REPORT

Cherrybrook Station Government Land State Significant Precinct

Concept Stormwater Management and Preliminary Flood Risk Assessment

Client: Landcom

Reference: PA2459

Status: Final/P02.01

Date: 06 April 2022

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Document title:	Cherrybrook Station Government Land State Significant Precinct
Document short title:	Cherrybrook Stormwater Assessment
Reference:	PA2459
Status:	P02.01/Final
Date:	06 April 2022
Project name:	Cherrybrook DGL
Project number:	PA2459
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Date:	06.04.2022
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Date:	06.04.2022

Classification
Project related

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Executive Summary

Overview

This study relates to a proposal to develop land called the ‘Cherrybrook Station Government Land State Significant Precinct’ (the State Significant Precinct) by Landcom on behalf of the landowner, Sydney Metro. The State Significant Precinct is centred around Cherrybrook Station on the Metro North West Line. The Metro North West Line delivers a direct connection with the strategic centres of Castle Hill, Norwest, Macquarie Park and Chatswood. It covers 7.7 hectares of government-owned land that comprises the Cherrybrook Station, commuter carpark and station access road (Bradfield Parade) and vacant land to the east of the station (referred to as the Developable Government Land) (DGL). It is bound by Castle Hill Road (south), Franklin Road (south east) and Robert Road (north west).

As a State Significant Precinct, the Minister for Planning and Public Spaces (the Minister) has determined that it is of State planning significance and should be investigated for rezoning. This investigation will be carried out in accordance with study requirements issued by the NSW Department of Planning, Industry and Environment (now Department of Planning and Environment (DPE)) in May 2020. These study requirements were prepared in collaboration with Hornsby Shire Council and The Hills Shire Council.

The outcome of the State Significant Precinct process will be new planning controls. This will enable the making of development applications to create a new mixed-use local centre to support Cherrybrook Station and the needs of the local community.

At the same time, DPE is also working with Hornsby Shire and The Hills Shire Councils, as well as other agencies such as Transport for NSW, to undertake a separate planning process for a broader area called the Cherrybrook Precinct. Unlike the State Significant Precinct, the outcome of this process will not be a rezoning. Instead, it will create a Structure Plan that will help set the longer term future for this broader area. Landcom will be consulted as part of this process.

Project Description

A Reference Scheme has also been prepared to illustrate one way in which the State Significant Precinct may be developed in the future under the proposed new planning controls. The Reference Scheme seeks to create a vibrant, transit-oriented local centre, which will improve housing choice and affordability and seeks to integrate with Hornsby’s bushland character. The Reference Scheme includes the following key components:

- Approximately 33,350m^2 of residential GFA, with a yield of approximately 390 dwellings across 12 buildings ranging in height from 2 to 5 storeys (when viewed from Bradfield Parade).
- A multi-purpose community hub with a GFA of approximately 1,300m².
- Approximately 3,200m² of retail GFA.
- Over 1 hectare of public open space, comprising:
    - A village square with an area of approximately 1,250m², flanked by active retail and community uses.
    - A community gathering space with an area of approximately 3,250m².
    - An environmental space around the pond and Blue Gum High Forest with an area of approximately 8,450m^2.
- Green corridors and pedestrian through site links, providing opportunities for potential future precinct-wide integration and linkages to the north.

Purpose

The purpose of this study is to address the relevant study requirements for the State Significant Precinct, as issued by DPE. It is part of a larger, overall State Significant Precinct Study. This report outlines a stormwater, water sensitive urban design (WSUD) strategy and flooding assessment to support the planning investigations for the proposed re-zoning of government land for the Cherrybrook Station Precinct.

Stormwater Quantity

It is expected that piped stormwater drainage system will be established to manage stormwater runoff from future development within the DGL. Where possible, the existing piped drainage system constructed by Sydney Metro would be utilised. However, some modifications may be required. It is expected that the system would be integrated with the detention storage and water quality treatment controls. Treated water will be discharged into the existing gully that is located to the north of the DGL.

An upper bound estimate of 3,200 m^3 for detention storage requirements was previously estimated by RHDHV (2017) based on a percentage imperviousness of 85%. Based on the DGL reference design, which is likely to incorporate WSUD philosophies with an emphasis on providing beneficial open space and soft landscaping areas, the imperviousness of the site could be less than previously estimated. Assuming a lower bound estimate of site imperviousness of 65%, the total detention storage volume requirement was calculated to be approximately 3,000 m^3. Further optimisation to reduce the detention storage volume requirement could be explored (e.g. using a high early discharge outlet configuration) during the detailed design process.

Detention storage requirements could be provided in several configurations by either:

- maintaining the Sydney Metro basin and provide additional lot scale detention storage within the future development lots. This is expected to be via underground storage tanks.
- expanding the existing Sydney Metro basin to provide the fully developed site storage requirements, or
- replacing the Sydney Metro basin with an underground detention storage tank(s) (not preferred).

A preferred configuration or combination of configurations would need to be established at future development stages.

Stormwater Quality

Water quality controls are required to improve the quality of stormwater runoff from the developed area. The relevant targets include average annual pollutant load reductions for TSS, TP and TN of 85%, 65% and 45% respectively. Water quality treatment controls arranged in a ‘treatment train’ would need to be integrated into any future development to satisfy the abovementioned pollutant load reduction targets.

A preliminary stormwater treatment strategy was conceptually modelled using the MUSIC to estimate the treatment effectiveness of water quality controls in addressing the stormwater quality targets. Stormwater controls including rainwater harvesting, vegetated buffers and swales, raingardens or biofiltration systems and underground propriety stormwater treatment systems (such as the Humes Jelly Fish unit) were modelled. Stormwater quality modelling results demonstrate that stormwater load reduction targets could be achieved for a future development using a combination of the abovementioned stormwater controls, but this would need to be confirmed against the layout and design of the proposed future development.

Preliminary Flood Risks and Flood Management

Due to the DGL site being located at the top of the catchment where the terrain is steep, flows are conveyed by a combination of existing stormwater drainage and natural overland flow paths or creeks. Consequently, flood extents near the DGL site are narrow and well-defined. Even during large (less frequent) flood events (e.g. 1% AEP event with and without Climate Change allowance), flooding within the DGL site is confined to the remnant creekline that traverses along the northernmost site boundary and a small backwater that occurs immediately downstream of the existing detention basin.

Overall, the existing flooding behaviour estimated near the DGL site does not present a significant risk to property or life associated with the proposed re-development. Detention storage and site discharge requirements are the standard mitigation measures/development controls to alleviate flooding impacts of the proposed development. Detention storage is required at the DGL site so that peak flows from the site do not increase and cause increased flooding to neighbouring/downstream properties.

The risk to property as a result of the flood planning (1% AEP design) event is effectively managed by the site detention storage and permissible site discharge requirements. The risk to life as a result of an extreme flood event would be considered very low for the DGL site as the site is located at the top of the catchment, and there are no overland flow paths from upstream catchments which impact on the DGL site, apart from on the northern side and downstream of the existing detention basin. Other mitigation measures carefully planned during the detailed design process of the DGL site could successfully eliminate the potential for loss of life for the proposed development. This would need to be considered in combination with the layout and design of the proposed future development.

The risk to life downstream of the DGL site is for a relatively small number of properties which could be considered to be at high risk or constituting a potential loss of life during an extreme flood event. Importantly, this flood risk is not a result of the proposed development of the DGL site. This is an existing flood risk that remains unchanged as a result of the proposed development.

1 Introduction

1.1 Overview

This study relates to a proposal to develop land called the 'Cherrybrook Station Government Land State Significant Precinct' (the State Significant Precinct) by Landcom on behalf of the landowner, Sydney Metro. The State Significant Precinct is centred around Cherrybrook Station on the Metro North West Line. The Metro North West Line delivers a direct connection with the strategic centres of Castle Hill, Norwest, Macquarie Park and Chatswood. It covers 7.7 hectares of government-owned land that comprises the Cherrybrook Station, commuter carpark and station access road (Bradfield Parade) and vacant land to the east of the station (referred to as the Developable Government Land) (DGL). It is bound by Castle Hill Road (south), Franklin Road (south east) and Robert Road (north west).

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The outcome of the State Significant Precinct process will be new planning controls. This will enable the making of development applications to create a new mixed-use local centre to support Cherrybrook Station and the needs of the local community.

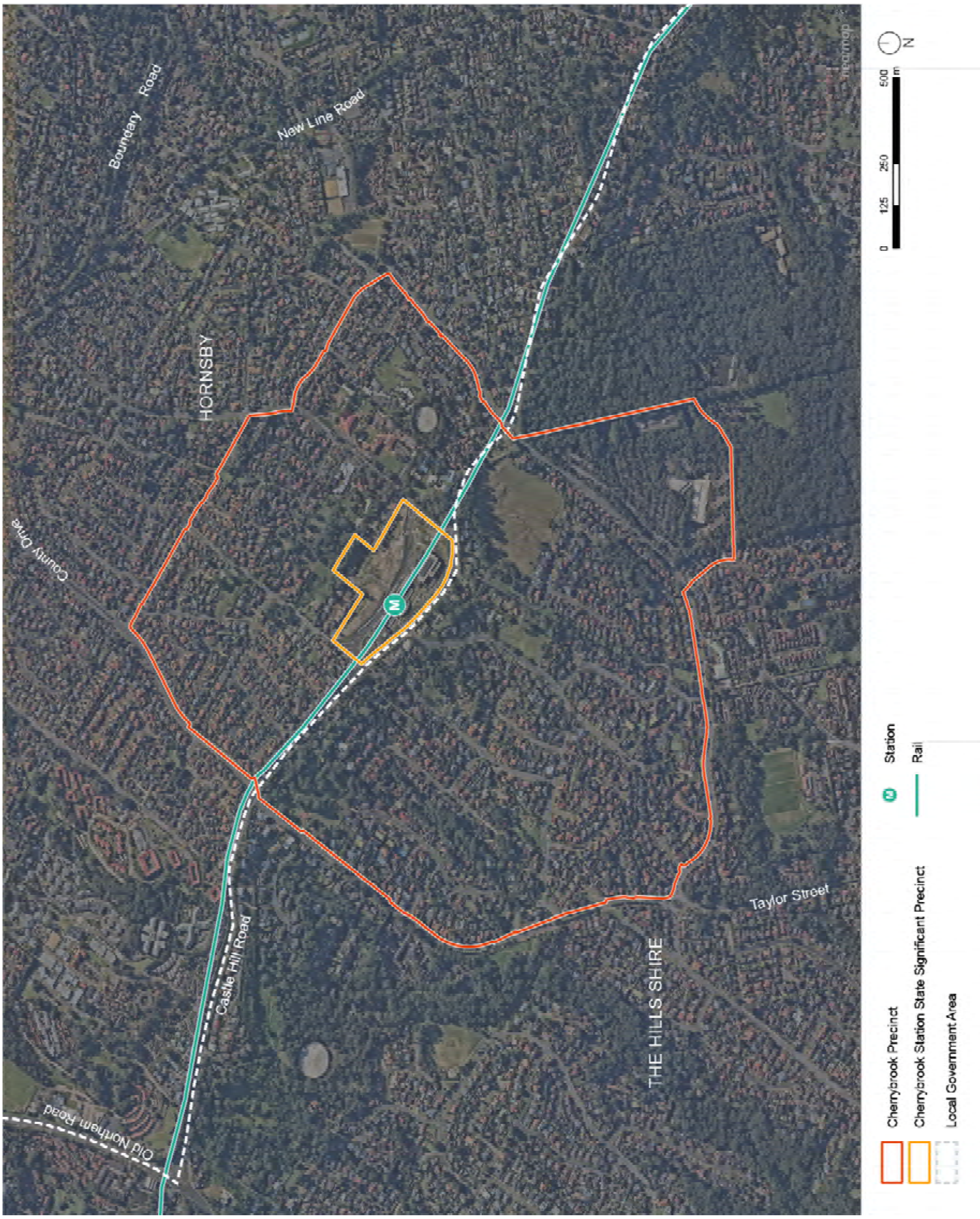
At the same time, DPE is also working with Hornsby Shire and The Hills Shire Councils, as well as other agencies such as Transport for NSW, to undertake a separate planning process for a broader area called the Cherrybrook Precinct. Unlike the State Significant Precinct, the outcome of this process will not be a rezoning. Instead, it will create a Place Strategy that will help set the longer term future for this broader area. Landcom will be consulted as part of this process.

Figure 1-1 Error! Reference source not found. illustrates the site boundaries of the State Significant Precinct and the Cherrybrook Precinct.

1.2 Purpose

The purpose of this study is to address the relevant study requirements for the State Significant Precinct, as issued by DPE. It is part of a larger, overall State Significant Precinct Study. This State Significant Precinct Study undertakes planning investigations for the precinct in order to achieve a number of objectives that are summarised as follows (refer to the State Significant Precinct Study Planning Report for a full list of the study requirements):

- facilitate a mixed-use local centre at Cherrybrook Station that supports the function of the station and the needs of the local community
- deliver public benefit through a mixed use local centre
- deliver transport and movement initiatives and benefits
- demonstrate the suitability of the site for the proposed land uses
- prepare a new planning framework for the site to achieve the above objectives.



Source: NSW Department of Planning, Industry and Environment

Figure 1-1: Cherrybrook Precinct and Cherrybrook Station State Significant Precinct (the subject of this proposal)

1.3 Assessment guidelines and requirements

This Concept Stormwater Management and Preliminary Flood Risk Assessment has been prepared to address key study requirements (NSW Government, 2020) relevant to water quality, flooding and stormwater for Cherrybrook Station Government Land issued in May 2020.

Table 1-1 lists the matters relevant to this assessment and where they are addressed in this report.

Table 1-1: Specific study requirements addressed in this report

Requirement	Section Addressed
Item 17.1 Provide a concept Stormwater Management Plan outlining the general stormwater management measures for the proposal, with particular emphasis on the relationship with the OSD system for Metro Station and Commuter Carpark stormwater, WSUD options and water quality in accordance with Hornsby Council's relevant policies including Hornsby Development Control Plan 2013.	Stormwater management guidelines, objectives and targets for managing stormwater quantity are discussed in **Section 5**. A conceptual stormwater management plan is presented in **Section 6**. Matters relating to stormwater drainage, detention storage requirements and detention storage options informed by hydrologic and hydraulic (DRAINS) modelling are discussed in **Section 6.2** and **Section 6.3.**
Item 17.2 Provide a Water Sensitive Urban Design Strategy for the proposal in accordance with the Hornsby Development Control Plan 2013 including a high-level indicative concept that addresses the key considerations listed.	Matters relating to stormwater quality including a conceptual strategy to manage common stormwater pollutants using WSUD elements and stormwater quality controls are discussed in **Section 6.4**. The treatment effectiveness of water quality controls in addressing stormwater quality targets for the site was estimated using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC).
Item 17.3 Provide a preliminary Flood Risk Assessment, developed in consultation with Councils, identifying behaviours for existing and developed scenarios, in accordance with the relevant Council flood studies to outline the suitability of the land for proposed uses.	A preliminary flood risk assessment informed by detailed hydrological and hydraulic models of the study area are presented in **Section 7**. Details of the topography and drainage pathways, the models used (DRAINS and TUFLOW) and the existing flood conditions near the site are discussed.
Item 17.4 Provide preliminary assessment on recommended flood management measures including mitigation works, development controls and the most appropriate emergency response strategy to manage risk to life.	Potential flood impacts and the risk to life and property near the DGL site is discussed in **Section 8.2**.

2 Project Description

The proposed new planning controls for the State Significant Precinct are based on the investigations undertaken as part of the State Significant Precinct Study process. A Reference Scheme has also been prepared to illustrate one way in which the State Significant Precinct may be developed in the future under the proposed new planning controls.

The proposed planning controls comprise amendments to the Hornsby LEP 2013 to accommodate:

- Rezoning of the site for a combination of R4 High Density Residential, B4 Mixed Use and RE1 Public Recreation zoned land;
- Heights of between 18.5m – 22m;
- FSR controls of 1:1 – 1.25:1;
- Inclusion of residential flat buildings as an additional permitted use on the site in the B4 Mixed Use zone;
- Site specific LEP provisions requiring the delivery of a minimum quantity of public open space, a maximum amount of commercial floor space and the preparation of a Design Guide; and
- New site-specific Design Guide addressing matters such as open space, landscaping, land use, built form, sustainability and heritage.

The Reference Scheme (refer to **Figure 2-1**) seeks to create a vibrant, transit-oriented local centre, which will improve housing choice and affordability and seeks to integrate with Hornsby's bushland character. The Reference Scheme includes the following key components:

- Approximately 33,350m^2 of residential GFA, with a yield of approximately 390 dwellings across 12 buildings ranging in height from 2 to 5 storeys (when viewed from Bradfield Parade).
- A multi-purpose community hub with a GFA of approximately 1,300m².
- Approximately 3,200m² of retail GFA.
- Over 1 hectare of public open space, comprising:
    - A village square with an area of approximately 1,250m², flanked by active retail and community uses.
    - A community gathering space with an area of approximately 3,200m².
    - An environmental space around the pond and Blue Gum High Forest with an area of approximately 8,450m^2.
- Green corridors and pedestrian through site links, providing opportunities for potential future precinct-wide integration and linkages to the north.

Parcel	*Area	Res GFA	Units	Non-Res GFA	Community	Portion FSR*
A	8,597	12,031	141	749		1.49
B	9,610	11,924	140	2,452	1,300	1.68
C	2,574	2,736	32			1.06
D	6,715	6,621	78			0.98
	27,272	**33,312**	**391**	**3,201**	**1,300**	

Notes:
Residential GBA > GFA : 75%
Non-residential GBA > GFA : 85%
Average unit size : 85m

Source: SJB

Figure 2-1: Reference Scheme

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3 Existing Conditions

This section describes the existing flooding and stormwater conditions in the vicinity of the DGL, which is based on a previous assessment of stormwater and flooding undertaken by RHDHV (2016).

3.1 Developable Government Lands

The DGL is wholly located within the upper extents of the Hornsby West Catchment, which drains to the north towards the Hawkesbury River via headwaters to Pyes Creek (RHDHV, 2016). The topography in the local catchment is characterised by moderately steep terrain that falls to the north from a well-defined ridgeline that is located along the Castle Hill Road alignment. **Figure 3-1** shows the topography of the above-mentioned catchment relative to the DGL.

3.2 Cherrybrook Metro Station

Cherrybrook Metro Station is located within the southern portion of the DGL site. The metro station is situated between Castle Hill Road and Bradfield Parade and incorporates:

- Non-pervious areas such as roofing, platform and hardstand areas
- Pervious areas including landscaped gardens, and
- Water Sensitive Urban Design (WSUD) features such as vegetated swales, buffer strips and green roofs.

Figure 3-2 shows a Nearmap aerial image (June 2019) of the recently constructed Cherrybrook Metro Station.

A stormwater management system was constructed as part of the greater Cherrybrook Station project to manage stormwater runoff from the 4.1 ha of land that includes the station and surrounding areas. This area is referred to as the Station Stormwater Management Area in the remainder of this report. The station's stormwater management system includes the following key components:

- A stormwater basin constructed to manage stormwater runoff from the Station Stormwater Management Area. This basin is located in the northern portion of the DGL and is intended to provide both stormwater detention and water quality treatment function. The basin design provides 1,637 m^3 of detention storage. Outflow from the basin is directed into the existing gully that is located in the northern portion of the DGL via low flow outlet pipes and high-flow spillway.
- A piped drainage system constructed to convey runoff from the Station Stormwater Management Area to the stormwater basin.
- A separate piped drainage system is being constructed to convey runoff from Castle Hill Road. This drainage line will outlet downstream of the above-mentioned stormwater basin.

A summary of the Cherrybrook Metro Station stormwater management system is shown on **Figure 3-3**. Key design drawings that have been provided by Sydney Metro are attached in **Appendix A**. It is noted that some aspects of the Cherrybrook Station stormwater management system may be reconstructed to accommodate the proposed development within the DGL.

Incorporated into the Station Stormwater Management Area were WSUD features that aimed to reduce stormwater pollutant loads (total suspended solids, total nitrogen and total phosphorus) to achieve HSC Development Control Plan (DCP) targets.

The WSUD features include:

- two vegetated swales with a total length of 260 m, that treat stormwater runoff through the removal of coarse and medium sediments and attached nutrients (mostly phosphorus). These swales ultimately drain into the piped stormwater network with one swale (160 m long) draining directly into the detention basin allowing for further treatment while the shorter swale (100 m long) drains directly into the Castlehill Road stormwater pipe that bypasses the basin.
- Buffer strips adjacent to hardstand areas and footpaths. These act in a similar way to vegetated swales removing coarse and medium sediments as surface flows pass over them.
- Green roofs with a total area of 1,400 m^2. These act to reduce total runoff from roofed areas where a portion of the rainfall is used to support vegetation.

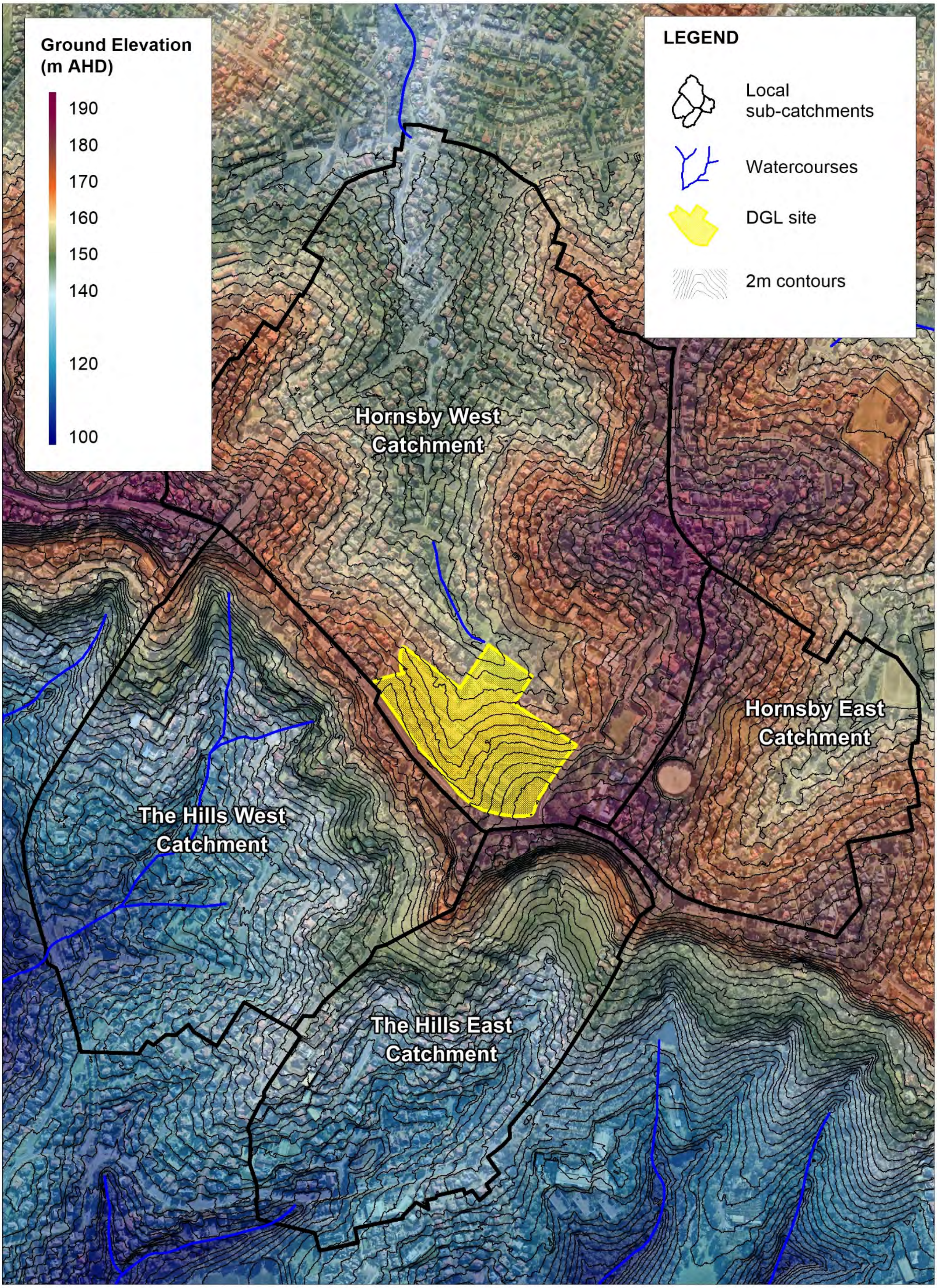

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FIGURE 3-1 Local catchments surrounding the DGL site

NORTH

0 100 200m
Approx. Scale

SCALE 1:10,000

PAGE SIZE A4

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.

