ADW JOHNSON PTY LIMITED
ABN 62 129 445 398

Sydney
Level 35 One International Towers
100 Barangaroo Avenue
Sydney NSW 2000
02 8046 7411
sydney@adwjohnson.com.au

Central Coast
5 Pioneer Avenue
Tuggerah NSW 2259
02 4305 4300
coast@adwjohnson.com.au

Hunter Region
7/335 Hillsborough Road
Warners Bay NSW 2282
02 4978 5100
hunter@adwjohnson.com.au

Engineering

Stormwater and Drainage Assessment

To accompany a Concept Development Application for the Ivanhoe Estate Masterplan a State Significant Development

Property:
The land currently comprising Ivanhoe Estate, Herring Road, Macquarie Park as well as a portion of Shrimptons Creek and part of Lot 1 in DP 859537

Applicant:
Aspire Consortium on behalf of NSW Land and Housing Corporation

Date:
27th February 2018

Working Beyond Expectations

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Project Management • Town Planning • Engineering • Surveying
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Document Control Sheet

Issue No.	Amendment	Date	Prepared By	Checked By
A	DRAFT	27th October 2017	BMY	IB
B	Issued for Approval	20th November 2017	BMY	IB
C	Minor rewording	24th November 2017	BMY	IB
D	Rewording	15th December 2017	BMY	IB
E	Rain Gardens added	27th February 2018	BMY	IB

Executive Summary

This report supports a Concept Development Application for the Ivanhoe Estate Masterplan, a State Significant Development (SSD) submitted to the Department of Planning and Environment (DPE) pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act). It has been prepared for Aspire Consortium on behalf of NSW Land and Housing Corporation.

As a part of the masterplan development application, a Stormwater and Drainage Assessment of the proposed development is required to be undertaken. This report has undertaken an assessment of the proposed development to determine compliance with the requirements set out in both the SEAR's and Ryde Council's DCP 2014 in regards to stormwater drainage.

The development is aiming to achieve a 6 star Green Star communities rating and as such is required to meet a number of stormwater objectives that are separate to the requirements of the SEAR's and Ryde Council's DCP 2014.

Ryde Council's DCP 2014 requires the development to comply with requirements for onsite detention, water sensitive urban design and flooding. This report considers both the onsite detention and water quality aspects with the flooding impact assessment been done by a third party.

It was indicated at early meetings with Ryde Council that OSD and WSUD requirements would only need to apply to areas within the site that are to remain in private ownership. Despite this, in order to meet the requirements of the Green Star communities, an end of line rain garden was proposed in order to treat runoff generated by the public road network.

In order to minimise the size of the end of line rain garden, OSD and WSUD control measures were provided on lot prior to flows entering the public drainage system. A concept drainage plan was developed on this basis and consisted of an on lot private system and a public drainage system located within the proposed public road reserves.

Using the XP-RAFTS software, an onsite detention model was created, using a combination of rainwater tanks and designated detention tanks to adequately attenuate peak flows to meet Council's requirements. It was found that a total of 1,270m^3 of dedicated detention storage was required, along with 742m^3 of storage within the rainwater tanks to meet the requirements set out by Ryde Council and the Green Star Communities guidelines.

A water quality model was created in the MUSIC software to determine the required water quality treatment measures to meet both Council's and the Green Star communities' water quality targets. A treatment train of rainwater tanks, gross pollutant traps and media filtration devices was proposed for the development. An analysis of the MUSIC model indicated that the proposed treatment train not only met but exceeded the targets set by Council and Green Star Communities guidelines.

A water balance model was developed to determine the reduction in potable water for each building within the development. Due to inefficiencies with reducing potable water demand on internal uses, this development proposes to reuse captured stormwater for irrigation purposes only.

An analysis was undertaken to determine the most efficient rainwater tanks size for each building. Based on the information available it was found that a 38kL was the most efficient tank and this was adopted on all buildings.

An erosion and sedimentation control plan was developed to ensure that during construction runoff generated on the site was adequately treated prior to it entering the downstream receiving waters. This plan will need to be regularly updated to adjust to changes in the proposed development over the life of the project.

A staging strategy was prepared to ensure that water quantity and water quality requirements were met, not only once the entire site has been developed but throughout the entire life of the development. A combination of early construction and temporary works was proposed to ensure requirements are met over the life of the project. This will need to be reviewed at each stage to ensure the most efficient solution is adopted.

The adjoining development to the North West of the subject site currently drains, under easement, through the site to the existing public drainage system. It was found that the proposed development would impact on this connection, however any designs will consider this connection to ensure it remains.

It should be noted that this report is for a masterplan development application and therefore there are some uncertainties around the final design of both the public domain and built form within the site. As such, the OSD and WSUD measures discussed in this report should be considered as a general guideline and not a final design. Development applications for individual stages will provide further details around the most appropriate solution for each stage.

This report shows that the from a stormwater management perspective, the proposed development can adequately meet the requirements set out by Ryde City Council and the SEAR's and meet the required targets within the Green Star Communities guidelines.

Table of Contents

1.0 Introduction

This report supports a Concept Development Application for the Ivanhoe Estate Masterplan, a State Significant Development (SSD) submitted to the Department of Planning and Environment (DPE) pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act). It has been prepared for Aspire Consortium on behalf of NSW Land and Housing Corporation.

1.1 BACKGROUND

In September 2015, the Ivanhoe Estate was rezoned by the Department of Planning and Environment as part of the Macquarie University Station (Herring Road) Priority Precinct, to transform the area into a vibrant centre that benefits from the available transport infrastructure and the Precinct's proximity to jobs, retail and education opportunities within the Macquarie Park corridor.

The Ivanhoe Estate is currently owned by NSW Land and Housing Corporation and comprises 259 social housing dwellings. The redevelopment of the Ivanhoe Estate is part of the NSW Government Communities Plus program, which seeks to deliver new communities where social housing blends with private and affordable housing, with good access to transport, employment, improved community facilities and open space.

The Communities Plus program seeks to leverage the expertise and capacity of the private and non-government sectors. As part of this program, Aspire Consortium, comprising Frasers Property Australia, Citta Property Group and Mission Australia Housing, was selected as the successful proponent to develop the site in July 2017.

The Masterplan DA is the first step of the planned redevelopment of the Ivanhoe Estate and will create an integrated neighbourhood including social housing mixed with affordable and private housing, as well as seniors housing, a new school, child care centres, community facilities and retail development.

1.2 SITE DESCRIPTION

The Ivanhoe Estate site is located in Macquarie Park near the corner of Epping Road and Herring Road within the Ryde Local Government Area (LGA). The site is approximately 8.2 hectares and currently accommodates 259 social housing dwellings, comprising a mix of townhouse and four (4) storey apartment buildings set around a cul-de-sac street layout. An aerial photo of the site is provided at **Figure 1** below.

Immediately to the north of the site are a series of four (4) storey residential apartment buildings. On the north-western boundary, the site fronts Herring Road and a lot which is currently occupied by four (4) former student accommodation buildings and is likely to be subject to redevelopment. Epping Road runs along the south-western boundary of the site and Shrimptons Creek, an area of public open space, runs along the south-eastern boundary. Vehicle access to the site is via Herring Road.

The site is comprised of 17 individual lots and a part lot and are owned and managed by Land and Housing Corporation. The Masterplan site also incorporates adjoining land, being a portion of Shrimptons Creek and part of the commercial site at 2-4 Lyon Park Road. This land is included to facilitate a bridge crossing and road connection to Lyon Park Road.

Figure 1: Ivanhoe Estate Site

1.2.1 Site Topography

The site generally falls from the north western corner, at the intersection of Epping and Herring Roads towards Shrimpton's Creek in the south eastern corner. As indicated in **Figure 2** overleaf, there is approximately 30m of fall across the site at an average grade of 7.5%.

The topography of 2-4 Lyon Park Road is very gentle with the site generally falling towards Shrimpton's Creek at an average slope of 1-2%. This is also indicated in **Figure 2** overleaf.

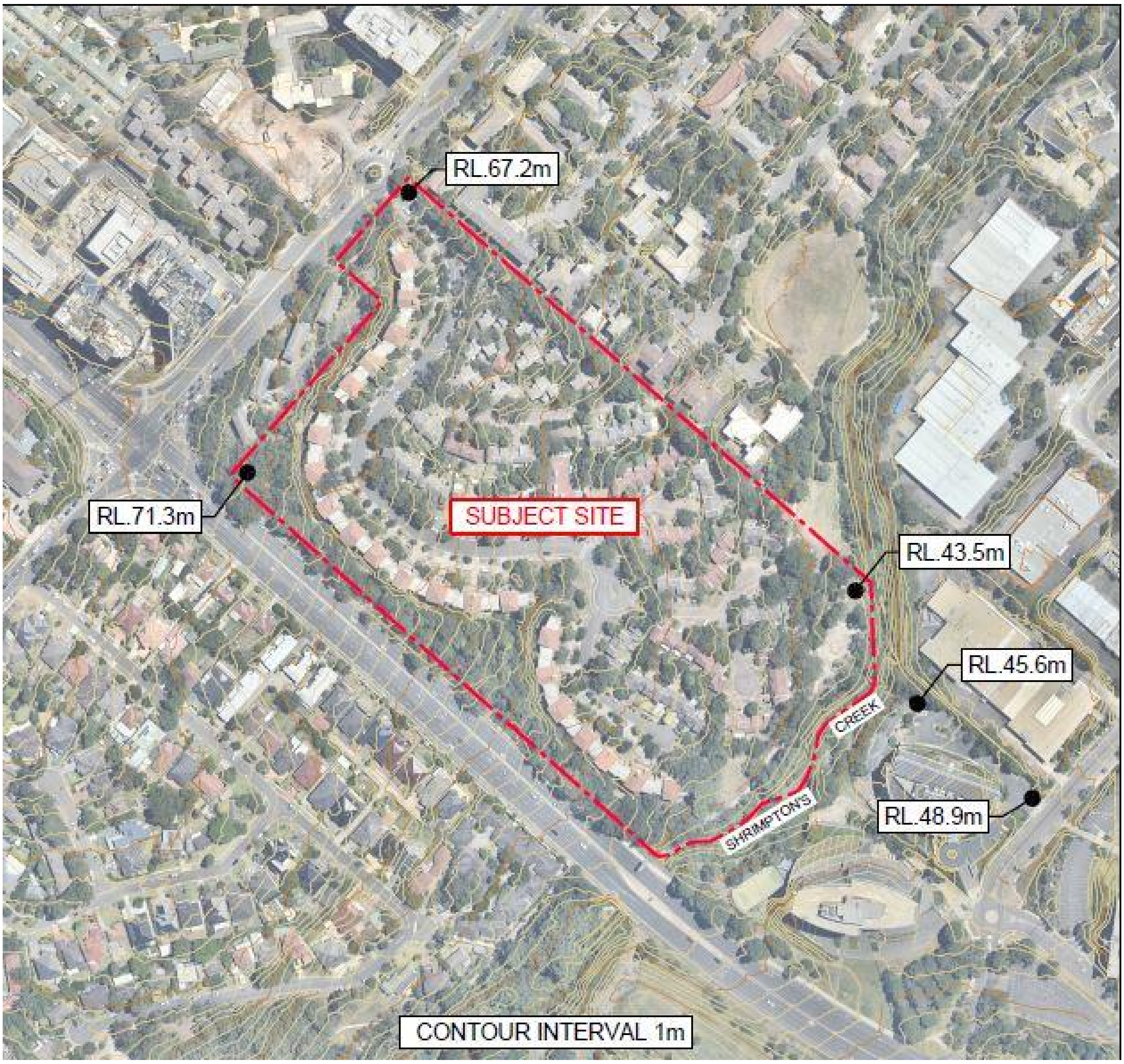

Figure 2: Existing Topography

1.2.2 Existing Stormwater Infrastructure

As mentioned above, the site currently consists of a mix of residential townhouses and apartment buildings set around a cul-de-sac street layout. Existing street drainage and interallotment drainage infrastructure currently drains runoff generated by the existing development south towards Shrimpton's Creek. There are currently three (3) outlet locations discharging into Shrimpton's Creek.

Prior to construction of the new development, all existing buildings, roads and associated infrastructure are to be demolished. As a part of this, the existing stormwater infrastructure is to be removed, with a new stormwater system to be constructed to cater for the new development.

It is noted that stormwater generated by the existing residential development to the North West of the subject site (Lot 1 D.P 609711) currently drains under easement through the site to the public drainage system in Ivanhoe Place. The proposed development will be designed to ensure that the existing site to the North West can continue to drain to the public drainage system.

1.3 PROPOSED DEVELOPMENT

The proposed Masterplan is a Concept DA (in accordance with Section 83B of the EP&A Act), which sets out the concept proposal for the development of the site. The concept contained in the Masterplan DA establishes the planning and development framework, which will form the basis for the detailed design of the future buildings and against which the future detailed DAs will be assessed.

The Masterplan DA seeks approval for the maximum building envelopes for future stages of development, the maximum gross floor area (GFA) and land uses for the development. Specifically:

- A mixed use development involving a maximum of GFA of 281,905m^2, including:
  - Residential flat buildings comprising private, social and affordable housing;
  - Seniors housing comprising residential care facilities and self-contained dwellings;
  - A new high school;
  - Child care centres;
  - Minor retail development;
  - Community uses;
- Maximum building heights and GFA for each development block;
- Public domain landscape concept, including parks, streets and pedestrian connections;
- Provision of the Ivanhoe Estate Design Guidelines to guide the detailed design of the future buildings; and
- Vehicular and intersection upgrades.

An image of the Masterplan DA is provided in **Figure 3** overleaf.

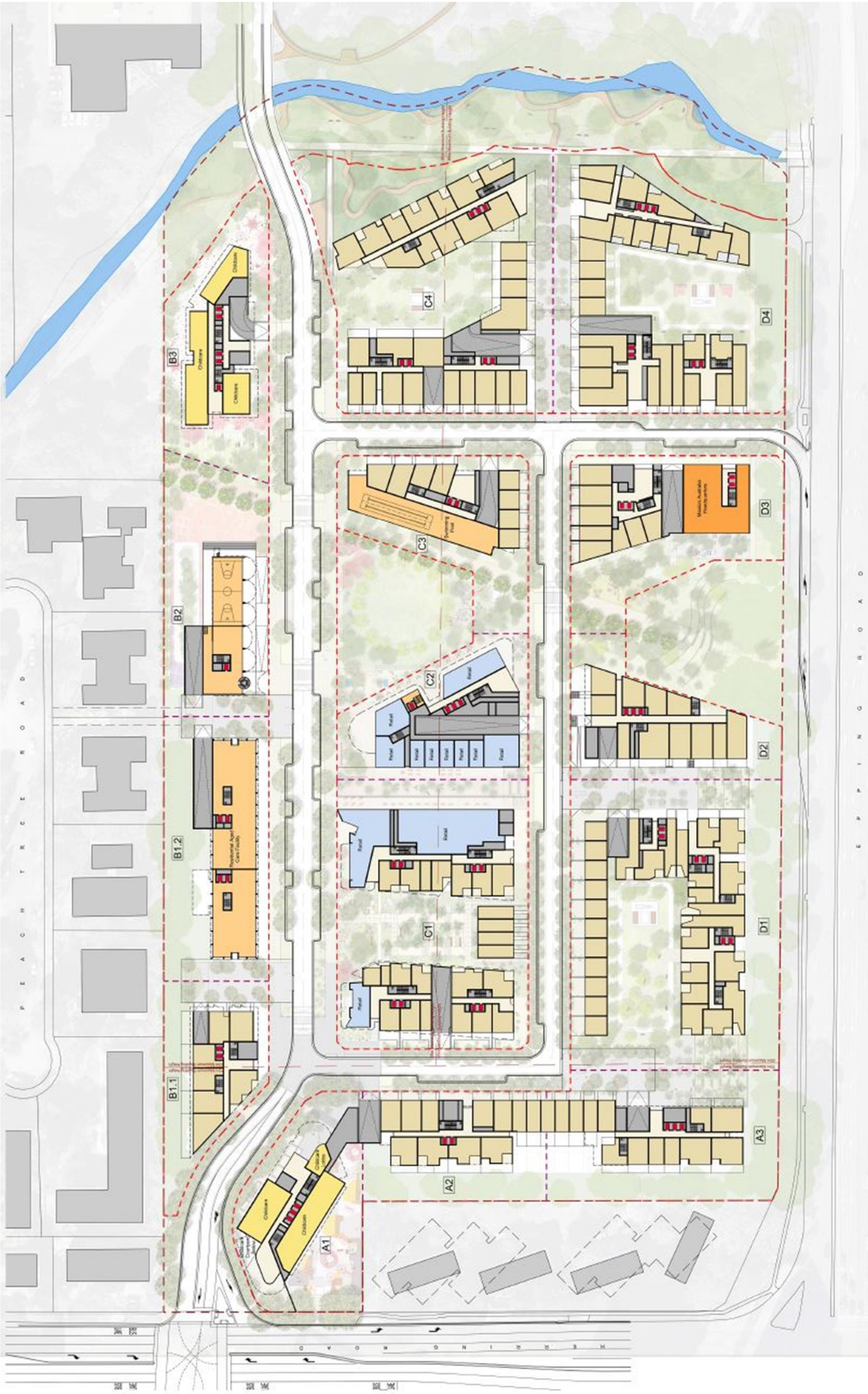

Figure 3: Ivanhoe Estate Masterplan

2.0 Authority Requirements

The proposed development is within the Ryde Council LGA and is therefore subject to the requirements of Ryde Council's Development Control Plan (DCP) 2014. Part 8.2 of Council's DCP contains specific information relating to the management of stormwater and contains the following documents:

- Stormwater Management Technical Manual;
- Water Sensitive Urban Design Guideline.

The proposed development is to satisfy the requirements of these documents and the broader Ryde Council DCP.

The development must also comply with the Secretary's Environmental Assessment Requirements (SEARs) provided by the NSW Department of Planning. A summary of the key SEARs requirements relating to this report can be seen below:

- *Prepare a Stormwater, Groundwater and Drainage Assessment;*
- *Detail Erosion, sediment and stormwater management controls during construction;*
- *Identify appropriate water quality management measures;*
- *Identify any water licensing requirements or other approvals;*
- *Prepare and integrated water management plan/drainage concept.*

The development is also aiming to achieve a 6 star Green Star Communities rating and as such is required to meet a number of stormwater objectives that are separate to the requirements of the SEAR's and Ryde Council's DCP 2014.

It should be noted that as a masterplan development application is highly conceptual in nature, this report aims to provide compliance with above requirements in a broad nature and provide a general framework from which future development applications can adhere to.

As further details around the individual stages of the development are established throughout the life of the project, the actual methods used to meet the requirements outlined in this report will also be developed.

2.1 STORMWATER QUANTITY

Ryde Council adopts a major/minor stormwater drainage philosophy for stormwater management throughout the LGA.

The minor drainage system is required to cater for runoff generated from all storm events up to and including the minor storm event without any surcharging within the system and minimising flow widths and ponding within the road carriageway. In accordance with the stormwater technical manual the minor storm event for an urban residential development is the 20 year ARI storm event.

The road network and dedicated overland flow paths are to be provided to safely convey flows which exceed the capacity of the minor storm event up to and including the 100 year ARI storm event.

This report considers stormwater quantity and quality requirements from a masterplan scale and as such does not provide details around the sizing of pits, pipes and overland flow paths. These details will be provided at the detail design stage.

2.1.1 Onsite Detention (OSD)

Onsite detention systems are designed to minimise the effect of increased runoff from developments by attenuating peak stormwater flows leaving the site.

In accordance with Ryde Council's Stormwater Technical Manual, OSD systems are to be designed to ensure that the peak discharge in the **post developed 100 year ARI** storm event does not exceed the peak discharge in the **post developed 5 year ARI** storm event.

A meeting was held with Ryde Council on 27th September 2017 to discuss the onsite detention requirements for the project. At this meeting, it was indicated by Council that the detention requirements outlined within Ryde Council's Stormwater Technical Manual would only need to apply to the areas within the development that are to remain in private ownership.

Despite this advice, in order to achieve the Green Star credit for on site detention, runoff generated by the public road network will need to be considered in the OSD calculations.

To achieve the Green Star Credit for onsite detention, the development must demonstrate that the post developed peak site discharge does not exceed the pre developed peak site discharge in the 5 year ARI design event.

2.1.2 Shrimpton's Creek

Shrimpton's Creek is a second order watercourse which flows from west to east along the southern boundary of the proposed development site.

Shrimpton's Creek and its catchment has been analysed in the "Macquarie Park Floodplain Risk Management Study and Plan". This flood study, completed in 2011 considers the entire Shrimpton's Creek catchment on a regional scale and provides indicative flood extents within the Creek.

Ryde Council has requested that an updated flood impact assessment, including the proposed development be undertaken to accurately calculate the flood extents within the vicinity of the proposed development. The flood impact assessment has been completed by BMT WBM and a copy of their report can be found in **Appendix A**.

2.2 WATER SENSITIVE URBAN DESIGN

Through the management of potable water, wastewater and stormwater, water sensitive urban design (WSUD) aims to manage the effects of urban development on the water cycle. Ryde Council's "Water Sensitive Urban Design Guidelines" outline the requirements for WSUD within the Ryde LGA. Similarly the Green Star Communities Guidelines outline the WSUD objectives required to achieve the Green Star credits. This development aims to comply with the requirements set out by Council and meet the requirements of the Green Star guidelines.

2.2.1 Stormwater Quality

In order to comply with the WSUD requirements, the stormwater drainage system must effectively remove nutrients and gross pollutants from the site prior to runoff entering the downstream drainage infrastructure. The stormwater treatment objectives have been taken from the Ryde Council "Water Sensitive Urban Design Guidelines" and the Green star Communities Guidelines documents and can be seen below in **Table 1**.

