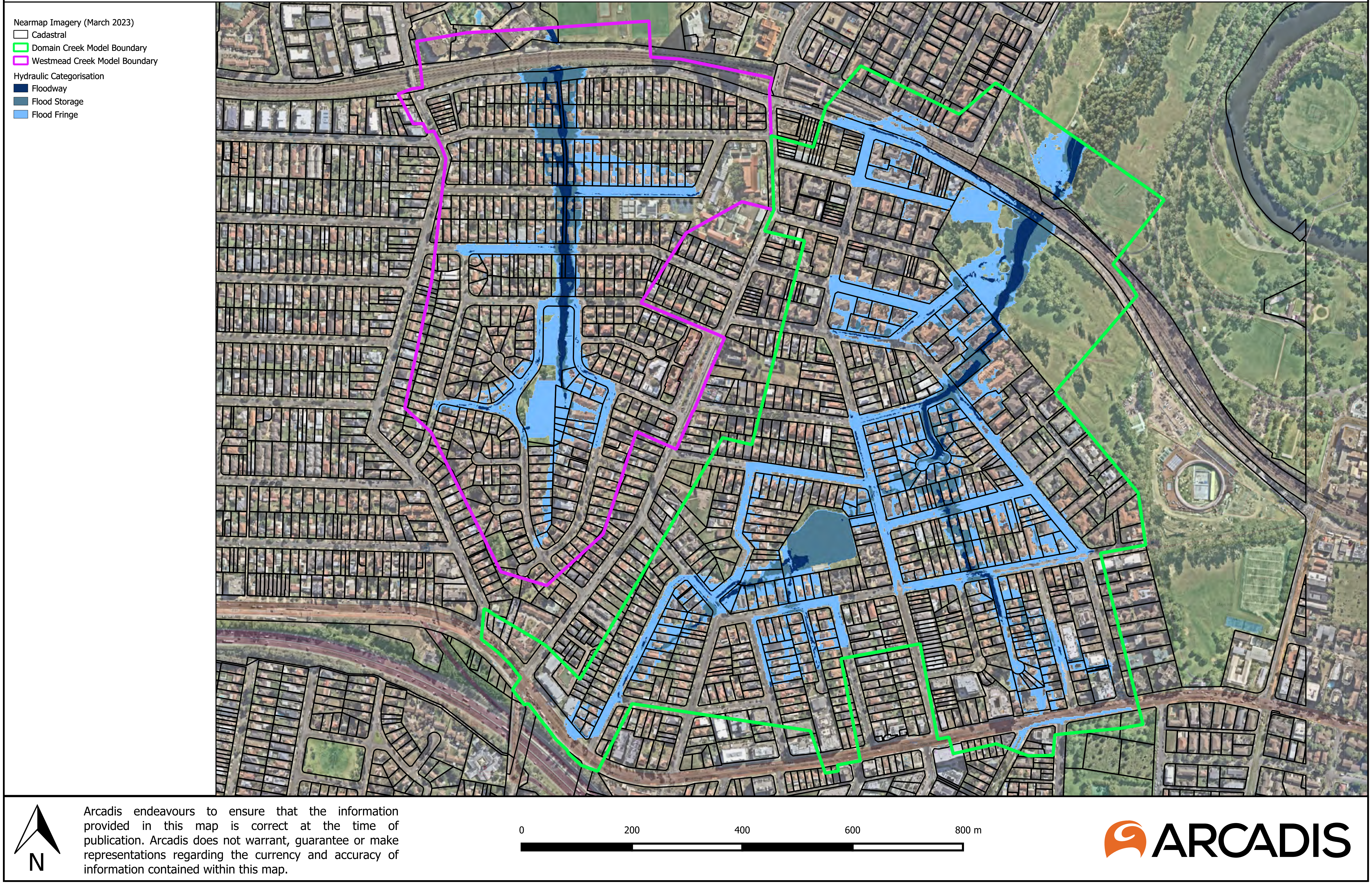
Figure B-41 - 0.2% AEP Flood Function
Existing Conditions

Westmead South
30181752
Cumberland City Council



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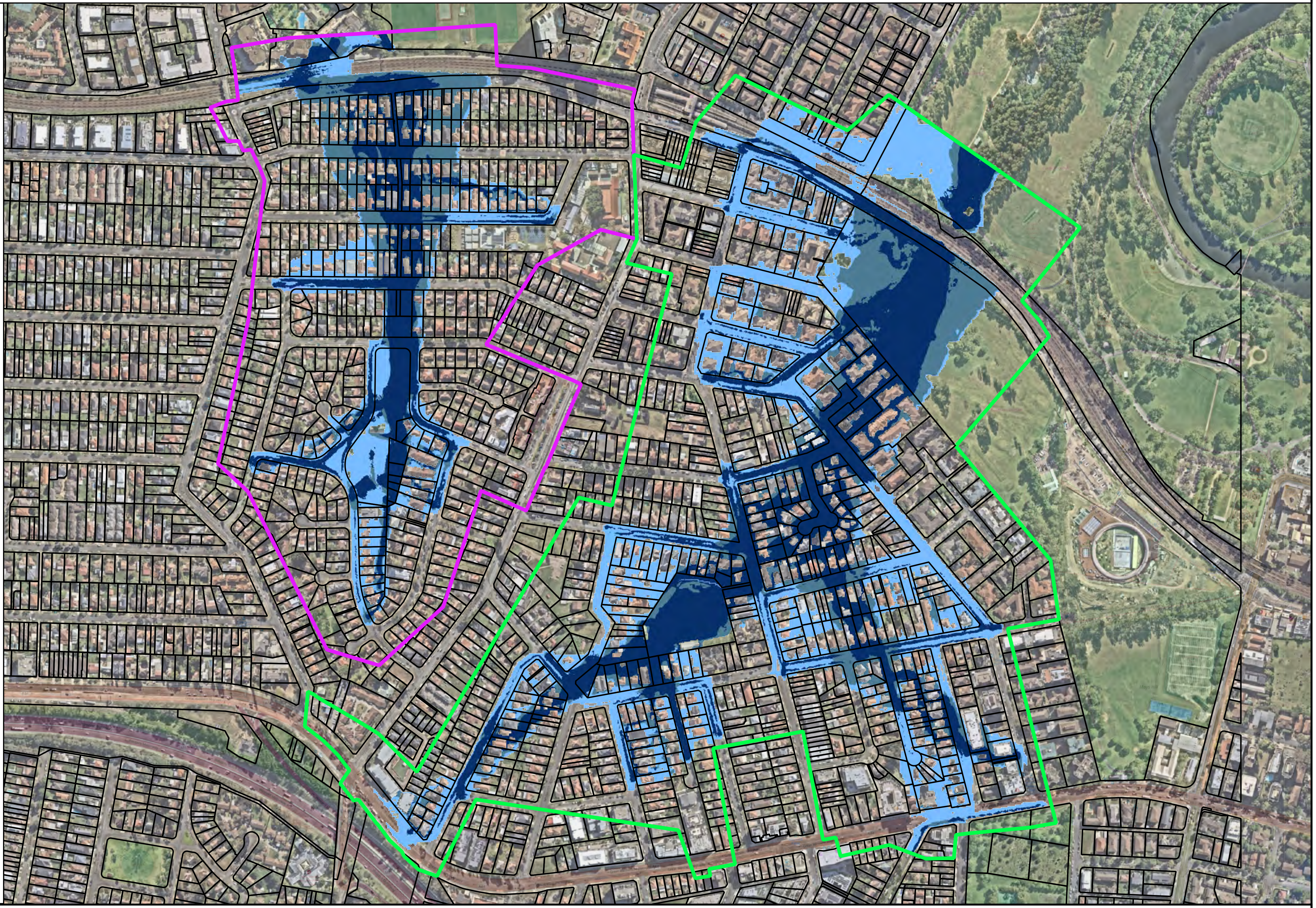
ARCADIS

Figure B-42 - PMF Flood Function
Existing Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary

