Our Ref: 59917042-L004:BCP/bcp
Contact: Dr Brett C. Phillips

9th July 2019

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The Meriton Group
Level 11 Meriton Tower
528 Kent Street
SYDNEY NSW 2000

Attention: Hannah Gilvear

Dear Hannah,

DEVELOPMENT APPLICATION FOR A 24 LOT COMMUNITY TITLE SUBDIVISION, 2 MACPHERSON STREET, WARRIEWOOD

On the 31 May 2019 the Meriton Group received approval for Development Application (N0398/17) which sought consent for the civil works including cut and fill to create a suitable building platform for future development, private road, drainage works and environmental management works for 2 Macpherson Street, Warriewood.

This approval was based in part on the following documents which informed the consideration of flooding and the creekline corridor requirements:

> Cardno (2018a) "Flood Impact Assessment, 2 Macpherson Street, Warriewood", *Final Report*, Revision 2, prepared for the Meriton Group, 24 January 2018, 32 pp + Apps.
>
> Cardno (2018b) "2 Macpherson Street, Warriewood, Revised Response to Statements of Facts and Contentions", *Letter Report*, prepared for the Meriton Group, 10 December 2018, 35 pp.
>
> Cardno (2018c) "2 Macpherson Street Warriewood - PMF Flood Condition and Time of Isolation Assessment", *Letter Report*, prepared for the Meriton Group, 11 December 2018, 9 pp

The current Development Application seeks consent for a 24 Lot Community Title Subdivision of 2 Macpherson Street, Warriewood to accommodate future residential development.

The works proposed under this application include:

- Proposed Lot 1 – Private access loop road;
- Proposed Lots 2 – 23 – future residential lots under community title; and
- Proposed Lot 24 – Land to be dedicated to Council, being the 25-metre inner creek line corridor in accordance with Item 1m in Warriewood Valley Development Contributions Plan Amendment 16, Revision 3, 2018.

The construction of new dwellings does not form part of this application.

The controls that are applicable to subdivision are found Section C of the Pittwater DCP 201 C6.1 – C6.10.

The proposed 24 Lot Community Title Subdivision does not change the development conditions which were assessed previously as documented in the aforementioned reports. Consequently it is our view that the three reports (Cardno 2018 a, b, c) address the Council's flooding and the creekline corridor requirements and inform the assessment of the the Development Application for a 24 Lot Community Title Subdivision of 2 Macpherson Street, Warriewood.

Yours faithfully

Brett C. Phillips

……

Dr Brett C. Phillips
Global Senior Principal, Hydrology
for **Cardno**

Flood Impact Assessment

2 Macpherson Street, Warriewood

59917042

Prepared for
Meriton Group

24 January 2018

Cardno
Shaping the Future

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Rev1	13/09/17	For Issue	DW	AR
Rev2	16/01/18	For Issue	NS	DW

Executive Summary

In order to determine and manage the flood impacts associated with the proposed development of 2 Macpherson Street, Warriewood a flood impact assessment for the site has been prepared. Hydraulic modelling of the site has been undertaken to determine the potential impacts of the development within the floodplain and to ensure that the impacts and risks posed by the development of the site are understood.

Based on the analysis undertaken the following outcomes have been established:

- The final fill level of dwellings onsite is 4.29 mAHD, which is the defined flood planning level for the site (1% AEP climate change and sea level rise (0.9m);
- No adverse flood impacts would occur upstream and downstream of the site;
- A potential excavation volume of 5,400 m^3 would result in a net gain of flood storage of 704 m^3 for the 1% AEP with climate change and 0.9 m sea level scenario. This storage however, is not necessary for the site to have no adverse impacts on surrounding properties; and
- Shelter in Place is a viable emergency response option and does not result in an increase in risk to life if appropriately incorporated into the development.

While some additional modelling is required to gain a complete understanding of the flood impacts of the site, overall the proposed development, in its preliminary state, demonstrates compliance against Council's flooding conditions. This additional detailed modelling and assessment will be undertaken at the Development Approval stage.

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Glossary

Average Recurrence Interval (ARI)	The long-term average period between occurrences equalling or exceeding a given value. For example a 20 year ARI flood would occur on average once every 20 years.
Annual Exceedance Probability (AEP)	The probability of an event occurring or being exceeded within a year. For example a 5% AEP flood would have a 5% chance of occurring in any year. An approximate conversion between ARI and AEP is provided.

AEP	ARI
63.2 %	1 year
39.3 %	2 year
18.1 %	5 year
10 %	10 year
5 %	20 year
2 %	50 year
1 %	100 year
0.5 %	200 year
0.2 %	500 year

Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Flood	The covering of normally dry land with water from a stream, river, estuary, lake, dam, major drainage and/or due to super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Freeboard	A height added to flood levels to provides reasonable certainty that the risk exposure accepted by deciding on a particular flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, driveway crest levels, etc.
Probable maximum flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.

1 Introduction

Cardno (QLD) previously issued the 'Flood Impact Assessment, 2 Macpherson Street, Warriewood (ref: 59917042/Rev1) dated 13 September 2017. Subsequently, Council issued a Request for Further Information (RFI) as per an email correspondence dated 22 December 2017. The RFI requested an assessment of open entrance conditions on local flood behaviour for the full range of design events listed in Table 6 (Refer to Section 3.5.3 of this report), based on both interim and ultimate creek design conditions.

Therefore, this revised flood impact assessment report (Rev2) has been prepared to address the relevant Council's RFI items. Due to the lack of complete design of the final creek works at this stage, this assessment considered the interim creek design conditions (incorporating the proposed design associated Macpherson Street Upgrade).

This report should be read in conjunction with the Rev1 report.

1.1 Site Characteristics

The proposed development site is located at 2 Macpherson Street, Warriewood .The site comprises approximately 2.1 Hectares of land at 2 Macpherson Street (the site) in Warriewood Valley. Legally, the site is described as Lot 25 Section C in DP5464 and is shown in Figure 1-1.

The parcel of land is of an irregular shape has a 120 metre frontage to Macpherson Street to the south. A central portion of the site has been raised and levelled and is currently surrounded by undeveloped land. Levels across the site range from 1.4 mAHD in the northern section of the site (within the creek) to a high point of 3.7 mAHD within the central portion of the site.

Figure 1-1 Site Locality Plan (Source – Urbis)

1.2 Relevant Documents

The report has regard to the following documents:

- Floodplain Development Manual by NSW Government (April 2005);
- Pittwater Local Environment Plan (LEP) 2014; and
- Warriewood Valley Urban Land Release Water Management Specification (WMS, 2001)

2 Flood Behaviour

Floods are discussed in terms of how likely the flood is to occur or be exceeded in any given year. This is called the Annual Exceedance Probability or “AEP”. For instance, a flood that occurs on average every 100 years has a 1% chance of occurring in any given year. Larger floods do occur, although they have less chance of occurring in any given year.

The site is subject to both flooding from Narrabeen Creek and the Narrabeen Lagoon Floodplain. Results from the Narrabeen Lagoon Flood Study (WBM BMT, 2013) indicate that Macpherson Street in its current arrangement is overtopped in the 1% AEP due to the flow present in Narrabeen Creek and the influence of backwater from Narrabeen Lagoon. In the PMF event the area is significantly inundated due to the levels present in the Narrabeen Lagoon Floodplain.

Currently Macpherson Street is in the process of being upgraded. This will result in the roadway having a level of immunity greater than 1% AEP with 30% climate change and 0.9 m sea level rise. The road will not be trafficable in the PMF event however.

For the purposes of the analysis undertaken, it is considered that Macpherson Street upgrade has been completed, as the development will not occur prior to this scenario.

2.1 Flood levels

Each LGA generally defines a flood planning level based upon an AEP with an allowance for freeboard to cater for uncertainties. In the Pittwater LGA, where the proposed development results in an *intensification of development* the flood event that is utilised as the flood planning level is the 1% AEP with 30% climate change and 0.9 m sea level rise. A freeboard of 0.5 m above this level is expected for all proposed dwellings.

While dwellings onsite will not be inundated by floodwaters in a 1% AEP with 30% climate change and 0.9 m sea level rise or smaller floods, the site is subject to inundation in extreme flood events greater than a 1% AEP with 30% climate change and 0.9 m sea level rise. The defined flood level for this site in this event is 3.79 mAHD.

The floor levels for all residential lots within the proposed development is 4.29 mAHD. This is equal to the required Flood Planning Level for the site. All proposed residential dwellings will be two storeys.

Based on information provided within Narrabeen Lagoon Flood Study (WBM BMT, 2013) this FPL is noted to be in excess of the predicted flood levels of the 0.1% AEP event under existing catchment conditions, with a freeboard of 700 mm present on this AEP scenario.

Once the water reaches the level of 4.29 mAHD floodwaters will enter the dwellings onsite resulting in flooding of the ground floor.

2.2 PMF Flood Event

The PMF Event is largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. The PMF event is generally considered to have an equivalent AEP of between 0.0001% and 0.00001% AEP.

Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.

The purpose of utilising the PMF flood event within an assessment is to ensure the residual risk (that is the risk that exists once the flood immunity of a development is exceeded) that is present onsite is considered and planned for.

Figure 2-1 provides an overview of the flooding experienced within the Narrabeen Lagoon area at a catchment level in the existing flood conditions. In the PMF flood event over 3000 properties are flood affected, with almost 1400 dwellings experiencing over floor flooding (Cardno, 2016).

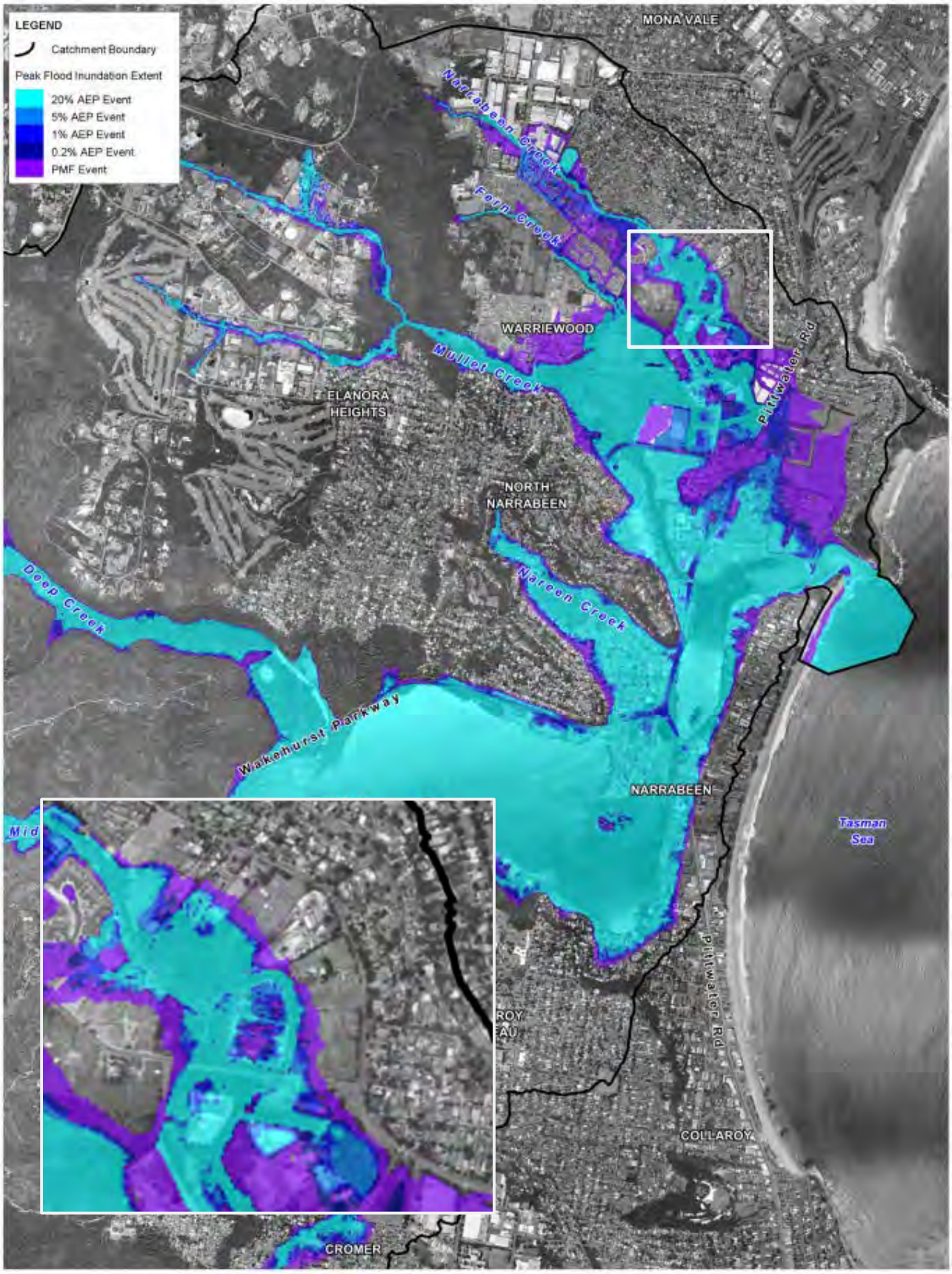

Figure 2-1 Peak Flood Extent – Catchment Derived Events

(Source: Narrabeen Lagoon Flood Study, BMT, 2013)

3 Proposed Development

3.1 Introduction

The development of the site will take into account the flood affectation of the site. Given that the majority of the site is Low Flood Hazard in the 1% AEP (as evidenced in the Narrabeen Lagoon Flood Study, 2013), development of the site will be confined to those Low Flood Hazard areas to connect the site to the Macpherson Street upgrade and the associated Narrabeen Creek works. The only works outside this Low Flood Hazard Area are being undertaken as part of the Macpherson Street upgrade, which provides access to the site from the new road level (which is approximately 2.2 m higher than the existing road level at the site entrance).

In the PMF event it is noted that under existing landform conditions the site sits within a high hazard region. the Flood Emergency Management Plan (Cardno, 2017a) discusses the treatment measures proposed to ensure risk to life is minimised.

The proposed development is to consist of 22 dwellings, all of which will be two storey. **Figure 3-1** shows the indicative site and lot arrangement.

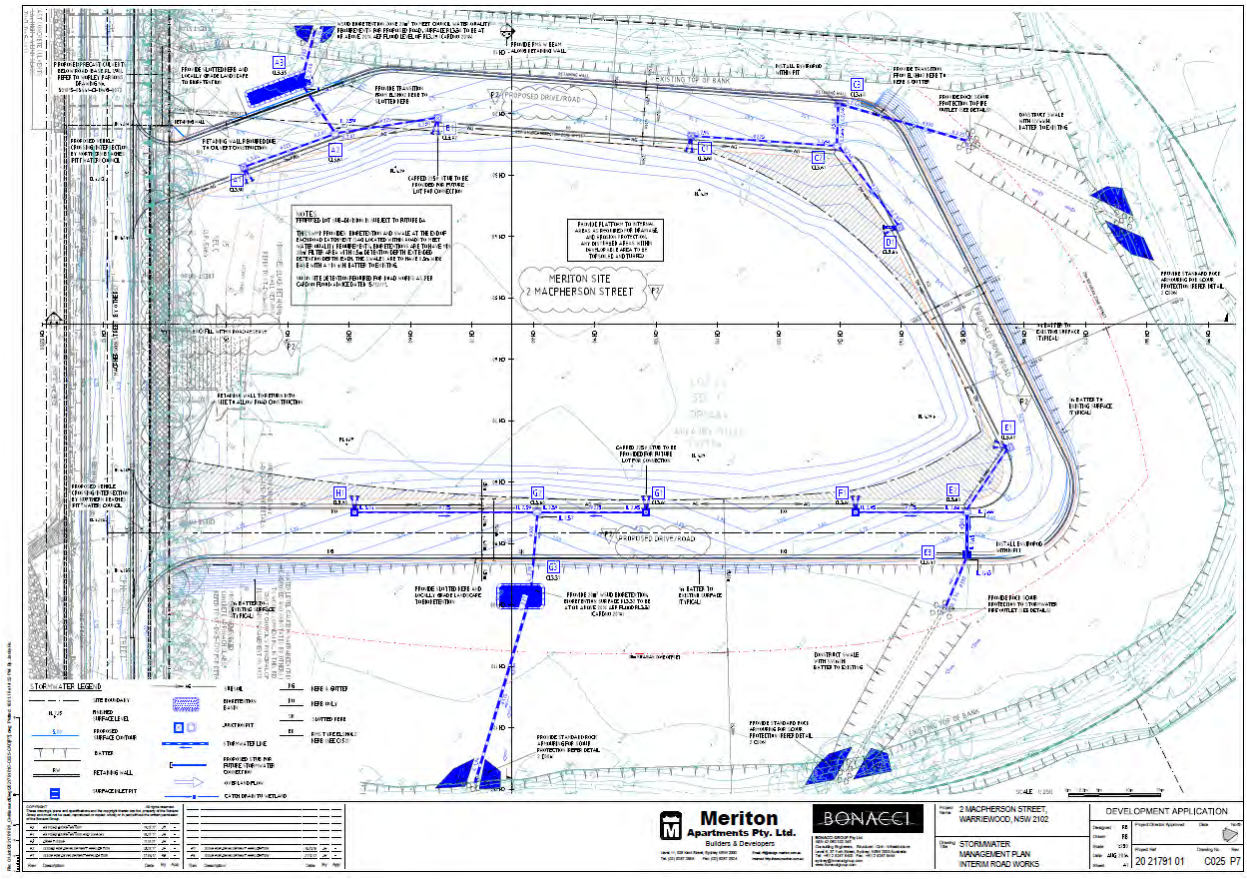

Figure 3-1 Indicative Lot and Site Layout

3.2 Fill Levels

The final proposed floor levels and fill levels are provided on drawing number C025 P7 provided in Appendix C. The following criteria are addressed within this earthworks plan:

- The development level should be above the planning level (above the 1% AEP with 30% climate change plus 0.9m sea level rise). The flood planning level for this site is considered to be 4.29 mAHD based on current flood mapping of the site;
- No adverse impacts upstream and downstream of the subject site; and
- No loss of flood storage up to the probable maximum flood (PMF) design flood

The finished floor level of the development is set to 4.29 mAHD. The internal roadway within the development ranges from 3.50 mAHD to 4.10 mAHD. The internal roadway does not have 1% AEP with 30% climate change and 0.9 m sea level rise immunity however is deemed trafficable in this event.

It is noted the drawing in Appendix C is not current however it is understood that the general earthworks and fill arrangements on the most current drawing is for all intents and purposes, consistent. Prior to the finalisation of the development design the above discussed criteria will need to be thoroughly reviewed and confirmed for conformance.

3.3 Integration with Stormwater and Water Cycle Management Systems

The water quality requirements for the site are nominated in Pittwater Council 2001, *Warriewood Valley Urban Land Release Water Management Specification (WMS)*. The water quality objectives are provided below:

"Specific standards have been developed for in-sector monitoring applicable to wet or dry weather stormwater discharge concentrations. However, as a minimum, a 'no worsening' of existing runoff quality is required".

The goal is to ensure that developed conditions do not worsen existing conditions and that this opportunity is taken to improve/reduce constituent loads. The proposed water quality strategy for the site, meets the above requirement set by Northern Beaches Council. It is proposed to utlise bio-retention and swales to meet the water quality objectives specified within the WMS. Due to the location of the site no increase in peak discharge is anticipated due to the development. As such, no detention of the roadway has been proposed.

The integration of these systems within the floodplain is necessary to ensure their functions are not impeded. Due to the relatively small size of the devices proposed and the location of the site in the floodplain it is considered that the impacts are likely minor and local in nature.

While the impacts are likely to be identified as minor, this assessment will be necessary prior to finalisation of development. This additional detailed modelling and assessment will be undertaken at the Development Approval stage.

3.4 Creek Corridor and Buffers

While flooding in the 1% AEP event surrounds the site, the mapped alignment of the Narrabeen Creek is to the north and east of the site. On the mapped alignment of the creek a 25 m private buffer is provided to the creek. In addition to this a minimum 25 m riparian zone offset to is present to the creek centreline. C025 P7 provided in Appendix A of this document shows the location and extent of these zones.

To the west of the site along the overflow channel of the creek it is likely a retaining wall is required to prevent encroachment into the channel. This will prevent the unnecessary modification of the channel and the removal of vegetation.

3.5 Flood Modelling

Flood modelling has been undertaken to determine the impact of flooding due to the proposed development. In order to assess this, Cardno have used the Council approved Narrabeen Lagoon Flood Model.

The Narrabeen Lagoon (and tributaries) TUFLOW model, was used as a basis for the flood impact assessment. Given the size and the long run time of the model, it was truncated for the purposes of this assessment.

The truncated model was run and compared to full model prior to modification to ensure consistent output. The model extends downstream past the site by approximately 800 m (Downstream of Jackson Road) where a time varying water level boundary, derived from the catchment wide model, was established.

As the approved flood model does not have the proposed Macpherson Street Road upgrade incorporated, the first task was to update this and redefine the base case flooding for the site. In addition to this, detailed ground survey of the development site was incorporated into the model. The additional works included in the truncated base case model are as follows:

ground survey of the development site was incorporated into the model. The additional works included in the truncated base case model are as follows:

- A site survey tin provided by Bonacci Group Pty Ltd was included in the model; and
- The design surface level of Macpherson Street were digitized based on the Issued for Construction Drawings of Macpherson Street which were obtained from the Northern Beaches Council. In addition, the proposed culvert and bridge details were obtained from these drawings and incorporated into the model.

3.5.1 Modelling of Macpherson Street Upgrade

In order to represent the Macpherson Street upgrade the proposed alignment was incorporated into the hydraulic model. The alignment and levels utilised are on the information provided by Northern Beaches Council (Macpherson Street Warriewood Road Upgrade April 2016 reduced.pdf).

The details of the proposed culverts and bridge under Macpherson Street are provided in the Table 3-1. Initial modelling showed that due to the large size of the culverts, model instabilities occurred around the culverts causing unrealistic flood levels. To overcome this issue, the culverts were modelled in the 2D domains using the layered flow constriction approach. Appropriate flow constriction parameters were determined to represent the head loss that would occur through the culvert structure. These losses were calibrated against a HEC-RAS model of the culverts to confirm their suitability. The adopted flow constriction parameters are provided in Table 3-2.