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NORTH

PAGE SIZE A3 | SCALE 1:1,500

PROJECT NO: PA2459

PROJECT TITLE: Cherrybrook Station Government Land State Significant Precinct

FIGURE 3-2 **Aerial image of Cherrybrook Metro Station and DGL site**

CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

CREATED BY: L. KIDD

REVISION A

DATE 22/09/2020

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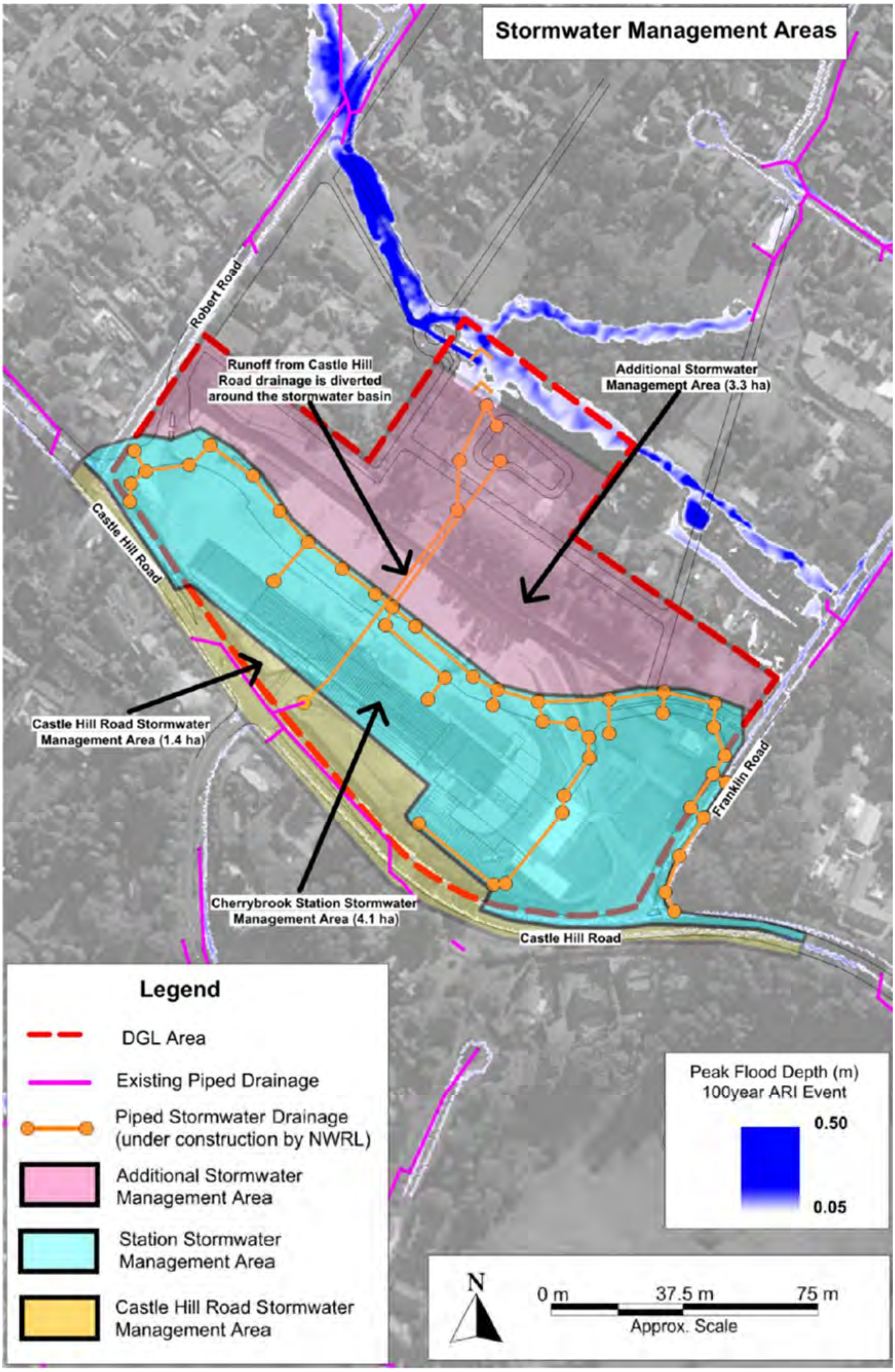

Figure 3-3: Summary of the Cherrybrook Metro Station Stormwater Management System

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4 Potential Changes to Catchment Hydrology

The proposed development within the DGL is expected to increase the extent of impervious surfaces and formalised piped drainage systems. These alterations, if unmitigated, are expected to result in the following hydrologic changes:

- Increases in runoff volumes and peak flow from the development area. Broadly, this will increase stormwater flooding risks in downstream areas.
- Increased potential for stormwater pollution due to higher runoff volumes and pollutant generation potential associated with the increase in impervious areas and change in land use.

The magnitude of these hydrologic changes will be a function of the relative change in the impervious fraction between existing and developed conditions. Accordingly, impervious fractions for existing and proposed conditions were calculated for use in this study by applying the following methods:

- The DGL was divided into a Cherrybrook Station Stormwater Management Area and a Future Development Stormwater Management Area. As discussed in **Section 3**, stormwater controls for the Station Stormwater Management Area were constructed by Sydney Metro.
- The impervious fraction for existing conditions was estimated by RHDHV (2017) from a 2011 aerial image that was taken before the commencement of construction of the Cherrybrook Station. This image is provided in **Appendix B**.
- The impervious fraction for proposed site conditions was previously estimated by RHDHV (2017) to be 85%. A revised estimate of the impervious fraction was calculated using concept designs provided by SJB Architects.

Figure 4-1 shows the extent of the above-mentioned stormwater management areas and **Table 4-1** provides a break-down of the impervious fractions for existing and proposed conditions in each area. These areas are applied to stormwater management calculations that are documented in **Section 5**.

Table 4-1: Fraction of impervious area for stormwater management areas

Stormwater management area	Area (ha)	Impervious Fraction (%)		
		Existing site condition [a]	*Developed site condition*	
			Upper estimate based on RHDHV (2017)	*Revised estimates based on current (August 2020) Cherrybrook station site condition and DGL Reference Design*
Cherrybrook station	4.1	15	85	58[b]
Future development	3.3	15	85	65-85[c]
Total	**7.4**	**15**	**85**	**61 – 70**

[a] estimate reported by RHDHV (2017) based on 2011 aerial photo
[b] revised estimate based on July 2020 Nearmap aerial photo of Cherrybrook station
[c] revised estimate based on concept designs provided by SJB Architects

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FIGURE 4-1 Stormwater management areas

NORTH

0 m 37.5 m 75 m
Approx. Scale

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5 Stormwater Management Guidelines, Objectives and Targets

5.1 Assessment Objectives

The objective of this stormwater assessment is to establish stormwater management requirements for future development proposed within the DGL site. The stormwater requirements have been established on the basis that no further development within the site occurs.

To calculate stormwater requirements such as detention storage volumes, existing conditions refer to pre-Cherrybrook Metro Station conditions and proposed conditions includes both the Cherrybrook Metro Station and proposed development within the DGL.

This approach was applied as the stormwater management system for any future development may be integrated with the Cherrybrook Metro Station stormwater management system.

5.2 Relevant guidelines and targets

5.2.1 Hornsby Shire Council guidelines

WSUD Reference Guideline

The WSUD reference guideline was published by HSC in 2015 and details water management assessment requirements for various forms of development. The guideline also provides recommended stormwater modelling approaches and parameters. Stormwater management objectives from this guideline are summarised in **Table 5-1**, which establishes recommended stormwater management objectives for the DGL.

Development Design Specification 0074: Stormwater Drainage (Design)

This development design specification was published by HSC in 2016 and is similar to HSC's Civil Works Specification Guideline that was published in 2002. The guideline provides information on HSC's civil design specifications and On-Site Detention (OSD) requirements. As part of the 2016 precinct wide stormwater assessment, RHDHV sought clarification on the OSD requirements and pipe blockage assumptions that are specified in the guideline. HSC advised that:

- at a minimum, OSD should be provided to fully mitigate any impacts associated with re-development in the DGL site (i.e. provide parity with existing peak flow estimates). Opportunities to provide OSD and/or larger scale detention storage to reduce peak flows below existing levels are to be assessed on merit.
- the guideline specifies that a 50% pipe blockage assumption is to be applied when calculating overland flows. HSC advised that this assumption does not need to be applied when designing adequate overland paths, but should be applied as a sensitivity scenario to assess the implications of pipe system blockages.

Stormwater management objectives from this guideline are summarised in **Table 5-1**, which establishes recommended stormwater management objectives for the DGL.

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5.2.2 Industry guidelines

Australian Runoff Quality

Australian Runoff Quality (ARQ) is an industry guideline document published in 2005 by the Institution of Engineers Australia (IEAust). The document guides all aspects of water sensitive urban design, including preventative measures, source controls, conveyance controls and end of pipe controls.

Australian Rainfall and Runoff

Australian Rainfall and Runoff (IEAust, 2019) (or AR&R 2019) refers to a series of documents and data that has been prepared by the Institution of Engineers, Australia and the Bureau of Meteorology. AR&R 2019 has been prepared to provide designers with the best available information on design flood estimation and is widely accepted as a design guideline for all flood and stormwater-related investigation and design in Australia.

Stormwater Bioretention Systems – Adoption Guidelines

The Adoption Guidelines for Stormwater Biofiltration Systems were developed by the Facility for Advancing Water Biofiltration in 2009. This guideline contains design recommendations for biofiltration systems.

5.2.3 Landcom sustainable places strategy targets

Landcom has the vision to deliver world-class sustainability outcomes across its portfolio. The Sustainable Places Stagey comprises four categories, namely Climate Resilient Places, Healthy and Inclusive Places, Productive Places and Accountable and Collaborative Places. Climate resilience in particular is related to achieving carbon-neutral, water positive, zero waste and net positive ecological outcomes by 2028.

For Climate Resilient Places, the objectives and targets relevant to this assessment include:

- **Environmental Management**: To maintain and enhance a culture of high environmental performance. BASIX water: All dwellings – 60.
- **Water**: To design our precincts based on best practice water sensitive urban design principles, and actively conserve potable water.

Each project is unique, with its own opportunities and challenges. As such, all targets may not be applicable or suitable for each development. This will be determined on a case by case approach.

5.3 Recommended stormwater management objectives

Table 5-1 provides a summary of the stormwater management objectives that are specified in the HSC guidelines for stormwater system design, OSD design and water quality treatment. These objectives have been applied to establishing stormwater management requirements for the DGL.

In place of stormwater quality targets adopted in Council's DCP, the Landcom NSW water quality objectives for redevelopment were adopted to assess stormwater quality pollutant reduction targets for post-construction stormwater runoff. These targets (which are higher than Councils) are considered to be current best practice and are presented in **Table 5-1**.

Table 5-1: Proposed stormwater management objectives for development with DGL

	Guideline Objectives Summary

Minor stormwater system criteria	• Piped drainage capacity to accommodate 20-year ARI.[1]
	• Apply the following pit blockage assumptions[1]:
	  o Sag pits 50% blockage
	  o On-grade pits 20% blockage.

Major stormwater system criteria	• Overland flow path capacity to accommodate 100-year ARI flow.[1] • Apply a 50% pipe blockage as a sensitivity to assess flood risks associated with pipe system blockages.[1] • Velocity-depth (VD) product on roads ≤0.4 m^2/s.[1] • 500 mm freeboard to habitable floor levels.[1]
Detention storage requirements	• OSD is to be provided to mitigate any increase in peak flows associated with re-development.[1] • Opportunities to provided OSD and/or detention storage to reduce peak flows below existing levels are to be assessed on merit.[1]

Stormwater quality	• Water quality controls are designed to achieve the following pollutant load reductions[2]:
	  o 85% reduction in the average annual load of TSS
	  o 65% reduction in the average annual load of TP
	  o 45% reduction in the average annual load of TN.

Potable water	• All new projects modelled to reduce mains potable water demand by 50% at the precinct scale, against a 2016 reference case.[2]

[1] *Refers to the Development Design Specification 0074: Stormwater Drainage (Design) (HSC, 2016) and associated clarification that are discussed in* ***Section 5.2.1****.*
[2] *Refers to targets adopted by Landcom as part of the Sustainable Places Strategy (available: https://www.landcom.com.au/approach/sustainability/why-sustainability/)*

6 Conceptual Stormwater Management Plan

6.1 Overview

As per Item 17.1 and 17.2 of the Study requirements, a concept Stormwater Management Plan (SMP) was prepared with the following detail:

- the general arrangement of stormwater management measures expected at the DGL site
- details of the relationship of additional detention storage with the OSD system for Cherrybrook Metro Station and Commuter Carpark stormwater, and
- WSUD options for stormwater quantity and quality control following Hornsby Council Development Control Plan 2013 (Part 1C 1.2 Stormwater Management).

The SMP makes recommendations on stormwater management and set objectives for the development proposal informed by a Stormwater Drainage System design and analysis program (DRAINS) to estimate the detention volume/site storage requirements for the government developable area based on Council's stormwater management requirements, i.e. to satisfy a 'no net increase' in stormwater peak flows. Detention volume was estimated on an average area basis (i.e. cubic metres per hectare of the developed site) for a range of developed (fraction impervious) site conditions.

As per Item 17.2 of the Study requirements, a preliminary WSUD strategy is provided consistent with recommended stormwater quality targets to mitigate potential stormwater quality impacts of re-development of the DGL. The strategy does not prescribe a detailed configuration for stormwater controls as it is expected that a range of configurations will be appropriate. However, information on possible options is provided.

The Model for Stormwater Urban Improvement Conceptualisation (MUSIC) was used to demonstrate the quantity and quality of stormwater from the development that can be appropriately managed within the site. The WSUD strategy provides reductions to stormwater pollutant loads (total suspended solids, total nitrogen and total phosphorus) to achieve both Council DCP targets and the targets set out by Landcom in their Sustainable Places Strategy (Landcom, 2019).

6.2 Stormwater drainage

It is expected that a piped stormwater drainage system will be established to manage stormwater runoff from future development within the DGL. Where possible, the piped drainage system that is being constructed by Sydney Metro will be utilised. However, some modifications may be required. It is expected that the system will be integrated with the detention storage and water quality treatment controls. Treated water will be discharged into the existing gully that is located to the north of the DGL.

The trunk drainage system would need to be designed to meet the following design objectives for the minor and major stormwater system that are provided in **Table 5-1**. The risk of pipe blockage is expected to be low as all inflows into the trunk drainage will be through either kerb inlet or grated inlet pits, which will prevent large debris entering the piped drainage system.

6.3 Stormwater detention

Section 4 established that the proposed ultimate development within the DGL area will increase the impervious faction from 15% to as high as 85%. Increased imperviousness will increase both peak flow rates and runoff volumes from the development area, potentially increasing stormwater flood risk in downstream areas. Stormwater detention storage is proposed to mitigate those hydrologic changes. The following section provides information on detention storage calculations and discusses some detention storage configurations that may be appropriate for implementation within the DGL.

6.3.1 Detention volume calculations

Detention storage volumes were calculated using DRAINS hydrologic and hydraulic modelling software. DRAINS was applied to calculate runoff hydrographs from the **7.4 ha** stormwater management area that was established in **Table 4-1**, for both existing and proposed conditions. Associated hydrologic parameters are provided in **Appendix C**.

The DRAINS model was applied to simulate the 2, 5, 10, 20 and 100-year ARI design storm events. A full range of storm durations was assessed using the ensemble storm method (AR&R 2019). Detention storage volumes and nominal low and high outflow rates were established to achieve no increase in peak flows for both the governing and 2-hour duration storm events. The 2-hour duration event was adopted as sizing criteria as it was identified to be the governing duration in the Hornsby West Catchment (RHDHV, 2016). *Note: To undertake stormwater calculations, existing conditions refers to pre-Cherrybrook Metro Station conditions and proposed conditions includes both the Cherrybrook Metro Station and proposed development within the DGL.*

The estimated peak flows for the 2, 5, 10, 20 and 100-year ARI events for both the critical and 2-hour duration events are provided for the upper estimate of site imperviousness (**Table 6-1**) and the reference design developed site conditions (**Table 6-2**).

Table 6-1: Peak flow analysis based on the upper estimate (85%) of developed site imperviousness

ARI (years)	Existing Conditions[1]		Development Conditions (no OSD)		Development Conditions (with OSD)	
	Critical Duration	2 Hour Duration	Critical Duration	2 Hour Duration	Critical Duration	2 Hour Duration
2	0.23	0.23	1.03	0.67	0.23	0.23
5	0.41	0.41	1.32	0.88	0.41	0.41
10	0.62	0.54	1.64	1.01	0.52	0.51
20	0.83	0.66	1.93	1.23	0.66	0.63
100	1.37	1.23	2.62	1.85	1.23	1.23

Source: RHDHV (2017)

Table 6-2: Revised peak flow analysis for the lower estimate (65%) of developed site imperviousness

ARI (years)	Existing Conditions[1]		Development Conditions (no OSD)		Development Conditions (with OSD)	
	Critical Duration	2 Hour Duration	Critical Duration	2 Hour Duration	Critical Duration	2 Hour Duration
2	0.23	0.23	0.70	0.47	0.16	0.16
5	0.41	0.41	1.10	0.75	0.31	0.31
10	0.62	0.54	1.41	0.89	0.44	0.44
20	0.83	0.66	1.69	1.11	0.57	0.57
100	1.37	1.23	2.38	1.79	1.07	1.07

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Table 6-3 provides the calculated OSD volume and outflow rates for both a unit area (i.e. per ha of development area) and the whole of DGL area basis based on the upper estimate and best estimate of developed site imperviousness. The DGL area requirements are inclusive of both the Cherrybrook Station and future development within the DGL.

Table 6-3: Required OSD volume and outflow rates

	Detention Storage Volume		Nominal Outflow Rates	
	Upper Bound Estimate (85%)	*Lower Bound Estimate (65%)*	*Upper Bound Estimate (85%)*	*Lower Bound Estimate (65%)*
Unit Area OSD Requirements	432 m^3/ha	408 m^3/ha	Low Flow: 31 L/s/ha High Flow: 166 L/s/ha	Low Flow: 31 L/s/ha High Flow: 145 L/s/ha
DGL Area Requirements	3 200 m^3	3 020 m^3	Low Flow: 228 L/s High Flow: 1 230 L/s	Low Flow: 228 L/s High Flow: 1 071L/s

The upper bound estimates of detention storage volume presented in **Table 6-3** can be reduced if:

- Impervious percentages are less than assumed (i.e. less than 85%)
- Source controls such as rainwater tanks, green roofs or permeable paving are adopted, and/or
- Water quality controls such as biofiltration systems are adopted.

Conversely, the lower bound estimate of the detention storage volume is based on existing (2020) Cherrybrook Metro Station site conditions and the concept designs for the DGL site and may need to be increased if impervious percentages are greater than assumed (i.e. greater than 65%).

6.3.2 Detention storage options

As discussed in **Section 4**, the stormwater management basin constructed as part of the Sydney Metro stormwater system was designed to provide 1,637 m^3 of detention storage. Based on the site storage requirements estimated by RHDHV (2016), a further 1,563 m^3 of storage is needed to satisfy the upper bound volume requirement that is provided in **Table 6-3** above.

The upper bound detention volume requirement assumed a site imperviousness of 85%, which is an upper bound (liberal) estimate. A lower bound or best estimate of site imperviousness of 65% was also considered based on preliminary concepts for the DGL reference design. With this best estimate of site imperviousness, the additional storage requirements were estimated to be 1,383 m^3 (i.e. a total detention storage volume requirement[3] of approximately 3,000 m^3).

Table 6-4 outlines potential OSD configurations. A preferred configuration or combination of configurations would need to be established at future development stages. To assist with the feasibility assessment of the options presented in **Table 6-4**, a preliminary cost estimate for each was undertaken and presented below. A more detailed breakdown of these cost estimates is provided in **Appendix E**. The costs provided are based on an evaluation of cost estimation data current as of 2020.

[3] *Further optimisation to reduce the detention storage volume requirement could be explored (e.g. using a high early discharge outlet configuration) during the detailed design process.*

Table 6-4: Potential OSD configurations

	Description	Comments
Configuration 1	Hybrid (existing basin with underground storage). Maintain the Sydney Metro basin and provide additional lot scale OSD within the future development lots. This is expected to be via underground storage tanks.	• Utilises Sydney Metro infrastructure • Can easily be staged with future development. • Reduces the potential for upgrades to the Sydney Metro piped drainage system.
Configuration 2	Expansion of existing basin as open-air storage only. Expand the existing Sydney Metro basin to provide the fully developed site storage requirements.	• Increase the size and amenity impact of the Sydney Metro basin.
Configuration 3	Double Trap System. Replace the Sydney Metro basin with underground detention storage tanks (not preferred)	• High-cost solution. • Removes the basin as an urban design constraint.

Preliminary cost estimates[4]:

- **Configuration 1** – approximately $1,800,000
- **Configuration 2** – approximately $700,000, and
- **Configuration 3** – approximately $3,600,000.

The cost estimates are relative to one another and preliminary at this stage i.e. indicative only. They have been calculated based on estimation data current as of 2020. These estimates make the following assumptions.

- **Configuration 1**:
  - Existing detention basin maintained (1,637 m^3) and retrofitted to work in combination with an additional underground storage tank (1,663 m^3).
  - Total Volume of approximately 3,300 m^3.
  - Approximate tank footprint of 34 m by 24 m, assuming 2.1 m of storage depth although this footprint can be reduced if depth increased.
  - Backfill depth approximately 1 m.
  - Half of the remaining excavated material is disposed of a Virgin Excavated Natural Material (VENM) and the other half as uncontrolled fill.
  - Only allows for very basic landscaping around the basin (topsoil and turf only).
- **Configuration 2**:
  - Existing basin extended to achieve the required addition volume of 1,563 m^3, therefore total volume equal to approximately 3,200 m^3.
  - Existing inlets, low flow outlet and high flow spillway maintained.

[4] *All cost estimates include a 30% contingency. Double trap system as costed by Humes.*

- Half of the excavated material is disposed of a Virgin Excavated Natural Material (VENM) and the other half as uncontrolled fill.
- Only allows for very basic landscaping around the basin (topsoil and turf only).

- **Configuration 3**:
  - The entire OSD is provided by a new underground tank and associated inlet/outlet structures (Humes Double Trap System or equivalent) with a volume of approximately 3,600 m^3.
  - Approximate basin footprint of 40 m by 50 m (the existing basin site is included in this area and the void left by the existing basin has been taken into account in the earthworks calculations).
  - Basin internal depth of approx. 2 m.
  - Backfill depth approximately 1 m.
  - Only allows for very basic landscaping around the basin (topsoil and turf only).

6.4 Stormwater quality

6.4.1 Water quality control options

Water quality controls are required to improve the quality of stormwater runoff from the development area **Table 5-1** established that water quality controls are to be designed to achieve the following pollutant load reductions:

- 85% reduction in average annual load of total suspended solids (TSS)
- 65% reduction in average annual load of total phosphorus (TP), and
- 45% reduction in average annual load of total nitrogen (TN).

The following water quality treatment controls arranged in a ‘treatment train’ are considered to be capable of meeting the abovementioned pollutant load reductions:

- Rainwater harvesting
- Vegetated buffers
- Vegetated swales
- Raingardens or biofiltration systems
- Underground propriety stormwater treatment systems (such as the Humes Jelly Fish unit or similar).

The following secondary controls could also be deployed in certain areas to assist meeting the above-mentioned pollutant load reductions (by reducing the effective impervious area in the site):

- Permeable pavement in low traffic or public open space areas.
- Green rooftops on building to reduce the effective impervious area. This would also reduce OSD requirements.

6.4.2 Effectiveness of stormwater quality controls

A preliminary stormwater treatment strategy was conceptually modelled using the MUSIC (see **Appendix D** for further detail) to estimate the treatment effectiveness of water quality controls in addressing the stormwater quality targets outlined in **Table 5-1**.

The concept for the future development of the DGL should accommodate conventional pit and pipe drainage for the conveyance of stormwater runoff from roof and hardstand areas to treatment measures. The effectiveness of water quality controls was assessed based on the following assumptions:

Cherrybrook Metro Station:

- Green roofs at Cherrybrook Station do not provide stormwater quality treatment; the surface was modelled as an impervious area with a higher impervious threshold to account for greater losses than typical hardstand surfaces, i.e. a majority of rainfall will be collected as stormwater by the underlying drainage collection system.
- Stormwater from green rooftops and landscaped/open space are collected and directed to vegetated swales via downpipes and surface contouring. Details of vegetated swales constructed at Cherrybrook station were estimated from Work-As-Executed (WAE) drawings.
- Station roof, road and hardstand areas are directed to the stormwater system, i.e. stormwater is untreated.
- A new Gross Pollutant Trap (GPT) could be installed immediately upstream of a bioretention system constructed near the existing stormwater basin.

Future Development of DGL:

- All building roof areas could be directed to a rainwater tank located in the basement of each building.
- The average occupancy rate for household apartments is 2.3 (based on similar density areas in the Hornsby Local Government Area).
- Average typical potable water use for a household is around 200 L/person/day. Toilet flushing and clothes washing has a relatively constant demand throughout the year and typically accounts for around 20% and 12% of household water use respectively (Sydney Water, 2019).
- Vegetated buffers could be provided adjacent to access roads as a source control measure
- 75% of road surfaces could be treated by vegetated swales.
- 80% of landscaped and open space could be treated by vegetated swales.
- A GPT could be installed immediately upstream of a bioretention system.
- A bioretention system could be retrofitted into the existing stormwater basin to provide final treatment before discharge to the local watercourse.

The size and configuration of the stormwater treatment measures modelled are summarised in **Table** 6-5. Mean annual pollutant loads estimated for the future development of the DGL site including the area shown in **Table 6-6**. The results demonstrate that best practice stormwater quality targets could be achieved for future development using a combination of the abovementioned water quality control options.

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Table 6-5: Summary of stormwater treatment measures

Stormwater Treatment Measure	Potential Configuration
Vegetated Swale	Total length = 100 m Slope = 1% Base width = 1.2 m Top width = 3 m Depth = 0.3 m Vegetation height = 0.075m Exfiltration rate = 0mm/hr
Vegetated buffer	1 m buffer strip along the access road Percentage of upstream area buffered = 90% Buffer area as a percentage of impervious area = 10% Exfiltration rate = 0 mm/hr
Bioretention basin	Surface area = 450 m^2 Extended detention depth = 0.30 m Total biofilter area = 300 m^2 Biofilter depth = 0.50 m Saturated hydraulic conductivity = 150 mm/hr TN content of filter media = 800 mg/kg Orthophosphate content of filter media = 40 mg/kg Exfiltration rate = 0 mm/hr
Gross Pollutant Trap (GPT) (Humes Jellyfish or similar)	Number of GPTs = 2 High flow by-pass = 0.0325 m^3/s Flow reduction = 0% TSS concentration reduction = 80% TP concentration reduction 42% TN concentration reduction = 34%
Rainwater tanks/basement storage	Number of tanks = 9 (one per building) Individual tank properties: *Volume below overflow pipe = 100 kL* *Surface area = 50 m^2* *Initial volume = 50 kL* *Overflow pipe diameter = 100 mm* Re-use demand for each tank: *Constant daily demand = 5 kL/day*

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Table 6-6: Mean annual pollutant load and treatment effectiveness

Parameter	Mean Annual Load and Treatment Effectiveness		
	Source	Residual	% Reduction
Flow (ML/yr)	59.7	48.9	18.1
Total Suspended Solids (kg/yr)	7170	1060	85.3
Total Phosphorus (kg/yr)	14.3	4.4	69.2
Total Nitrogen (kg/yr)	121	47.3	60.8
Gross Pollutants (kg/yr)	1210	5.64	99.5

7 Preliminary Flood Risk Assessment

7.1 Overview

A stormwater and flooding assessment was previously undertaken by RHDHV (2016) to inform masterplan development of the Cherrybrook Station Precinct. RHDHV (2016) utilised the flood and urban stormwater model software (TUFLOW) to estimate the capacity of the existing piped drainage system and to identify overland flow paths and areas where surface flooding issues may occur.

The 2016 flood model covers the Hornsby West Catchment (refer **Figure 3-1**) and provides the most up-to-date model representation of urban stormwater and flooding processes for the local catchment by incorporating:

- surface levels from LiDAR survey
- approximate pipe alignment and diameters
- major culvert crossings, and
- indicative pit locations, pit type and internal dimensions.

As per Item 17.3 and 17.4 of the Study requirements, a preliminary flood risk assessment (FRA) for the DGL site was undertaken using the 2016 flood model to:

- obtain an estimate of existing flood conditions (level, depth/extent, velocity, hazard) near the SSP site (local catchment only) for the 5-year, 20-year and 100-year ARI design flood events
- identify the existing flooding behaviour of the proposed developable area, including peak flood levels, flood depth/extents, peak flood velocities and hazard categories for the above design flood events
- simulate an extreme flood event for the assessment of the risk to loss of life at the DGL site
- simulate the proposed development (including any proposed ground elevation changes, flow diversions, increased imperviousness/runoff, proposed OSD) to estimate potential flood impacts, and
- undertake a sensitivity analysis of increased rainfall intensity (due to climate change) on flooding behaviour and potential impacts at the site (to address Item 11.3 of the Study Requirements).