Hydraulic Categorisation
- Floodway
- Flood Storage
- Flood Fringe



N

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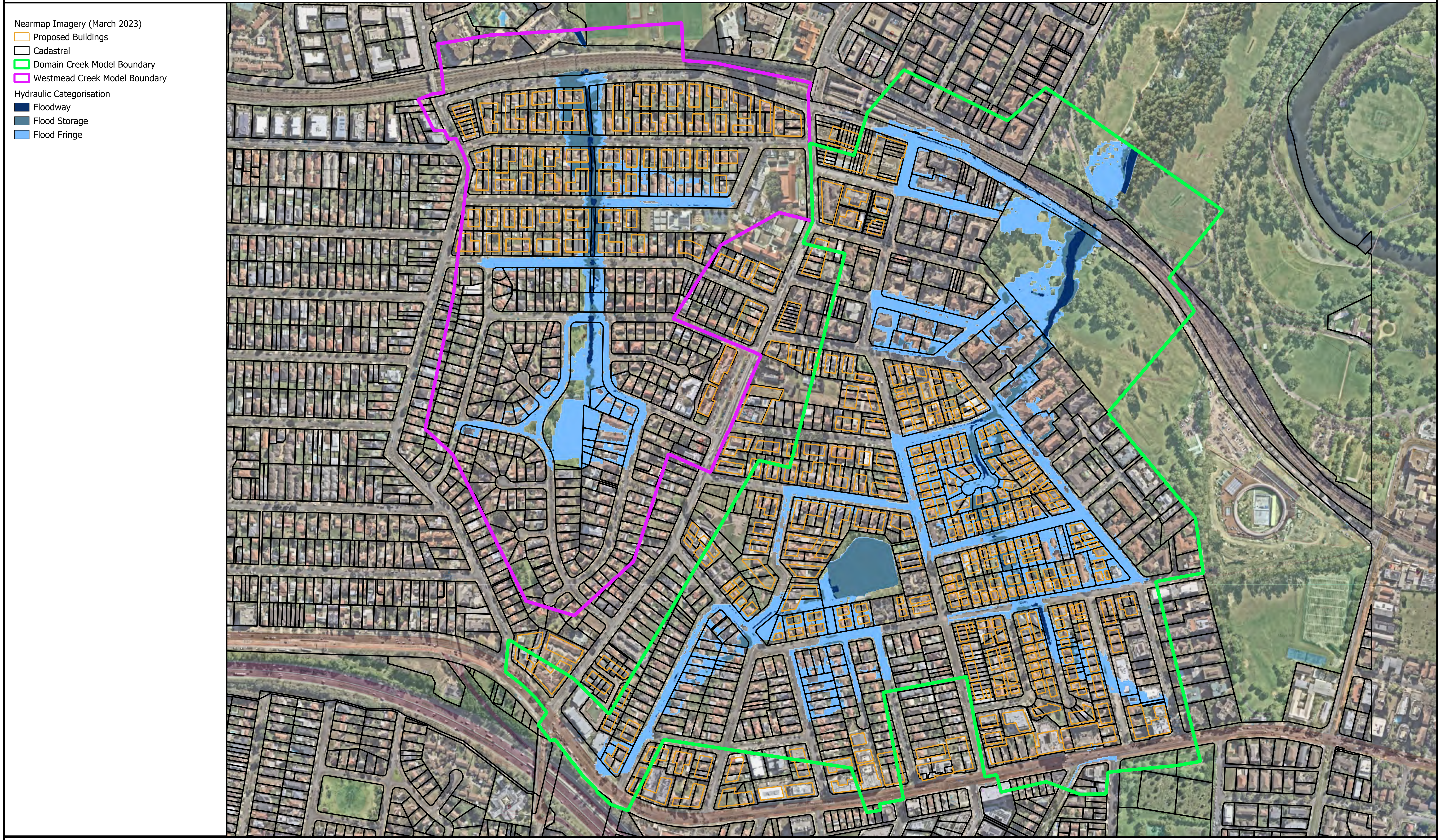
0 200 400 600 800 m

ARCADIS

Figure B-43 - 5% AEP Flood Function
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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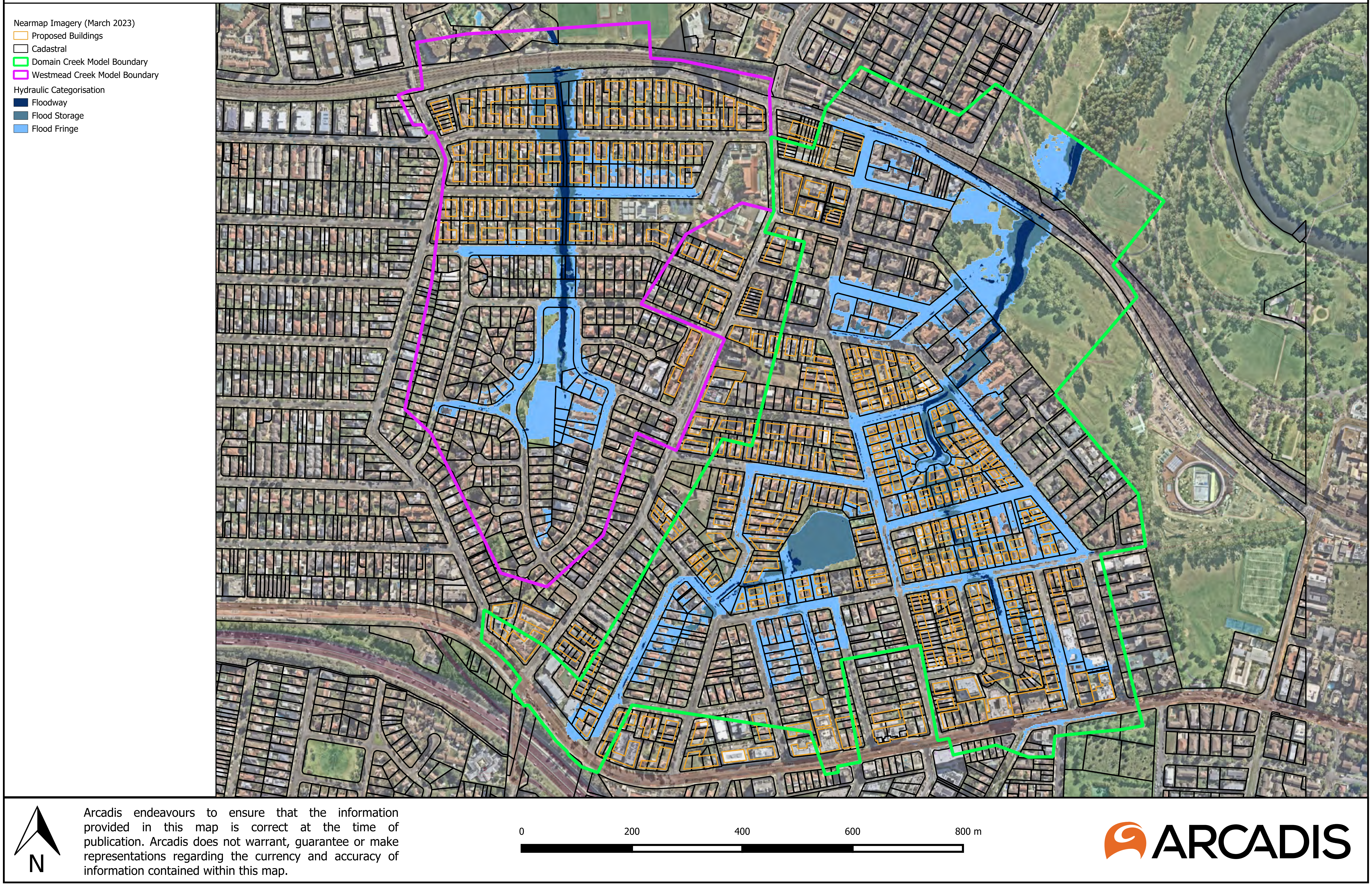
ARCADIS

