Appendix H

Flood Assessment

Cessnock Road Upgrade at Testers Hollow

Flood Assessment

Roads and Maritime Services | December 2018

NSW GOVERNMENT

JACOBS

M195 CESSNOCK ROAD UPGRADE AT TESTERS HOLLOW – FLOOD ASSESSMENT

FINAL

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DECEMBER 2018

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M195 CESSNOCK ROAD UPGRADE AT TESTERS HOLLOW – FLOOD ASSESSMENT

FINAL

DECEMBER 2018

Project M195 Cessnock Road Upgrade at Testers Hollow – Flood Assessment	**Project Number** 118020
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Cover image: Inundation of Cessnock Road at Testers Hollow causing closure of the road during the 2015 flood event. Source: Sonia Warby, ABC News http://www.abc.net.au/news/2015-05-05/testers-hollow-flooding.jpg/6444818

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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DECC	Department of Environment and Climate Change (now OEH)
DNR	Department of Natural Resources (now OEH)
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
GIS	Geographic Information System
GPS	Global Positioning System
IFD	Intensity, Frequency and Duration (Rainfall)
mAHD	meters above Australian Height Datum
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
SRTM	Shuttle Radar Topography Mission
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2016) recommends terminology that is not misleading to the public and stakeholders. Therefore the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2016 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality.

Therefore the term Exceedances per Year (EY) is recommended. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events rarer than the 50 % AEP and EY for all events more frequent than this.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			↓	
			PMP/ PMPDF	

EXECUTIVE SUMMARY

Jacobs Group (Australia) Pty Ltd (Jacobs) has been engaged by Roads and Maritime Services to undertake certain services in connection with the *M195 Cessnock Road at Testers Hollow* (proposal). The proposal aims to reduce flood risk to traffic and improve access reliability along the road. Jacobs engaged WMAwater to undertake flood modelling and a flood assessment for the preferred road upgrade option. This report documents the scope of work, the flood modelling undertaken and the results of the assessment.

Cessnock Road at Testers Hollow can be subject to flooding from both Wallis/Swamp Creek and Hunter River flood events. The recent flood events of June 2007, March 2013, April 2015 and January 2016 were all examples that were primarily caused by local (Wallis and Swamp Creek) flooding. . These four flood events were relatively major, and more than would be expected in a typical 10 year period. In contrast, flooding from the Hunter River over the last 40 years has been less than would be expected. Significant flooding of Wallis Creek and Testers Hollow has not occurred since the 1970s. In June 2007, although some flow into the area did come from the Hunter River, the flooding was primarily produced by local (Wallis and Swamp Creek) rainfall.

The existing road is more likely to be inundated at Testers Hollow from local rainfall than from the Hunter River. The current road would be expected to be overtopped every 5 years on average from local rainfall (a 20% chance each year, referred to as a 20% AEP). There have been more local floods in the last 10 years than this long term average would suggest. For Hunter River floods, the existing road has a 5% chance each year of inundation (5% AEP), although there has been an unusually low amount of major Hunter River floods in the last 40 years compared to the long term average.

The depth of flooding over the road can be quite deep and remain for a long period; for example, the 1% AEP Hunter River flood (similar to the February 1955 flood) would inundate the existing road to a depth of approximately 5 m for just over 10 days. Cessnock Road also crosses Fishery Creek to the north of Testers Hollow. When both crossings are cut off due to flooding, the suburb of Gillieston Heights can be isolated for over a week, as occurred in April 2015.

The proposal involves a new alignment for Cessnock Road at Testers Hollow and raising the minimum level to 6.2 mAHD, providing immunity for the 5% AEP Wallis Creek and Hunter River flood events. This means the road would only have a 5% chance of inundation every year compared to a 20% chance currently. A larger culvert is also proposed to protect the road and reduce damage during flood events, further reducing road closure time by reducing the repairs required after floods. A summary of the features and benefits of the proposal is outlined in the table below.