Based on the findings of the baseline flood mapping, the DGL was assessed with respect to its suitability for the proposed mixed uses.

7.2 Topography and drainage pathways

The topography downstream of the DGL site is characterised by moderately steep terrain that drains in a northerly direction. The existing detention basin adjacent to the northern DGL site boundary is located immediately upstream of a confluence of three small tributaries that combine and flow through an existing drainage easement within 18 Robert Road.

An overview of the key drainage and catchment features downstream of the DGL site are shown in **Figure 7-1** below.

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Figure 7-1: Key drainage features downstream of the DGL site

The drainage easement within 18 Robert Road creates a small informal detention basin before these flows enter a 2.1 m wide x 0.9 m high box culvert which flows under Robert Road where it becomes a DN1650 pipe. The DN1650 pipe runs from Robert Road under Robert Road Park until it reaches the pedestrian path at the southern end of Ashford Road where it becomes a DN2250 pipe which drains towards the north under Ashford Road. For the sake of consistency, this trunk line is referred to only as a DN2250 throughout the following sections.

In the previous work undertaken by RHDHV in 2016, hydraulic model results indicated that the pipe system capacity for this area was greater than the 5% AEP and the major trunk drainage line under Ashford Road is estimated to have an approximate 80-year ARI capacity.

7.3 Hydrological and hydraulic modelling

7.3.1 DRAINS hydrological model

A review of the previous Cherrybrook DRAINS model used in the RHDHV 2016 Stormwater and Flooding Assessment was undertaken, including catchment delineation, catchment losses and parameterisation. The review determined that the DRAINS model was appropriate for use in the preliminary flood risk assessment with the following changes:

- Update of the impervious area of the DGL catchment from 15% (before the construction of the Cherrybrook Train Station) to 47% based on the footprint of the completed Cherrybrook Train Station;
- Inclusion of the current 1,637 m^3 detention basin at the northernmost boundary of the DGL site; and
- Addition of the 1% AEP with a 30% increase in rainfall intensity to account for climate change impacts and an extreme flood event based on three times the 1% AEP to assess the risk to loss of life.

7.3.2 TUFLOW hydraulic model

A review of the previous TUFLOW model used by RHDHV (2016) was undertaken. The Cherrybrook TUFLOW model was previously developed using the 2016 version of TUFLOW 'Classic'. For this assessment, the model was updated to the latest version (TUFLOW HPC 2020) which uses a more accurate computational method whilst also reducing model run times.

The Cherrybrook TUFLOW model was initially run in both the TUFLOW 'Classic' and TUFLOW HPC 2020 versions to confirm consistency of results for the 20%, 5% and 1% AEP events. The comparison of results indicated a change of less than 1% for both flood depths and velocities due to the change in the version of TUFLOW software and therefore the HPC 2020 version of TUFLOW was adopted.

The TUFLOW HPC 2020 model was updated to include the footprint of the new Cherrybrook Station as well as the DN1350 pipe that drains Castle Hill Road on the southern side of Cherrybrook Station and discharges downstream of the existing detention basin at the north of the DGL site.

7.4 Proposed developed conditions

The proposed development within the remaining undeveloped 3.3 ha of the DGL site will be subject to the Stormwater Management Plan (SMP) and On-Site Detention (OSD) requirements discussed in **Section 5** and **Section 6** above.

HSC's stormwater management requirements discussed in the conceptual SMP in **Section 6** necessitate a 'no net increase' in stormwater peak flows from the proposed development compared to the current situation. As indicated in the analysis shown in **Section 6.3**, Council's requirements can be adequately met or exceeded through the use of OSD in the form of underground tanks, an enlarged detention basin, or a combination of both.

Therefore, for documentation and discussion of the results for the preliminary FRA, the modelled outputs for the existing conditions, including all of the changes made to the TUFLOW and DRAINS models, were adopted and are presented in the following section.

7.5 Existing flood conditions

The TUFLOW HPC 2020 model was run to simulate the 20%, 5%, 1%, 1% Climate Change design events and an extreme flood event (defined as being three times the 1% AEP design flood). Key observations for each of the simulated flood events are described in the following sections. Flood depth and flood hazard category maps are also provided to illustrate the modelled flood impacts.

Flood hazard category mapping was undertaken following the Australian Emergency Management Institute (AEMI) guidelines. The AEMI hazard classification diagram is shown on **Figure 7-2** below.

A compendium of peak flood level, flood depth, flow velocity and hazard category maps for each of the design flood events is provided in **Appendix F**.

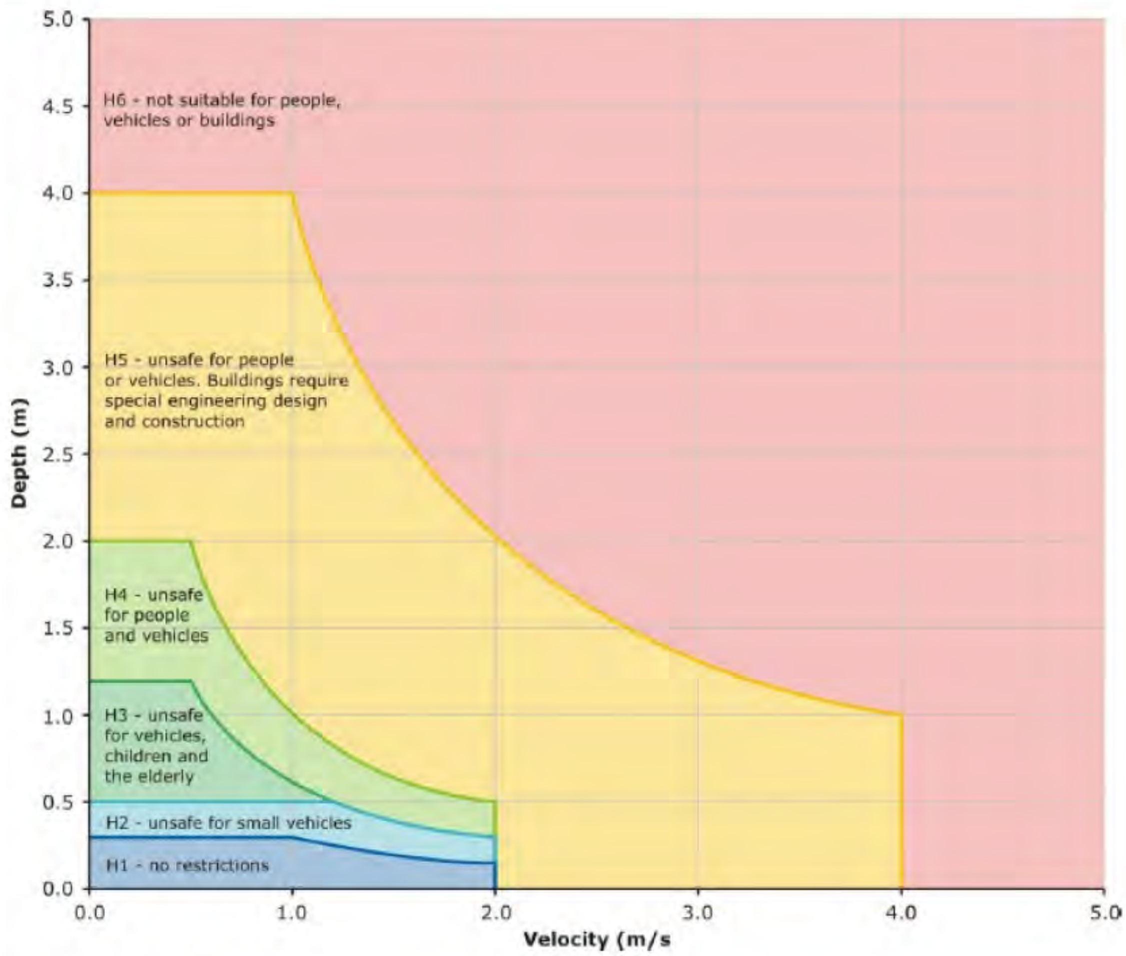
7.5.1 20% AEP Flood event

Flood impacts during a 20% AEP flood event downstream of the DGL site are generally minor and mainly consist of overland flows entering from neighbouring catchment runoff areas. The DRAINS model indicates that runoff during the 20% AEP flood event, from the DGL catchment, is fully contained within the existing detention basin and the peak flow discharging from the detention basin through the twin DN450 pipes is 0.53 m^3/s.

The depth map shown on **Figure 7-3** below indicates that the 20% AEP is fully conveyed by the DN2250 pipe under Robert Road and peak depth of 1.6 m occurs in the informal detention basin area identified in the land parcel.

The flood hazard category map shown on **Figure 7-4** below indicates that hazards within the residential property and road reserves generally do not exceed the 'H1 – No vulnerability constraints' except for the following areas:

- an isolated area on the southern side of Robert Road between Louise Way and Arundel Way where gutter flows of more than 2 m/s results in an H5 flood hazard category within the road reserve, and
- within the low-lying informal detention basin area, flood depths up to 1.6 m and high velocity flows immediately upstream of the pipe inlet result in H4 to H5 flood hazard categories.



Hazard Classification	Description
H1	Relatively benign flow conditions. No vulnerability constraints.
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. Buildings require special engineering design and construction.
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure.

Figure 7-2: Australian Emergency Management Institute Flood Hazard Categories

Figure 7-3: 20% AEP Flood Depth Map

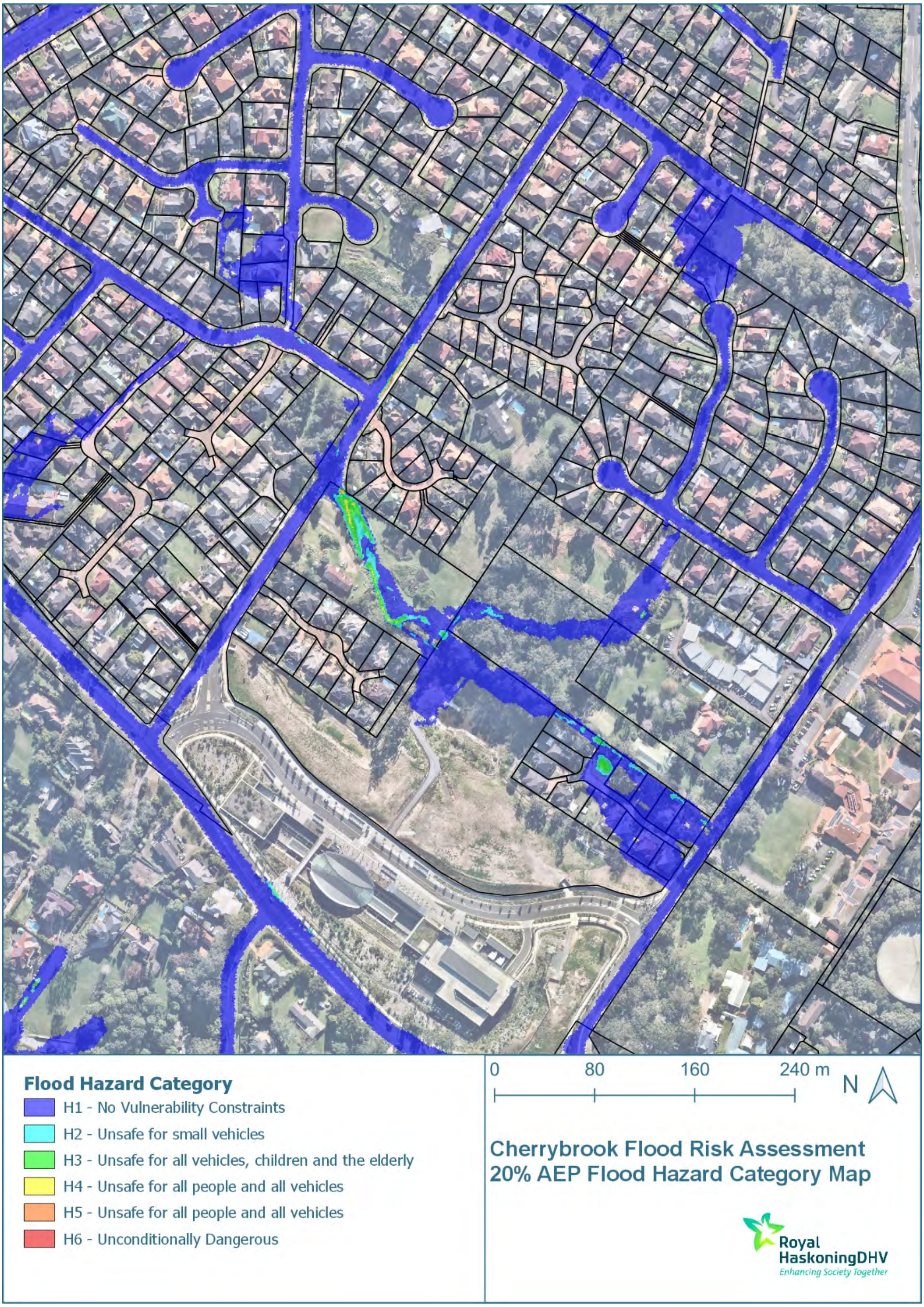


Figure 7-4: 20% AEP Flood Hazard Category Map

7.5.2 5% AEP Flood Event

Flood impacts during a 5% AEP flood event downstream of the DGL site result in partial inundation of Robert Road Park on the corner of Robert Road and Dalkeith Road. The TUFLOW model indicates that the depth of flooding within the park is less than 0.2 m and the hazard category does not exceed the H1 flood hazard category.

The DRAINS model indicates that runoff in the 5% AEP flood event, from the DGL catchment, is fully contained within the existing detention basin and the peak flow discharging from the detention basin through the twin DN450 pipes is 0.71 m^3/s.

The depth map shown on **Figure 7-5** below indicates that the 5% AEP results in minor overtopping of the informal detention basin which subsequently discharges into Robert Road creating maximum flood depths up to 0.6 m within the road reserve.

The flood hazard category map shown on **Figure 7-6** below indicates that hazards within residential property and road reserves generally do not exceed the H1 flood hazard category except for the following areas:

- an isolated area on the southern side of Robert Road between Louise Way and Arundel Way where gutter flows of more than 2 m/s results in an H5 flood hazard category within the road reserve
- within the informal detention basin, flood depths up to 1.7 m and high velocity flows immediately upstream of the pipe inlet result in H4 to H5 flood hazard categories
- an isolated area immediately downstream of the informal detention basin in Robert Road where flows are temporarily stored before overtopping into Robert Road Park resulting in an H3 flood hazard category, and
- within the road reserve of Dalkeith Road where gutter flow velocities exceed 2 m/s resulting in an H5 flood hazard category.

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Figure 7-5: 5% AEP Flood Depth Map

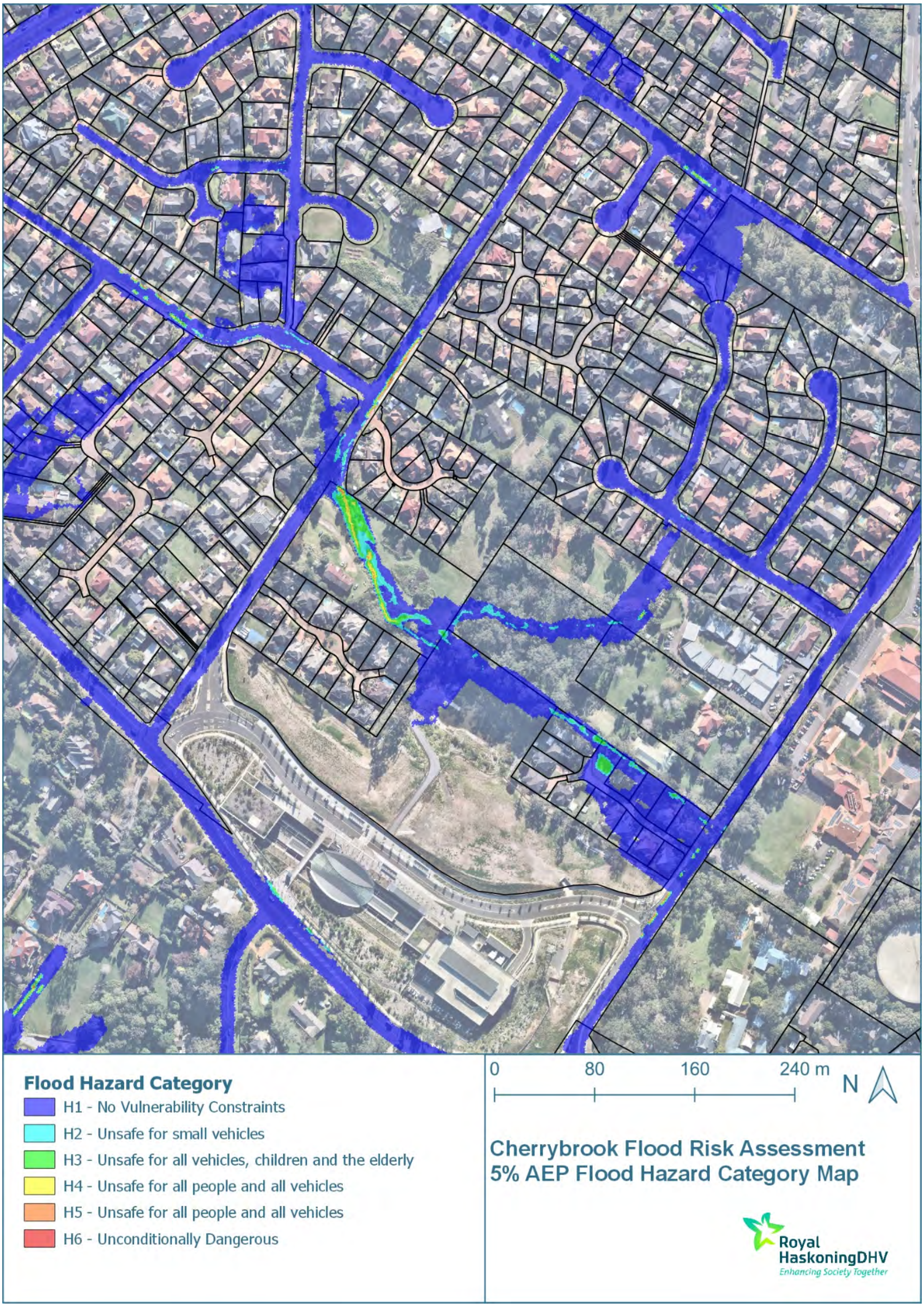

Figure 7-6: 5% AEP Flood Hazard Category Map

7.5.3 1% AEP Flood Event

Flood impacts during a 1% AEP flood event downstream of the DGL site include the inundation of approximately half of Robert Road Park where flows (that are more than the capacity of the trunk drainage system) are conveyed downstream as an overland flow path. The TUFLOW model indicates that the depth of flooding within the park is just over 0.5 m and the hazard category is between H2 and H3.

The DRAINS model indicates that runoff during the 1% AEP flood event, from the DGL catchment, overtops the existing detention basin with a peak overtopping flow of 0.33 m^3/s and a peak flow discharging from the detention basin through the twin DN450 pipes of 0.84 m^3/s.

The depth map shown on **Figure 7-7** below indicates that the 1% AEP event overtops the informal detention basin which, combined with local catchment flow, results in maximum water depths of up to 0.8 m within the road reserve of Robert Road.

The flood hazard category map shown on **Figure 7-8** indicates that flood hazards within residential property and road reserves generally do not exceed the H1 flood hazard category except for the following areas:

- an isolated area on the southern side of Robert Road between Louise Way and Arundel Way where gutter flows of more than 2 m/s results in an H5 flood hazard category within the road reserve
- from the downstream outlet of the existing detention basin at the north of the DGL site to the informal detention basin at the inlet of the DN2250 trunk drainage system. Flood hazard categories in this area peak with an H5 flood hazard category due to a combination of velocities being greater than 2 m/s and flood depths of 1 m or more.
- the area immediately downstream of the informal detention basin in Robert Road where flood flows are temporarily stored before overtopping into Robert Road Park resulting in an H3 flood hazard category
- within the road reserve of Dalkeith Road where gutter flows with velocities greater than 2 m/s results in an H5 hazard category, and
- within the road reserve immediately downstream of Robert Road Reserve where velocities exceed 2 m/s resulting in an H5 hazard category.

Figure 7-7: 1% AEP Flood Depth Map

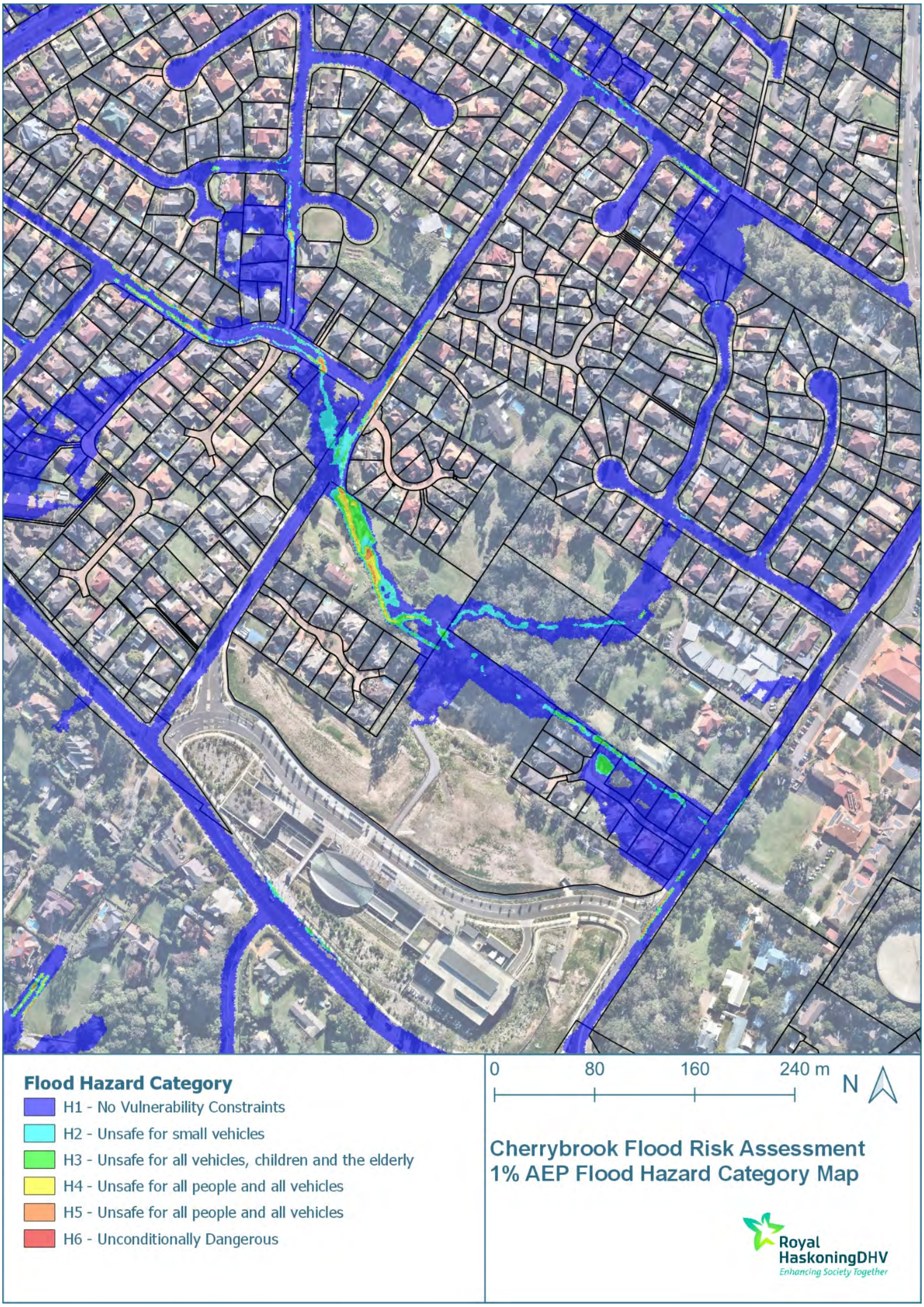

Figure 7-8: 1% AEP Flood Hazard Category Map

7.5.4 1% AEP with Climate Change Flood Event

Flood impacts during a 1% AEP with climate change flood event downstream of the DGL site result in inundation of approximately 90% of Robert Road Park where the park acts as a flow path for the overland flow that is more than the capacity of the trunk drainage system. The TUFLOW model indicates that the depth of flooding is just over 0.7 m, which combined with velocities of more than 1.5 m/s resulting in an H4 hazard category for Robert Road Park.

The DRAINS model indicates that runoff in the 1% AEP with climate change flood event, from the DGL catchment, overtops the existing detention basin with a peak overtopping flow of 1.3 m^3/s and a peak flow discharging from the detention basin through the twin DN450 pipes of 0.89 m^3/s.

The depth map shown on **Figure 7-9** below indicates that the 1% AEP with climate change flood event results in overtopping of the informal detention basin which results in peak flood depths in the flow path of up to 0.5 m. The flows overtopping the informal detention basin subsequently discharge into Robert Road creating maximum water depths up to 1.0 m within the road reserve.

The flood hazard category map shown on **Figure 7-10** below indicates that flood hazards within the residential property and road reserves generally do not exceed the H1 flood hazard category except for the following areas:

- an isolated area on the southern side of Robert Road between Louise Way and Arundel Way where gutter flows of more than 2 m/s results in an H5 flood hazard category within the road reserve
- from the downstream outlet of the existing detention basin at the north of the DGL site to the informal detention basin at the inlet of the DN2250 trunk drainage system. Flood hazard categories in this area peak in the 'H5 – Unsafe for people and vehicles' due to a combination of flood velocities >2 m/s and flood depths of greater than 1 m
- the area immediately downstream of the informal detention basin in Robert Road where flows are temporarily stored before overtopping into Robert Road Park resulting in an H3 flood hazard category
- within the road reserve of Dalkeith Road where gutter flows with velocities greater than 2 m/s results in an H5 hazard category
- within the road reserve immediately downstream of Robert Road Reserve where velocities exceed 2 m/s resulting in an H5 hazard category
- within the road reserve of Ashford Road including the pedestrian access easement at the upstream end of Ashford Road. Insufficient hydraulic capacity within the trunk drainage system results in increased overland flows from Robert Road Park flowing at velocities over 2 m/s down the pedestrian access path and into the road reserve at the southern end of Ashford Road. These high velocity flows combined with flood depths of up to 0.5 m result in an H5 flood hazard category for the access path and Ashford Road.