Table 3-1 Macpherson Street Culvert and Bridge Details

Parameters	Parameters	
	Culvert	Bridge
Size	9x 3.6x1.2 RCBCs	Open Bridge with no piers in the waterway
		Base width of 3.6m
		Top width to waterway 6.9m
		Underside of Bridge 3.42 mAHD
Length	15	15
Upstream Invert Level	1.90	0.79
Downstream Invert Level	1.84	0.73

Table 3-2 Macpherson Street Culvert and Bridge Loss Details

Bridge Layer	Levels	Form Loss Coefficient (K)	Blockage (%)
Layer 1 (below deck)	Invert level of 1.9 mAHD Obvert level 3.1 mAHD	0.5	11
Layer 2 (deck level)	Underside of deck 3.1 mAHD Road Level 4.2 mAHD	1.2	100
Layer 3 (above road level)	Level to top of handrail 5.11 mAHD	0.5	10

3.5.2 Modelling of Developed Conditions

Subsequent to base case modelling and calibration, a post-development model was created to reflect the proposed development of the site. The proposed design tin of the development site was provided by Bonacci Group Pty Ltd which was included in the flood model to assess the flood impacts. The design surface information is illustrated on drawing C025 P5 provided in Appendix C of this document.

The assessment has been undertaken to prove the site has the capacity to be developed in accordance with the intent of the DCP and WMS and thus in the future will be able to adhere to the requirements set out in

the documents. Future refinement of the development extent for the consideration of other constraints will require further modelling to be undertaken to ensure the final development arrangement meets these criteria.

This additional detailed modelling and assessment will be undertaken at the Development Approval stage.

3.5.3 Scenarios

Council's RFI requested additional scenarios and/or design flood events listed in Table 6 below.

Table 6 Design Flood Event and Requirement for Development in the Warriewood Valley

Design Event	WMS (2001), LEP or P21 DCP Requirement	Critical Duration (Peak Flood Level) from 2013 Flood Study (Catchment-Derived)	Potential Other Scenarios for Impact Assessment
50% AEP	Flow to be carried in-bank (WMS)	Unknown – likely to be of the order of 2 hours	N/A
50% AEP + CC	Requirement of P21 DCP 2014	Unknown – likely to be of the order of 2 hours	N/A
20% AEP +CC	Walkways/cycleways to be above 20% AEP (WMS) Water quality facilities to be above 20% AEP (WMS)	Unknown – likely to be of the order of 2 hours	N/A
5% AEP	Flood assessment requirements (WMS)	Unknown – likely to be of the order of 2 hours	N/A
1% AEP	Carried within public corridor (WMS)	2 hours	Low lagoon tailwater condition (lagoon at 0.6 mAHD) could be considered to identify any local effects on flow velocities that are masked by tailwater conditions and to calculate potential scouring velocities under this scenario
Design Event	**WMS (2001), LEP or P21 DCP Requirement**	**Critical Duration (Peak Flood Level) from 2013 Flood Study (Catchment-Derived)**	**Potential Other Scenarios for Impact Assessment**
1% AEP + CC	OSD to be above 1% AEP + Climate Change (WMS + DCP) Floor levels to be above 1% AEP + CC + freeboard (WMS and DCP) Building platforms to be at or above the flood planning level (DCP C6.1) Bridge deck obvert 0.5 m above 1%AEP (WMS)	Unknown – likely to be of the order of 2 hours	Low lagoon tailwater condition (lagoon at 0.6 mAHD) could be considered to identify any local effects on flow velocities and peak levels that are masked by tailwater conditions and to calculate potential scouring velocities under this scenario
PMF	Evacuation Planning (WMS) Flood hazards and risk to life	Unknown – likely to be of the order of 30 – 60 minutes	N/A
PMF + CC	Evacuation Planning (WMS) Flood hazards and risk to life under climate change	Unknown – likely to be of the order of 30 – 60 minutes	N/A

To address the above, the revised flood assessment considered both open and closed entrance conditions, with sea level rise (SLR) and climate change (CC). The scenarios are summarised in Table 3-3.

It is noted that an assessment of the PMF event was provided in Section 4.2 the previous report. The PMF with a climate change tailwater scenario has not been established within the Council provided model and thus cannot be quantified.

In addition, no modelling was undertaken for 50% AEP event within the hydraulic model, as the model resolution is not fine enough to allow accurate assessment of in-bank flows. From the Warriewood Valley Water Management Specification, the 50% AEP flow is to be carried in-bank. No alteration to the bank or in bank is proposed as part of this development and as such, no change to the bank flow conditions will be present. It is noted that development to the north of the site has resulted in alteration to the channel. This is considered temporary. Once finalised, these works are to be removed and the flow regime returned to its

natural state. As on works in-bank are proposed it has been deemed unnecessary at this stage to confirm the in-bank conveyance of the 50% AEP.

Note it is considered the intent of the intent of the low tailwater scenario specified by Council is to ensure the site does not result in increased velocities through sensitive areas downstream of the site, while also ensuring the development is not detrimental to the current channel. As such a static low tailwater (0.6 mAHD or 1.5 mAHD in CC considerations) has been applied, which is considered conservative for this analysis.

Table 3-3 Summary of TUFLOW Model Scenarios

TUFLOW	Scenario	Description	Tailwater Condition	Design Events	Requirements
E11_CC	Base Case	Closed entrance with 0.9m SLR & 30% CC	Dynamic	1% AEP event with 9hr and 12hr storms	
E15_DES	Base Case	Open entrance with tailwater @ 0.6mAHD & no CC	Static	1% AEP event with a 2 hr storm	
E15_CC	Base Case	Open entrance with tailwater @ 0.6mAHD + 0.9m SLR & 30% CC	Static	1% AEP event with a 2 hr storm	
DE04_CC	Developed Case	Closed entrance with 0.9m SLR & 30% CC	Dynamic	1% AEP event with 9hr and 12hr & 20% AEP with 2hr, 6hr and 9hr storms	WMS- 1% AEP with respect to OSD and building floor level freeboard. 20% AEP for walkways, cycle ways and water quality devices
DE04_DES	Developed Case	Open entrance with tailwater @ 0.6mAHD & no CC	Static	1% AEP event with a 2 hr storm	Alternate scenario for local velocity(scour) impact
DE04a_CC	Developed Case	Open entrance with tailwater @ 0.6mAHD + 0.9m SLR & 30% CC	Static	1% AEP event with a 2 hr storm	Alternate scenario for local velocity(scour) and peak flood level
DE05_DES	Developed Case	Closed entrance with no SLR & no CC	Dynamic	1% and 5% AEP events with the 2hr storm	1% AEP conveyance within public corridor, and 5% flood assessment WMS

4 Flood Modelling Results

4.1 Impacts of the Roadway Upgrade

A comparison of the base model vs the model with the proposed Macpherson Street upgrade was undertaken to confirm the impact of the alignment. In general, no actionable impacts were noted. A minor increase in flood levels (20 mm) is noted to the west of the proposed fill pad; however, this does not extend off the site.

Table 4-1 Base Case Model Validation Results

Reporting Location	1% AEP with 30% climate change Flood Levels (mAHD)	
	Model without Road Upgrade	Model with Road Upgrade
Upstream of Macpherson Street, West of Development	3.78	3.80
Upstream of Macpherson Street, East of Development	3.78	3.78
Immediately Downstream of Macpherson Street	3.77	3.77

4.2 Developed Flood Mapping

Figures 4-1 to Figure 4-5 show the maximum flood depth plots for the various scenarios when the development is considered onsite.

4.2.1 1% AEP + CC (Closed Outlet)

Figure 4-1 shows the depth extent of the 1% AEP + CC for the site. This design scenario has been utilised to confirm design levels for the site and for impact analysis.

4.2.2 20% AEP + CC (Closed Outlet)

Figure 4-2 shows the depth extent of the 20% AEP + CC for the site. In accordance with the WMS, walk ways, cycle ways and water quality devices are to be above this level. The proposed water quality devices are confirmed to be above this level.

4.2.3 1% AEP (Closed Outlet)

Figure 4-3 shows the depth extent of the 1% AEP for the site. This design scenario has been utilised to confirm the 1% AEP sits within the public corridor. Based on the preliminary design the full flow path to the north of the site encroaches by approximately 10 m into the private buffer. The average depth in the area is approximately 300 mm. It is preferred to maintain the corridor in its natural state however if required earthworks in this area can be developed to satisfy the criteria specified. To the east of the site the 1% AEP flood extent is generally contained within the public corridor.

4.2.4 5% AEP (Closed Outlet)

Figure 4-4 shows the depth extent of the 5% AEP for the site. This design scenario has been utilised to confirm that stormwater water quality treatment systems can be located above the 5% AEP design flood event.

4.2.5 1% AEP + CC (Open Outlet)

Figure 4-5 shows the depth extent of the 1% AEP + CC for the site with a low tailwater level. This scenario has been utilised to determine if the development of the site results in changes to the velocity profile within and surrounding the site.

4.2.6 1% AEP (Open Outlet)

Figure 4-6 shows the depth extent of the 1% AEP for the site with a low tailwater level. Similar to the above, this scenario has been utilised to determine if the development of the site results in changes to the velocity profile within and surrounding the site.

4.2.7 Hazard Assessment

Figure 4-7 shows the hazard profile for the site in the 1% AEP with 30% climate change plus 0.9 m sea level rise. The roadway, while inundated in some areas is considered to be low hazard and trafficable. In events that exceed the roadway level however, it is recommended that residents onsite do not evacuate. Further discussion on emergency management procedures is provided in Section 5.

Figure 4-8 shows the maximum depth experienced onsite during the PMF event. The PMF event exceeds the proposed finished floor level of the site. As a result, the site must be considered at risk of flooding and flood emergency management considered to ensure the safety of persons onsite. The Warriewood FEMP (Cardno 2017a) provides this assessment. Depths of approximately 0.7 m are present in the area where dwellings are proposed. The PMF Event is largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. The PMF event is generally considered to have a probability of occurrence between 1:10,000 and 1:100,000.

4.2.8 Flood Impacts

Figure 4-9 shows the water level impact map of 1% AEP with 30% climate change plus 0.9m sea level rise when the development is considered onsite, comparing the developed condition to the base condition model with the Macpherson Street Road upgrade incorporated.

The results of the modelling confirm that virtually no adverse impacts external to the site are present in the 1% AEP with 30% climate change plus 0.9m sea level rise. A maximum afflux of 20 mm has been obtained for the 1% AEP with 30% climate change plus 0.9m sea level rise at the north western boundary of the site which extends slightly into the overflow channel to the west. It is considered minor refinement of the model schematisation will resolve this issue. Minor reductions are present to the east of the site of up to 20 mm.

The above impact maps confirm that no adverse impacts external to the site are present in the 120% AEP with 30% climate change plus 0.9m sea level rise. A maximum afflux of 20 mm has been obtained for the 1% AEP with 30% climate change plus 0.9m sea level rise at the north western boundary of the site. Minor reductions are present to the east of the site of up to 20 mm.

In the PMF event the site is completely inundated, and the site flood level is within 30 mm of the lagoon tailwater level. This flood level is present for at least another 300 m upstream of the site. As the flood level at the site is driven by Narrabeen Lagoon Flood level, the impact of the fill of the site is unable to exceed 50 mm due to the very minor increase in fill relative to the flood storage of the floodplain at this level. This due to the location of the site. The PMF is 4.89 mAHD onsite while the Narrabeen Lagoon PMF level is 4.87 mAHD. Thus the flood levels onsite are almost completely driven by the downstream flood levels and will not exceed the 50 mm impact discussed.

4.2.9 Velocity Impact

Figure 4-10 and Figure 4-11 show the velocity impact of the 1% AEP and 1% AEP + CC with the open entrance conditions. These figures show that the development will not result in any significant increase in the peak velocity with the in-bank velocities only slightly higher onsite than the existing condition. If deemed necessary, minor local scour protection can be provided in the channel to offset these increases. No increase downstream of the site under the proposed design is noted. Minor variances outside the site are noted however these are primarily attributed to minor model noise, which explains the scattered nature of the changes shown.

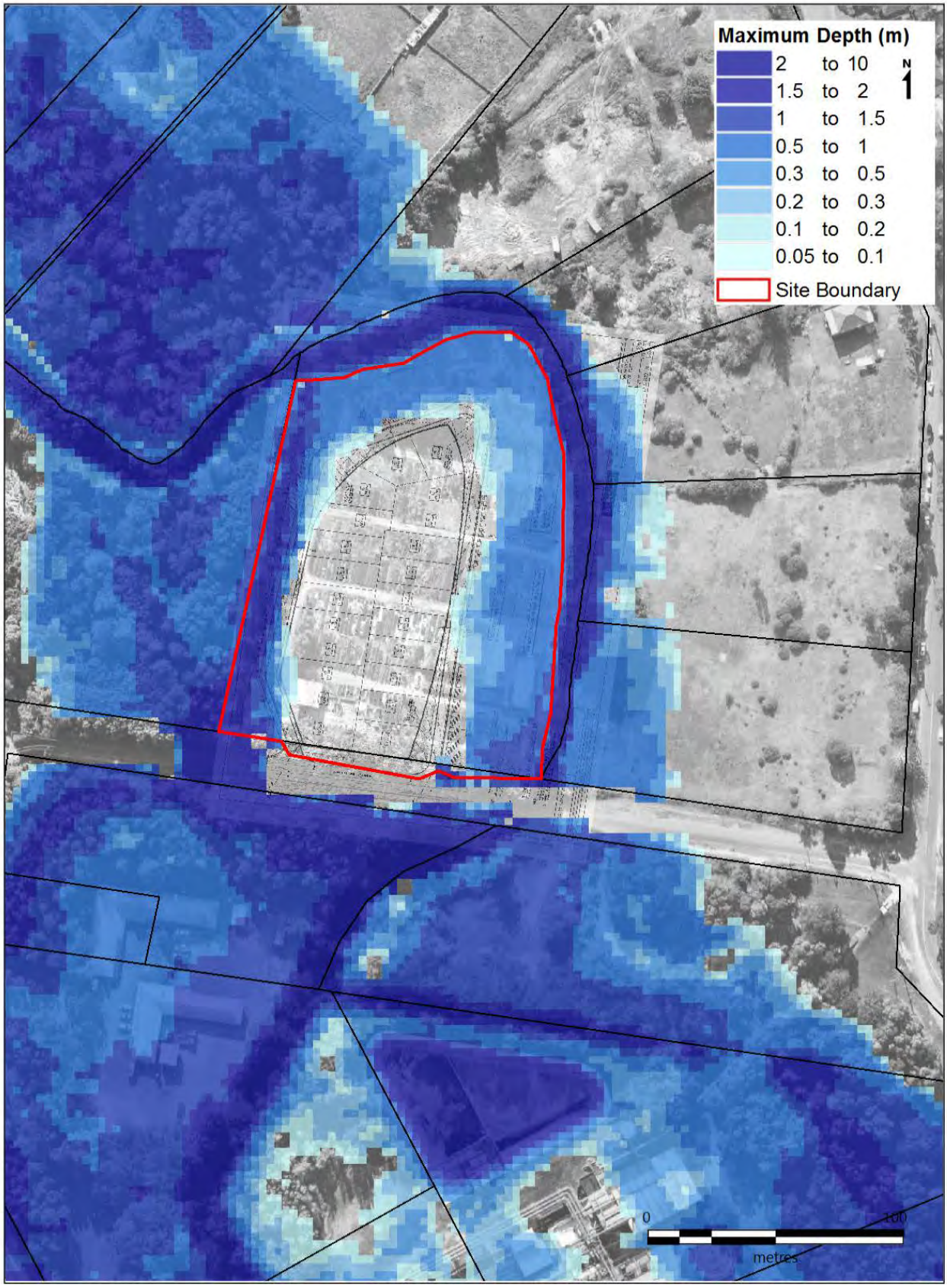

Figure 4-1 1% AEP Event Maximum Depth (DE04_CC)

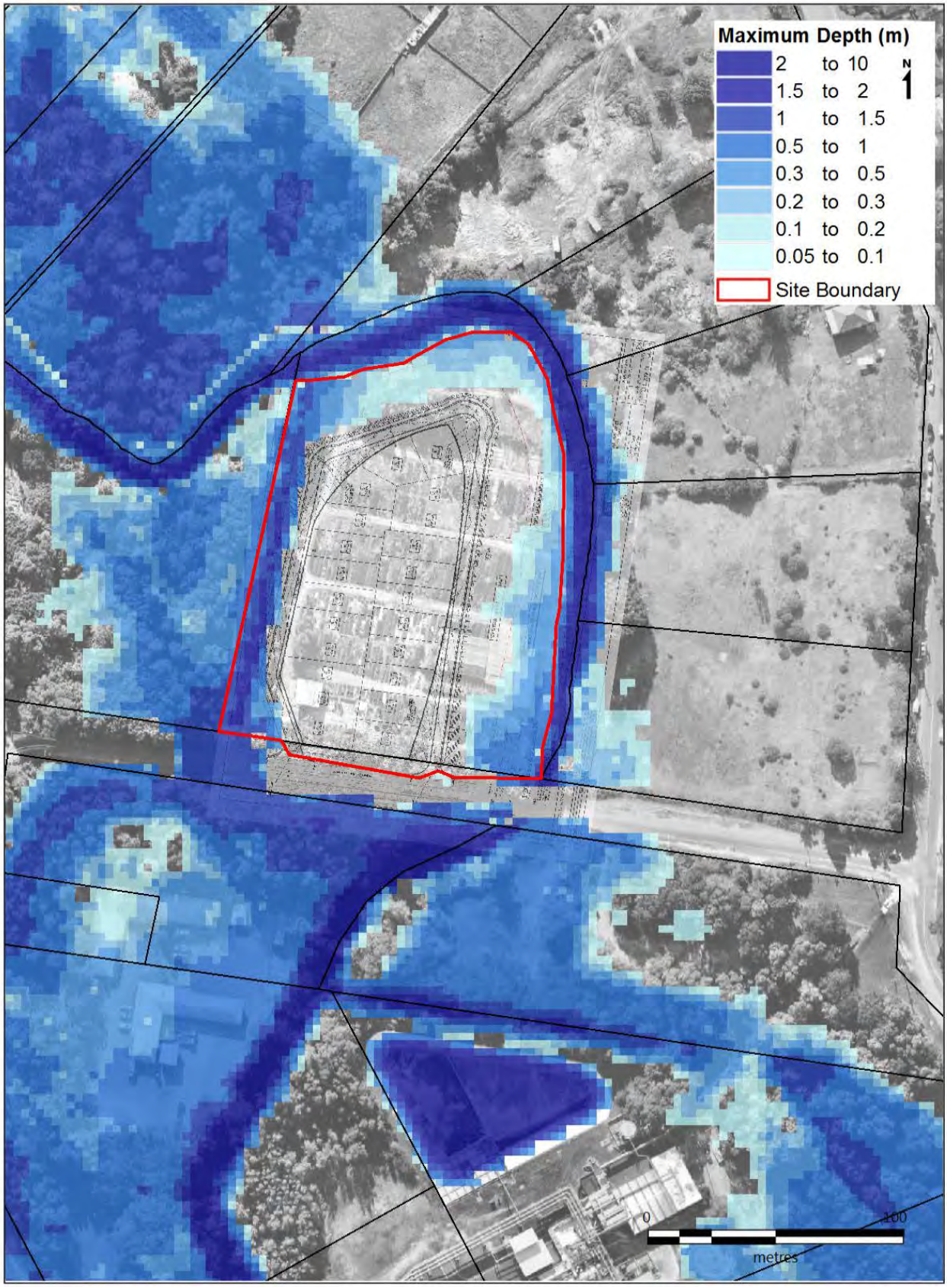

Figure 4-2 20% AEP Event Maximum Depth (DE04_CC)

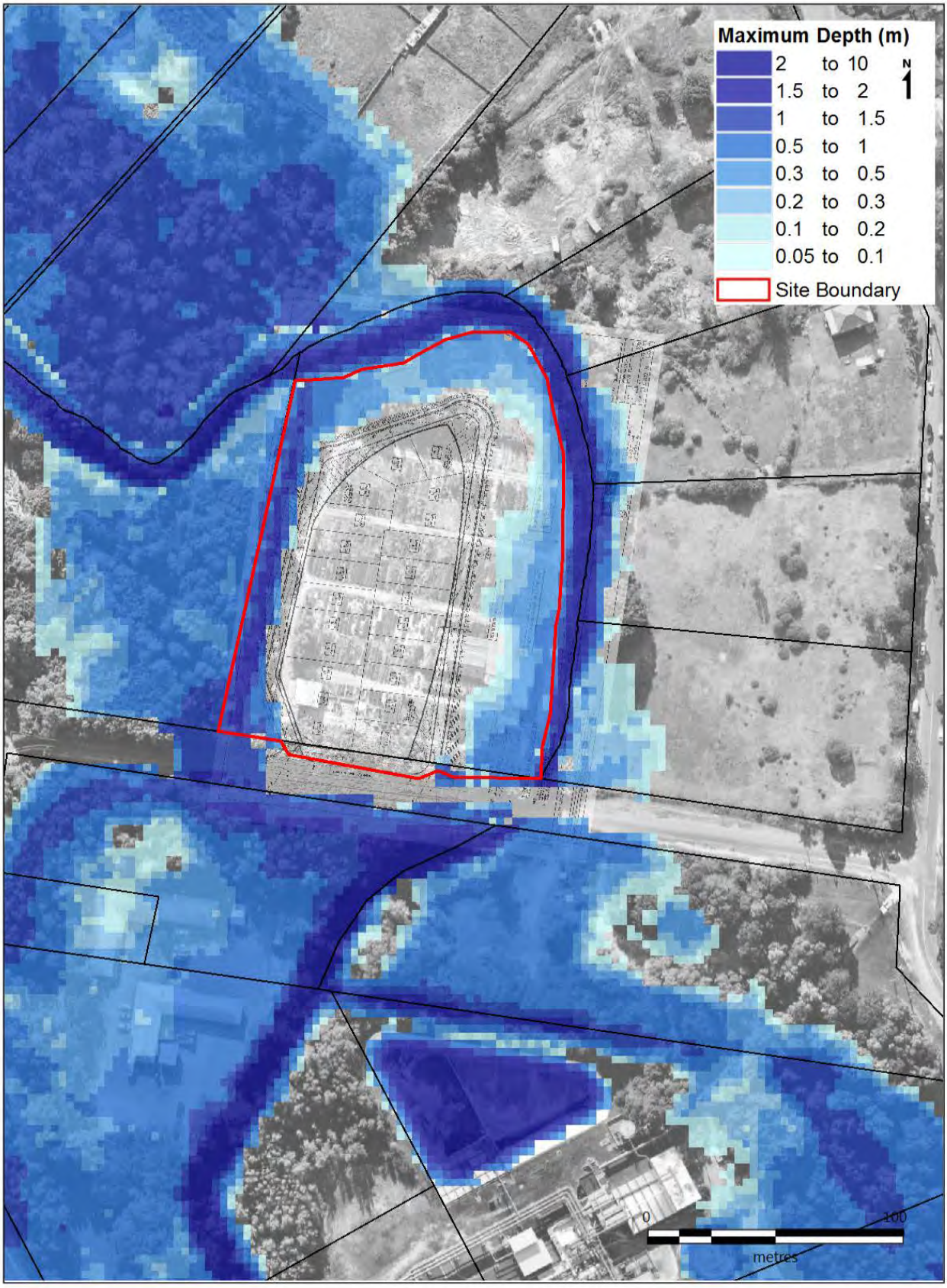

Figure 4-3 1% AEP Event Maximum Depth (DE05_DES)