	Existing	Proposed
Road Level at Testers Hollow(RL)	4.6 mAHD	6.2 mAHD
Drainage Structure	1 x 1200 mm pipe	3 x 1500 mm pipes
Flood Immunity (Wallis Creek Flooding)	20% AEP	5% AEP
Flood Immunity (Hunter River Flooding)	< 5% AEP	5% AEP
Length of Road to be Raised (m)	N/A	670 m
Average Annual Duration of Inundation at Testers Hollow (hours)	23.5	5.0
Average Annual Duration of Isolation of Gillieston Heights (hours)	6.2	4.8
Peak Velocity through Culvert – Wallis Creek Flooding (excluding PMF) (m/s)	3.4	2.8
Peak Velocity through Culvert – Hunter River Flooding (excluding PMF) (m/s)	5.2	3.9
Maximum water level difference across road embankment – Wallis Creek Flooding (excluding PMF) (m)	0.99	0.76
Maximum water level difference across road embankment – Hunter River Flooding (excluding PMF) (m)	2.38	1.47

The proposal results in an increase in flood immunity, decrease in depth and duration of inundation, lower culvert velocities and lower water level differences across the embankment.

The proposal would have resulted in Cessnock Road at Testers Hollow being flood free in the March 2013 and January 2016 flood events, saving approximately 100 to 170 hours of road inundation time. The June 2007 and April 2015 flood events would have inundated the upgraded road, but to a depth of less than 0.5 m and reducing the time of inundation by approximately 100 hours for each of these floods.

The proposal would mitigate flood impacts through the provision of the larger culverts. The associated increase in flood levels are generally negligible (within 0.01 m), except in the 5% AEP Wallis Creek flood event, where the increase in flood level is between 0.01 m and 0.03 m across the Wallis Creek floodplain. The flood hazard across Cessnock Road at Testers Hollow generally reduces, except in the Hunter River PMF event, where it remains the same.

Further safeguards and management measures are recommended during the construction phase, such as dewatering, flow path management, location of stockpiles at least above the 5% AEP Hunter River flood level, development of a Soil and Water Management Plan and preparation of a Flood Management Plan. For the operational phase, consideration should be given to whether scour protection measures are required, particularly at the culvert inlet and outlet locations.

1. INTRODUCTION

Jacobs Group (Australia) Pty Ltd (Jacobs) has been engaged by Roads and Maritime Services to undertake certain services in connection with the *M195 Cessnock Road at Testers Hollow* (proposal). The proposal aims to reduce flood risk to traffic and improve access reliability along the road. Jacobs engaged WMAwater to undertake flood modelling and a flood assessment for the preferred road upgrade option. This report documents the scope of work, the flood modelling undertaken and the results of the assessment.

1.1. Scope of Work

The scope of work was agreed with Jacobs and includes the following tasks:

1. Provide flood model calibration and verification results for all events in the vicinity of Testers Hollow and Cessnock Road at Fishery Creek crossing. In particular, define depth and duration of road overtopping at the two locations for the calibration and verification events.
2. Define existing flood behaviour (flood depth, velocity and hazard mapping as well as depth and duration of road overtopping) for the 20% annual exceedance probability (AEP), 5% AEP, 2% AEP and 1% AEP events and the probable maximum flood (PMF) event for both local catchment (Wallis Creek) and regional (Hunter River) flooding.
3. Define flood behaviour for the proposed conditions (operational stage of the proposal), in a similar manner as above.
4. Assess the flood impacts and benefit to access of the proposal.

This report has been produced for the purpose of assessing the flood impacts of the proposal.

2. BACKGROUND

2.1. Study Area

The study area is located in the Hunter Valley, approximately 30 km northwest of Newcastle. Cessnock Road (M195) is an important regional transport route that connects the New England Highway at Maitland with the Hunter Expressway at Kurri Kurri (Figure 1). The road runs through the suburbs of Heddon Greta, Cliftleigh and Gillieston Heights. The southern half of M195 is also referred to as Main Road, however, Cessnock Road will be used herein to refer to the entire stretch of road.