Table 1 – Stormwater Treatment Objectives

Pollutant	Treatment Objective (Council)	Treatment Objective (Green Star)
Gross Pollutants	**90%** retention of the average annual load for gross pollutants	**90%** retention of the average annual load for gross pollutants
Suspended Solids	**85%** retention of the average annual load for particles and suspended solids	**80%** retention of the average annual load for particles and suspended solids
Total Phosphorus	**65%** retention of average annual pollutant load	**60%** retention of average annual pollutant load
Total Nitrogen	**45%** retention of average annual pollutant load	**45%** retention of average annual pollutant load

A meeting was held with Ryde Council on 19th October 2017 to discuss the WSUD requirements for the project. Similar to the onsite detention requirements, it was indicated by Council that the WSUD requirements contained within the Ryde DCP would only need to apply to the areas within the development that are to remain in private ownership.

Despite this advice, in order to achieve the Green Star credit for water quality, runoff generated by the public road network will be considered in the water quality calculations. As council does not require the public areas to be treated, any runoff generated by the public road network will be subject to the Green Star objectives only.

2.2.2 Potable Water Conservation

The reduction of potable water usage can be achieved for a development through a number of methods, including the reuse of captured stormwater. This report details the requirements for stormwater reuse only, however it is noted that other methods may be used within the development.

Ryde Council requires that a water balance model be prepared to demonstrate how stormwater runoff from the site is reused. It should be noted that for a high density development, as is proposed, it is extremely difficult to capture enough water to effectively reduce the extremely high potable water demand for internal uses. Due to the inefficiencies associated with internal reuse applications, it has been decided at this stage to limit reuse to external uses such as irrigation and car washing. It should be noted that other methods may be used within the development and these will be explored on a stage by stage basis as required.

In order to achieve a Green Star credit for potable water conservation, it must be demonstrated that 100% of the buildings within the development are connected to an alternative water source. This objective is to be met by providing a rainwater tank within each building.

This report will provide a water balance model to indicate how the captured stormwater is reused within the development.

3.0 Stormwater Quantity

As discussed in Section 2.0, this report will provide a high level drainage concept that will be further refined through individual stage applications over the life of the project.

A concept stormwater drainage plan has been prepared to demonstrate how the stormwater runoff generated by the proposed development is captured and conveyed to Shrimpton's Creek.

Although Council has indicated that they do not require runoff from the road reserves to be detained or treated, in order to achieve the Green Star Credit for OSD, the site needs to be considered as a whole.

To cater for the runoff generated by the public road reserves it is proposed to provide an end of line rain garden within the development. In order to minimise the size of the rain garden it is proposed to use the rain garden for water quality purposes only. In order to achieve the detention requirements for the entire site it the runoff generated by the lots will be over detained to cater for the runoff generated by the public road network. As such the stormwater system has been split into an on lot private system and an on street public system.

The private system has been designed to capture runoff from the lots and private access roads within the site, whilst the public system has been designed to capture runoff generated by public areas and convey these flows, along with flows from the private system to the receiving waters in Shrimpton's Creek.

The private system will capture and attenuate the flows generated within the private lots before discharging to the public system. The private system consists of the following elements:

- Rainwater Tanks – Rainwater tanks will be used to capture and store runoff from roof areas for external reuse within the lots;
- OSD Tanks – OSD tanks will be used to attenuate peak flows before discharging into the public drainage system;
- Surface Drainage – Surface drainage pits will be provided to capture and convey runoff from both hardstand and pervious areas to the OSD tanks.

At this high level stage, the exact configuration of the private system is unknown. As each stage is developed, the exact location of the drainage infrastructure within each lot can be provided.

The public system consists of the following elements:

- Pit and Pipe Drainage System – The public drainage system has been designed to capture runoff generated from the public road reserve areas and convey it, along with the attenuated lot runoff, to the receiving waters in Shrimpton's Creek;
- Overland Flow Paths – Major overland flow paths and the road reserves have been designed to safely convey runoff from major storm events to Shrimpton's Creek.

Whilst the public system will ultimately drain to the end of line rain gardens a high flow bypass system will ensure that only low flows enter the rain gardens. This is discussed further in section 4.

A plan showing the concept stormwater drainage system can be seen in **Exhibit 1.**

3.1 ONSITE DETENTION

In accordance with Ryde Council's Stormwater Technical Manual, OSD systems are to be designed to ensure that the peak discharge in the **post developed 100 year ARI** storm event does not exceed the peak discharge in the **post developed 5 year ARI** storm event.

In order to achieve a Green Star Credit for onsite detention, the development must demonstrate that the post developed peak site discharge does not exceed the pre developed peak site discharge in the **5 year ARI** storm event.

It is proposed to use a series of rainwater tanks and dedicated OSD tanks located within the lots and under private roads to adequately attenuate the peak discharges generated by each lot. Runoff generated from the site is conveyed to the proposed tanks via the following systems:

- Roof Areas – Runoff generated from the building roofs is directed via the building hydraulics to rainwater tanks located within the basement of each building. Overflow from these rainwater tanks is then directed to an OSD tank. It is understood that typically 50% of the roof areas will be taken up by rooftop gardens.

  A water balance model was performed on the rainwater tanks to determine the average volume available within the tanks at any given time. This number was adopted within the OSD model as available storage for detention. The water balance model is discussed further in section 4.2.

- Remaining Lot Areas – Runoff generated from the remaining lot areas is captured in a series of surface drainage pits and conveyed to the detention tanks. It has been assumed that 75% of the remaining lot area is captured and directed to the OSD tanks, with the remaining 25% discharging directly to the public road network.

  Similar to the roof areas, once more detailed information around the lot areas is available, the actual area draining the OSD tank can be calculated in more detail.

An XP-RAFTS model was created using the parameters outlined in the following sections in order to accurately model the proposed system.

3.1.1 Catchment Parameters

The proposed masterplan and site topography were reviewed to determine the best locations to provide detention tanks. Overall catchments were then calculated for each individual detention tank. In order to accurately determine the amount of runoff entering each tank, the overall catchments were broken down into the sub catchments mentioned above.

To account for the runoff generated by the public road network, a catchment encompassing the remaining area within the site was calculated.

The catchment areas can be seen in **Exhibit 2** and **Table 2** below.

Table 2. Catchment Areas

	CATCHMENT AREA (ha)			
Catchment	**Roof**	**Remaining Lot (Captured)**	**Remaining Lot (Not Captured)**	**Road**
A1	0.125	0.122	0.041	-
A2	0.089	0.07	0.023	-
A3	0.131	0.193	0.064	0.048
B1	0.234	0.167	0.056	0.080
B2	0.093	0.172	0.057	-
B3	0.126	0.123	0.041	-
C1	0.355	0.178	0.059	-
C2/C3	0.310	0.346	0.115	-
C4	0.291	0.272	0.091	-
D1	0.261	0.295	0.098	0.046
D2/D3	0.273	0.383	0.128	-
D4	0.263	0.320	0.107	0.053
Public Roads	-	-	-	1.58
Total	2.551	2.641	0.880	1.807

In order to produce runoff hydrographs for each catchment, a number of hydrological parameters are required to be input into the XP-RAFTS model. These parameters include:

- **Percentage of Impervious Area** – The overall masterplan was used to estimate the percentage of impervious area for each catchment:
  - Roof areas were assumed to 50% impervious to account for the proposed rooftop gardens;
  - Private driveways were assumed to be 80% impervious;
  - The remaining lot areas were calculated on an individual basis;
  - Public roads were assumed to be 80% impervious

- **Manning's 'n'** – the Manning's 'n' coefficient is a measure of the surface roughness of a catchment:
  - The rooftop gardens were modelled with a Manning's 'n' of 0.05 to account for the effect of dense planting and garden beds whilst the remaining half of the roofs were modelled with a Manning's 'n' of 0.01;
  - Remaining impervious areas around the site were modelled with a Manning's 'n' of 0.015;
  - Remaining pervious areas around the site were modelled with a Manning's 'n' of 0.04.

- **Catchment Slope** – An average catchment slope of 3% was adopted for all catchments within the site with the exception of the roofs and public roads. Rooftop gardens were assumed to be relatively flat and modelled with a slope of 1% whilst the remaining half of the roof was modelled with a slope of 5%. The public roads were modelled with an average slope of 5% in order to reflect the steeper nature of the public roads.

A summary of the impervious percentages adopted within the model for each catchment can be seen in **Table 3** below. The remaining parameters were modelled as described above.

Table 3. Percentage Impervious

	Percentage Impervious		
Catchment	**Roof**	**Lot**	**Road**
A1	50%	50%	-
A2	50%	50%	-
A3	50%	25%	80%
B1	50%	25%	80%
B2	50%	60%	-
B3	50%	25%	-
C1	50%	25%	-
C2/C3	50%	50%	-
C4	50%	25%	-
D1	50%	25%	80%
D2/D3	50%	50%	-
D4	50%	25%	80%
Public Road	-	-	80%

3.1.2 Detention Modelling

Detention modelling was undertaken using an XP-RAFTS model in order to determine the required size of the proposed detention tanks. Modelling was undertaken on a catchment by catchment basis to ensure the detention tanks were accurately sized.

As discussed in Section 3.1 above, rainwater tanks were used in the model to supplement the storage volume provided by the proposed detention tanks. The rainwater tanks have been modelled to have an orifice 300mm from the top of the tank and as such only provide a small amount of detention storage. The storage below the orifice does however buffer the peak discharge generated by the roof catchments to assist in reducing the overall lot peak discharge.

The rainwater tank sizes used in the XP-RAFTS model were determined using a water balance model. This is discussed further in Section 4.2.

Ryde Council's Stormwater Management Technical Manual indicates that XP-RAFTS models are suitable for use in sizing detention structures, however it is required that the flow rates calculated are checked against another method. In accordance with this, a DRAINS model was set up to provide a check of the XP-RAFTS flow rates. A comparison of the 5 year and 100 year post developed flows for a typical roof and lot catchment can be seen in **Table 4** below.

Table 4. DRAINS vs RAFTS

	RAFTS (5 Year ARI) (m^3/s)	DRAINS (5 Year ARI) (m^3/s)	Difference (%)	RAFTS (100 Year ARI) (m^3/s)	DRAINS (100 Year ARI) (m^3/s)	Difference (%)
Roof	0.098	0.11	10%	0.169	0.188	10%
Lot	0.067	0.063	-6%	0.119	0.113	-5%
Combined	0.165	0.173	5%	0.288	0.301	4%

It can be seen from **Table 4** above that the flows calculated by DRAINS compare well with those calculated by the RAFTS model. The DRAINS model was found to produce slightly higher roof flows and slightly lower lot flows than the RAFTS model.

Based on this comparison, it was concluded that the RAFTS model was suitable to use for the detention modelling. The results of the detention modelling can be seen below in **Table 5.**

Table 5. Post Developed RAFTS Results

Catchment	5 Year ARI Flow (m3/s)	100 Year ARI Flow - Without Detention (m3/s)	100 Year ARI Flow - With Detention (m3/s)	Rain Water Tank Size (kL)*#	Detention Tank Size (m^3)
A1	0.085	0.146	0.085	38	55
A2	0.058	0.10	0.052	38	40
A3	0.126	0.221	0.126	38	95
B1	0.163	0.28	0.159	38 (x2)	125
B2/B3	0.16	0.272	0.155	38 (x2)	100
C1	0.165	0.288	0.163	38 (x2) + 20 (x1)	145
C2/C3	0.225	0.394	0.225	38 (x2)	145
C4	0.173	0.314	0.169	38 (x2)	155
D1	0.191	0.346	0.191	38 (x2)	125
D2/D3	0.215	0.395	0.214	38 (x2)	150
D4	0.201	0.366	0.20	38 (x2)	135
Total	1.761	3.122	1.74	742	1270

* *Multiple tanks are due to multiple buildings within each catchment*
# *Only a percentage of the actual tank volume was used in the modelling*

It can be seen from **Table 5** above that, through the use of rainwater tanks and dedicated detention tanks, the post developed 1 in 100 year ARI peak discharges can be adequately attenuated back to the post developed 1 in 5 year ARI peak discharges for the areas of the site that are to remain in private ownership.

In order to achieve the Green Star Credit for OSD, the 5 year ARI post developed peak discharge is required to be less than or equal to the 5 year ARI pre developed peak discharge for the entire development. The public road network catchment was added to the model to ensure the entire development was considered.

Due to the urbanised nature of the existing site, the pre developed site was calculated as being 60% impervious and was modelled as such in RAFTS. The results of this modelling can be seen in **Table 6** below.

Table 6. Pre to Post RAFTS Results

Catchment	5 Year ARI Pre Developed Flow (m3/s)	5 Year ARI Post Developed Flow - Without Detention (m3/s)	5 Year ARI Post Developed Flow - With Detention (m3/s)
Pre Developed Site	2.46	-	-
Post Developed Lots	-	1.76	0.693
Post Developed Roads	-	0.61	0.61
Total	2.46	2.37	1.30

It can be seen from **Table 6** above that the pre developed flow for the site in its existing state is actually less than the post developed flow without detention. This is due to the nature of the existing site being an existing residential development and therefore of a similar impervious percentage to the post developed site. The development therefore satisfies the criteria to achieve the Green Star credit for on-site detention.

Detailed sizing of both the rainwater tanks and dedicated detention tanks will be undertaken on a stage by stage basis once further information around the development is provided.

A summary of the rainwater and detention tanks for each catchment can be seen in **Exhibit 3.** A screenshot of the XP RAFTS model can be seen in Appendix B.

4.0 Water Sensitive Urban Design

Through the management of potable water, wastewater and stormwater water sensitive urban design (WSUD) aims to manage the effects of urban development on the water cycle. Ryde Council's "Water Sensitive Urban Design Guidelines" outline the requirements for WSUD within the LGA. Similarly the Green Star Communities Guidelines outline the WSUD objectives required to achieve the relevant credits.

4.1 STORMWATER QUALITY

The stormwater drainage system, as discussed in Section 3 above, will incorporate a number of water quality treatment devices to effectively treat runoff generated by the development prior to it being discharged to Shrimpton's Creek.

As discussed in Section 2.2.1, council only requires areas within the development that are to remain in private ownership to be treated, however in order to achieve the Green Star Credit for WSUD the public road network is also required to be treated.

4.1.1 Treatment Devices

It is proposed to use a combination of at source, conveyance and end of line controls to treat the runoff prior to it discharging to Shrimpton's Creek. The proposed treatment train has been modelled in the water quality software "Model for Urban Stormwater Improvement Conceptualisation" (MUSIC) to demonstrate compliance with the treatment targets.

The following devices are proposed within the development to achieve the required targets:

<u>Rainwater Tanks</u>

Rainwater tanks are proposed within each building to capture and store runoff generated from the roof area for reuse. Each rainwater tank will be fitted with a first flush system to provide pretreatment prior to runoff entering the tanks. Rainwater tank sizes for each building can be seen in section 4.2.

<u>Gross Pollutant Traps</u>

It is proposed to provide Stormwater 360 "Enviropods" or council approved equivalent litter traps in all grated surface inlet pits within the private stormwater system to capture gross pollutants and coarse sediments. Further details of the Stormwater 360 "Enviropod" can be seen in **Appendix C.**

<u>Media Filtration</u>

It is proposed to provide two (2) types of media filtration devices throughout the development:

- Stormwater 360 'Stormfilter" or council approved equivalent system – The "Stormfilter" is a proprietary media filtration device consisting of multiple cartridges that will be housed within the proposed OSD tanks. Further details of the "Stormfilter" cartridges can be seen in **Appendix C.**

- Bio filtration Rain Gardens – It is proposed to provide a series of bio retention rain gardens at the end of line to treat runoff prior to it entering Shrimpton's Creek.

A graphical representation of the treatment train can be seen in **Figure 4** below.

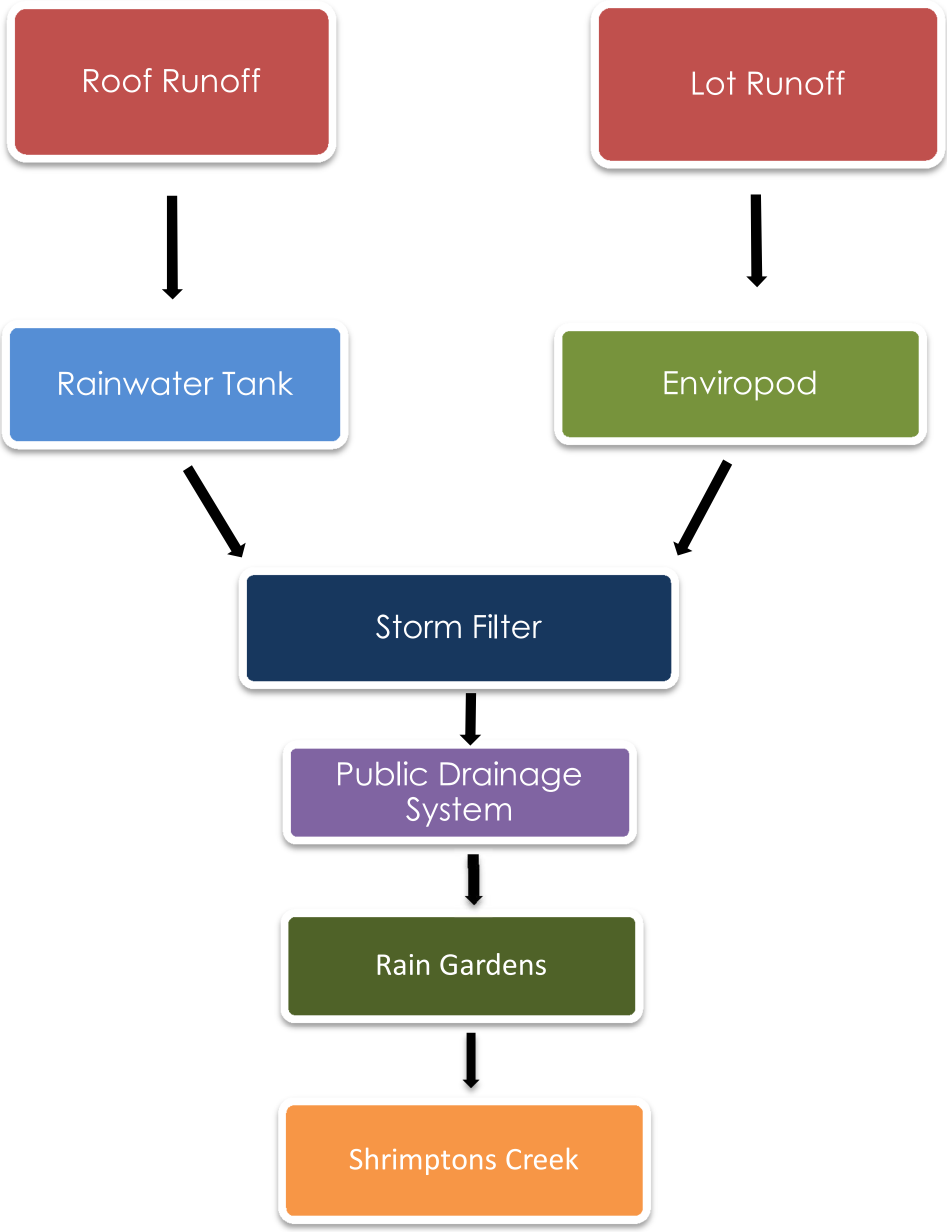

Figure 4: Proposed Treatment Train

4.1.2 MUSIC Parameters

The MUSIC model was set up in accordance with the "Using MUSIC in Sydney's Drinking Water Catchment" guidelines and Ryde Council's "Water Sensitive Urban Design Guidelines".

Catchment areas for the MUSIC modelling were adopted to correspond with those used within the detention model. Similar to the detention model, the overall catchments were broken down into smaller sub catchments in order to accurately determine the pollutant loads.

Similar to the detention model, it has been assumed that 75% of each lot catchment will reach the media filtration devices whilst the remaining 25% is captured by pits containing "Enviropods" before being directly discharged to the public stormwater network.

A summary of the catchment areas and parameters can be seen in **Tables 2** and **3** in Section 3.1.1 above.

4.1.3 Water Quality Modelling

The MUSIC model was created using the parameters outlined above to determine compliance with council's water quality targets. Similar to the detention modelling, the water quality modelling was done on a lot by lot basis to ensure the required reduction targets were met prior to the runoff entering the public system.

To achieve the Green Star credit for WSUD, an end of line bio retention rain garden was added to the proposed treatment train. The rain garden has been designed to cater for the public road system along with the 'A', 'C' and 'D' lots. Due to the topography of the site it has been assumed that the 'B' lots will be unable to drain to the rain garden.

The results of the water quality modelling can be seen in **Table 7** below.

Table 7. MUSIC Modelling Results

	Pollutant Load Reduction			
Catchment	**Gross Pollutants**	**Total Suspended Solids**	**Total Phosphorus**	**Total Nitrogen**
A1	100.0%	93.0%	79.2%	65.7%
A2	100.0%	93.7%	81.9%	68.6%
A3	100.0%	93.8%	79.6%	63.6%
B1	100.0%	84.8%	74.5%	62.5%
B2/B3	100.0%	90.5%	73.5%	60.2%
C1	100.0%	88.6%	76.4%	63.4%
C2/C3	100.0%	89.4%	72.5%	61.1%
C4	100.0%	88.7%	73.5%	60.1%
D1	100.0%	85.4%	72.5%	58.0%
D2/D3	100.0%	89.3%	72.7%	61.7%
D4	100.0%	90.6%	73.4%	59.0%
Outlet – Including Public Road	100.0%	80.7%	64.9%	56.6%

From **Table 7** above, it can be seen that the proposed treatment train of rainwater tanks, gross pollutant traps, media filtration devices and rain gardens not only meets, but exceeds the targets set by Council.

The modelling also demonstrates that the council water quality targets are met on a lot by lot basis with the Green Star targets being met for the overall development. It was found through the modelling that the rain garden requires a minimum filter surface area of 150 m^2 in order to meet the required targets.

The exact configuration and sizing of all water quality devices will be provided on a stage by stage basis as the development progresses.

A screenshot of the MUSIC model can be seen in **Appendix D.**

4.2 POTABLE WATER CONSERVATION

The reduction of potable water usage can be achieved for a development through a number of methods, including the reuse of captured stormwater. This report considers stormwater reuse only, however it is noted that other methods may be used throughout the development.