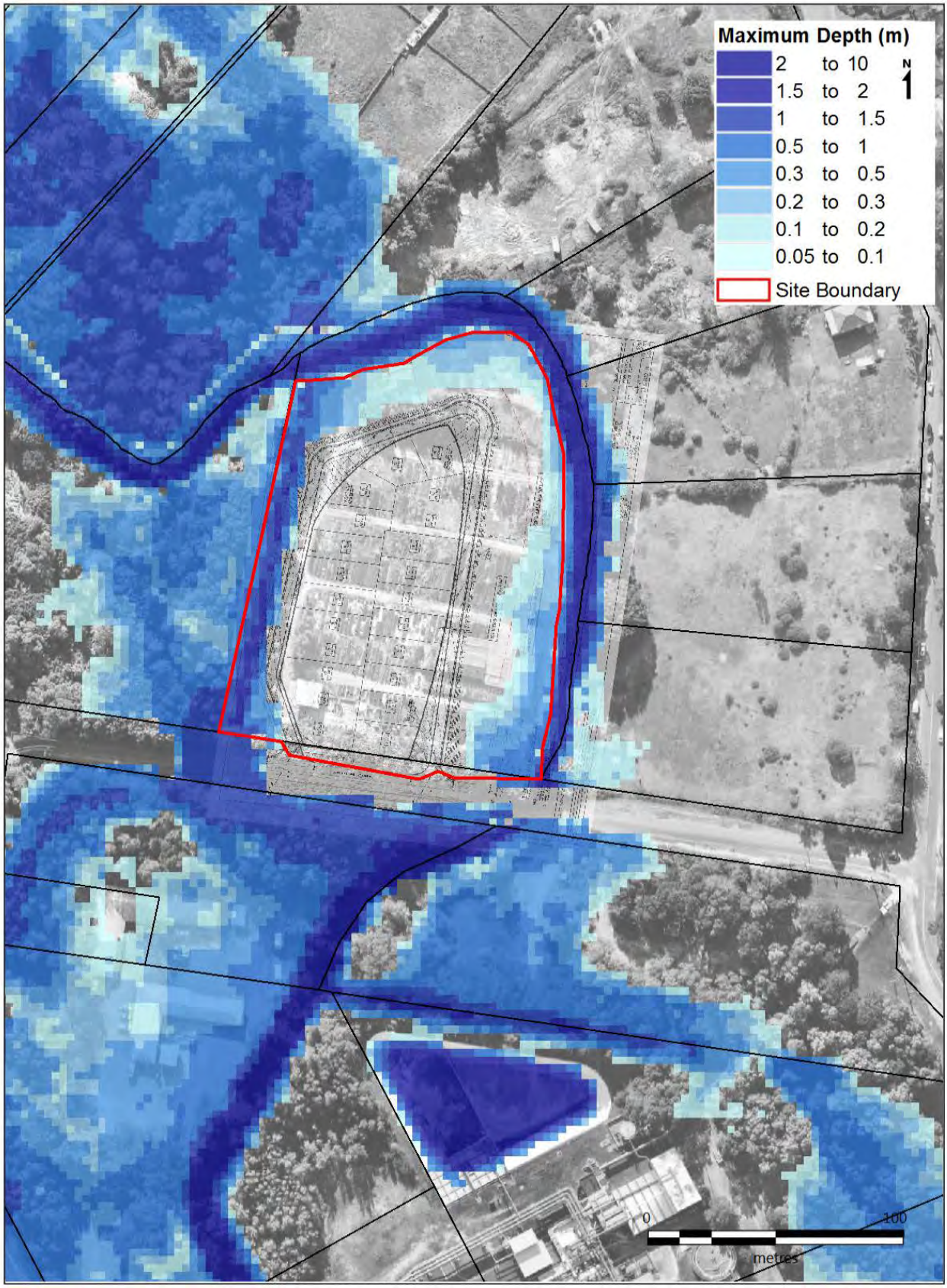

Figure 4-4 5% AEP Event Maximum Depth (DE05_DES)

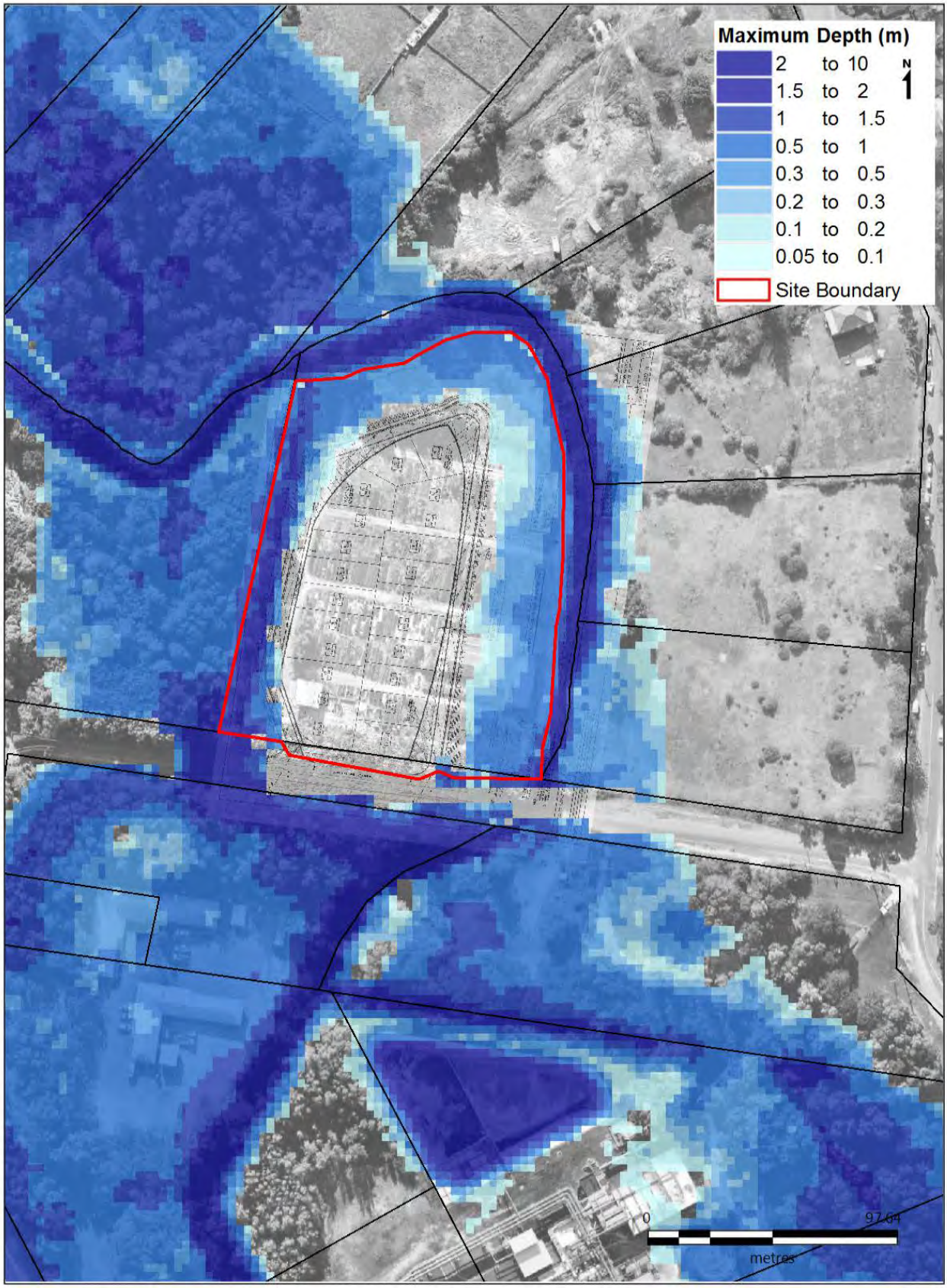

Figure 4-5 1% AEP Event Maximum Depth (DE04a_CC)

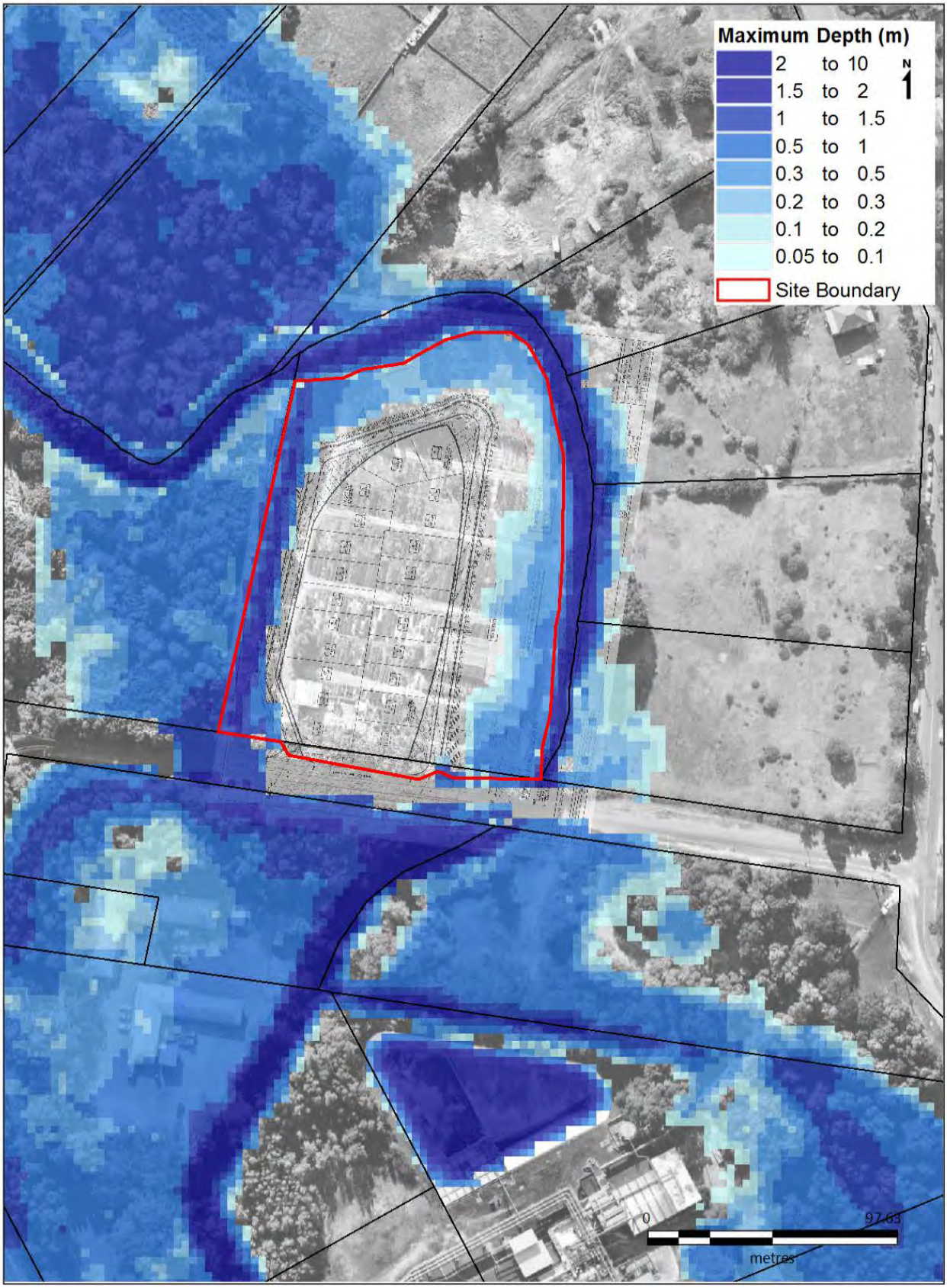

Figure 4-6 1% AEP Event Maximum Depth (DE04_DES)

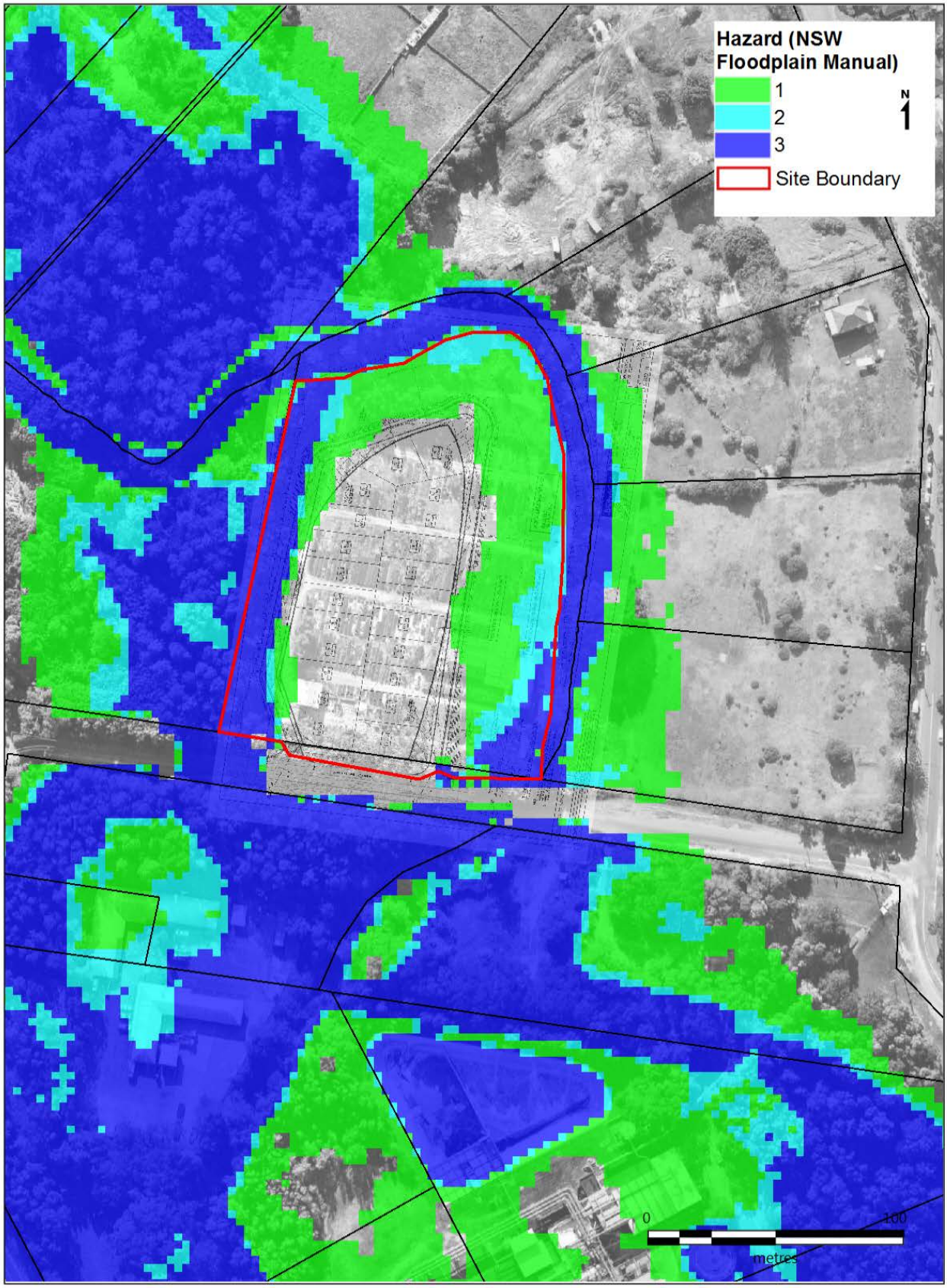

Figure 4-7 1% AEP Event Maximum Hazard (DE04_CC)

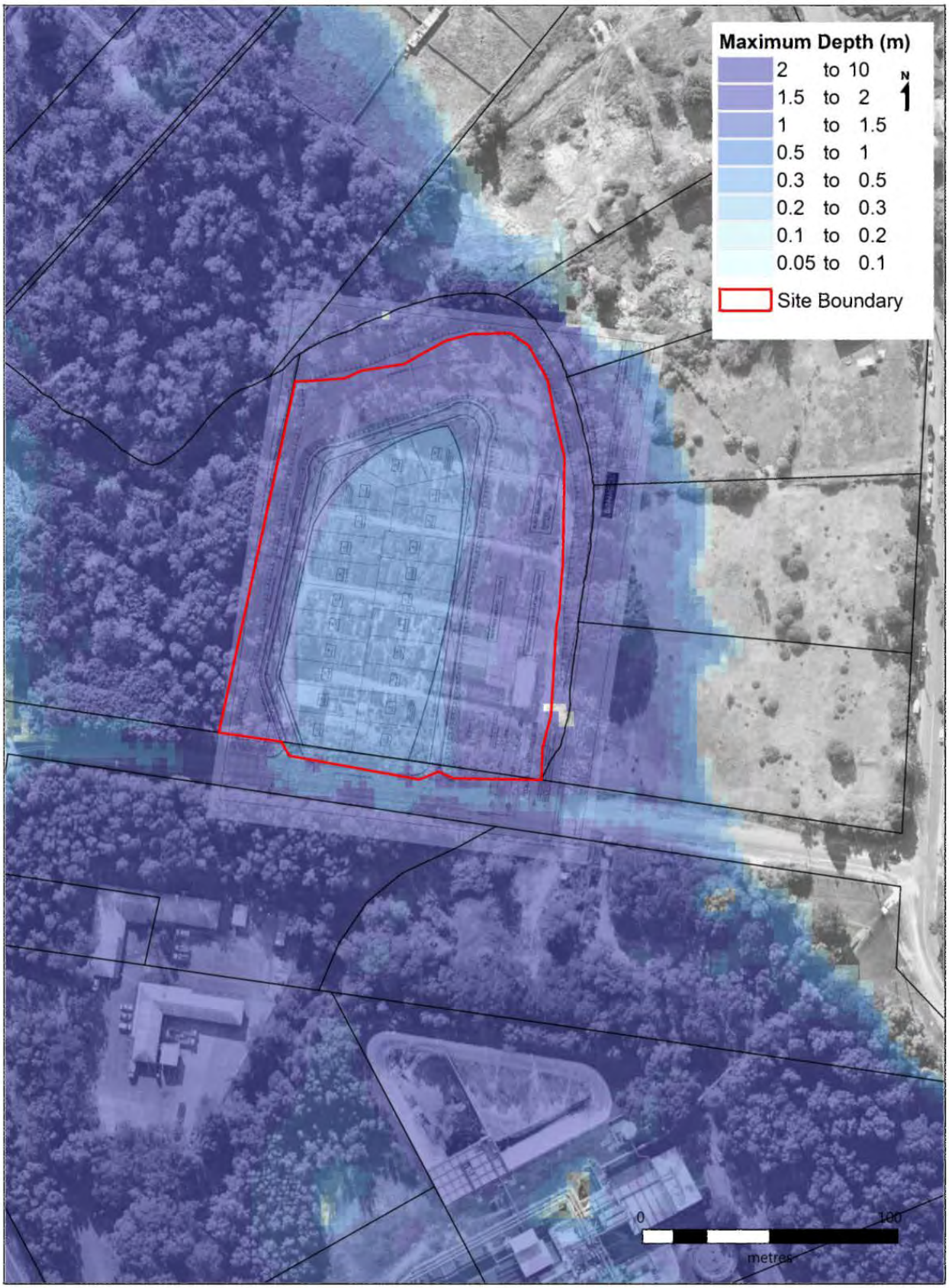

Figure 4-8 PMF Maximum Depth

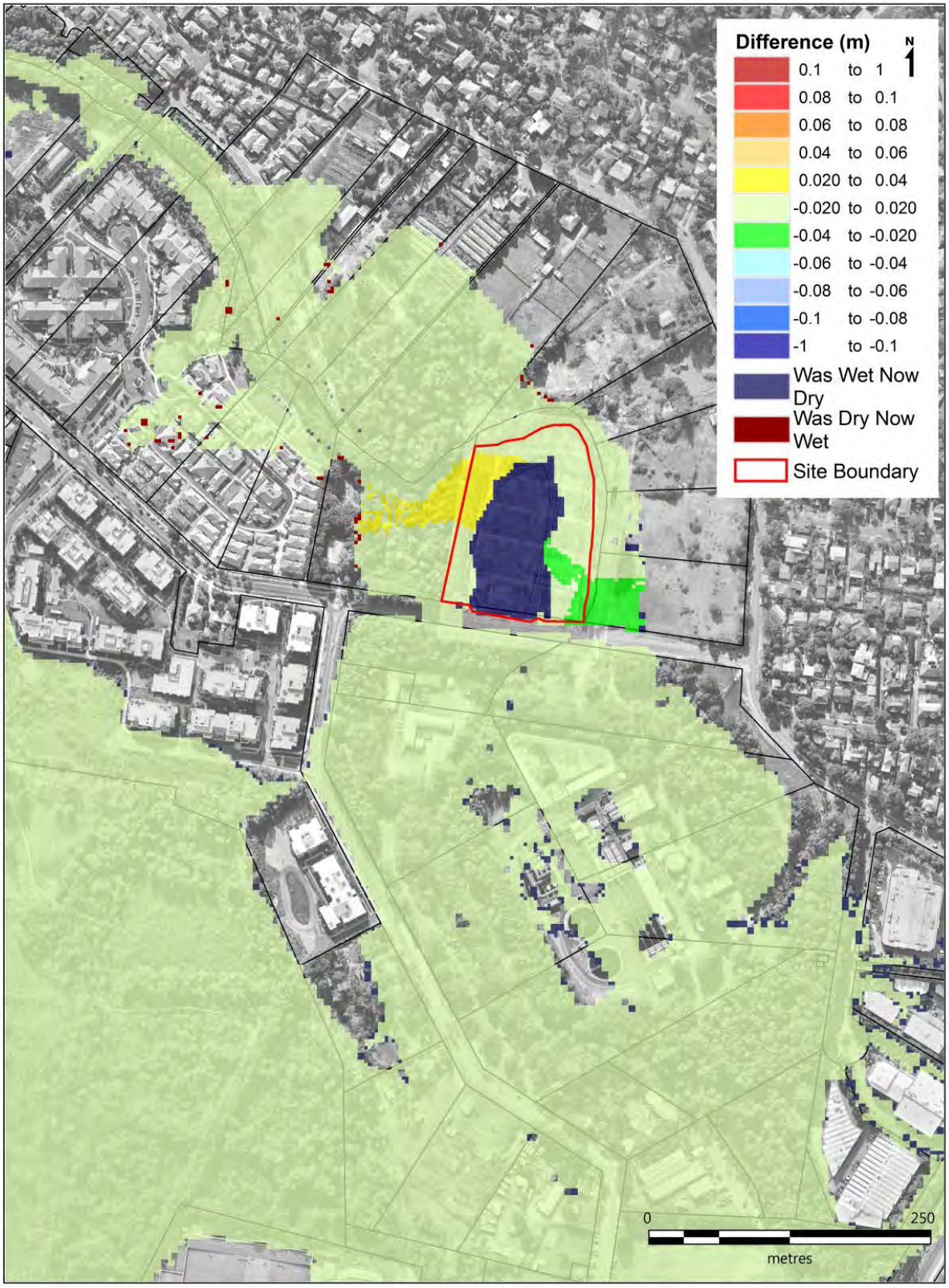

Figure 4-9 1% AEP Event Flood Level Impact (DE04_CC – E11_CC)

