BMT Commercial Australia Pty Ltd
Suite G2, 13-15 Smail Street
Ultimo, Sydney, NSW, 2007
Australia
PO Box 1181, Broadway NSW 2007

Tel: +61 2 8960 7755
Fax: +61 2 8960 7745

ABN 54 010 830 421

www.bmt.org

Our Ref: JMH:
L.N20951.006.01_45_Warriewood_Rd_FIA.docx

18 May 2021

Warriewood Developers Pty Ltd
3 Kerrie Road
Oatlands NSW 2117

Attention: Sanjeev K Loura

Dear Sanjeev

**RE: 45 WARRIEWOOD ROAD, WARRIEWOOD FLOOD IMPACT ASSESSMENT – RESPONSE TO COUNCIL COMMENTS ON NATURAL ENVIRONMENT (FLOODING)**

We understand that Northern Beaches Council ("Council") has reviewed the '*45 Warriewood Road, Warriewood Flood Impact Assessment' (BMT, 30 September 2020)* that was submitted with Development Application DA2020/1517.

Based on Council's response documented in the "Natural Environment Referral Response – Flood" dated 22 January 2021, we understand that the overall methodology and outcomes of the Flood Impact Assessment (FIA) were found to be sound. However, Council requested further clarification related to the inclusion of the proposed 900mm stormwater pipe through 43 Warriewood Road and the modelling of the 1% AEP flood plus climate change. Council's "Request for further information of Development Application DA2020/1517" dated 7 May 2021 also identified that further clarification on the flood modelling approach is required (assumed to be related to those items raised by Council in their letter dated 22 January 2021). Please find below our response to each of Council's specific queries.

***"Whether the proposed 900mm stormwater pipe to replace the concrete lined open channel at 43 Warriewood Road has been reflected in the TUFLOW model and adequately considered in the flood impact assessment".***

**Proposed 900mm stormwater pipe at 43 Warriewood Road:**

The proposed 900mm pipe at 43 Warriewood Road has not been included in the TUFLOW model.

The dominant flooding mechanism at the site for flood impact assessment and flood planning requirements is mainstream Narrabeen Creek flooding. Therefore, the Flood Impact Assessment (FIA) considers mainstream flooding only and there is no component of local catchment flooding within the model (noting the TUFLOW model was originally based on a truncated version of the Narrabeen Lagoon mainstream TUFLOW model approved for use by Northern Beaches Council). Therefore, no aspect of the results presented within the FIA would be altered by the inclusion of the proposed 900mm pipe because there is no component of local catchment flows applied within our model upstream of the proposed 900mm pipe inlet.

Furthermore, it is assumed that the 900mm pipe has been designed to ultimately convey the same flow volume from the upstream local drainage catchment that was conveyed by the open channel. Thus, the flow volume discharged into Narrabeen Creek at the pipe outlet should not vary from the flow volume under

pre-piped conditions and accordingly, the 900mm pipe and its outflows should not result in any impact on flood behaviour within Narrabeen Creek itself or mainstream flood conditions within the site.

However, it should be noted that if a coincident local catchment and Narrabeen Creek event were to occur, the 900mm pipe outlet (invert level ~2.7 mAHD, obvert level ~3.6 mAHD) would be partially submerged at peak of the 2 year ARI event (peak flood level ~3.3 mAHD) and completely submerged during a 20% AEP flood (peak flood level ~3.9 mAHD).

**Other Modifications within 43 Warriewood Road:**

We understand that there will be other modifications and improvements within 43 Warriewood Road associated with this development. This includes the proposed extension of Lorikeet Grove across 43 Warriewood Road that connects to the completed section of Lorikeet Grove within the site to the east (i.e. the former 41 Warriewood Road), as well as associated earthworks.

We can confirm that the extension to Lorikeet Grove within 43 Warriewood Road has been included in the TUFLOW model. However, no other earthworks outside of the proposed Lorikeet Grove extension and within 43 Warriewood Road have been modelled.

Any filling that may be proposed to the north of Lorikeet Grove and within 43 Warriewood Road would only impact on the post-development PMF flood extent (i.e. no inundation of this area is predicted in events up to and including the 1% AEP + climate change event under developed conditions). Potential impacts resulting from any filling of this small area are predicted to be negligible, particularly when considering the volume of proposed fill below the PMF flood level in this portion of 43 Warriewood Road against the overall proposed fill volumes considered within the modelling and the associated negligible impacts on peak PMF flood levels and minor impacts on peak PMF flow velocities documented in the FIA report.

***"Figures 4 and 5 of the Flood Impact Assessment Report prepared by BMT represent the 1% AEP event and the 1% AEP event plus climate change, respectively. However the flood extents appear identical despite Figure 5 representing a larger magnitude flood event. This is inconsistent with Figures B-3 and B-4 which also represent the same flood events. Has the impact of the 1% AEP plus climate change been adequately modelled and represented in the report?"***

The impact of the 1% AEP plus climate change event has been adequately modelled. However, unfortunately there is an error in the mapping shown in the climate change figures included in the '*45 Warriewood Road, Warriewood Flood Impact Assessment' (BMT, 30 September 2020)*.

This mapping has now been checked for all climate change results and rectified, as necessary. Please find attached an updated version of the report that includes this revised mapping.

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We trust that this response suitably addresses Council's outstanding issues relating to the Flood Impact Assessment. Further information or clarification can be obtained by contacting the undersigned (*ph.: (02) 8960 7755 or email: jacquie.hannan@bmtglobal.com*).

Yours Faithfully

**Jacquie Hannan**
**Principal Engineer**
**BMT**

*Attached: '45 Warriewood Road, Warriewood Flood Impact Assessment' (BMT, 4 February 2021)*

BMT Commercial Australia Pty Ltd
Suite G2, 13-15 Smail Street
Ultimo, Sydney, NSW, 2007
Australia
PO Box 1181, Broadway NSW 2007

Tel: +61 2 8960 7755
Fax: +61 2 8960 7745

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4 February 2021

Sanjeev K Loura
Warriewood Developers Pty Ltd
3 Kerrie Rd, Oatlands NSW 2117

Attention: Sanjeev K Loura

Dear Sanjeev,

**RE: 45 WARRIEWOOD ROAD, WARRIEWOOD FLOOD IMPACT ASSESSMENT**

BMT was commissioned to provide a flood impact assessment for the proposed development at 45-49 Warriewood Road, Warriewood (the site). This report has been prepared to accompany the Environmental Impact Statement (EIS) for the site.

The proposed development is comprised of the residential subdivision and civil works of Lot 2 DP349085 and Lot 1 DO349085 45-49 Warriewood Road, Warriewood (see Figure 1). The site is located adjacent to Narrabeen Creek (flowing along the southern boundary of the site) and is classified as Flood Category 1 – High Hazard, with the southern portion of the site being inundated by floodwaters in the 1% annual exceedance probability (AEP) flood event.

## Council Requirements

In accordance with the *Pittwater Local Environment Plan 2014, Pittwater 21 Development Control Plan* and the *Flood Prone Land Design Standard* (Northern Beaches Council) the following flood planning requirements are applicable to the site:

**Table 1 *Pittwater Local Environment Plan 2014* flood planning requirements**

| Pittwater LEP 2014 Clause | Response |
|---|---|
| ***7.3 Flood planning***<br>***(1) (1)*** *The objectives of this clause are as follows;* | |
| *(a) to minimise the flood risk to life and property associated with the use of land,* | The lots will be filled above the flood planning level plus an allowance for climate change. Most of the lots are also flood free in the probable maximum flood (PMF) with the exception of the two south-eastern lots where flood depths are up to 0.2m in the PMF. Lorikeet Grove provides egress from these lots out of the floodplain to Bubalo Street. |
| *(b) to allow development on land that is compatible with the land's flood hazard,* | The total development area is approx. 10,800m$^2$ of which approx. 3,900m$^2$ is currently within the low hazard area of the 1% AEP floodplain under the future |

| Pittwater LEP 2014 Clause | Response |
|---|---|
| *taking into account projected changes as a result of climate change,* | climate scenario. Post development, the lots will be above the flood planning level and outside the 1% AEP floodplain under the future climate scenario. |
| *(c) to avoid significant adverse impacts on flood behaviour and the environment.* | There are no significant flood impacts on surrounding properties for events up to the PMF under the existing or future climate scenarios. |
| ***(2)** This clause applies to land at or below the flood planning level.* | Noted |
| ***(3)** Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development—* | |
| *(a) is compatible with the flood hazard of the land, and* | As per (1)(b) the total development area is approx. 10,800m$^2$ of which approx. 3,900m$^2$ is currently within the low hazard area of the 1% AEP floodplain under the future climate scenario. Post development, the lots will be above the flood planning level and outside the 1% AEP floodplain under the future climate scenario. |
| *(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and* | As per (1)(c) above there are no significant flood impacts on surrounding properties for events up to the PMF under the existing or future climate scenarios. |
| *(c) incorporates appropriate measures to manage risk to life from flood, and* | As per (1)(a) above the lots will be filled above the flood planning level. Most of the lots are also flood free in the PMF with the exception of the two south-eastern lots where flood depths are up to 0.2m in the PMF. Lorikeet Grove provides egress from these lots out of the floodplain to Bubalo Street. |
| *(d) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding*<br>. | As per (1)(a) and (c) above the lots will be filled above the flood planning level. Most of the lots are also flood free in the PMF with the exception of the two south-eastern lots where flood depths are up to 0.2m in the PMF. Lorikeet Grove provides egress from these lots out of the floodplain to Bubalo Street. There are also no significant flood impacts on surrounding properties for events up to the PMF under the existing or future climate scenarios. |
| ***(4)** A word or expression used in this clause has the same meaning as it has in* | Noted |

| Pittwater LEP 2014 Clause | Response |
|---|---|
| *the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.* | |
| ***(5)** In this clause—* | |
| *(a) flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metres freeboard, or other freeboard determined by an adopted floodplain risk management plan.* | The adopted flood planning level for the site is the 1% AEP flood level plus 0.5 metres freeboard. |
| *(b) floodplain risk management plan has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0), published in April 2005 by the NSW Government.* | Noted |

**Table 2 Pittwater 21 DCP flood planning requirements**

| Pittwater 21 DCP Clause | Response |
|---|---|
| **B3 Hazard Controls: B3.11 Flood Prone Land** | |
| **A1;** *Development (including earthworks and subdivision) shall not be approved unless it can be demonstrated in a Flood Management Report that it complies with the Flood Prone Land Design Standard found on Council's webpage.* | Refer Table 3. |
| **A3;** *The applicant shall include in their submission, calculations to illustrate that any fill or other structures that reduce the total flood storage are replaced by Compensatory Works.* | The total flood storage on site in the 1% AEP is 35,900m$^3$. The extent of development and associated fill requirements are defined by the alignment of Lorikeet Grove. To fill this area to the flood planning level there is a net loss of flood storage of approx. 6,600m$^3$, of which 3,100m$^3$ is to raise Lorikeet Grove and 3,500 m$^3$ to fill the lots between Lorikeet Grove and flood free land. Compensatory works are not proposed in the floodplain due to ecological constraints. |
| **B1;** *Flood mitigation works or stormwater devices that modify a major drainage system, stormwater system, natural water course, floodway or flood behaviour within or outside the development site may be permitted subject to demonstration through a Flood Management Report that they comply with the Flood Prone Land Design Standard found on Council's webpage.* | Refer Table 3. |
| **E1;** *Development shall comply with Council's Flood Emergency Response Planning for Development in* | Most of the lots are flood free in the PMF with the exception of the two south-eastern lots |

| Pittwater 21 DCP Clause | Response |
|---|---|
| *Pittwater Policy and the outcomes of any Flood Risk Emergency Assessment Report where it applies to the land.* | where flood depths are up to 0.2m in the PMF. Lorikeet Grove provides egress from these lots out of the floodplain to Bubalo Street. |
| ***E2;*** *New development must provide an appropriately sized area to safely shelter in place above the Probable Maximum Flood level and appropriate access to this area should be available from all areas within the development.* | |
| ***F1;*** *New floor levels within the development shall be at or above, the Flood Planning Level. A reduced Flood Planning Level may be considered only where it is permitted in this Development Control Plan.*<br>*The structure must be flood proofed (wet or dry) to the Flood Planning Level. This control cannot be applied to critical or vulnerable uses.* | The development will be filled above the flood planning level. |
| ***F2;*** *All development structures must be designed and constructed so as not to impede the floodway or flood conveyance on the site, as well as ensuring no loss of flood storage in a 1% AEP Event. Where the dwelling is located over a flow path it must be elevated on suspended pier/pile footings such that the level of the underside of all floors including balconies and decks within the flood affected area are at or above, or raised to the Flood Planning Level to allow clear passage of the floodwaters under the building. The development must comply with the Flood Prone Land Design Standard.* | The development does not impede the floodway.<br>There are no significant impacts due to changes in conveyance for any event up to the PMF under the existing or future climate scenarios.<br>As per A3, the total flood storage on site in the 1% AEP is 35,900m$^3$. The extent of development and associated fill requirements are defined by the alignment of Lorikeet Grove. To fill this area to the flood planning level there is a net loss of flood storage of approx. 6,600m$^3$, of which 3,100m$^3$ is to raise Lorikeet Grove and 3,500 m$^3$ to fill the lots between Lorikeet Grove and flood free land. Compensatory works are not proposed in the floodplain due to ecological constraints. |
| ***H1;*** *Fencing, including pool fencing, shall be designed so as not to impede the flow of flood waters and not to increase flood affectation on surrounding land. Appropriate fencing must comply with the Flood Prone Land Design Standard in addition to other regulatory requirements of pool fencing.* | Refer Table 3. |
| **B3.12 Climate Change Assessment for Land Identified on Flood Hazard Maps** | |
| *3) The climate change assessment shall include the impacts of climate change on the property over the life of the development and the adaptive measures to be incorporated in the design of the project. The following climate change scenarios shall be considered:*<br>• ***Scenario 1:*** *Impacts of sea level rise only*<br>• ***Scenario 2:*** *Impacts of sea level rise combined with increased rainfall volume* | Flood impacts have been assessed for a range of flood magnitudes for climate change scenario 2 (worst case). |

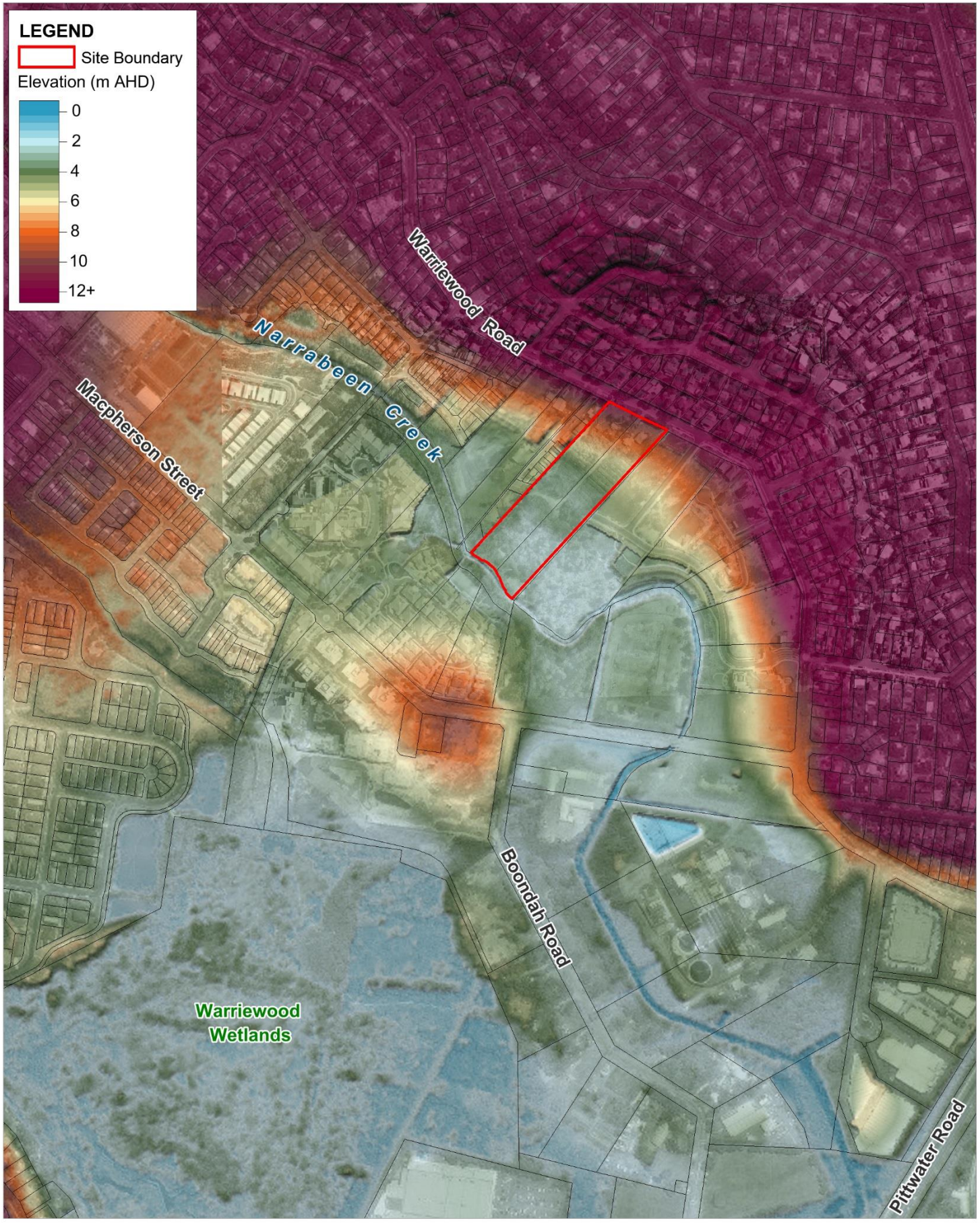
| Pittwater 21 DCP Clause | Response |
|---|---|
| **C6.1 Flooding** | |
| *The flood levels are to be determined as part of the Water Management Report. The information to be obtained includes:* | |
| • *the 50% Annual Exceedance Probability (AEP) flood levels with climate change impacts including sea level rise combined with increase rainfall volume;* | Based on the 2 Year ARI from the Narrabeen Lagoon Flood Study<br>Climate change based on the 1% AEP + CC downstream boundary and 30% increase in rainfall volume (Figure D-1) |
| • *the 20% AEP flood levels with climate change impacts including sea level rise combined with increase rainfall volume;* | Based on the 20% AEP from the Narrabeen Lagoon Flood Study<br>Climate change based on the 1% AEP + CC downstream boundary and 30% increase in rainfall volume (Figure D-2) |
| • *the 1% AEP flood levels with climate change impacts including sea level rise combined with increase rainfall volume;* | Based on the 1% AEP from the Narrabeen Lagoon Flood Study<br>Climate change based on the 1% AEP + CC downstream boundary and 30% increase in rainfall volume (Figure D-3) |
| • *the Flood Planning Level (FPL) - equal to the 1% AEP flood level plus freeboard (as defined within clause A1.9 of this DCP) with climate change impacts including sea level rise combined with increase rainfall volume;* | Based on the 1% AEP from the Narrabeen Lagoon Flood Study plus 0.5 metre freeboard<br>Climate change based on the 1% AEP + CC downstream boundary and 30% increase in rainfall volume |
| • *the Probable Maximum Flood (PMF) level with climate change impacts including sea level rise combined with increase rainfall volume;* | Based on the PMF from the Narrabeen Lagoon Flood Study<br>Climate change based on the 1% AEP + CC downstream boundary and 30% increase in rainfall volume (Figure D-4) |
| • *the flow velocities for the 1% AEP flood and Probable Maximum Flood with climate change impacts including sea level rise combined with increase rainfall volume; and* | Based on the 1% AEP and PMF from the Narrabeen Lagoon Flood Study (Appendices A, B and D) |
| • *the Flood Category and Flood Hazard Classification as defined in clause A1.9 of this DCP with climate change impacts including sea level rise combined with increase rainfall volume.*<br>• *Flood Hazard is classified as either Low Hazard or High Hazard.* | Flood categorisation and flood hazard results based on the 1% AEP (Appendix A and B) |
| *Likely flood impacts from the development must also be assessed and where required, mitigated. The filling of land will only be permitted where it can be demonstrated within the Water Management Report that:*<br>• *there is no net decrease in the floodplain volume of the floodway or flood storage area within the property, for any flood event up to the 1% AEP flood event and the PMF event including climate* | The development does not impede the floodway.<br>There are no significant impacts due to changes in conveyance for any event up to the PMF under the existing or future climate scenarios.<br>As per A3, the total flood storage on site in the 1% AEP is 35,900m$^3$. The extent of development and associated fill requirements |

| Pittwater 21 DCP Clause | Response |
|---|---|
| *change considerations for both design events; and/or*<br>• *there is no additional adverse flood impact on the subject and surrounding properties and flooding processes for any flood event up to the PMF event including climate change impacts*. | are defined by the alignment of Lorikeet Grove. To fill this area to the flood planning level there is a net loss of flood storage of approx. 6,600m$^3$, of which 3,100m$^3$ is to raise Lorikeet Grove and 3,500 m$^3$ to fill the lots between Lorikeet Grove and flood free land. Compensatory works are not proposed in the floodplain due to ecological constraints. |
| *The Water Management Report must identify the minimum floor level requirements for development in accordance with the Flood Hazard and Flood Category applicable to the proposed land use specified in Flood Risk Management Policy.*<br><br>*The subdivision of land requires the building platforms for each additional allotment to be created at or above the Flood Planning Level (plus climate change). The Plan of Subdivision is to include the Flood Planning Level (plus climate change) for each new allotment created.* | The adopted flood planning level for the site is the 1% AEP plus 0.5 metres freeboard. All lots will be filled to the flood planning level plus climate change. |