2.2. Relevant Studies

2.2.1. Hunter River: Branxton to Green Rocks Flood Study

WMAwater was commissioned by Maitland City Council to undertake a flood study of the Lower Hunter River between Braxton and Green Rocks (Reference 1). The study area included the lower reaches of Swamp Creek and Wallis Creek.

TUFLOW modelling software was used to undertake 2D hydraulic modelling for this study. Design flow rates for the Hunter River were estimated using Flood Frequency Analysis, and WBNM software was used for hydrologic modelling of local catchment and tributary runoff contributions within the hydraulic model extent. This study provides the most recent design flood information for the Hunter River in the vicinity of the study area, using up-to-date modelling techniques and providing information on flooding in the Hunter River that can affect both Swamp Creek and Wallis Creek.

The design flood mapping from the study indicates the following:

- In the 0.5%, 1%, 2% and 5% AEP events there is significant discharge from the Hunter River down the Oakhampton Floodway, which passes to the west of Maitland.
- Significant ponding and storage occurs in the Wentworth and Dagworth Swamp areas (located just downstream of the proposal, within the Wallis and Swamp/Fishery Creek flood storage areas) to the south of Maitland due to this flow down the Oakhampton Floodway, and also potentially due to overtopping of the Wallis Creek floodgates and Pitnacree levees in larger events.
- In moderate Hunter River floods such as the 20% and 10% AEP, the Hunter River water level is significantly higher than the water level in the Wentworth and Dagworth Swamp areas produced by local runoff. The Wallis Creek floodgates prevent backflow into these areas from the Hunter River, but also prevent drainage until the Hunter River levels have subsided.

2.2.2. Wallis and Swamp Fishery Creek Flood Study

A study was undertaken by WMAwater to define the flood behaviour for the Wallis and Swamp/Fishery Creek catchment (Reference 3). It was commissioned by Maitland City Council and Cessnock City Council. The study has developed a WBNM hydrologic model of the entire catchment area, with a total of 108 subcatchments. A TUFLOW hydraulic model was developed of the downstream catchment area to simulate flood behaviour. The two-dimensional (2D) model domain was developed with a 16m regular grid mesh, with a nested 4m regular grid for the upstream urban areas of Abermain and Weston. Bridges were modelled as 2D structures while culverts were modelled as one-dimensional (1D) elements dynamically linked to the 2D domain. The TUFLOW model was calibrated to four historical flood events:

- June 2007
- March 2013
- April 2015
- January 2016

Recorded rainfall data was used in the WBNM model to simulate rainfall runoff. These were used as inflows into the TUFLOW model and recorded water levels in the Hunter River were used as the downstream boundary. The model was calibrated using two water level gauges in the lower catchment, at Louth Park and upstream of the Wallis Creek Flood Gates. For each event, there were also a number of observed flood levels based on a community survey. Model parameters were adjusted to obtain the best fit of water levels at these gauges and with the observed flood levels and depths. The model is regarded to be suitably calibrated with these events.

Design flood events were also modelled, including the 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF events using the approach outlined in Australian Rainfall and Runoff 2016 (ARR 2016, Reference 4). Inflows were sourced from the WBNM model. Typically, two storm durations were run for each event, one representing the peak flow for the upstream areas where conveyance dominates, and one representing the peak runoff volume for the downstream areas where the peak flood level is dominated by flood storage. For each of these storms, the temporal pattern producing the peak flow just greater than the average peak flow of the 10 temporal patterns was selected. Initial losses were obtained from the ARR 2016 Data Hub and the calibrated continuing loss value of 5 mm/hr was adopted. Areal reduction factors were also applied.

Hunter River flooding dominates flooding in the Wallis and Swamp-Fishery Creek catchment for events rarer than the 5% AEP event, where the Hunter River levees are overtopped and significant flow occurs down the Oakhampton floodway. Since this study investigated the flooding from the Wallis and Swamp-Fishery Creek catchment only, a tailwater level of 4.5 mAHD in the Hunter River was adopted for the rising limb of the flood (restricting the flow out of the catchment), and was then lowered to 1 mAHD to allow floodwater to drain out of the catchment. The period of elevated Hunter River tailwater preventing drainage out of the floodgates was based on an assessment of the behaviour in historical flood events, particularly June 2007 and April 2015.