Figure B-44 - 1% AEP Flood Function

Proposed Conditions

Westmead South
30181752
Cumberland City Council



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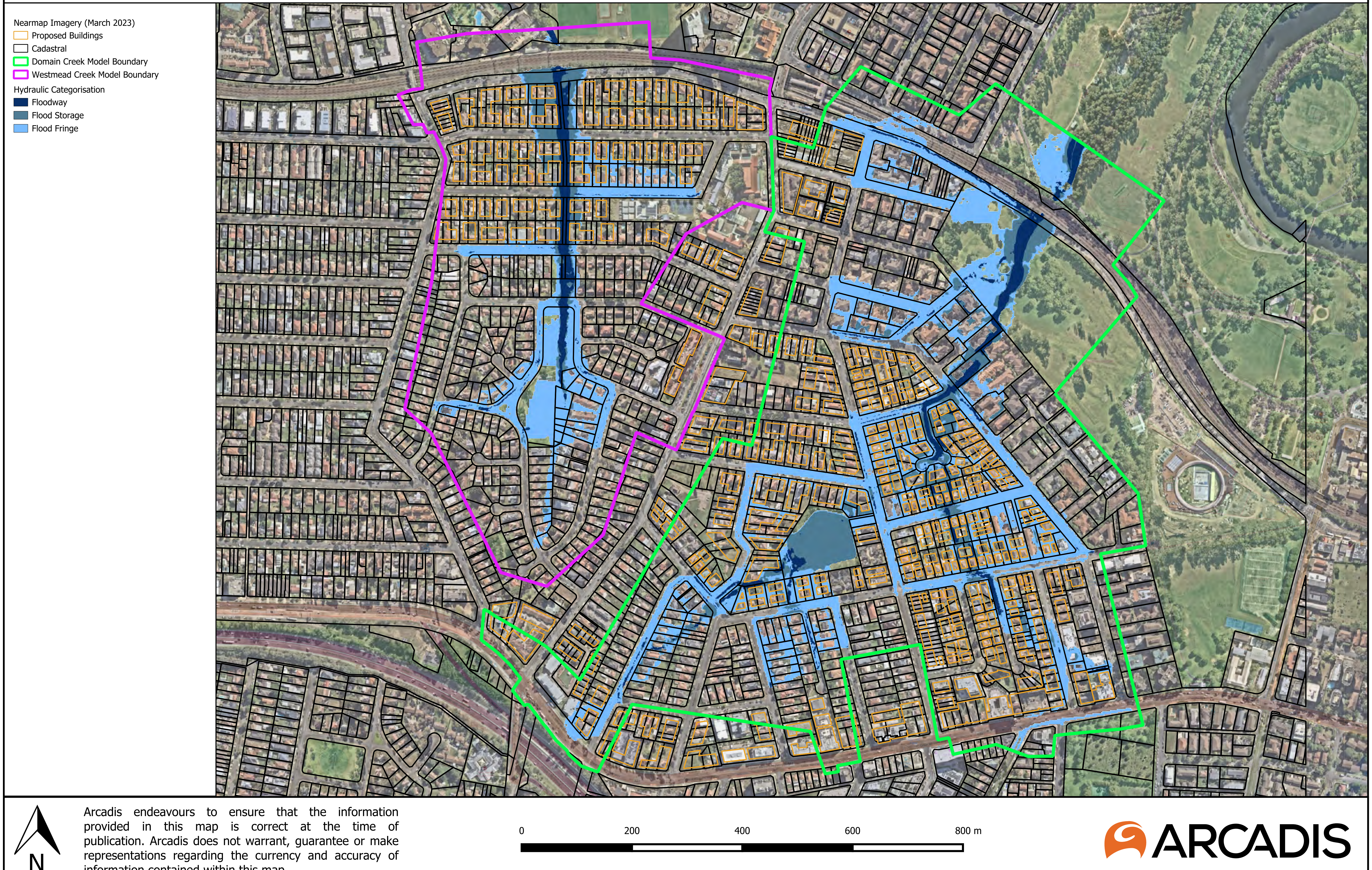
ARCADIS

Figure B-45 - 1% AEP with CC Flood Function
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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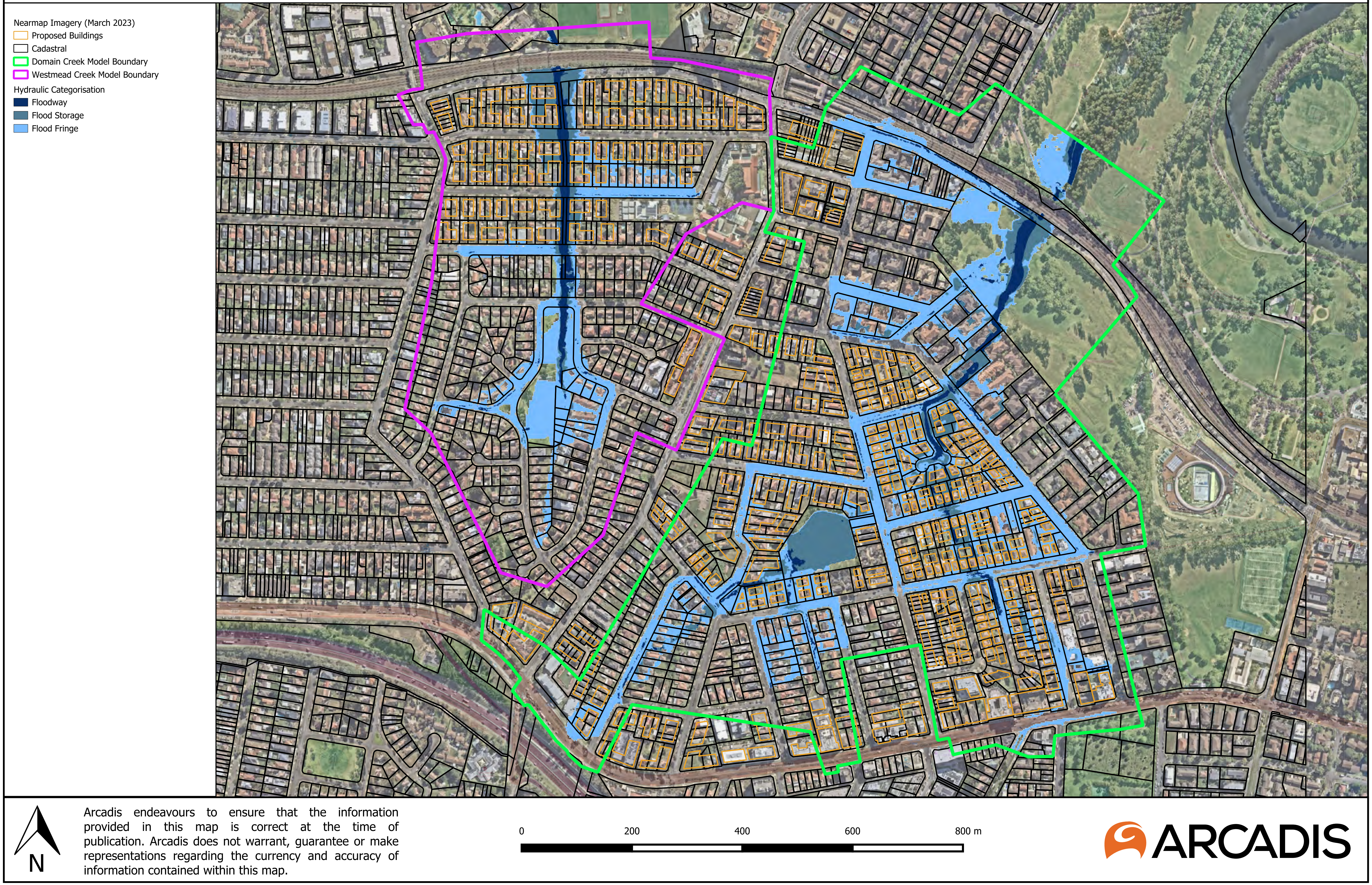
ARCADIS