**Table 3 *Northern Beaches Flood Prone Land Design Standard* flood planning requirements**

| Flood Prone Land Design Clause | Response |
|---|---|
| A1 The development has been designed and can be constructed so that in a 1% AEP flood event:<br>(a) There is no net loss of flood storage/ floodway;<br>(b) There are no adverse changes in flood levels and velocities caused by alterations to the flood conveyance;<br>(c) There are no adverse effects on surrounding properties; and<br>(d) It is sited to minimise exposure to flood hazard | (a) As per A3, the total flood storage on site in the 1% AEP is 35,900m$^3$. The extent of development and associated fill requirements are defined by the alignment of Lorikeet Grove. To fill this area to the flood planning level there is a net loss of flood storage of approx. 6,600m$^3$, of which 3,100m$^3$ is to raise Lorikeet Grove and 3,500 m$^3$ to fill the lots between Lorikeet Grove and flood free land. Compensatory works are not proposed in the floodplain due to ecological constraints.<br>(b) (c) There are no significant impacts due to changes in conveyance for any event up to the PMF under the existing or future climate scenarios.<br>(d) The development is located on a combination of flood free land and the edge of the floodplain to Lorikeet Grove filled above the flood planning level. |
| B1 The development has been designed and can be constructed so that in a 1% AEP flood event:<br>(a) There is no loss of flood storage/floodway;<br>(b) There are no adverse effects on surrounding properties;<br>(c) The works do not have an adverse impact on the environment. (This includes but is not limited to the altering of natural flow regimes, the clearing of riparian vegetation, | (a) and (c) As per A1 (a) above.<br>(b) As per A1 (b) above. |

| Flood Prone Land Design Clause | Response |
|---|---|
| artificial modification of the natural stream, such as by relocation, piping etc, in accordance with Council's Protection of Waterways and Riparian Land Policy). | |
| F2 Fencing (including pool fencing, boundary fencing, balcony balustrades and accessway balustrades) shall be open for passage of flood waters - All new fencing on the property must be flood compatible with 50-75% of the fence being of an open design between the natural ground level and the Flood Planning Level. Only 25-50% of the perimeter fence would be permitted to be solid. Openings should permit a 75 mm sphere to pass through, and should not impede the flow of water. | The development is located above the flood planning level. |




Title:
**Site Locality**

Figure: **1**

Rev: **A**

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

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Approx. Scale

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# Existing Flood Risk

## Background

BMT previously completed a flood study of the Narrabeen Lagoon catchment on behalf of Pittwater and Warringah Councils in 2013. This study included the hydraulic modelling of the Narrabeen Lagoon catchment including the reach of Narrabeen Creek adjacent to the study site.

The original model developed as part of the Narrabeen Lagoon Flood Study (BMT WBM, 2013) was a detailed two-dimensional TUFLOW hydraulic computer model of the catchment with a 6 m grid resolution, for the simulation of catchment-wide design flood behaviour. The model was calibrated to previous major flood events in the catchment including April 1988 and March 2011. Due to the relatively coarse grid resolution, the reach of Narrabeen Creek between Jubilee Avenue and Macpherson Street was modelled as a 1D channel embedded within the 2D representation of the wider floodplain.

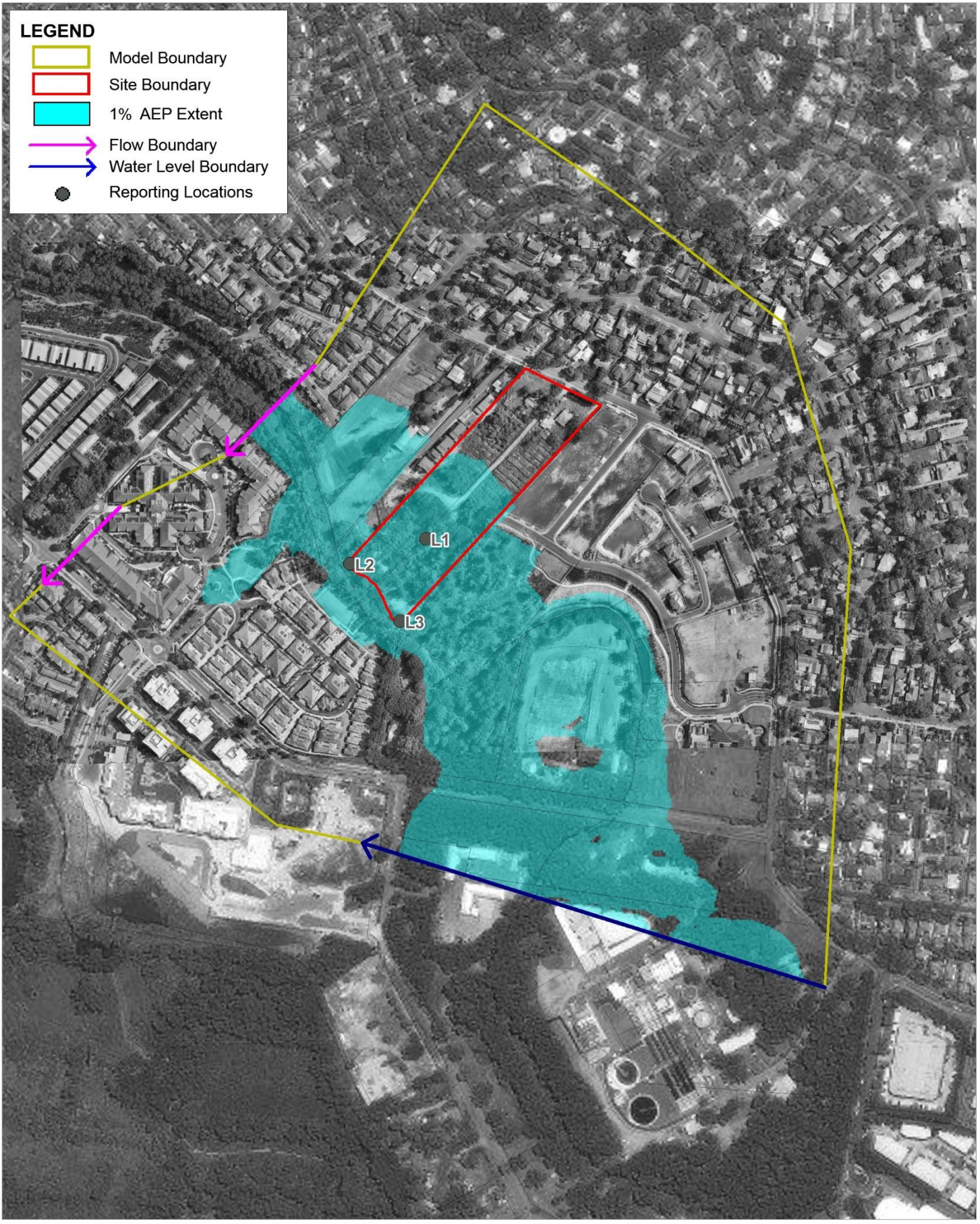
To better represent the existing design flood behaviour and enable the assessment of the channel modification proposed as part of the earthworks for the site, a refined local model of the Narrabeen Creek catchment was developed with a 2 m grid resolution, extending from 60 m downstream of Brands Lane to 130 m downstream of Macpherson Street, as shown in Figure 2. The refined model consisted of an upstream flow time series and downstream water level time series, both of which were extracted from the original Narrabeen Lagoon catchment-wide TUFLOW model. The model topography was defined by a combination of LiDAR data and site survey provided by Forge Venture Management and Craig and Rhodes (site survey provided from a previous flood impact assessment completed for 41 Warriewood Road). The modelled reach of Narrabeen Creek was converted to a 2D representation based on the available survey data.

The refined model was used to determine flooding extents and behaviour for a range of design flood events, including the 20% AEP, 10% AEP, 5% AEP, 1% AEP and PMF events, as well as the 1% AEP design event with climate change (2100 sea level rise and 30% increase in rainfall intensity, herein referred to as 1% AEP+CC event).The 2-hour storm duration was identified as the critical design event duration at the site, with the exception of the PMF event which had a critical duration of 5-hours due to the backwater influence of Narrabeen Lagoon.

## Baseline Flood Behaviour

The baseline model topography is a combination of LiDAR data and site survey provided by CMS Surveyors (15843detail 1.dwg), and also includes the finished landforms for the 29-31 Warriewood Road development as defined in 3D surface model 170925.dwg provided by Craig and Rhodes, 41 Warriewood Road development as defined in 3D surface model 063-16 Design DTM 170227.dwg provided by Craig and Rhodes, and 51C Warriewood Road development (based on PW5197583 Stamped Approved Plans provided by Council). This baseline approach is consistent with previous flood impact assessments undertaken by BMT in the Narrabeen Creek corridor. In addition, modifications were made to the topography at 19-21 Lorikeet Grove, and the Anglicare Warriewood Retirement Village based on aerial imaging along with street view images.

Modelled existing peak flood levels at selected locations (as presented in Figure 2) are provided in Table 4, for the full range of design flood events considered. The existing 20% AEP, 1% AEP, 1% AEP+CC and PMF design flood conditions are shown in Appendix A – Baseline/Existing Design Flood Behaviour (Figure A-1 – Figure A-3).




Title:
# Refined Model Configuration

Figure: 2

Rev: A



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Approx. Scale

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**Table 4 Simulated Existing Peak Flood Levels**

| Design Event (AEP) | Peak Flood Level (m AHD) | | |
|---|---|---|---|
| | Location 1 (L1) | Location 2 (L2) | Location 3 (L3) |
| **2 Year ARI (50% AEP)** | 3.17 | 3.73 | 3.25 |
| **20%** | 3.44 | 3.90 | 3.47 |
| **10%** | 3.53 | 3.96 | 3.55 |
| **5%** | 3.61 | 4.04 | 3.63 |
| **2%** | 3.68 | 4.10 | 3.70 |
| **1%** | 3.74 | 4.15 | 3.76 |
| **1% + Climate Change** | 3.84 | 4.24 | 3.86 |
| **PMF** | 4.88 | 4.89 | 4.88 |

It is evident that the design peak flood levels are relatively consistent across L1 and L3, with increases in peak levels at L2 at the upstream boundary of the site. During all events the capacity of Narrabeen Creek is exceeded, causing overbank flows to fill low-lying floodplain storage areas. This includes a small portion of the proposed development area along the proposed Lorikeet Grove roadway at the southern extremity of the development.

The peak flood levels in the lower sections of Narrabeen Creek are dominated by the Narrabeen Lagoon water levels. The limit of the 1% AEP Narrabeen Lagoon water level influence on Narrabeen Creek is approximately Macpherson Street Bridge. Upstream of the bridge, peak flood levels are driven by the local Narrabeen Creek channel capacity and catchment flows. As such, it is evident that an increase in rainfall as modelled in the 1% AEP climate change scenario results in minor increases in peak flood levels across the site.

During the PMF event, more extensive inundation across the site and broader area occurs, filling overbank areas from the low-lying floodplain as the conveyance of the creek is exceeded. Gradual inundation of the southern portion of the site occurs before extending to the northern portion of the site.

## 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.

There are no prescriptive methods for determining what parts of the floodplain constitute floodway, flood storages and flood fringes. Descriptions of these terms within the Floodplain Development Manual (FDM) (NSW Government, 2005) are essentially qualitative in nature and emphasis is placed on the need for site specific consideration when determining appropriate methods for hydraulic category classification. The hydraulic categories as defined in the FDM, and the advised general guidelines to assist in the delineation of flooding and flood storage areas, 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 significantly affect the flood pattern or flood levels.

The adopted hydraulic classification is consistent with Council's DCP and is defined in Table 5.

**Table 5 Hydraulic Categories**

| | | |
|---|---|---|
| **Floodway** | Velocity * Depth > 0.5 | Areas and flow paths where a significant proportion of floodwaters are conveyed (including all bank-to-bank creek sections). |
| **Flood Storage** | Velocity * Depth < 0.5 and Depth > 0.5 metres | Areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks. |
| **Flood Fringe** | Velocity * Depth < 0.5 and Depth < 0.5 metres | Areas that are low-velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour. |

The existing 1% AEP hydraulic categories are shown in Appendix A – Baseline/Existing Design Flood Behaviour (Figure A-5). As shown, most of the inundated portion of the study site is classified as flood storage, with some areas of flood fringe along the northern edge of the flood extent and western boundary and some localised areas of floodway in the southern section of the lot along Narrabeen Creek.

### Flood Hazard Classification

Flood hazard is defined in the Pittwater DCP as a determination of the safety of people and property and is based on a combination of flood depth (above ground level) and flood velocity for a particular sized flood.

Flood hazard can be classified as either low or high hazard. In high flood hazard areas, there is a possible danger to personal safety, able-bodied adults would have difficulty wading and there is the potential for significant structural damage to buildings. In low flood hazard areas, able-bodied adults would have little difficulty wading and nuisance damage to some structures would be possible.

The method for determining provisional low and high hazard categories is outlined in the NSW Government's Floodplain Development Manual (2005). The existing 1% AEP flood hazard map is shown in Appendix A – Baseline/Existing Design Flood Behaviour (Figure A-6). High flood hazard areas are located at the southern portion of the site, with low hazard areas located near the centre of the site for the 1% AEP event.

## Flood Impact Assessment

### Modelling Approach

To represent the post-development catchment conditions, the TUFLOW model terrain was modified to include the finished ground levels for the proposed development. The surface was created using the design surface data (30949-CI-100 Warriewood BE (NO flood storage)_v2013.dwg) supplied by Wood & Grieve Engineers, as shown in Figure B-1 in Appendix B – Post-Development Design Flood Behaviour. The

proposed earthworks include filling of the northern portion of the site for the construction of a residential subdivision including the associated roads. To the south of the lots, bordering the floodplain, is a proposed cycleway and Lorikeet Grove road linking the study site to the neighbouring 41 Warriewood Road to the east. The low-lying floodplain area in the southern portion of the site is largely unchanged from existing conditions with the exception of a shallow infiltration basin (19m x 14m x 0.3m) immediately downstream of Lorikeet Grove. This basin has not been included in the model due to its small size and as it will not have any adverse impact on flooding; there is no fill associated with the works (only shallow cut / excavation). The basin is also not expected to provide any compensatory flood storage as it is relatively shallow and would be assumed full in a Narrabeen Creek flood event. Topographical modifications are restricted to the northern portion of the site, with Lorikeet Grove to be raised to the flood planning level (1% AEP + 0.5 metre freeboard) and the minimum lot level to be filled to the flood planning level including an allowance for climate change (1% AEP + climate change + 0.5 metre freeboard). A comparison in topography between the existing and developed scenario is shown in Figure 3.

## Modelling Results

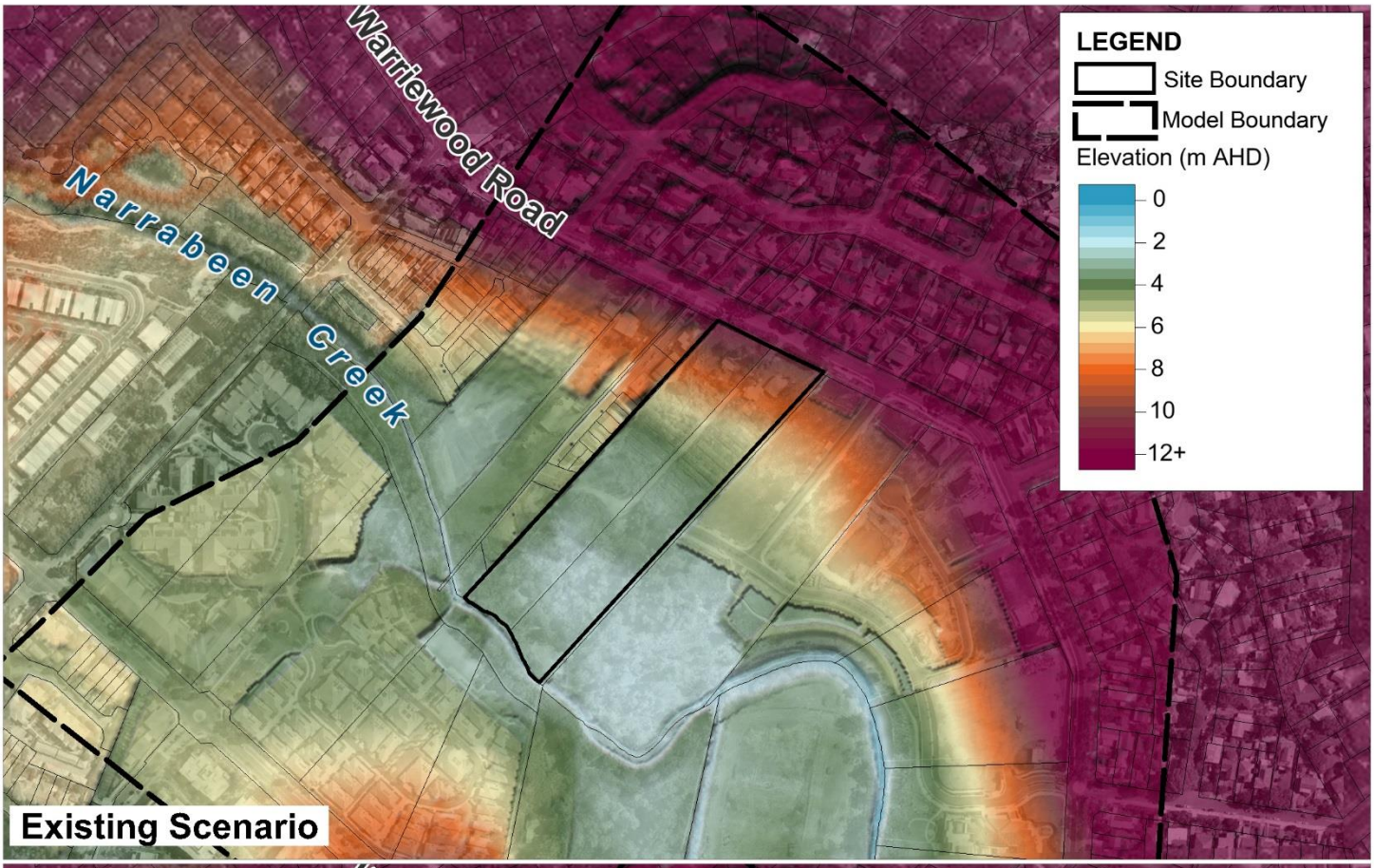
Modelled post-development peak flood levels at selected locations (as presented in Figure 2) are provided in Table 6, for the full range of design flood events considered. Changes in modelled peak flood levels at the site are within ±0.01m for all design events. The post-development 20% AEP, 1% AEP, 1% AEP+CC and PMF design flood conditions at the site are presented in Appendix B – Post-Development Design Flood Behaviour (Figure B-1 – Figure B-4).