3. EXISTING ENVIRONMENT

3.1. Catchment Description

The proposal is located in the Wallis and Swamp-Fishery Creek catchment, which discharges into the Hunter River at Maitland (Figure 1). The catchment covers an area of approximately 400km^2 and is subject to flooding from both local runoff and Hunter River flooding in the lower portion of the catchment, where the proposed road upgrade is located. There are two main creeks in the lower portion of the catchment – Swamp-Fishery Creek and Wallis Creek. Cessnock Road runs in between these two creeks, with Wallis Lake on the eastern side and Swamp-Fishery Creek on the Western side.

Cessnock Road crosses the Wallis Creek floodplain at two main locations – Testers Hollow near Cliftleigh and Fishery Creek near Maitland (Figure 1). Testers Hollow is a swamp area which drains eastward to Wallis Creek, approximately 200m downstream of the Cessnock Road crossing. The area is heavily influenced by backwater from Wallis Creek, since the ground elevation of the swamp area is approximately 1.5 mAHD, and the local catchment to this area is relatively small. There is currently a 1200 mm diameter culvert underneath Cessnock Road to provide cross-drainage connectivity between the eastern and western sides of the road embankment. The lowest level at which the road is overtopped is approximately 4.6 mAHD.

Further north, Cessnock Road also crosses Fishery Creek, the name given to the section of Swamp Creek that continues downstream of the Wentworth Swamp (the main swamp area). This creek flows in a south easterly direction at the Cessnock Road crossing before discharging into Wallis Creek less than 1 km downstream. Cessnock Road crosses Fishery Creek with a bridge approximately 35 m in length and 10 m in width. The soffit is at approximately 5.7 mAHD, with a deck level of approximately 6.2 mAHD. Immediately to the south west of the Fishery Creek crossing, Cessnock Road crosses a swamp area. It is here that the low point of the road occurs at approximately 5.95 mAHD, and where flooding of the road is most likely to occur first. When referring to the 'Fishery Creek crossing' of Cessnock Road in this report, it is the combined stretch of the Fishery Creek bridge crossing and this low point.

3.2. Existing Flood Models

Two existing flood models were utilised in this study, as outlined below.

3.2.1. Hunter River Flood Model

This flood model was obtained from the Hunter River: Branxton to Green Rocks Flood Study (Reference 1). The TUFLOW model focusses on inundation due to Hunter River flooding, but incorporates inflows from the Wallis/Swamp Creek catchments, and covers the lower part of this floodplain. The existing model extended up to the Cessnock Road crossing of Testers Hollow.

Design Flood hydrographs for the Hunter River were based on a scaling of the February 1955 Hunter River flood hydrograph. Coincident local tributary inflows (including Wallis Creek) are also included in the model, with the assumed joint probabilities defined in Table 1. Local tributary inflows were based on the 36 hour design storm event from a WBNM hydrologic model, using Australian Rainfall and Runoff (ARR) 1987 (Reference 2).

Table 1: Coincident storm events assumed for the Hunter River flood model

Flood Event	Hunter River Design Event	Local Tributary Inflows
5% AEP	5% AEP	10% AEP
2% AEP	2% AEP	6.7% AEP
1% AEP	1% AEP	5% AEP
Extreme	3 x 1% AEP	0.5% AEP

A sensitivity analysis was conducted for the flood study to investigate how changes in the magnitude of local tributary inflows influence the 1% AEP results. It was found that there was no significant change in peak flood levels, with changes being less than 0.05m at most locations. The areas around South Maitland and Pitnacree were found to be the most sensitive, with increases in peak flood levels of up to 0.15m where tributary inflows were increased from the 5% to the 2% AEP.