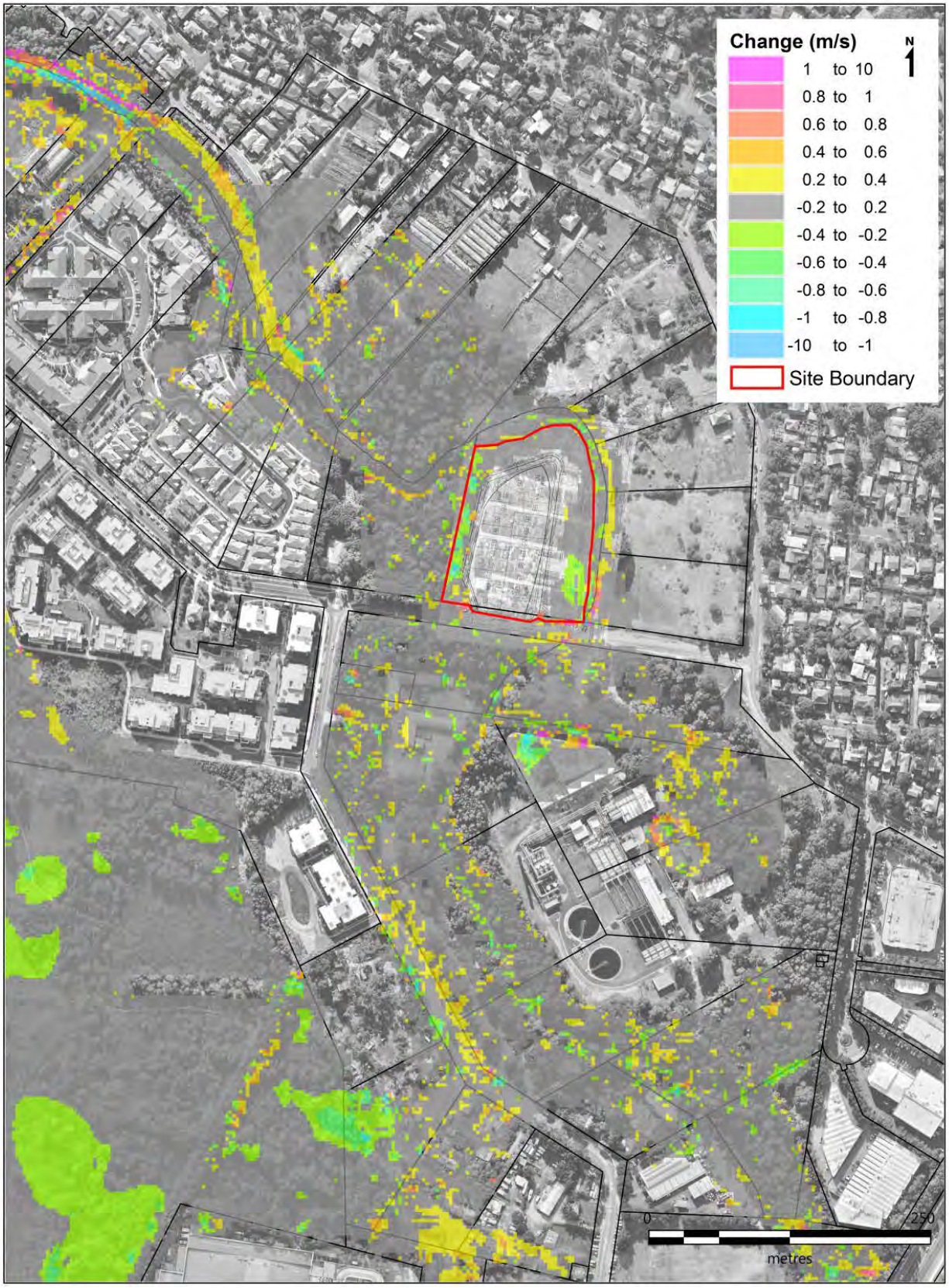

Figure 4-10 1% AEP Event Velocity Change (DE04_DES – E15_DES)

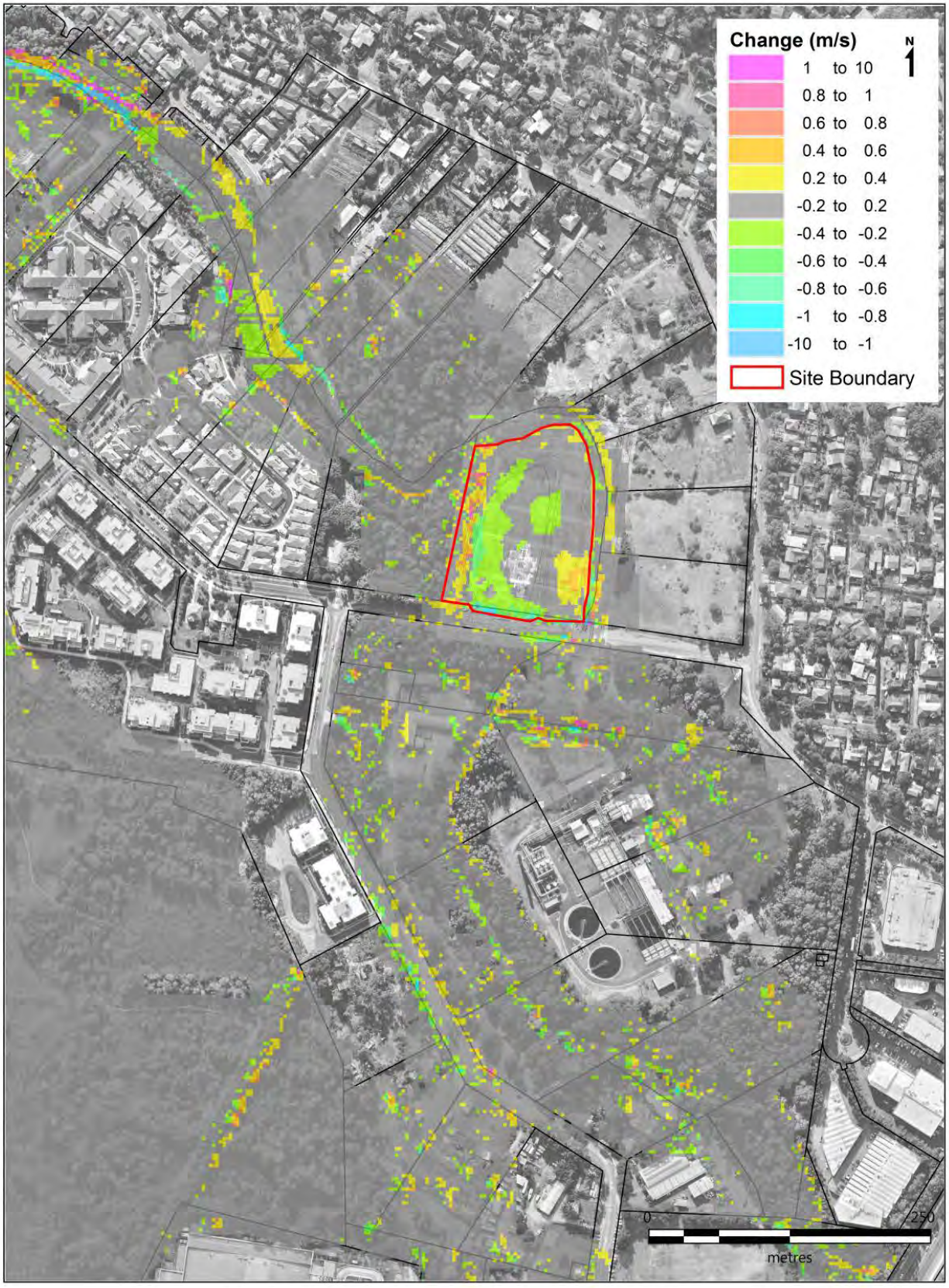

Figure 4-11 1% AEP Event Velocity Change (DE04a_CC – E15_CC)

4.3 Frequent Flood Events

The GHD review (GHD, 2017) noted that to date the hydraulic analysis undertaken has not considered events lower than the 1% AEP 30% CC plus 0.9 m. At this stage it is not proposed to undertake this analysis as there are significant unknowns with regards to the final landform of the site.

As the development aims to minimise / eliminate encroachment into the existing creek banks and other development features which would influence this assessment (such as the exact size and local of integrated water management devices) are not yet designed, no assessment is considered necessary at this stage.

Irrespective, an assessment of the 20% AEP 30% CC plus 0.9 m event has been undertaken to confirm that no impacts are presented onsite during this event. Figure 4-12 confirms no adverse impact.

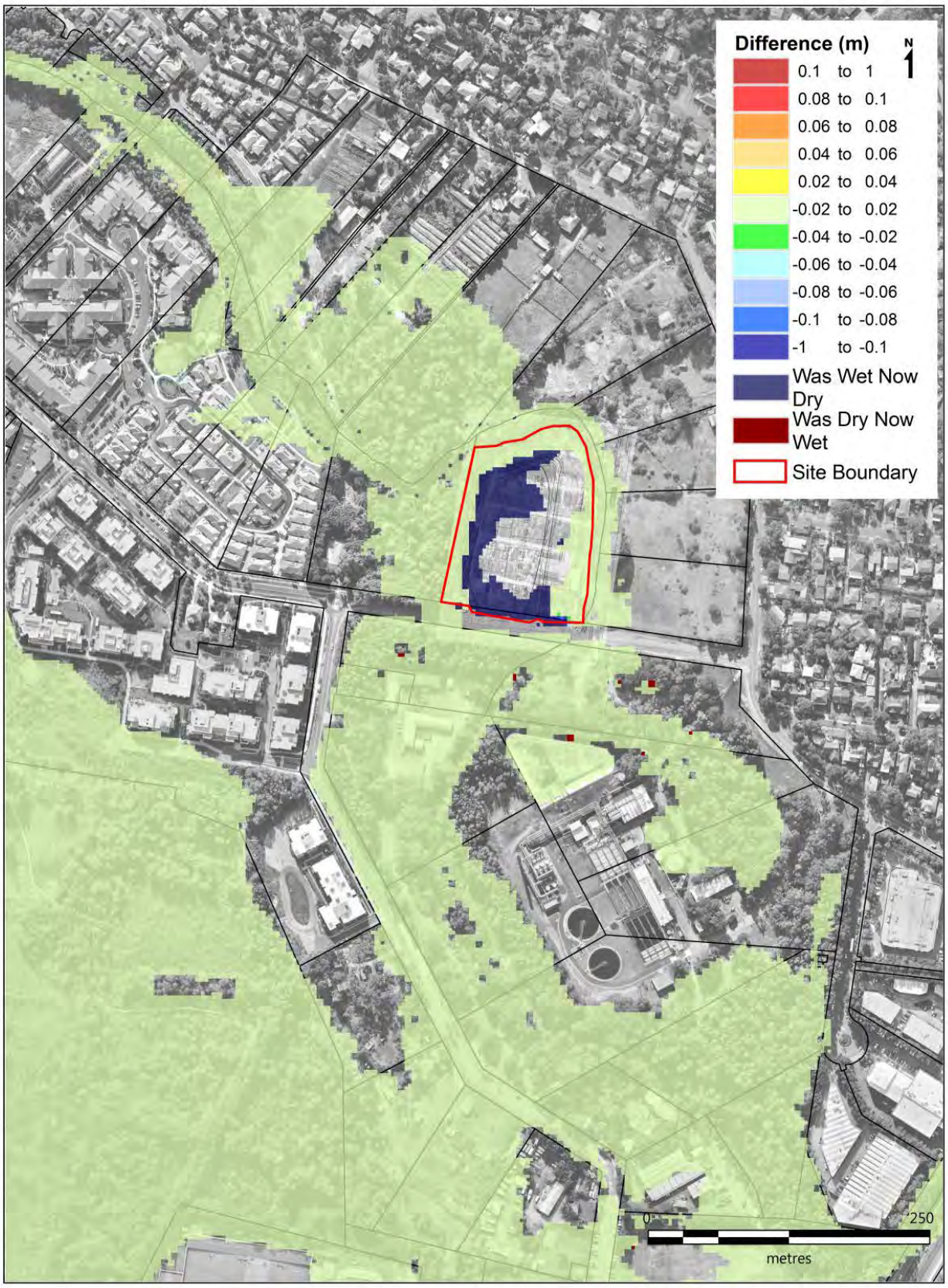

Figure 4-12 20% AEP Event Flood Level Impact (DE04_CC – E11_CC)

4.4 Flood Storage

Opportunities to compensate for the loss of flood storage due to the proposed fill within the subject site have been analysed. The maximum potential excavation is constrained by the following:

- No encroachment in the vegetation protection area along the creek;
- Minimal encroachment into the 25 m bushfire offset line; and
- Maximum batter slope of 1:4.

Based on the above constraints, an excavation volume of approximately 5,400 m^3 is achievable. A comparison of the flood storage for the 1% AEP plus 30% climate change and sea level rise (0.9 m) is presented in Table 4-2. The results show the proposed excavation would result in a net gain of flood storage of 740 m^3 for 1% AEP climate change design event.

The flood modelling and flood impact maps included in this report did not include this excavation volume and hence represent a conservative scenario.

In the case of the PMF design event, with the above excavation in place a net loss flood storage of 3,100 m^3 would occur. A further investigation showed that no loss of flood storage for the PMF could be achieved by encroaching into the vegetation protection and bushfire offset line.

As the flood storage capacity of the floodplain in the PMF event is so large, this additional flood storage would provide no net benefit to the flood condition. This is discussed within Narrabeen Lagoon Flood Study (BMT WBM, 2013) which states that filling in areas such as this development (Flood Fringe) has minimal impact on the overall flood behaviour. The additional cut required will however will result in both environmental and visual amenity issues in the region.

Table 4-2 Flood Storage Calculations

Scenario	1% AEP with climate change Volume (m^3)	Net Loss (-) or Gain (+) Volume (m^3)
Pre-development	18,000	n/a
Post-development without excavation	13,263	-4,737
Post-development excavation	18,704	+740

Based on this assessment it is considered that the majority of compensatory cut can be provided for flood storage for events up to the 1% AEP climate change and sea level rise (0.9 m) however as proven within the hydraulic modelling this would result in little to no change in the flood behaviour onsite or on surrounding properties.

5 Flood Emergency Management Planning

As highlighted in Council responses, while the proposed residential properties onsite are flood immune up to the 1% AEP climate change and sea level rise (0.9m) plus 0.5 m in the PMF event properties onsite are subject to inundation with depths of approximately 0.7 m potentially present onsite in this event. Figure 4-4 shows the PMF depth extent for the site.

Similarly, Macpherson Street in the PMF event is significantly overtopped and cannot be relied upon to enable evacuation of the site.

The proposed development has a prescribed finished floor level that will ensure that the development encounters flooding in only very unlikely events. A flood emergency management plan (Cardno, 2017a) to identify the residual risk onsite and provide solutions which minimise the risk to life to residents has been developed.

The following outcomes are identified within the FEMP (Cardno 2017a):

- The defined FPL is in excess of the predicted flood levels of the 0.1% AEP event under existing catchment conditions
- There is insufficient warning time to enable safe evacuation thus Shelter-In-Place is required;
- Two storey dwellings are required to enable vertical Shelter-In-Place;
- Dwellings will not be required to be specially engineered to enable Shelter-In-Place; and
- The time of inundation of the site is relatively short with the maximum expected time of inundation of the site in the order of 6.0 hours.

Based upon the assessment undertaken it is considered that Shelter-In-Place is an appropriate emergency management solution for the proposed development and is consistent with other measures in place for similar developments in the area.

6 Conclusions

In order to determine and manage the flood impacts associated with the proposed development of 2 Macpherson Street, Warriewood a flood impact assessment for the site has been prepared. Hydraulic modelling of the site has been undertaken to determine the potential impacts of the development within the floodplain and to ensure that the impacts and risks posed by the development of the site are understood.

Based on the analysis undertaken the following outcomes have been established:

- The final fill level of dwellings onsite is 4.29 mAHD, which is the defined flood planning level for the site (1% AEP climate change and sea level rise (0.9m);
- No adverse flood impacts would occur upstream and downstream of the site;
- A potential excavation volume of 5,400 m^3 would result in a net gain of flood storage of 704 m^3 for the 1% AEP with climate change and 0.9 m sea level scenario. This storage however, is not necessary for the site to have no adverse impacts on surrounding properties; and
- Shelter in Place is a viable emergency response option and does not result in an increase in risk to life if appropriately incorporated into the development.

While some additional modelling will be required to gain a complete understanding of the flood impacts of the site, in its preliminary state, demonstrates compliance against Council's flooding conditions. This additional detailed modelling and assessment will be undertaken at the Development Approval stage.

2
Macpherson
Street,
Warriewood

APPENDIX
A

DRAWING C025 P7

WSUD BIORETENTION ZONE 20m² TO MEET COUNCIL WATER QUALITY REQUIREMENTS FOR PROPOSED ROAD. SURFACE RL3.30 TO BE AT OR ABOVE 20% AEP FLOOD LEVEL OF RL3.29 (CARDNO 2018)

PROVIDE RMS W BEAM ALONG RETAINING WALL

PROPOSED PRECAST CULVERTS BELOW ROAD (BASE RL 1.90). REFER TO WORLEY PARSONS DRAWING No. 301015-03441-CI-DWG-0072

PROVIDE SLOTTED KERB AND LOCALLY GRADE LANDSCAPE TO BIORETENTION

PROVIDE TRANSITION FROM ELSHOZ KERB TO SLOTTED KERB

RETAINING WALL REQUIRED DUE TO CULVERT CONSTRUCTION

PROPOSED VEHICLE CROSSING/INTERSECTION BY NORTHERN BEACHES (PITTWATER) COUNCIL

CAPPED 225Ø STUB TO BE PROVIDED FOR FUTURE LOT FOR CONNECTION

EXISTING TOP OF BANK

INSTALL ENVIROPOD WITHIN PIT

PROVIDE TRANSITION FROM ELSHOZ KERB TO KERB & GUTTER

PROVIDE ROCK SCOUR PROTECTION TO PIPE OUTLET (SEE DETAILS)

CONSTRUCT SWALE WITH 1(V):4(H) BATTER TO EXISTING

PROVIDE STANDARD ROCK ARMOURING FOR SCOUR PROTECTION (REFER DETAIL 2 C006)

PROPOSED DRIVE/ROAD

1:4 BATTER TO EXISTING SURFACE (TYPICAL)

25m RIPARIAN ZONE OFFSET

20m ASSET PROTECTION ZONE OFFSET

NOTES

PROPOSED LOT SUB-DIVISION IS SUBJECT TO FUTURE DA

THIS SWMP PROVIDES BIORETENTION AND SWALE AT THE END OF EACH ROAD CATCHMENT (SAG LOCATED WITHIN ROAD) TO MEET WATER QUALITY REQUIREMENTS. BIORETENTIONS ARE TO HAVE MIN 20m² FILTER AREA WITH 0.5m DETENTION DEPTH (EXTENDED DETENTION DEPTH) EACH. THE SWALES ARE TO HAVE 0.5m WIDE BASE WITH A 1 IN 4(H) BATTER TO EXISTING.

NO ON SITE DETENTION REQUIRED FOR ROAD WORKS AS PER CARDNO FLOOD ADVICE DATED 15/12/17.