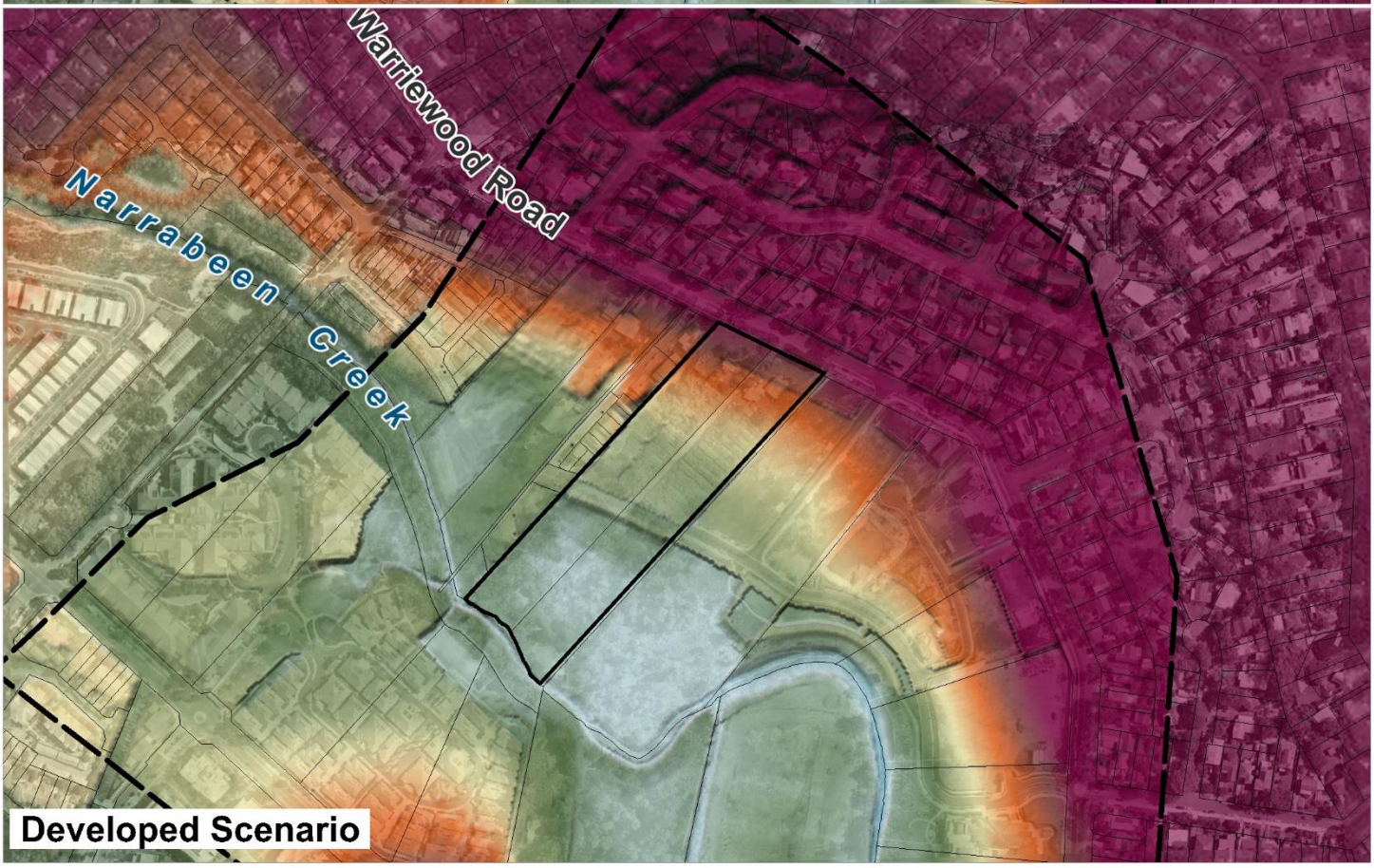
**Table 6 Simulated Post-Development Peak Flood Levels**

| Design Event (AEP) | Peak Flood Level (m AHD) | | |
|---|---|---|---|
| | Location 1 (L1) | Location 2 (L2) | Location 3 (L3) |
| **2 Year ARI (50% AEP)** | 3.17 (0.00) | 3.73 (0.00) | 3.24 (-0.01) |
| **20%** | 3.45 (+0.01) | 3.90 (0.00) | 3.47 (0.00) |
| **10%** | 3.53 (0.00) | 3.96 (0.00) | 3.56 (+0.01) |
| **5%** | 3.62 (+0.01) | 4.04 (0.00) | 3.64 (+0.01) |
| **2%** | 3.68 (0.00) | 4.10 (0.00) | 3.70 (0.00) |
| **1%** | 3.74 (+0.01) | 4.15 (0.00) | 3.76 (0.00) |
| **1% + Climate Change** | 3.84 (0.00) | 4.24 (0.00) | 3.86 (0.00) |
| **PMF** | 4.88 (0.00) | 4.89 (0.00) | 4.88 (0.00) |

Note: Bracketed value is change in peak flood level from base design conditions

The peak flood level impacts for the 1% AEP, 1%AEP+CC and PMF design flood events are presented in Figure 4 to Figure 6, respectively. It is evident that the proposed development has no significant impact on simulated existing condition peak design flood levels. The peak flood level impact for the 20% AEP event is presented in Appendix C – Change in Peak Design Flood Level (Figure C-1).




Title:
**Comparison of Pre and Post-Development Topography**

Figure: **3**

Rev: **A**



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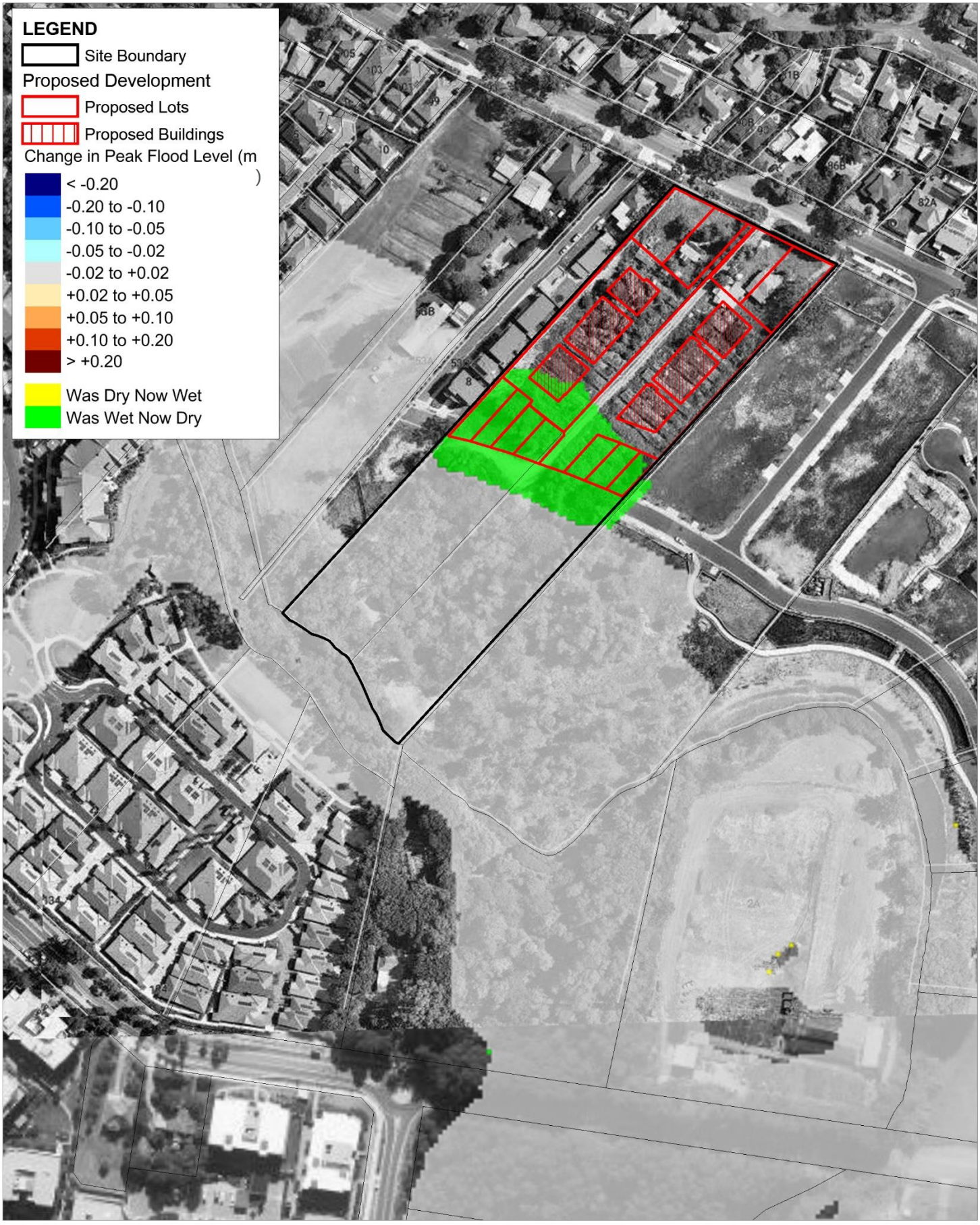


Title:

# Change in Peak Flood Level
# 1% AEP Event

Figure: 4

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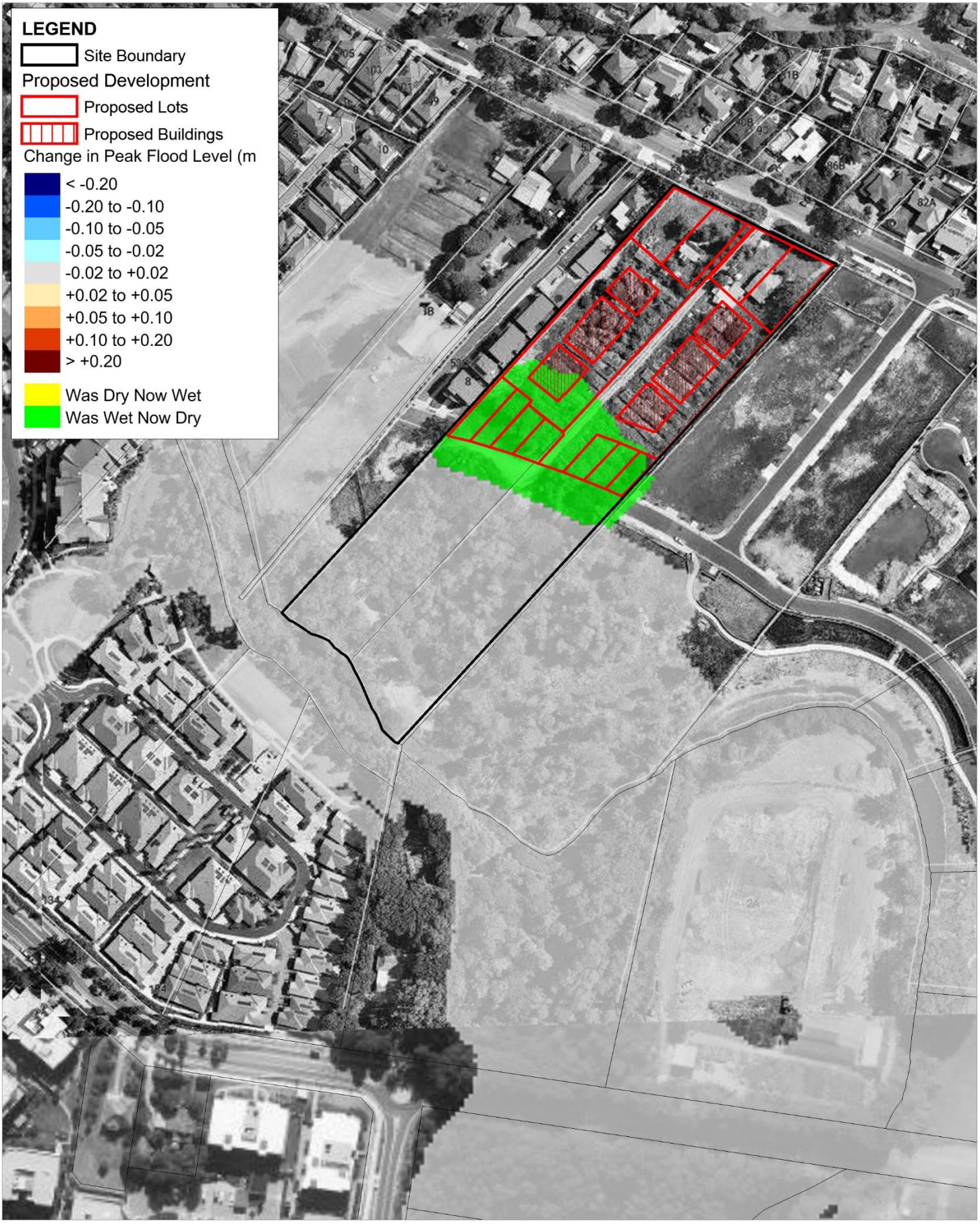


Title:

# Change in Peak Flood Level - 1% AEP Event +2100 Sea Level Rise +30% Increase in Rainfall Intensity

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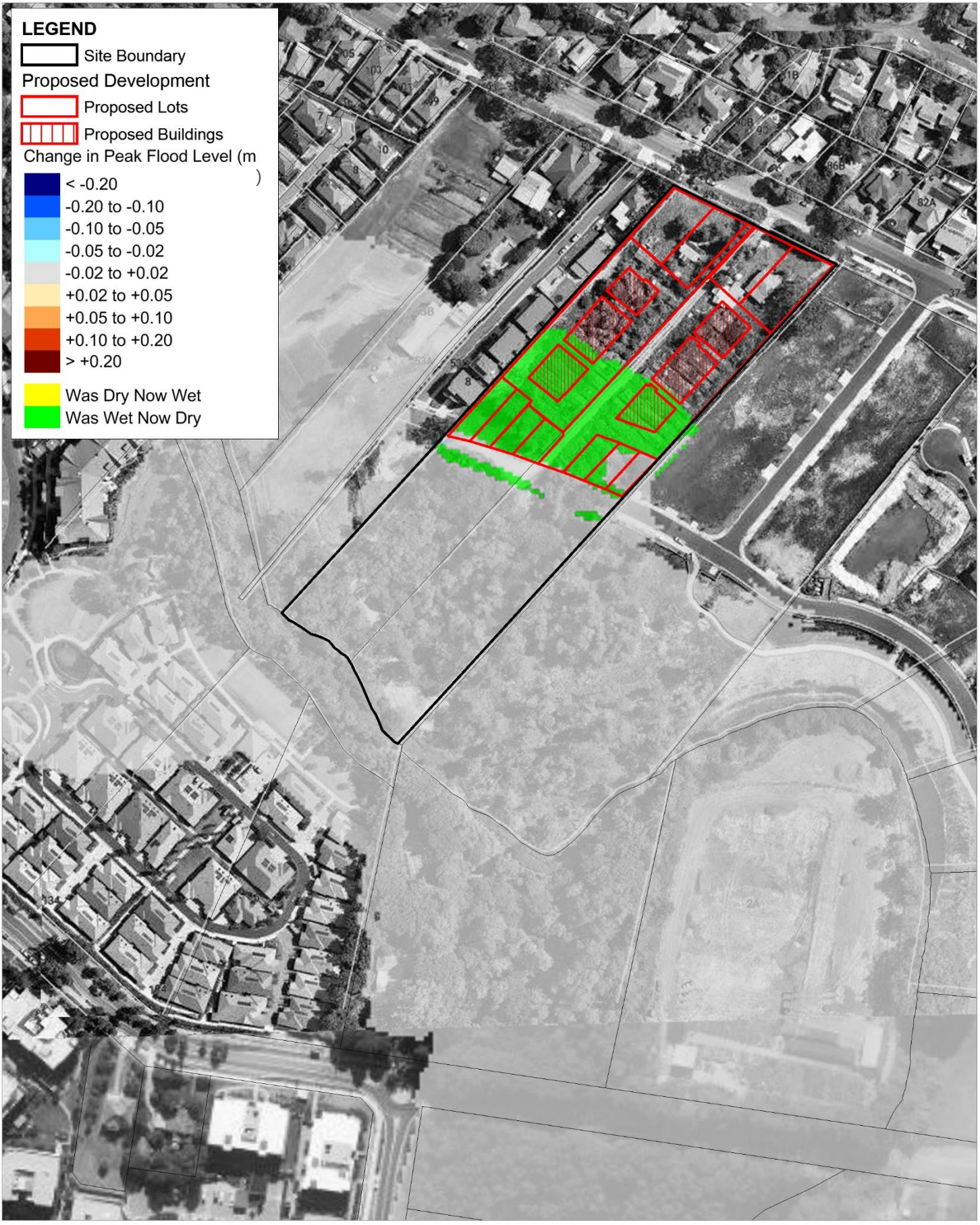


Title:

# Change in Peak Flood Level
# PMF Event

Figure: 6

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### *1% AEP Event*

The simulated 1% AEP post-development flood conditions are largely similar to the existing flood conditions in that floodwaters exceed the capacity of Narrabeen Creek and spill into the adjacent floodplain, inundating the southern portion of the site. As the proposed development does not encroach or modify the existing Narrabeen Creek channel or floodway, there are no changes to the overall flow capacity of the channel. As noted above, the proposed earthworks include filling along the northern fringe of inundation from Narrabeen Creek and a small portion of flood storage within the northern floodplain and as such, the existing flood conditions are similar in the post-development scenario. This is evident in the flood impact mapping presented in Figure 4, whereby there are no significant changes to peak flood levels upstream or downstream of the proposed development. Changes to peak flood velocity outside of the site are localised in nature and within ±0.1 m/s (Figure C-6).

The total flood storage on the existing site in the 1% AEP is 35,900m$^3$. The extent of development and associated fill requirements are defined by the alignment of Lorikeet Grove. To fill this area to the flood planning level there is a net loss of flood storage of approx. 6,600m$^3$, of which 3,100m$^3$ is to raise Lorikeet Grove and 3,500 m$^3$ to fill the lots between Lorikeet Grove and flood free land. Compensatory works are not proposed in the floodplain due to ecological constraints.

### *1% AEP Event +CC*

At the 1% AEP+CC event, the modelled impact shows peak flood levels are within ±0.01 m at the site, as the majority of the proposed development is limited to the fringe of the flood extent (similar to the 1% AEP flood behaviour detailed above). Figure 5 also shows there are no significant changes to peak flood levels at neighbouring properties. Changes to peak flood velocity outside of the site are also localised in nature and within ±0.1 m/s (Figure C-7).

### *PMF Event*

Flood impacts are not typically assessed at the PMF event, which is used principally to assess risk to life and flood emergency response requirements, however the flood modelling indicates that there are also no significant impacts associated with the proposed development in the PMF, as shown in Figure 6. During the PMF, the majority of the proposed development is flood free with the exception of the most south-eastern lot and the Lorikeet Grove roadway. Changes to peak flood velocity outside of the site are also localised in nature and within ±0.2 m/s (Figure C-8).

## Climate Change Impacts

The impacts of climate change were assessed by modelling the flood conditions at the site under the scenario of sea level rise combined with an increase in rainfall volume. The 2100 sea level rise scenario (+0.9 m) has been adopted for this study, in combination with a 30% increase in rainfall volume. The climate change parameters were applied to both the existing and the developed scenario and a comparison of the peak water level results at the site (and its surrounds) for the climate change scenarios are presented in Appendix D. As shown by these results, the proposed development does not significantly alter flood levels in this future climate change scenario.

### Flood Emergency Response

Given the small size of the upstream catchment there will be no practical flood warning available at the site. Therefore, people on-site will have to react and respond to flood events as and when they occur, which is similar for all other flood affected locations in the area. However, the proposed development platform and adjoining flood free land means that the majority of the lots remain flood free in the PMF. The exception to this is the two most south-eastern lots which are inundated up to 0.2m during the PMF event (see Figure B-4) however increasing elevations along Lorikeet Grove to Bubalo Street would provide rising road egress for these residents.