A water balance model was prepared for the development to determine the reduction in potable water consumption achieved through the reuse of stormwater captured within the rainwater tanks.

4.2.1 Water Balance Model Parameters

To accurately determine the potable water reduction for the development, a daily water balance model was set up for each individual building. In order to create the water balance model, the following parameters were required for each building:

- Catchment Area – As with the detention and water quality models, it was assumed that 50% of the roof catchment is impervious with the remaining 50% being a rooftop garden. Due to the expected low runoff from the rooftop garden (in the order of 4-5 l/s in the 1 year ARI event) it has been assumed for the water balance model that only 50% of the roof catchment reaches the tank.

- Water Demand – To determine the amount of water used each day within the lots a water demand is required. The water demand for each building was determined by calculating the proposed irrigation areas (rooftop gardens and ground plane gardens) and applying an application rate. A maximum application rate of $2mm/m^2/day$ was adopted for summer whilst a rate of $0.5mm/m^2/day$ was adopted for winter. The model only accounts for significant rainfall and only applies irrigation on days where there has been less than 5mm of rain.

  Due to the large unknowns around the number of cars that will be washed on site, water demand for car washing has not been included in this water balance model.

- Daily Rainfall – To ensure consistency between models, the same rainfall data adopted within the MUSIC model was adopted for the water balance model.

A summary of the reuse demand adopted for each building can be seen below in **Table 8**.

Table 8. Water Reuse Demand

Lot	Indicative Total Reuse Demand (L/day) – Summer*	Indicative Total Reuse Demand (L/day) – Winter*
A1	3,000	750
A2	1,640	410
A3	4,185	1,045
B1.1	2,455	614
B1.2-B1.4	3,935	985
B2	1,230	310
B3	3,010	750
C1.1	2,105	525
C1.2	2,590	650
C1.3	180	45
C2	7,345	1,835
C3	2,705	675
C4	5,890	1,475
D1	5,625	1,405
D2	4,225	1,055
D3	4,360	1,090
D4	6,905	1,725

** The total indicative reuse demand is based on reuse for external irrigation only. This includes ground plane gardens and rooftop gardens.*
#A higher application rate was adopted for C2 and C3 to account for the village park oval.

It should be noted that the reuse demands shown above in **Table 8** are based on indicative irrigation areas and are likely to change based on final development layout.

The water balance modelling was undertaken using the parameters discussed above to determine the reduction in potable water for each building within the development.

Rainwater tank sizes for each block were adopted based on the commentary in Section 4.2.2. The results of the water balance model can be seen in **Table 9** below.

Table 9. Water Balance Model Results

Block	Tank Size (kL)	Reduction in Potable Water *	Average Volume Available in tank (kL)
A1	38	54.6%	23.3
A2	38	69.03%	18.7
A3	38	41.80%	26.5
B1.1	38	53.80%	23.3
B1.2-B1.4	38	45.70%	25.4
B2	38	80.04%	14.5
B3	38	53.00%	23.3
C1.1	38	67.60%	18.2
C1.2	38	67.40%	17.8
C1.3	20	99.96%	2.5
C2	38	30.15%	29.2
C3	38	58.70%	21.1
C4	38 (x2)	56.70%	43.5
D1	38 (x2)	56.30%	44.3
D2	38	41.10%	26.8
D3	38	42.60%	26.3
D4	38 (x2)	48.80%	49.2

***** *Reduction in potable water used for irrigation purposes only.*

From **Table 9** above, it can be seen that the reduction in potable water for all of the buildings varies significantly depending on the actual demand. It should be noted that this reduction in potable water demand is for irrigation only and does not consider internal building uses.

Table 9 also indicates that the average volume (empty space) available within the tanks. These volumes have been adopted within the OSD model as described in section 3.1.2

4.2.2 Rainwater Tank Sizing

An analysis of the effect of the rainwater tank size on the reduction in potable water demand was undertaken to determine the most appropriate rainwater tank size for each building. The analysis investigated multiple tank sizes and their effect on the potable water demand. A graph of this analysis for the typical building sizes can be seen in **Figure 5** below.

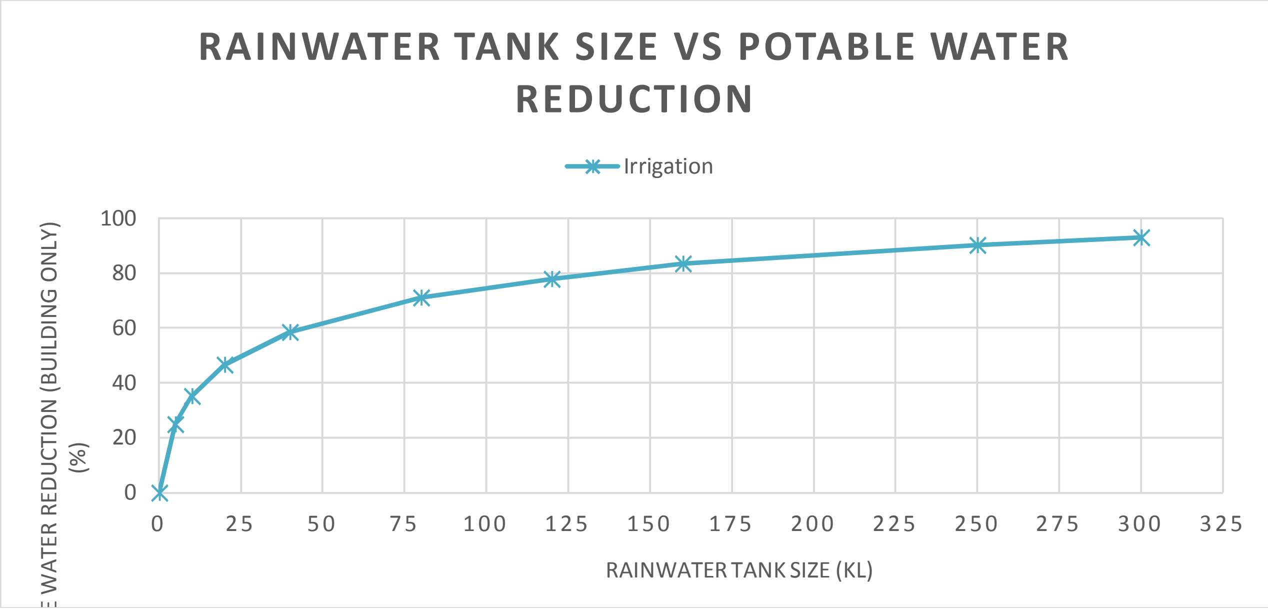

Figure 5: Rainwater Tank Size vs Potable Water Reduction

From **Figure 5** above, it can be seen that increasing the tank size increases the potable water reduction. This increase does however start to flatten out and increasing the tank size provides only a small jump in potable water reduction.

As there is a plateau in the graph, there is an obvious point at which increasing the tank size offers little in the way of an increase in potable water reduction. Due to this a tank size of 38kL was adopted for all buildings. It is noted that once more details are known around the proposed buildings, the most efficient system can be developed at the individual development application stage.

5.0 Erosion and Sedimentation Control

Erosion and sediment control is an important environmental control measure to ensure downstream receiving water are not adversely affected during construction. A high level concept erosion and sediment control plan has been developed for the overall masterplan and can be seen in **Exhibit 4**.

Detailed erosion and sediment control plans will be submitted with stage specific development applications to ensure all aspects are covered. Erosion and sediment control plans should be constantly updated during construction to ensure that adequate protection is provided at all times.

6.0 Staging and Temporary Works

As the development will be constructed in multiple stages, careful consideration needs to be given to the timing of each stage and how each stage can individually meet the requirements outlined within this report. A proposed staging plan can be seen in **Exhibit 5**.

As mentioned previously, this report provides a broad high level concept for the entire development with further details for each stage provided in their respective development applications. Based on the concept drainage plan provided within this report, a stage by stage strategy to ensure compliance with Council's requirements has been prepared.

The proposed staging strategy involves a combination of early construction of water quantity and quality devices along with the construction of temporary measures. The proposed strategy is illustrated in a series of figures within **Appendix E**.

7.0 Adjoining Development Drainage

As mentioned in Section 1.2.2, the existing development to the North West of the site (Lot 1 D.P 609711) currently drains under easement through the proposed development site to the public drainage system in Ivanhoe Place. The location of the existing stormwater line can be seen in **Figure 7** below.

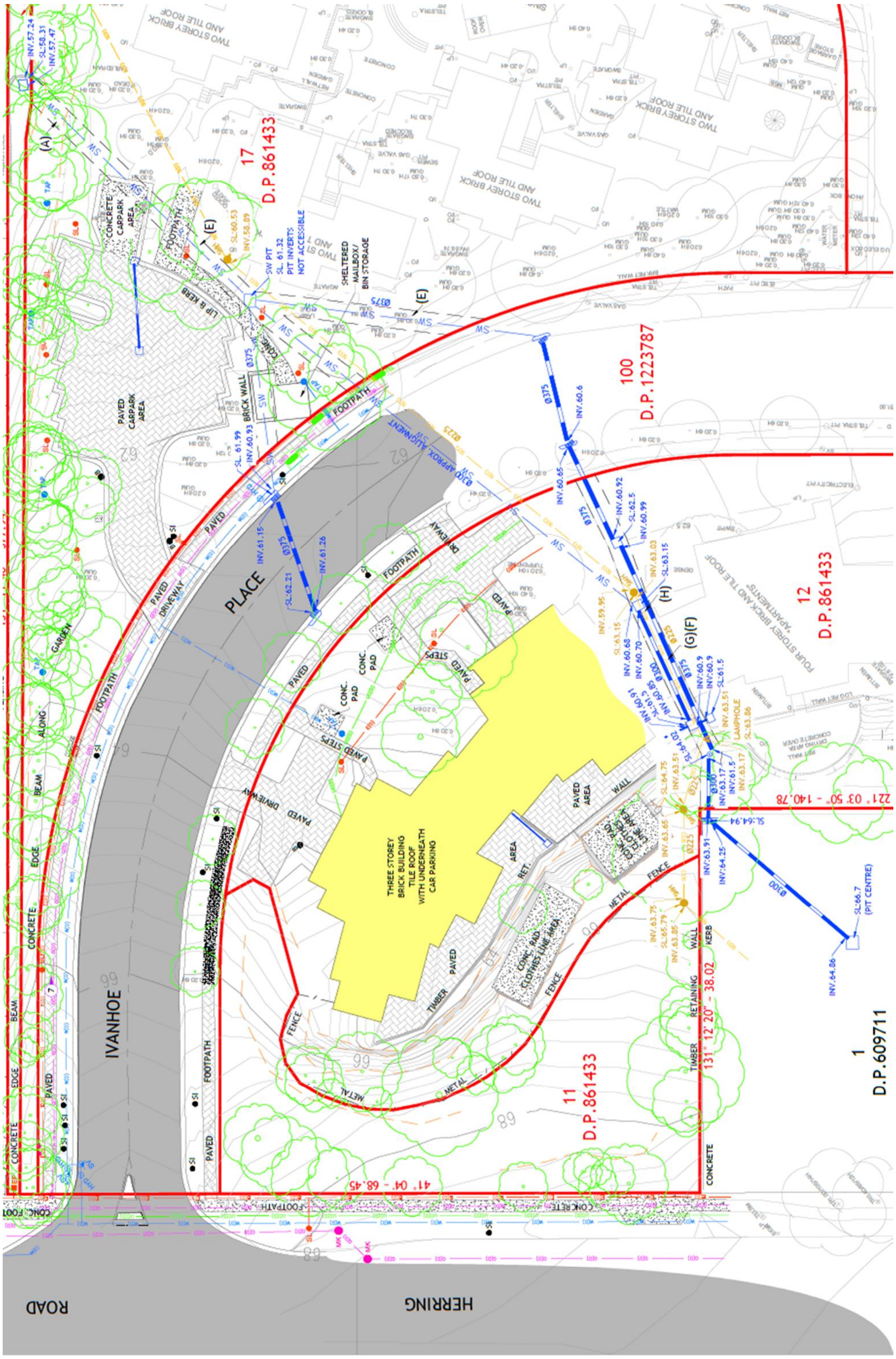

Figure 7: Adjoining Development Drainage

It can be seen from **Figure 7** that the adjoining site is currently drained via a 375mm dia stormwater pipe under the existing buildings and into the public drainage system within the existing Ivanhoe Place.

Whilst the existing pipe may be required to be relocated to suit the proposed development, the design of any new structures within this area will take into account the need to maintain a drainage connection.

It is likely that the new connection will be required to drain through a basement in the new development and into the new public drainage system. Further details on this connection will be provided with the Stage 1 development application.

8.0 Groundwater Assessment

A groundwater assessment of the subject site has been undertaken by Douglas Partners. A copy of their report can be found in **Appendix F**.

9.0 Water Licensing Requirements and Other Approvals

Potable water for use within the site will be provided via the Sydney Water Corporation's existing carrier water mains, with this being supplemented by captured stormwater for reuse within buildings. No other permanent water sources are proposed to be utilised by the development and accordingly an ongoing water license for the site is not required.

Water licensing requirements for dewatering during construction, if required, will be dealt with on a stage by stage basis in conjunction with future design work.

As some works encroach within 40m of Shrimpton's Creek, approvals from the office of water will be required and will be obtained on a stage by stage basis, where applicable, prior to commencement of any works on-site.

10.0 Conclusion

This report supports a concept development application for the Ivanhoe Estate Masterplan, a State Significant Development (SSD) submitted to the Department of Planning and Environment (DPE) pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act). It has been prepared for Aspire Consortium on behalf of NSW Land and Housing Corporation.

This report considered the stormwater drainage aspects of the proposed development, with specific focus on onsite detention and Water Sensitive Urban Design. Flood modelling within the adjacent Shrimpton's Creek was considered in a separate report.

The requirements for the development to satisfy are set out within both the Ryde Council Development Control Plan 2014 and the Secretary's Environmental Assessment Requirements (SEARs). This report demonstrated that the proposed development complies with all of the relevant requirements.

The development is aiming to achieve a 6 star Green Star communities rating and as such is required to meet a number of stormwater objectives that are separate to the requirements of the SEAR's and Ryde Council's DCP 2014. This report demonstrated that the appropriate Green Star Credits could be achieved.

It was indicated at early meetings with Ryde Council that OSD and WSUD requirements would only need to apply to areas within the site that are to remain in private ownership. Despite this, in order to meet the requirements of the Green Star communities, an end of line rain garden was proposed in order to treat runoff generated by the public road network.

In order to minimise the size of the end of line rain garden, OSD and WSUD control measures were provided on lot prior to flows entering the public drainage system. A concept drainage plan was developed on this basis and consisted of an on lot private system and a public drainage system located within the proposed public road reserves.

Through the use of rainwater tanks and dedicated detention tanks, it was shown that the private stormwater system could adequately attenuate peak flows generated by the proposed development and comply with the OSD requirements set out by Ryde Council. Similarly, through the use of rainwater tanks, gross pollutant traps and filtration devices, it was shown that the proposed development complies with the WSUD requirements set by Council and Green Star Communities.

In accordance with Council's requirements, a water balance model was developed to demonstrate how captured stormwater was reused within the site to reduce the demand on potable water. It was found that within a development of such high density, and therefore high reuse demand, it was difficult to capture enough rainwater to provide a significant reduction in potable water for internal uses and therefore this report only consider reuse for irrigation purposes. It was found that the most efficient rainwater tank size was a 38kL tank.

An erosion and sedimentation control plan was developed to ensure that during construction runoff generated on the site was adequately treated prior to it entering the downstream receiving waters. This plan will need to be regularly updated to adjust to changes in the proposed development over the life of the project.

A staging strategy was prepared to ensure that water quantity and water quality requirements were met, not only once the entire site has been developed but throughout the entire life of the development. A combination of early construction and temporary works was proposed to ensure requirements are met over the life of the project. This will need to be reviewed at each stage to ensure the most efficient solution is adopted.

The adjoining development to the North West of the subject site currently drains, under easement, through the site to the existing public drainage system.

It was found that the proposed development would impact on this connection, however any designs will consider this connection to ensure it remains.

It should be noted that this report is for a masterplan development application and therefore there are some uncertainties around the final design of both the public domain and built form within the site. As such, the OSD and WSUD measures discussed in this report should be considered as a general guideline and not a final design. Development applications for individual stages will provide further details around the most appropriate solution for each stage.

Appendix A

BMT WBM FLOODING REPORT

A part of BMT in Energy and Environment

BMT WBM

Flood Impact Assessment for Ivanhoe Estate Master Plan

Reference: L.S20319.03.Flood Impact Assessment for Ivanhoe Estate Masterplan.docx

Date: December 2017

FINAL

Flood Impact Assessment for Ivanhoe Estate Master Plan

Prepared for:	Frasers Property Australia
Prepared by:	BMT WBM Pty Ltd (Member of the BMT group of companies)

Offices

Brisbane
Denver
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Mackay
Melbourne
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Document Control Sheet

BMT WBM Pty Ltd Suite G2, 13-15 Smail St Ultimo NSW 2007 Australia PO Box 1181, Broadway NSW 2007 Tel: +61 2 8987 2900 Fax: +61 2 8987 2999 ABN 54 010 830 421 www.bmtwbm.com.au	**Document:**	L.S20319.03.Flood Impact Assessment for Ivanhoe Estate Masterplan.docx
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	Project Manager:	Sebastian Froude
	Author:	Sam Drysdale, Sebastian Froude
	Client:	Frasers Property Australia
	Client Contact:	Joe Zannino, Cameron Jackson
	Client Reference:	
Synopsis:	**Flood Impact Statement for Ivanhoe Estate Master Plan prepared to satisfy the Environmental Impact Statement (EIS) conditions of the Secretary's environmental assessment requirements (SEARs)**	

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
00	01/11/2017	09/11/2017	SF	09/11/2017	SF
01	16/11/2017	23/11/2017	SD	23/11/2017	SD
02	27/11/2017	27/11/2017	SF	27/11/2017	SF
03	12/12/2017	12/12/2017	SF	12/12/2017	SF

DISTRIBUTION

Destination	Revision										
	0	1	2	3	4	5	6	7	8	9	10
Frasers Property Australia	1	1	1	1							
BMT WBM File	1	1	1	1							
BMT WBM Library	-	-	-	-							

Executive Summary

Introduction

BMT WBM was commissioned by Frasers Property Ivanhoe Pty Ltd to undertake a flood impact assessment for the proposed Ivanhoe Estate Master Plan, Macquarie Park to satisfy the Environmental Impact Statement (EIS) conditions of the Secretary's environmental assessment requirements (SEARs).

The aim of the flood impact assessment has been to assess the impacts of the proposed Master Plan on flooding, primarily within Shrimptons Creek. Ancillary impacts giving consideration to localised overland flooding have also been considered.

The flood impact assessment is reflective of the Ivanhoe Estate Master Plan received on the 25th of November 2017, and utilises the AR&R 2001 method for estimating rainfall intensities. It is understood that future design iterations will provide further detail and analysis of the potential impacts of climate change, specifically:

- potential increase in rainfall intensity.

Furthermore, it is understood that additional analysis will be undertaken at a later stage on:

- mitigation measures for buildings near existing flood risk areas; and
- water-sensitive urban design opportunities for more flood-resilient public domain.

Catchment Description

The Ivanhoe Estate is located north-west of Sydney within the City of Ryde's Local Government Area (LGA). The estate is currently owned by the Land and Housing Corporation (LAHC) and comprises 259 social housing dwellings totalling 8.3 ha in size. The area surrounding the study site is typified by low to medium density residential development to the south and commercial developments to the north interspersed with parks and recreational areas.

The Ivanhoe Estate is located within the Shrimptons Creek catchment which has a contributing upstream area of approximately 600 ha. The Shrimptons creek catchment includes the suburbs of Ryde, North Ryde, Marsfield and Macquarie Park.

Data Collection and Review

The Shrimptons Creek catchment has previously been modelled during investigations into catchment flooding. Flood studies, floodplain risk management studies and historic flood event analysis have all been undertaken for the Shrimptons Creek catchment.

The Shrimptons Creek TUFLOW model developed by Bewsher in 2010 was created as a part of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). The Macquarie Park catchment was broken up into several smaller catchments, constituting the tributary creeks of Lane Cover River, one of which is Shrimptons Creek.

The Shrimptons Creek TUFLOW model was provided by the City of Ryde Council to be used for the sole purpose of satisfying the Secretary's Environmental Assessment Requirements (SEARs).

Flood Model Development

The existing Shrimptons Creek TUFLOW model utilised runoff-routing software DRAINS to generate sub-catchment flow hydrographs. With the exception of Ivanhoe Estate, the existing DRAINS model hydrographs were maintained within the revised TUFLOW model. Within Ivanhoe estate, the DRAINS sub-catchment hydrographs were replaced with 'rainfall on grid', which applies design rainfall directly onto the individual cells of the TUFLOW model.

Additional updates were made to the TUFLOW model as follows:

(1) The underlying Digital Elevation Model (DEM) was updated to include recent ground elevation data including; 2013 LPI LiDAR and ground elevation survey provided by ADW Johnson Pty Ltd (drawing ref: 300001-DET-001-A).

(2) The existing drainage network was updated to include the details of survey undertaken by ADW Johnson Pty Ltd including; pipe diameter, invert levels and additional drainage network.

Design Event Modelling and Output

The developed hydrological and hydraulic models have been applied to derive design flood conditions within the Ivanhoe Estate study area. Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves based on IFD data and utilising the procedures outlined in AR&R (2001). For simplicity, this study has adopted the temporal patterns and initial and continuing loss guidance in accordance with ARR (2001) to ensure consistency with the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010).

The design events considered in this study include the 20 year ARI, 100 year ARI and Probable Maximum Flood (PMF) events. The model results for the design events considered have been presented in Appendix B. Maps have been produced showing flood depth, flood velocity, flood velocity-depth product, provisional flood hazard, provisional hydraulic category and flood risk mapping.