PROVIDE PLATFORM TO INTERNAL AREAS AS REQUIRED FOR DRAINAGE AND EROSION PROTECTION. ANY DISTURBED AREAS WITHIN DEVELOPABLE AREA TO BE TOPSOILED AND TURFED

MERITON SITE
2 MACPHERSON STREET

MACPHERSON STREET (BY OTHERS)

BACKFILL WITHIN ROAD RESERVE

RETAINING WALL TO RETURN INTO SITE TO ALLOW ROAD CONSTRUCTION

PROPOSED BLOCK RETAINING WALL RETURNS - REFER TO ST-DWG-0072 FOR DETAILS

LOT 25
SEC. C
DP5464
AREA (BY TITLE)
2.327 ha

STORMWATER LEGEND

- SITE BOUNDARY
- RL 7.25 FINISHED SURFACE LEVEL
- 5.00 PROPOSED SURFACE CONTOUR
- BATTER
- RW RETAINING WALL
- SURFACE INLET PIT
- AG SUBSOIL
- BIORETENTION BASIN
- JUNCTION PIT
- STORMWATER LINE
- PROPOSED STUB FOR FUTURE STORMWATER CONNECTION
- OVERLAND FLOW
- CO CATCH DRAIN TO WETLAND
- KG KERB & GUTTER
- KO KERB ONLY
- SK SLOTTED KERB
- EK RMS TYPE ELSHOLZ KERB (SEE C052)

SCALE 1:250 0m 2.5m 5m 10m 15m

Rev	Description	Date	By	App
P5	REVISED BIORETENTION	19.12.17	JH	-
P4	REVISED BIORETENTION AND SWALES	18.12.17	JH	-
P3	DRAFT ISSUE	11.12.17	JH	-
P2	ISSUED FOR DEVELOPMENT APPLICATION	13.10.17	JF	-
P1	ISSUE FOR DEVELOPMENT APPLICATION	17.08.17	RB	-
P7	ISSUE FOR DEVELOPMENT APPLICATION	18.01.18	JH	-
P6	ISSUE FOR DEVELOPMENT APPLICATION	21.12.17	JH	-

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www.bonaccigroup.com

Project Name: 2 MACPHERSON STREET, WARRIEWOOD, NSW 2102

Drawing Title: STORMWATER MANAGEMENT PLAN INTERIM ROAD WORKS

DEVELOPMENT APPLICATION

Designed	RB
Drawn	RB
Scale	1:250
Date	AUG 2016
Sheet	A1
Project Director Approved	Date
Project Ref	20 21791 01
Drawing No	C025
Rev	P7

File: G:\Job\2021791\01_Civil\Issued\Dwg\20217910 1C-C025-CAD[P7].dwg Plotted: 18.01.18 at 4:32 PM By: Jacky Hu

2
Macpherson
Street,
Warriewood

APPENDIX
B

GHD COMMENTS

10 August 2017

Wayne Williamson
Team Leader, Sydney Region East
NSW Department of Planning & Infrastructure
Level 22, 320 Pitt Street
Sydney NSW 2001

Our ref: 2126705-34527
Your ref: PO 45382343

Dear Wayne

2 Macpherson Street Planning Proposal
Review of flood assessment

1 Background

The Department of Planning and Environment has issued a Gateway determination for a Planning Proposal, which seeks to amend the Pittwater Local Environmental Plan (LEP, 2014) to permit 22 residential dwellings on land at 2 Macpherson Street, Warriewood. Northern Beaches Council has reviewed the flood assessment report and recommended additional information must be provided before the Planning Proposal can proceed to public exhibition. Northern Beaches Council does not support the Planning Proposal.

The Department needs to confirm that the proposed amendments to the LEP are satisfactory and adequately justified by appropriate flooding assessment, as these changes will allow residential development on land that has been identified as flood prone. To achieve this GHD has:

- Reviewed the observations and recommendations of the flood assessment report prepared by Bonacci Group (NSW) Pty Ltd.
- Reviewed the additional information request from the Northern Beaches Council (NBC).
- Reviewed and advise if the additional information provided in response to NBC's request is adequate.
- Recommended any additional information that could be provided or any aspects of the flooding assessment that need to be clarified.

Our findings are summarised in the following letter report of findings.

2 Correspondence Chronology

Our advice is underpinned by the chronology of correspondence/events tabulated in Table 1.

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Level 15, 133 Castlereagh Street Sydney NSW 2000 Australia
T 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com **W** www.ghd.com

Table 1 Chronology of Correspondence/Events

Date	Reference	Comments
13 October 2016	Bonacci, 2016	Original flood report in support of the Planning Proposal
31 January 2017	Referenced in NBC, 2017	Planning Proposal considered and rejected by NBC
27 February 2017	Cardno, 2017 a and b	Resubmission of Planning Proposal, answering some of the queries that NBC raised in the January 2017 rejection
10 March 2017	Referenced in NBC, 2017	Department of Planning & Environment notification to NBC of resubmission of Planning Proposal
30 March 2017	NBC, 2017	NBC comments on Planning Proposal, noting that it would not be supported. NBC also confirmed the proposal submitted for a Rezoning Review is the same proposal, as is the documentation, considered and rejected by NBC on 31 January 2017.
18 July 2017	Meriton, 2017	Additional information in addressing Point 1 of the Gateway Determination

3 Planning Matters

- The LEP, amongst others:
  - Identifies the Warriewood Valley Release Area on the Urban Release Area Map (6370_COM_URA_012_010_20150921).
  - The Urban Release Area Map identifies 2 Macpherson Street as being located in Buffer Area 1m.
  - Nominates permissible numbers of dwellings in buffer areas/sectors and notes “no dwellings” for Buffer Area 1m.
  - Identifies the subject (and adjacent) lots as “High Hazard – Affected by The Flood Planning Level (FPL) and the Probable Maximum Flood (PMF)
- The Pittwater 21 Development Control Plan (DCP, 2014), amongst others:
  - Outlines controls for Integrated Water Cycle Management, which requires compilation of a Water Management Report by appropriately qualified professionals and certified by an experienced and qualified engineer specialising in hydraulics. The purpose is to incorporate an integrated approach to water management and conservation in the design of the development, addressing water quality and quantity, watercourse and creek corridors, stormwater and groundwater, and minimises the risk posed by flooding and adapts to climate change impacts.
  - Stipulates that the Water Management Report is to be in accordance with NBC’s Warriewood Valley Urban Land Release Water Management Specification (WMS, 2001) and relevant

legislation taking into account the Narrabeen Lagoon Flood Study (September 2013 as amended) and the Pittwater Overland Flow Flood Study (2013 as amended).

  - Stipulates requirements/controls for creek corridors, flood and stormwater management in accordance with the DCP and the WMS.
  - Nominates Locality Specific Development Controls for the Warriewood Valley

- The WMS, amongst others:
  - Specifies requirements for creek corridors, for example the requirement to contain the 100-year ARI flood within the inner creek corridor.
  - Specifies requirements for stormwater quality treatment facilities, for example their location in reference to the creek corridor and above specific flood events.
  - Specifies requirements for stormwater quantity management, for example the location of stormwater volume control structures and detention basins if proposed, and their location in reference to the creek corridor and above specific flood events.

4 Assessment

- Should rezoning be approved, the development of Buffer Area 1m would likely need to comply with LEP, DCP and associated guidelines/specifications such as the WMS.
- These plans, guidelines and specifications seek to incorporate Integrated Water Cycle Management within the Warriewood Valley, supported by a Water Management Report. Furthermore, they recognise the interaction of the creek corridor, flooding and stormwater management as part of the development of sectors and buffers within the Warriewood Valley, and that these matters need to be managed in an integrated way.
- The information provided in support of the Planning Proposal (Bonacci, 2016, Cardno, 2017a and b and Meriton 2017) discuss primarily the proposed flood management of the site in isolation to the other aspects of Integrated Water Cycle Management. Flood management in the context of the WMS does not appear to be addressed, nor is it stated that the requirements of the specification will be able to be met as part of future development. Further:
  - No details are provided on the definition and impact of more frequent flood events as required by the DCP and the WMS.
  - No details are provided on the creek corridor in accordance with the WMS and containment of the 100-year ARI flood event within the inner creek corridor.
  - Preliminary details are provided on the proposed stormwater quality management strategy. If basins are proposed, their location in relation to the creek corridor satisfying the requirement for these facilities to be above stipulated flood levels in accordance with the WMS, should be provided. In addition, it is not clear, if embankments of these facilities (if proposed) were considered in the flood impact assessment.
  - Preliminary details are provided on the proposed stormwater quantity management strategy. The location of stormwater volume control structures in relation to the creek corridor, satisfying the

requirement for these facilities to be above stipulated flood levels in accordance with the WMS, should be provided.

  - The requirements for a creek corridor and stormwater treatment facilities need to be considered when determining fill platforms and assessing flood impacts. In addition, the impact on flood velocities, redistribution of flows and risk of erosion should be discussed.

- From the information provided, it is not clear what was simulated as part of the flood impact of the fill platform, as the Bonacci 201279101 (Sk02 P2) drawing seems to differ to the plans underlain on figures 1 to 4 of Cardno 2017a. In addition, there appears to be some anomaly in the geo-referencing of this image with respect to the cadastral information, making it difficult interpret the information provided on the figures.

5 Findings

It is considered that there are a number of key matters that need to be addressed under the LEP, DCP and the WMS, that demonstrate that flooding in the context of Integrated Water Cycle Management can be achieved on the site. Further information should be provided to demonstrate that guideline and specification requirements associated with the creek corridor, flood management and facilities for stormwater quality and quantity management, in accordance with the WMS, can be achieved in an integrated way at the site.

6 References

- Bonacci, 2016, letter to Meriton Group, 2 Macpherson Street, Warriewood, Flood Assessment Report, Bonacci Group (NSW) Pty Ltd, Ref: 2021791, 13 October 2016
- Cardno 2017a, letter to Meriton Group, 2 Macpherson Street, Warriewood - Addendum Flood Impact Assessment, Ref 59917042\Lt02:DW, 27 February 2017
- Cardno 2017b, report to Meriton Group, Flood and Emergency Management Plan 2 Macpherson Street, Warriewood, 59917042, 27 February 2017
- NBC, 2017, letter to Department of Planning & Environment, Re: Request for a Rezoning Review – 2 Macpherson Street Warriewood (PGR_2017_NBEAC_001_00), Ref: 2017/085100, 30 March 2017
- Meriton 2017, letter to Department of Planning & Environment, Gateway Determination – 2 Macpherson Street, Warriewood, Department reference: PP_2017_NBEAC_003_00, 18 July 2017
- LEP 2014, Pittwater Local Environmental Plan
- DCP, 2014, Pittwater 21 Development Control Plan
- WMS, 2001, Warriewood Valley Urban Land Release Water Management Specification (2001), Pittwater Council, 2001

Sincerely
GHD Pty Ltd

Dr Rainer Berg
Principal Civil Engineer
+61 2 8898 8815

2
Macpherson
Street,
Warriewood

APPENDIX C

PREVIOUS REPORTING

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Ref: 2021791

13 October 2016

Meriton Group
Level 11, 528 Kent St
Sydney NSW 2000

Attn: Mr Tim Franzen

Re: 2 Macpherson Street, Warriewood
Flood Assessment Report

Dear Tim,

Bonacci Group (NSW) has been engaged by Meriton group to provide advice with regard to the flood affectation of the subject site. We have reviewed relevant documents including correspondence from Northern Beaches Council, Narrabeen Lagoon Flood Study (BMT WBM September 2013), Cardno modelling and the site survey plan.

1.0 Site Location

The site is located at 2 Macpherson Street, Warriewood in the Northern Beaches Local Government Area (formerly Pittwater Council) as indicated in Figure 1 below.

Figure 1: Locality Plan (Source: Nearmap)

The site is bounded by Narrabeen Creek to the north and east, Macpherson Street to the south and number 4 Macpherson Street to the west (which contains a residential dwelling).

2.0 Flood Affectation

Flood modeling by Cardno Pty Ltd has demonstrated that the site flood level is RL 3.78m (1% AEP with Climate Change) downstream of Macpherson Street.

This corresponds to advice from Council (dated 20 June 2016, reference 2016/193570) stating that the Flood Planning Level (with climate change) for the site is RL 4.29m AHD. Given that the flood planning level is generally the 1% Average Exceedance Probability (100 Year Average Recurrence Interval) flood level with 0.5m freeboard, the assumed corresponding flood level for the site is RL 3.79m.

The Narrabeen Lagoon Flood Study shows that a minor portion of the site is subject to high flood hazard (refer Figure 2 below). The high flood hazard area is confined to the outer limits of the site – as this area is the floodway (including Narrabeen Creek), it will be excluded from development. This area will be maintained as floodway (to the extent that the Council upgrade to Macpherson Street allows), and it is anticipated that rehabilitation of the creek/floodway will be possible with redevelopment of the site as Council is also undertaking creek works with the current Macpherson Street bridge project. The majority of the site is low flood hazard.

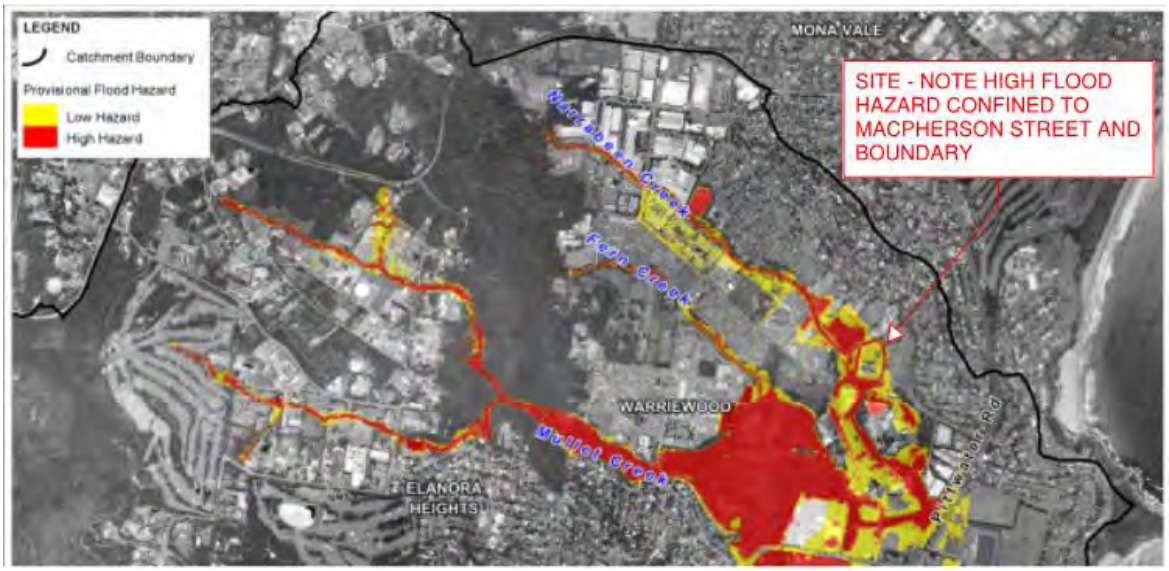


Figure 2: Flood Hazard Extract (From Narrabeen Lagoon Flood Study,[Map A28] BMT WBM 2013)

3.0 Proposed Development

The development of the site will take into account the flood affectation of the site. Given that the majority of the site is Low Flood Hazard (as evidenced in the Narrabeen Lagoon Flood Study, 2013), development of the site will be confined to those Low Flood Hazard areas to connect the site to the Macpherson Street upgrade and the associated Narrabeen Creek works. The only works outside this Low Flood Hazard Area are being undertaken as part of the Macpherson Street upgrade, which provides access to the site from the new road level (which is approximately 2.2m higher than the existing road level at the site entrance).

The majority of the site is identified as flood fringe (refer Figure 3 below) in the Narrabeen Lagoon Flood Study (BMT WBM November 2014). Filling of these areas is required to ensure that the habitable floor levels of proposed buildings are at (or above) the flood planning level. The filling of these areas is in keeping with the Council upgrade to Macpherson Street (which will see the road level raised by approximately 2.2 m). In contrast, the filling of the site to provide habitable floor

levels at the flood planning level is limited to approximately 1m. As noted in the Narrabeen Lagoon Flood Study, "filling of these areas generally has little consequence to overall flood behavior". Filling will be minimized, and will have less impact than the filling of the high hazard/floodway/storage area which is proposed as part of the Macpherson Street upgrade.

Cardno modeling demonstrated that the proposed development results in a flood level (1% AEP with Climate Change) of RL 3.8m. Cardno has modeled the impact of the proposed filling for the development, and concluded that the filling does not cause an actionable impact to flood levels. As noted by Cardno, provision of offsetting excavation does not provide demonstrable benefit for the flood level greater than the 1% AEP – and may cause harm to sensitive flora/fauna if required. Provision of 5400m^3 of cut provides a net gain in flood storage (1% AEP with Climate Change) of approximately 740m^3.

The provision of the upgrade to Macpherson Street (which consists of a bridge, culvert and raised road alignment) will provide access to the site during a 1% AEP (100 year) flood event. The provision of a flood management plan will be required for the development – the road upgrade will allow an evacuation route from the site in the event storms up to and including the 1% AEP flood event. Shelter in place can be adopted for storm events that exceed this.

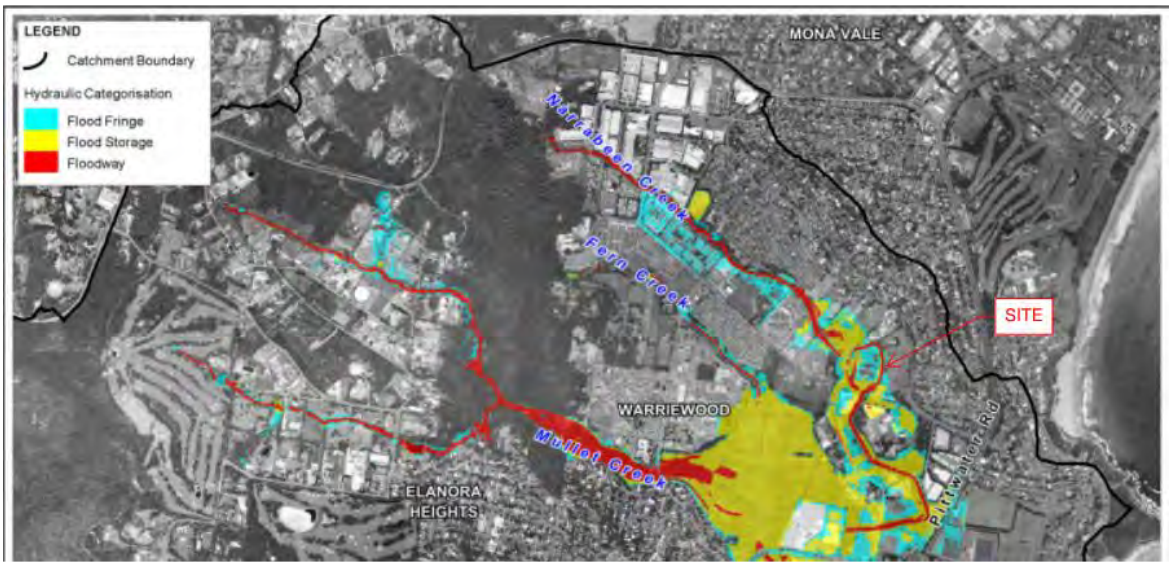


Figure 3: Hydraulic Categories Extract (From Narrabeen Lagoon Flood Study,[Map A24] BMT WBM 2013)

It is expected that a riparian zone, consisting of the existing trees that are to be retained (where they are deemed to be suitable by the arborist – we refer to the previous Arboricultural Assessment Report by TALC November 2014) and new landscaping planting, will be provided. The riparian zone could also provide habitat for flora and fauna (there is the opportunity for restoration of the riparian zone during redevelopment of the site). The riparian zone will also incorporate appropriate Water Sensitive Urban Design measures to ensure that water quality requirements (as detailed in the Warriewood Valley Water Management Specification) are met.

The Flora and Fauna assessment completed by Total Earth Care (referenceC3798-KC), November 2014, considers that the remnant vegetation to the north and south west of the site is of high conservation value. The restrictions to development imposed by flood affectation mean that these areas will be part of the buffer to the flood water level, ensuring that there is the opportunity to conserve and improve the habitat in these locations. The required in-bank works should be further developed with regard to the flooding requirements (provision of off-setting excavation),

conservation of remnant vegetation and provision of water sensitive urban design elements and stormwater devices.

Refer to the attachment, Bonacci Preliminary Development Plan Sketch SK02, for a developable area layout.

This plan demonstrates the site developable area, taking into consideration key issues including flooding, riparian zone, asset protection zone and flora & fauna.

The riparian zone is taken to be 20m from the top of the creek bank (in accordance with NSW Department of Primary Industries:Water definition). It is noted that other uses may occur in this zone, provided that the average width of the vegetated riparian zone is achieved over the length of watercourse through the site (an equivalent fully vegetated area connected to the riparian zone must be provided). The option to encroach on the riparian zone (to provide asset protection zones or other uses) may be considered during detail design – but any such encroachment will meet the offset requirements specified by the NSW Office of Water. The plan also demonstrates there is provision for the 25m dedication under Councils current Draft Section 94 Plan and required Asset Protection Zones.

The filling to the developable area of 2 Macpherson Street, to meet the freeboard requirements of RL 4.29m, will be approximately 4700m^3. Given that the proposed development of 2 Macpherson Street will not involve restricting any waterways or filling of any floodway/flood storage (except where connection to the reconstructed road requires it), it can be reasonably assumed that a similar or lesser impact on flood levels to that arising from the road reconstruction would result. Modeling completed by Cardno has verified this, with flood levels increasing by less than an actionable impact level (20mm is noted as the maximum afflux).

The road reconstruction project notes that impacts to flood levels resulting from the works would be limited to 20mm or less – which is the requirement to demonstrate no adverse affect. It can be similarly assumed that the development of 2 Macpherson Street would have no adverse impact on flood levels (not only due to the conclusion of flood impact assessment of the Macpherson Street upgrade, but also due to the statement in the Narrabeen Lagoon Flood Study).

3.0 Flood Evacuation

The provision of the upgraded road access to Macpherson Street ensures that site access is maintained to all storm events up to and including the 1% AEP event (the 100 year ARI event). This will provide a flood evacuation route if required for all storms up to and including the 1% AEP event.

In the event of a larger storm, or if it is impractical to evacuate by road in a storm event (due to wind, debris, rainfall intensity or other factors), it is expected that shelter in place could be adopted (as the site is unlikely to be isolated for unacceptable periods of time).

4.0 Conclusion

Whilst flood affected, the site could be redeveloped as demonstrated in the Concept Plan Sketch SK02. This plan demonstrates provision of a riparian zone, provision of habitable floor levels at or above the flood planning level, provision of an asset protection zone and minimising filling on the site (including prevention of any filling to the floodway to the north, west and east of the site).

A water management plan (in accordance with Warriewood Valley Water Management Specification) will need to be developed during the development submission, however the provision of the required water sensitive urban design measures has been.