### Planning Considerations

The adopted flood planning level for the site is 4.65mAHD based on the 1% AEP post-development flood level at location L2 (4.15mAHD as per Table 6) plus 0.5 metres freeboard. Minimum lot levels were based on the flood planning level plus an allowance for climate change (4.74mAHD) based on the 1% AEP plus climate change post-development flood level (4.24mAHD as per Table 6) plus 0.5 metres freeboard.

With regard to the aforementioned flood planning considerations applicable to the site, the flood impact assessment has shown that (for the full range of planning considerations refer to Table 1 to Table 3):

- All lots are above the flood planning level including an allowance for climate change (1% AEP + climate change + 0.5 metre freeboard).
- All lots, apart from the two south-eastern lots, are flood-free in the PMF. Lorikeet Grove provides rising road egress out of the floodplain to Bubalo Street.
- The fill requirements are defined by the alignment of Lorikeet Grove which result in a net loss of flood storage of approx. 6,600m$^3$ to fill the lots between Lorikeet Grove and flood free land to the flood planning level. Compensatory works are not proposed in the floodplain due to ecological constraints.
- There are no significant impacts on surrounding properties for any event up to the PMF event under the existing or future climate scenarios.

## Conclusions

The objective of the study was to undertake a detailed flood impact assessment for a proposed residential development at 45-49 Warriewood Road, Warriewood. Central to this was the development of a refined 2D TUFLOW model with a 2 m grid resolution. The boundary conditions for the refined model were based on the TUFLOW model (6 m grid resolution) of the Narrabeen Lagoon catchment developed as part of the Narrabeen Lagoon Flood Study (BMT WBM, 2013).

Specifically, the modelling undertaken for the proposed development aimed to:

- Confirm existing flood conditions across the site, including flood levels, flows and velocities, to establish baseline conditions for impact assessment, and the flood planning requirements for the proposed development; and
- Identify the potential flood impacts of the proposed development over a range of design flood events under existing and future climate scenarios.

The results of the modelling and flood impact assessment have confirmed:

- All lots are above the flood planning level including an allowance for climate change (1% AEP + climate change + 0.5 metre freeboard).
- All lots, apart from the two south-eastern lots, are flood-free in the PMF. Lorikeet Grove provides rising road egress out of the floodplain to Bubalo Street.
- The fill requirements are defined by the alignment of Lorikeet Grove which result in a net loss of flood storage of approx. 6,600m$^3$ to fill the lots between Lorikeet Grove and flood free land to the flood planning level. Compensatory works are not proposed in the floodplain due to ecological constraints.
- There are no significant impacts on surrounding properties for any event up to the PMF event under the existing or future climate scenarios.

We trust the above information satisfies your requirements. Please do not hesitate to contact the undersigned if further information is required.

Yours Faithfully

**Jacquie Hannan**
**Principal Engineer**
**BMT**

# References

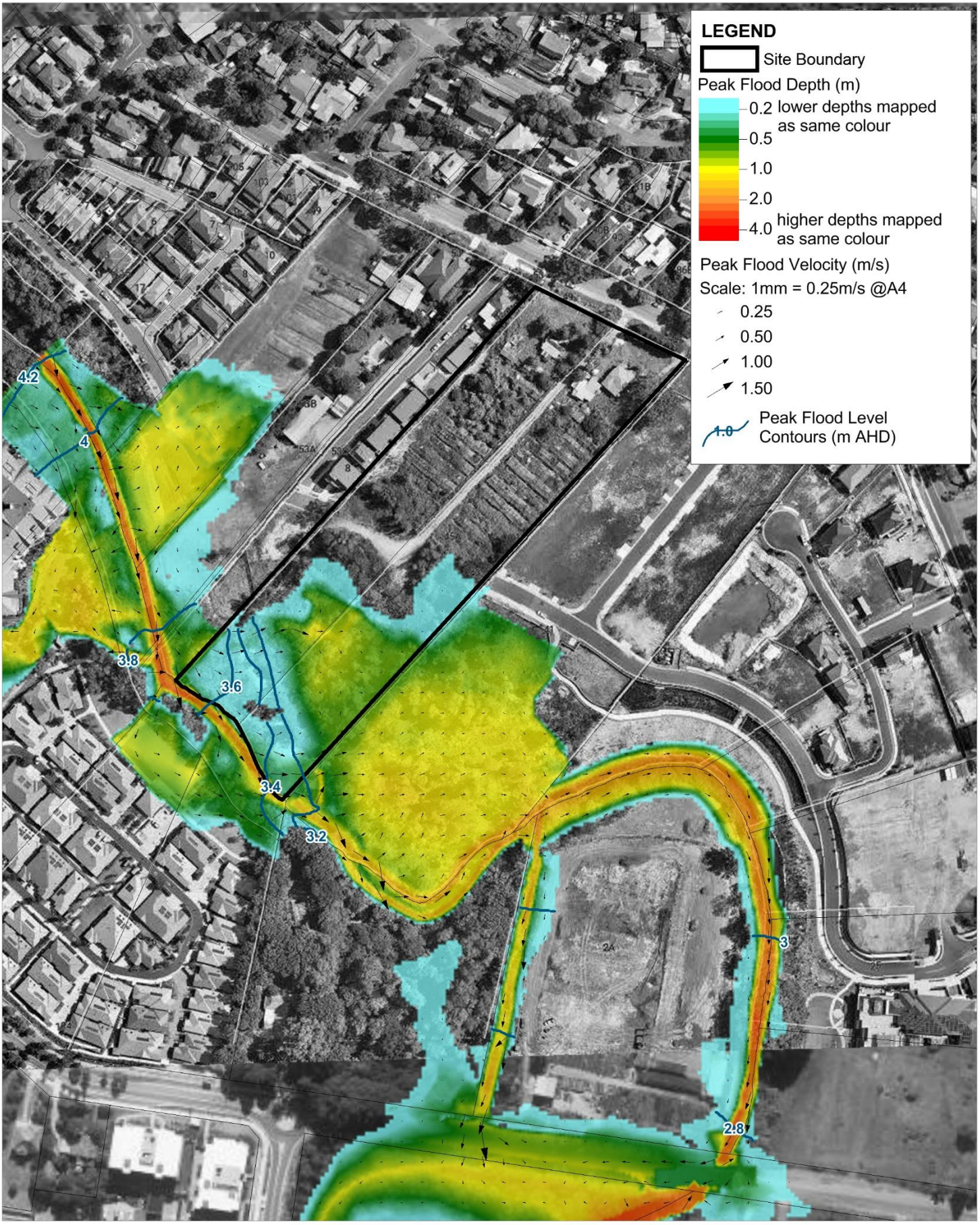
BMT WBM Pty Ltd, 2013, Narrabeen Lagoon Flood Study. NSW, BMT WBM.

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

Northern Beaches Council, 2019, Pittwater 21 Development Control Plan.

Northern Beaches Council, 2014, Pittwater Local Environmental Plan 2014.

# Appendix A – Baseline/Existing Design Flood Behaviour




Title:

# 2 Year ARI Event - Existing Scenario Modelled Peak Flood Conditions

Figure: **A-1**

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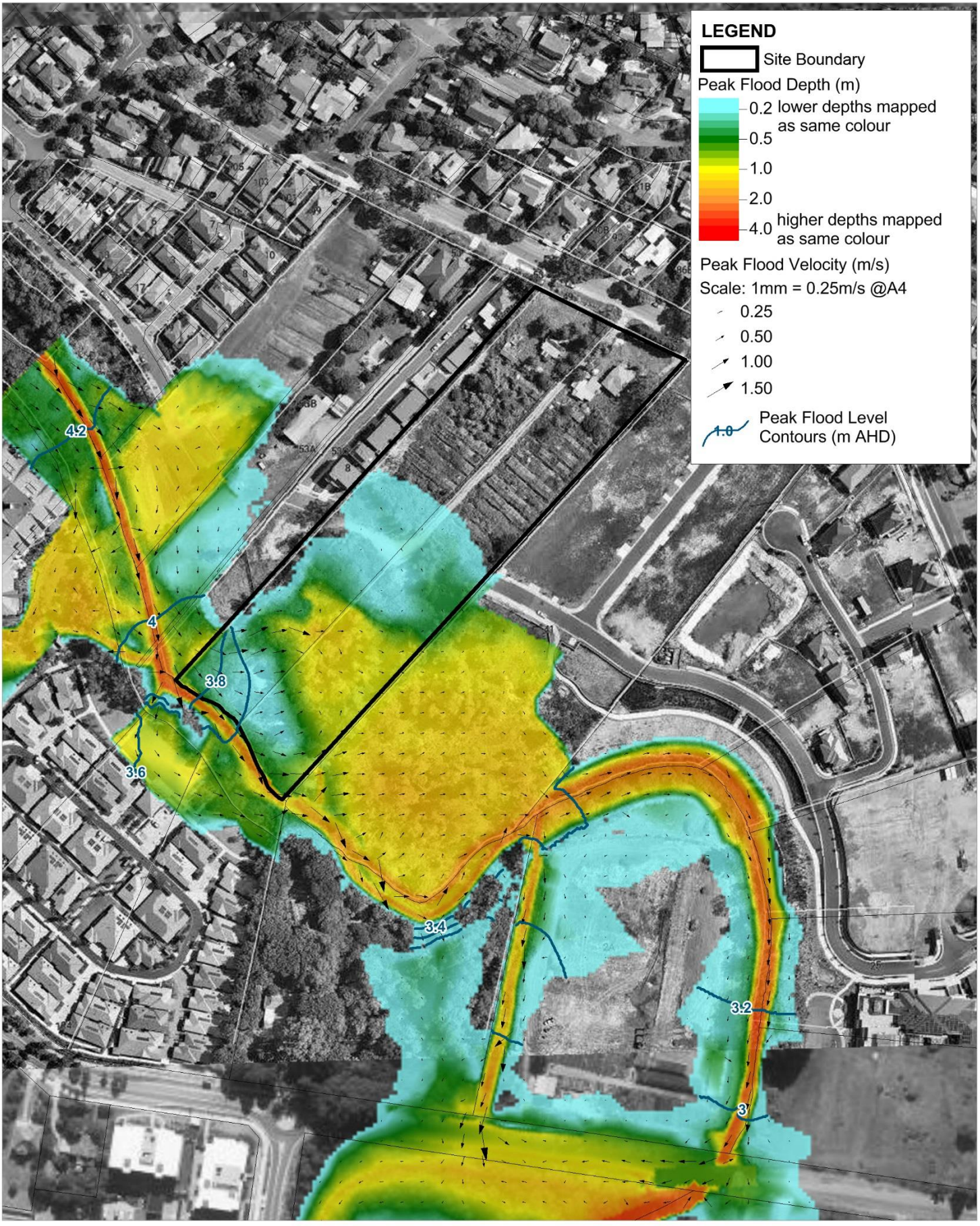


Title:

# 20% AEP Event - Existing Scenario Modelled Peak Flood Conditions

Figure: **A-2**

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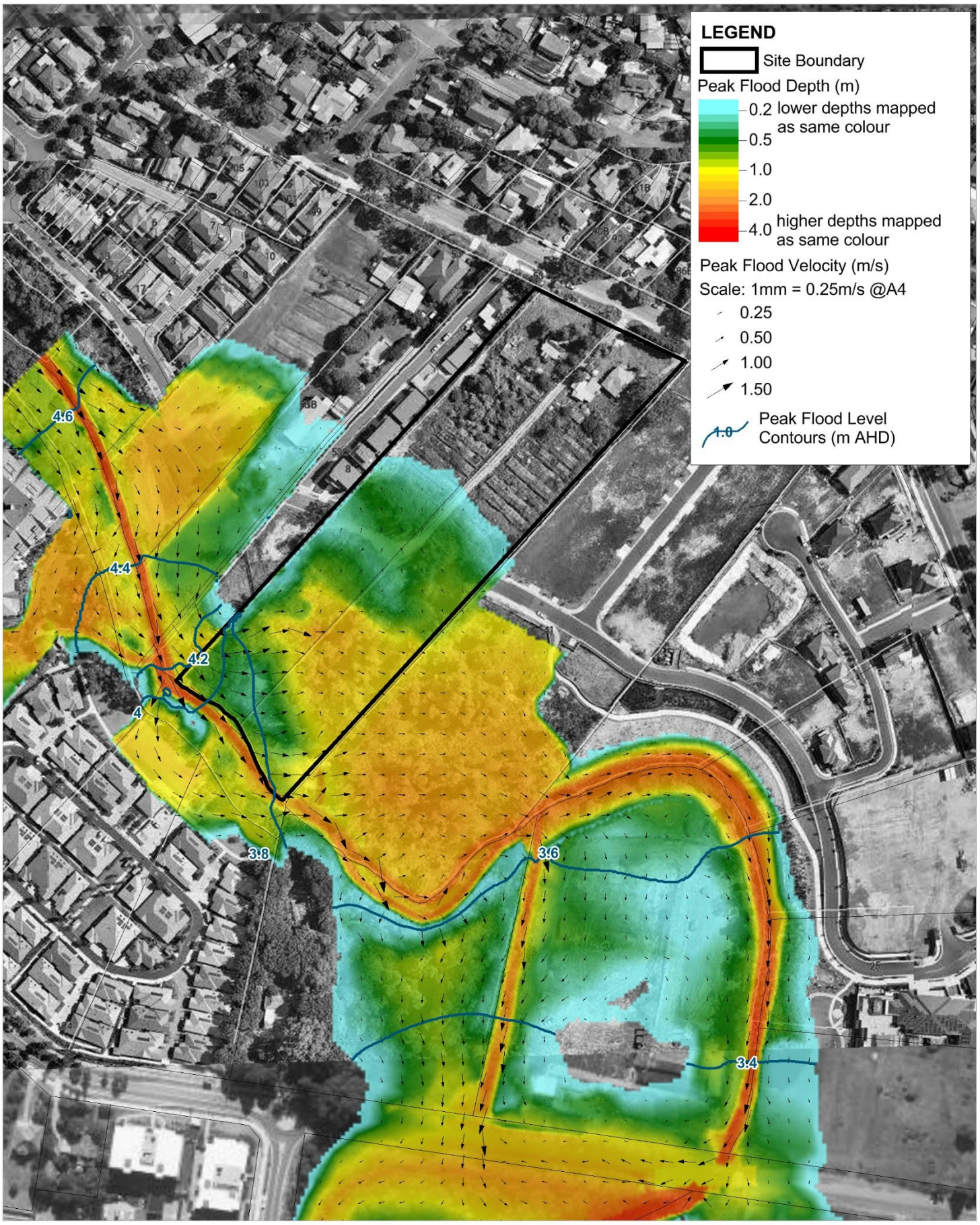


Title:

# 1% AEP Event - Existing Scenario Modelled Peak Flood Conditions

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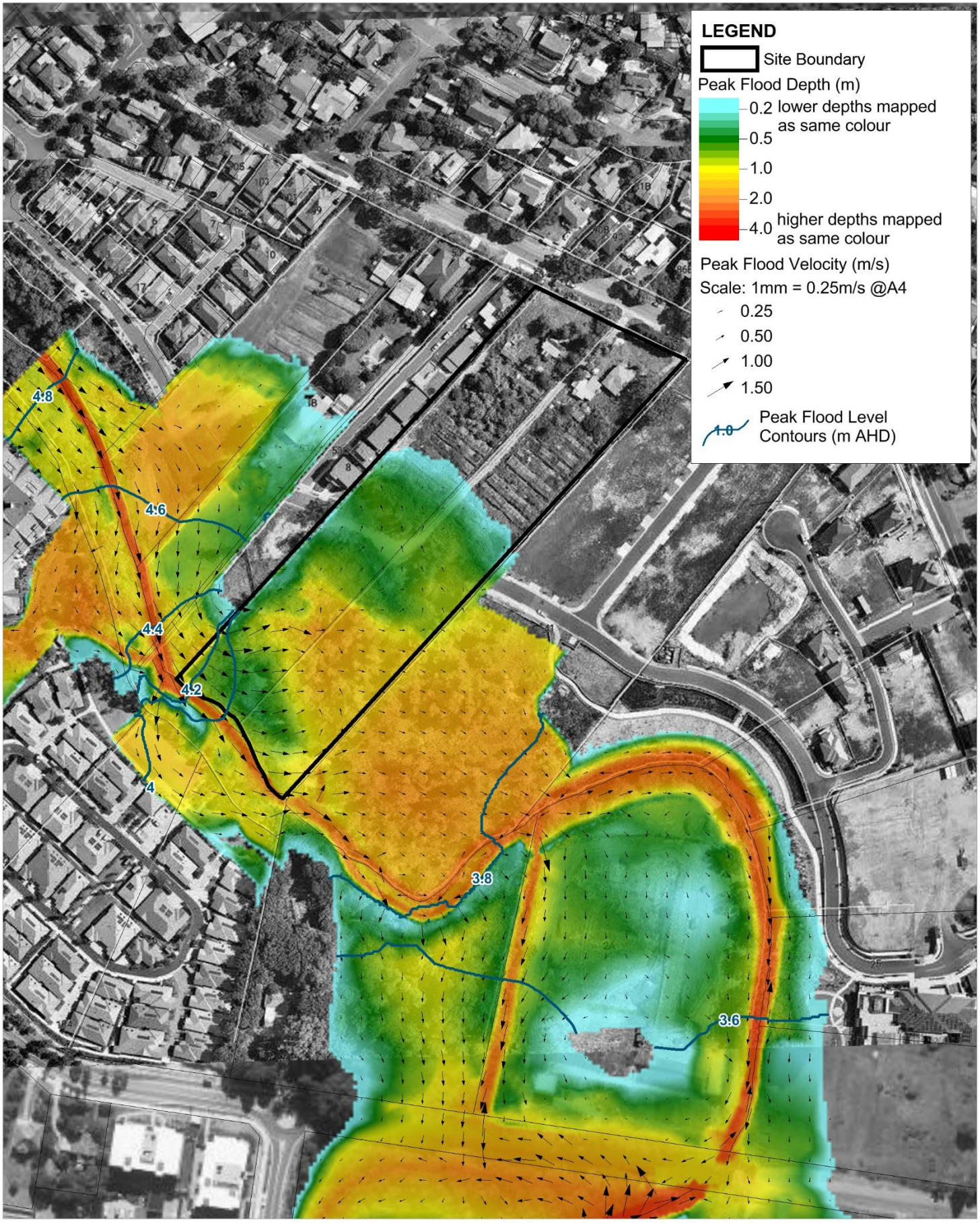


Title:

# 1% AEP with Climate Change Event - Existing Scenario Modelled Peak Flood Conditions

Figure: **A-4**

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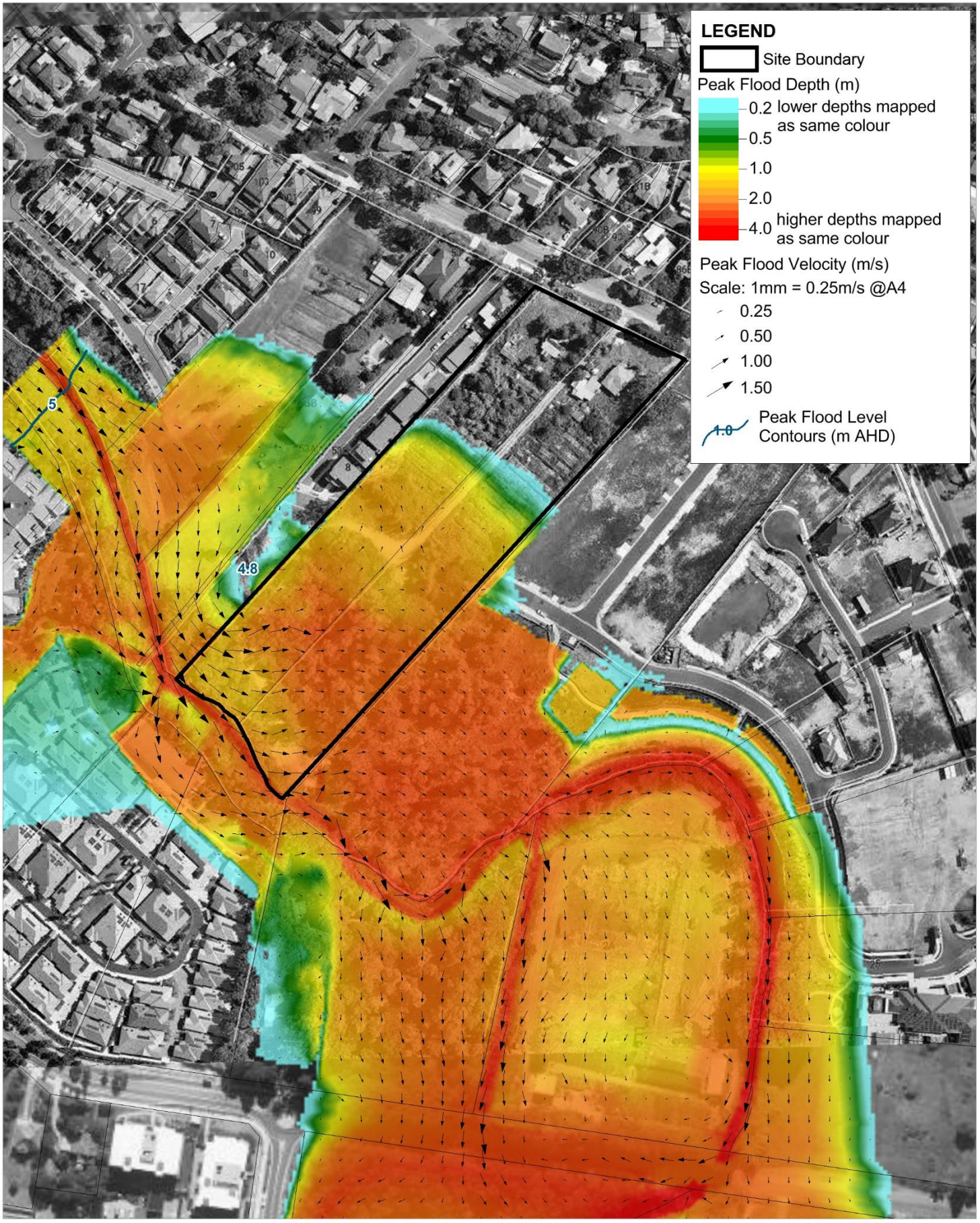


Title:

# PMF Event - Existing Scenario Modelled Peak Flood Conditions

Figure: **A-5**

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Title:

# 1% AEP Event - Existing Scenario Hydraulic Categories

Figure: A-6

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Title:

# 1% AEP Event - Existing Scenario Hazard Classification

Figure: **A-7**

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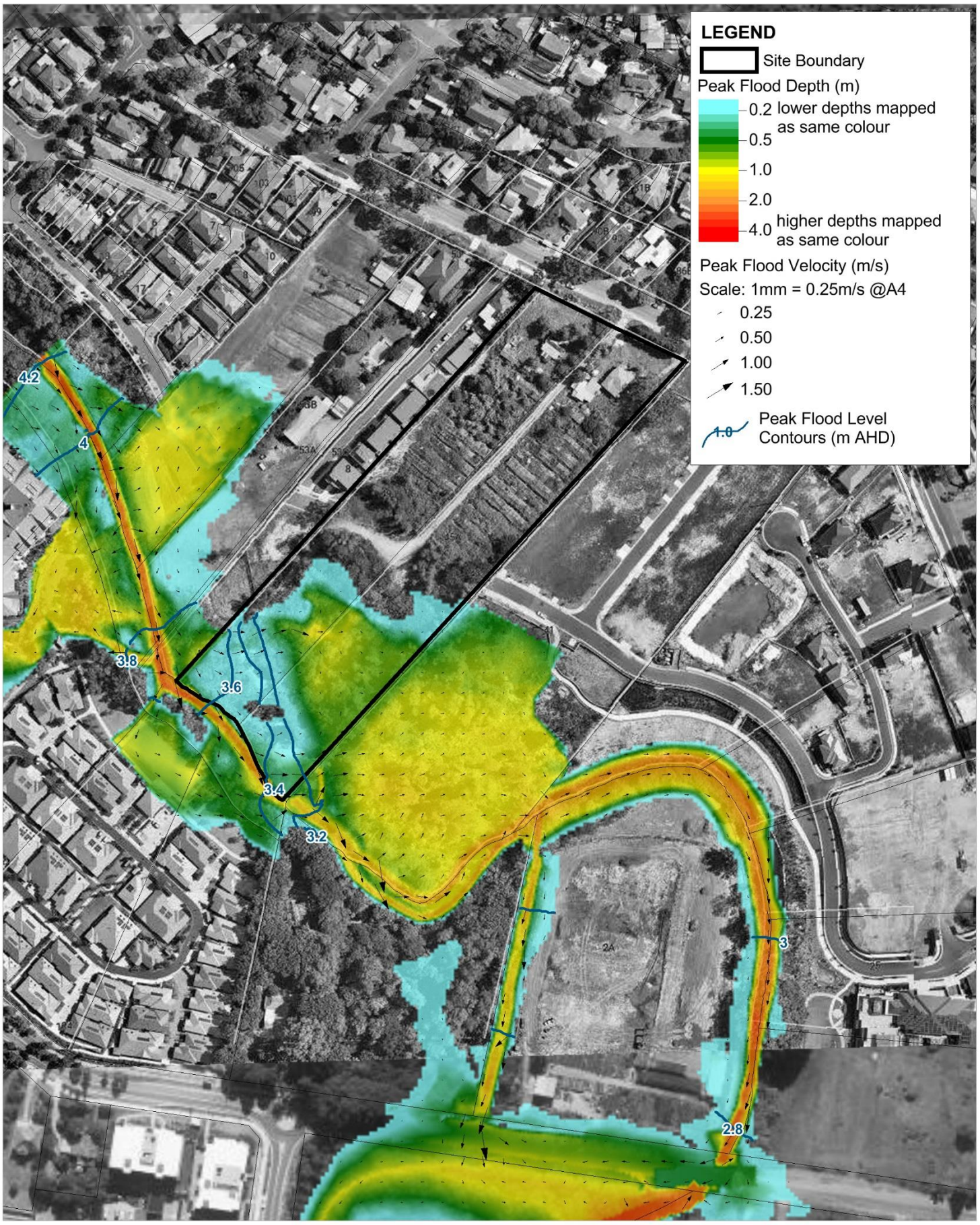
# Appendix B – Post-Development Design Flood Behaviour




Title:

# 2 Year ARI Event - Developed Scenario Modelled Peak Flood Conditions

Figure: **B-1**

Rev: **-**



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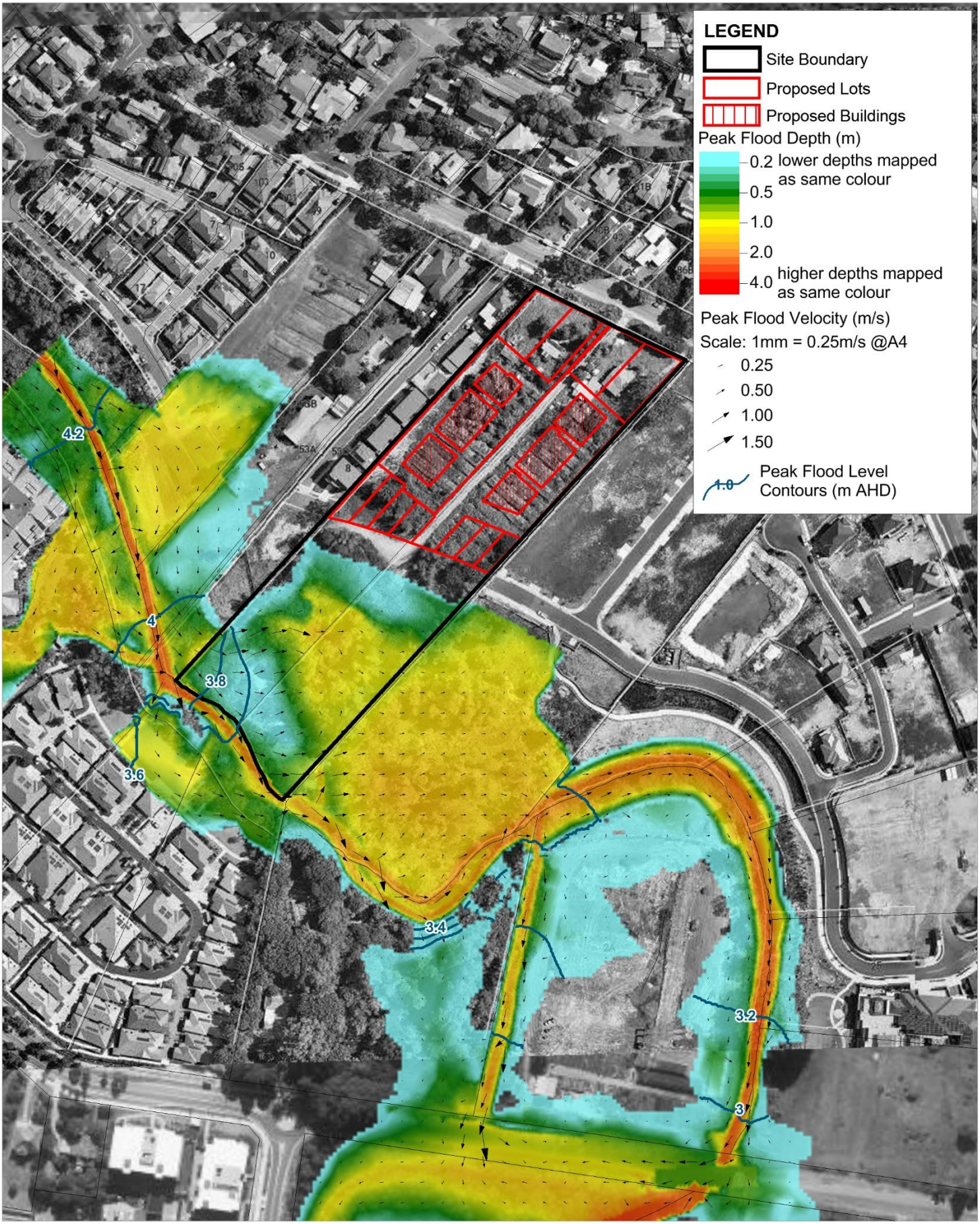


Title:

# 20% AEP Event - Developed Scenario Modelled Peak Flood Conditions

Figure: **B-2**

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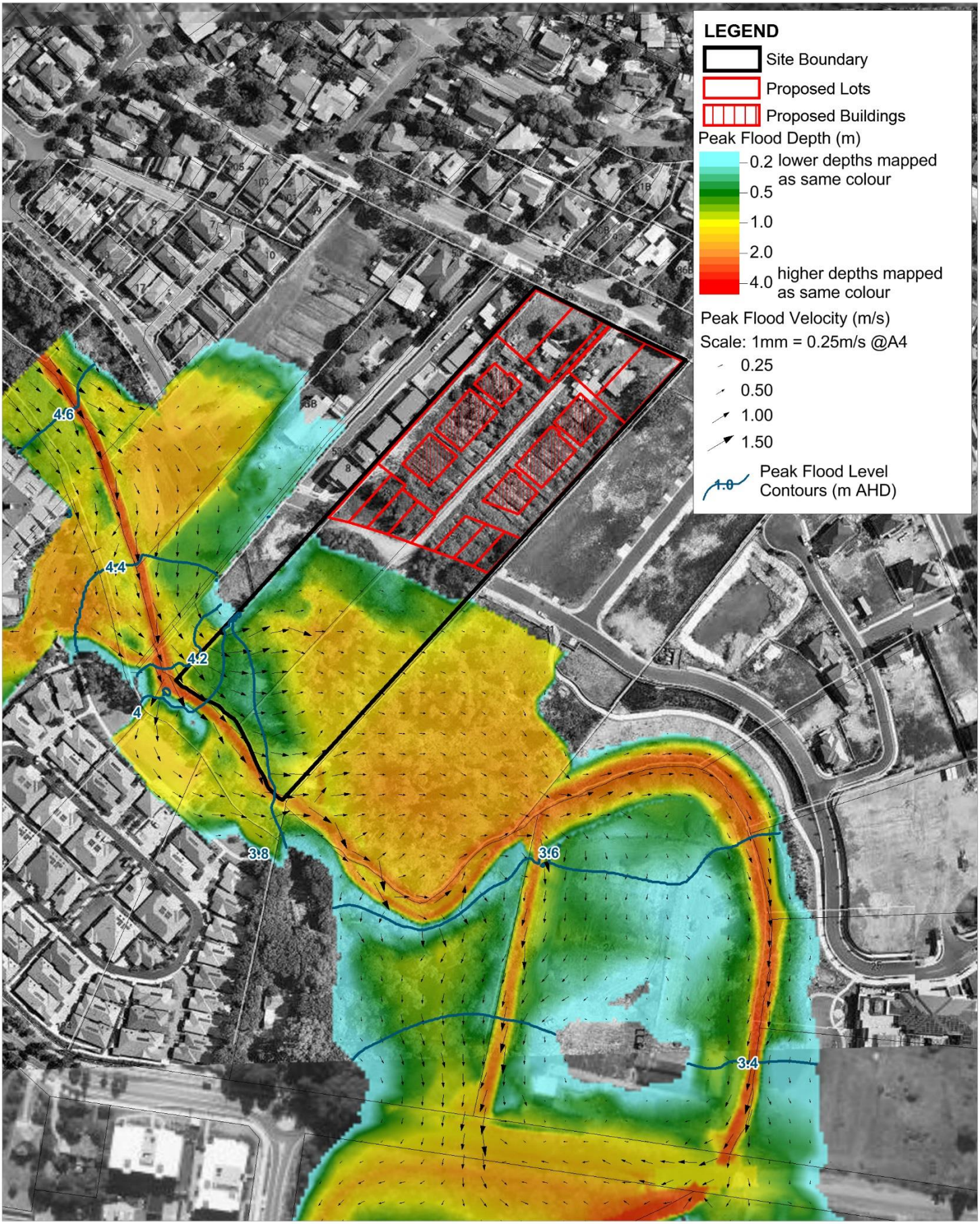


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# 1% AEP Event - Developed Scenario Modelled Peak Flood Conditions

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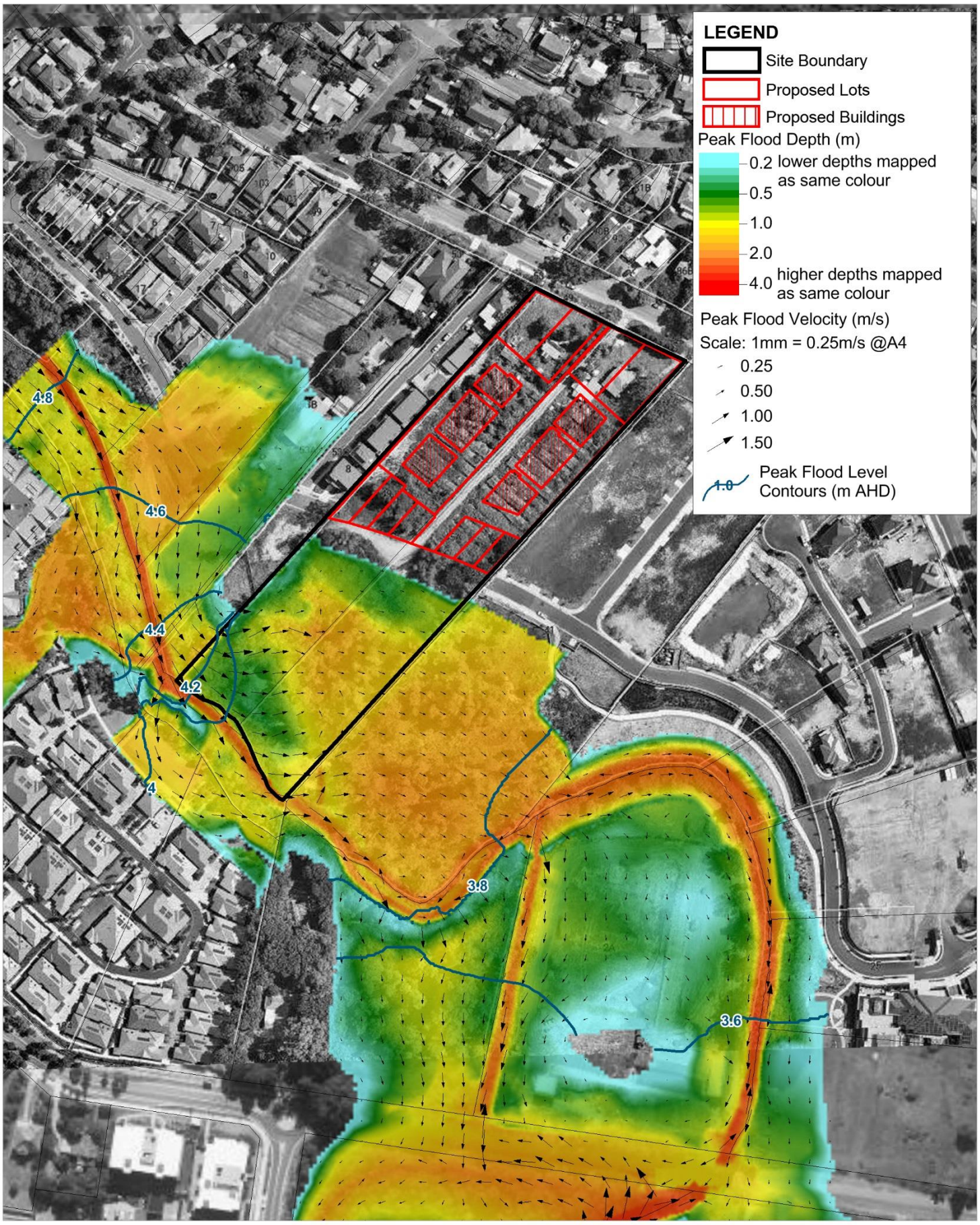


Title:

# 1% AEP with Climate Change Event - Developed Scenario Modelled Peak Flood Conditions

Figure: **B-4**

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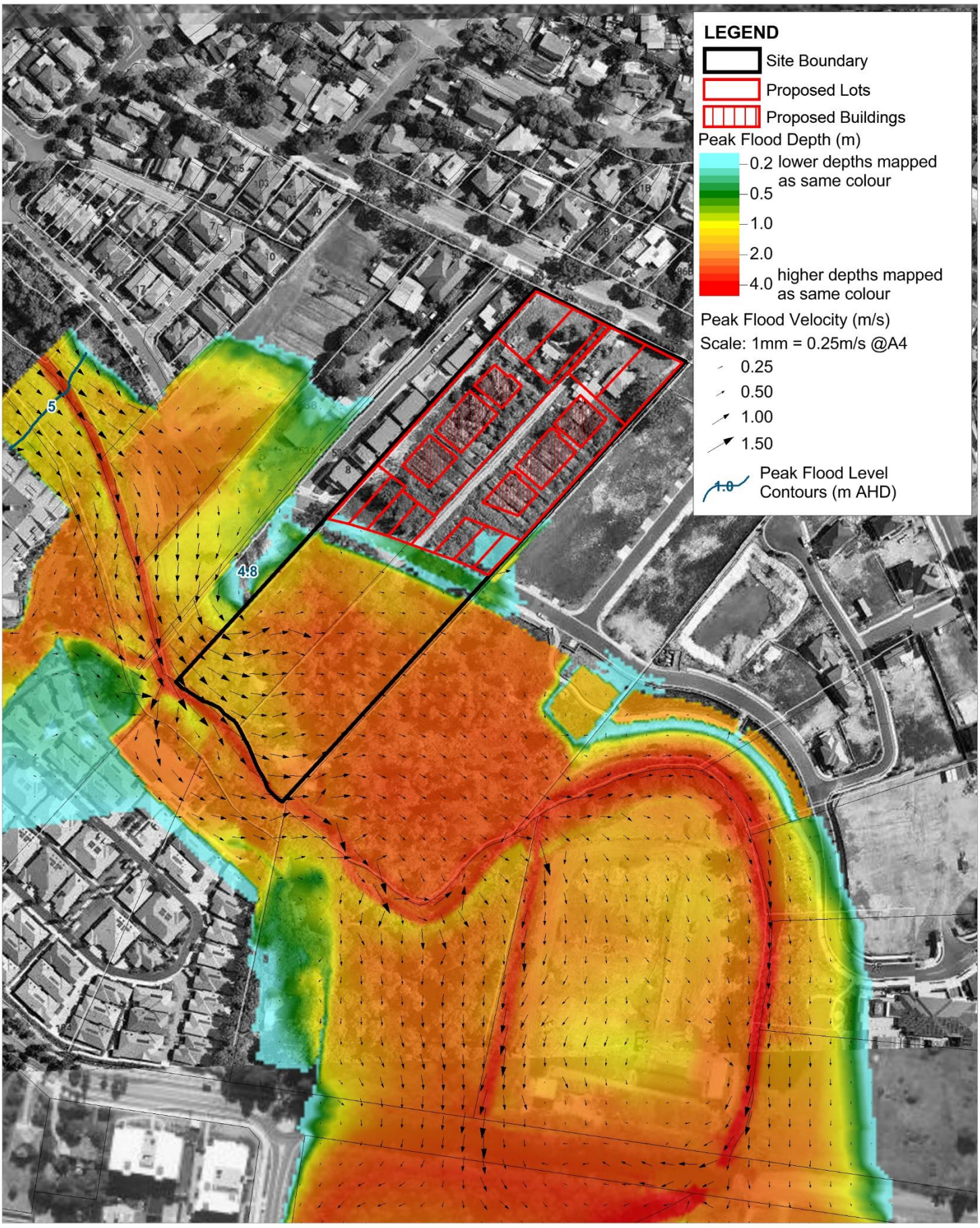