Flood Impact Assessment

In order to assess the proposed Ivanhoe Estate Master Plan, modelling was undertaken to represent the development within the TUFLOW hydraulic model (proposed scenario model). The proposed scenario TUFLOW model was updated to incorporate revisions to land use, model topography, drainage network and building layout at the site to represent the proposed Master Plan. Appendix C presents the results of the proposed Ivanhoe Estate Master Plan and Appendix D presents the change in design flood conditions due to the proposed development.

The results of the flood modelling indicated that the proposed Ivanhoe estate Master Plan caused minimal impacts when considering the 20 year ARI and 100 year ARI Shrimptons Creek flood events. No notable changes in water level or velocity were observed in the 20 year ARI event. In the 100 year ARI event, minor increases at the location of building 'Lot B3' were present due to the buildings encroachment into the 100 year ARI flood extent.

The magnitude of impacts for the PMF event are larger. Increases in peak water levels are present upstream of the site with significant decreases in water levels downstream from the site. However, the PMF event is typically used for emergency planning purposes only, rather than the assessment of absolute changes to modelled flood levels and velocities.

Conclusion

The flood impact assessment for the proposed Ivanhoe Estate Master Plan found negligible differences in design flood conditions and hence impacts on; emergency planning and evacuation, social and economic cost to the community and erosion, siltation, riparian vegetation and bank stability have not been altered due to the proposed Ivanhoe Estate development.

Contents

List of Figures

List of Tables

1 Background

1.1 Introduction

BMT WBM was commissioned by Frasers Property Ivanhoe Pty Ltd to undertake a flood impact assessment for the proposed Ivanhoe Estate Master Plan, Macquarie Park to satisfy the Environmental Impact Statement (EIS) conditions of the Secretary's environmental assessment requirements (SEARs). The proposed Master Plan includes:

- residential flat buildings comprising private, social and affordable housing;
- seniors house comprising residential care facilities and self-contained dwellings;
- a new high school;
- child care centres;
- public open space and roads;
- minor retail development; and
- community uses.

The aim of this flood impact assessment has been to assess the impacts of the proposed Master Plan on flooding, primarily within Shrimptons Creek. Ancillary impacts giving consideration to localised overland flooding have also been considered.

The flood impact assessment has been undertaken using a modified version of the TUFLOW hydraulic model developed for Shrimptons Creek as a part of the City of Ryde's Macquarie Park Floodplain Risk Management Study and Plan (Bewsher, 2010). The model was provided by the City of Ryde Council to be used for the sole purpose of satisfying the Secretary's Environmental Assessment Requirements (SEARs).

In order to assess the impacts of the proposed Master Plan, the following TUFLOW hydraulic models have been developed:

- Current scenario model (refer Section 2) – the Shrimptons Creek TUFLOW model modified to include the latest aerial survey, drainage conduit survey and detailed survey of Shrimptons Creek.
- Proposed development scenario model (refer to Section 5) - builds on the current scenario model, incorporating revisions to the land uses, drainage network and building layout at the site to represent the proposed Master Plan.

The hydraulic models for the current and proposed scenarios were simulated using the 20 year Average Recurrence Interval (ARI), 100 year ARI and Probable Maximum Flood (PMF) design flood events for the critical storm duration, for both blocked and unblocked scenarios, as described in Section 3.3.

The flood impact assessment is reflective of the Ivanhoe Estate Master Plan received on the 25th of November 2017, and utilises the AR&R 2001 method for estimating rainfall intensities. It is understood that future design iterations will provide further detail and analysis of the potential impacts of climate change, specifically:

- Potential increase in rainfall intensity;

Furthermore, it is understood that additional analysis will be undertaken on:

- Mitigation measures for buildings near existing flood risk areas;
- Water-sensitive urban design opportunities for more flood-resilient public domain.

1.2 Study Area and Catchment Topography

The locality of Ivanhoe Estate is shown in Figure 1-1. The site is located north-west of Sydney within the City of Ryde's Local Government Area (LGA). The Ivanhoe Estate is currently owned by the Land and Housing Corporation (LAHC) and comprises 259 social housing dwellings totalling 8.3 ha in size. The area surrounding the study site is typified by low to medium density residential development to the south and commercial developments to the north interspersed with parks and recreational areas.

The Ivanhoe Estate is located within the Shrimptons Creek catchment which has a contributing upstream area of approximately 600 ha. The Shrimptons creek catchment includes the suburbs of Ryde, North Ryde, Marsfield and Macquarie Park.

1.3 Local Council Development Controls

A summary of potential site constraints, in relation to the proposed Master Plan and in accordance with the City of Ryde's Development Control Plan 2014 is given below. This list is not exhaustive, and where necessary, reference should be made to Councils *Part: 8.2 Stormwater Management Technical Manual* to ensure compliance with development controls.

(1) For Commercial and Recreational developments floor levels of habitable and non-habitable areas must comply with the freeboard requirements as stated in Table 2.1 of the Stormwater Technical Manual, reproduced below in Table 1-1. If these levels cannot be practically achieved for the entire floor area (E.g. for reasons of accessibility from a public space) then a lesser level may be considered subject to consideration of the extent or scale of property damage and risk to public safety

(2) Sensitive Uses and Facilities, defined as; Development accommodating services or facilities which are essential to evacuation during periods of flooding or if affected would unreasonable affect the ability of the community to return to normal activities after flood events. Examples of this include educational establishments, residential care facilities, fuel stations, public utility buildings, etc.
For Sensitive Uses and Facilities developments all floor levels must be no lower than the PMF level. Exemption from this may be considered, subject to consideration of the extent or scale of impact to the community that would occur in the event the structure is inundated.

(3) Critical Uses and Facilities, defined as; Emergency services facilities, administration building or public administration building that may provide an important contribution to the notification or evacuation of the community during flood events.

Title:
Site Locality

Figure: 1-1

Rev: -

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 75 150m

Approx. Scale

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(4) Basement parking or parking at levels below the adjacent flood levels, a bunded crest at the estimated PMF (probable maximum flood) level prior to descent into the parking area, must be provided such that inundation of the area is prevented.

Table 1-1 Freeboard Requirements

Drainage System/ Overland Flow	Residential			Industrial/Commercial	
	Land Level	Habitable Floor Level	Non-Habitable Floor Level	Land Level	Floor Level
Surface Drainage/ Adjoining Ground Level	-	0.15	-	-	0.15
Public Drainage Infrastructure, Creeks and Open Channels	0.5	0.5	0.1	0.3	0.3
Flooding and Overland Flow (Overland Flow Precincts and Low Risk)	N/A	0.3	0.14	N/A	0.3
Flooding and Overland Flow (Medium Risk and greater)	N/A	0.5	0.3	N/A	-
Onsite Detention	N/A	0.2	0.1	N/A	0.2
Road Drainage Minor Systems (Gutter and Pipe Flow)		0.15 below top of grate			
Road Drainage		Refer to Figure 2-1 of *Part: 8.2 Stormwater Management Technical Manual*			
Detention Basins		The top water level shall be designed to be 0.5 below the top of embankment (100 year ARI)			

1.4 Shrimptons Creek Model Review, Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010)

The Shrimptons Creek TUFLOW model developed by Bewsher in 2010 was created as a part of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). The Macquarie Park catchment was broken up into several smaller catchments, constituting the tributary creeks of Lane Cover River, one of which is Shrimptons Creek.

The initial stages of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010) involved the Macquarie Park Flood Study, which defined flood behaviour within the catchment, including the analysis of flows within the underground pipe drainage network and surface runoff. The flood study modelled a range of design flood events, from relatively frequent events to more extreme floods.

A numerical computer model was developed for the catchment to simulate flood behaviour, utilising the 2D surface water modelling software TUFLOW. TUFLOW has the capability to simulate the dynamic interaction of in-bank flows in open channels, major underground drainage systems, and overland flows through complex overland flow paths using a linked 1D/2D flood modelling approach.

The stormwater pit and pipe network and in-bank creek areas were modelled utilising one-dimensional elements linked dynamically with the 2D grid. The adopted grid size for this study is 3m, providing an appropriate level of resolution and detail across the catchment, while keeping model simulation times reasonable.

2 Flood Model Development – Current Scenario

2.1 Introduction

The purpose of the flood modelling for the flood impact assessment is to investigate the flood behaviour within the vicinity of the proposed Ivanhoe Estate Master Plan and the impacts of the proposed development on this flood behaviour. This includes the consideration of:

- Stormwater runoff within the vicinity of and across the Ivanhoe site (overland flow);
- Flows within the underground pipe drainage network; and
- Flows within the Shrimptons Creek at the south-eastern boundary of the site (mainstream flow).

Whilst consideration has been given to all flooding mechanisms at the proposed development site, the primary flood consideration is those within Shrimptons Creek, which constitute mainstream flooding.

The following Section details the updates which were made to the existing Shrimptons Creek flood model, such that the design flood conditions could be re-established for use in the flood impact assessment.

2.2 Hydrologic Model

The hydrologic model predicts the amount of runoff from rainfall and the attenuation of the flood wave as it travels down the catchment. This process is dependent on catchment area, slope and vegetation; variation in distribution, intensity and amount of rainfall; and antecedent conditions of the catchment.

The existing Shrimptons Creek model utilised runoff-routing software DRAINS to generate sub-catchment flow hydrographs for inclusion into the hydraulic model. With the exception of Ivanhoe Estate, the existing DRAINS model hydrographs were maintained within the current scenario model.

Within Ivanhoe estate, the DRAINS sub-catchment hydrographs were replaced with ‘rainfall on grid’, which applies design rainfall directly onto the individual cells of the TUFLOW model. This is particularly useful for studies where model results are desired in areas with small contributing catchments.

For design events, rainfall depths are usually determined by the estimation of intensity-frequency-duration (IFD) design rainfall curves for the catchment. Standard procedures for derivation of these curves are defined in ARR (2001). Table 2-1 shows design rainfall intensities utilised within the Ivanhoe estate.

Table 2-1 Design Rainfall Intensities (mm/h)

Duration (h)	Design Event	
	2 yr ARI	50 yr ARI
1	27.5	74.2
12	8.38	18.5
72	2.72	6.11

The recently released ARR update (2016) revised the recommended application of temporal patterns for use in design flood estimation. For simplicity, this study has adopted the temporal patterns and initial and continuing loss guidance in accordance with ARR (2001) to ensure consistency with the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). Similarly, a critical storm duration of 120 minutes for 20 year ARI and 100 year ARI events was maintained for this study as well as a 15-minute duration for the PMF event.

2.3 Hydraulic Model

BMT WBM has updated the existing Shrimptons Creek TUFLOW model. TUFLOW has the capability to simulate the dynamic interaction of in-bank flows in open channels, major underground drainage systems, and overland flows through complex overland flow paths using a linked 1D/2D flood modelling approach

The updates made to the existing Shrimptons Creek TUFLOW model are discussed in further detail below.

2.3.1 2D Model Domain and Topography

The 2D model cell size of 3 m utilised in the existing Shrimptons Creek model was maintained for this study. A cell size of 3 m was determined to be accurate to define the floodplain, including local topographical controls (e.g. perched channel banks, underpasses and road embankments) at and around the site. TUFLOW samples elevation points at the cell centres, mid sides and corners, so a 3 m cell size results in DEM elevations being sampled every 1.5 m.

The underlying DEM in the areas immediately surrounding the Ivanhoe site were updated utilising the latest available LiDAR (Light Detection and Ranging) survey, captured by the NSW Government's Land and Property Information (LPI) in 2013.

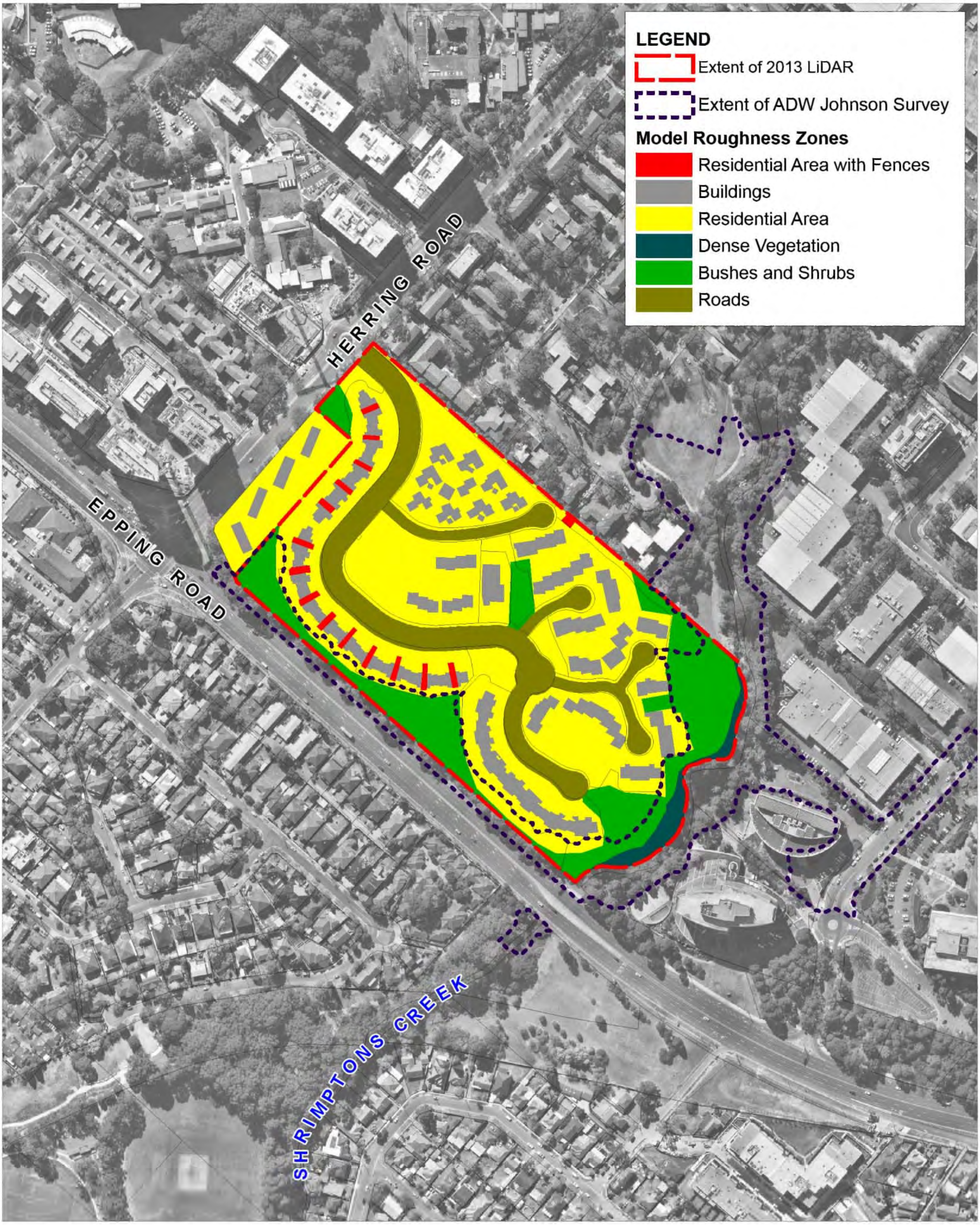
Additional survey of Shrimptons Creek was provided by ADW Johnson Pty Ltd (drawing ref: 300001-DET-001-A). The survey was conducted the 5th of July 2017, and represents the most accurate definition of Shrimptons Creek available at the time of modelling.

Figure 2-1 shows the different sources of underlying topography, in addition to the model roughness zones discussed further below.

Hydraulic Roughness (Manning's 'n')

Another input required in the development of the TUFLOW model is the assignment of different hydraulic roughness zones to represent the variation in flow resistance. These zones (e.g. creek channel, cleared land or vegetated areas) were maintained from the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). Manning's 'n' roughness values were determined by using the adopted values from the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010).

The Manning's 'n' roughness values are listed in Table 2-2. The spatial distribution of materials roughness zones representing variations in hydraulic roughness is presented in Figure 2-1.



Title:
2D Model Domain

Figure: **2-1**

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Table 2-2 Adopted Model Roughness Values (Manning's n)

Material Description	Model Roughness (Manning's 'n')
Urban Properties (with Fencing)	0.100
Urban Properties	0.025
Water Body	0.020
Roads	0.020
Short Grass / Bare Earth	0.030
Forest	0.100
Buildings	20.000

Buildings

The influence of buildings and other obstacles to the passage of flow in urban floodplains is an important issue in the context of urban floodplain management (Engineers Australia, 2012). In a typical urban floodplain, some buildings will be elevated on fill and totally obstruct the passage of floodwater, others may be inundated with floodwater ponding inside the building, whilst others may be elevated on piers allowing flow under the building.

The buildings of the existing Shrimptons Creek model were modelled by elevating 0.2 m above the underlying DEM with an increased roughness (n = 20) to represent the energy dissipation of water flowing through and around buildings. The methodology utilised in the existing Shrimptons Creek model was maintained for this study.

Drainage Network

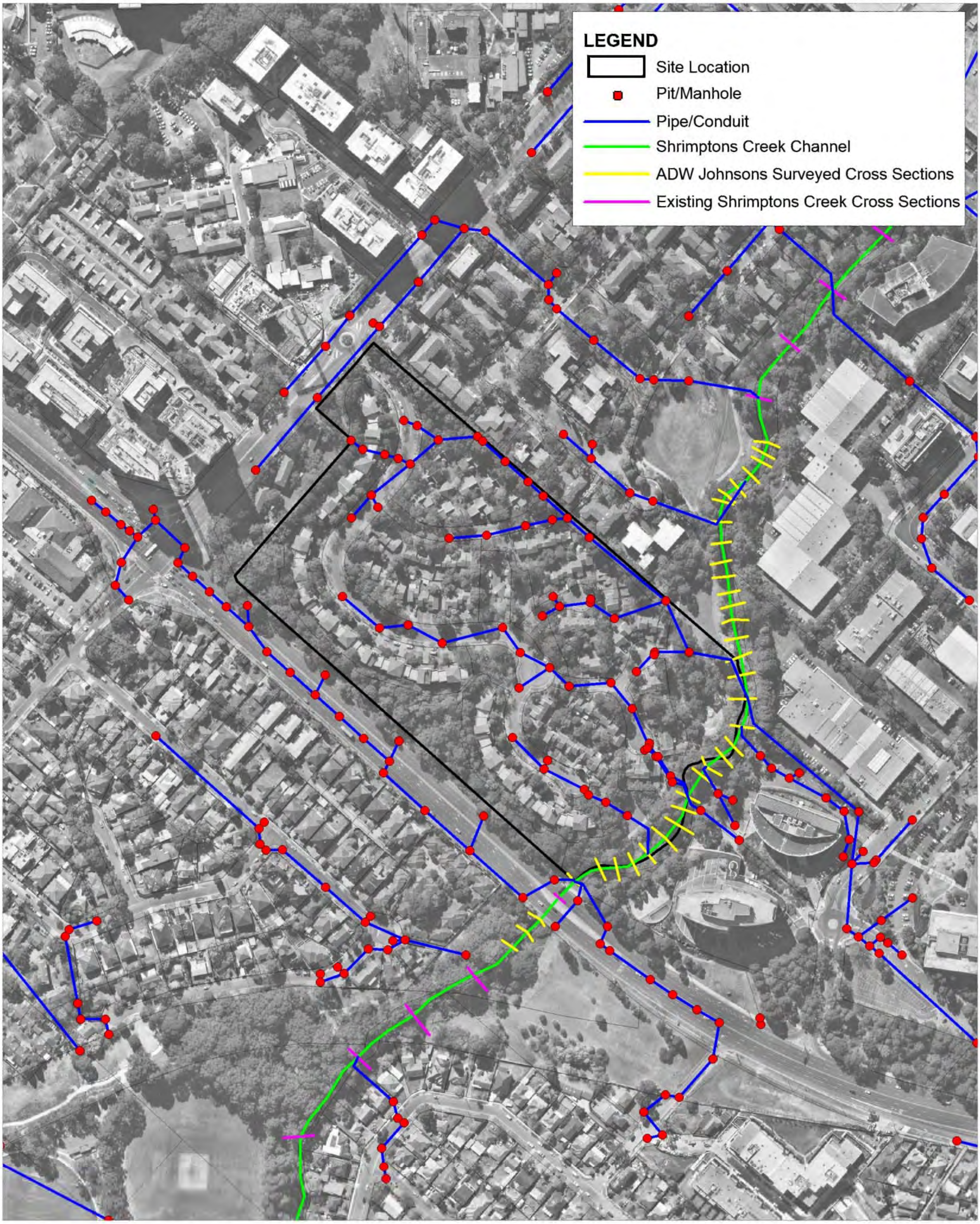
The existing Shrimptons Creek TUFLOW model utilised 1D cross-sections to model the in-bank flows of Shrimptons Creek. Cross-sections were placed at approximate 100 m intervals, and were '*directly extracted from specifically commissioned supplementary field measurements undertaken by registered surveyors*' (Bewsher 2010).

To provide greater definition of flooding within the section of Shrimptons Creek immediately adjacent to Ivanhoe Estate, 1D cross-sections were spaced at 20m intervals and updated utilising the survey data provided by ADW Johnson Pty Ltd (drawing ref: 300001-DET-001-A).

Pipe and Pit drainage networks from the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010) were updated with Survey Data by ADW Johnson Pty Ltd (drawing ref: 300001-DET-001-A). Updates included;

- Updating pipe diameters with survey information;
- Updating drainage pipe and pit network to match surveyed invert levels;
- The inclusion of local stormwater drainage which had not previously been included.

Figure 2-2 illustrates the 1D model elements included within the current scenario model for this study.



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1D Model Domain

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2.3.3 Rainfall on Grid

As discussed in Section 2.2, the DRAINS sub-catchment hydrographs located within Ivanhoe Estate were replaced with 'rainfall on grid', which applies design rainfall directly onto the individual cells of the TUFLOW model.