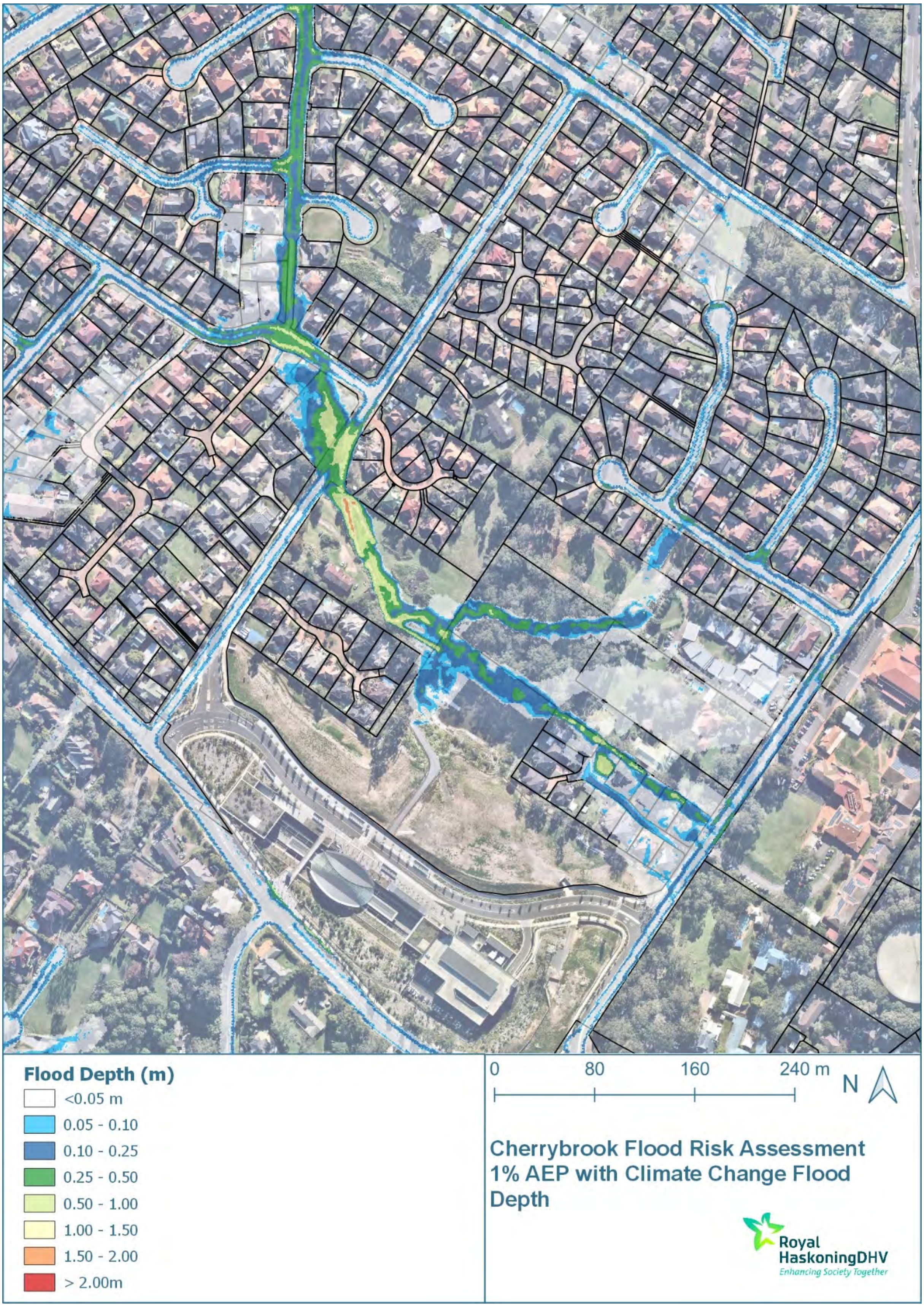

Figure 7-9: 1% AEP with Climate Change Flood Depth Map

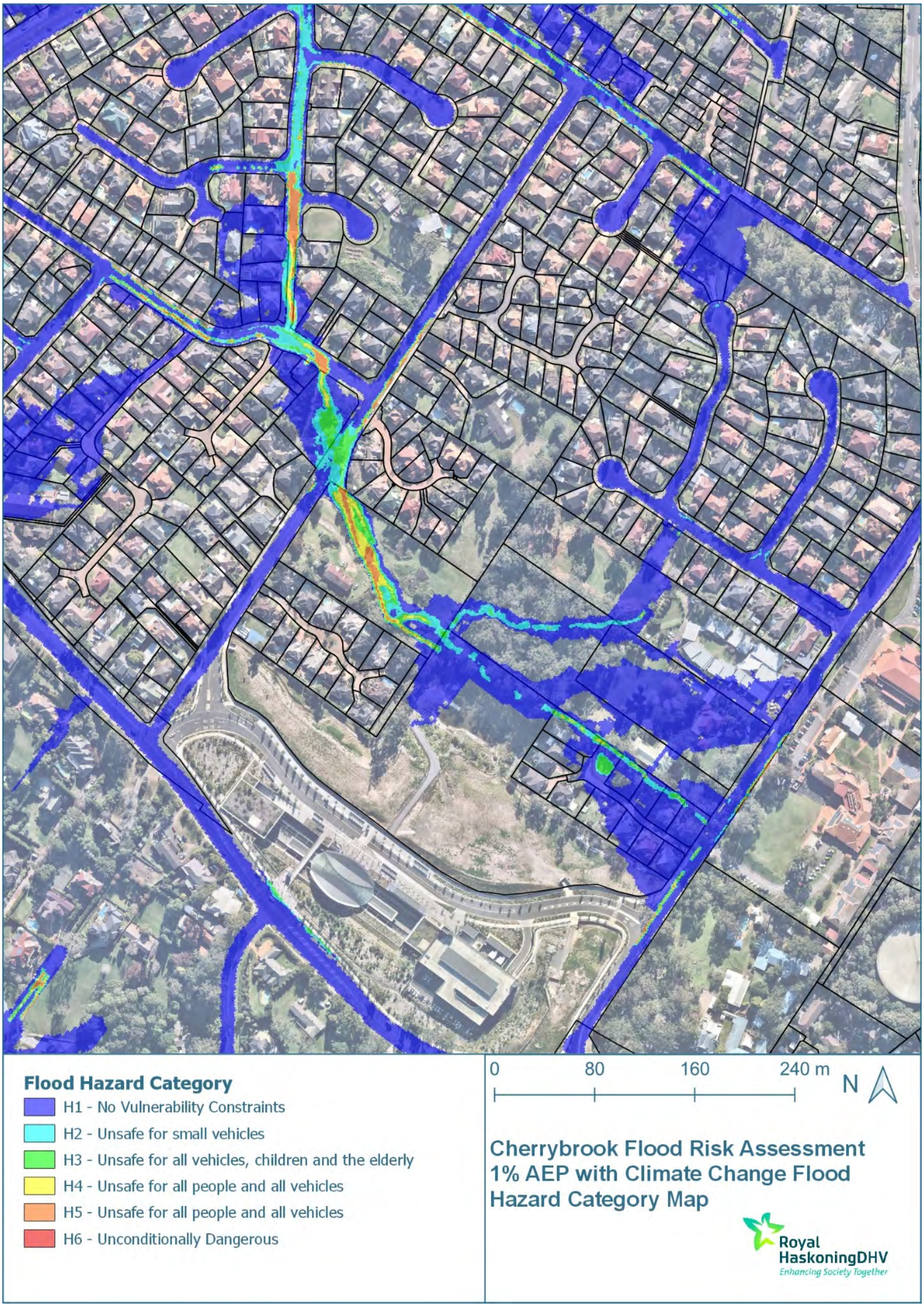

Figure 7-10: 1% AEP with Climate Change Flood Hazard Category Map

7.5.5 Extreme Flood Event

Flood impacts during an extreme flood event downstream of the DGL site result in inundation depths of more than 1 m for the entire length of the overland flow path (i.e. from the existing detention basin to the edge of the model boundary at Pyes Creek off Woodgrove Avenue approximately 1.1 km to the north). The TUFLOW model indicates that the depth of flooding within Robert Road and Robert Road Park exceeds 1.3 m downstream of the informal detention basin. Velocities along the overland flow path downstream of the existing detention basin, through Robert Road Park and downstream into Ashford Road, are generally greater than 1.5 m/s resulting in flood hazard categories between H5 and H6.

The DRAINS model indicates that runoff in the extreme flood event, from the DGL catchment, overtops the existing detention basin with a peak overtopping flow of 5.4 m^3/s and a peak flow discharging from the detention basin through the twin DN450 pipes of 1.0 m^3/s.

The depth map shown on **Figure 7-11** below indicates that the extreme flood event results in the inundation of properties by up to 0.7 m adjacent to the primary overland flow path downstream of Robert Road Park. The properties impacted most severely include 8, 8a, 10, 10a and 10b Dalkeith Road and 22 Ashford Road which are all located near the pedestrian access path at the southern end of Ashford Road.

At the northern end of the catchment downstream of Ashford Road, the flow path crosses John Road and County Drive before flowing down Janice Place into Pyes Creek. Some properties including 88 and 90 John Road; 53, 55A and 57 County Drive and 1 and 3 Whitbar Way are inundated or surrounded by water depths of up to 1.8 m.

The flood hazard category map shown on **Figure 7-12** below indicates that properties located away from the primary overland flow path, between the existing detention basin down through Ashford Road, generally do not exceed the H1 flood hazard category. Most roads within the downstream catchment are also subject to the H1 flood hazard category except for the following areas:

- All of Ashford Road as the magnitude of the extreme flood event makes Ashford Road the major overland flow path for the upstream catchment resulting in flood hazard categories between H5 and H6.
- Robert Road between the southern end of Robert Road Park and Arundel Way where overland flows from the upstream catchment cross Robert Road into Robert Road Park. The combination of large flood depth and velocity results in an H5 flood hazard category within this section of the road reserve.
- Dalkeith Road between the intersection with Robert Road to the east and Rochford Way to the west where gutter flows with velocities of between 2 m/s and 4 m/s result in H5 to H6 flood hazard categories, and
- County Drive, John Road, Roslyn Place and Janice Place at the northern and downstream end of the catchment also experience flood hazard categories between H5 and H6 due velocities of between 2 m/s and 3 m/s and flood depths of up to 1.8 m within Country Drive.

Figure 7-11: Extreme Flood Depth Map

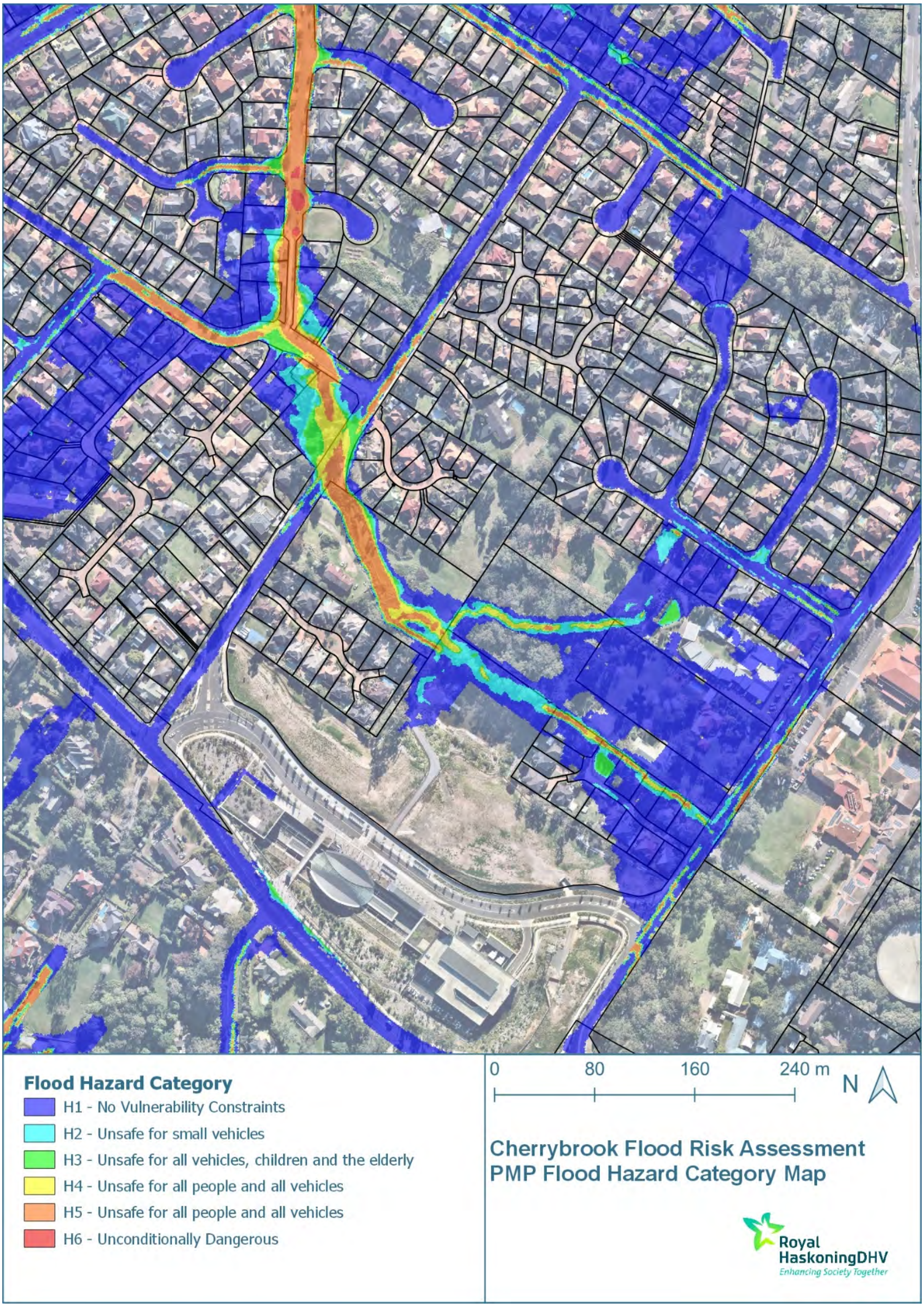

Figure 7-12: Extreme Flood Hazard Category Map

8 Conclusion

8.1 Stormwater management

An additional piped stormwater drainage system would need to be established to manage stormwater runoff from future development within the DGL site, and connected with the stormwater system constructed by Sydney Metro for Cherrybrook Metro Station. Some modifications to the existing drainage system may be required to accommodate future stormwater detention and water quality treatment requirements (e.g. an alternate inlet arrangement to the existing/future detention storage facility, a GPT on the Cherrybrook Station trunk drainage line). The stormwater drainage system would need to be integrated with the future detention storage and water quality treatment controls identified for the site. Treated stormwater from the DGL site would ultimately discharge into the gully located downstream of the existing stormwater detention basin.

Detention storage and site discharge requirements are the standard mitigation measures/development controls to alleviate flooding impacts of the proposed development. Detention storage is required at the DGL site so that peak flows from the site do not increase and cause increased flooding to neighbouring/downstream properties. Lower and upper bound estimates of detention storage requirements for the DGL site (combined with the Cherrybrook Station area) is 3,000 m^3 to 3,200 m^3 respectively. If the DGL reference design incorporates WSUD philosophies to reduce directly connected impervious areas and provides beneficial open space and soft landscaping areas, the lower estimate may be adequate.

At this stage, detention storage could be provided in several configurations by either:

i) maintaining the Sydney Metro basin and provide additional lot scale detention storage within the future development lots,
ii) expanding the existing Sydney Metro basin to provide the fully developed site storage requirements, or
iii) replacing the Sydney Metro basin with an underground detention storage tank(s). A preferred configuration or combination of configurations would need to be established at future development stages.

Water quality treatment controls would need to be integrated into any future development to satisfy pollutant load reduction targets of 85%, 65% and 45% for TSS, TP and TN respectively. Preliminary stormwater quantity and quality modelling indicate that the above targets could be achieved for the DGL site using rainwater tanks, vegetated buffers and swales, raingardens or biofiltration systems and underground propriety stormwater treatment systems (such as GPTs and the Humes Jelly Fish unit). Further modelling in combination with the layout and design of the proposed future development would need to be undertaken to confirm the size and arrangement of treatment measures at the Development Application stage.

8.2 Flood impacts and risks

8.2.1 Near the DGL site

Due to the DGL site being located at the top of the catchment where the terrain is comparably steep, flows are conveyed by a combination of existing stormwater drainage and natural overland flow paths or creeks resulting in narrow/well-defined flood extents. Even during larger less frequent flood events (e.g. 1% AEP event with and without Climate Change allowance), flooding within the DGL site is confined to the remnant creekline that traverses along the northernmost site boundary and a small backwater immediately downstream of the existing detention basin. A majority (more than 90%) of the DGL is not subject to flooding during events up to and including an extreme flood event (refer **Figure 8-1**).

Overall, the existing flooding behaviour (level, depth/extent, velocity, hazard) estimated near the DGL site does not present a significant risk to property or life associated with the proposed re-development. The risk to property as a result of the flood planning (1% AEP design) event is effectively managed by the site detention storage and permissible site discharge requirements, which would reduce the peak flood discharge from the site post-development to an amount less than (or equivalent to) the existing site discharge condition.

The risk to life as a result of an extreme flood event would be considered very low for the DGL site as the site is located at the top of the catchment. There are no overland flow paths from upstream catchments which impact on the DGL site, apart from on the northern side and downstream of the existing detention basin. Localised stormwater drainage issues/nuisance flooding may occur during an extreme event within Bradfield Parade to the north of Cherrybrook Station as the underground stormwater system may not be designed to convey such a large storm event. However, carefully planned mitigation measures during the detailed design process of the DGL site could successfully eliminate the potential for loss of life for the proposed development. This would need to be considered in combination with the layout and design of the proposed future development.

8.2.2 Downstream of the DGL site

Flood impacts during the 20% and 5% AEP events are generally contained within the underground stormwater network and in the kerb and gutter systems downstream of the DGL site. The modelling indicates the capacity of the existing detention basin within the DGL site is sufficiently sized to contain the 20% and 5% AEP flow generated by the existing DGL catchment. The twin DN450 pipes allow a controlled release of the basin storage without exceeding the downstream overland flow capacity.

Flood impacts during the 1% AEP and 1% AEP with climate change flood events exceed the capacity of the trunk drainage system downstream of the DGL site. The TUFLOW model indicates that Robert Road, Robert Road Park, Dalkeith Road and Ashford Road provide a sufficient flow area to allow these flood events to pass without hazardous flood conditions negatively impacting on properties neighbouring the overland flow path.

The combination of hilly terrain and the location of roads and parks means that the overland flow paths downstream of the DGL site result in a relatively small number of properties which could be considered to be at high risk or constituting a potential loss of life during an extreme flood event. These properties are located adjacent to the primary overland flow path downstream Robert Road Park at 8, 8a,10,10a and 10b Dalkeith Road and 22 Ashford Road. Downstream of Ashford Road, a further seven properties at 88 and 90 John Road; 53, 55A and 57 County Drive and 1 and 3 Whitbar Way were identified as being of high risk. The flood model indicates that these properties would experience a velocity depth product that constitutes an H5 flood hazard categorisation requiring special engineering design and construction techniques to withstand flood conditions during an extreme flood event. Importantly, this flood risk is **not** a result of the proposed development of the DGL site. This is an existing flood risk that remains unchanged as a result of the proposed development.

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Figure 8-1: DGL site flooded area during an extreme flood event

9 References

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10 Glossary

100-year event	An event that occurs on average once every 100 years. Also known as a 1% AEP event. See annual exceedance probability (AEP) and average recurrence interval (ARI).
2-year event	An event that occurs on average once every 2 years. Also known as a 50% AEP event. See annual exceedance probability (AEP) and average recurrence interval (ARI).
Afflux	The change in water level from existing conditions resulting from a change in the watercourse or floodplain – e.g. construction of a new bridge.
Annual Exceedance Probability (AEP)	Measured as a percentage and a term used to describe the size of an event. AEP is the long term probability between events of a certain magnitude. For example, a 1% AEP event is one that has a 1% probability of occurring in any given year. The AEP is closely related to the ARI.
Australian Height Datum	A common national plane of level approximately equivalent to the height above sea level. All water levels presented in this report have been provided in metres AHD.
Australian Rainfall and Runoff (AR&R)	Engineers Australia publication about rainfall and flooding investigations in Australia.
Average daily flowrate	The value (which can also be expressed in m^3/s) determined from measured or modelled daily flows (typically expressed in ML/day). It represents the average flow rate over 24 hours and is different to peak or instantaneous daily flow.
Average Recurrence Interval (ARI)	Measured in years and a term used to describe event size. It is a means of describing how likely an event is to occur in a given year. For example, a 100-year ARI event is one that occurs or is exceeded on average once every 100 years.
Calibration	The adjustment of model configuration and key parameters to best fit an observed data set.
Concentration	The amount of mass of a substance present in a given volume or mass of the sample usually expressed as milligram per litre (water sample) or micrograms per kilogram (sediment sample).
Conceptual model	A simplified and idealised representation of the physical hydrologic setting and the understanding of the essential flow and water quality processes of the system.

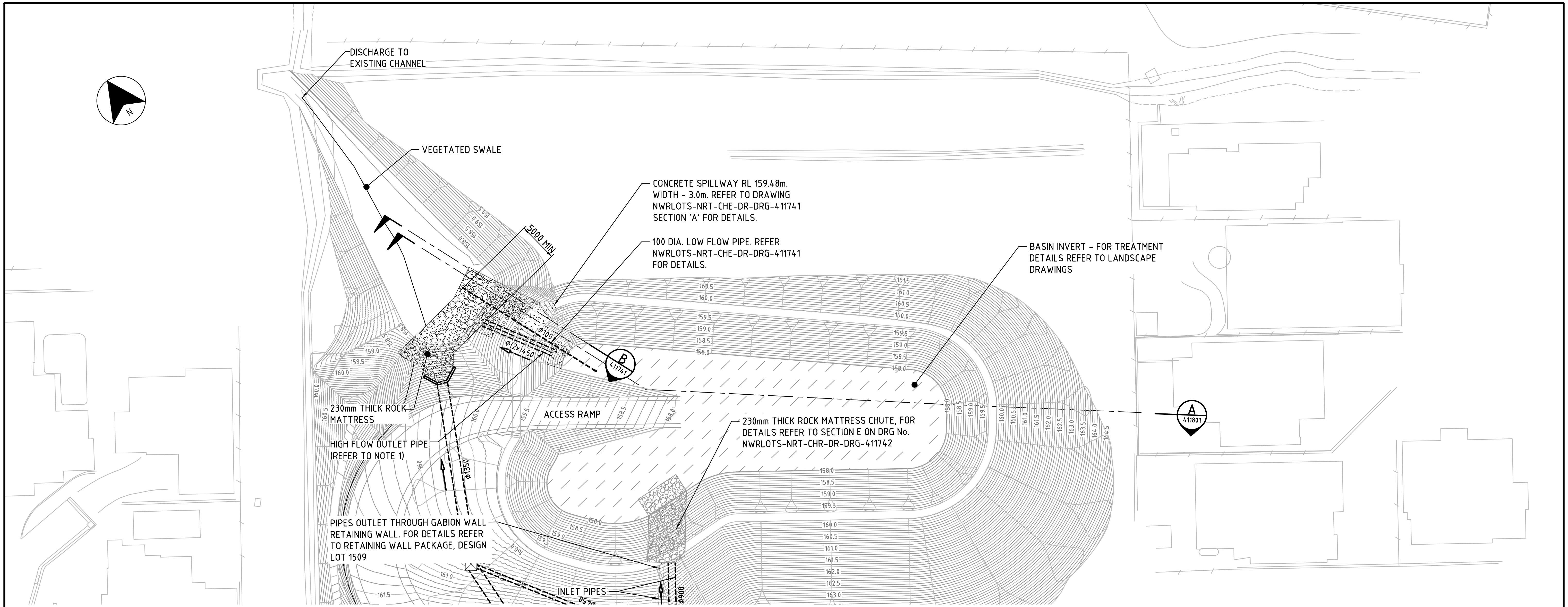
Design flood event	A hypothetical flood representing a specific likelihood of occurrence (for example the 100yr ARI or 1% AEP flood).
Development	Existing or proposed works that may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.
Digital Elevation Model	A digital representation of ground surface topography or terrain.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving, for example, metres per second (m/s).
DRAINS	Stormwater Drainage System design and analysis program widely used in Australia.
Drinking water	A common name utilised for potable water.
Flood	Relatively high river or creek flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood behaviour	The pattern, characteristics and nature of a flood.
Flood fringe	Land that may be affected by flooding but is not designated as floodway or flood storage.
Flood hazard	The potential risk to life and limb and potential damage to property resulting from flooding. The degree of flood hazard varies with circumstances across the full range of floods.
Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum). Also referred to as “stage”.
Flood liable land	See flood-prone land.
Floodplain	Land adjacent to a river or creek that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood (PMF) event.
Floodplain management	The coordinated management of activities that occur on the floodplain.
Flood planning levels (FPL)	Flood planning levels selected for planning purposes are derived from a combination of the adopted flood level plus freeboard, as determined in floodplain management studies and incorporated in floodplain risk management plans. Different FPLs may be appropriate for different categories of land use and different flood plans. The concept of FPLs supersedes the “standard flood event”.

	As FPLs do not necessarily extend to the limits of flood-prone land, floodplain risk management plans may apply to flood-prone land beyond that defined by the FPLs.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event. Under the merit policy, the flood-prone definition should not be seen as necessarily precluding development.
Hydraulic conductivity	The rate at which water of a specified density and kinematic viscosity can move through a permeable medium.
Hydraulic head	A specific measurement of water pressure above a datum. It is usually measured as a water surface elevation, expressed in units of length. The hydraulic head can be used to determine a hydraulic gradient between two or more points.
Flood source	The source of the floodwaters. In this assessment, urban stormwater from the local catchment is the primary source of floodwaters.
Flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
Floodway	A flow path (sometimes artificial) that carries significant volumes of floodwaters during a flood.
Freeboard	A factor of safety usually expressed as a height above the adopted flood level thus determining the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.
Hydraulic	The term given to the study of water flow in creeks, rivers, estuaries and coastal systems. Deals with practical applications (such as the transmission of energy or the effects of flow) of liquid (such as water) in motion.
Hydrodynamic	Pertaining to the movement of water.
Hydrograph	A graph showing how a river or creek’s discharge changes with time.
Hydrologic	The term related to the study of the rainfall-runoff process in catchments.
Hyetograph	A graph showing the depth of rainfall over time.
Intensity Frequency Duration (IFD) Curve	A statistical representation of rainfall showing the relationship between rainfall intensity, storm duration and frequency (probability) of occurrence.