Title:

# PMF Event - Developed Scenario Modelled Peak Flood Conditions

Figure: **B-5**

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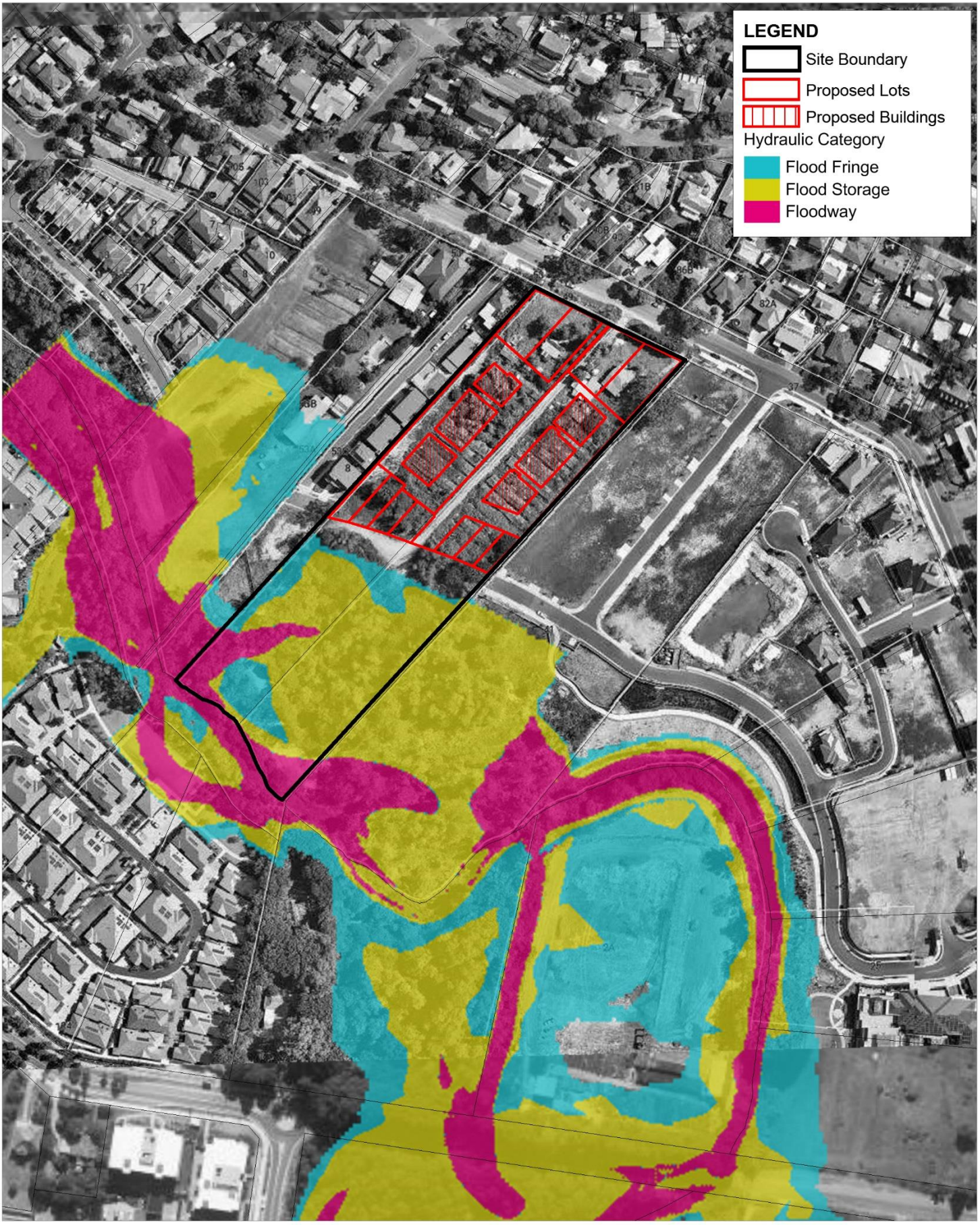


Title:

# 1% AEP Event - Developed Scenario Hydraulic Categories

Figure: **B-6**

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Title:

# 1% AEP Event - Developed Scenario Hazard Classification

Figure: **B-7**

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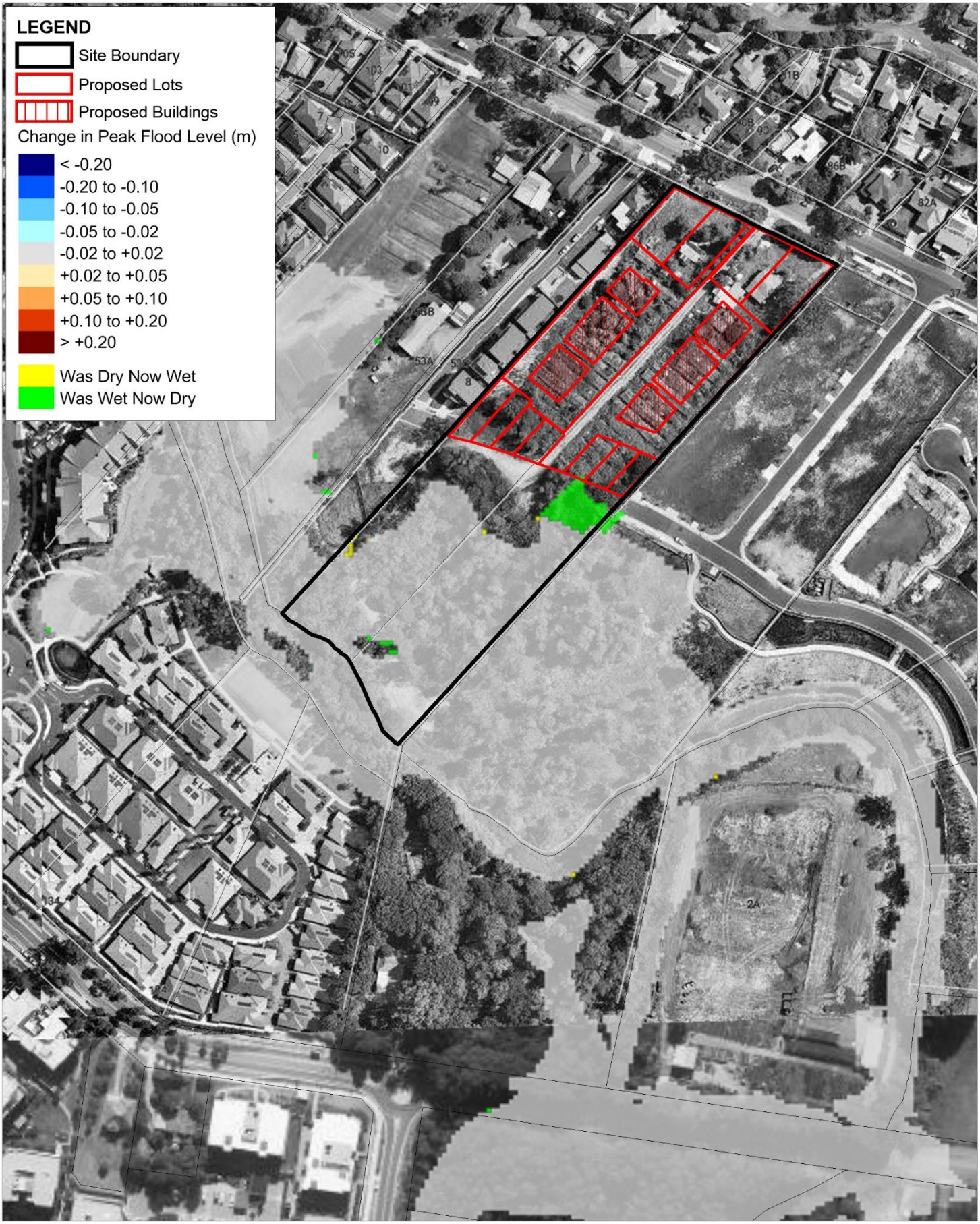
# Appendix C – Change in Peak Design Flood Levels and Velocities




Title:

# 2 Year ARI Event
# Change in Peak Flood Level

Figure: C-1

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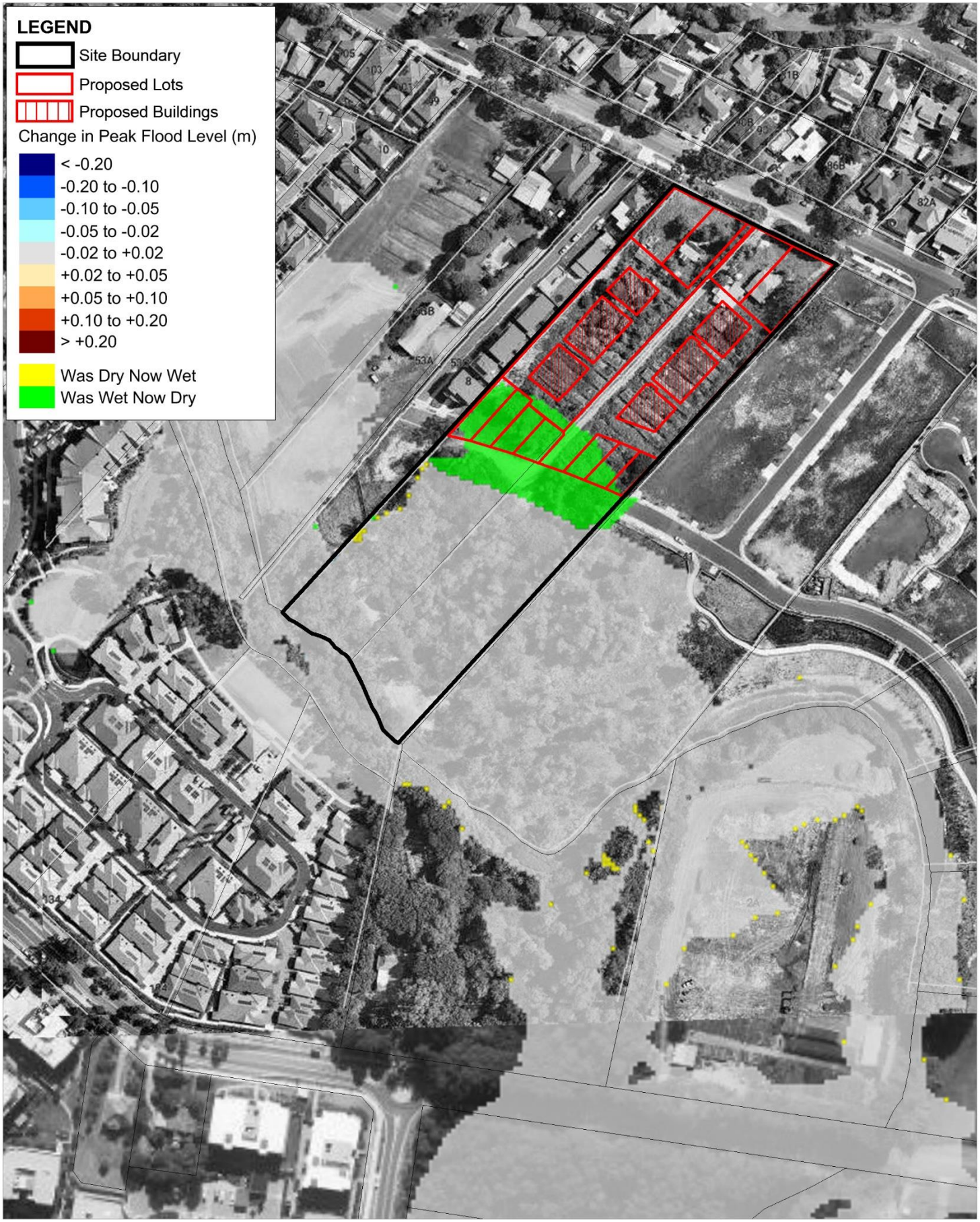


Title:

# 20% AEP Event
# Change in Peak Flood Level

Figure: **C-2**

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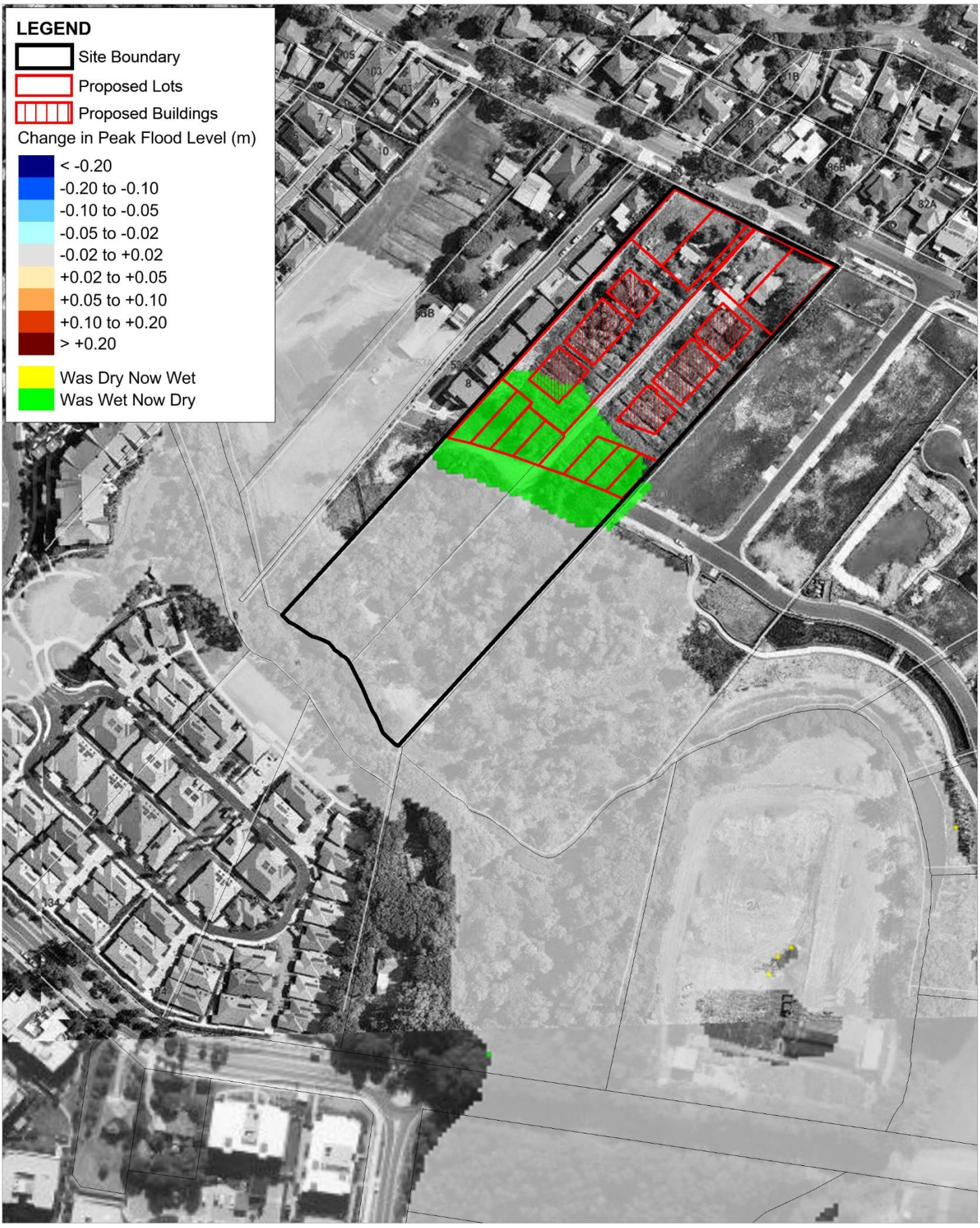


Title:

# 1% AEP Event
# Change in Peak Flood Level

Figure: C-3

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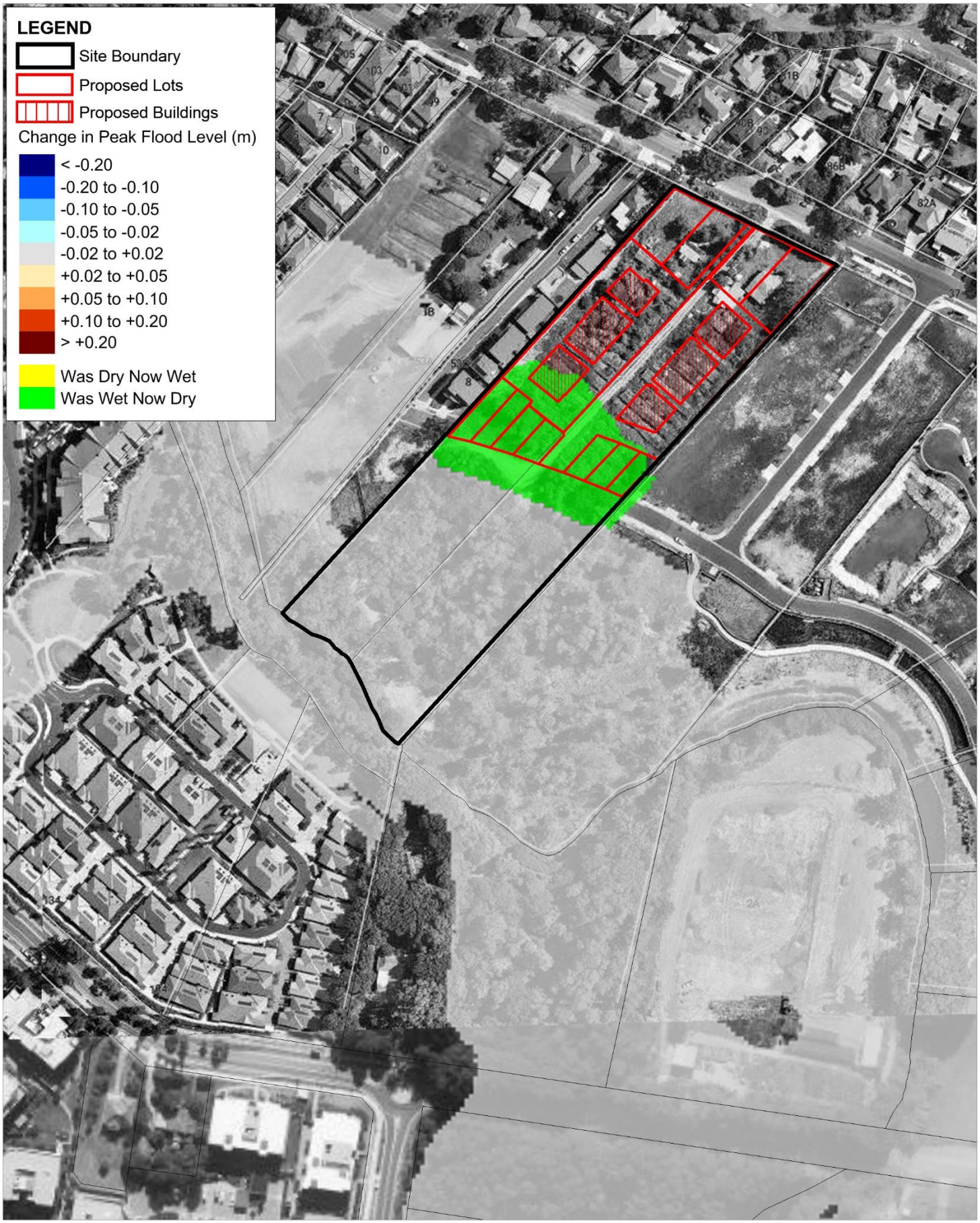