The flood model was updated for the current flood assessment with the following features:

- Model was extended to incorporate the Testers Hollow swamp area to the west of Cessnock Road, and Cessnock Road itself
- The existing 1200 mm diameter culvert under Cessnock Road at Testers Hollow was included
- The Wallis Creek channel was incorporated in more detail into the model, along with the flood gates on Wallis Creek at the Hunter River
- Additional reporting locations for the proposal were included and the simulation run time was extended to model the recession of floodwater from the swamp areas and assess duration of inundation. The model was updated to run in version 2016-03-AE version of TUFLOW.

The updated flood model was run for the 5% AEP, 2% AEP, 1% AEP and PMF design flood events. The difference in peak flood levels in the vicinity of Testers Hollow (compared to the results presented in the flood study) was within 0.2 m. This updated model was used to define the existing flood behaviour at the Cessnock Road crossing of Testers Hollow based on Hunter River flooding.

3.2.2. Wallis Creek Flood Model

This flood model was obtained from the Wallis and Swamp Fishery Creek Flood Study (Reference 3). This study modelled flooding due to the Wallis and Swamp/Fishery Creek local catchment and includes Testers Hollow. The model was modified slightly to enable detailed information around Cessnock Road to be extracted. The model was used to simulate the historic flood events of 2007, 2013, 2015 and 2016, the same events used to calibrate the model for the flood study. The model was also run for the 20% AEP, 5% AEP, 2% AEP, 1% AEP and

PMF design flood events using ARR 2016 (Reference 4).

The road can be impacted by both the small local catchment draining to Testers Hollow and Wallis Creek flooding. To model each of these mechanisms, separate design storm durations were simulated. The six hour storm was assessed to be the critical storm duration draining Testers Hollow and for Wallis Creek, the critical storm duration ranged from 24 hours to 72 hours across the range of events modelled. These long duration storms are critical since flood levels are primarily driven by volume in the large swamp areas.

Tailwater levels in the Hunter River were also varied for each mechanism. For the local catchment flooding, a low tailwater level was used in the Hunter River to assess flooding from the local catchment without the impact of backwater. For Wallis Creek flooding, the same Hunter River tailwater level adopted in the flood study was used for this investigation. This involves simulating a high tailwater of 4.5 mAHD in the Hunter River as the Wallis Creek flood storages fill. This high tailwater prevents water from draining efficiently from the catchment, which has been observed during flood events. Following this, the tailwater is reduced to 1 mAHD to assess the drainage time for the catchment through the floodgates.

This model was used to define the existing flood behaviour at the Cessnock Road crossing of Testers Hollow based on Wallis Creek flooding.