The losses applied to the Ivanhoe Estate rainfall on grid were maintained from the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010), utilising an initial loss of 5 mm and 1 mm for pervious and impervious areas respectively with no continuing losses. Design temporal pattern Zone 1 was utilised as is recommended for catchments located in eastern NSW.

A comparison between the original model results and the current scenario model is shown in Section 4.2 to validate the use of rainfall on grid.

3 Design Flood Conditions

3.1 Introduction

Design storm events are hypothetical events that are used to estimate design flood conditions. They are based on a probability of occurrence, usually specified as an ARI or as an Annual Exceedance Probability (AEP). Chapter 5 of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010) describes the design storm conditions which have been utilised in this study. The 20 year ARI, 100 year ARI and PMF events have been assessed as part of this study. Table 3-1 lists the variables assessed for each design event. Further discussion on each of these variables is in the following report sections.

Table 3-1 Design Flood Combinations

Design Flood Condition	Design Rainfall	Blockage Scenario
20 Year ARI	20 Year ARI, 2 Hour Storm	Unblocked
		Blocked
100 Year ARI	20 Year ARI, 2 Hour Storm	Unblocked
		Blocked
Probable Maximum Flood (PMF)	PMF, 15 Minute Storm	Unblocked

3.2 Design Rainfall

The Australian Rainfall and Runoff (AR&R, 2001) method has been used to estimate design rainfall intensities and depth for the 20 year and 100 year ARI design storm events and the Bureau of Meteorology's Generalised Short-Duration Method has been used to estimate the probable maximum flood event.

A critical duration of 2 hours for the 20 year and 100 year ARI design storm events, and 15 minutes for the PMF was utilised for this assessment based on the modelling previously undertaken for the Shrimptons Creek catchment.

3.3 Drainage Blockage

The blockage of drainage conduits for this study utilises the same methodology documented in the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). The blockage factors applied for the blocked design condition in both the current and proposed scenario models is given below:

- A blockage factor of 25% was applied to culverts/bridges whose diagonal dimension exceeds 6m;
- A blockage factor of 35% was applied to culverts/bridges whose diagonal dimension is between 2m and 6m;
- A blockage factor of 50% was applied to culverts whose diagonal dimension is less than two meters.

Peak flood depth, velocity, velocity depth product, provisional flood hazard, provisional hydraulic categorisation and impacts have been determined from the combined ‘maximum envelope’ of both the blocked and unblocked conditions.

4 Model Results

4.1 Introduction

The following results for the current scenario are presented in Appendix B:

- Peak flood depth maps for each of the modelled design flood events;
- Peak flood velocity maps for each of the modelled design flood events;
- Peak flood velocity depth product maps for each of the modelled design flood events;
- Provisional hazard category map for the 100 year ARI and PMF events;
- Provisional hydraulic categorisation map for the 100 year ARI and PMF events; and
- Provisional Flood Risk Precinct mapping.

Flood mapping has been undertaken using the combined ‘maximum envelope’ of both the blocked and unblocked drainage scenarios for the critical 120-minute storm event for the 20 year and 100 year ARI events and 15-minute storm for the PMF. Flood mapping is shown for predicted peak water depths higher than 0.1m, consistent with that of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010).

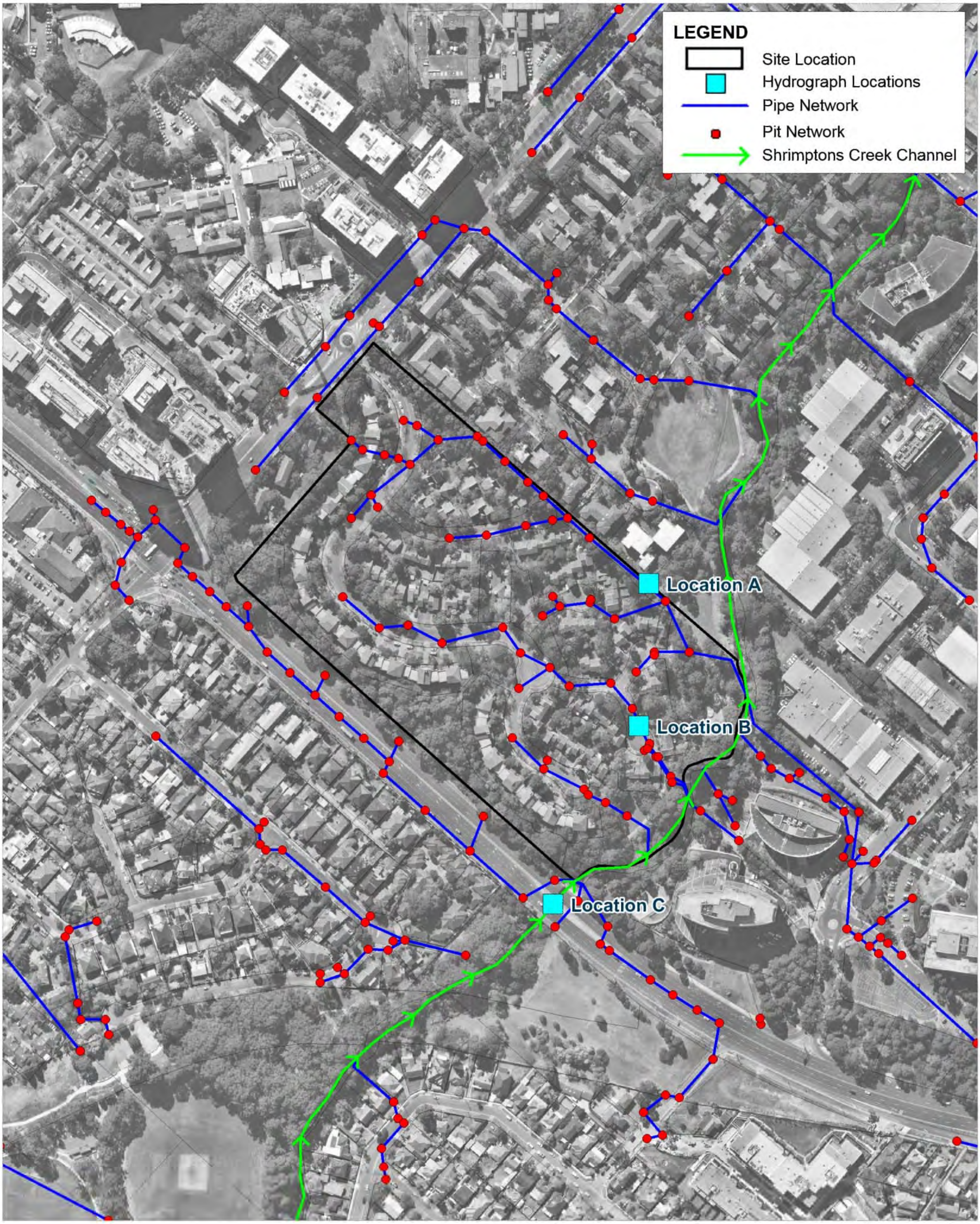
4.2 Comparison of Peak Flows with Existing Shrimptons Creek Model

To ensure conformance with the existing Shrimptons Creek model, peak flows at a number of drainage conduits (pipe and channels) were compared with the current scenario model. The comparison was undertaken primarily to validate the use of rainfall on grid within the Ivanhoe estate, and ensure conformance with the existing Shrimptons Creek model which utilised DRAINS sub-catchment inflows.

Figure 4-1 shows the locations where flood hydrographs were compared between the current scenario model, discussed in Section 2, and the TUFLOW model used in Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). Figure 4-2 shows the design event hydrographs for each location.

In general, the current scenario model conformed well with the Shrimptons creek model; with locations A and C recording peak flows within 3%. Furthermore, the rate of rise and fall of the hydrograph limbs generally matched.

Location B indicated some differences in peak flow, most notably in the 20 year ARI. This is due to the difference in routing between the DRAINS model and TUFLOW rainfall on grid. DRAINS models internally route the excess run-off utilising the ‘time-area’ method which combines the rainfall hyetograph of 3 separate sub-areas (paved, supplementary and grassed) into a single hydrograph utilising separate parameters for each sub-area. The resulting hydrograph is injected directly into the 1D TUFLOW elements (pits and pipes). The rainfall on grid approach does not apply rainfall directly onto the 1D TUFLOW elements, but rather on the entire 2D mesh. The TUFLOW model routes the excess run-off via the underlying DEM, accounting for model roughness and slope to determine the run-off route across the 2D mesh. The TUFLOW parameters are represented spatially in GIS, and are typically of greater definition and detail than can be accounted for in a DRAINS model.



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Hydrograph Locations

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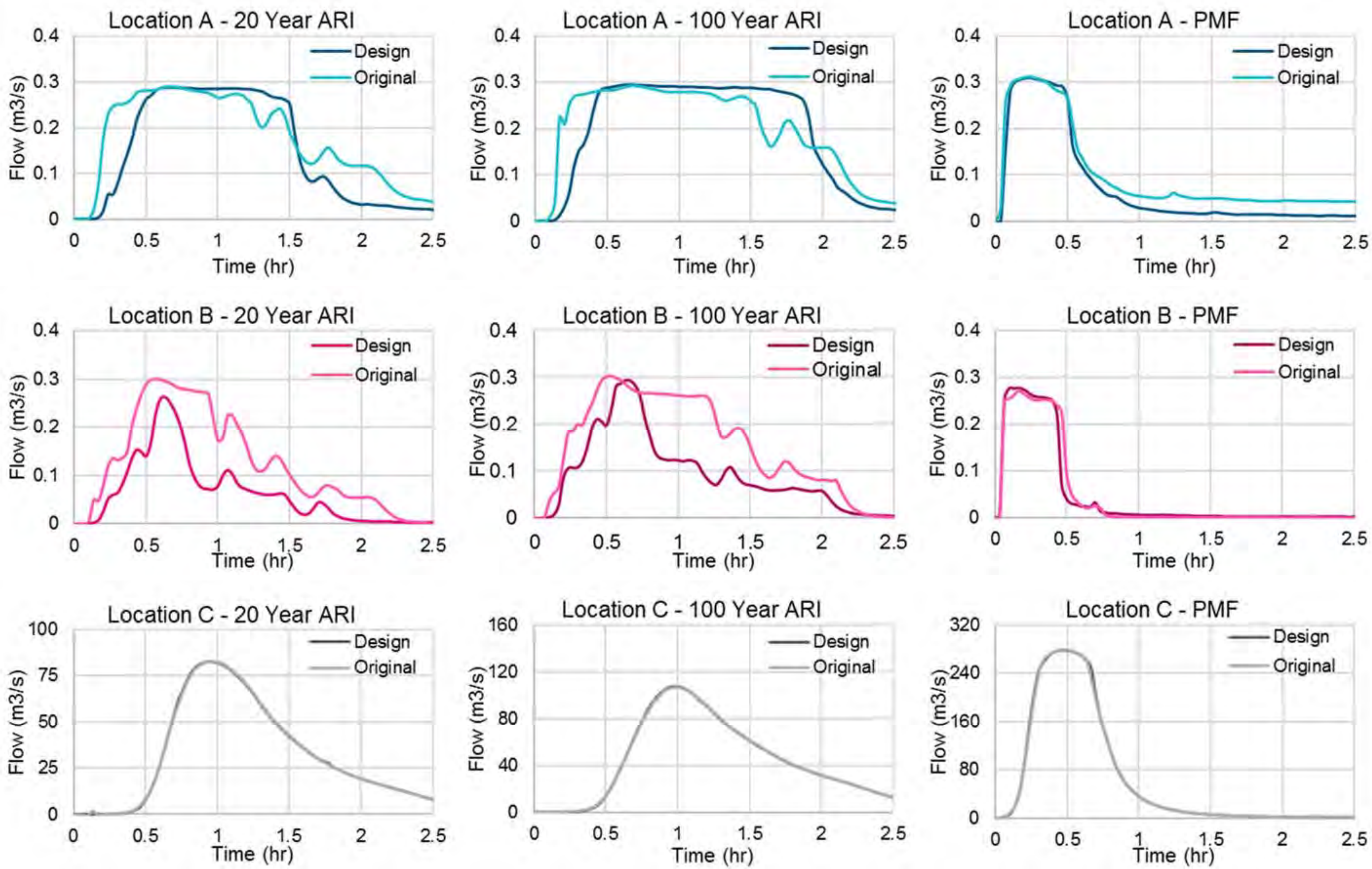


Figure 4-2 Hydrographs at Location A, Location B and Location C

4.3 Description of Flood Behaviour under Current Conditions

Design flood simulations were undertaken for the 20 year ARI, 100 year ARI and PMF design events. Figure 4-3 shows the peak flood depth at the site for the 100 year ARI event, all other results are presented in Appendix B.

In all design events, local drainage flows are conveyed across the site in a south-easterly direction. These flows are typified by shallow inundation (low depths), and minor velocities (<0.2m/s). These areas are referred to as 'Local Drainage' under the Floodplain Development Manual, and as such are omitted from further analysis (i.e. not considered within the Flood Impact Assessment, refer Section 5).

As shown in Figure 4-3, mainstream flood inundation within Ivanhoe Estate is largely confined to the distinct left and right bank of Shrimptons Creek. In the 100 year flood, Shrimptons creek is elevated approximately 2 m above the typical low-flow depth, causing the left bank of Shrimptons Creek to encroach onto Ivanhoe Estate by approximately 30 m. In the PMF event, this increases to 45 m.

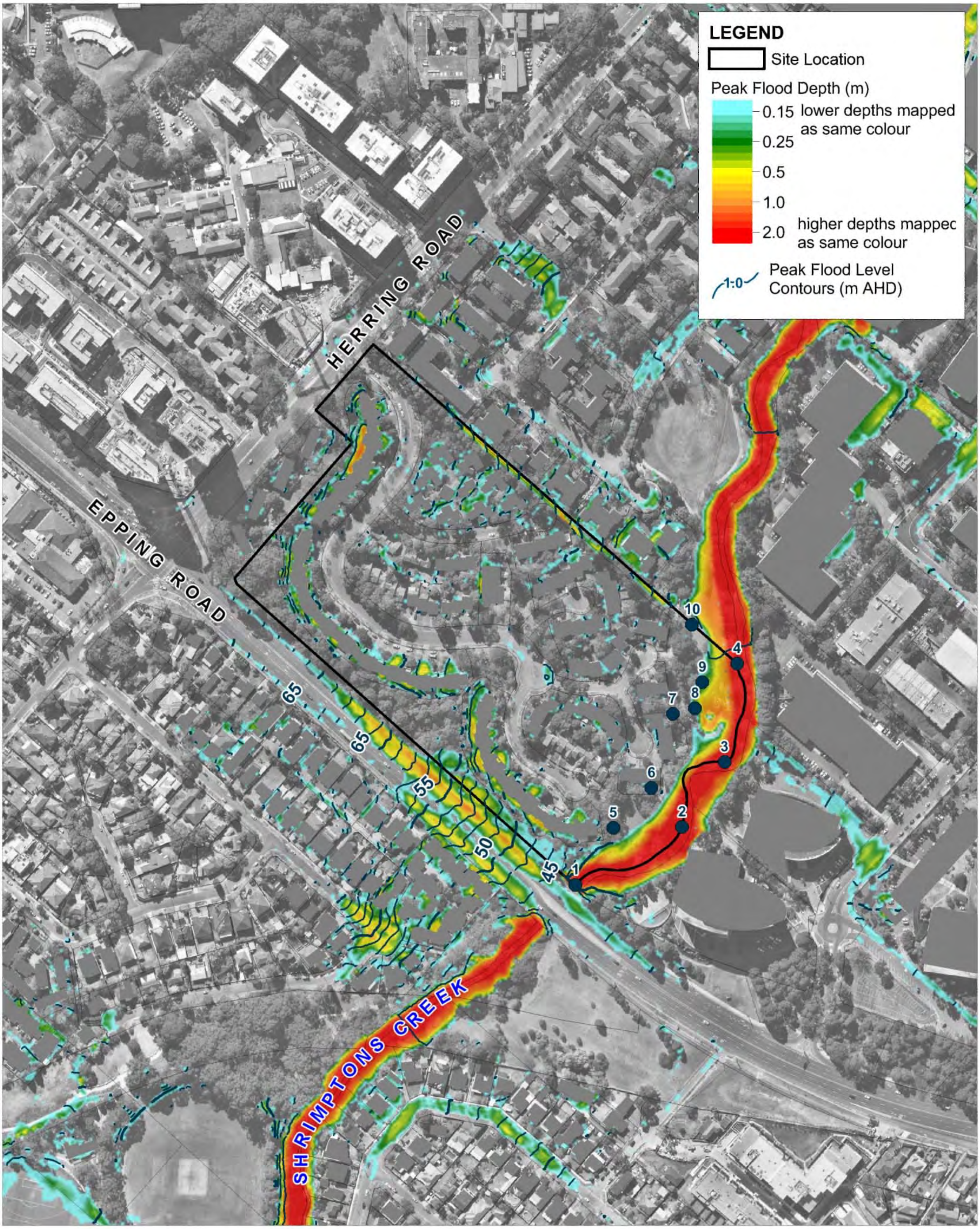
Flood depths in Shrimptons Creek range from 0 m at the bank sides, to depths of greater than 2 metres at the creek centreline. Shrimptons Creek velocities exceed 2 m/s at the creek centreline falling to 0-0.5m/s at the bank sides.

Peak flood levels within Shrimptons Creek for each modelled design event have been tabulated below in Table 4-1.

Table 4-1 Design Peak Flood Levels (m AHD) at Ivanhoe Estate

Location (refer Figure 4-3)	X co-ordinate	Y co-ordinate	Design Event		
			20 yr ARI	100 yr ARI	PMF
1	325659.3097	6260198.446	44.74	44.99	46.71
2	325742.8566	6260243.747	44.37	44.64	46.27
3	325776.3017	6260294.816	44.14	44.40	45.96
4	325786.1555	6260371.621	43.76	44.04	45.75
5	325688.8216	6260243.167	NFI	NFI	46.58
6	325718.8612	6260274.38	NFI	NFI	46.18
7	325735.5343	6260332.289	NFI	NFI	45.77
8	325753.0237	6260336.808	NFI	NFI	45.79
9	325758.8288	6260357.134	NFI	44.18	45.78
10	325750.6654	6260402.184	NFI	NFI	45.61

*NFI = No Flooding Indicated



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Peak Flood Depth 100 yr ARI

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4.4 Provisional Hazard Classification

The Updating National Guidance on Best Practice Flood Risk Management (NFRAG, 2014) considers a holistic approach to consider flood hazards to people, vehicles and structures. It recommends a composite six-tiered hazard classification, reproduced in Figure 4-4. The six hazard classifications are summarised in Table 4-2.

The key factors influencing flood hazard or risk are:

- Size of the Flood
- Rate of Rise - Effective Warning Time
- Community Awareness
- Flood Depth and Velocity
- Duration of Inundation
- Obstructions to Flow
- Access and Evacuation

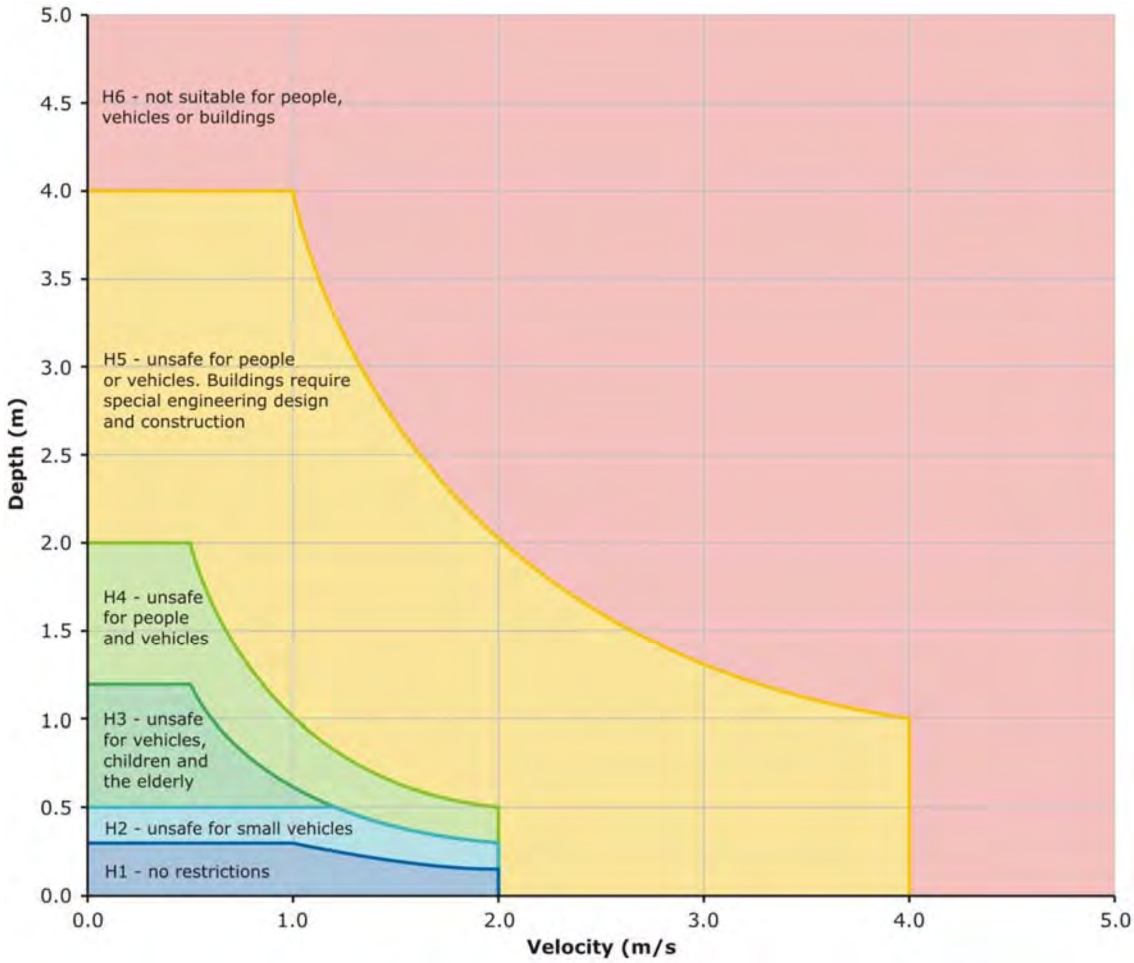


Figure 4-4 Combined Flood Hazard Curves

Table 4-2 Combined Flood Hazard Curves – Vulnerability Thresholds

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 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.