Figure B-46 - 0.5% AEP Flood Function
Proposed Conditions

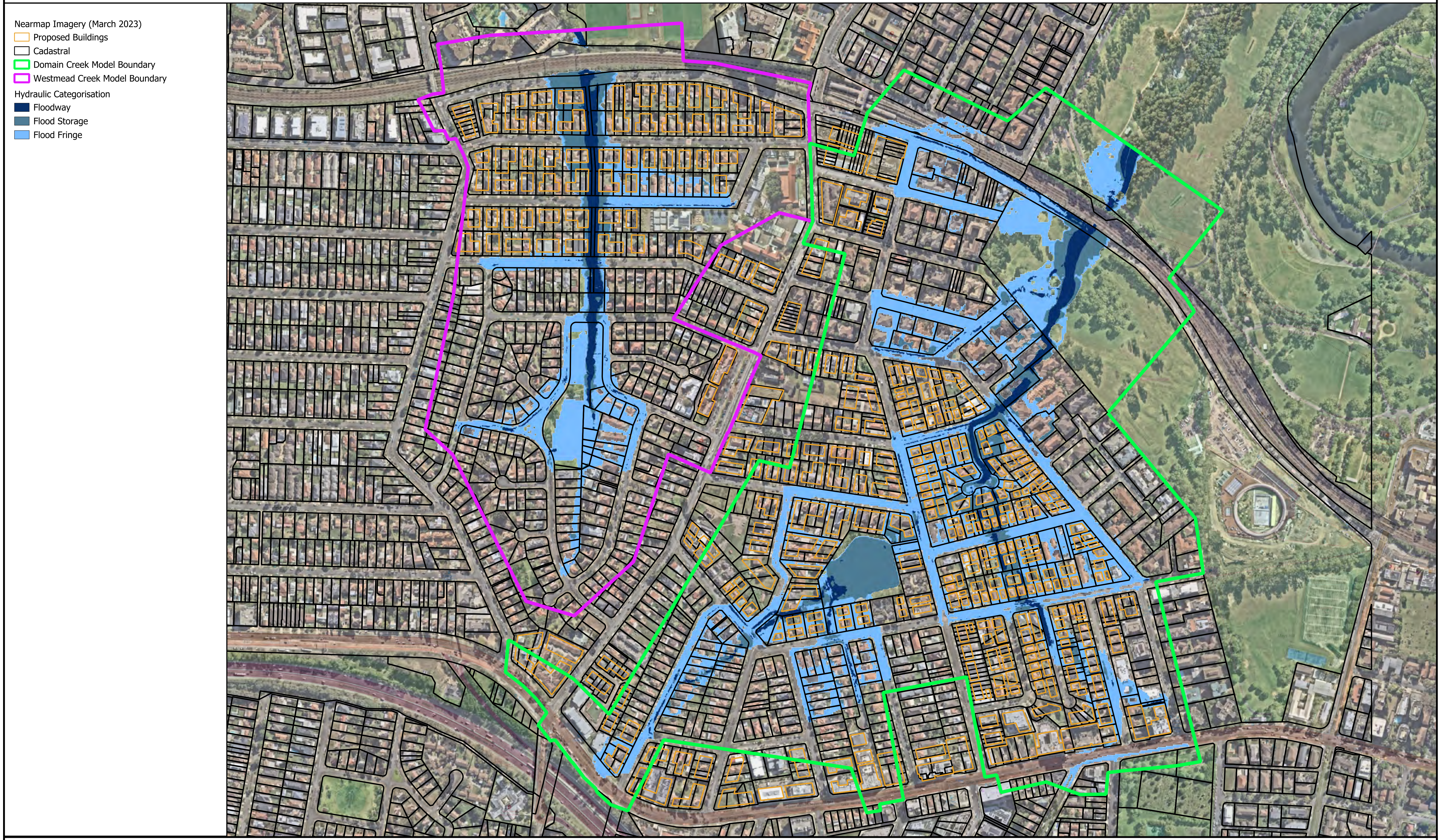
Westmead South
30181752
Cumberland City Council



ARCADIS

Figure B-47 - 0.2% AEP Flood Function
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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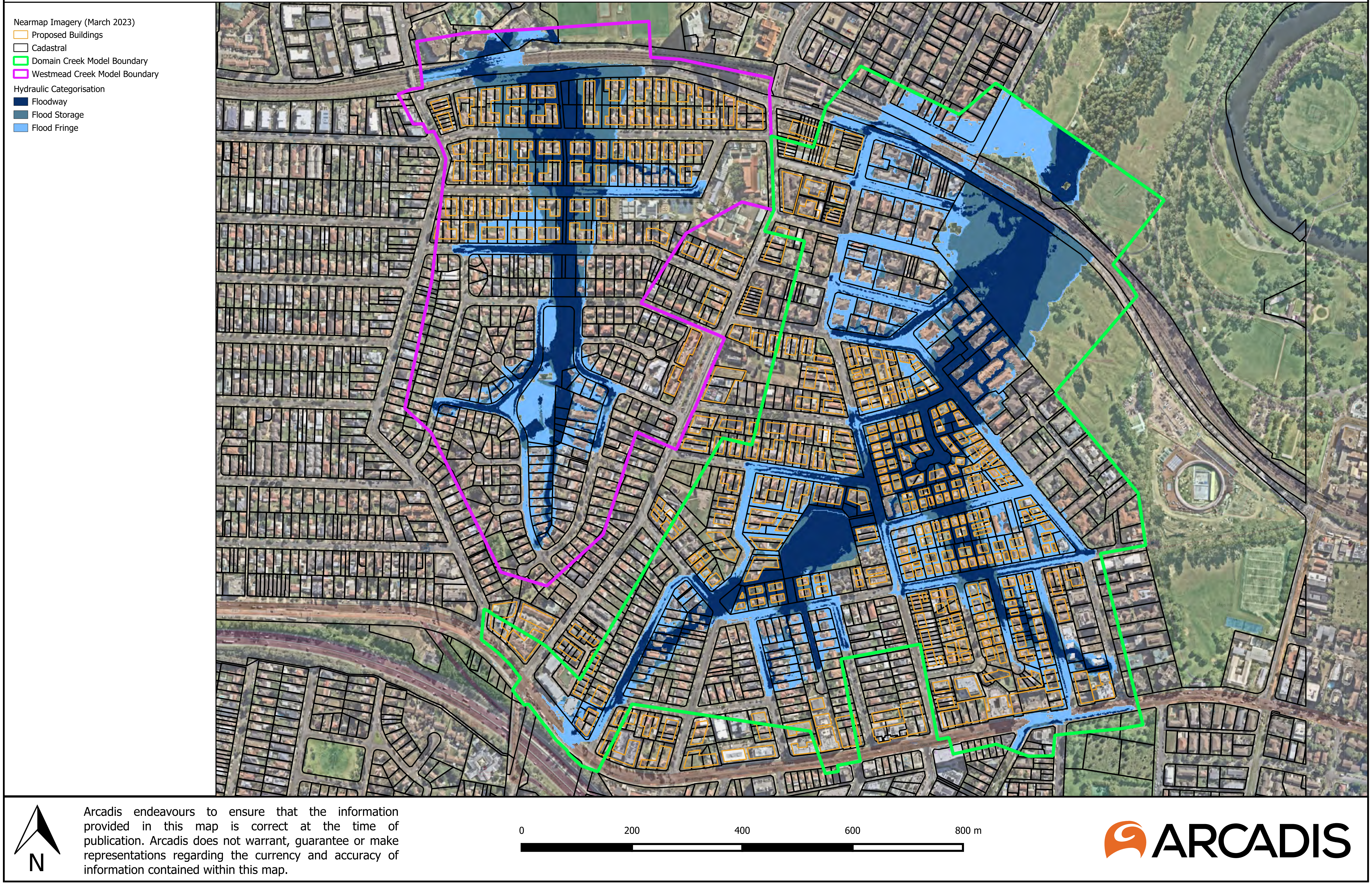
ARCADIS

Figure B-48 - PMF Flood Function
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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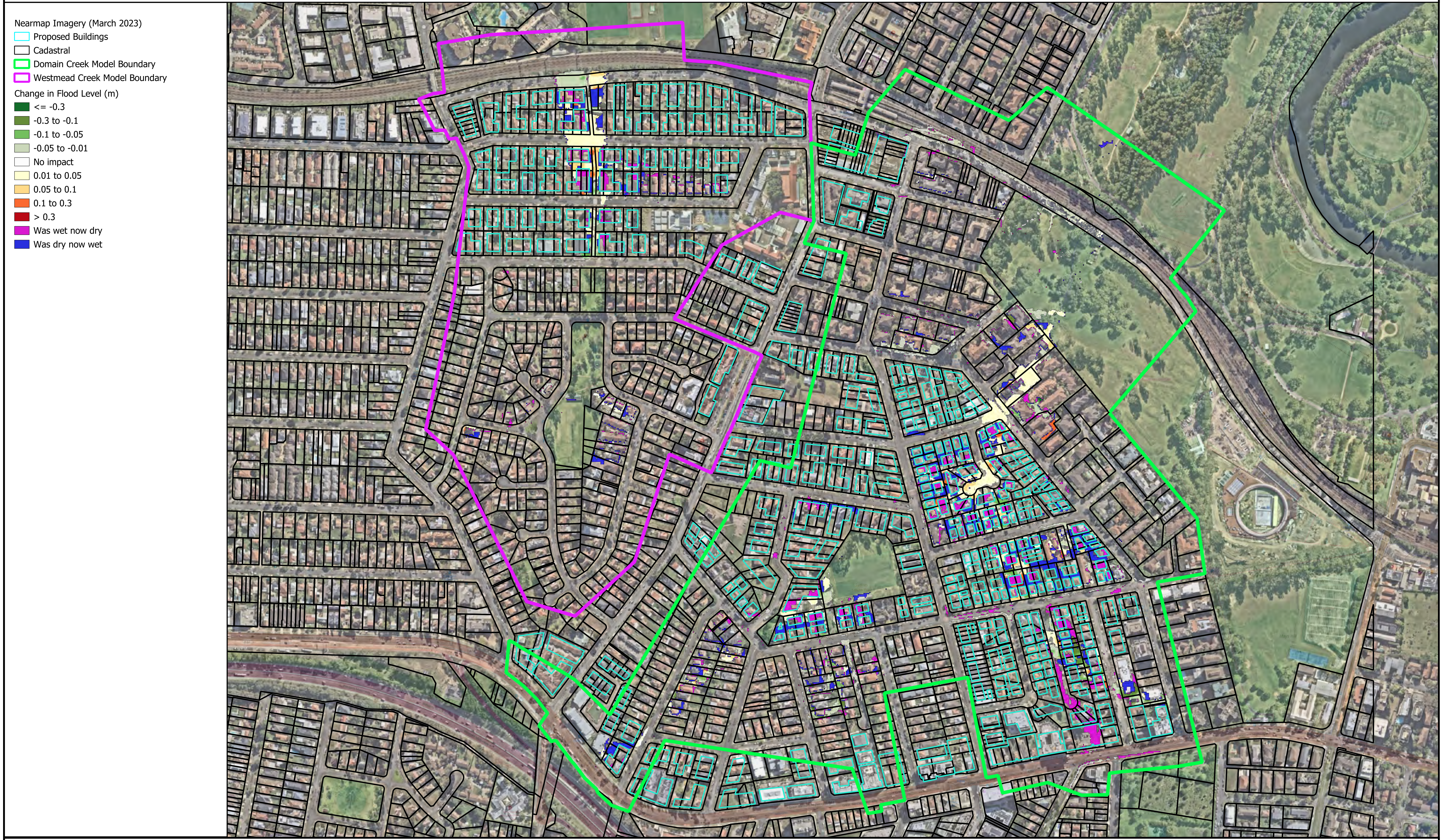
ARCADIS