3.3. Existing Flood Behaviour

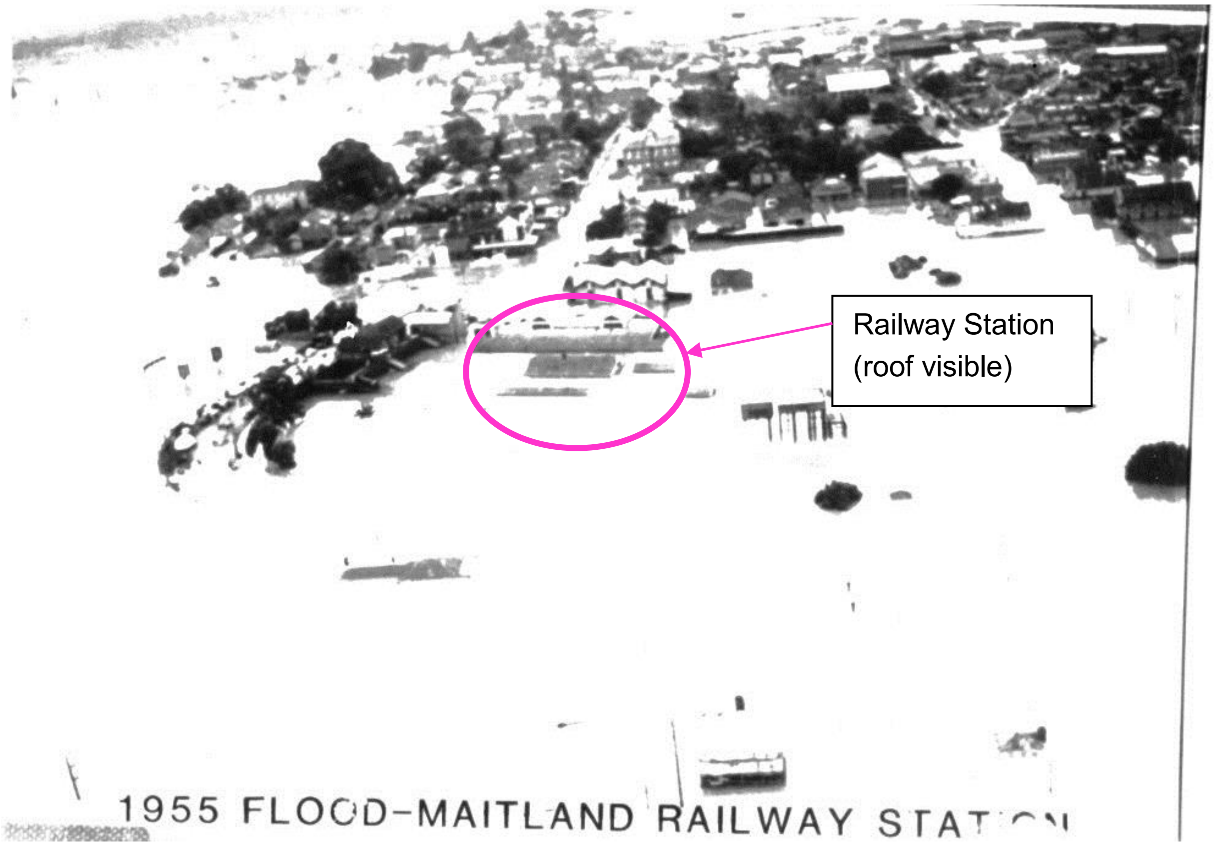
Flooding of Cessnock Road at Testers Hollow is potentially affected by three mechanisms of flooding:

- Local catchment draining to Testers Hollow (west of Cessnock Road)
- Wallis Creek flooding
- Hunter River flooding

Each of these mechanisms were investigated using the flood models described above. A description of flooding at Cessnock Road for both the historic and design flood events is provided in the following sections.

There are several records of major flooding for the floodplain of the Hunter River below Oakhampton, including the lower Wallis and Swamp-Fishery Creek areas, dating back to the early 1800s. The most significant recent major Hunter River flood was the February 1955 event, which was in the order of a 1% AEP to 0.5% AEP peak level around Maitland. A major flood level was recorded in 1820 which probably equalled the February 1955 flood peak, although the accuracy of this 1820 level can never be ascertained. The early non-indigenous settlers constructed a series of farm levees and uncoordinated river bank levees which were frequently overtopped and/or failed. Many were then subsequently modified. Some were constructed in an attempt to confine the flood to a defined river corridor. In the February 1955 flood many of these were overtopped and failed resulting in devastating flooding within the City of Maitland. Unfortunately, there is no accurate record of these pre-1955 levees.

Photo 1: February 1955 flooding of Maitland



A recently completed book on flooding of the Hunter River at Maitland (Reference 5) provides the most detailed history of flooding at Maitland available.

The 1956 Hunter Valley Flood Mitigation Act (now the Water Management Act 2000) allowed for the construction of a comprehensive flood mitigation scheme for the City of Maitland and comprises a series of:

- *Floodways* that confine the flow to defined paths,
- *Spillways* that allow the controlled overtopping of levees,
- *Levees* that prevent inundation of areas,
- *Control structures* that reduce the velocity of flow,
- *Floodgates* that prevent the backflow of floodwaters through culverts within the levees, the culverts are required to drain the area during non flood times.