MUSIC	Model for Urban Stormwater Improvement Conceptualisation predicts the performance of stormwater quality management systems. It is intended to help organisations plan and design (at a conceptual level) appropriate urban stormwater management systems for their catchments.
Overland flows	Surface runoff flows that migrates to the receiving environment when an area is over irrigated beyond its hydraulic capacity limits.
Peak flood level, flow or velocity	The maximum flood level, flow or velocity that occurs during a flood event.
Pluviometer	A rainfall gauge capable of continuously measuring rainfall intensity.
Probable maximum flood (PMF)	An extreme flood deemed to be the maximum flood likely to occur.
Probability	A statistical measure of the likely frequency of occurrence of flooding.
Riparian	The interface between land and waterway. Literally means “along the river margins”.
Runoff	The amount of rainfall from a catchment that ends up as flowing water in the river or creek.
Stage	See flood level.
Stage hydrograph	A graph of water level over time.
Sub-critical	Refers to flow in a channel or watercourse that is relatively slow and deep.
TN	Total Nitrogen, the sum of all forms of nitrogen in surface waters comprising a dissolved component (nitrate, nitrite), ammonia and ammonium, and an organic component (organic nitrogen).
Topography	The shape of the surface features of the land.
TP	Total Phosphorus, the sum of all forms of phosphorus in surface waters comprising soluble and particulate fractions of organic and inorganic phosphorus.
TSS	Total Suspended Solids, the total quantity measurement of solid material per unit volume of water. Units commonly expressed as mg/L.
TUFLOW	A computational engine that provides one-dimensional (1D) and two-dimensional (2D) solutions of the free-surface flow equations to simulate flood and tidal wave propagation. The application includes simulation of river flooding, urban flooding, pipe network modelling,

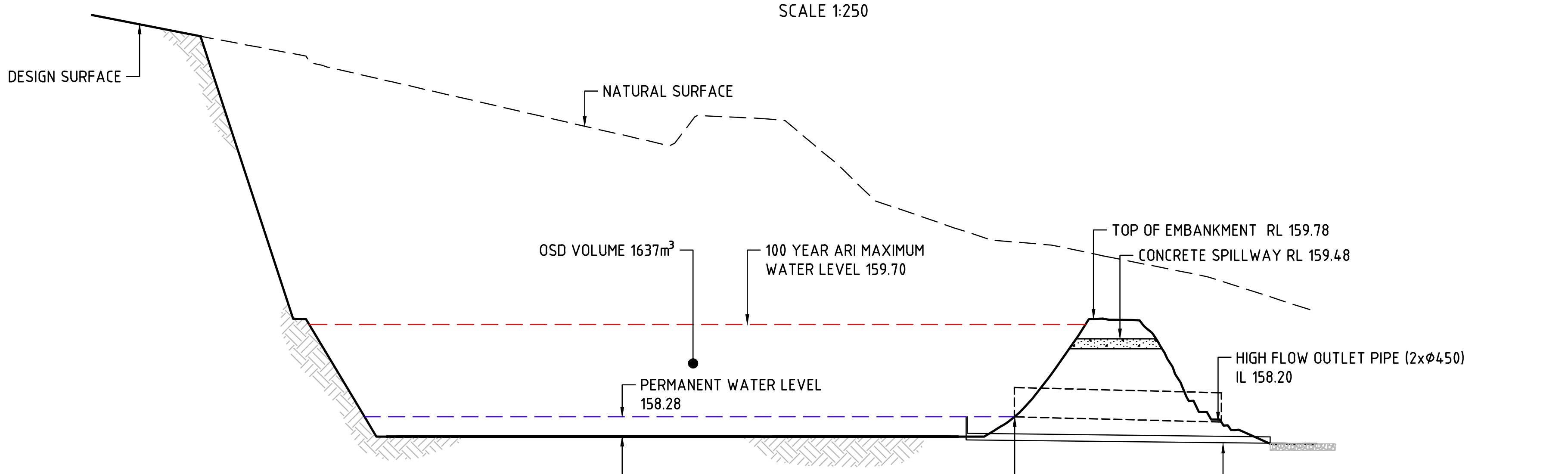
	storm tide and tsunami inundation, estuarine and coastal tidal hydraulics.
Velocity	The speed at which the floodwaters are moving. A flood velocity predicted by a 2D computer flood model is quoted as the depth-averaged velocity, i.e. the average velocity throughout the depth of the water column. A flood velocity predicted by a 1D or quasi2D computer flood model is quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section.
Water level	See flood level.
Water quality	A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Appendix A: Sydney Metro Design Drawings



DETENTION BASIN DETAIL - PLAN

SCALE 1:250



SECTION A

SCALE 1:250 (H)
SCALE 1:50 (V)

NOTES

1. HIGH FLOW OUTLET PIPE FOR DETAILS REFER TO DRG No. NWRLOTS-NRT-CHE-DR-DRG-411741.
2. ACCESS RAMP TO BASIN TO BE GRAVEL PAVED, FOR DETAILS REFER TO PAVEMENT DRAWINGS

WORK AS EXECUTED

REV	BY	DATE	DESCRIPTION	APPD
X0	GG	01/05/19	DESIGN LOT 1504 - WORK AS EXECUTED	GT

SCALES: 1:250 FULL SIZE A1 (2.5 0 2.5 5 7.5m)

DESIGN MODEL FILE(S) USED FOR DOCUMENTATION OF THIS DRAWING

INDEPENDENT CERTIFIER CERTIFICATE
NWRLOTS-OIC-CHE-CE-CER-000010

CLIENT: NSW GOVERNMENT Transport for NSW

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SERVICE PROVIDERS: northwest rapid transit – caring for life's journeys

DRAWN A.BLACK
DESIGNED J.TOTH
DRG CHECK A.T.WILSON
DESIGN CHECK G.THOMAS
APPROVED W.V.EDE 01/05/19

NORTH WEST RAIL LINK
CHERRYBROOK STATION
DRAINAGE
BASIN GENERAL ARRANGEMENT
PLAN

STATUS: WORK AS EXECUTED
SHEET 1 OF 1
DRG No NWRLOTS-NRT-CHE-DR-DRG-411801 NWRL REV X0

A1 Original | Co-ordinate System: MGA Zone 56 | Height Datum: A.H.D. | This sheet may be prepared using colour and may be incomplete if copied | NOTE: Do not scale from this drawing.

100mm AT FULL SIZE Plot Date: 02/05/19 - 15:55 Cad File: C:\CHE\NWRLOTS-NRT-CHE-DR-DRG-411801.dwg

Appendix B: 2011 Aerial Image


DGL area (indicative)
Impervious surfaces comprise approximately 15% of the total area
Google earth

Appendix C: DRAINS Hydrologic Parameters

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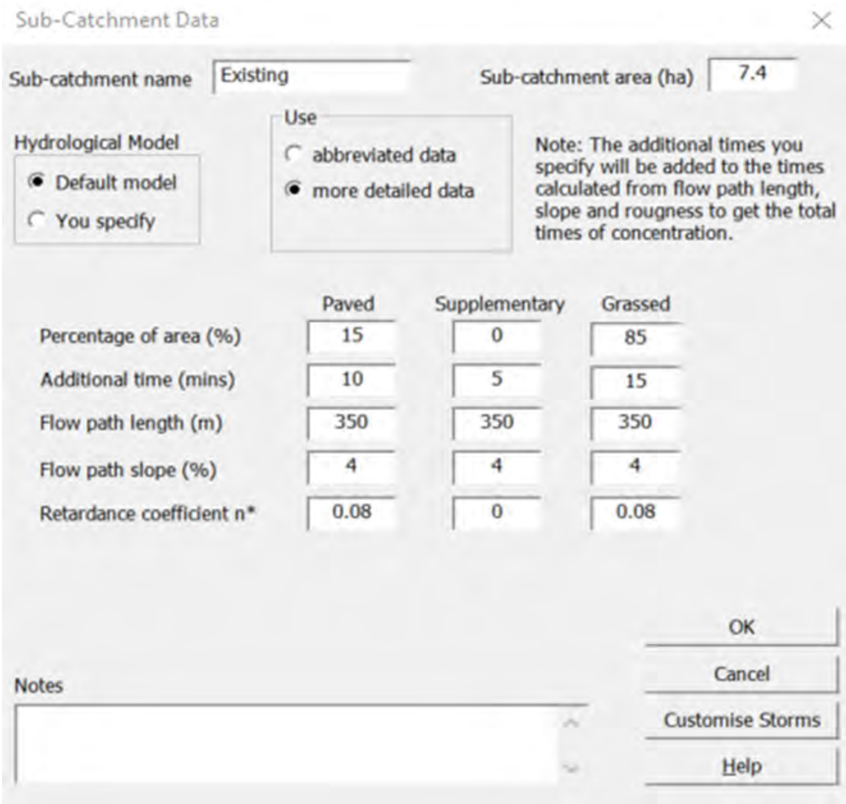

Sub-Catchment Data

Sub-catchment name: Existing

Sub-catchment area (ha): 7.4

Hydrological Model
- (•) Default model
- ( ) You specify

Use
- ( ) abbreviated data
- (•) more detailed data

Note: The additional times you specify will be added to the times calculated from flow path length, slope and rougness to get the total times of concentration.

	Paved	Supplementary	Grassed
Percentage of area (%)	15	0	85
Additional time (mins)	10	5	15
Flow path length (m)	350	350	350
Flow path slope (%)	4	4	4
Retardance coefficient n*	0.08	0	0.08

OK

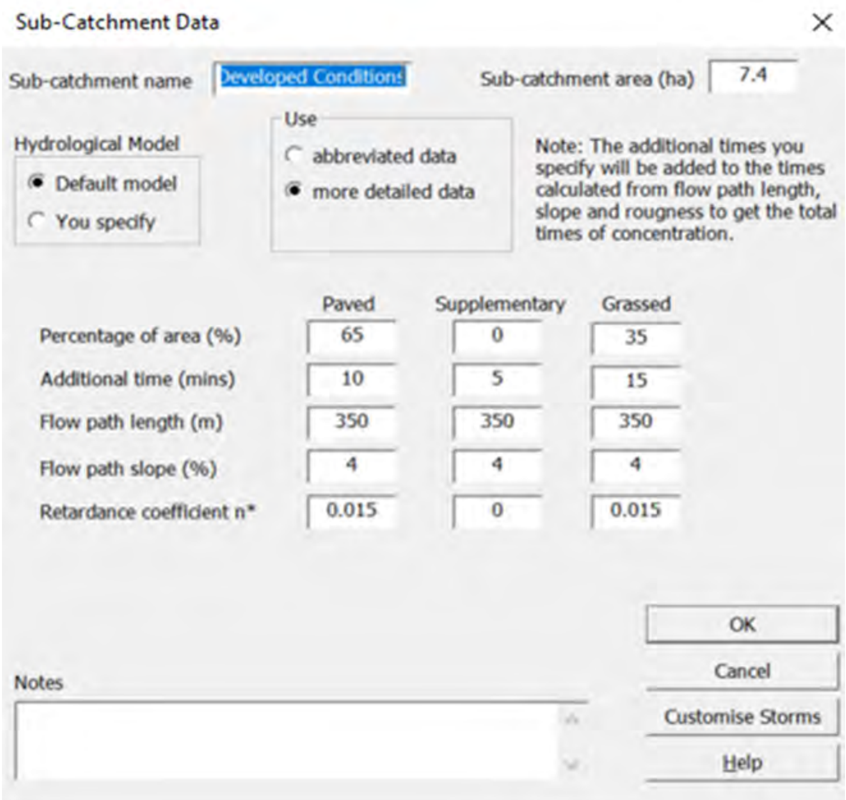
Cancel

Customise Storms

Help

Notes

Existing catchment


Sub-Catchment Data

Sub-catchment name: Developed Conditions

Sub-catchment area (ha): 7.4

Hydrological Model
- (•) Default model
- ( ) You specify

Use
- ( ) abbreviated data
- (•) more detailed data

Note: The additional times you specify will be added to the times calculated from flow path length, slope and rougness to get the total times of concentration.

	Paved	Supplementary	Grassed
Percentage of area (%)	65	0	35
Additional time (mins)	10	5	15
Flow path length (m)	350	350	350
Flow path slope (%)	4	4	4
Retardance coefficient n*	0.015	0	0.015

OK

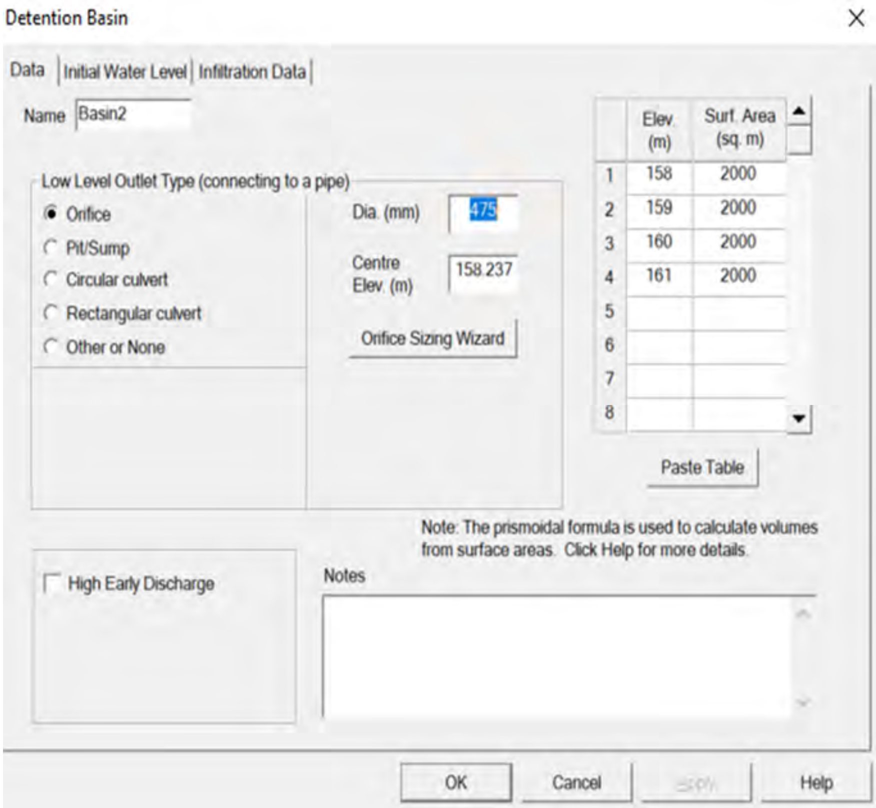
Cancel

Customise Storms

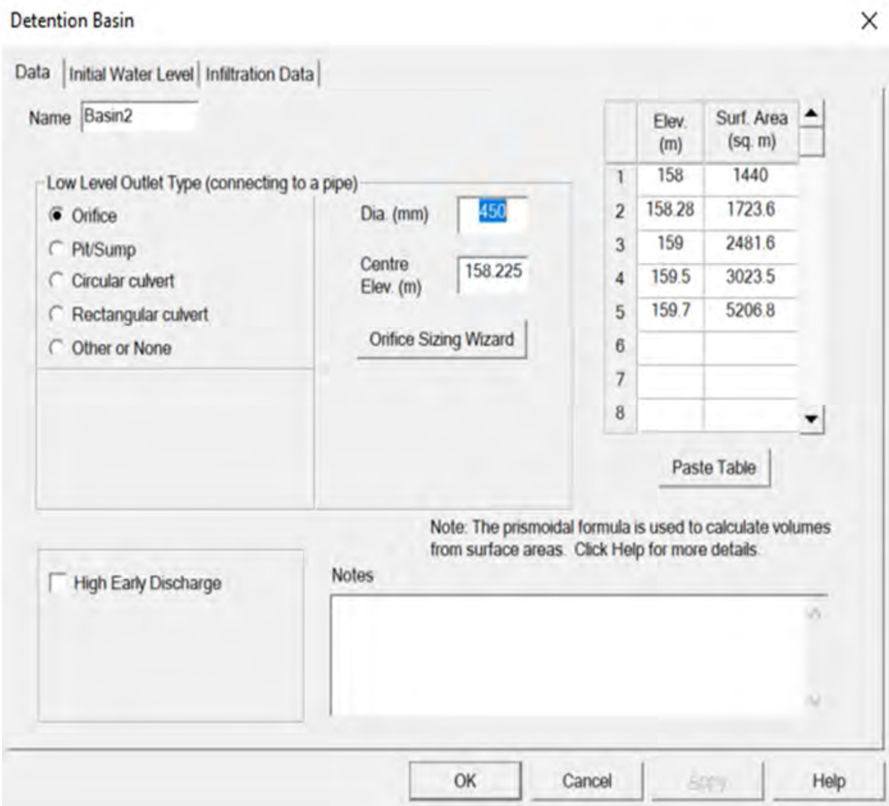
Help

Notes

Developed catchment



Underground Tank – DRAINS run7 Tank



Existing Basin – DRAINS run5

Appendix D: Stormwater Quantity and Quality Modelling (MUSIC)

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MUSIC Model Configuration

Model description

Stormwater quality modelling was undertaken to estimate the hydrology and load of common stormwater pollutants (i.e. TSS, TP and TN) generated by the site. MUSIC modelling was undertaken to estimate continuous hydrology and runoff water quality for the DGL site. MUSIC includes algorithms to evaluate the hydrology and concentrations/loads from urban catchments and estimate the performance of stormwater management measures at capturing these pollutants. MUSIC was designed to continuously simulate urban stormwater systems over a range of temporal and spatial scales utilising historically representative rainfall data.

MUSIC is considered within the industry to be an appropriate conceptual design tool for the analysis of runoff water quality in the urban environment. The hydrologic algorithm in MUSIC simplifies the rainfall-runoff processes and requires the input of the following variables to perform the hydrological assessment:

- Rainfall data (time steps varying from 6 minutes to 1 day)
- Areal potential evapotranspiration (PET) rates
- Catchment parameters (area, % impervious and pervious areas)
- Impervious and pervious area parameters (rainfall threshold, soil and groundwater parameters)
- Storm event and base flow stormwater (event mean) pollutant concentrations.

MUSIC can be applied for comparison of alternative scenarios that adopt the same base inputs. Although the magnitude of the estimates may not be equivalent to actual site conditions (due to limitations in available data for a particular site), the relative differences between scenarios are expected to be appropriate for decision making.

The MUSIC modelling approach applied to estimate stormwater runoff and pollutant loads for the local catchment is described in the following sections.

Delineation of surface types and area

Surface types and areas were mapped in a GIS-based on Nearmap aerial image of the Cherrybrook Metro Station and reference design drawings (re-development Masterplan) of the DGL site provided by SJB.

Rainfall and PET

The MUSIC meteorological template includes the rainfall and areal potential evapotranspiration data. It forms the basis for the hydrologic calculations within MUSIC. To simulate the performance of stormwater quality treatment measures, MUSIC requires the input of data from a representative continuously recording rainfall station (pluviograph).

The sub-daily rainfall and average monthly areal potential evapotranspiration (PET) rates were obtained from the MUSIC-Link data Version 6.34 for Hornsby Shire Council.

Model time step

A 6-minute time step was adopted to simulate water quality and characterise pollutant loads across the site.

Site parameters

Source nodes, linked to varying surface types, were utilised for the development of the MUSIC Model; namely: Urban-Roof, Urban-Sealed Road, Urban-Mixed. The area and percentage imperviousness of the sources nodes used to represent the major surfaces across the site were estimated from the reference design for the DGL provided by SJB.

The area and imperviousness of each surface type are presented in **Table D-1**.

Table D-1: Modelled areas and imperviousness

Surface Type	Area (ha)	Imperviousness (%)
Buildings, roads and hardstand areas	3.30	100
Green roof areas (higher rainfall threshold)	0.15	100
Landscaped and open Space	3.95	14
Total	**7.40**	**54**

Rainfall-runoff parameters

Modelling of the rainfall-runoff process in MUSIC requires the definition of one impervious surface parameter and eight pervious surface parameters. The rainfall-runoff parameters were defined using MUSIC-Link data Version 6.34 for Hornsby Shire Council. The impervious surface parameter (rainfall threshold) was adjusted for major surfaces as follows:

- Building roofs – 0.3 mm
- Sealed road – 1.5 mm
- Green roofs – 3 mm
- Landscaped and Open Space – 1 mm

Runoff quality parameters

The MUSIC stormwater constituent pollutant concentrations were adopted from those provided by MUSIC Link data detailed above.

Treatment nodes

Treatment nodes were configured to represent the type and size of treatment measures outlined by the conceptual stormwater management plan and WSUD strategy identified for the DGL site. These treatment measures were represented within the MUSIC model by the parametrisations outlined in **Table D-2**.

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Table D-2: Treatment node parameters

Stormwater Treatment Measure	Modelled Configuration
Vegetated Swale	Total length = 100 m Slope = 1% Base width = 1.2 m Top width = 3 m Depth = 0.3 m Vegetation height = 0.075 m Exfiltration rate = 0 mm/hr
Vegetated buffer	1 m buffer strip along the access road Percentage of upstream area buffered = 90% Buffer area as a percentage of impervious area = 10% Exfiltration rate = 0mm/hr
Bioretention basin	Surface area = 450 m^2 Extended detention depth = 0.30 m Total biofilter area = 300 m^2 Biofilter depth = 0.50 m Saturated hydraulic conductivity = 150 mm/hr TN content of filter media = 800 mg/kg Orthophosphate content of filter media = 40 mg/kg Exfiltration rate = 0 mm/hr
Gross Pollutant Trap (Humes Jellyfish or similar)	Number of GPTs = 2 High flow by-pass = 0.0325 m^3/s Flow reduction = 0% TSS concentration reduction = 80% TP concentration reduction 42% TN concentration reduction = 34%
Rainwater tanks/basement storage	Number of tanks = 9 (one per building) Individual tank properties: *Volume below overflow pipe = 100 kL* *Depth above overflow = 0.2 m* *Surface area = 50 m^2* *Initial volume = 50 kL* *Overflow pipe diameter = 100 mm* *Max drawdown height = 2 m* Re-use demand for each tank: *Constant daily demand = 5 kL/day*

The arrangement of source nodes and treatment nodes for the DGL site is shown on **Figure D-1**.

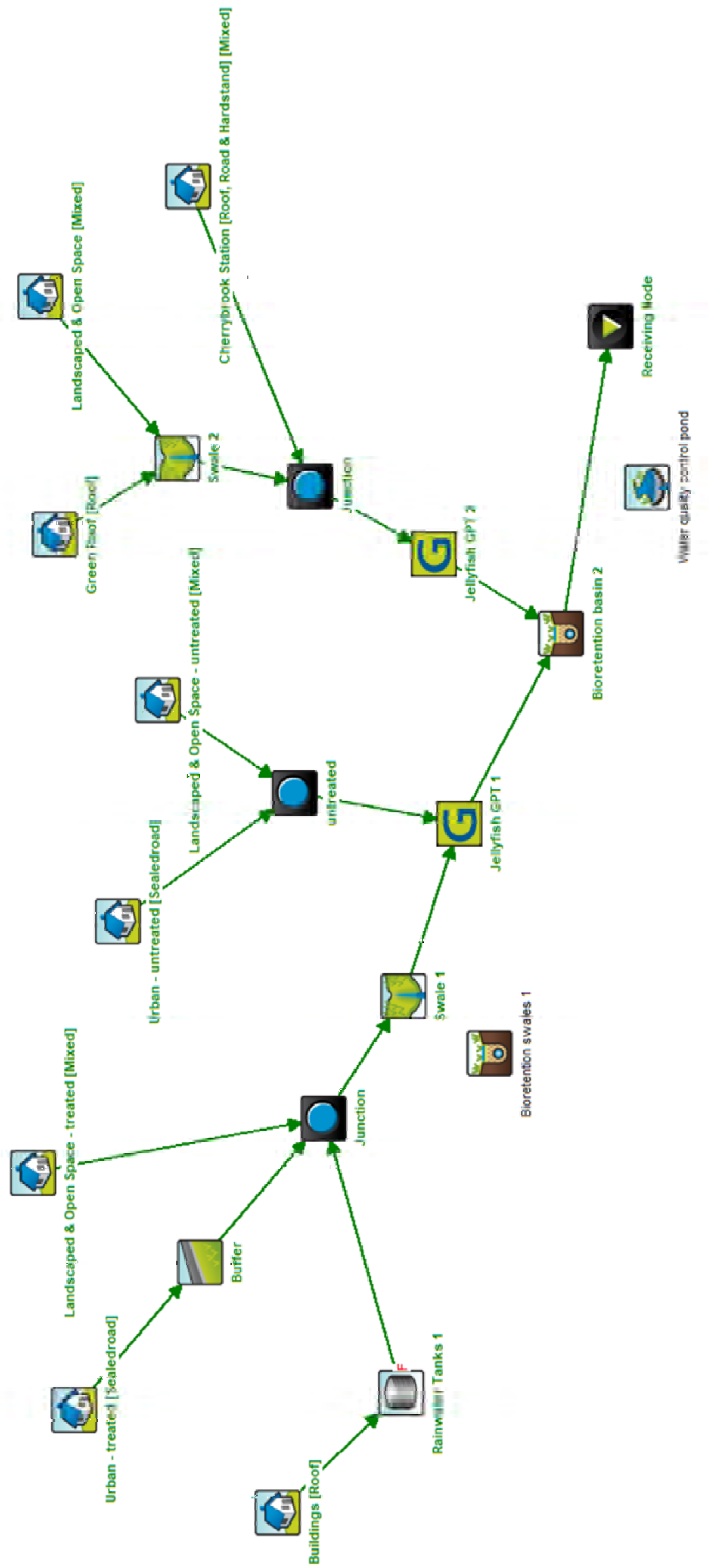

Figure D-1: MUSIC Model Schematisation

Appendix E: Detention Option Cost Estimates

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Configuration 1

Item	Rate	Qty	Unit	Cost ($)
Preliminaries	$ 30,000.00	1	item	$ 30,000.00
Cut to spoil	$ 43.55	3508.81	m^3	$ 153,000.00
Disposal of spoil as VENM	$ 25.00	678.75	t	$ 17,000.00
Disposal of spoil as fill	$ 220.00	678.75	t	$ 150,000.00
Trim and Compact Subgrade	$ 2.11	800.00	m^2	$ 2,000.00
Select Layer 250mm Thick	$ 18.73	800.00	m^2	$ 15,000.00
Base Slab 300mm Thick	$ 265.55	800	m^2	$ 213,000.00
Box Culverts (S:3600 x H:2100 x L:2400)	$ 5,381.14	50		$ 270,000.00
Link Slabs	$ 3,992.36	40		$ 160,000.00
Backfill	$ 85.00	2794.338	m^3	$ 238,000.00
Low Flow Outlet	$ 30,595.40	1	item	$ 31,000.00
High Early Discharge System	$ 81,818.40	1	item	$ 82,000.00
Spillway	$ 50,000.00	1	item	$ 50,000.00
Subsoil Drainage	$ 8.00	442.26	m	$ 4,000.00
Strip and Replace Top Soil	$ 7.57	1686.377	m^2	$ 13,000.00
Turf	$ 8.19	1686.377	m^2	$ 14,000.00

Sub-Total RCBC =	$ 1,412,000.00
Contingency 30% =	$ 424,000.00
TOTAL =	**$ 1,836,000.00**

Note: Rates are based on data current as of 2020.