Figure B-49 - 5% AEP Change in Flood Level
Proposed Conditions

Westmead South
30181752
Cumberland City Council

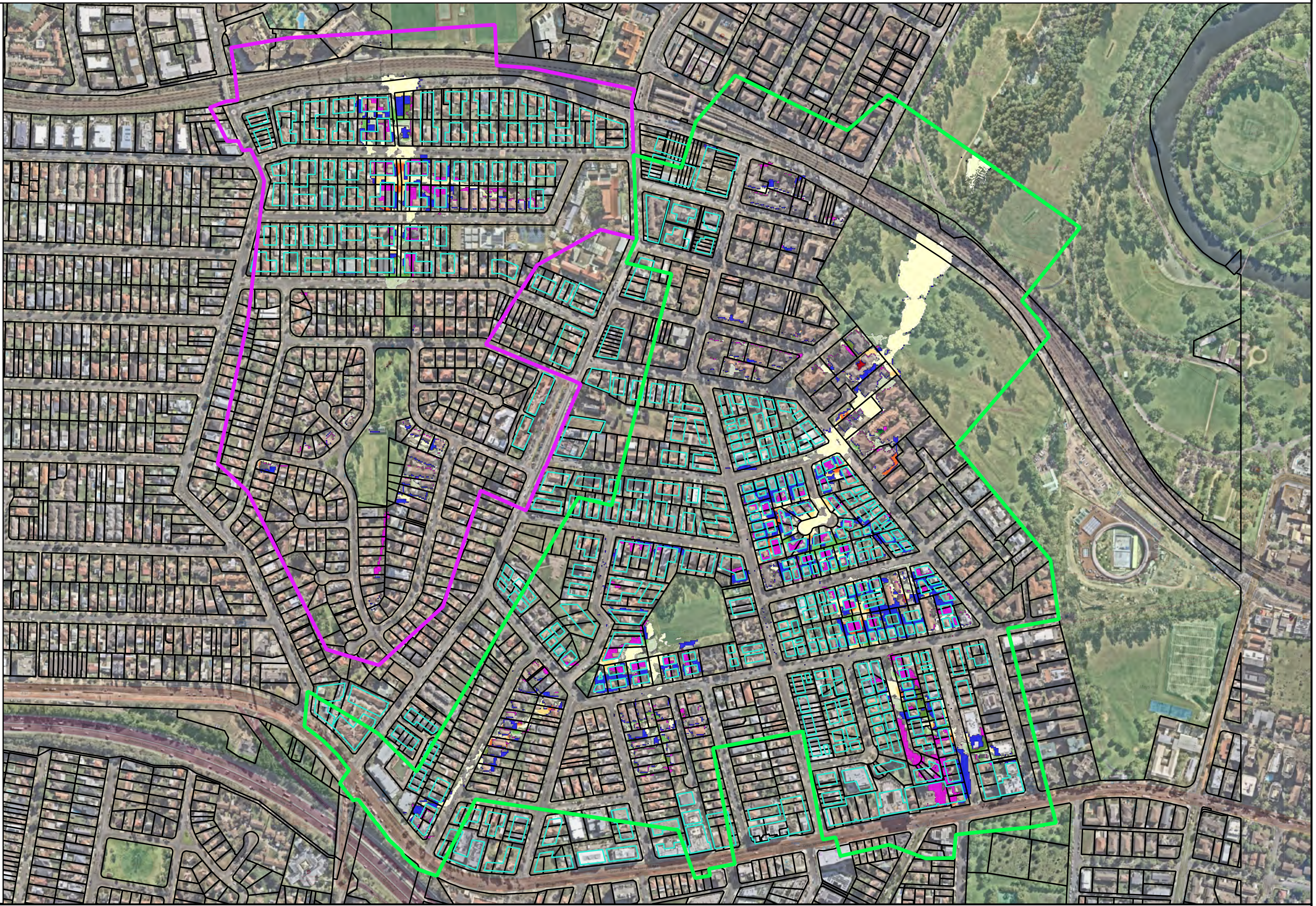


ARCADIS

Figure B-50 - 1% AEP Change in Flood Level
Proposed Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
Proposed Buildings
Cadastral
Domain Creek Model Boundary
Westmead Creek Model Boundary
Change in Flood Level (m)
<= -0.3
-0.3 to -0.1
-0.1 to -0.05
-0.05 to -0.01
No impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.3
> 0.3
Was wet now dry
Was dry now wet



N

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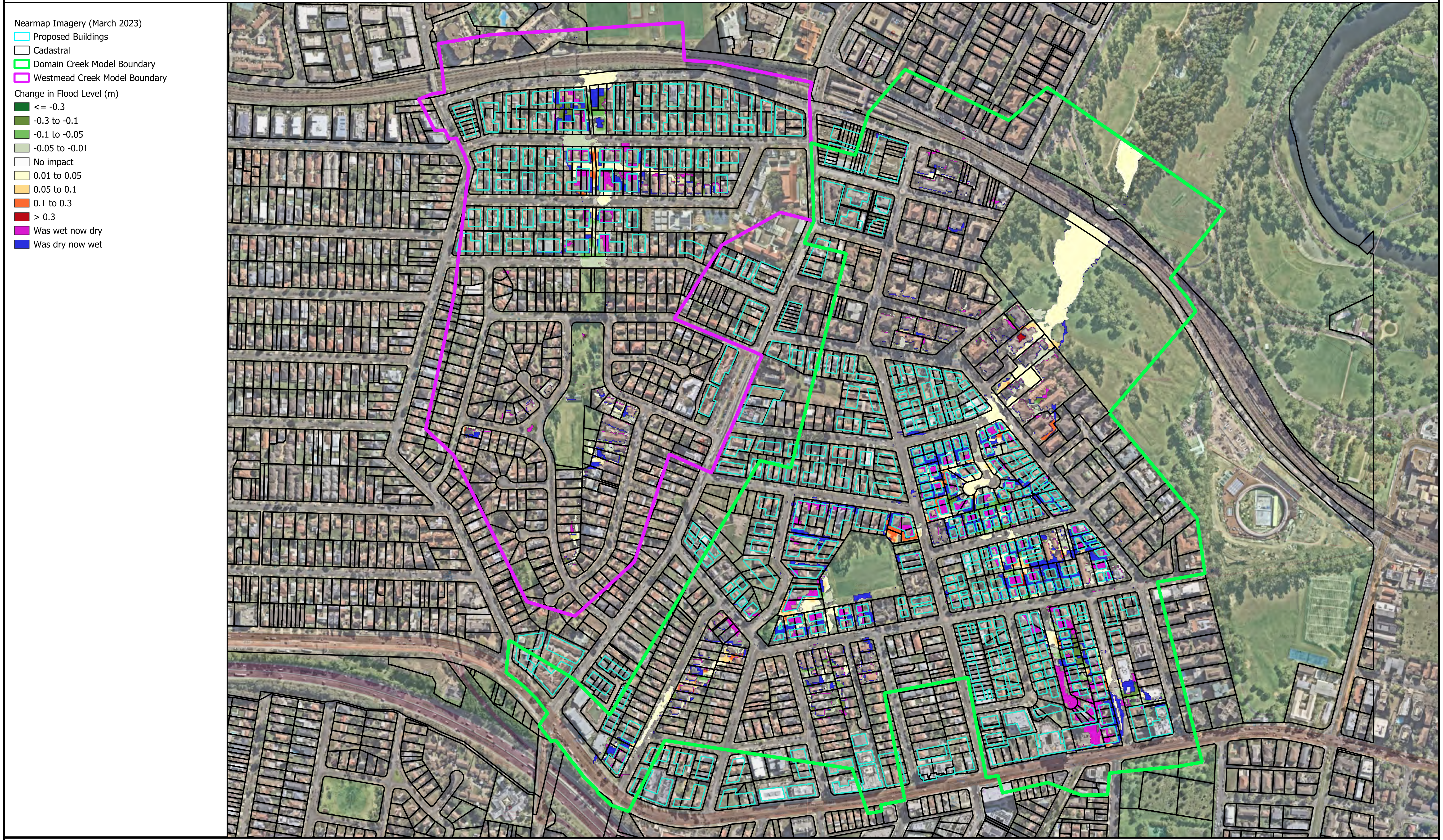
0 200 400 600 800 m