The provisional flood hazard level is often determined on the basis of the predicted flood depth and velocity. This is conveniently done through the analysis of flood model results. A high flood depth will cause a hazardous situation while a low depth may only cause an inconvenience. High flood velocities are dangerous and may cause structural damage while low velocities generally do not.

Provisional hazard category mapping in the vicinity of the proposed development is included in Appendix B, and is presented for the 100 year ARI and PMF events.

4.5 Hydraulic Categorisation

Hydraulic categorisation is one of the tools used to identify flood behaviour and risk. Outcomes of the categorisation are primarily used to inform future land use planning. The categorisation is not used to assess individual developments, but rather to give a catchment-scale overview of which areas may be appropriate for various types of land use.

There are no prescriptive methods for determining what parts of the floodplain constitute floodways, flood storages and flood fringes. Descriptions of these terms within the Floodplain Development Manual (DIPNR, 2005) are essentially qualitative in nature. Of particular difficulty is the fact that a definition of flood behaviour and associated impacts is likely to vary from one floodplain to another depending on the circumstances and nature of flooding within the catchment.

The hydraulic categories as defined in the Floodplain Development Manual are:

- Floodway. Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- Flood Storage. Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.
- Flood Fringe. Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

Hydraulic categorisation was not undertaken for the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010), however Council's DCP gives reference to flood storage areas (refer Appendix A). Consequently, BMT WBM have undertaken a provisional hydraulic categorisation, utilising the approach defined by the criteria proposed by Howells et al, 2003:

Floodway is defined as areas where:

- Velocity x depth greater than 0.25 m^2/s and velocity greater than 0.25 m/s; or
- Velocity greater than 1 m/s.

Flood storage areas were identified as those areas which do not operate as floodways but where the depth of inundation exceeded 1 m.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined.

Provisional hydraulic category mapping in the vicinity of the proposed development is included in Appendix B, and is presented for the 100 year ARI and PMF events.

5 Flood Impact Assessment

5.1 Introduction

In order to assess the proposed Ivanhoe Estate Master Plan, modelling was undertaken to represent the development within the TUFLOW hydraulic model (proposed scenario model). The Master Plan development includes:

- residential flat buildings comprising private, social and affordable housing;
- seniors house comprising residential care facilities and self-contained dwellings;
- a new high school;
- child care centres;
- public open space and roads;
- minor retail development; and
- community uses.

The resultant change in flood conditions have been assessed against the current scenario model (refer Section 2), and are presented in the following section.

5.2 Flood Model Development – Master Plan

5.2.1 Hydraulic Model

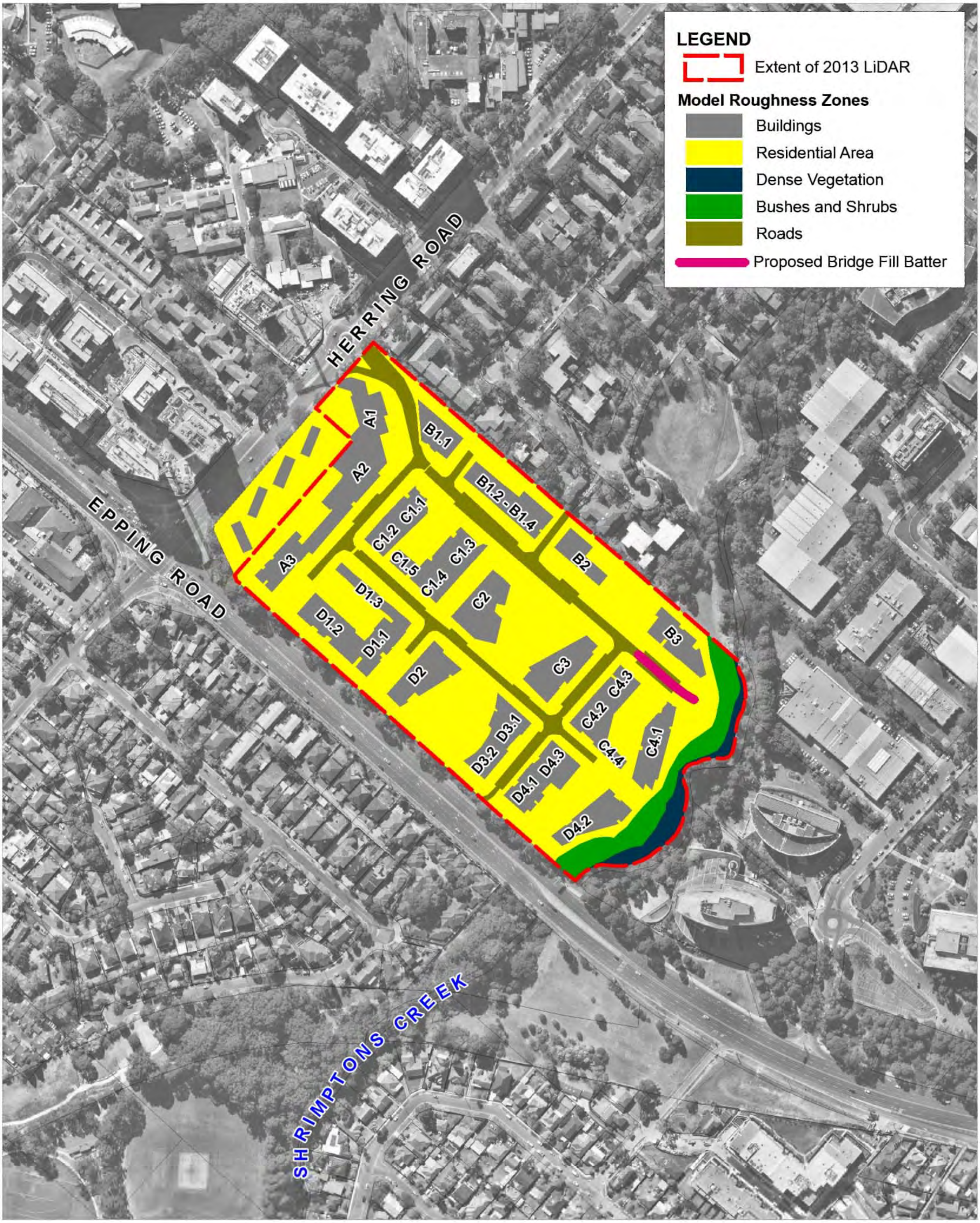
Details of the proposed Ivanhoe Estate Master Plan were provided by Bates Smart Pty Ltd (drawing ref: DA02.MP.101(G).pdf). The following Section details the updates which were made to the ‘current scenario’ Shrimptons Creek flood model; incorporating revisions to land use, drainage network and building layout at the site to represent the proposed Master Plan (‘proposed development scenario’).

Hydraulic Roughness (Manning’s ‘n’)

Model Roughness zones representing land-use at the site, were revised to incorporate the Master Plan building footprints, roads, residential areas and green areas. The Manning’s ‘n’ roughness values are listed in Table 2-2. The spatial distribution of materials roughness zones representing variations in hydraulic roughness is presented in Figure 5-1.

Buildings

The proposed building ground floor levels provided by Bates Smart (drawing ref: DA02.MP.101(G).pdf). have been represented in the TUFLOW model using a z-shape to set the finished ground floor level. Above the finished floor level, buildings have been represented utilising an increased Manning’s roughness (n = 20) to represent the energy dissipation of water flowing through and around buildings. This methodology is consistent with the flood models developed as part of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010).



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2D Model Domain Developed Scenario

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Concept Bridge Design

Preliminary longitudinal sections were provided by ADW Johnson (drawing ref: 300001-ESK-074-A-2017-10-06_ Bridge.pdf) for the proposed bridge spanning Shrimptons Creek. The proposed bridge is to provide vehicle access between Ivanhoe Estate on the north-western side of Shrimptons Creek, and Lyonpark Road to the south-east.

The bridge design has been included within the TUFLOW hydraulic model by modelling the fill batter on the north-western side of Shrimptons Creek. The batter on the eastern side of Shrimptons Creek was not modelled, as it was sufficiently above the PMF flood level at the proposed location. The proposed bridge soffit levels are above the current PMF level for the site, and hence have not been modelled. No provision has been made for the modelling of piers within Shrimptons Creek, as it is expected that this will be undertaken during detailed design.

The location of the bridge fill batter is shown in Figure 5-1.

Drainage Network

The network of pits and pipes contained within Ivanhoe Estate have been removed from the 'proposed development scenario' model. Details of the proposed drainage network for the Ivanhoe Estate Master Plan were not available at the time of modelling, however as discussed earlier in Section 4.3, the areas outside of the main channel of Shrimptons Creek are considered 'Local Drainage' under the Floodplain Development Manual, and hence will have no major impact on the mainstream flood levels.

Figure 5-2 illustrates the 1D model elements included within the proposed development scenario model.

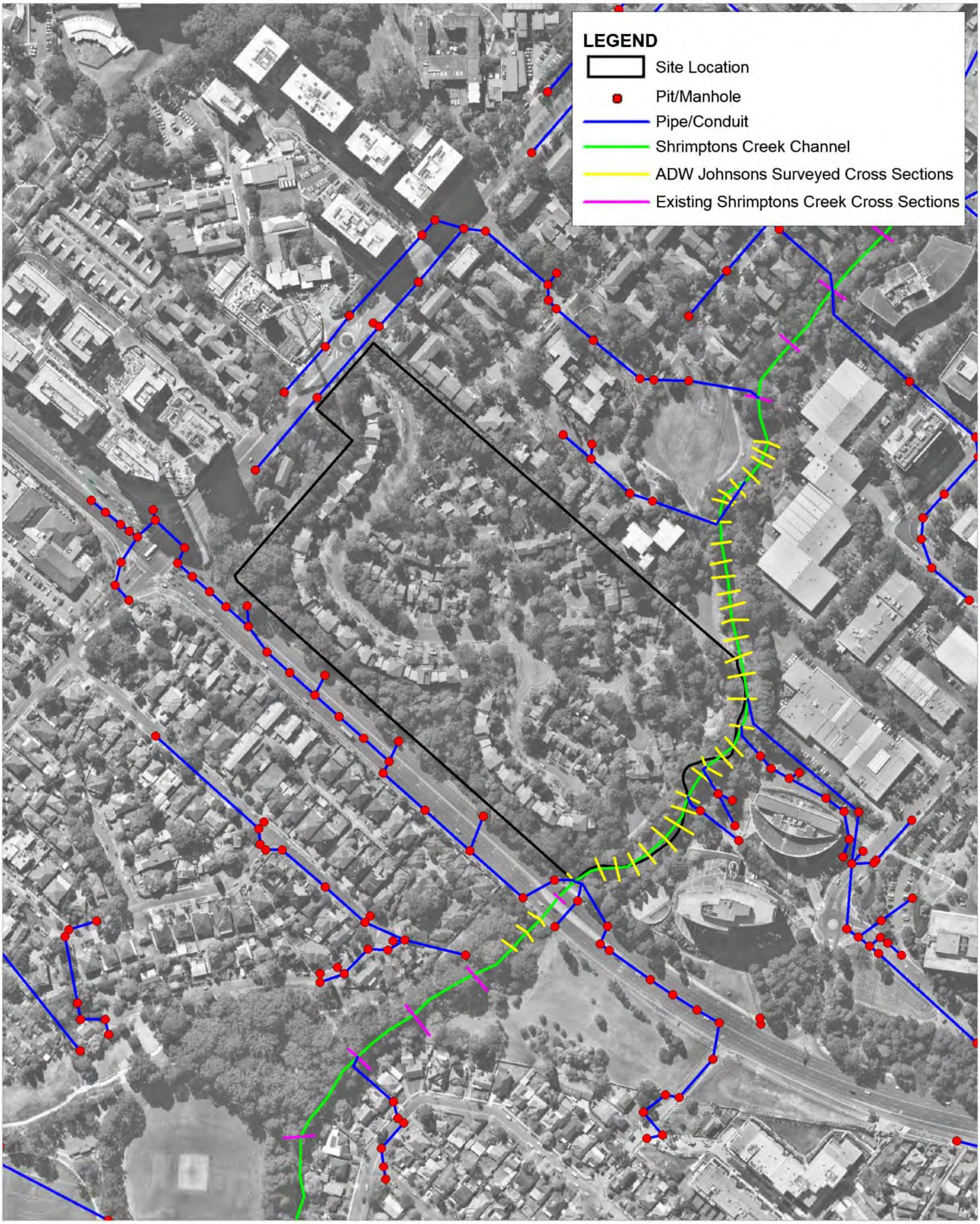
5.3 Flood Impacts

The "proposed development scenario" TUFLOW hydraulic model has been used to derive the peak flood conditions for the 20 year ARI, 100 year ARI and the PMF (Probable Maximum Flood) design events. Appendix C presents the results of the 'proposed development scenario' and includes; peak flood depth, peak flood velocity, peak velocity-depth product, provisional hazard, hydraulic categorisation and provisional flood risk precinct mapping.

Afflux diagrams are presented in Appendix D for peak flood level and peak flood velocity for the design events simulated. These diagrams show the afflux (increase) between flood conditions resulting from the proposed development and the existing baseline flood conditions. They are useful for presenting the magnitude and extent of potential flood impacts associated with development of the site. The following impact results are presented below:

- Figure 5-3 – Prospect Creek 100 year ARI Peak Water Level Afflux
- Figure 5-4 – Prospect Creek 100 year ARI Peak Velocity Afflux

Peak water levels and depths have been extracted from a number of point locations around the study area boundary and within the proposed development site for the "current" and "proposed development" scenarios (please refer to Table 5-1 and Table 5-2). Figure 5-3 shows the locations reported in these tables.



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1D Model Domain Developed Scenario

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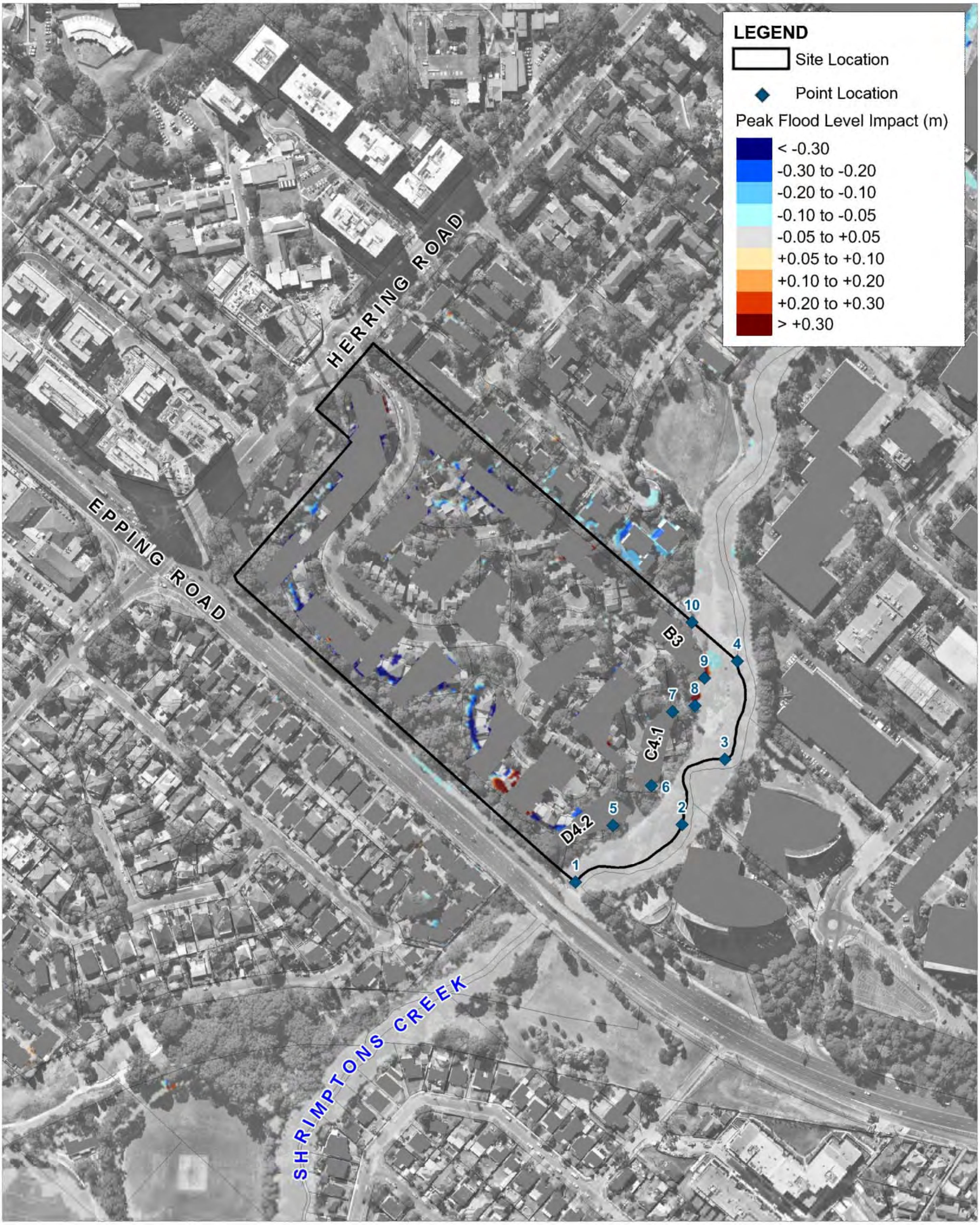

Title:

Peak Flood Level Impact 100 yr ARI

Figure: **5-3**

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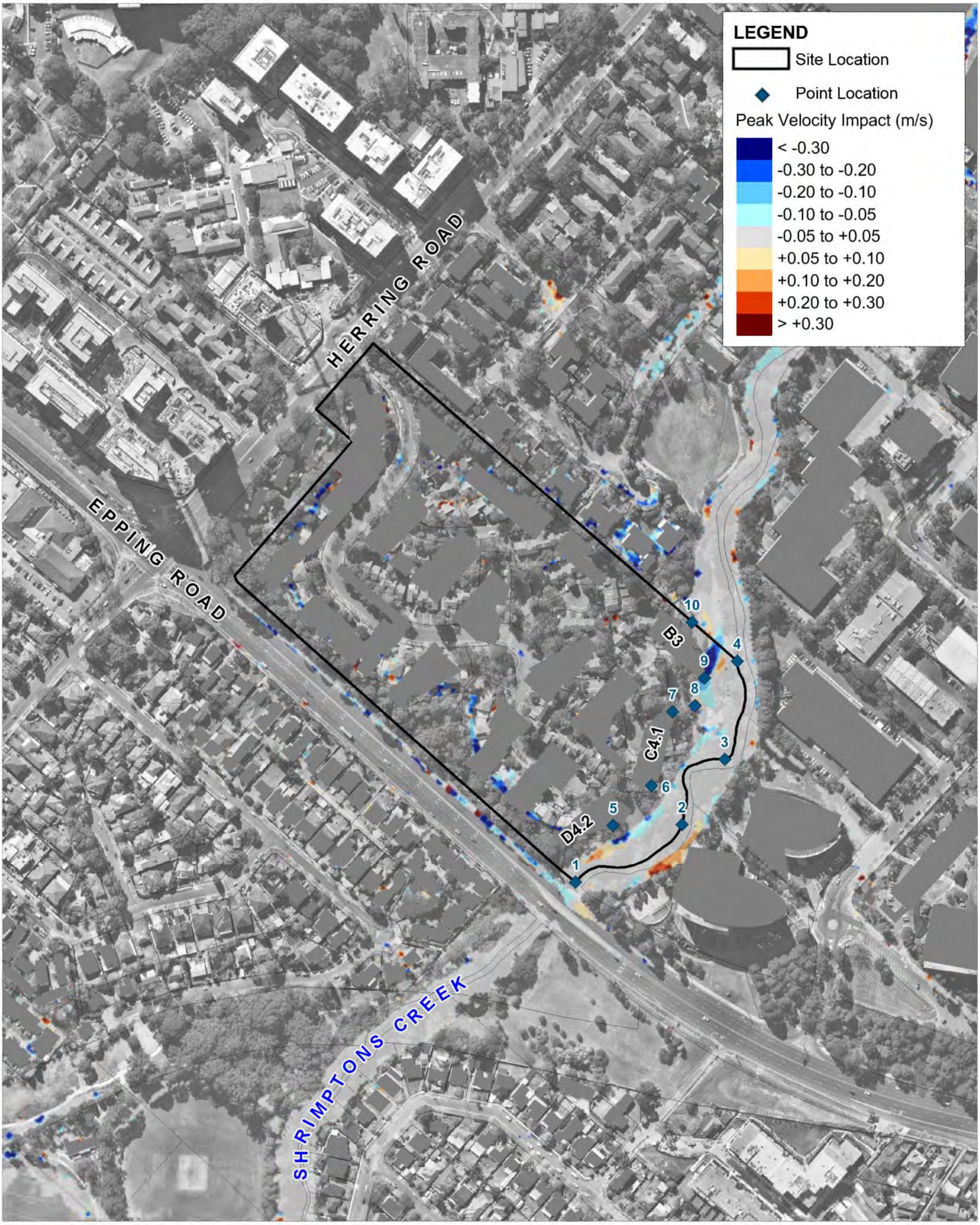

Title:

Peak Velocity Impact 100 yr ARI

Figure: 5-4

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Table 5-1 Peak Flood Level Results

Location (Refer to Figure 5-3)	Current Scenario (m AHD)			Proposed Development Scenario (m AHD)			Difference in Peak Flood Levels (m)		
	20yr ARI	100yr ARI	PMF	20yr ARI	100yr ARI	PMF	20yr ARI	100yr ARI	PMF
1	1	44.74	44.99	46.71	44.74	44.98	46.72	0.00	-0.01
2	2	44.37	44.64	46.27	44.37	44.63	46.28	0.00	-0.01
3	3	44.14	44.40	45.96	44.13	44.39	45.98	0.00	-0.01
4	4	43.76	44.04	45.75	43.75	44.03	45.77	0.00	-0.01
5	5	NFI	NFI	46.58	NFI	NFI	NFI	NFI	NFI
6	6	NFI	NFI	46.18	NFI	NFI	46.98	NFI	NFI
7	7	NFI	NFI	45.77	NFI	NFI	NFI	NFI	NFI
8	8	NFI	NFI	45.79	NFI	NFI	45.95	NFI	NFI
9	9	NFI	44.18	45.78	NFI	44.42	45.94	NFI	0.24
10	10	NFI	NFI	45.61	NFI	NFI	45.61	NFI	NFI

*NFI No Flooding Indicated

Table 5-2 Peak Flood Velocity Results

Location (Refer to Figure 5-4)	Current Scenario (m/s)			Proposed Development Scenario (m/s)			Difference in Peak Flood Velocity (m/s)		
	20yr ARI	100yr ARI	PMF	20yr ARI	100yr ARI	PMF	20yr ARI	100yr ARI	PMF
1	2.65	3.04	5.62	2.65	3.05	5.60	0.00	0.01	-0.02
2	0.98	1.10	1.80	0.99	1.09	1.78	0.00	0.00	-0.01
3	1.49	1.66	2.15	1.49	1.66	2.09	0.00	0.00	-0.06
4	1.43	1.53	2.10	1.42	1.54	2.47	0.00	0.01	0.36
5	NFI	NFI	NFI	NFI	NFI	NFI	NFI	NFI	NFI
6	NFI	NFI	0.25	NFI	NFI	0.07	NFI	NFI	-0.18
7	NFI	NFI	0.18	NFI	NFI	NFI	NFI	NFI	NFI
8	NFI	NFI	1.71	NFI	NFI	0.97	NFI	NFI	-0.74
9	NFI	0.72	1.93	NFI	0.22	0.79	NFI	-0.50	-1.14
10	NFI	NFI	1.13	NFI	NFI	NFI	NFI	NFI	NFI

*NFI No Flooding Indicated

As shown in Figure 5-3, the proposed Ivanhoe estate Master Plan development results in minimal impacts when considering the 20 year ARI and 100 year ARI Shrimptons Creek flood events. No notable changes in water level or velocity were observed in the 20 year ARI event. In the 100 year ARI event, minor increases at the location of building 'Lot B3' were present due to the buildings encroachment into the 100 year flood extent. These impacts are in the order of 0.00 to 0.25 m. A resultant reduction in velocity in the order of 0.50 m/s is present at building 'Lot B3'.