Title:

# 1% AEP with Climate Change Event Change in Peak Flood Level

Figure: C-4

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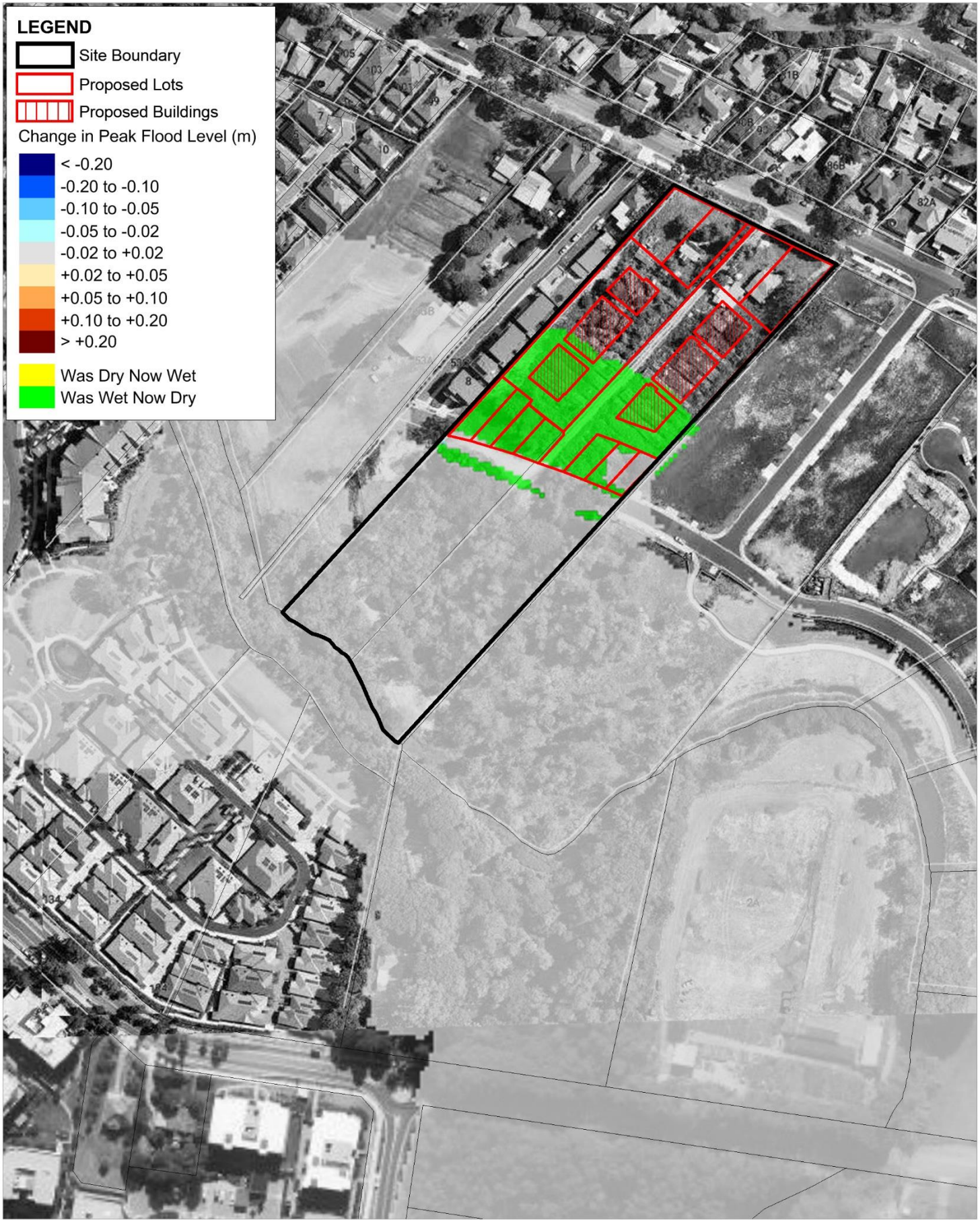


Title:

# PMF Event
# Change in Peak Flood Level

Figure: **C-5**

Rev: **-**



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Approx. Scale

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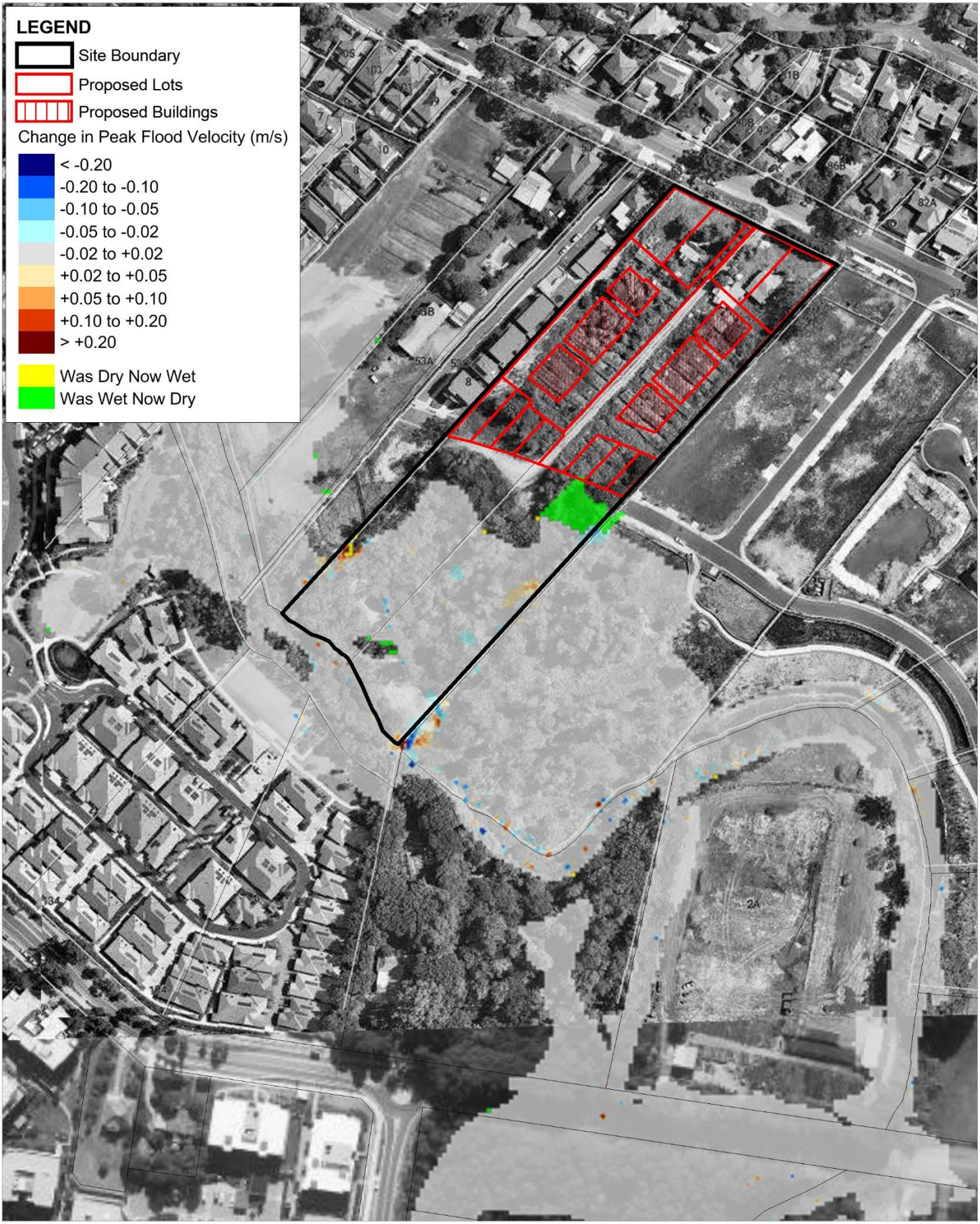


Title:

# 2 Year ARI Event
# Change in Peak Flood Velocity

Figure: C-6

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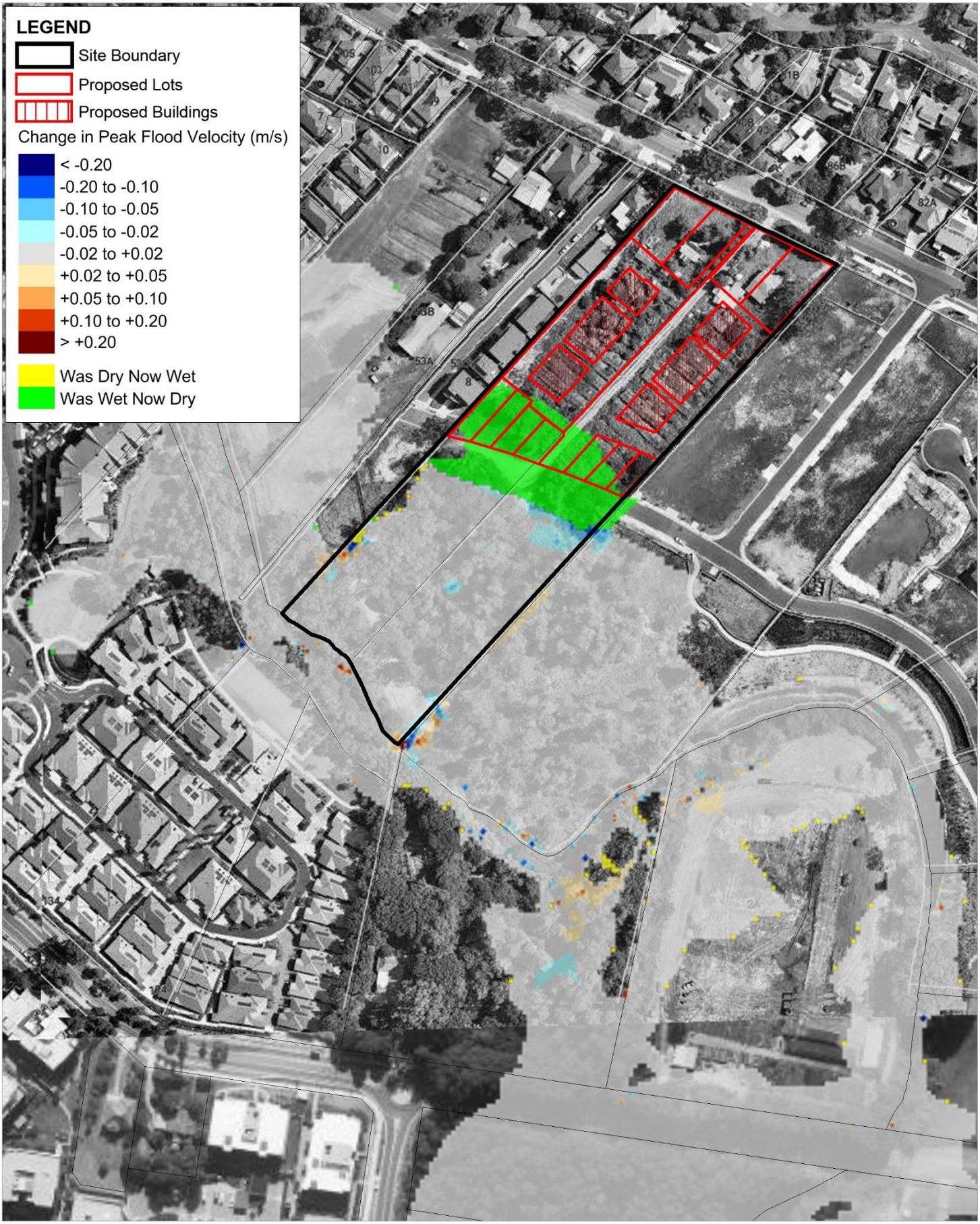


Title:

# 20% AEP Event
# Change in Peak Flood Velocity

Figure: C-7

Rev: -



N

0 50 100m

Approx. Scale

BMT
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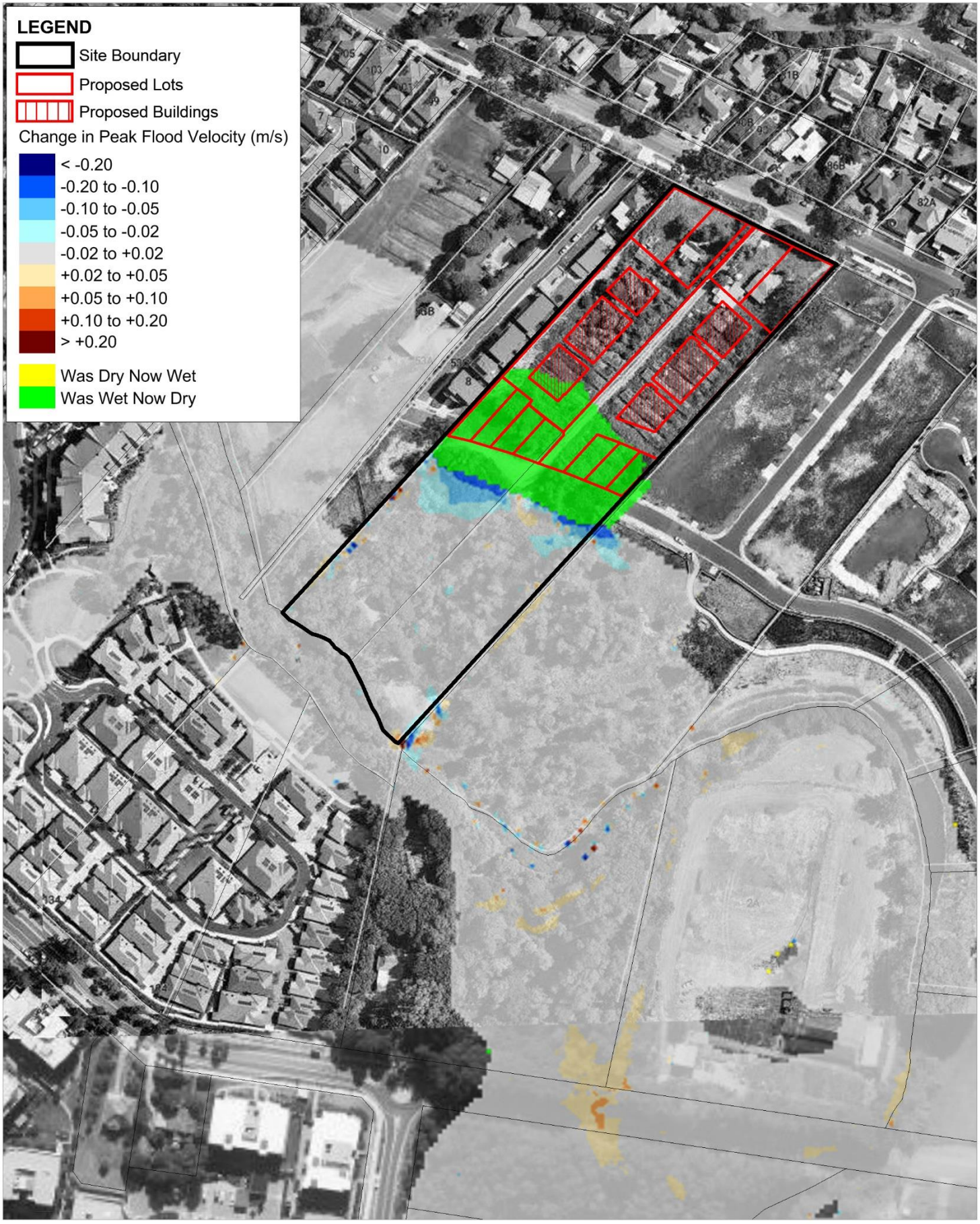


Title:

# 1% AEP Event
# Change in Peak Flood Velocity

Figure: **C-8**

Rev: **-**



N

0 50 100m

Approx. Scale

BMT
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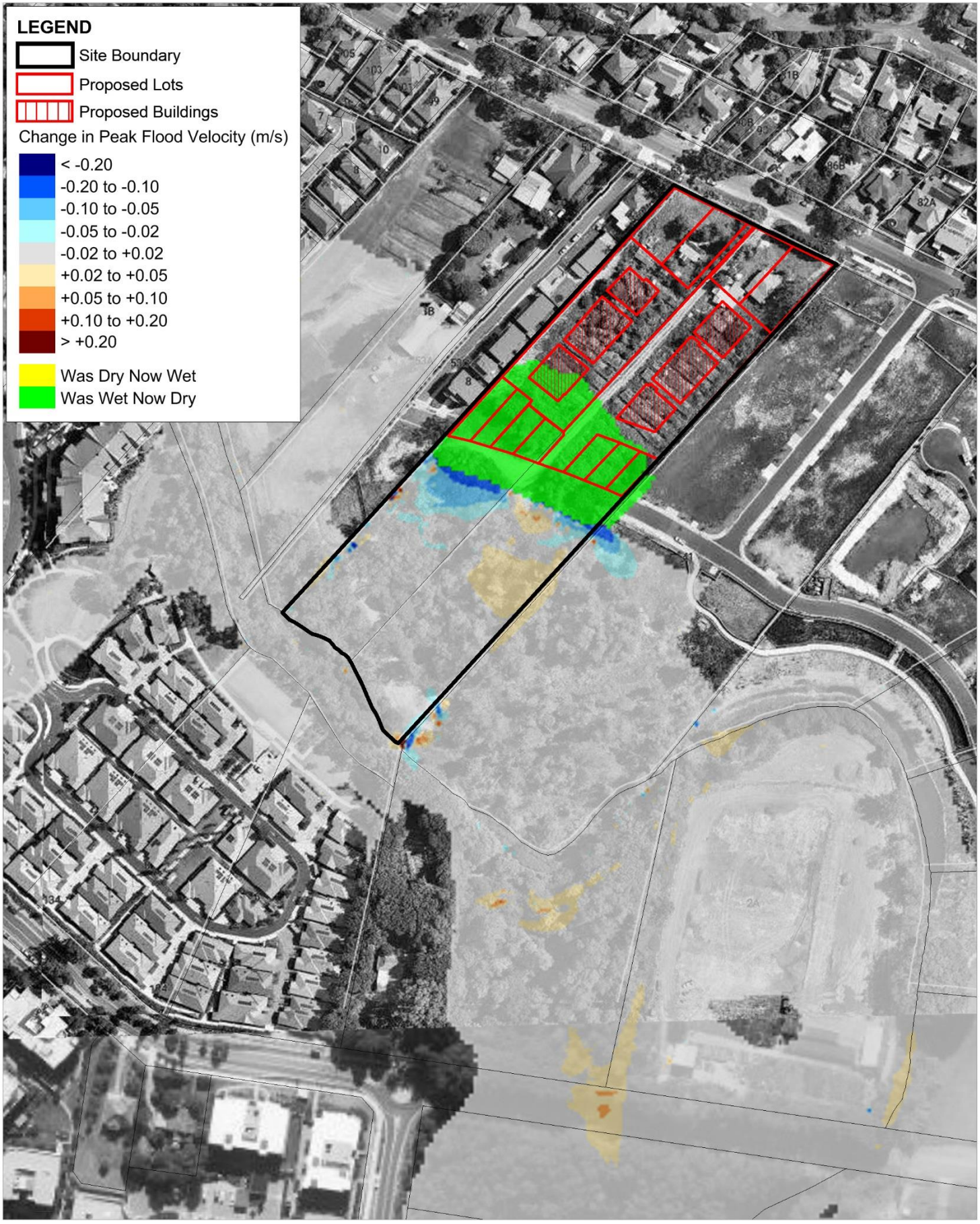


Title:

# 1% AEP with Climate Change Event Change in Peak Flood Velocity

Figure: C-9

Rev: -



N

0 50 100m

Approx. Scale

BMT

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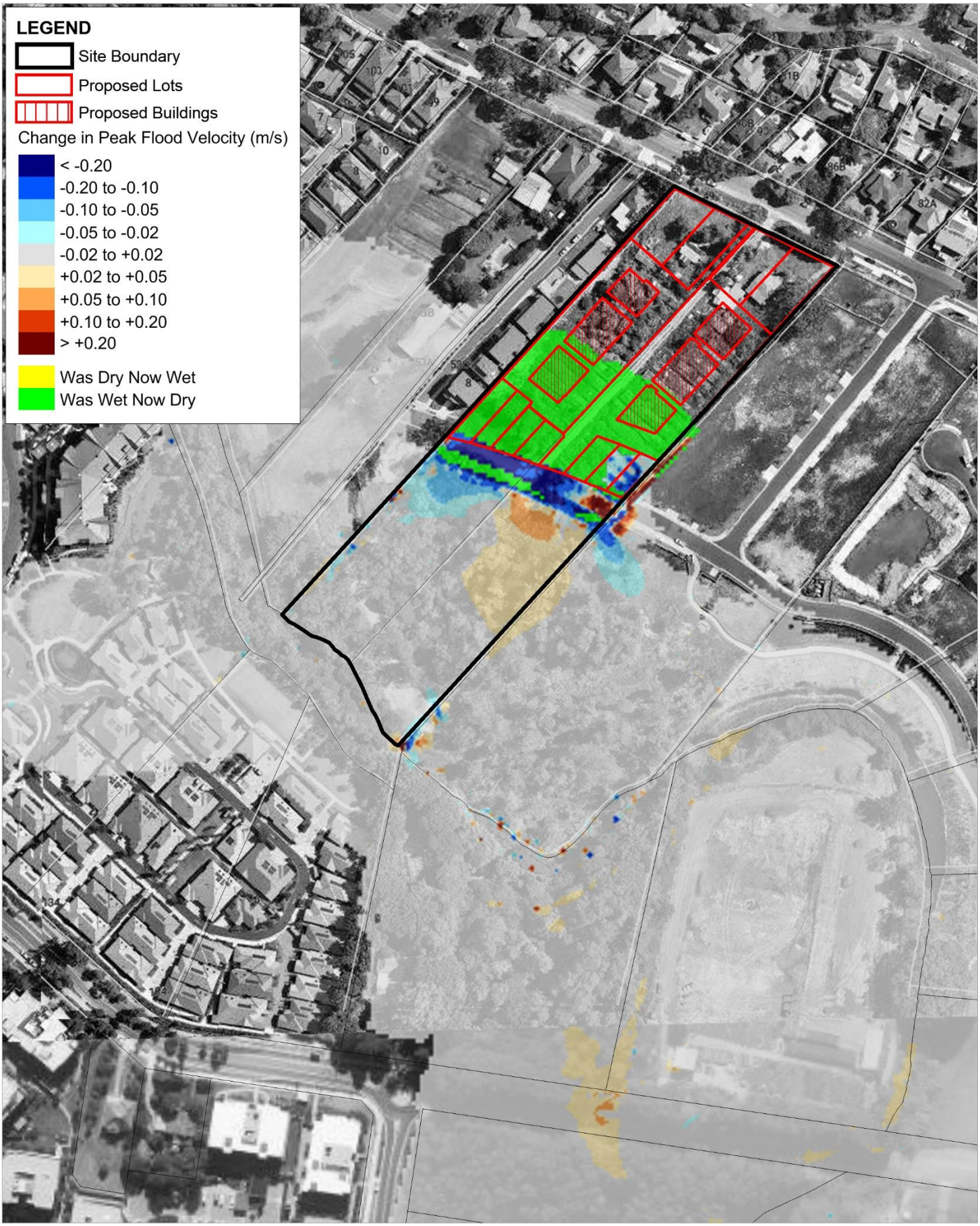
Filepath: K:N20951_45WarriewoodRd_FIAMapInfoWorkspaces0200731_Figures




Title:

# PMF Event
# Change in Peak Flood Velocity

Figure: **C-10**

Rev: **-**



N

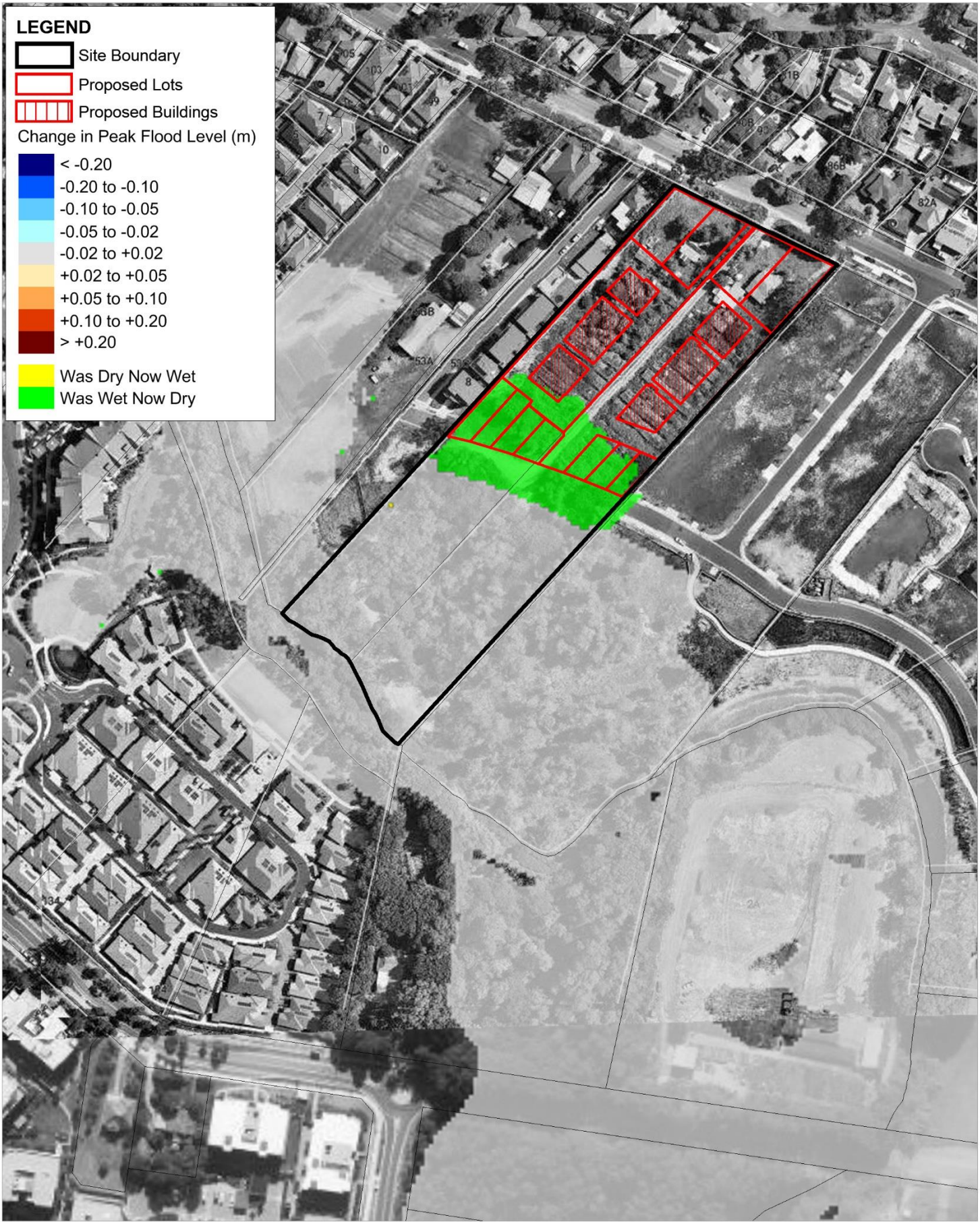
0 50 100m

Approx. Scale

BMT
www.bmt.org

Filepath: K:N20951_45WarriewoodRd_FIAMapInfoWorkspaces0200731_Figures

# Appendix D – Change in Peak Design Flood Level for Climate Change Events




Title:

# 2 Year ARI with Climate Change Event Change in Peak Flood Level

Figure: **D-1**

Rev: **-**



N

0 50 100m

Approx. Scale

BMT

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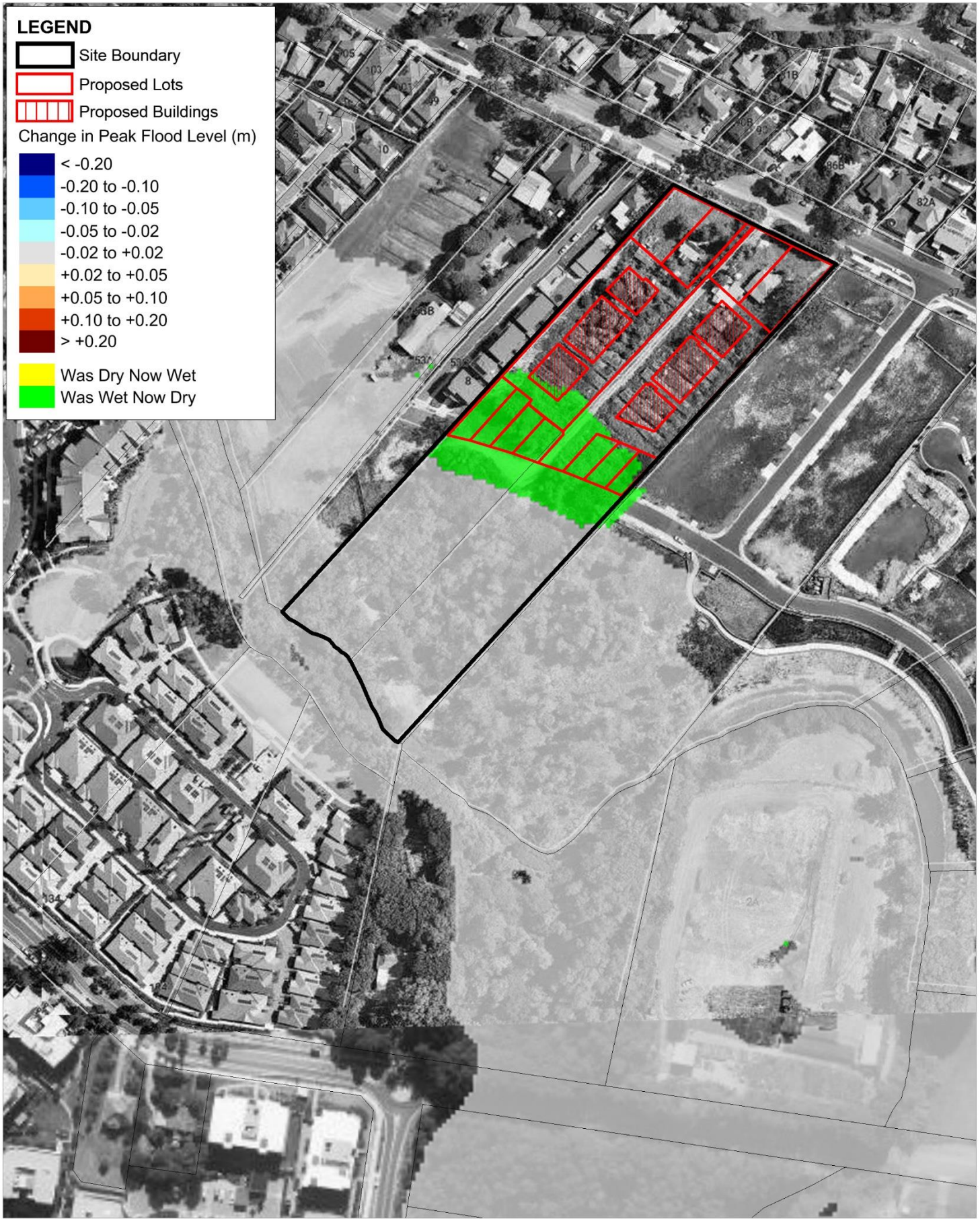
Filepath: K:N20951_45WarriewoodRd_FIAMapInfoWorkspaces0200731_Figures




Title:

# 20% AEP with Climate Change Event Change in Peak Flood Level

Figure: D-2

Rev: -



N

0 50 100m

Approx. Scale

BMT

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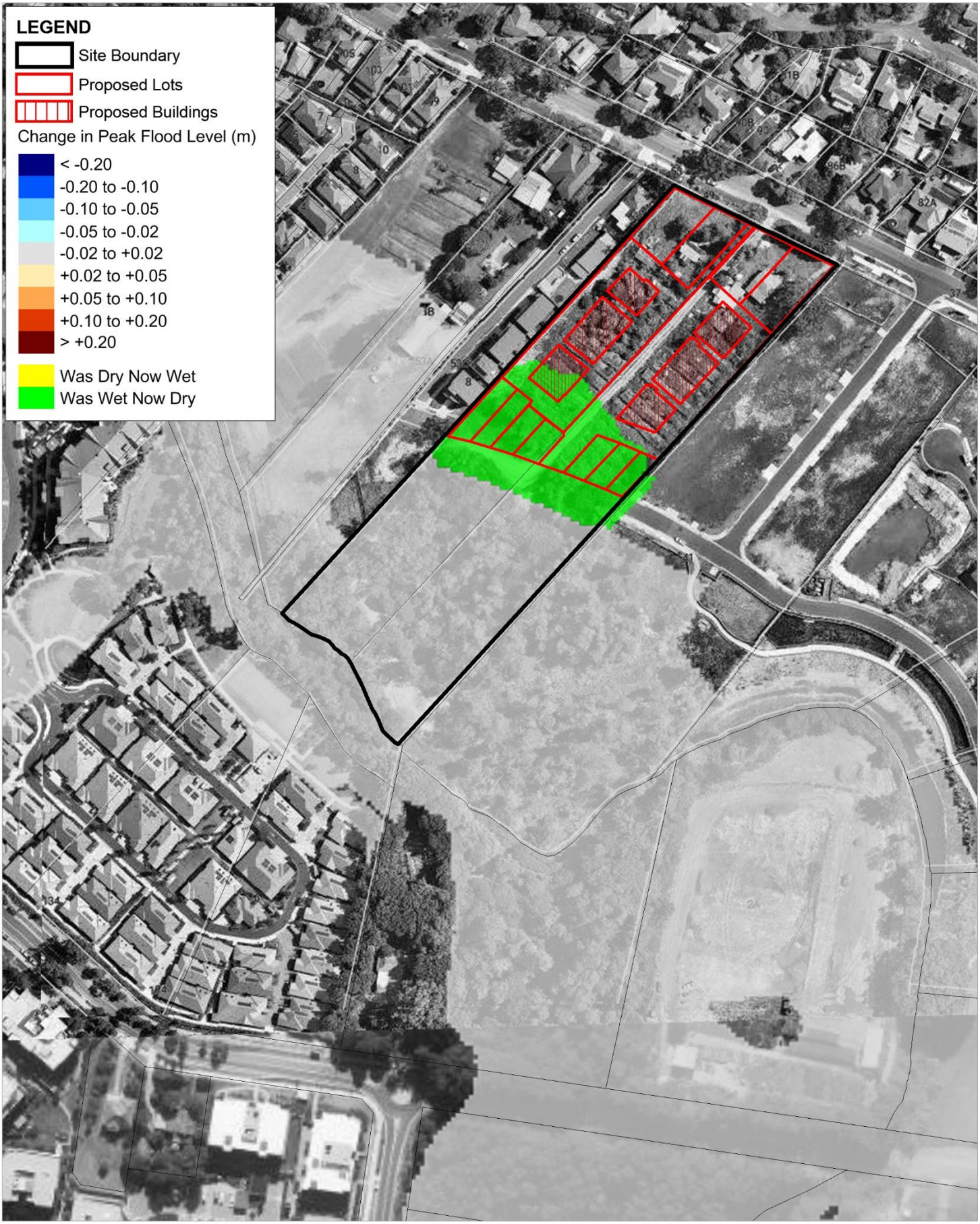
Filepath: K:N20951_45WarriewoodRd_FIAMapInfoWorkspaces0200731_Figures




Title:

# 1% AEP with Climate Change Event Change in Peak Flood Level

Figure: **D-3**

Rev: **-**



N

0 50 100m

Approx. Scale

BMT

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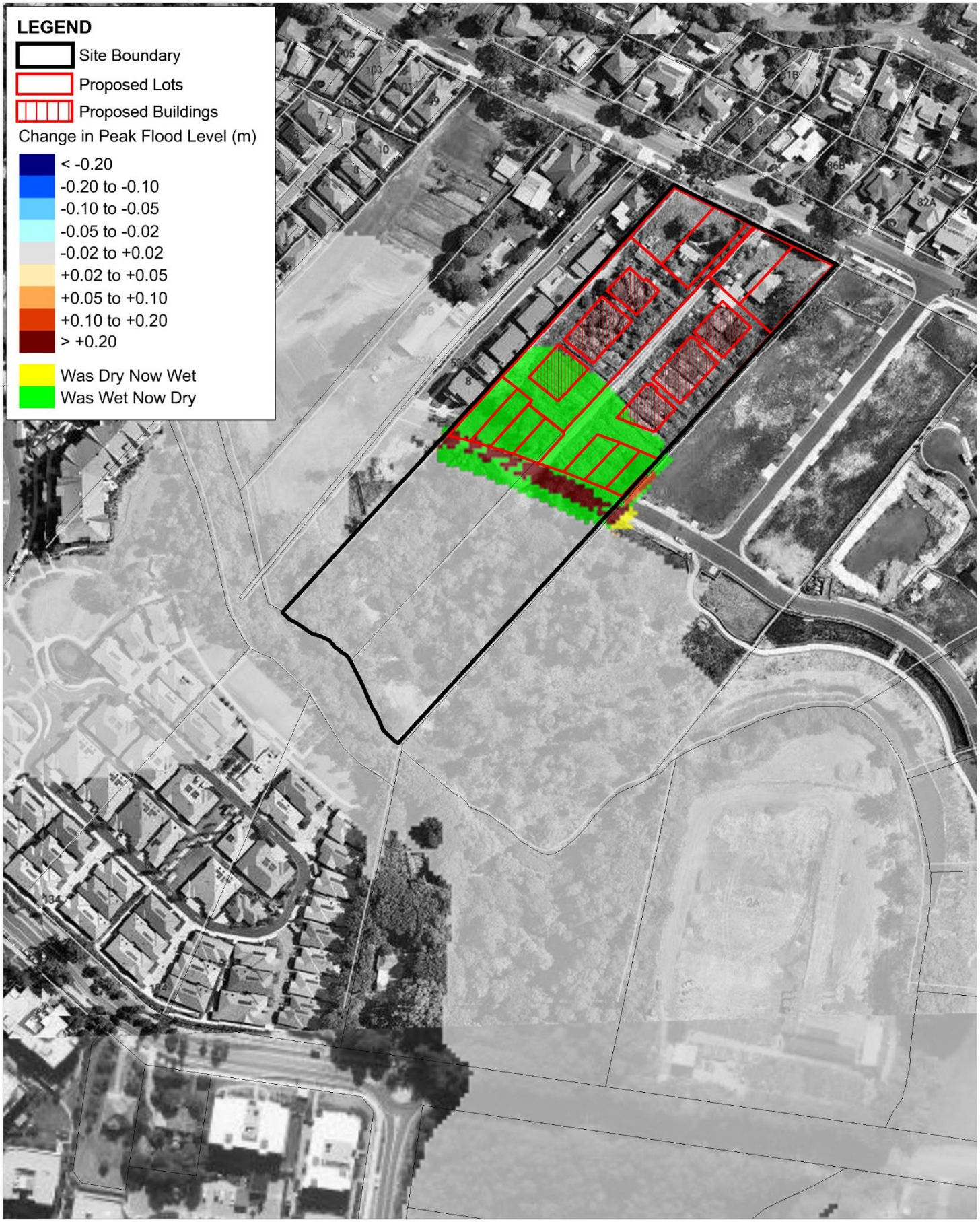
Filepath: K:N20951_45WarriewoodRd_FIAMapInfoWorkspaces0200731_Figures




Title:

# PMF with Climate Change Event Change in Peak Flood Level

Figure: **D-4**

Rev: **-**



N

0 50 100m

Approx. Scale

BMT

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