With regard to flood affectation, the Cardno modeling demonstrates that the site is capable of being developed – it shows that the filling of site to provide floor levels above the flood planning level does not result in adverse affects on upstream or downstream properties, nor on flood levels.

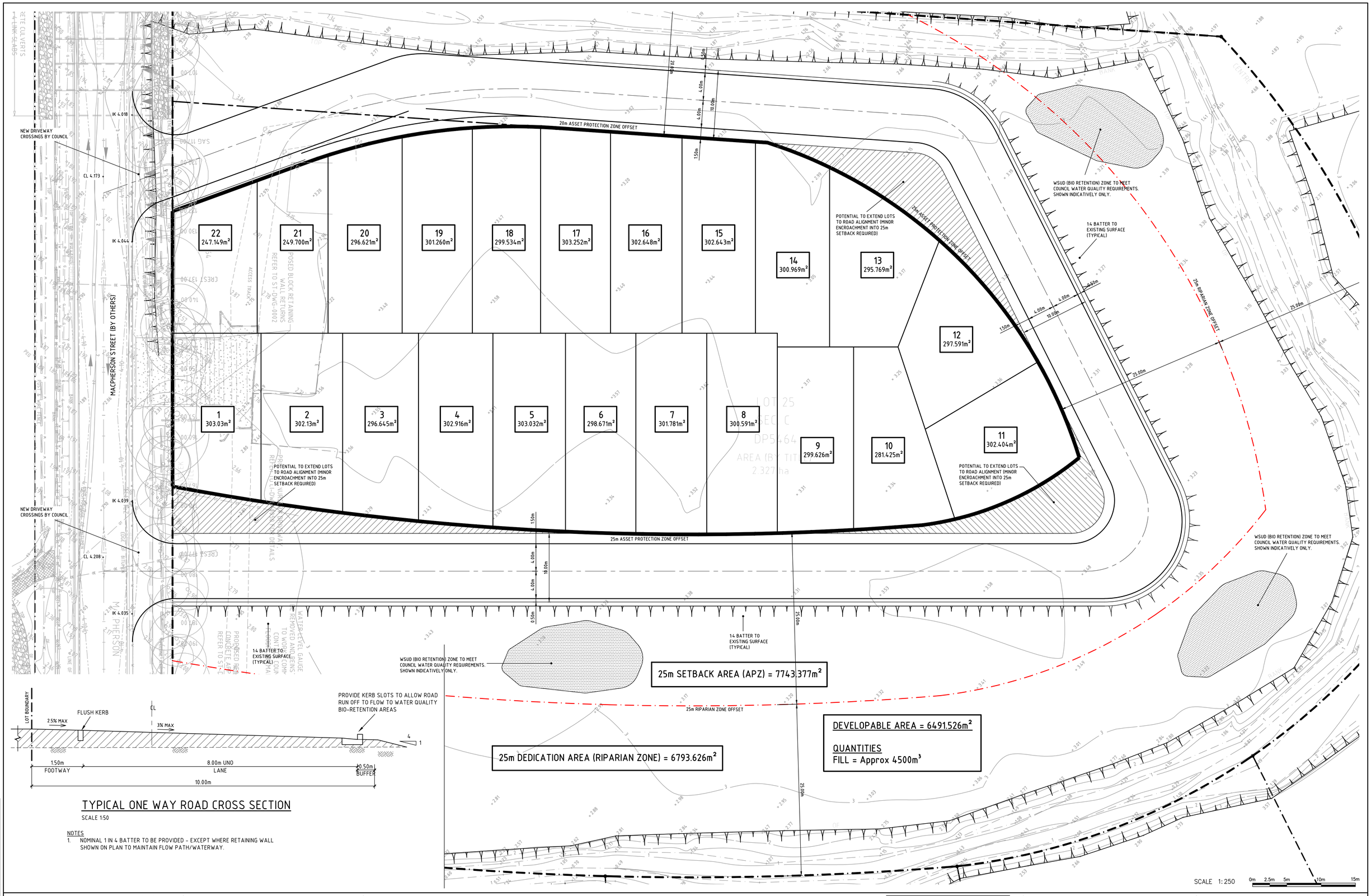
Given the additional Flood modelling by Cardno and giving consideration to other key site issues (including bushfire, flora and fauna), we do not believe that there are any development constraints that can't be overcome with appropriate planning and design.

Yours Sincerely
For Bonacci Group (NSW) Pty Ltd

Stephen Naughton MIEAust
Associate Director

Tim Hoare FIEAust NPER
Director

Enc. Cadrno Flood Study Map
Bonacci Sketch 2021791-01C-SK02 – Site Redevelopment Concept Plan



TYPICAL ONE WAY ROAD CROSS SECTION

SCALE 1:50

NOTES
1. NOMINAL 1 IN 4 BATTER TO BE PROVIDED - EXCEPT WHERE RETAINING WALL SHOWN ON PLAN TO MAINTAIN FLOW PATH/WATERWAY.

Rev	Description	Date	By	App
P2	COUNCIL SUBMISSION	18.10.16	JF	-
P1	PRELIMINARY ISSUE	26.08.16	JF	-

Rev	Description	Date	By	App

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Project Name: 2 MACPHERSON STREET, WARRIEWOOD, NSW 2102

Drawing Title: SITE REDEVELOPMENT CONCEPT PLAN ONE-WAY ROAD

PRELIMINARY

Designed	JF
Drawn	JF
Scale	1:250
Date	AUG 2016
Sheet	A1

Project Director Approved | Date | North

Project Ref: 20 21791 01 | Drawing No: SK02 | Rev: P2

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Our Ref 59917042\Lt02:DW

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27 February 2017

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Dear Sir,

2 MACHPERSON STREET, WARRIEWOOD - ADDENDUM FLOOD IMPACT ASSESSMENT

1.0 Introduction

Council has recently reviewed the documentation provided as part of the rezoning submission and, concerning flooding, found the following deficiencies in the information provided:

- *The Flood Report (lodged with the Planning Proposal), is unclear as to if the site will be filled to 3.8m AHD (1% AEP plus climate change) or 4.3m AHD (Flood Planning Level plus climate change).*
- *The Flood Report merely states that the proposed filling for the subject site will have less impact than the filling proposed as part of the Macpherson Street upgrade. First, this is not considered to be adequate justification, and second, the Flood Report does not provide sufficient information to demonstrate the impact of filling (i.e. the resultant flood behaviour), particularly on surrounding, upstream and downstream properties.*
- *It is stated that 'Cardno has modelled the impact of the proposed filling for the development, and concluded that the filling does not cause an actionable impact to flood levels' (whereby 20mm is noted as the maximum afflux), however the Flood Report does not incorporate any 'difference' mapping (or similar) to demonstrate whether or not there may be any adverse impacts upstream or downstream of the subject site as a result of the proposed fill. This is considered to be vital to making an informed decision regarding whether it is appropriate to permit dwellings on the subject site.*
- *The Flood Report (lodged with the Planning Proposal) states that habitable floor levels will be at the Flood Planning Level (plus climate change) (though it should be noted that there is an inconsistency in the documentation provided as to the proposed floor levels), however this would still result in any future dwellings being subject to 1m of water in a PMF event. This means that should dwellings be permitted on the subject site, they would need to be two-storey dwellings to facilitate vertical refuge or shelter-in-place during a Probable Maximum Flood event (the detail of any potential future dwellings is not clear in the information submitted with the Planning Proposal).*
- *The Flood Report does not provide any further information to support the potential need for vertical refuge or shelter-in-place, including the potential length of time for the floodwater to recede around this site – the report simply states that '…the site is unlikely to be isolated for unacceptable periods of time'. This is, however, contrary to the Warriewood Valley Strategic Review Report (2013), which identifies 2 Macpherson Street, Warriewood as Category F whereby '…flood isolation/entrapment (beyond short durations)…' is a criterion. Subsequently, it is considered that the Flood Report does not contain enough detail to adequately and satisfactorily address risk to life and property.*

- *It is noted that the submission from the SES incorporates the fact that the risks associated with sheltering in place should be 'adequately assessed to determine the tolerability of isolation', and that the subject Planning Proposal does not incorporate such information*

This addendum flood impact assessment provides further advice to support the rezoning of 2 Macpherson Street, Warriewood. The aim of this document is to provide further advice with regards to the above deficiencies and provide council with sufficient information to confidently assess the applications intent with regards to flooding.

2.0 Summary of Issues

The following addendum provides clarity with regards to the following key issues, derived from the above comments:

- Final fill levels of the site
- The impact of the proposed fill level on the floodplain and surrounding properties
- The proposed flood emergency response for the site in events that exceed the floor levels of dwellings on site.

3.0 Final Fill Levels

The final proposed floor levels and fill levels are provided on drawing number SK02 P3 provided as an attachment to this document. The following criteria are addressed within this earthworks plan:

- The development level should be above the planning level (above the 1% AEP with 30% climate change plus 0.9m sea level rise). The flood planning level for this site is considered to be 4.29 mAHD based on current flood mapping of the site;
- No adverse impacts upstream and downstream of the subject site; and
- No loss of flood storage up to the probable maximum flood (PMF) design flood

The finished floor level of the development is set to 4.29 mAHD. The internal roadway within the development ranges from 3.50 mAHD to 4.10 mAHD. The internal roadway does not have 1% AEP with 30% climate change and 0.9 m sea level rise immunity however is deemed trafficable in this event. Further discussion on trafficability is provided in section 5.

4.0 Impact of Fill on Floodplain and Surrounding Properties

As discussed within the provided flood report, Cardno has undertaken flood modelling to determine the impact of flooding due to the proposed development. In order to assess this, Cardno have used the Council approved Narrabeen Lagoon Flood Model.

As the approved flood model does not have the proposed Macpherson Street Road upgrade incorporated, the first task was to update this and redefine the base case flooding for the site. In addition to this, detailed ground survey of the development site was incorporated into the model.

The Narrabeen Lagoon (and tributaries) TUFLOW model, was used as a basis for the flood impact assessment. Given the size and the long run time of the model, it was truncated for the purposes of this assessment.

The truncated model was run and compared to full model prior to modification to ensure consistent output. The model extends downstream past the site by approximately 800 m (Downstream of Jackson Road) where a time varying water level boundary, derived from the catchment wide model, was established.

Upon verification the truncated model was modified to reflect the site survey and the proposed Macpherson Street design. The additional works included in the truncated base case model are as follows:

- A site survey tin provided by Bonacci Group Pty Ltd was included in the model; and
- The design surface level of Macpherson Street were digitized based on the Issued for Construction Drawings of Macpherson Street which were obtained from the Northern Beaches Council. In addition, the proposed culvert and bridge details were obtained from these drawings and incorporated into the model.

Modelling of Macpherson Street Upgrade

In order to represent the Macpherson Street upgrade the proposed alignment was incorporated into the hydraulic model. The alignment and levels utilised are on the information provided by Northern Beaches Council (Macpherson Street Warriewood Road Upgrade April 2016 reduced.pdf).

The details of the proposed culverts and bridge under Macpherson Street are provided in the Table 3-1. Initial modelling showed that due to the large size of the culverts, model instabilities occurred around the culverts causing unrealistic flood levels. To overcome this issue, the culverts were modelled in the 2D domains using the layered flow constriction approach. Appropriate flow constriction parameters were determined to represent the head loss that would occur through the culvert structure. These losses were calibrated against a HEC-RAS model of the culverts to confirm their suitability. The adopted flow constriction parameters are provided in Table 3-2.

Table 3-1 Macpherson Street Culvert and Bridge Details

Parameters	Parameters	
	Culvert	Bridge
Size	9x 3.6x1.2 RCBCs	Open Bridge with no piers in the waterway
		Base width of 3.6m
		Top width to waterway 6.9m
		Underside of Bridge 3.42 mAHD
Length	15	15
Upstream Invert Level	1.90	0.79
Downstream Invert Level	1.84	0.73

Table 3-2 Macpherson Street Culvert and Bridge Details

Bridge Layer	Levels	Form Loss Coefficient (K)	Blockage (%)
Layer 1 (below deck)	Invert level of 1.9 mAHD Obvert level 3.1 mAHD	0.5	11
Layer 2 (deck level)	Underside of deck 3.1 mAHD Road Level 4.2 mAHD	1.2	100
Layer 3 (above road level)	Level to top of handrail 5.11 mAHD	0.5	10

Developed Case Model

Subsequent to base case modelling and calibration, a post-development model was created to reflect the proposed development of the site. The proposed design tin of the development site was provided by Bonacci Group Pty Ltd which was included in the flood model to assess the flood impacts. The design surface information utilised is provided on drawing SK02 P3 provided as an attachment to this document.

Results of Flood Modelling

Impacts of the Roadway Upgrade

A comparison of the base model vs the model with the proposed Macpherson Street upgrade was undertaken to confirm the impact of the alignment. In general no actionable impacts were noted however a minor increase in flood levels (20 mm) are noted to the west of the fill pad.

Table 4-1 Base Case Model Validation Results

Reporting Location	1% AEP with 30% climate change Flood Levels (mAHD)	
	Model without Road Upgrade	Model with Road Upgrade
Upstream of Macpherson Street, West of Development	3.78	3.80
Upstream of Macpherson Street, East of Development	3.78	3.78
Immediately Downstream of Macpherson Street	3.77	3.77

Development Flood Impacts

Figure 1 shows the depth plot of the 1% AEP with 30% climate change plus 0.9m sea level rise when the development is considered onsite. Figure 2 shows the water level impact map of the same event when comparing the developed condition to the base condition model with the Macpherson Street Road upgrade incorporated.

Figure 3 shows the hazard profile for the site in the 1% AEP with 30% climate change plus 0.9 m sea level rise. The roadway, while inundated in some areas is considered to be low hazard and trafficable. In events that exceed the roadway level however, it is recommended that residents onsite do not evacuate. Further discussion on emergency management procedures is provided in section 5.0.

Figure 4 shows the maximum depth experienced onsite during the PMF event. In this event the finished floor level of the proposed development is exceeded. Depths of approximately 0.7 m are present in the area where dwellings are proposed. The PMF Event is largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. The PMF event is generally considered to have a probability of occurrence between 1:10,000 and 1:100,000.

The results of the modelling confirm that no adverse impacts external to the site are present in the 1% AEP with 30% climate change plus 0.9m sea level rise. A maximum afflux of 20 mm has been obtained for the 1% AEP with 30% climate change plus 0.9m sea level rise at the north western boundary of the site. Minor reductions are present to the east of the site of up to 20 mm.

The PMF event exceeds the proposed finished floor level of the site. As a result the site must be considered at risk of flooding and flood emergency management considered to ensure the safety of persons onsite.

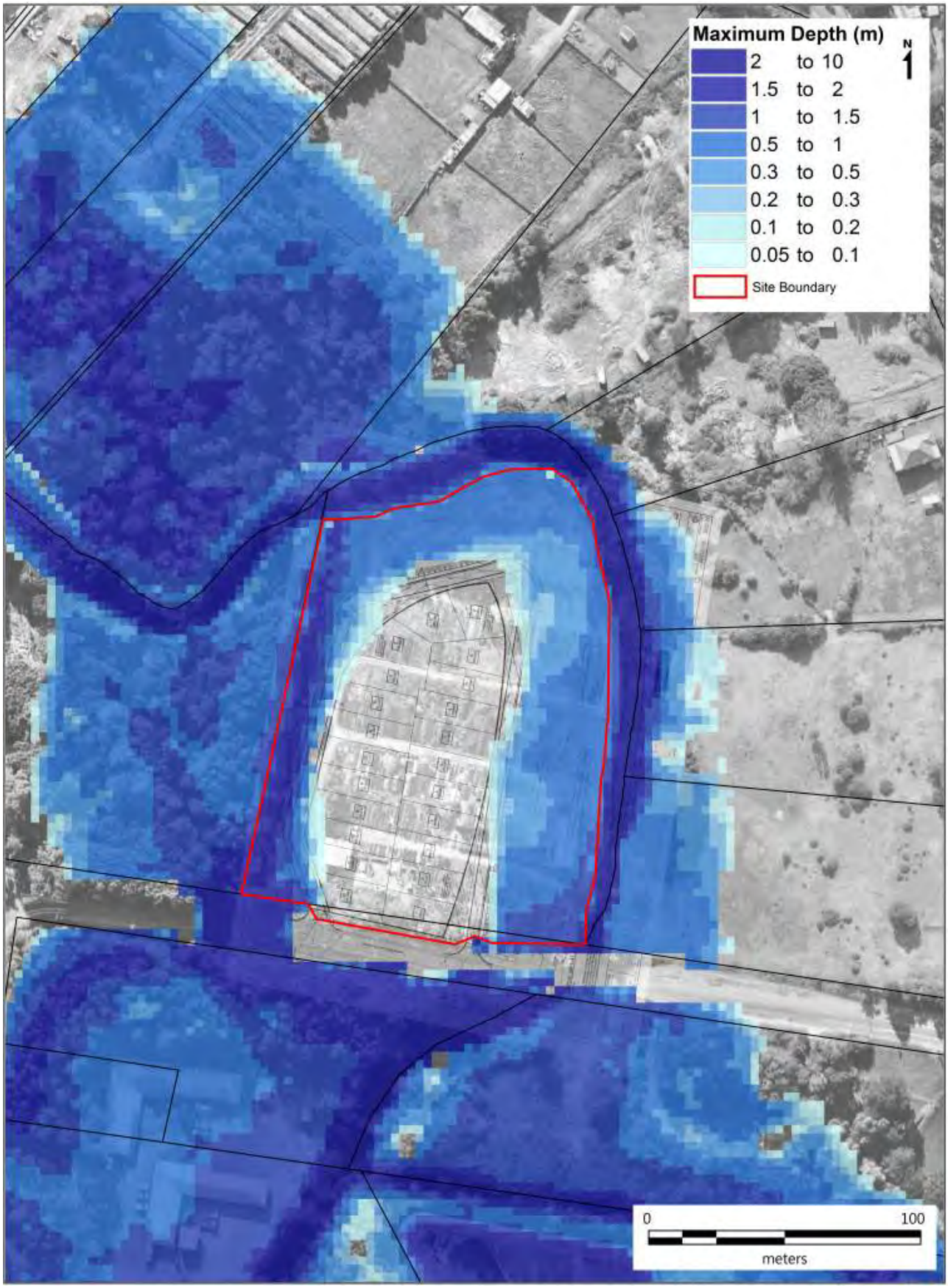

Figure 1 – 1% AEP with 30% climate change plus 0.9m sea level rise Maximum Depth

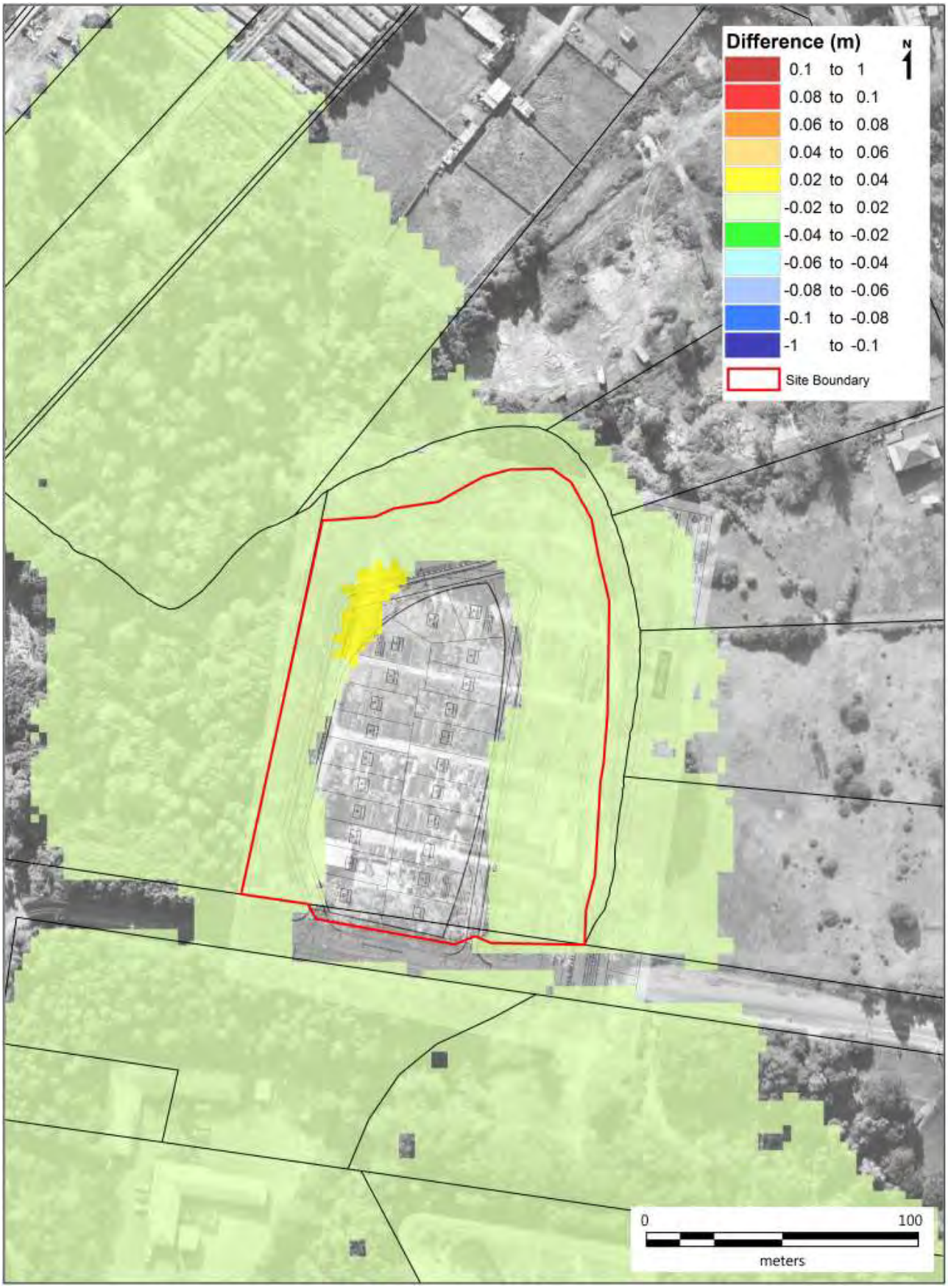

Figure 2 – Impacts 1% AEP with 30% climate change plus 0.9m sea level rise Maximum Depth – Developed v Existing Condtions