The magnitude of impacts for the PMF event are larger. Increases in peak water levels are present upstream of the site with significant decreases in water levels downstream from the site due to the proposed bridge obstructing the active PMF flow path. Peak flood levels from mainstream flooding for Shrimptons Creek at buildings ‘Lot B3’, ‘Lot C4.1’ and ‘Lot D4.2’ are 45.65 mAHD, 46.40 mAHD and 46.75 mAHD respectively.

Changes in velocity during the PMF event are relatively localised to the proposed development footprint with some effects upstream and downstream. Increases in velocity within Shrimptons Creek are observed due to shifting in flow paths around the development. The PMF event is usually used for emergency planning purposes only, rather than the assessment of absolute changes to modelled flood levels and velocities. Further discussion is provided in the following section.

5.3.1 Emergency Planning and Evacuation Considerations

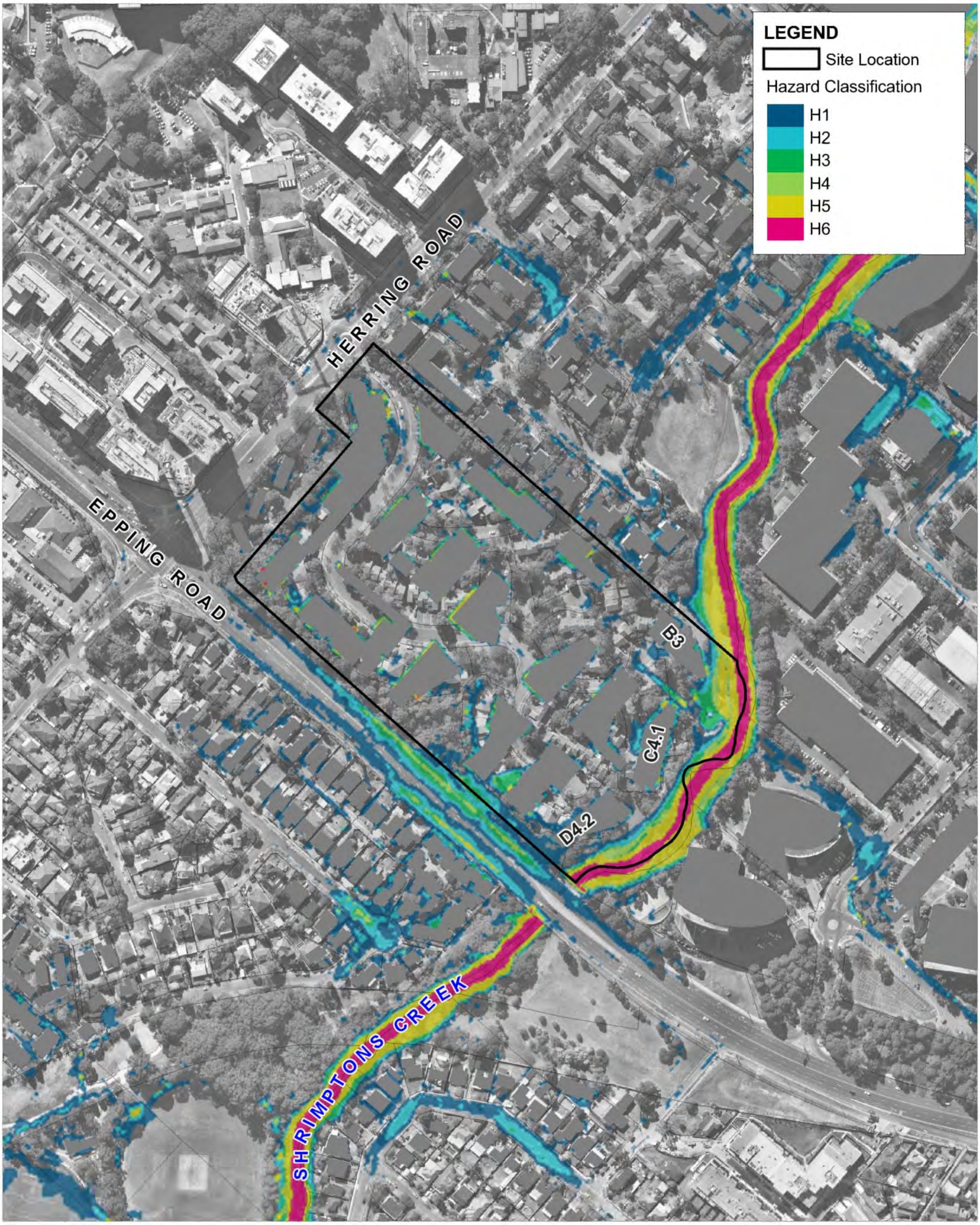
To consider potential impacts on risk to life and structural stability during extreme flood events, preliminary hazard classification has been considered. The Hazard Classification thresholds detailed in *Updating National Guidance on Best Practice Flood Risk Management* (D. McLuckie et. al., 2014) have been adopted for this assessment. Descriptions of each hazard threshold have been reproduced in Table 5-3.

Table 5-3 Hazard Classification Thresholds

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.

Hazard classification mapping has been included within Appendix B and Appendix C for the ‘current’ and ‘proposed development’ scenarios respectively. Figure 5-5 shows the provisional hazard classification for the 100 year ARI under the proposed development scenario.

As shown in Figure 5-5, all buildings with the exception of ‘Lot B3’ are located outside of the 1% AEP extent of Shrimptons Creek, and hence outside of the hazard classification thresholds given in Table 5-3. The eastern side of building ‘Lot B3’ is located partly within the H1-H2 hazard classifications, limiting evacuation opportunities east. However, as rising road access is available to the west of the property, and Shrimptons Creek lies to the east, an eastern evacuation route would not be a viable option. The finished floor level of ‘Lot B3’ is 46 mAHD, which is above the 100yr ARI peak flood level (44.35 mAHD) and the PMF peak flood level (45.65 mAHD).



Title:

Flood Hazard Classification - Developed Scenario 100 yr ARI

Figure: 5-5

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The most significant hazard at the site occurs during the Shrimptons Creek PMF event (refer Appendix C, Figure C-11). Buildings denoted 'Lot C4.1' and 'Lot D4.2' are all located on the fringe of Hazard classification zones H1-H4. A small segment of Building 'Lot B3' is located within the H5 zone of the PMF.

During the PMF event, all proposed Ivanhoe Estate Master Plan buildings floor levels are above the Shrimptons Creek PMF mainstream flood level, providing flood-free-refuge for all events up to the PMF. In addition, rising road access from Shrimptons Creek is available up to Herring Road for all modelled design events. Construction on buildings 'Lot B3', 'Lot C4.1' and 'Lot D4.2' would be required to be specially designed to structurally withstand the expected high depth and velocity condition of floodwaters during an extreme event.

In conclusion, the Ivanhoe Estate Master Plan does not change the current emergency planning and evacuation considerations for the site. There is no considerable risk to life, due to the availability of rising road access to Herring Road in the event of flood. Furthermore, buildings 'Lot B3', 'Lot C4.1' and 'Lot D4.2' provide flood-free-refuge for all events up to the PMF. All other buildings are subject to 'local drainage' conditions only, and do not pose a significant hazard.

5.3.2 Impacts of Social and Economic Cost to the Community

As discussed above, there are no tangible flood impacts due to the proposed development for the modelled 20 year ARI and 100 year ARI flood events. Increases in peak flood level are of greater magnitude in the PMF event, however these remain local to the development. There are no impacts upstream or downstream of the proposed Ivanhoe Estate development in all modelled design events, hence there is no potential the Ivanhoe Estate development to cause an increase in flood frequency, or flood inundation which may cause social or economic costs to the community.

5.3.3 Impacts on Erosion, Siltation, Riparian Vegetation and Bank Stability

As discussed in Section 5.2, the modelling of the Ivanhoe Estate Master Plan considered revisions to land use, drainage network, building layout and proposed bridge location. Due to the preliminary nature of the planning process, this modelling did not consider any changes to the Shrimpton Creek corridor, which may potentially include;

- land-forming;
- change in vegetation; and
- landscape features.

The results of the proposed scenario model, did not indicate any substantial change in flood level, or changes to in-channel flood velocity. Changes in in-channel flood velocity, especially those in greater frequency flood events (i.e. less than the 20 year ARI), have the potential to cause erosion which may reduce bank stability. If velocities are substantially decreased, then there is potential for siltation, which may cause issues to the growth of riparian vegetation. However, given there are no flood impacts in the modelled design events up to the 100 year ARI, there is limited potential for there to be any changes to erosion, siltation or bank stability due to the modelled conditions of the Ivanhoe Estate development.

We trust the above provides a suitable description of the existing flood behaviour at the site and the potential flood impacts associated with the proposed development. Please feel free to contact the undersigned to discuss further as required.

Yours Faithfully,
BMT WBM

Sebastian Froude
Engineer

6 References

NSW Department of Infrastructure, Planning and Natural Resources (DIPNR) (2005), *Floodplain Development Manual*.

Howells, L., McLuckie, D., Collings, G., Lawson, N. (2003). *Defining the Floodway – Can One Size Fit All?* Floodplain Management Authorities of NSW 43rd Annual Conference, Forbes

McLuckie, D., Babister, M., Smith, G., Thomson, R., (2014). *Updating National Guidance on Best Practice Flood Risk Management*, Floodplain Management Association Conference, Deniliquin, May 2014

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Appendix A Summary of DCP Controls

Summary of Relevant City of Ryde Development Controls Regarding Flooding at Ivanhoe Estate Redevelopment

Definitions and understandings for the development controls according to City of Ryde's Development Control Plan 2014.

- **In accordance with the NSW Floodplain Development Manual, flood levels are determined from the 100yr ARI (Annual Recurrence Interval) storm event.**
- The level of flood risk is basically a product of flood depth and the velocity of flow and can be categorised as follows.
  - High Flood Risk – Areas where there is a potentially catastrophic damage to property, risk to life, evacuation problems or where development would significantly or adversely alter flood behaviour. Most development is restricted in these locations.
  - Medium Flood Risk – Areas whereby there would be potential flood damage or public safety is a concern but could be addressed by the application using appropriate measures.
  - Low Flood Risk – Land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified as either High Flood Risk, Medium Flood Risk Precinct or as an Overland Flow Precinct.
  - Overland Flood Risk – Areas identified as Overland Flow Precincts are distant from watercourses where shallow inundation (relative to major flooding) occurs following heavy rain. Typically, the depth of inundation will be less than 0.3 m to 0.5 m but more than 0.1 m to 0.2 m in a 100 year ARI event.
- Minor overland flow depths may typically be around 50mm to 100mm and, whilst they do not present great risk to development, must meet the minimum development control requirements to ensure there is adequate protection from any stormwater inundation.
- **Freeboard – An additional level difference applied above the flood level**
- **Habitable – Floor areas which are furnished or provide dry storage of goods. Inundation of these areas would result in a great loss of amenity and property damage to the development.**
- **Non-Habitable – Enclosed or partially open floor area which is not habitable.**

Development and Land Use Categories likely to be present in the redevelopment:

- Residential Development
- Retail, Commercial & Industrial Development
- Recreation and Non-Urban Development
- Landform Development
- Carparking Areas
- **Sensitive Uses and Facilities, defined as; Development accommodating services or facilities which are essential to evacuation during periods of flooding or if effected would**

unreasonable affect the ability of the community to return to normal activities after flood events. Examples of this include educational establishments, residential care facilities, fuel stations, public utility buildings, etc.

- **Critical Uses and Facilities, defined as; Emergency services facilities, administration building or public administration building that may provide an important contribution to the notification or evacuation of the community during flood events.**

Corresponding to the likely Development and Land Use Categories the following controls must be adhered according to City of Ryde's Development Control Plan 2014:

1. A Flood Impact Statement is to be prepared in accordance with Section 2.2 of the Stormwater and Floodplain Management Technical Manual and is required to address the various controls related to the following development types.
2. To minimise property damage, the following finished surface levels must be attained for new parking areas;
    a. For open parking areas, no less than the 100yr ARI flood level.
    b. For enclosed parking areas, the parking area must be no less than the 100yr ARI flood level plus 150mm freeboard.
    c. Basement parking or parking at levels below the adjacent flood levels, a bunded crest at the estimated PMF (probable maximum flood) level prior to descent into the parking area, must be provided such that inundation of the area is prevented.
    d. For new parking areas associated with concessional development, parking areas are to be elevated to habitable floor level.
3. New parking areas must not divert overland flow or reduce flood storage such to adversely impact the surrounding area.
4. Large open parking areas (greater than 10 carspaces) must provide adequate restraints or barriers to prevent vehicles leaving the site up to the 100yr ARI flood event.
5. The utilisation of existing parking areas must not result in the increased risk to property damage or threat to public safety.
6. **For landform development exposed to Low Risk and above Flood Risk Category (or where this is not known, the indicative extent of inundation on Councils mapping system) the following must occur.**
    a. Fences are permeable, open or otherwise a frangible structure, such to permit the conveyance of floodwaters below the 100yr ARI flood event. In the event the flood level is unknown, 200mm above ground level is to be adopted.
    b. The face of retaining walls, pools or garden beds aligned towards overland flows are no greater than 200mm in height, unless it can be demonstrated such a structure will not have an adverse impact to the surrounding area by way of a Flood Impact Statement.

7. Residential development on land subject to flood risk categorised as high will not be permitted unless it can be clearly demonstrated that development under this section can be undertaken on the land without jeopardising public safety and access, property damage or adverse ramifications of the pre-developed flood regime by means of a Flood Impact Statement.

8. For Residential development floor levels of habitable and non-habitable areas must comply with the freeboard requirements as stated in Table 2.1 of the Stormwater Technical Manual, reproduced below.

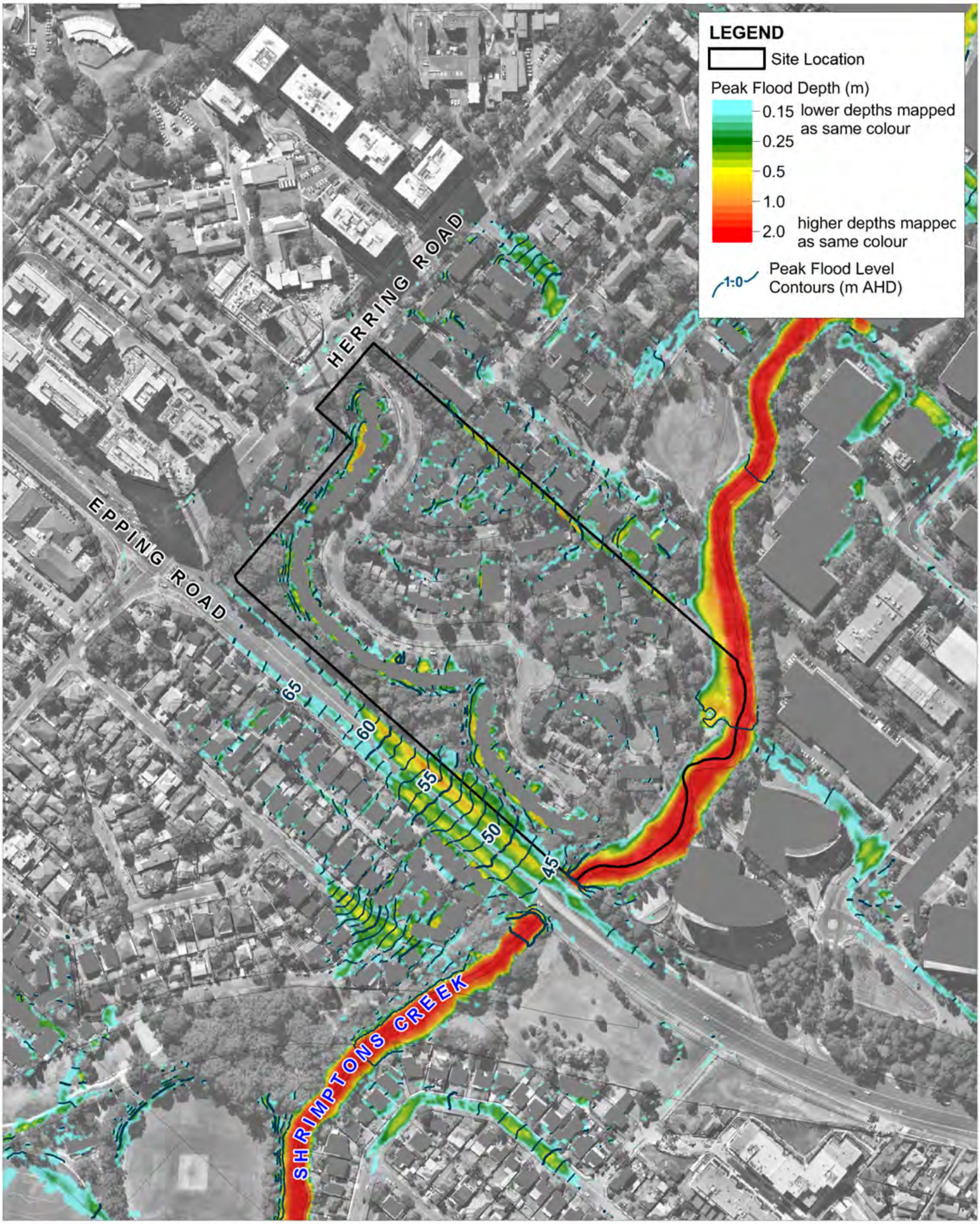
Drainage System/ Overland Flow	Residential			Industrial/ Commercial	
	Land Level [(b)]	Habitable Floor Level	Non-Habitable Level [(c)]	Land Level [(b)]	Floor Level
Surface Drainage/ adjoining ground level [(a)]	-	.15m	-	-	.15m
Public drainage infrastructure, creeks and open channels	0.5m	0.5m	0.1m	0.3m	0.3m
Flooding and Overland Flow (Overland Flow Precincts and Low Risk)	N/A	0.3m	0.15m	N/A	0.3m
Flooding and Overland Flow (Medium Risk and greater)	N/A	0.5m	0.3m	N/A	-
Onsite Detention [(d)]	N/A	0.2m	0.1m	N/A	0.2m
Road Drainage Minor Systems (Gutter and pipe flow)		0.15m below top of grate			
Road Drainage		Refer to Figure 2-1.			
Detention Basins [(4)]		The top water level shall be designed to be 0.5m below top of embankment (100yr ARI)			

Table 2.1 Freeboard requirements.