Configuration 2

Item	Rate	Qty	Unit	Cost ($)
Preliminaries	$ 30,000.00	1	item	$ 30,000.00
Cut to spoil	$ 43.55	1600.00	m^3	$ 70,000.00
Disposal of spoil as VENM	$ 25.00	1520.00	t	$ 38,000.00
Disposal of spoil as fill	$ 220.00	1520.00	t	$ 335,000.00
High Early Discharge System	$ 81,818.40	1	item	$ 82,000.00
Strip and Replace Top Soil	$ 3.85	941.6367	m^2	$ 5,000.00
Turf	$ 8.19	941.6367	m^2	$ 8,000.00

Sub-Total RCBC =	$ 538,000.00
Contingency 30% =	$ 162,000.00
TOTAL =	**$ 700,000.00**

Note: Rates are based on data current as of 2020.

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Configuration 3

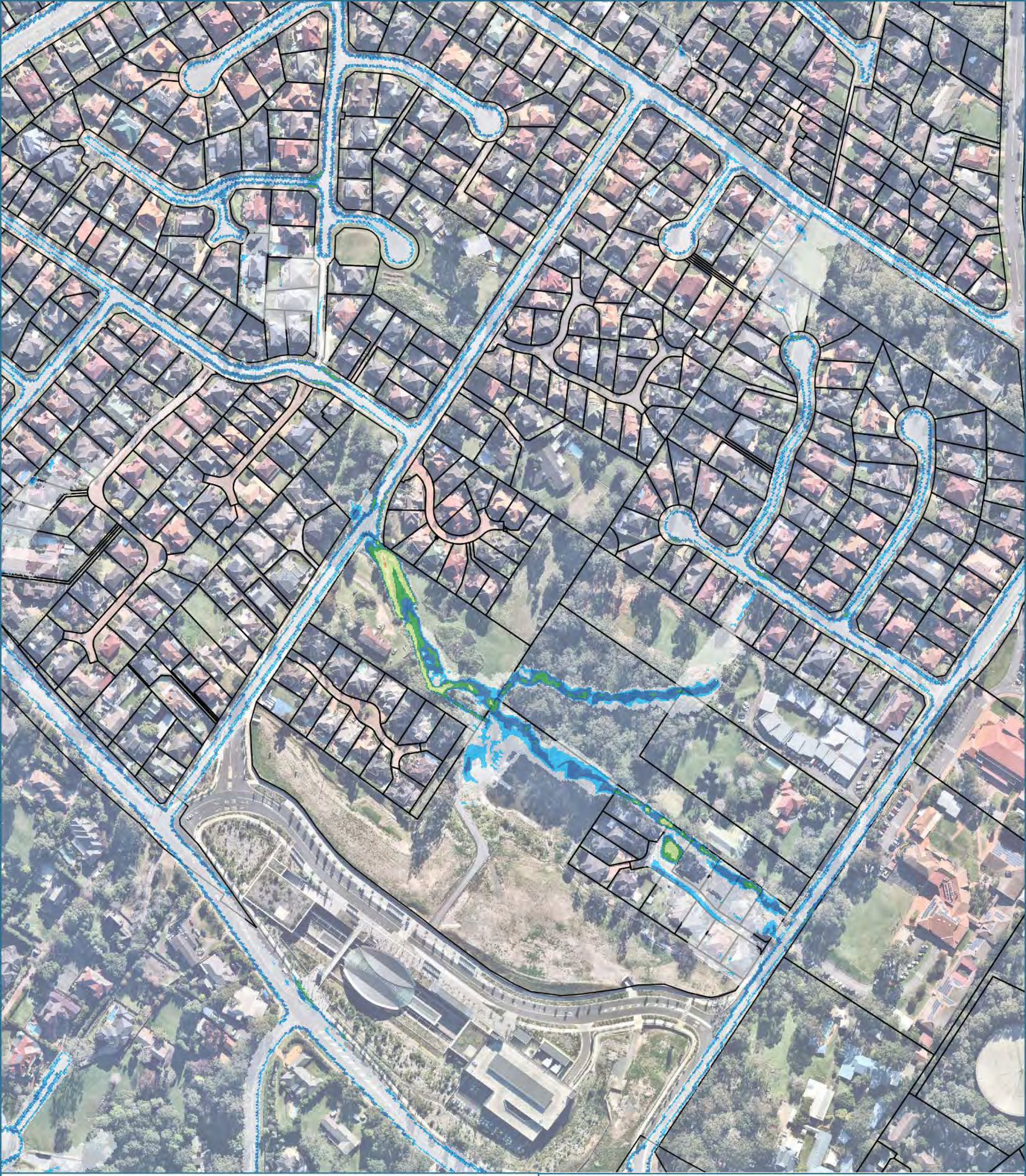
Item	Rate	Qty	Unit	Cost ($)
Preliminaries	$ 30,000.00	1	item	$ 30,000.00
Cut to spoil	$ 43.55	5228.44	m^3	$ 228,000.00
Disposal of spoil as VENM	$ 25.00	591.87	t	$ 15,000.00
Disposal of spoil as fill	$ 220.00	591.87	t	$ 131,000.00
Trim and Compact Subgrade	$ 2.11	2015.78	m^2	$ 5,000.00
Select Layer 250mm Thick	$ 18.73	2015.78	m^2	$ 38,000.00
Double Trap Detention Basin (DTDB)	$ 1,740,783.40	1	item	$ 1,741,000.00
Cost Esitmate using Reinforced Concrete Box Culvert (RCBC)				
Base Slab 300mm Thick	$ 265.55	2015.782	m2	$ 536,000.00
Box Culverts (S:3600 x H:1800 x L:2400)	$ 5,381.14	126		$ 679,000.00
Link Slabs	$ 3,992.36	105		$ 420,000.00
Backfill	$ 85.00	4605.419	m^3	$ 392,000.00
Low Flow Outlet	$ 32,954.60	1	item	$ 33,000.00
High Early Discharge System	$ 81,818.40	1	item	$ 82,000.00
Spillway	$ 50,000.00	1	item	$ 50,000.00
Subsoil Drainage	$ 8.00	1047.231	m	$ 9,000.00
Strip and Replace Top Soil	$ 7.57	3164.762	m^2	$ 24,000.00
Turf	$ 8.19	3164.762	m^2	$ 26,000.00

Sub-Total RCBC =	$ 2,668,000.00
Contingency 30% =	$ 801,000.00
TOTAL =	**$ 3,469,000.00**

Sub-Total DTDB =	$ 2,774,000.00
Contingency 30% =	$ 833,000.00
TOTAL =	**$ 3,607,000.00**

Note: Rates are based on data current as of 2020.

Appendix F: Flood Mapping



Flood Depth (m)

- <0.05 m
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00m

0 80 160 240 m

N

Cherrybrook Flood Risk Assessment
20% AEP Flood Depth

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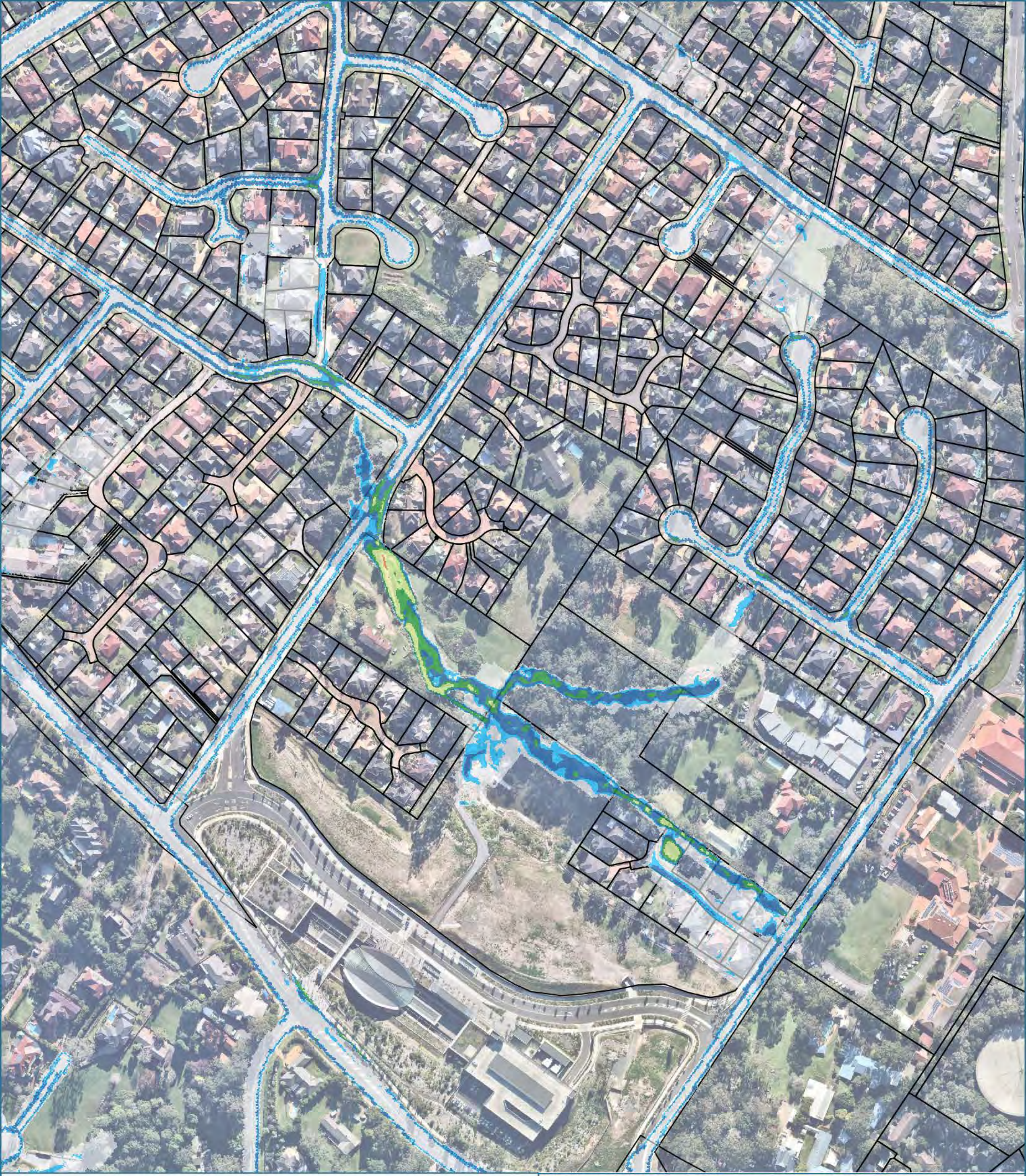

Flood Depth (m)

- <0.05 m
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00m

0 80 160 240 m N

Cherrybrook Flood Risk Assessment
5% AEP Flood Depth

Royal HaskoningDHV
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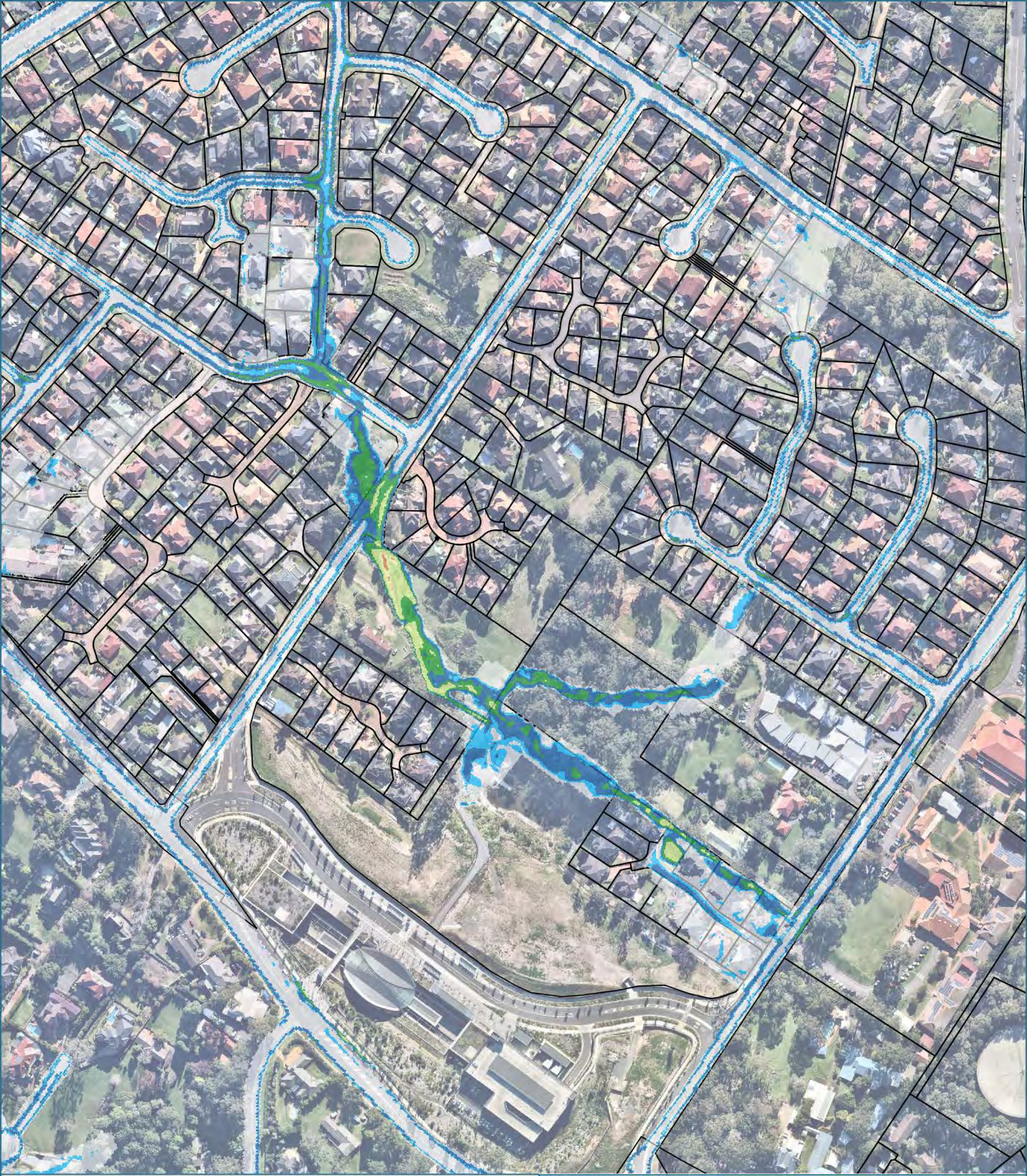

Flood Depth (m)

- <0.05 m
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00m

0 80 160 240 m

N

Cherrybrook Flood Risk Assessment
1% AEP Flood Depth

Royal HaskoningDHV
Enhancing Society Together

Flood Depth (m)

- <0.05 m
- 0.05 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00m

0 80 160 240 m

N

Cherrybrook Flood Risk Assessment 1% AEP with Climate Change Flood Depth

Royal HaskoningDHV
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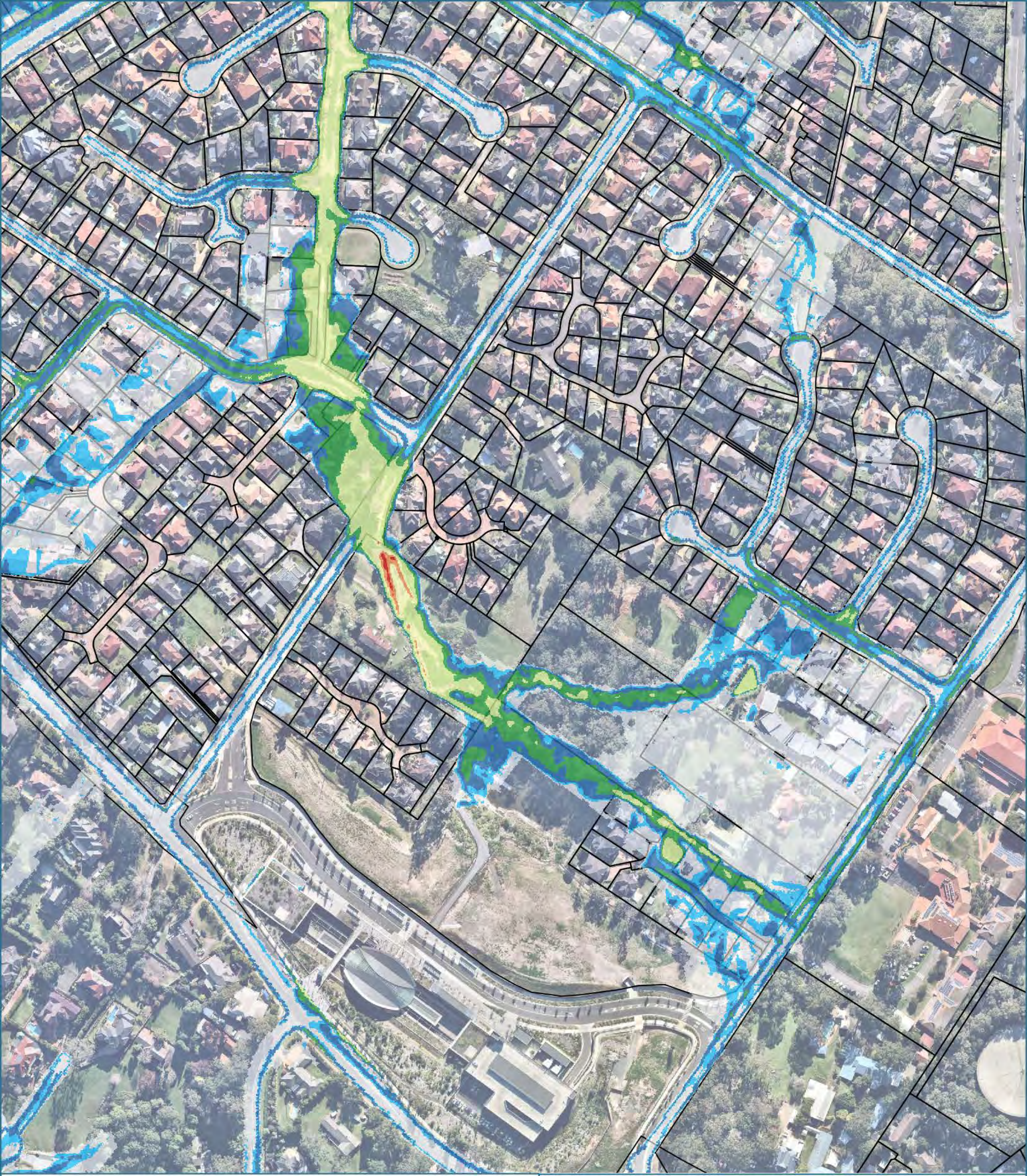


Flood Depth (m)

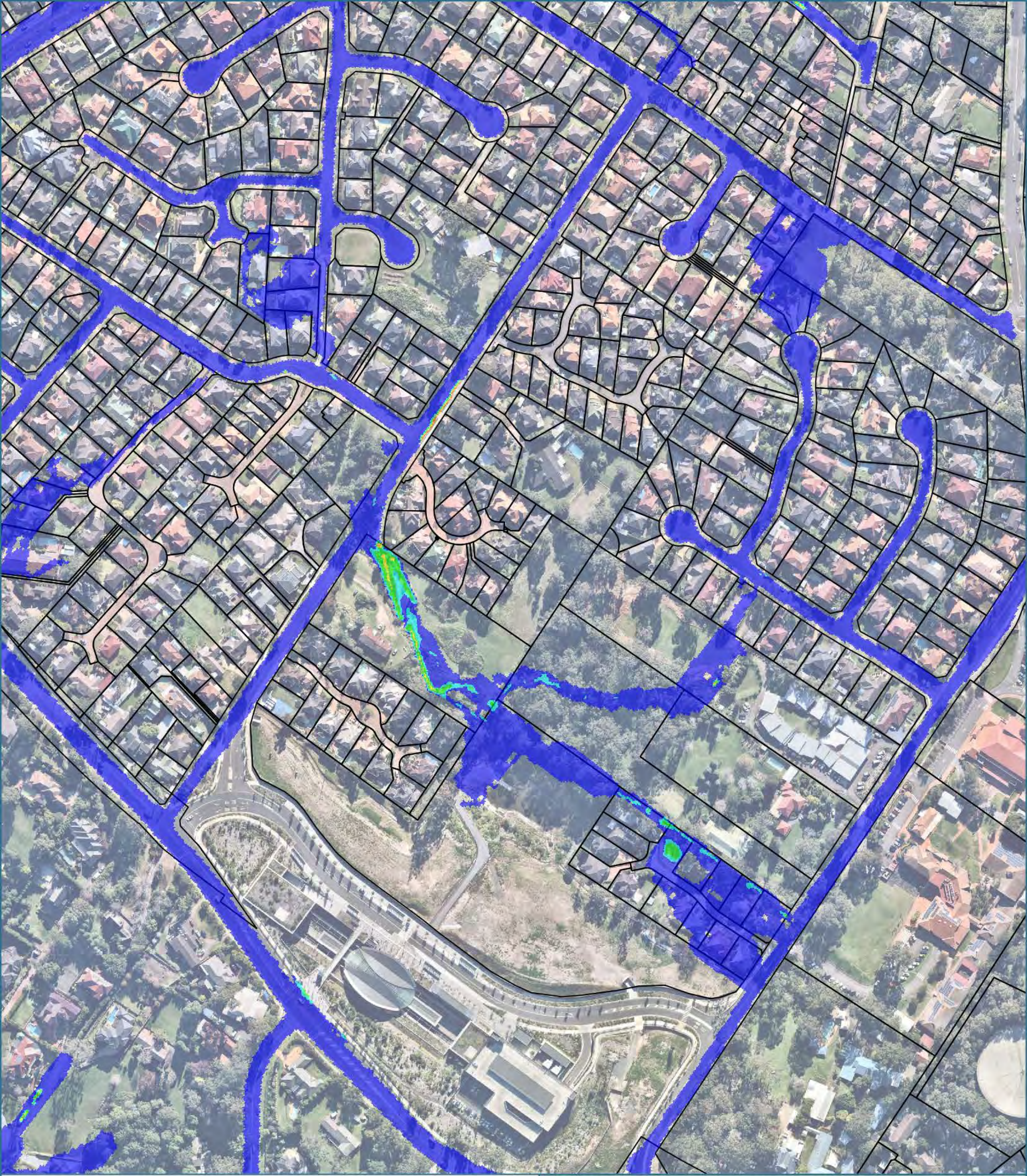
	<0.05 m
	0.05 - 0.10
	0.10 - 0.25
	0.25 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.00
	> 2.00m

0 80 160 240 m

N

Cherrybrook Flood Risk Assessment
Extreme Flood Event - Depth

Royal HaskoningDHV
Enhancing Society Together



Flood Hazard Category

- H1 - No Vulnerability Constraints
- 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
- H6 - Unconditionally Dangerous

Cherrybrook Flood Risk Assessment
20% AEP Flood Hazard Category Map

Royal HaskoningDHV
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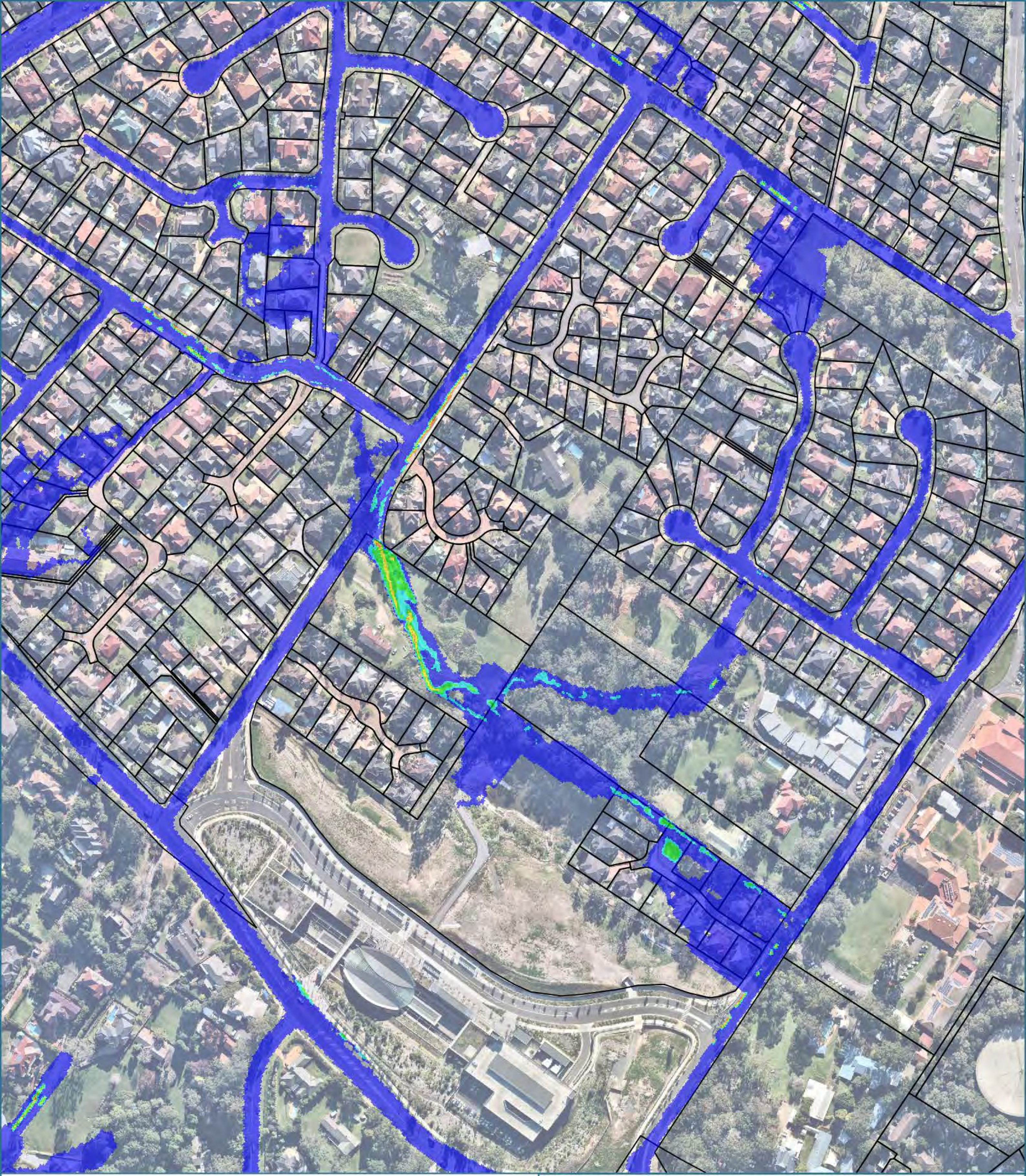