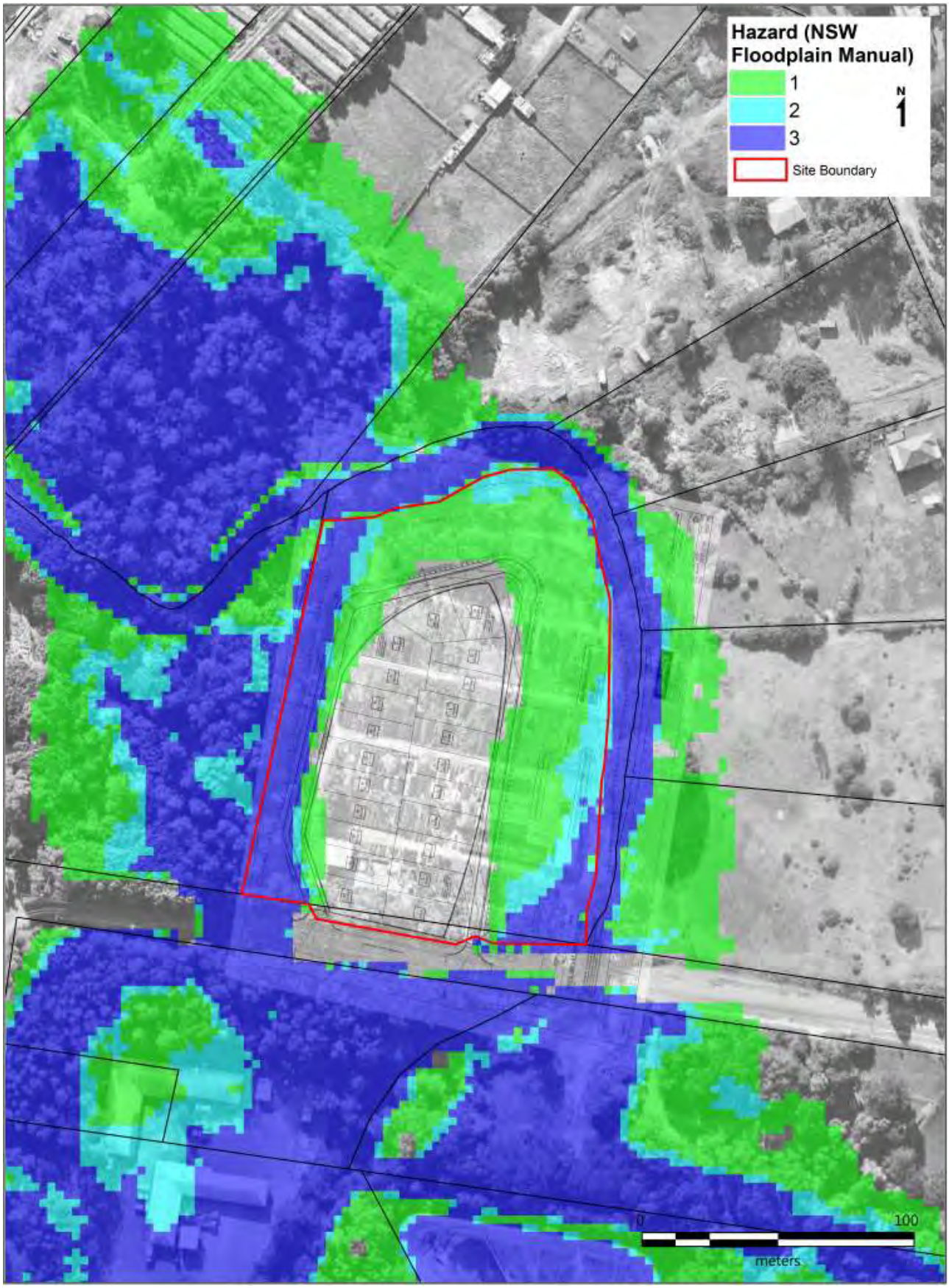

Figure 3 – Hazard 1% AEP with 30% climate change plus 0.9m sea level rise Maximum Depth

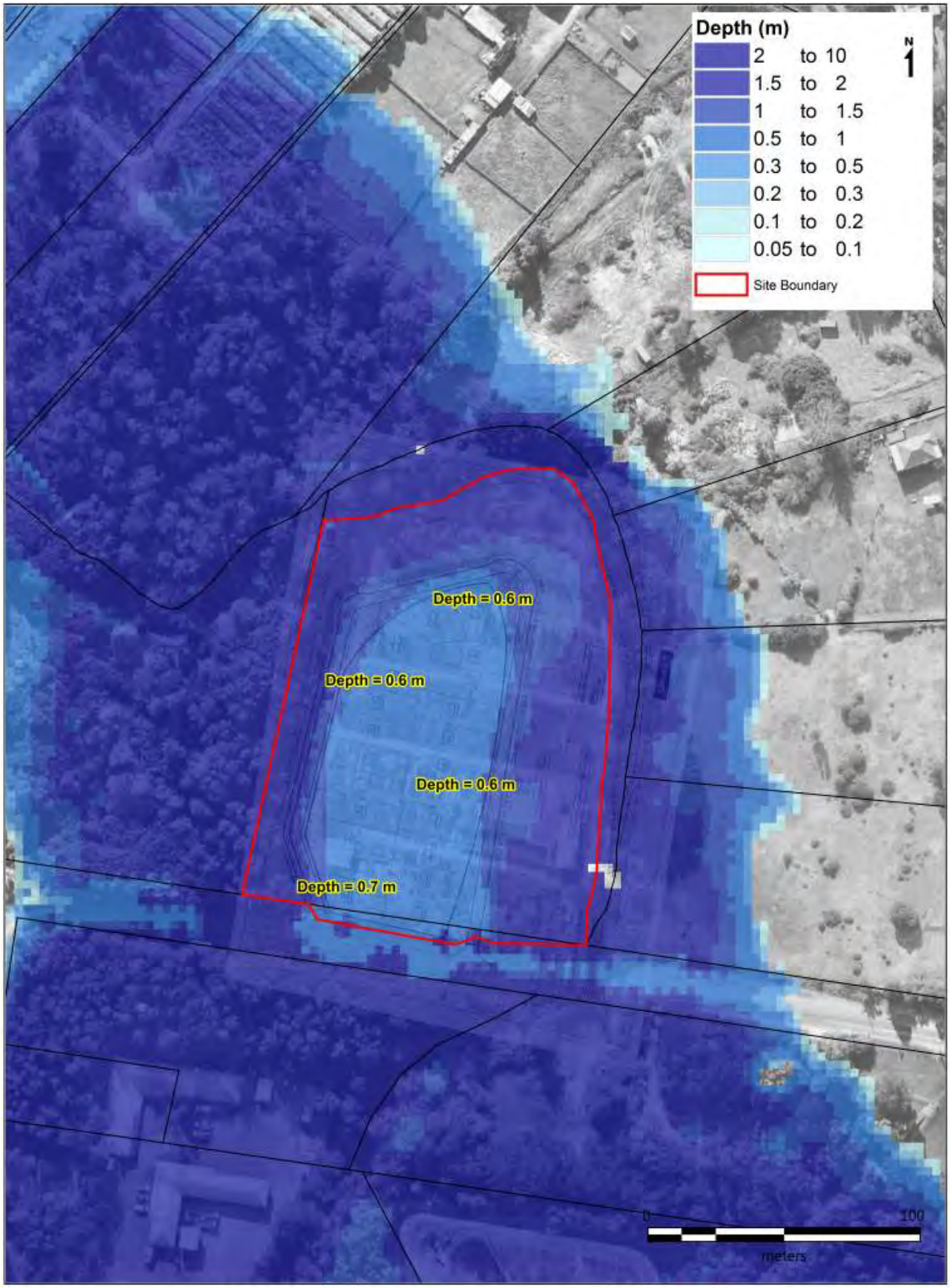

Figure 4 – PMF Maximum Depth

Flood Storage

Opportunities to compensate for the loss of flood storage due to the proposed fill within the subject site have been analysed. The maximum potential excavation is constrained by the following:

- No encroachment in the vegetation protection area along the creek;
- Minimal encroachment into the 25 m bushfire offset line; and
- Maximum batter slope of 1:4.

Based on the above constraints, an excavation volume of approximately 5,400 m^3 is achievable. A comparison of the flood storage for the 1% AEP climate change and sea level rise (0.9m) is presented in Table 4-2. The results show the proposed excavation would result in a net gain of flood storage of 740 m^3 for 1% AEP climate change design event.

The flood modelling or flood impact maps included in this report did not include this excavation volume and hence represent a conservative scenario.

In the case of the PMF design event, with the above excavation in place a net loss flood storage of 3,100 m^3 would occur. A further investigation showed that no loss of flood storage for the PMF could be achieved by encroaching into the vegetation protection and bushfire offset line.

As the flood storage capacity of the floodplain in the PMF event is so great, this additional flood storage would provide no net benefit to the flood condition. This is discussed within Narrabeen Lagoon Flood Study (BMT WBM, 2013) which states that filling in areas such as this development (Flood Fringe) has minimal impact on the overall flood behaviour. The additional cut required will however will result in both environmental and visual amenity issues in the region.

Table 4-2 Flood Storage Calculations

Scenario	1% AEP with climate change Volume (m^3)	Net Loss (-) or Gain (+) Volume (m^3)
Pre-development	18,000	n/a
Post-development without excavation	13,263	-4,737
Post-development excavation	18,704	+740

Based on this assessment it is considered that the majority of compensatory cut can be provided for flood storage for events up to the 1% AEP climate change and sea level rise (0.9 m) however as proven within the hydraulic modelling this would result in little to no change in the flood behaviour onsite or on surrounding properties.

5.0 Flood Emergency Management Planning

As highlighted in council responses, while the proposed residential properties onsite are flood immune up to the 1% AEP climate change and sea level rise (0.9m) plus 0.5 m in the PMF event properties onsite are subject to inundation with depths of approximately 0.7 m potentially present onsite in this event. Figure 4 shows the PMF depth extent for the site.

Similarly, Macquarie Street in this event is significantly overtopped and cannot be relied upon to enable evacuation of the site.

The proposed development has a prescribed finished floor level that will ensure that the development encounters flooding in only very unlikely events. A flood emergency management plan to identify the residual risk onsite and provide solutions which minimise the risk to life to residents has been developed. This document is provided as an attachment to this addendum.

The following outcomes have been identified:

- The defined FPL is in excess of the predicted flood levels of the 0.1% AEP event under existing catchment conditions
- There is insufficient warning time to enable safe evacuation thus Shelter-In-Place is required;
- Two storey dwellings are required to enable vertical Shelter-In-Place;
- Dwellings will not be required to be specially engineered to enable Shelter-In-Place; and
- The time of inundation of the site is relatively short with the maximum expected time of inundation of the site in the order of 6.0 hours

Based upon the assessment undertaken it is considered that Shelter-In-Place is an appropriate emergency management solution for the proposed development and is consistent with other measures in place for similar developments in the area.

6.0 Conclusion

The aim of this addendum was to provide council with greater clarity concerning the following:

- Final fill levels of the site
- The impact of the proposed fill level on the floodplain and surrounding properties
- The proposed flood emergency response for the site in events that exceed the floor levels of dwellings on site.

These issues were raised as being deficient in the previously submitted assessment. The addendum has confirmed:

- The final fill level of dwellings onsite is 4.29 mAHD, which is the defined flood planning level for the site (1% AEP climate change and sea level rise (0.9m))
- No adverse flood impacts would occur upstream and downstream of the site; and
- A potential excavation volume of 5,400 m^3 would result in a net gain of flood storage of 704 m^3 for the 1% AEP with climate change and 0.9m sea level scenario. However is not necessary for the site to have no adverse impacts on surrounding properties.
- Shelter in Place is a viable emergency response option and does not result in an increase in risk to life if appropriately incorporated into the development.

Overall, on the basis of this information the proposed development would demonstrate compliance against Council's flooding conditions

Yours sincerely

Daniel Wood
Senior Engineer, Water & Environment
for Cardno

Enc SK02 P3
2 Machpherson St Warriewood FEMP

Our Ref: 59917042:DW
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11 December 2018

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Dear Sir,

2 MACHPHERSON STREET WARRIEWOOD - PMF FLOOD CONDITION AND TIME OF ISOLATION ASSESSMENT

As part of ongoing Court Proceedings (case number 2018/244034) upon 2 Macpherson Street, Warriewood it was identified that the site, while in accordance with the general requirements to achieve shelter-in-place set by Council, may be subject to times of isolation of greater than 6-hours in a PMF event.

The Council DCP states that under these circumstances, in non-land release areas, a minimum land area above the PMF level of 2m^2 per occupant is required when assuming a shelter-in-place evacuation procedure (B3.13, Control 3). However, because this site is located within a land release area, it is subject to greater scrutiny. It is noted that no specific measure of this is provided within the DCP.

During the Section 34 meeting, it was highlighted that the site, in its proposed form, would meet the requirements of the DCP and have, in a 6-hours (critical water level) PMF event, a period of approximately 3 hours when the road would be closed. Each potential lot onsite would exceed the 2 m^2 of flood free area above the PMF required for shelter in place for isolation times greater than 6 hours. While the key DCP criteria have been met, one party considered that, due to the land release nature of the site, a greater level of rigour, was required in the assessment of the site. It was postulated that, while the peak water level in a PMF event may occur in the 6-hours event, a longer duration PMF event may result in a longer time of isolation.

As identified within the Section 34 proceedings, no longer-duration flooding has previously been assessed within the Narrabeen Lagoon Catchment. In order to assess the site for this mechanism of flooding in a time and cost effective manner, it was agreed within the proceedings to undertake the assessment within the hydrologic model rather than the hydraulic model. Based on this position, the following approach was established during the proceedings:

- Undertake a review of current best practice PMP and PMF assessments, relevant to the Narrabeen Lagoon Catchment;
- Develop Rainfall Depths for the longer duration PMP events in accordance with current best practice;
- Update the current Narrabeen Lagoon Hydrologic Model to incorporate the developed PMP rainfall depths and appropriate temporal patterns
- Run the hydrologic model to determine the flow at the site and at the Narrabeen Lagoon Entrance
- Undertake an assessment and prepare a discussion of the findings and then determine the implications of the findings relevant to flood level and time of isolation of 2 Macpherson Street.

Narrabeen Lagoon Catchment Characteristics

The Narrabeen Lagoon catchment is located on the northern edge of the Warringah LGA and the south eastern edge of Pittwater LGA on Sydney's northern beaches. The catchment occupies a total area of approximately 55km^2 and drains to the Tasman Sea through a narrow channel to the lagoon entrance at North Narrabeen Beach (*Narrabeen Lagoon Flood Study*, BMT, 2013).

2 Macpherson Street, Warriewood, is located within the Narrabeen Creek sub-catchment of the Narrabeen Lagoon Catchment. However, the location of the site means that during very severe flood events that cause extreme water levels in Narrabeen Lagoon, that it has the potential to be affected by the backwater associated with the event.

Within the Narrabeen Lagoon Flood Study (BMT, 2013) the PMF has been assessed for events up to the 6-hours duration. This information is deemed accurate and has not been revised for this task. In the previously assessed 6-hours PMF, due to the inflow reaching the entrance of the lagoon and exceeding the discharge capacity of the entrance, water levels in the lagoon reach approximately 4.85 mAHD.

Chart 1 shows the time series results associated with this event based on the modelling undertaken as part of the *Narrabeen Lagoon Flood Study* (BMT, 2013). During the 6-hours PMF event, flows from the catchment into the lagoon exceed 1800 m^3/s. At the time of this peak flow into the lagoon, discharge through the entrance is approximately 1450 m^3/s. As the water levels within the lagoon rise, the entrance scours out, thereby increasing its effective discharge capacity. The discharge capacity in this event, at its maximum, reaches approximately 1500 m^3/s.

During the 6-hours PMF event, Macpherson Street suffers inundation for approximately 4 hours and is 'untrafficable' for approximately 3 hours. The closure occurs when the discharge into the lagoon is approximately 1250 m^3/s peak flows are higher than 1250 m^3/s for approximately 3 hours. This closure time is significantly shorter than 6 hours. Additionally the closure occurs generally while the rainfall event is still occurring, with the road returning to flood free 7 hours after the onset of rainfall. This is visually represented in attachment 1 of this document.

Based on the relationship between flow and water level at the road in this scenario, it is identified that the road is inundated for approximately 15% longer than the discharge is above 1250 m^3/s.

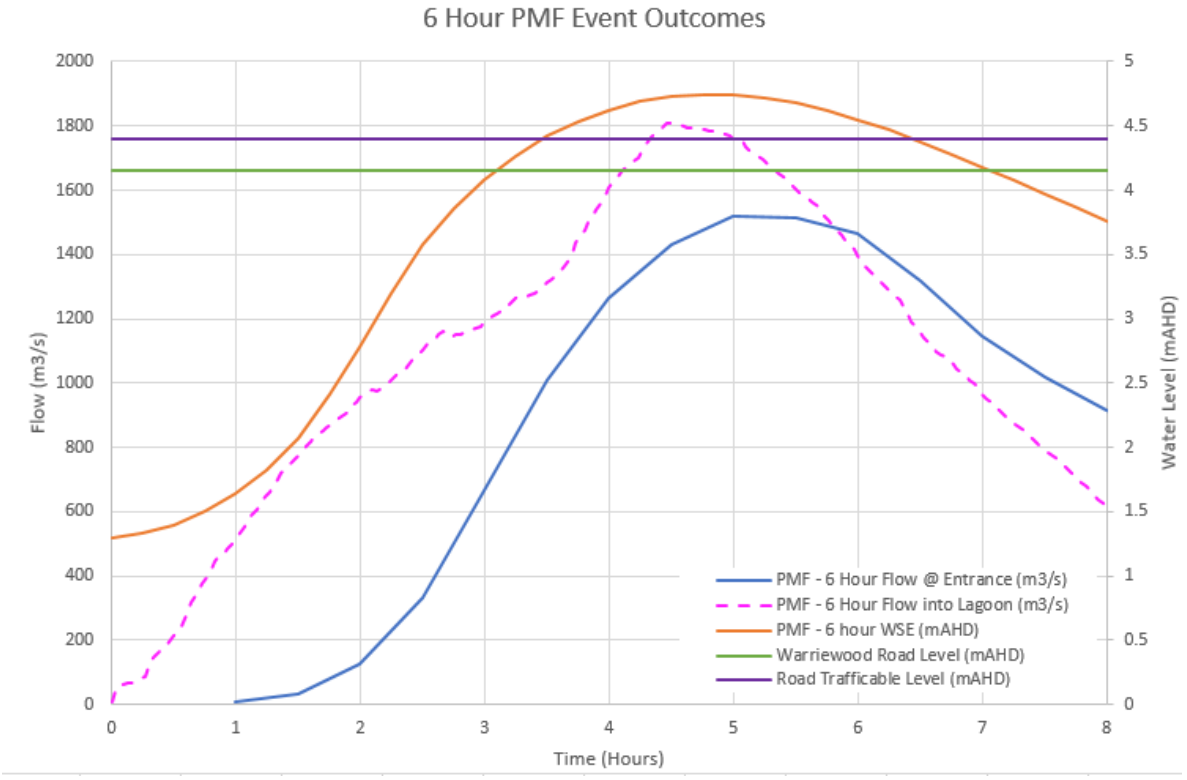


Chart 1 - 6-hours PMF Event Results

The information that is available indicates that while Macpherson Street in front of 2 Macpherson Street may not be immune from PMF flood events, in PMF flood events deemed to generate the peak water level in the area the time of closure along the road is less than 6-hours.

During the Section 34 proceedings it was highlighted that while this event may cause the peak water level, it may not cause the peak time of closure. As such, an assessment of longer duration PMF flooding has been undertaken. Note also that the discharge hydrograph peaks shown in Chart 1 indicate that there is only a 1 to 2 hours lag between peak inflow and outflow – maximum peak water level and entrance scour.

Best Practice PMP and PMF Assessments

Currently within Australia, Probable Maximum Precipitation is assessed utilising three methods:

- Generalised Short Duration Method (GSDM)
- Generalised Southeast Australia Method (GSAM); or
- Generalised Tropical Storm Method (GTSMR)

Depending on the location of the catchment, its area and the purpose of the study, there are several options for selecting the correct PMP method. These take into account such factors as seasonality, short duration/long duration requirements and method zone. To help appreciate this, a list of the methods for estimating PMP in Australia and their limits of applicability is presented on Image 1 (*Guidebook to the Estimation of Probable Maximum Precipitation: GENERALISED SOUTHEAST AUSTRALIA METHOD,* BoM, 2006)

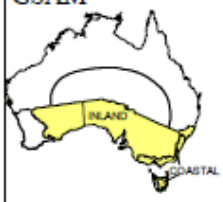
METHOD	AREA (KM²)	ZONE	LOCATION	SEASON	DURATION (HOURS)
GSDM	≤ 1000	3 Hour	Inland and south coast	annual	≤ 3
		Intermediate		annual	4 to 5
		6 Hour	West, north and east coast	annual	≤ 6
	≤ 500	3 Hour	south of 30°S	monthly	≤ 3
		Intermediate	south of 30°S	monthly	4 to 5
		6 Hour	south of 30°S	monthly	≤ 6
GSAM	1 to 1000	Inland	South Aust	annual	24(1) to 72
			Victoria	annual	24(1) to 72
			NSW	annual	24(1) to 96*
		Coastal	Tasmania	annual	24(1) to 72
			Victoria	annual	24(1) to 72*
			NSW	annual	24(1) to 96*
	1000 to 40,000	Inland	South Aust	annual	24* to 72*
			Victoria	annual	24* to 72*
			NSW	annual	24* to 96*
		Coastal	Tasmania	annual	24* to 72
			Victoria	annual	24* to 72*
			NSW	annual	24* to 96*
	> 40,000	Only issued on special request.			* One more (or one less) duration available on special request.
GTSMR	up to 150,000	Inland		annual	24(2) to 96
		Coastal		summer	24(2) to 120
			minus SW WA	winter	24(2) to 96
		SW WA	SW WA	winter	24(2) to 96
West Coast Tasmania	up to 3,000		Southwest Tasmania	annual	24 to 72

Image 1 - Area, duration and zone limits for application of PMP methods in Australia (BoM, 2006)

Based on the catchment characteristics and the location, both the GSDM and the GSAM approaches are relevant to this catchment.