9. **For Residential, Commercial and Recreational developments, new structures subject to flooding and overland flow (excluding those sites located in Overland Flow Precincts) must be designed and constructed to withstand the anticipated hydrostatic forces. For all parts of the development potentially exposed to floodwater, below the minimum freeboard requirement, the development structure must:**
    a. **Be constructed of flood compatible building components in accordance with the Stormwater and Floodplain Management Technical Manual.**
    b. **A structural engineer must certify that the completed works are designed and capable of withstanding forces subject to forces of floodwater, debris, buoyancy forces anticipated by the 100yr ARI flood event.**
10. Residential, Commercial and Recreational developments must not divert major overland flows or reduce flood storage such to adversely impact the neighbouring property or surrounding area. It must be demonstrated the development does not;
    a. Reduce the pre-developed level of flood storage.
    b. Increase flood levels or velocities such to adversely impact adjoining dwellings.
11. If Residential and Commercial developments involve subdivision of the land, it must be demonstrated that any potential development of this newly created allotment can comply with the controls under this section.
12. For Residential and Commercial developments, a restrictive covenant must be placed on the title of the land to ensure there are no further significant works and alterations to the landform or development are undertaken without the approval of Council such to impact on flooding.
13. Commercial development on land subject to flood risk categorised as high will not be permitted unless it can be clearly demonstrated that development under this section can be undertaken on the land without jeopardising public safety and access, property damage or adverse ramifications of the pre-developed flood regime by means of a Flood Impact Statement.
14. **For Commercial and Recreational developments floor levels of habitable and non-habitable areas must comply with the freeboard requirements as stated in Table 2.1 of the Stormwater Technical Manual. If these levels cannot be practically achieved for the entire floor area (E.g. for reasons of accessibility from a public space) then a lesser level may be considered subject to consideration of the extent or scale of property damage and risk to public safety**
15. For Commercial and Recreational developments, all goods and materials must be stored at the minimum habitable floor level, complying with the freeboard requirements as stated in Table 2.1 of the Stormwater Technical Manual, unless the site is located in an Overland Flow Precinct in which case this may be reduced to 500mm above the adjoining ground level. Exemptions from this may be considered if it can be demonstrated in the Flood Impact Statement, that the materials will not adversely impact the surrounding environment or can be damaged if subject to stormwater inundation.
16. Recreational developments located on large lots subject to full inundation must demonstrate that adequate refuge is provided for all occupants above the PMF (probable maximum flood) event. This is to ensure that public safety is maintained.

17. **Development categorised as "Sensitive Uses and Facilities" as per Schedule 2 subject to flood risk categorised as MEDIUM or HIGH will not be permitted.**
18. **For Sensitive Uses and Facilities developments all floor levels must be no lower than the PMF level. Exemption from this may be considered, subject to consideration of the extent or scale of impact to the community that would occur in the event the structure is inundated.**
19. For Sensitive Uses and Facilities developments, new structures subject to flood waters and major overland flows must be designed and constructed to withstand the anticipated hydrostatic forces. For all parts of the development potentially exposed to floodwater up to the PMF event, the development structure must:
    a. be constructed of flood compatible building components in accordance with the Stormwater Technical Manual.
    b. A structural engineer must certify that the completed works are designed and capable of withstanding forces subject to forces of floodwater, debris, buoyancy forces anticipated by the PMF flood event.
20. Sensitive Uses and Facilities developments must not adversely impact the existing flood regime in terms of diverting major overland flows or reduce flood storage such to adversely impact the surrounding area. The submitted Flood Impact Statement must demonstrate the development does not;
    a. Reduce the pre-developed level of flood storage.
    b. Increase flood levels or velocities such to adversely impact adjoining dwellings.
21. Development categorised as "Critical Uses and Facilities" as per Schedule 2 will not be permitted on land subject to major overland flows and floodwaters, excluding lots identified as Overland Flow Precincts.

Appendix B Flood Mapping for Current Scenario



Title:

Peak Flood Depth
20 yr ARI

Figure: **B-1**

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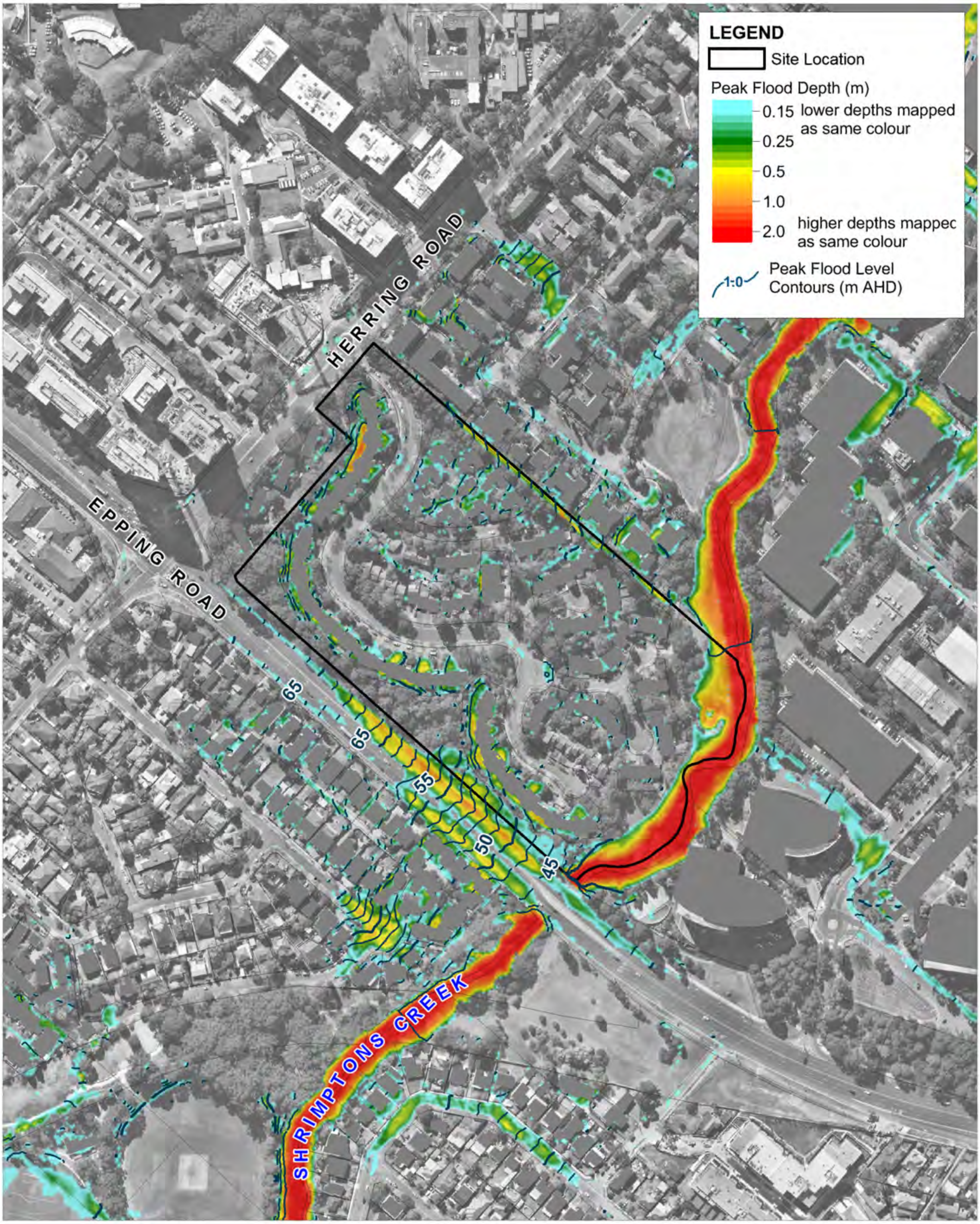

Title:

Peak Flood Depth
100 yr ARI

Figure: **B-2**

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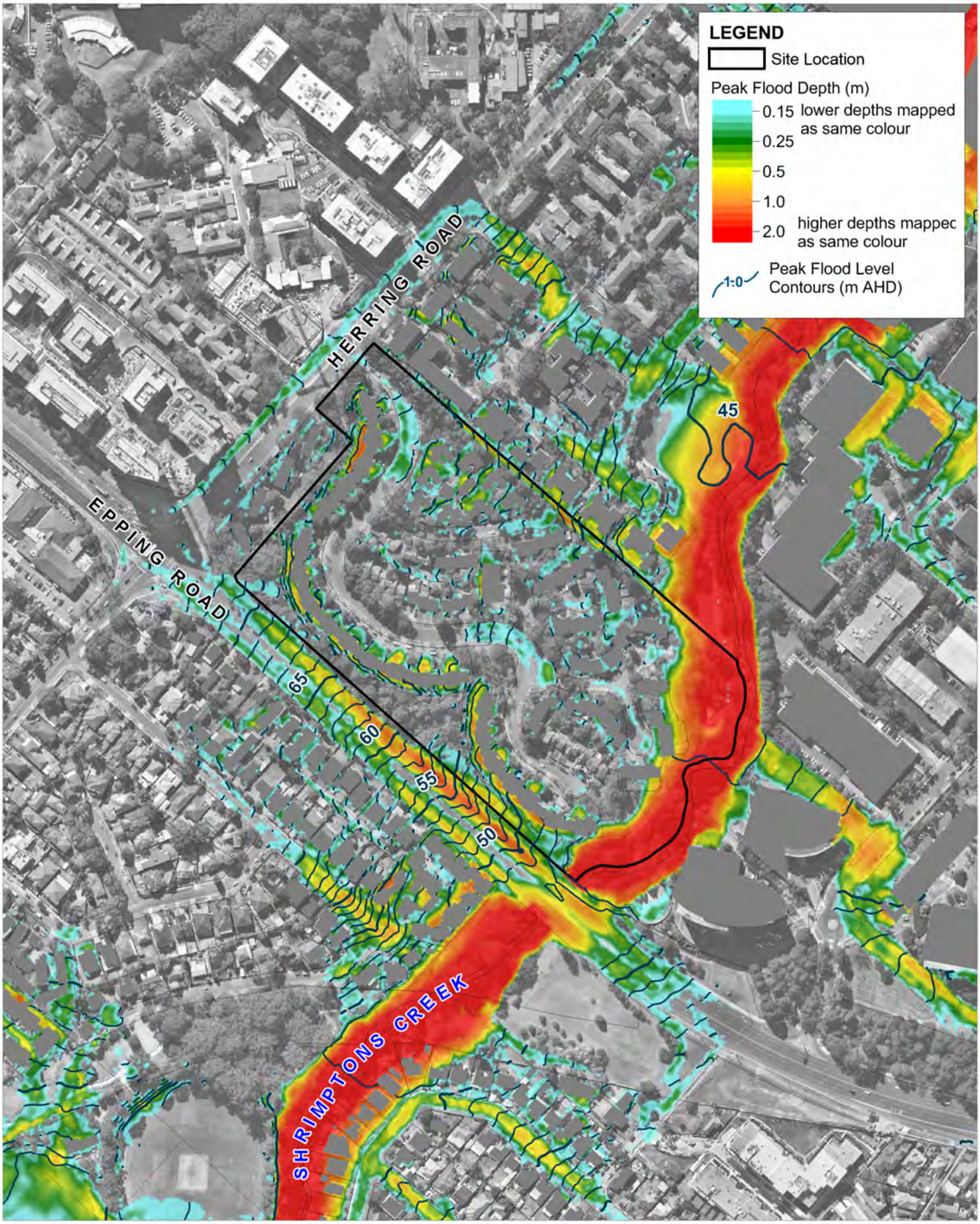

Title:

Peak Flood Depth
Probable Maximum Flood (PMF)

Figure:

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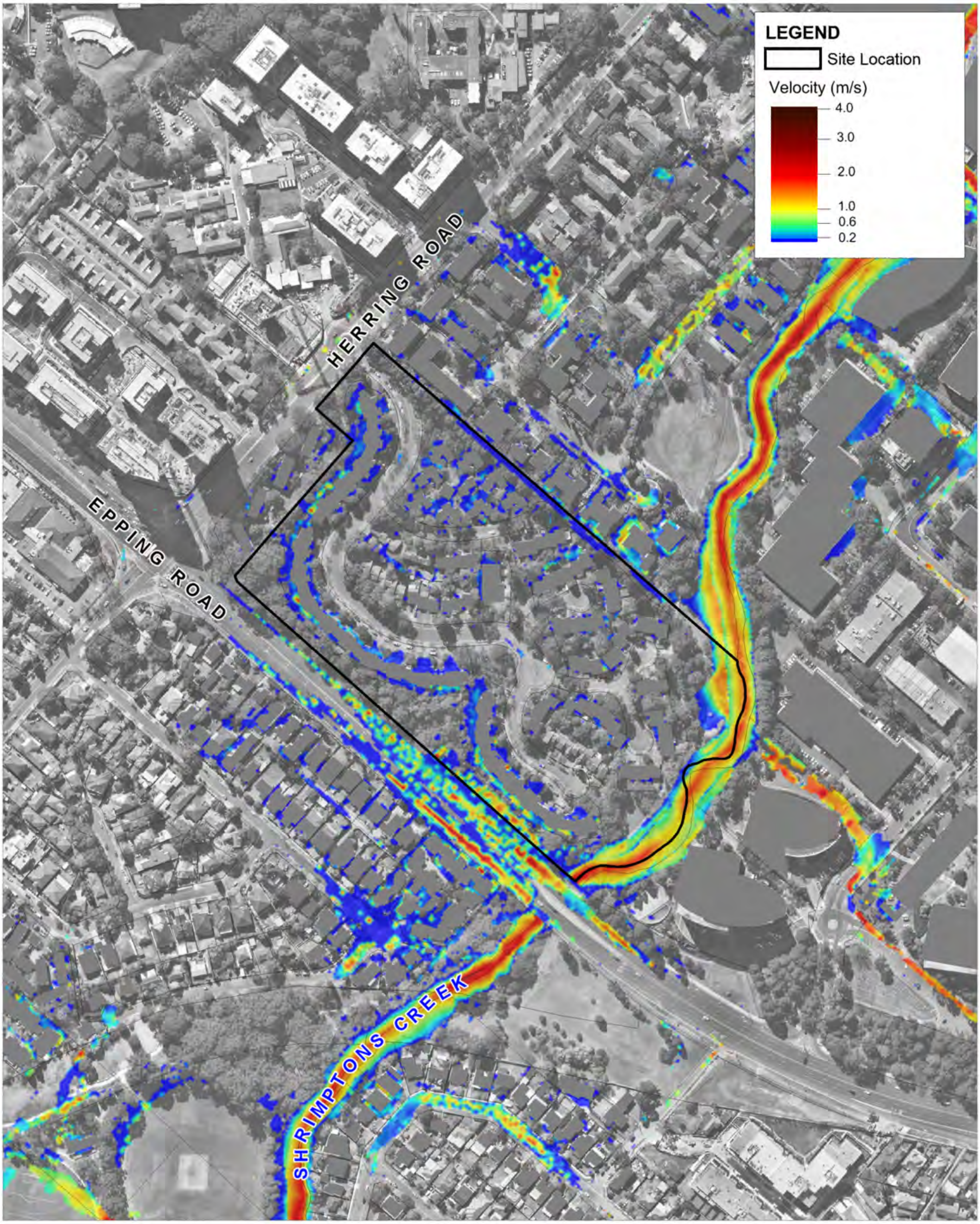

Title:

Peak Flood Velocity
20 yr ARI

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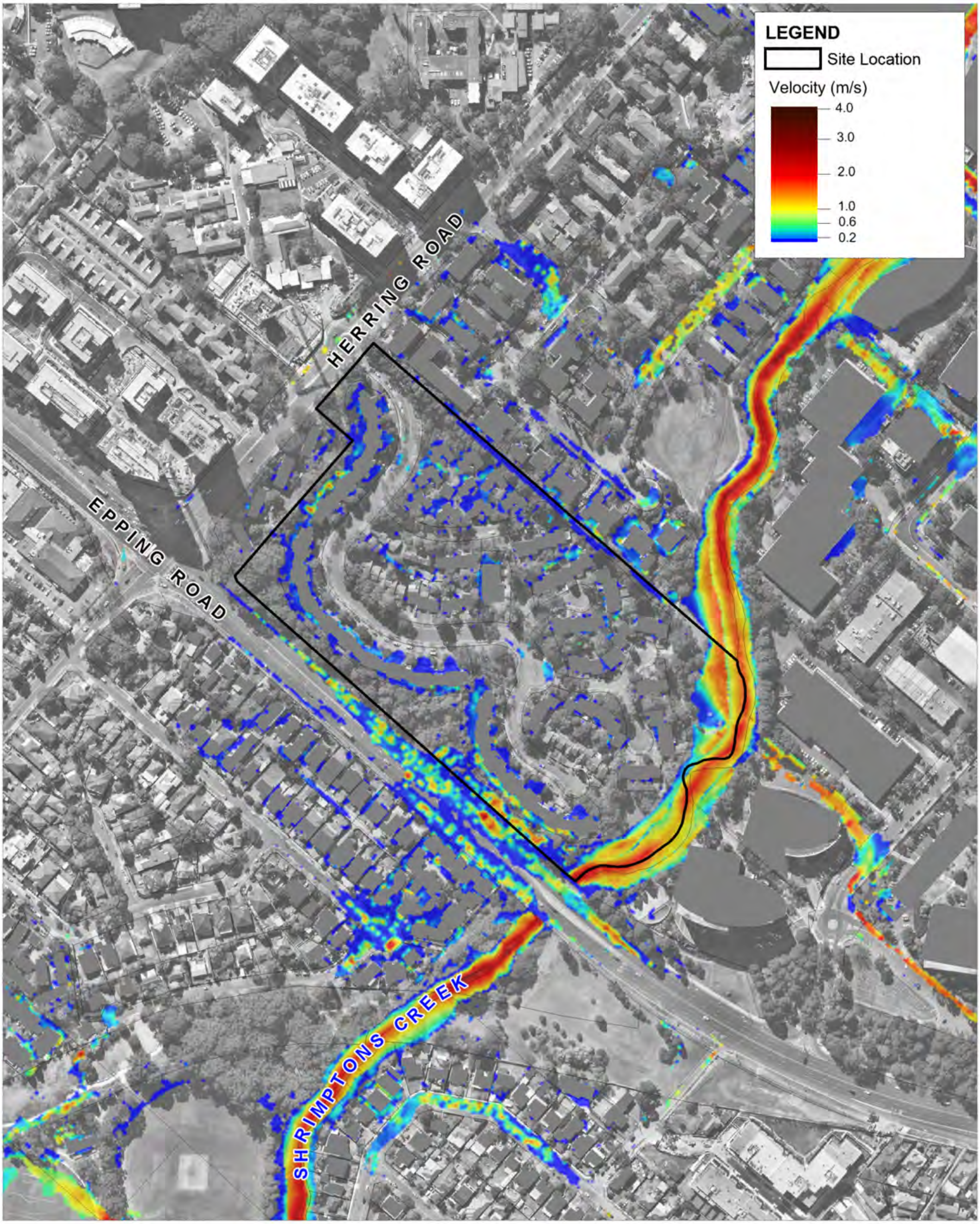

Title:

Peak Flood Velocity
100 yr ARI

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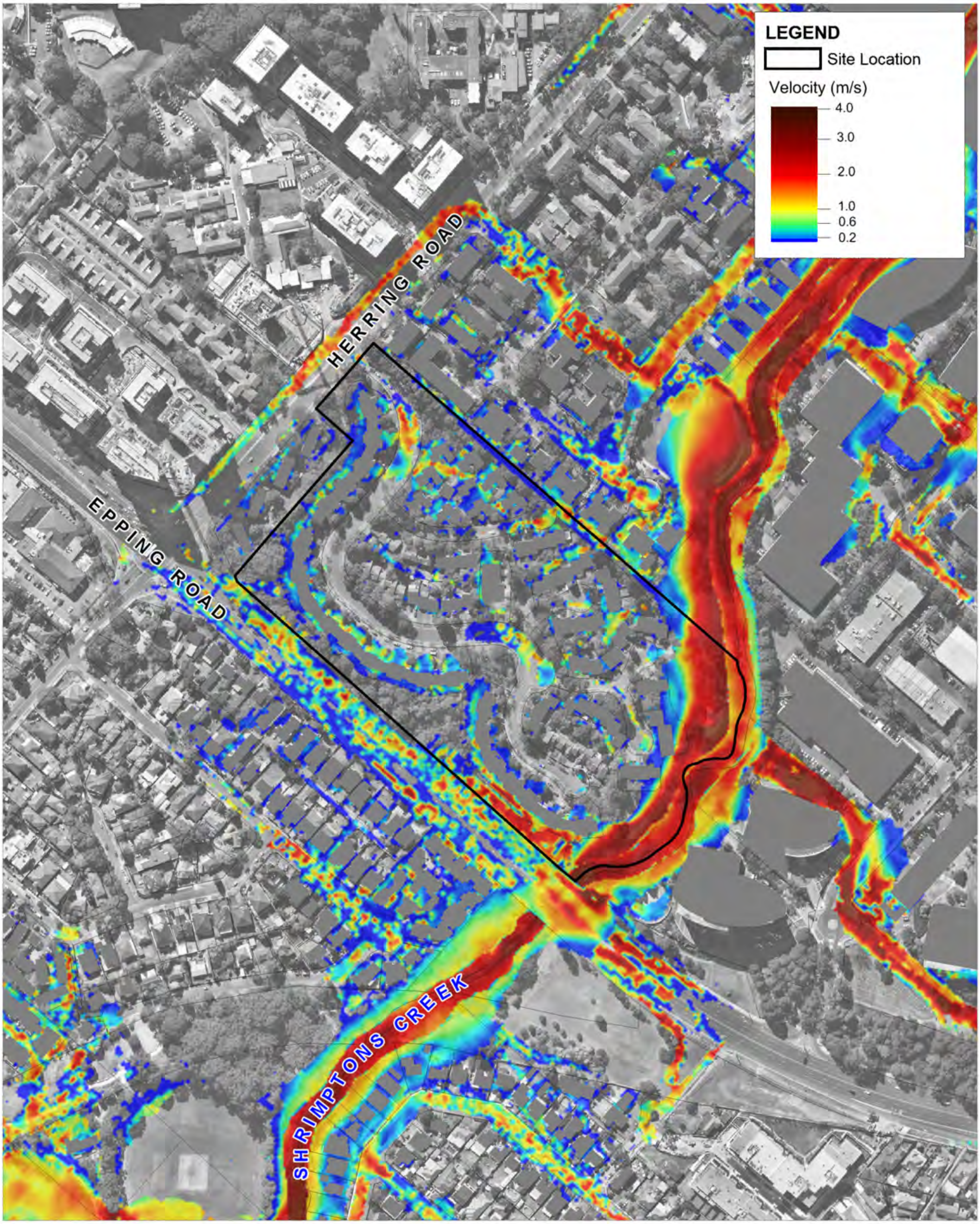

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Peak Flood Velocity
Probable Maximum Flood (PMF)

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