ARCADIS

Figure B-51 - 1% AEP with CC Change in Flood Level
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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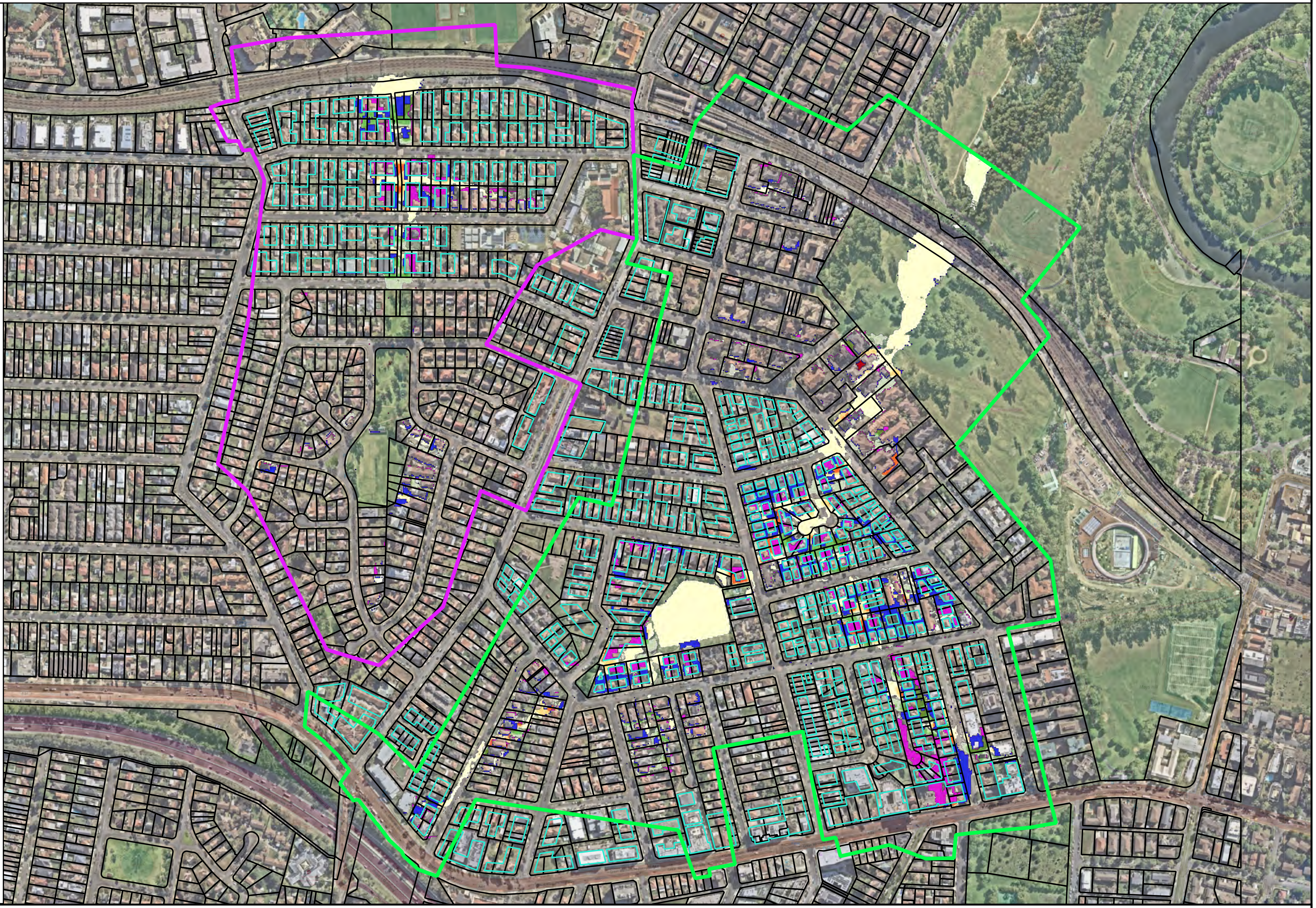
ARCADIS

Figure B-52 - 0.5% AEP Change in Flood Level
Proposed Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Proposed Buildings
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary

Change in Flood Level (m)
- <= -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- No impact
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- > 0.3
- Was wet now dry
- Was dry now wet



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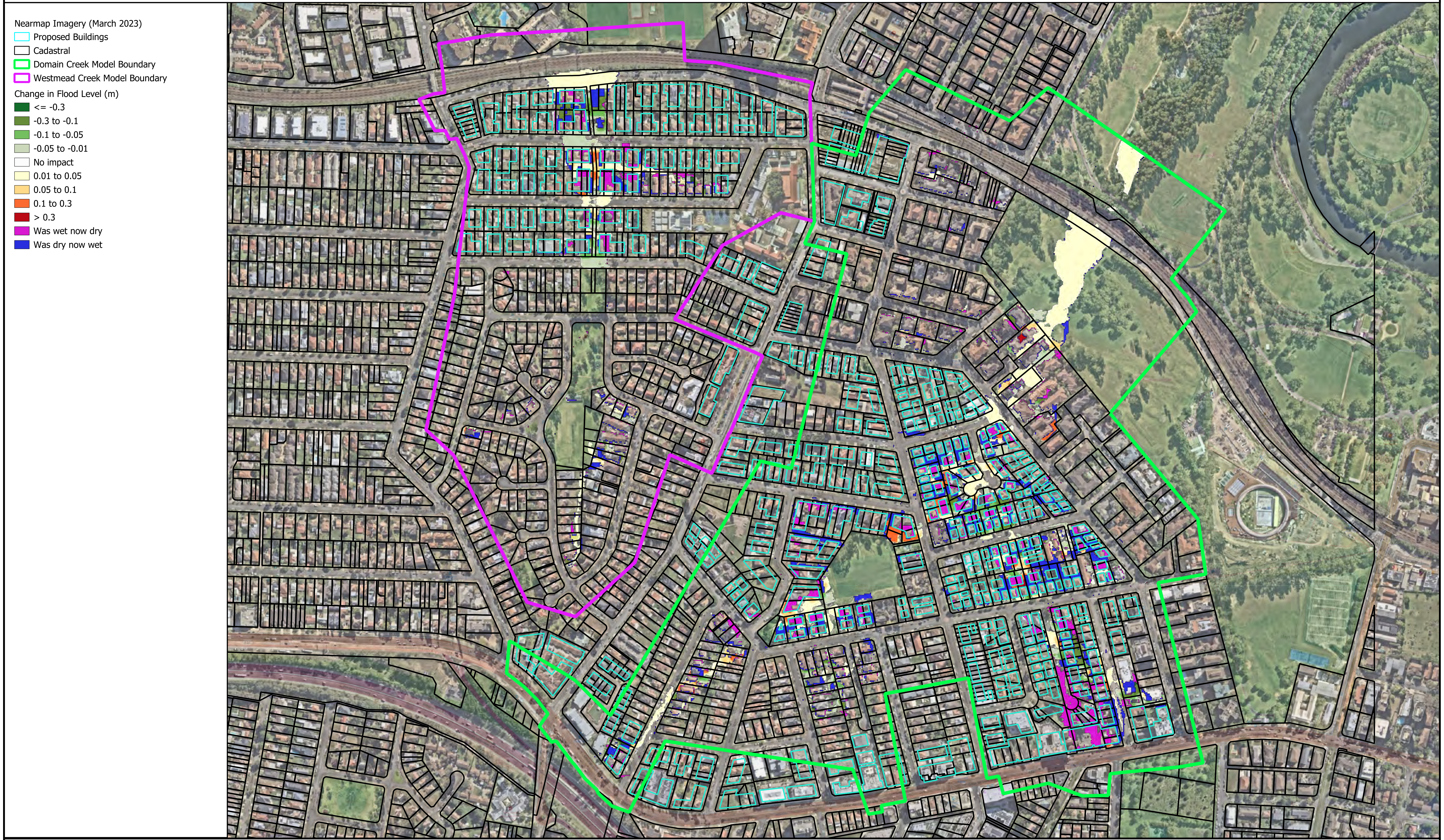
0 200 400 600 800 m