The GSDM is to be utilised up to and including the 6-hours rainfall event. This was previously adopted for the *Narrabeen Lagoon Flood Study* (BMT, 2013). This information is deemed accurate and has not been revised for this task. The GSDM is also used to estimate the 12 hour rainfall depth, which is not provided directly via either the GSDM or the GSAM approaches, however it is considered appropriate to estimate the depth by combining the two approaches.

The GSAM is to be utilised for durations of 24 hours and longer. For the 12-hours event the longer duration GSAM values should be utilised to inform the interpolation.

Development of Long Duration Rainfall Depths

Based on a review of current approaches, the PMP rainfall depths for the GSAM approach have been developed in accordance with the process described in *Guidebook to the Estimation of Probable Maximum Precipitation: GENERALISED SOUTHEAST AUSTRALIA METHOD,* BoM, 2006. As per Image 1, an annual assessment within the Coastal Zone has been completed. Raw depths were taken from a 55 km^2 area and the following adjustment factors applied:

- Moisture Adjustment Factor – MAF of 0.905
- Topographic Adjustment Factor – TAF of 1.35

Table 1 provides the outcomes of the estimation of PMP depths. In addition, this table provides the GSDM estimates used as part of the *Narrabeen Lagoon Flood Study* (BMT, 2013). Note values have been rounded to the nearest 5 mm. Chart 2 provides a visual representation of the values, including the interpolated 12-hours PMP estimate. Of note is that relative to the intensity of the PMP 6-hours event, the 12-hours and 24-hours event values are significantly diminished. Noting this significant drop off, events longer than the 24-hours event have not been assessed further.

Table 1 – Estimated PMP Rainfall Depths

PMP Estimation Tool	Duration (Hours)	Rainfall Depth (mm)	Rainfall Intensity (mm/hr)
GSDM	3	510	170
GSDM	4	580	145
GSDM	6	690	115
Interpolated	12	825	69
GSAM	24	1005	42
GSAM	36	1120	31
GSAM	48	1185	25

Following the development of the rainfall depths, appropriate temporal patterns have been adopted for the 12-hours and 24-hours events. The advice set out within the GSDM guidebook indicates that temporal patterns for these events should not be utilised for longer duration events. Hence, the temporal pattern for the 24-hours event has been utilised for the 12-hours interpolated event. The duration of each time-step has been halved to ensure the duration of the storm is 12 hours.

The rainfall events have then been incorporated into the XP-RAFTs model developed as part of the *Narrabeen Lagoon Flood Study* (BMT, 2013).

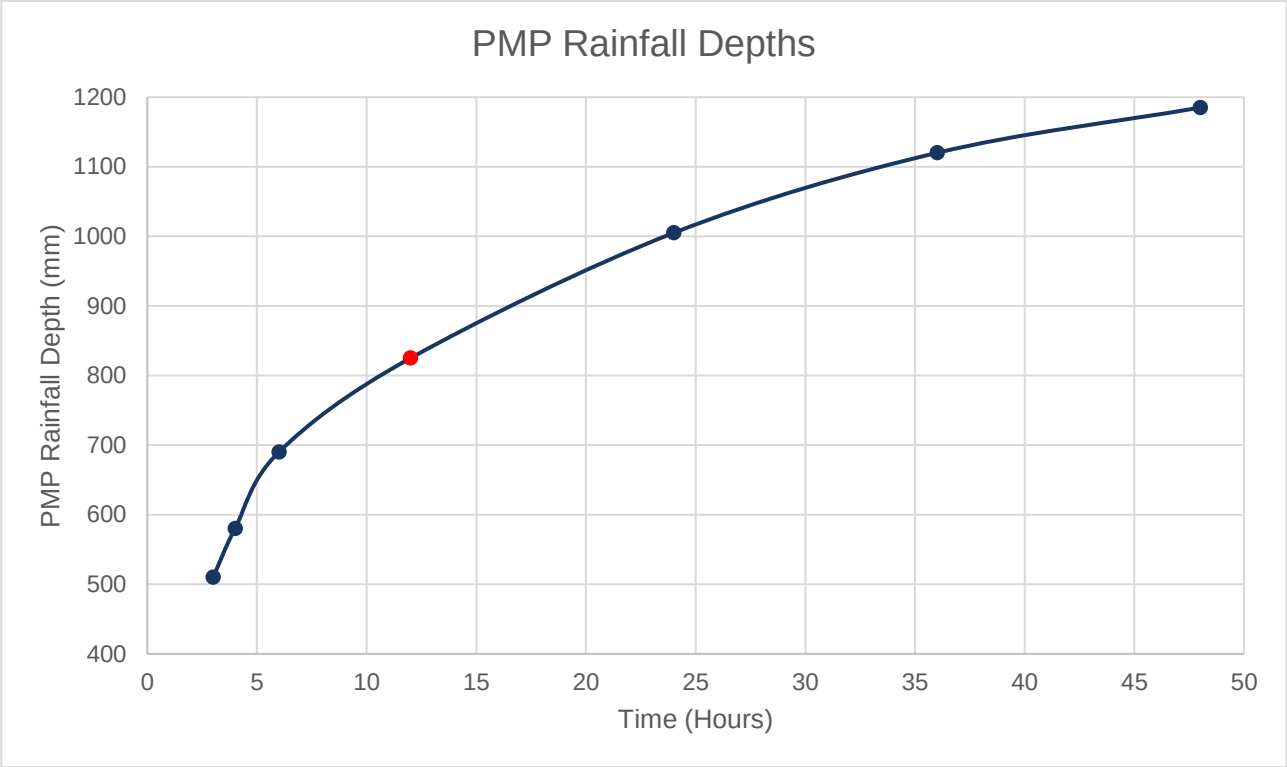


Chart 2 – PMP Rainfall Depths

Scour and Flow Capacity of the Entrance

In order to assess the potential impacts of the 12-hours and 24-hours PMF events within the lagoon, it is necessary to make some physically realistic assumptions with regard to the entrance scour and flow capacity. For the purposes of this assessment, it has been assumed that the theoretical capacity of the entrance is reached in the hydraulically modelled 6-hours PMF event. Based on this, the theoretical capacity of the entrance is approximately 1500 m^3/s – consistent with Chart 1.

Assessment Results

Chart 3 shows the outcomes of the flow assessment of the 6, 12 and 24-hours PMF events. What is immediately apparent is that the 24-hours event peak flow rate does not exceed the theoretical capacity of the outlet – that is 1500m^3/s. As such, while flooding may potentially occur in this event it is unlikely to result in a time of closure that exceeds what is predicted in the 6 hour PMF event.

In the 12-hours PMF event, the peak flow calculated is approximately 1300 m^3/s. This is 500 m^3/s lower than the recorded 6-hours PMF peak flow and 50 m^3/s higher than the peak flow recorded to cause road overtopping.

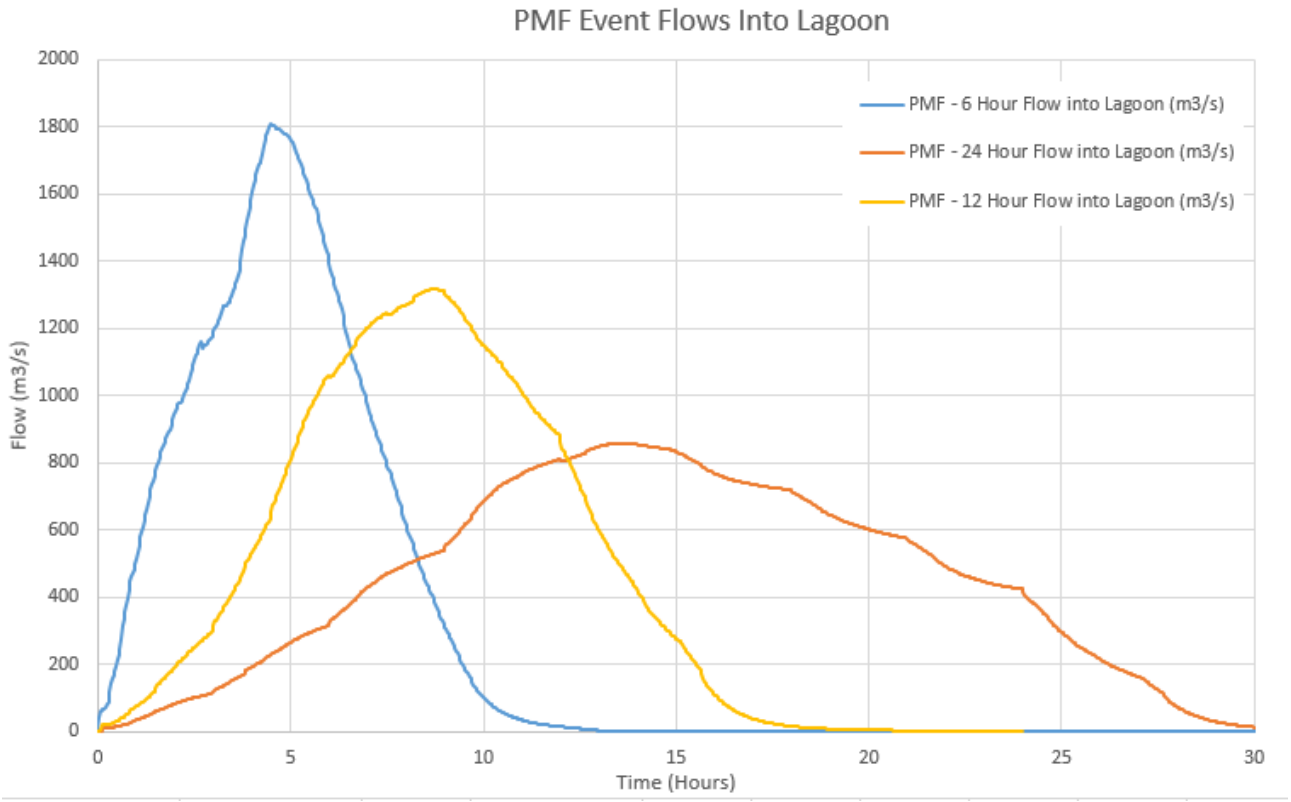


Chart 3 – PMP Event Flows

Analysis and Discussion

Based on this assessment, no PMF event of duration greater than 6-hours exceeds the theoretical discharge capacity of the outlet – 1500 m^3/s. In the 12-hours event however, the peak flow exceeds 1250 m^3/s, which, in the hydraulically modelled 6-hours PMF event was the flow rate (Flow into Lagoon), at which road closure occurs.

For the purposes of this assessment it is considered that a similar flow rate may result in road closure during the 12-hours event. It is noted that this assumption is likely conservative in nature, because the 12-hours PMF event has significantly more volume prior to reaching this peak flow. As such, it is likely that by the time the peak flow rate in the 12 hour event is experienced the entrance will be more open (greater scouring, or up to the maximum entrance opening), than at the equivalent time in the 6-hours PMF event.

A review of this flow rate, assuming that this is a flow rate that will result in overtopping of the road, identifies that, in this scenario the flow is in excess of 1250 m^3/s for a significantly shorter period. Chart 4 shows this in detail, comparing the 6-hours PMF and the 12-hours PMF results. Assuming that the water elevation response in the location is similar to that in the 6-hours PMF event (i.e. 15% longer than the peak flow above 1250 m^3/s) the 12 hour PMF event would result in the road overtopping for less than 2 hours, less than the expected inundation time present in the 6-hours PMF event.

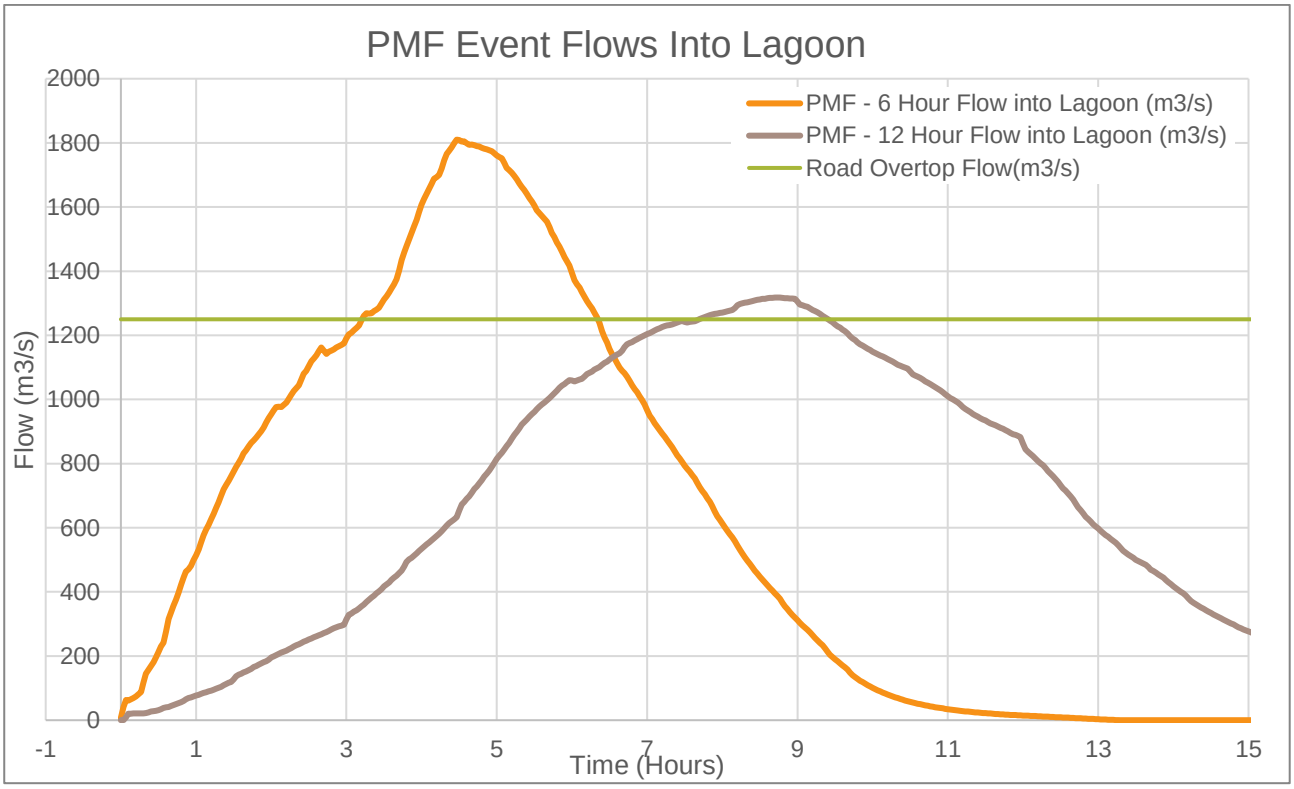


Chart 4 – PMF Event Flows v Entrance Capacity

Further Analysis

Based on feedback from Council, the aforementioned linear discussion relating the closure time of Macpherson Street in the 6-hours PMF event to the 12-hours PMF event, was not considered sufficient. A concern raised, that the period of closure may be longer in the 12-hours PMF, due to the entrance response not being comparable and by the storage in the Lagoon being non-linear, required further hydrodynamic analysis to be undertaken.

Due to limitations of the Council approved model, to confirm the response of the storage and entrance morphology in the 12-hours PMF event a Delft 3D Model, developed in an aim to replicate the Council approved model of Lagoon storage and entrance morphology response was developed.

Chart 5 provides a summary of the water levels achieved in this model. It is noted that within the Delft3D modelling environment, in the 6-hours PMF the time of closure and the peak water levels at Macpherson Street are slightly longer and higher than the Tuflow model results. Further calibration of the entrance morphologic regime within the Delft3D model would likely achieve an improved correlation to the Tuflow results. As the results are conservative with regards to both water level and time of closure however, the model is deemed to be conservative for the purposes of assessing alternative model scenarios.

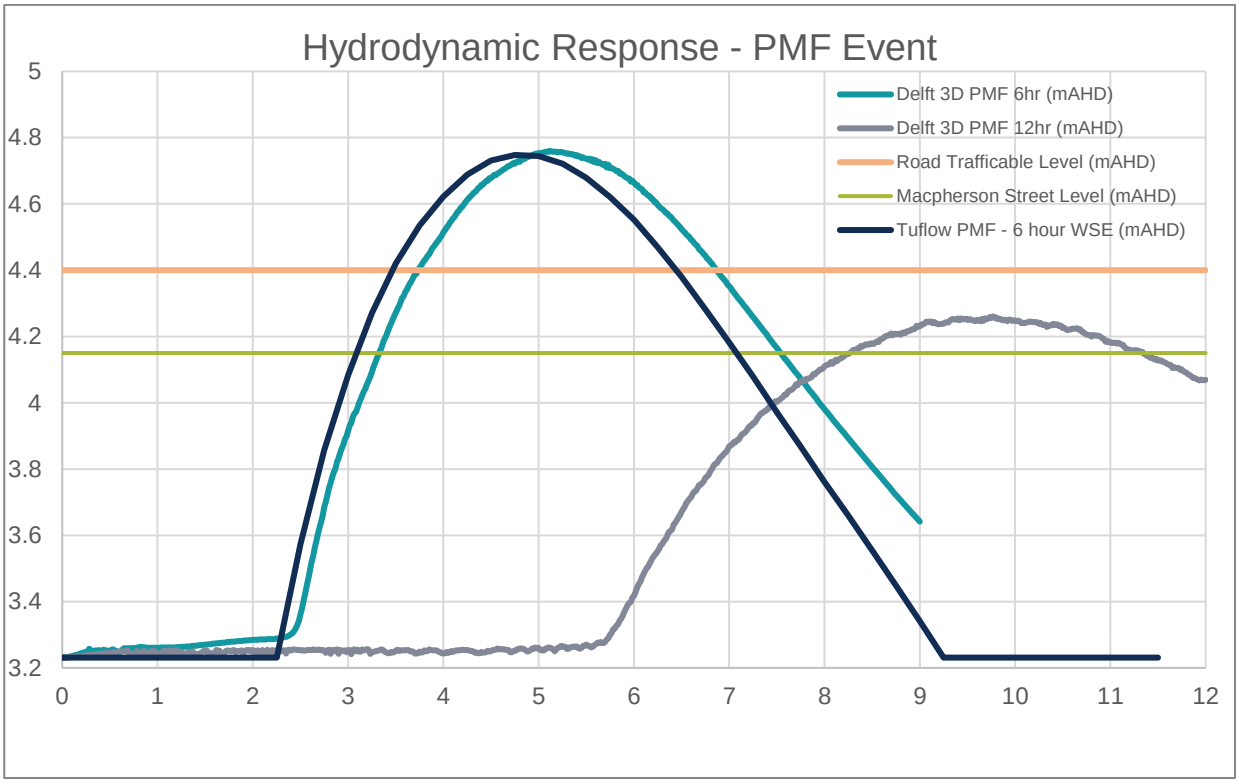


Chart 5 – PMF Water Levels – Model Response

The 12-hour PMF model was setup within Delft3D based on the hydrology discussed in previous sections. The hydrology was input into the Council approved Tuflow model (without the morphologic component active) and flows at the discharge locations of each creek into the lagoon recorded. These flows, coupled with a direct rainfall surface covering the area downstream were input into the Delft3D model as flow inputs. The 1% AEP storm tide was input as the tidal boundary condition, timed to peak at 9 hours, equivalent to the peak flow entering the lagoon. Chart 5 shows the results of this assessment.

In the 12-hours PMF within the Delft3D model the peak water level recorded at Macpherson Street is 4.25 mAHD. This is 100 mm higher than the road level and deemed trafficable. In this scenario, Macpherson Street is estimated to be inundated for less than 3 hours. This result confirms the previous assumptions utilised, and also confirms the 12-hours PMF event does not result in a time of inundation or a time of closure greater than the estimated times associated with the 6 hour PMF event.

Additional Sensitivity

In addition to confirming the assumptions within the previous assessment with regards to lagoon response, a review of the influence of the tide was undertaken. For the assessment, the tide within the Delft3D model (the 1% AEP storm surge) was shifted by 2 hours, to have the peak tide and flow offset. The change resulted in less than 1 cm of variance within the model compared to the base results, indicating the water level in the lagoon is not sensitive to changes in tide timing within the PMF flood event. This is a logical outcome as the water levels within the lagoon are over 2m greater than the peak predicted 1% AEP storm tide level.

Outcomes

Cardno has undertaken an expert review of the current PMF flood condition within Narrabeen Lagoon Catchment.

Analysis of existing PMF flood results generated within the *Narrabeen Lagoon Flood Study* (BMT, 2013) identified that under a 6-hours PMF event a period of inundation of Macpherson Street of 4 hours is anticipated. It has also been identified that the discharge capacity of the entrance is driven by water level in the lagoon and has a theoretical upper limit of approximately 1500 m^3/s. The road begins to overtop in the 6-hours PMF event when a flow into the lagoon of 1250 m^3/s is present.

Hydrologic review of longer duration PMF events identified that no event greater than 6-hours generates a peak flow rate into the lagoon in excess of the theoretical (modelled) maximum discharge rate through the entrance. In the 12-hours PMF event, flows do however exceed the flow rate at which overtopping of Macpherson Street is experienced in the 6-hours event. In the 12-hours PMF event, this flow rate is exceeded for approximately 1.5 hours, resulting in a potential inundation time of 3.0 hours. No closure period is predicted for the event. This is shorter than in the anticipated 6-hours PMF inundation time of 4 hours and closure period of 3 hours.

Further hydrodynamic review, undertaken to respond to Council concerns with regards to entrance and lagoon storage response, was completed following the hydrologic analysis. This additional analysis confirmed the assumptions made within the hydrologic review and validated the expectation that the 12-hours PMF peak flood level would not exceed the closure time experienced within the 6-hours PMF. Similarly, additional analysis of the timing of the tide relative to the peak of PMF flows confirmed the water levels experienced within the lagoon during a PMF event are not sensitive to tidal peak timing.

Based on this analysis, it is advised that in a 12-hours PMF event, and any longer PMF event, the time of closure of Macpherson Street will be less than the time of closure estimated in the modelled 6-hours PMF event.

Yours sincerely,

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Att:6-Hours PMF Time Series Imagery