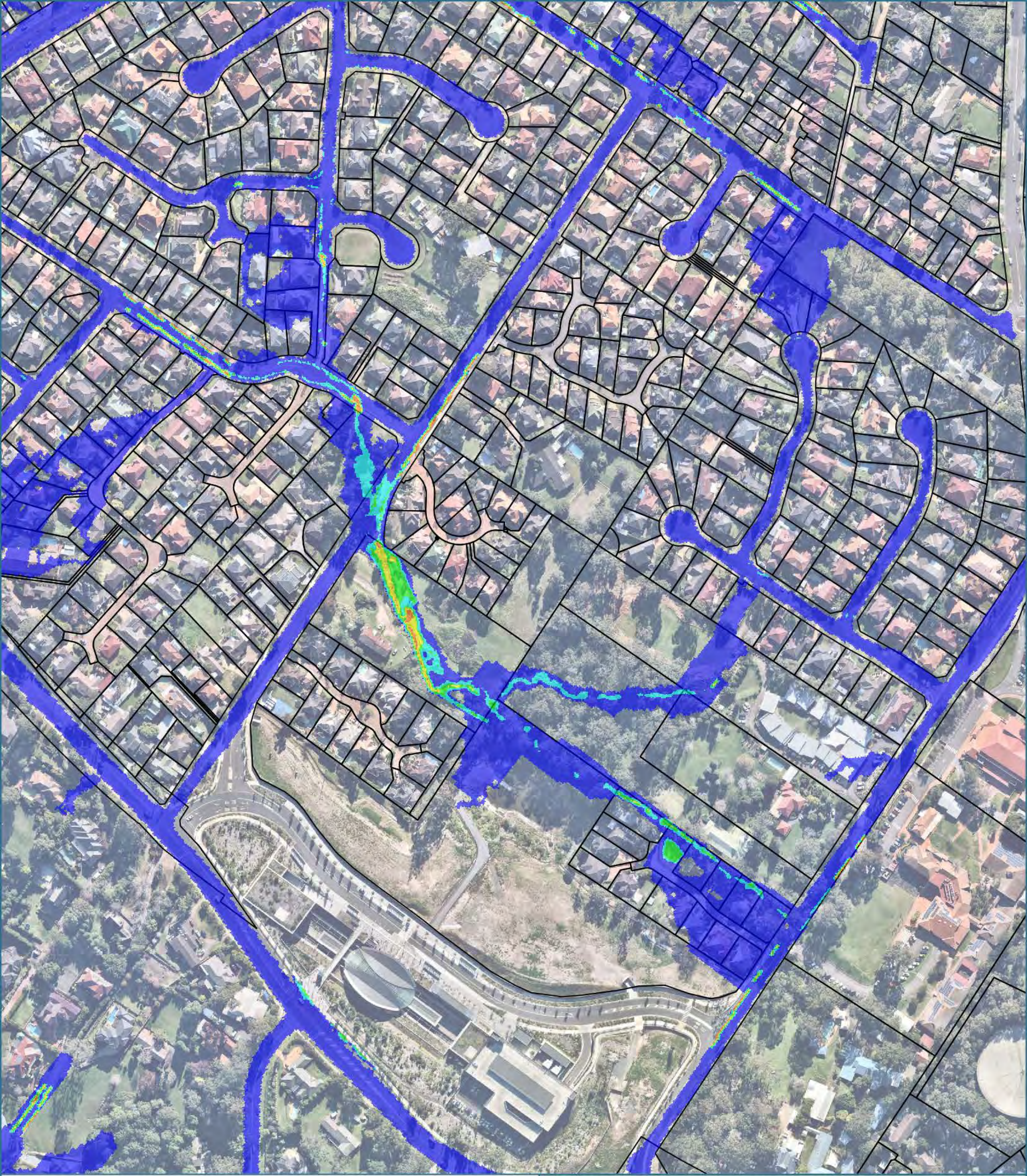
Flood Hazard Category

- H1 - No Vulnerability Constraints
- 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
- H6 - Unconditionally Dangerous

0 80 160 240 m N

Cherrybrook Flood Risk Assessment
5% AEP Flood Hazard Category Map

Royal HaskoningDHV
Enhancing Society Together



Flood Hazard Category

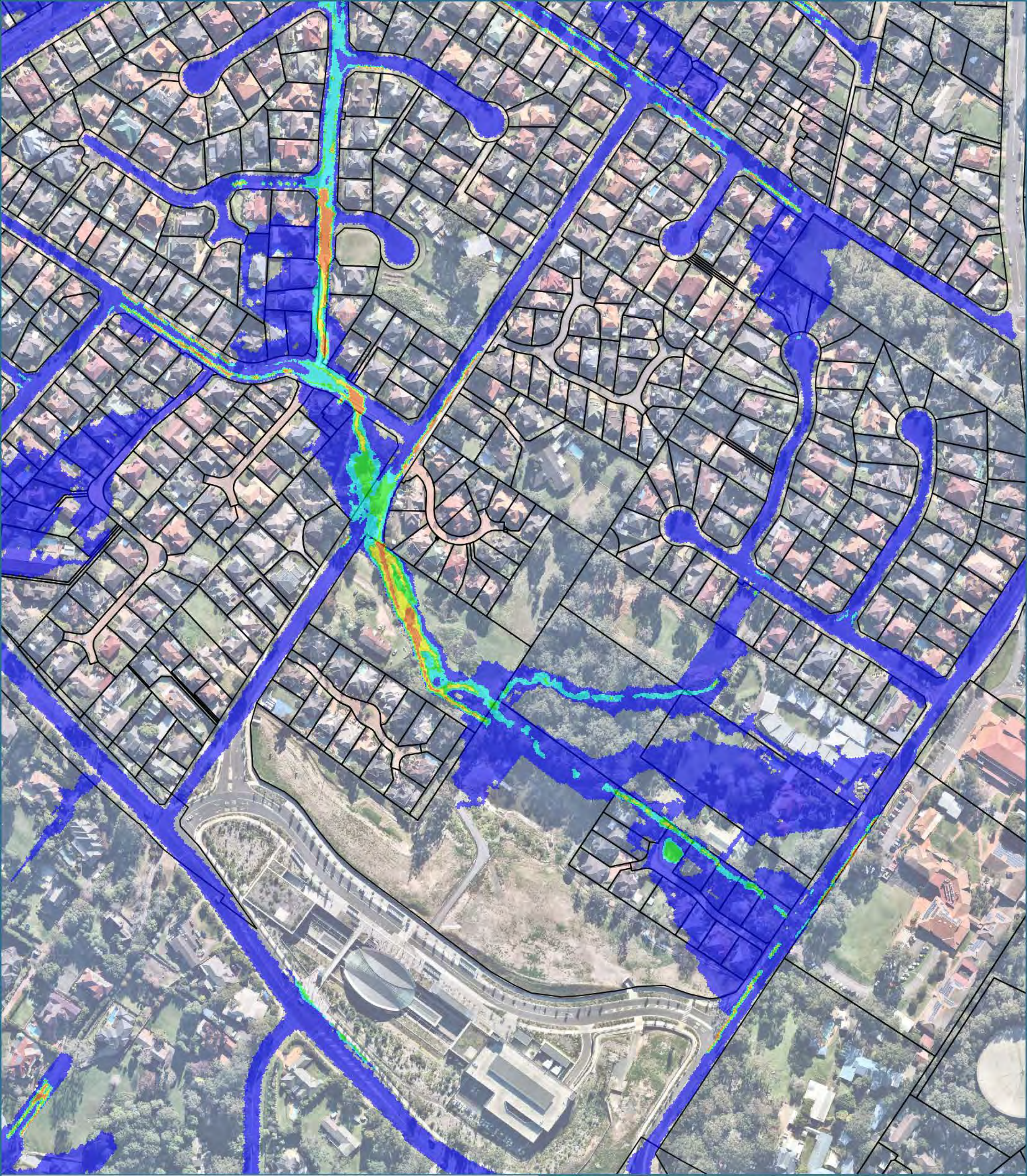
- H1 - No Vulnerability Constraints
- H2 - Unsafe for small vehicles
- H3 - Unsafe for all vehicles, children and the elderly
- H4 - Unsafe for all people and all vehicles
- H5 - Unsafe for all people and all vehicles
- H6 - Unconditionally Dangerous

0 80 160 240 m

N

Cherrybrook Flood Risk Assessment
1% AEP Flood Hazard Category Map

Royal HaskoningDHV
Enhancing Society Together



Flood Hazard Category

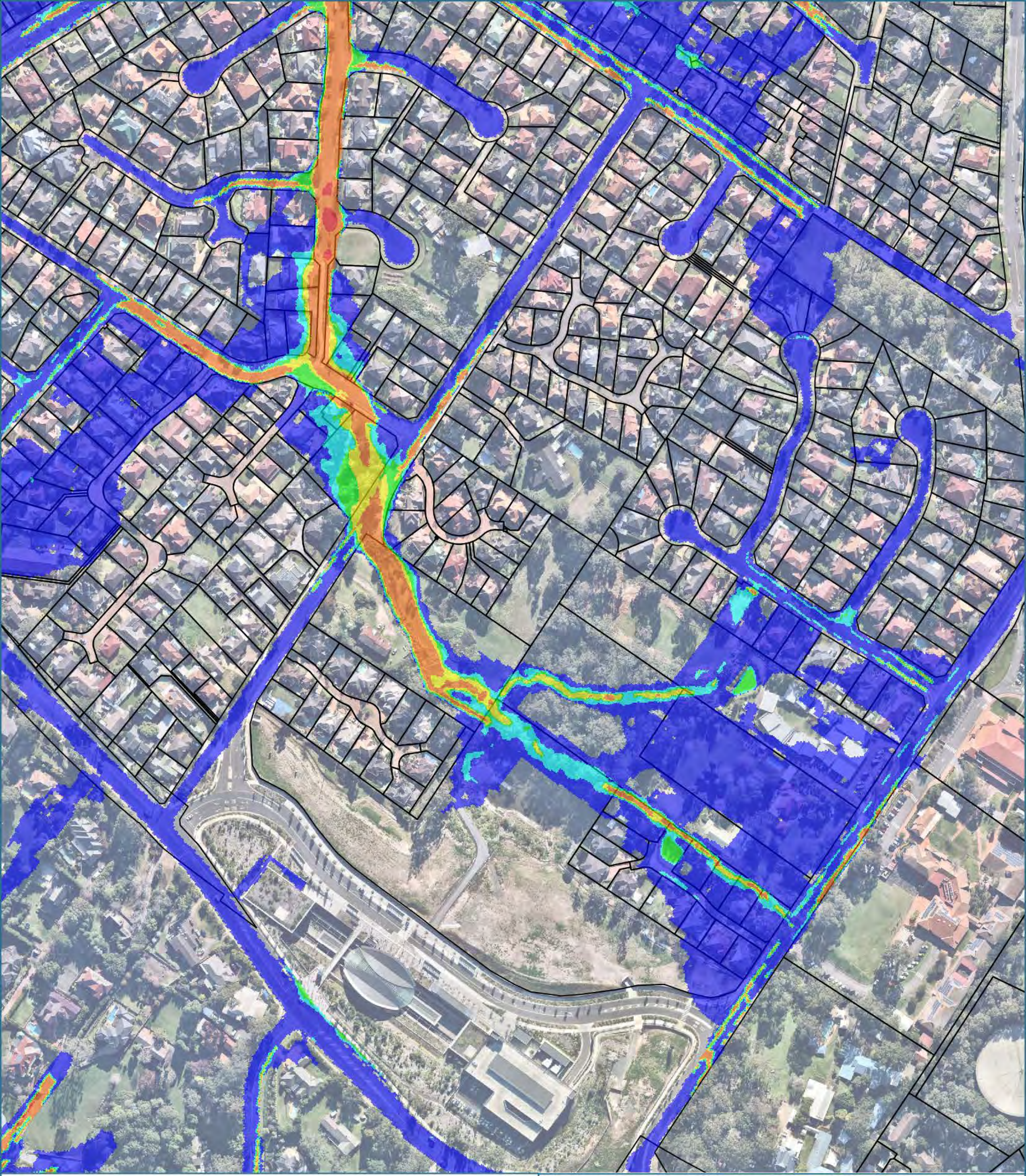
- H1 - No Vulnerability Constraints
- H2 - Unsafe for small vehicles
- H3 - Unsafe for all vehicles, children and the elderly
- H4 - Unsafe for all people and all vehicles
- H5 - Unsafe for all people and all vehicles
- H6 - Unconditionally Dangerous

0 80 160 240 m

N

Cherrybrook Flood Risk Assessment 1% AEP with Climate Change Flood Hazard Category Map

Royal HaskoningDHV
Enhancing Society Together



Flood Hazard Category

- H1 - No Vulnerability Constraints
- 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
- H6 - Unconditionally Dangerous

Cherrybrook Flood Risk Assessment Extreme Flood Event - Hazard Category Map

Royal HaskoningDHV
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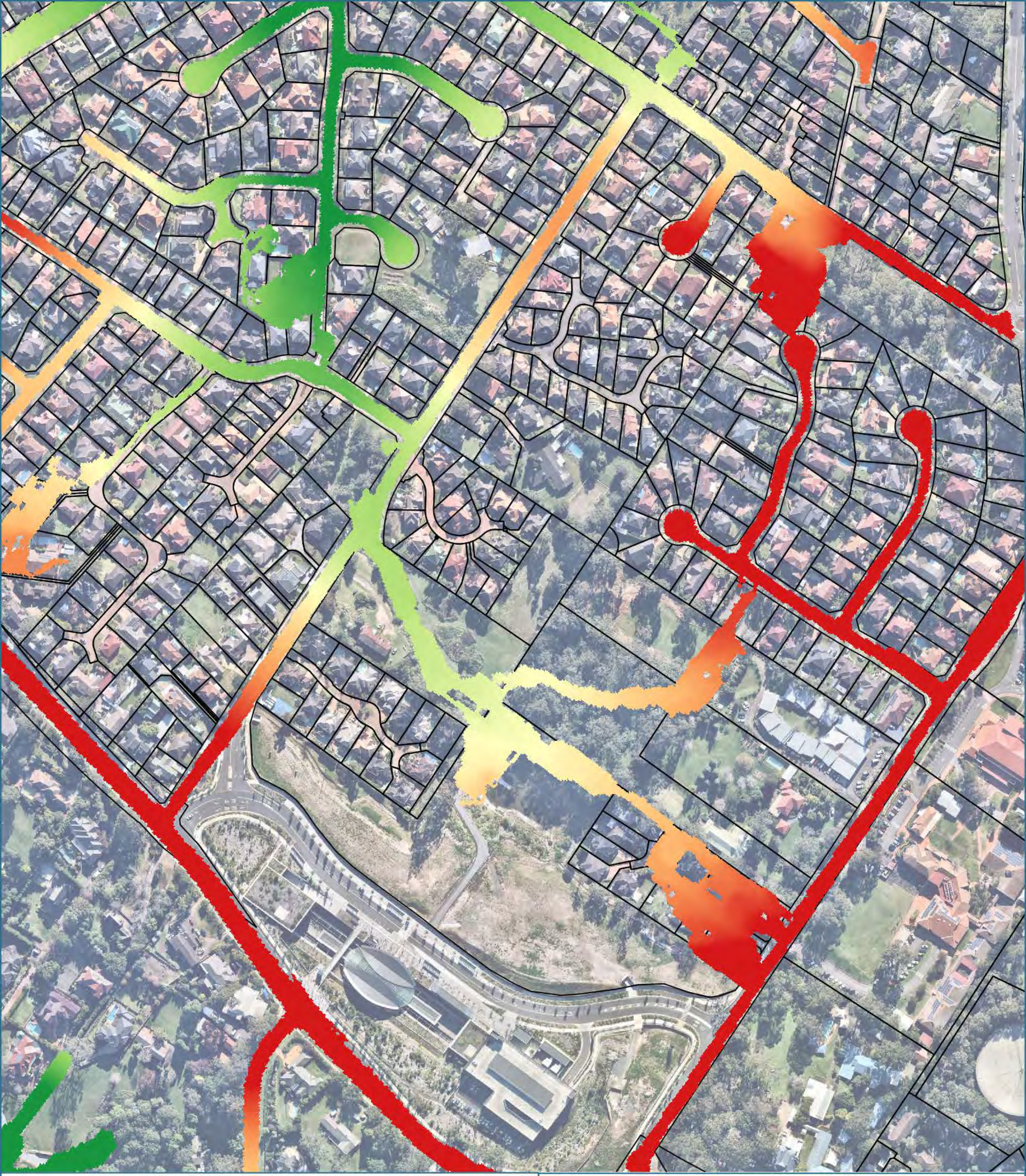


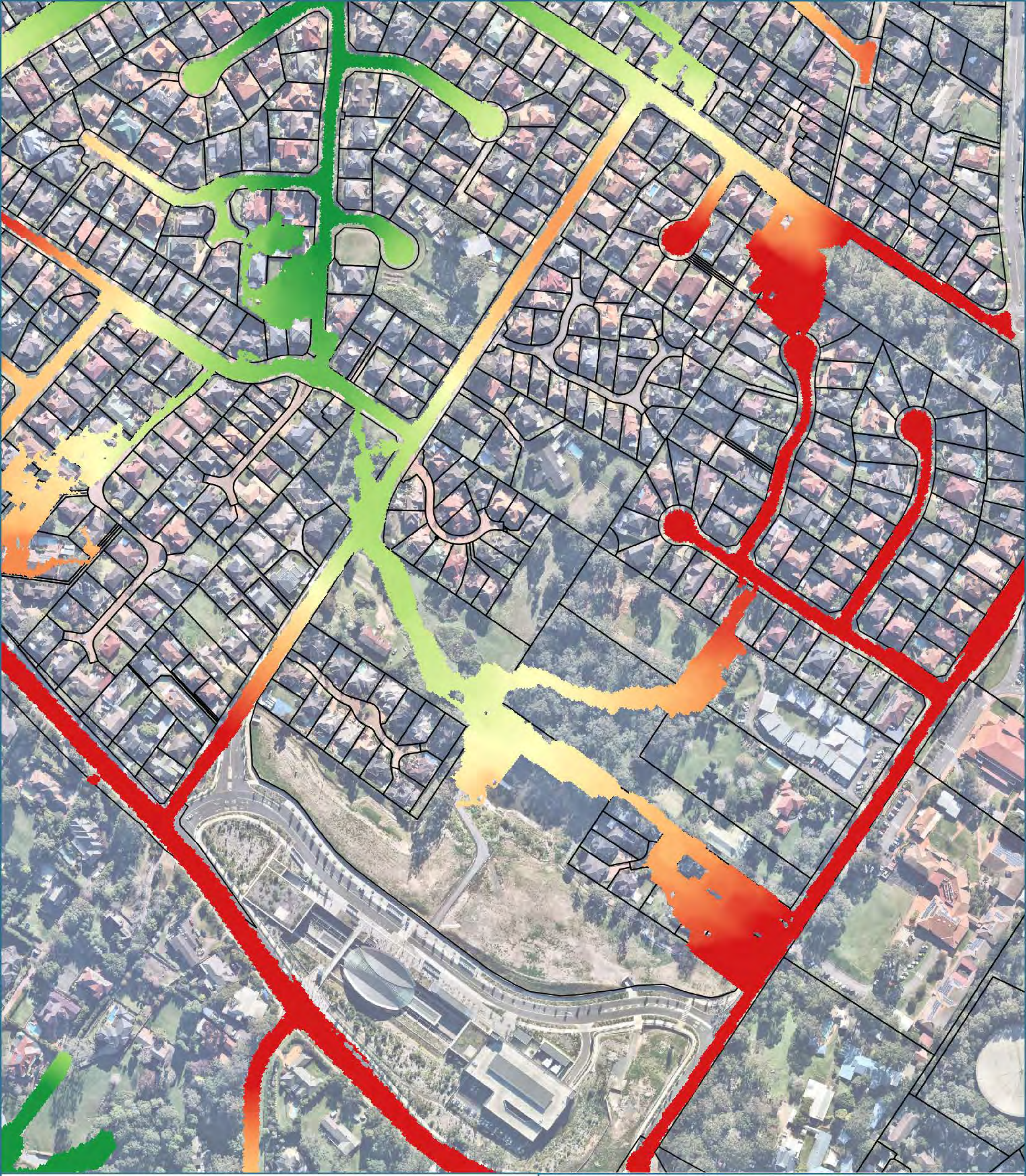
Flood Height (mAHD)			
	150		160
	152		162
	154		164
	156		166
	158		168
			170

0 80 160 240 m

N

Cherrybrook Flood Risk Assessment
20% AEP Flood Height

Royal HaskoningDHV
Enhancing Society Together



Flood Height (mAHD)

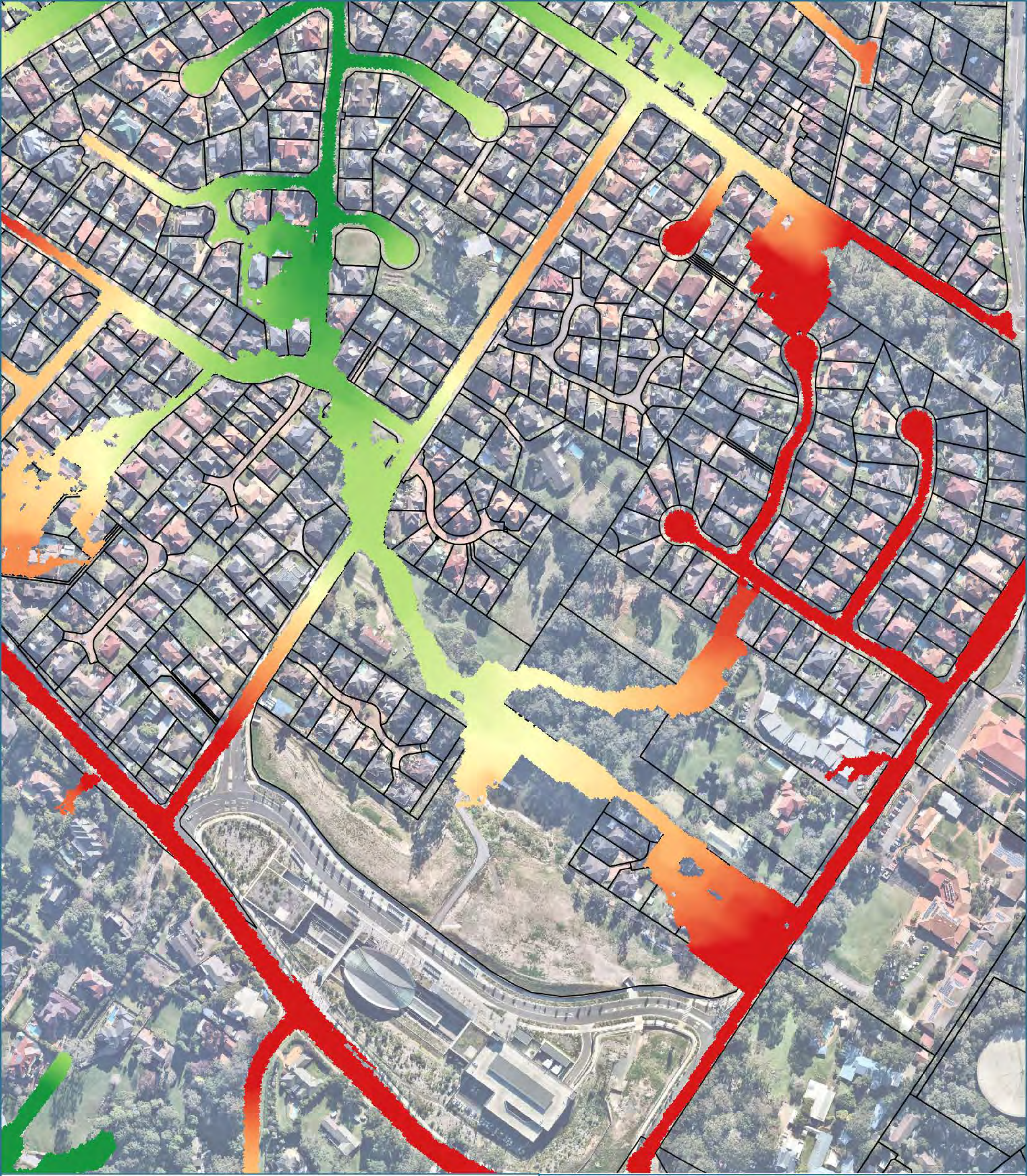
- 150
- 152
- 154
- 156
- 158
- 160
- 162
- 164
- 166
- 168
- 170

0 80 160 240 m

N

Cherrybrook Flood Risk Assessment
5% AEP Flood Height

Royal HaskoningDHV
Enhancing Society Together



Flood Height (mAHD)