ARCADIS

Figure B-53 - 0.2% AEP Change in Flood Level
Proposed Conditions

Westmead South
30181752
Cumberland City Council



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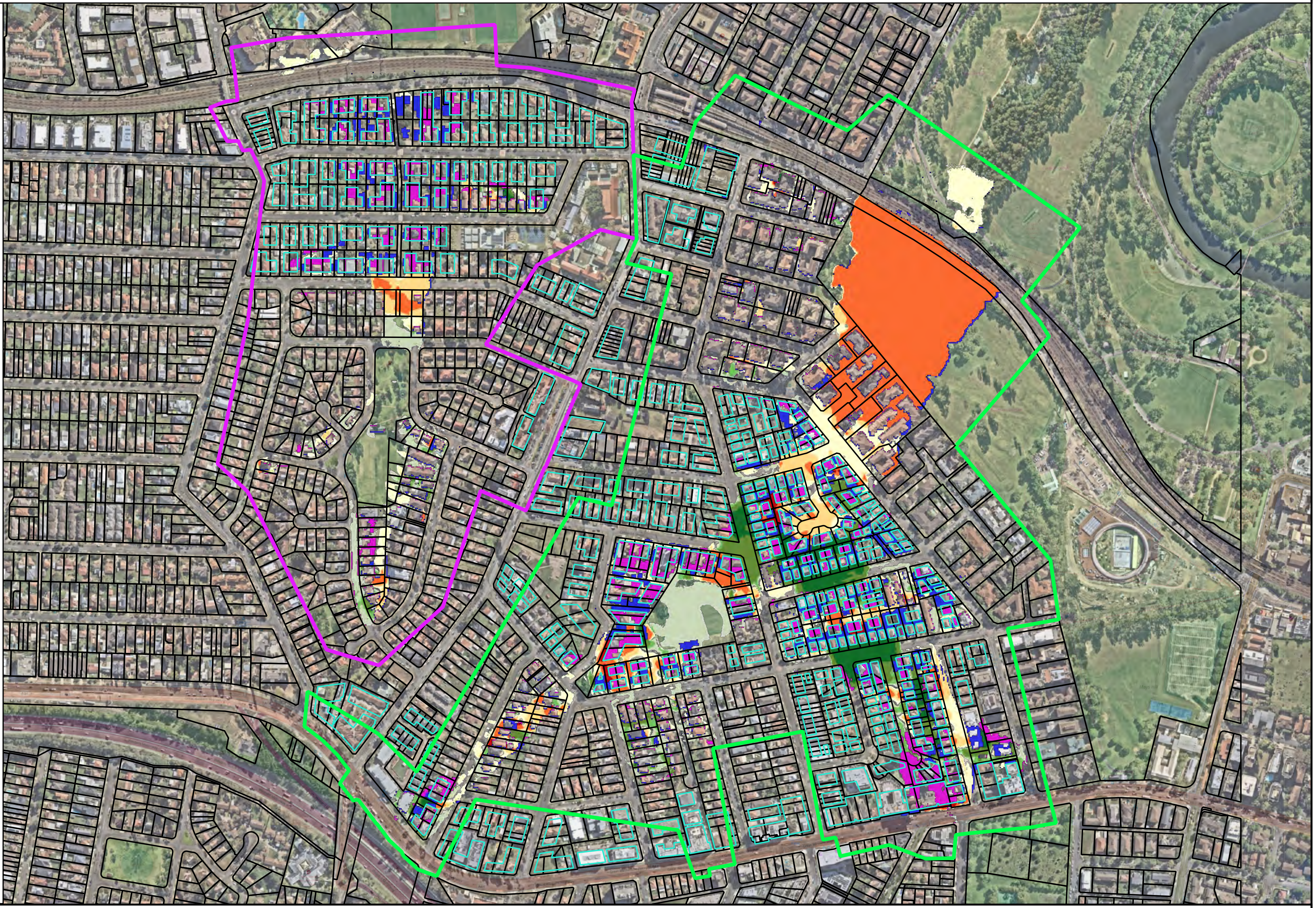
ARCADIS

Figure B-54 - PMF Change in Flood Level
Proposed Conditions

Westmead South
30181752
Cumberland City Council

Nearmap Imagery (March 2023)
- Proposed Buildings
- Cadastral
- Domain Creek Model Boundary
- Westmead Creek Model Boundary

Change in Flood Level (m)
- <= -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- No impact
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- > 0.3
- Was wet now dry
- Was dry now wet



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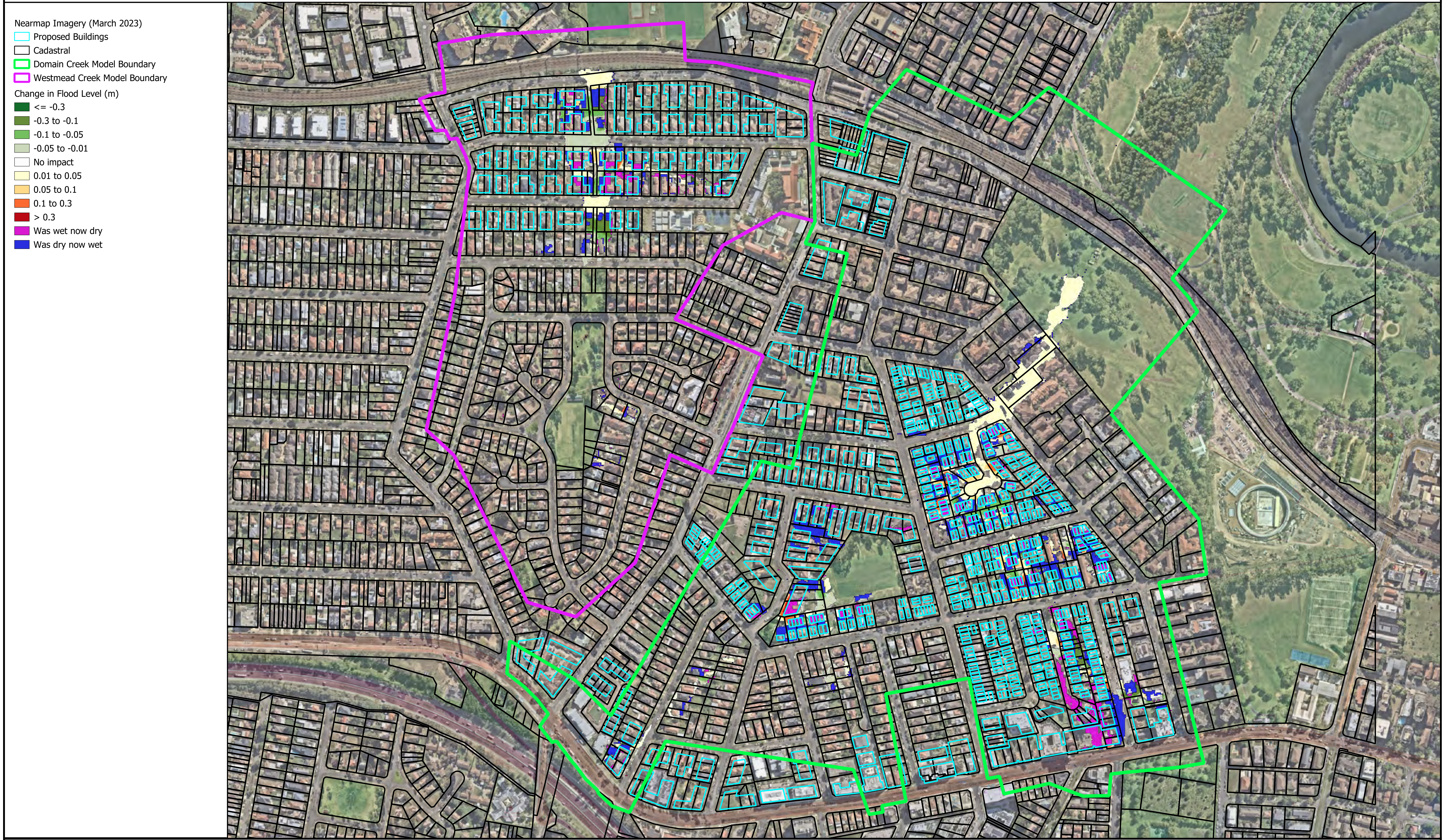
0 200 400 600 800 m

ARCADIS

Figure B-55 - 1% AEP Change in Flood Level
Sensitivity Test (Existing Conditions Hydrology with Proposed Conditions Buildings Layout)

Westmead South
30181752
Cumberland City Council



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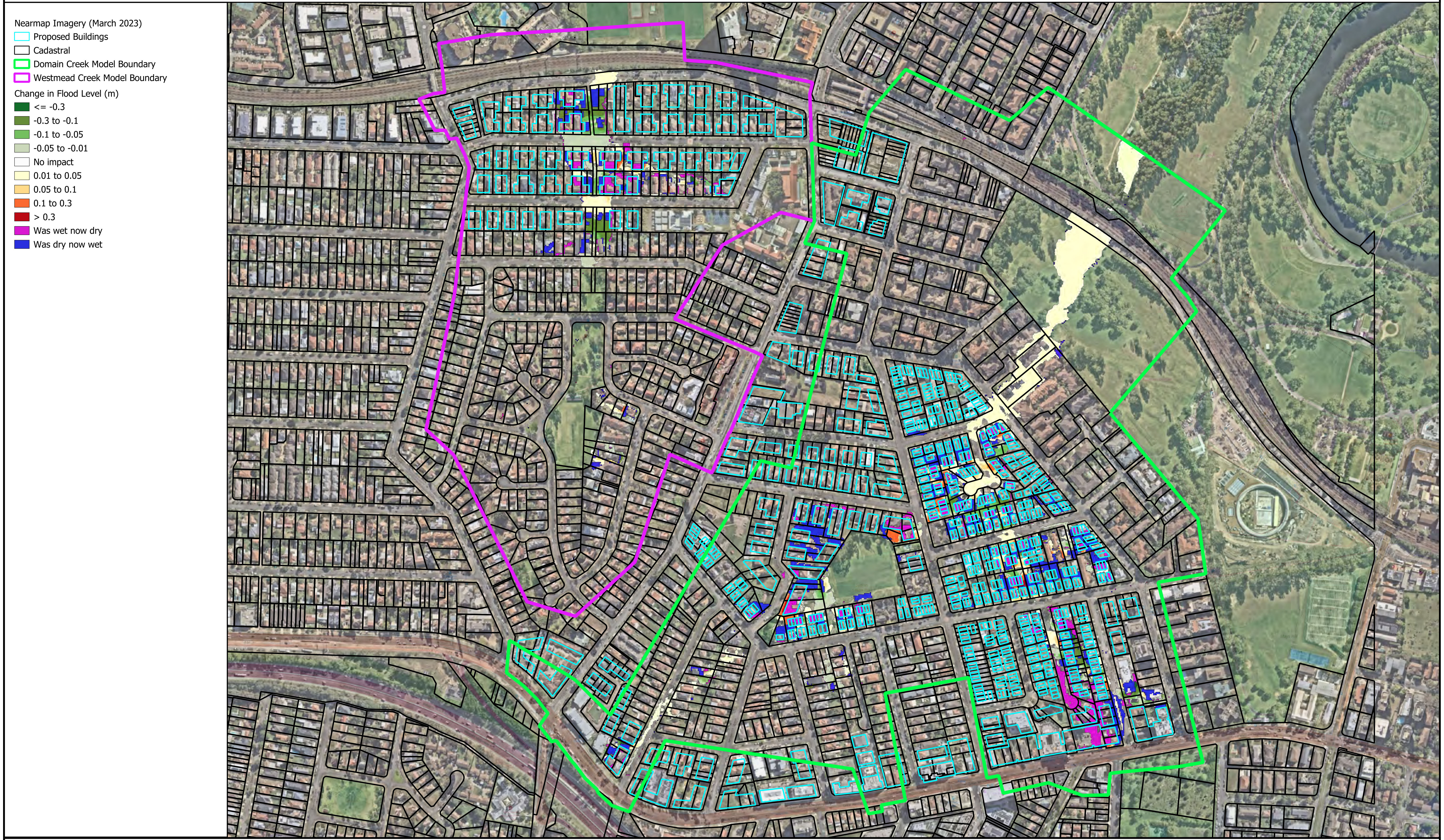
ARCADIS

Figure B-56 - 1% AEP with CC Change in Flood Level
Sensitivity Test (Existing Conditions Hydrology with Proposed Conditions Buildings Layout)

Westmead South
30181752
Cumberland City Council



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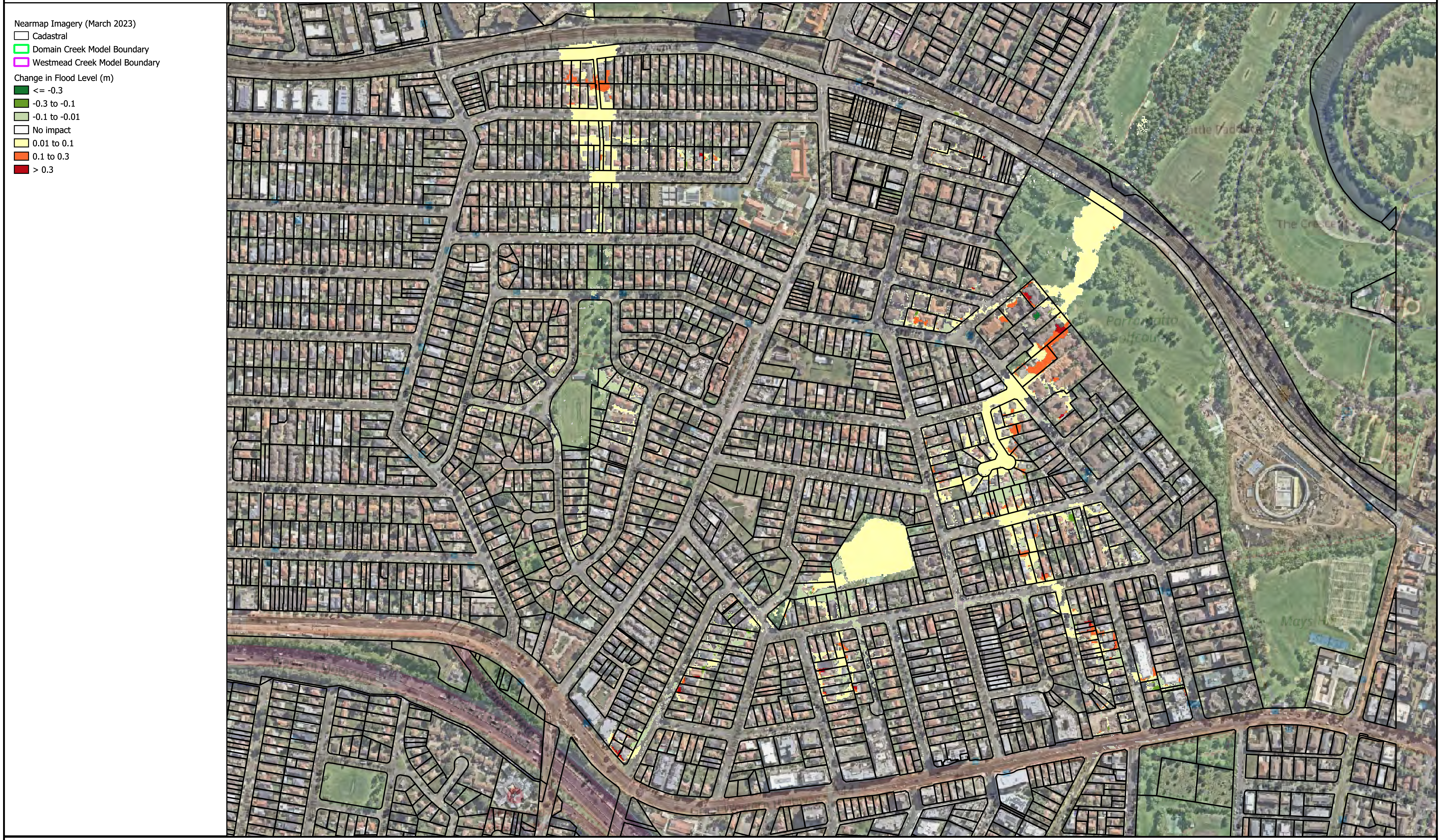
APPENDIX C COMPARISON TO PREVIOUS MODEL

Figure C-1 - 1% AEP Change in Flood Level
Existing Condition (Current model) - Existing Condition (Previous model)

Westmead South
30181752
Cumberland City Council



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