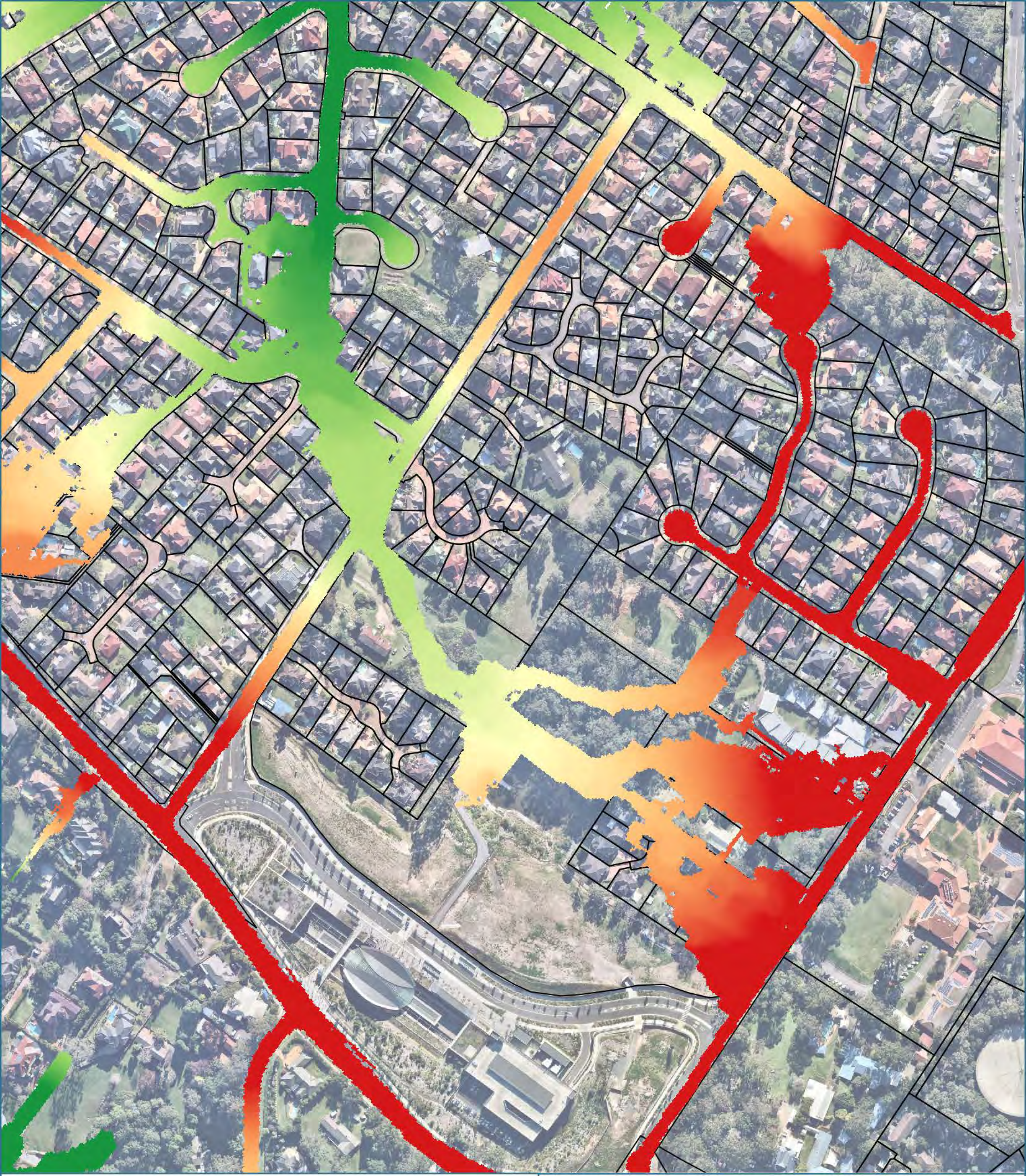
- 150
- 152
- 154
- 156
- 158
- 160
- 162
- 164
- 166
- 168
- 170

0 80 160 240 m

N

Cherrybrook Flood Risk Assessment
1% AEP Flood Height

Royal HaskoningDHV
Enhancing Society Together



Flood Height (mAHD)

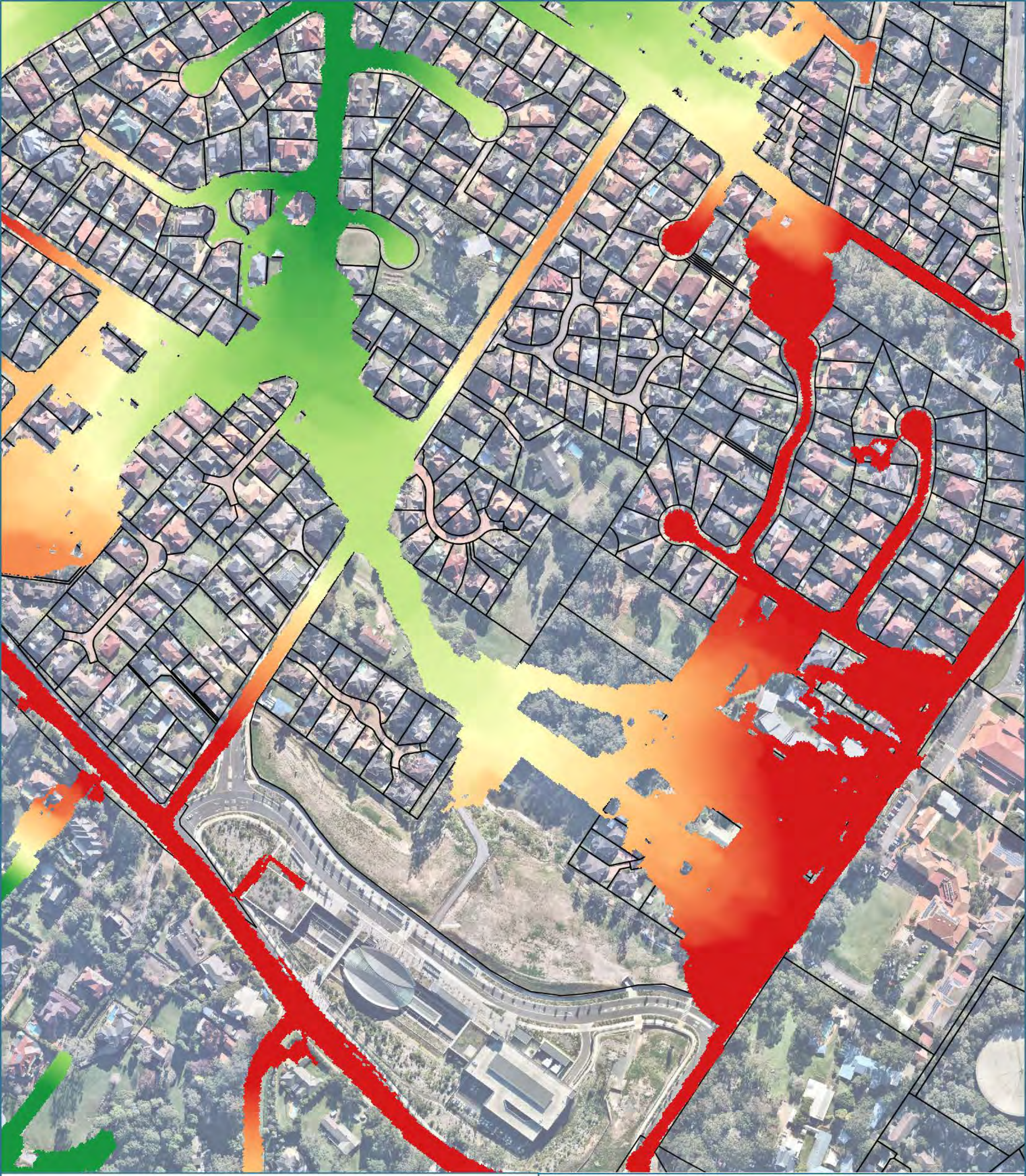
150	160
152	162
154	164
156	166
158	168
	170

0 80 160 240 m

N

Cherrybrook Flood Risk Assessment 1% AEP with Climate Change Flood Height

Royal HaskoningDHV
Enhancing Society Together



Flood Height (mAHD)

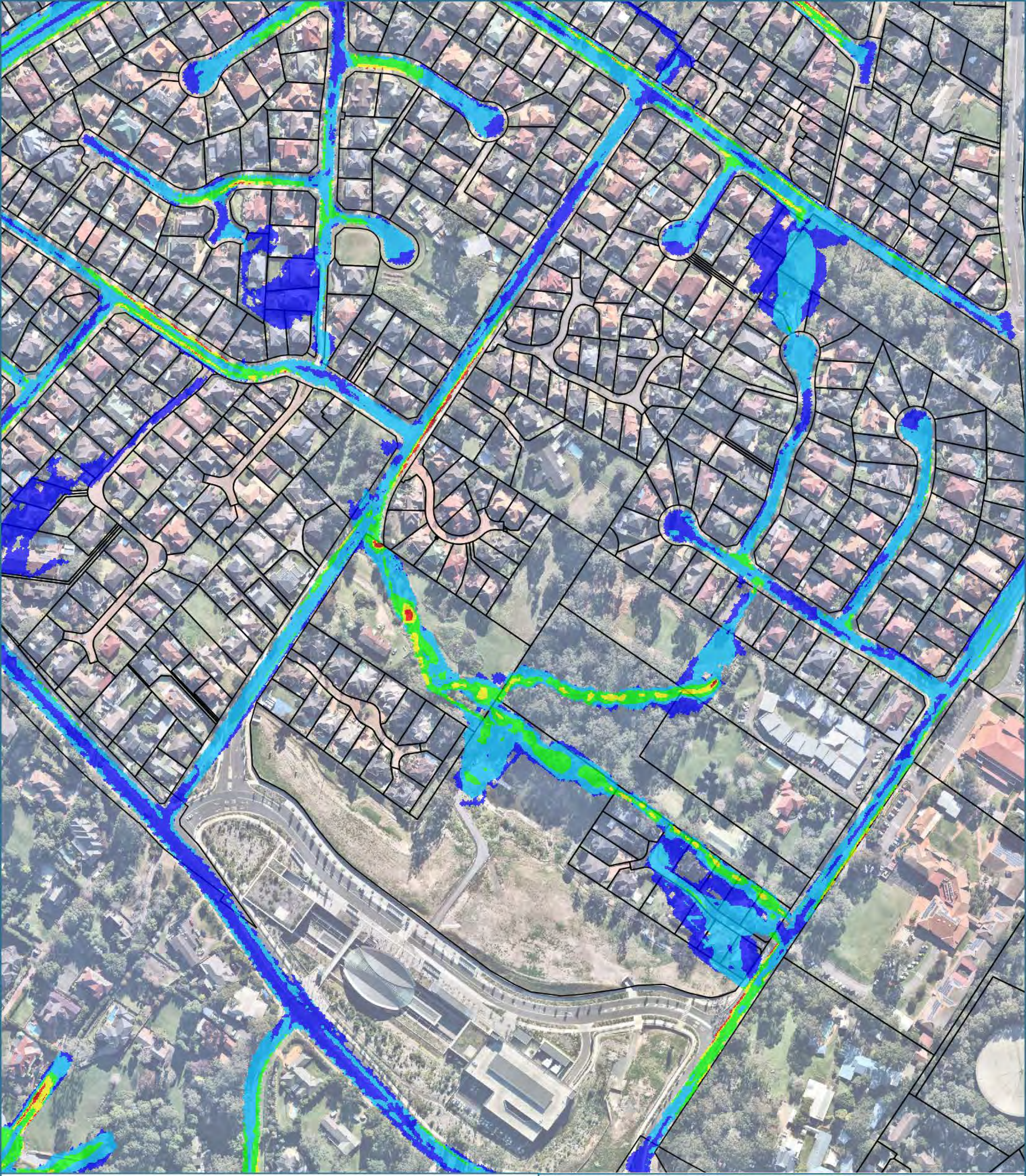
- 150
- 152
- 154
- 156
- 158
- 160
- 162
- 164
- 166
- 168
- 170

0 80 160 240 m

N

Cherrybrook Flood Risk Assessment
Extreme Flood Event - Height

Royal HaskoningDHV
Enhancing Society Together



Flood Velocity (m/s)

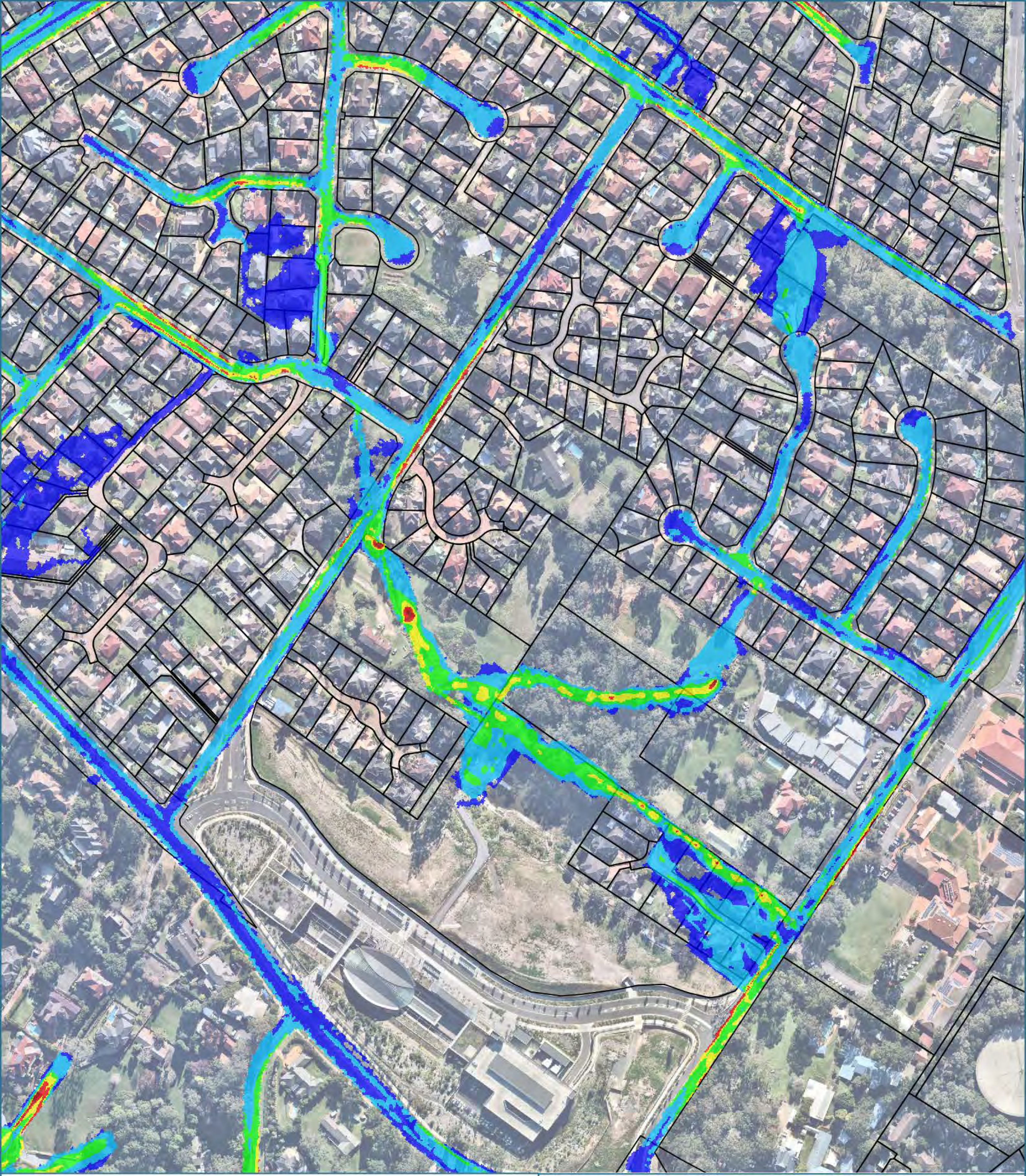
- <= 0.1 m/s
- 0.1 - 0.5 m/s
- 0.5 - 1.0 m/s
- 1.0 - 1.5 m/s
- 1.5 - 2.0 m/s
- >= 2.0 m/s

0 80 160 240 m

N

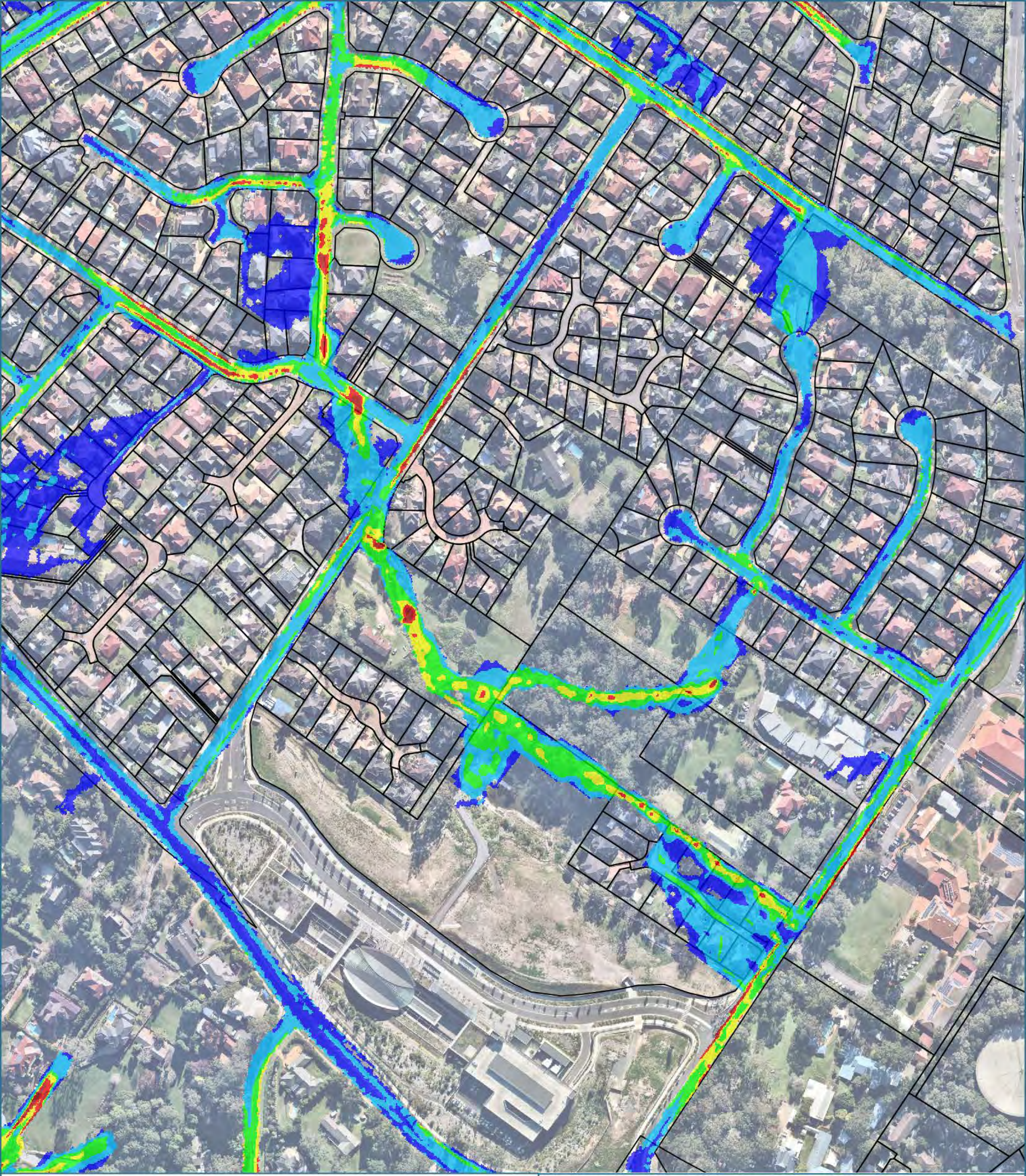
Cherrybrook Flood Risk Assessment
20% AEP Flood Velocity

Royal HaskoningDHV
Enhancing Society Together



Cherrybrook Flood Risk Assessment
5% AEP Flood Velocity

Royal HaskoningDHV
Enhancing Society Together



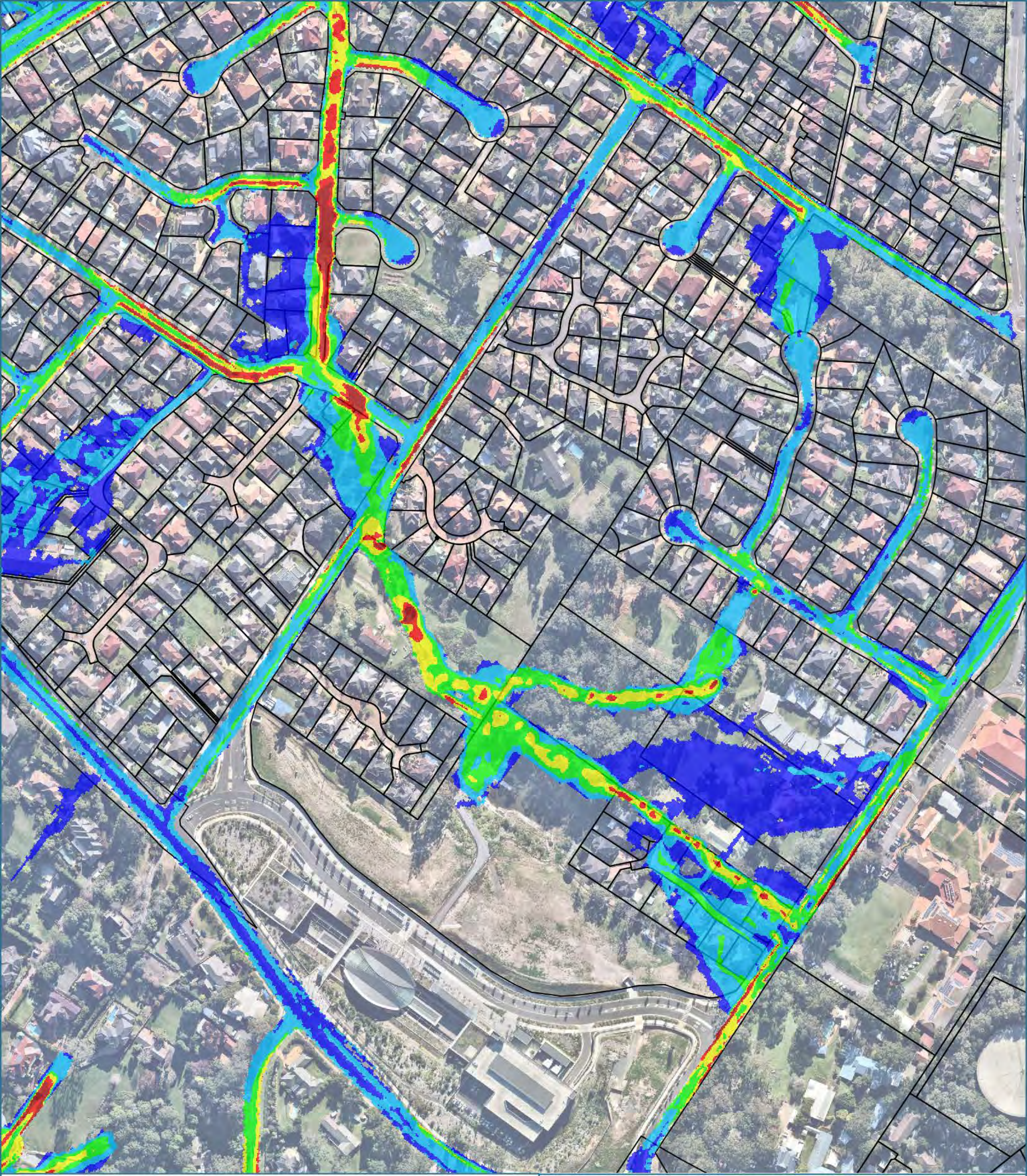
Flood Velocity (m/s)

- <= 0.1 m/s
- 0.1 - 0.5 m/s
- 0.5 - 1.0 m/s
- 1.0 - 1.5 m/s
- 1.5 - 2.0 m/s
- >= 2.0 m/s

0 80 160 240 m N

Cherrybrook Flood Risk Assessment
1% AEP Flood Velocity

Royal HaskoningDHV
Enhancing Society Together



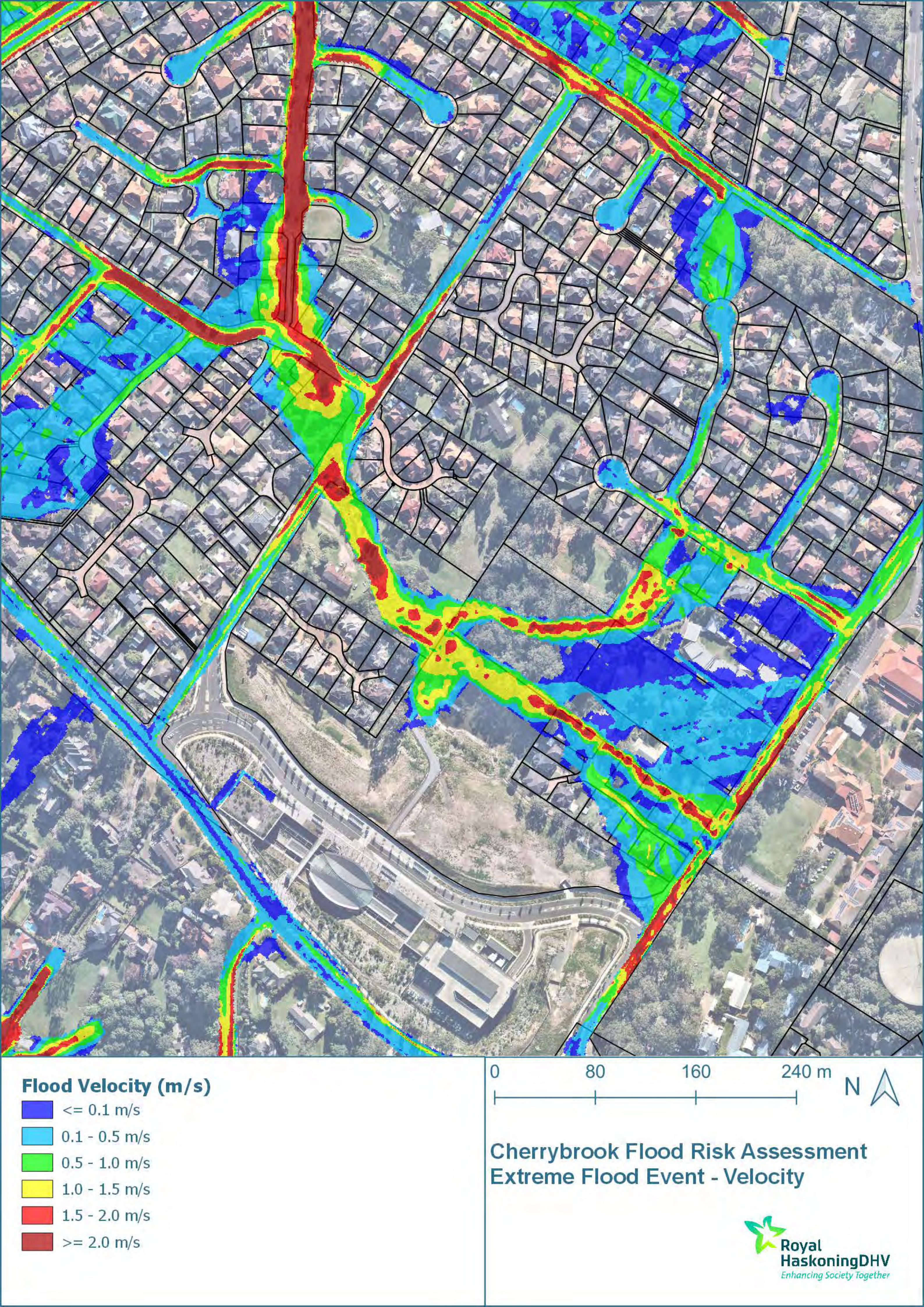
Flood Velocity (m/s)

- <= 0.1 m/s
- 0.1 - 0.5 m/s
- 0.5 - 1.0 m/s
- 1.0 - 1.5 m/s
- 1.5 - 2.0 m/s
- >= 2.0 m/s

0 80 160 240 m N

Cherrybrook Flood Risk Assessment 1% AEP with Climate Change Flood Velocity

Royal HaskoningDHV
Enhancing Society Together



Cherrybrook Flood Risk Assessment
Extreme Flood Event - Velocity

Royal HaskoningDHV
Enhancing Society Together