The Lower Hunter Scheme (as it is known) was constructed following physical model studies undertaken in the 1960s. Subsequently parts of the scheme have been refurbished but no substantive changes from the original scheme have occurred.

Further details of the Scheme are provided on the Hunter-Central Rivers Catchment Management Authority web site (www.hcr.cma.nsw.gov.au).

In large Hunter River floods (greater than about a 15 year Average Recurrence Interval or ARI), floodwaters will overtop the Oakhampton spillways north of Long Bridge, flow down the Oakhampton Floodway, and inundate the swamp areas in the lower floodplains of Swamp-

Fishery and Wallis Creeks, including the area around Testers Hollow.

Photo 2: Inundation of New England Highway from Fishery Creek flooding in June 2007.

Photo 3: Oakhampton Floodway on 15 June 2007, after re-opening of New England Hwy

This area is also subject to inundation from local catchment flooding, as occurred in both June 2007 and April 2015, when the New England Highway was cut for several days (Photographs 2 and 3). Testers Hollow was also closed for extended periods in these events, isolating the area of Gillieston Heights. In June 2007 floodwaters from the Hunter River did overtop the Oakhampton Spillways, but the volume of water from the Hunter River alone was not significant enough to cause the prolonged inundation of the highway that occurred. In April 2015, the flooding in the Maitland region was entirely from local catchment runoff, rather than Hunter River flows. Local flooding causing disruption and road closures also occurred in March 2013 and January 2016.

3.4. Historic Flood Events

The Wallis Creek flood model was used to simulate the historic flood events of June 2007, March 2013, April 2015 and January 2016. These were the same events that were used to calibrate the flood model in the 'Wallis and Swamp-Fishery Creek Flood Study' (Reference 3), where a good match to water levels recorded at the nearby gauges at Louth Park and upstream of the Wallis Flood Gates was obtained. In each of these events, Cessnock Road at Testers Hollow was inundated and cut off. Figure 2 shows the flood stage hydrographs at Testers Hollow for the four flood events modelled. The peak depth over the road and duration of inundation for each event can be seen in Table 2 below, along with an estimate of the AEP of each event.

Table 2: Inundation of Cessnock Road at Testers Hollow for the historic flood events

Historic Flood Event	Approximate AEP[1]	Modelled Peak Flood Level at Cessnock Road (mAHD)	Modelled Peak Flood Depth Over Cessnock Road (m)	Modelled Duration of Inundation of Cessnock Road (hours)
June 2007	1% to 0.5% AEP (WC) 10% to 5% AEP (HR)	6.69	2.12	214
March 2013	10% to 5% AEP (WC)	5.43	0.86	169
April 2015	1% to 0.5% AEP (WC)	6.65	2.08	209
January 2016	10% to 5% AEP (WC)	5.72	1.15	99

Note 1: Based on a comparison of modelled water levels at Cessnock Road (Testers Hollow) with simulated design flood levels at the same location (see Section 3.5), for Wallis Creek (WC) or Hunter River (HR) flooding

The 2007 and 2015 flood events were a similar magnitude (approximately 1% to 0.5% AEP event considering Wallis Creek flooding) and inundated Cessnock Road at Testers Hollow to a similar peak depth (approximately 2 m) and for a similar duration (approximately 8 days). The April 2015 was a more extreme event than June 2007 for localised urban catchment flooding in and around Maitland, but for the lower Wallis Creek floodplain the events were similar. The 2013 and 2016 events were smaller flood events at Testers Hollow (approximately 10% to 5% AEP event considering Wallis Creek flooding), however, the road was still inundated for more than 3 days.

These estimates indicate that there were 4 events exceeding 10% AEP magnitude in a span of 10 years, including 2 events exceeding 1% AEP magnitude. The area has therefore been subjected to worse flooding in this 10 year period than would be expected during a typical 10 year period over the long term.

These simulated levels and durations of inundation are similar to what was observed. The simulated flood levels at Testers Hollow are within 0.1 m of the recorded water levels at the nearby Louth Park gauge for the 2013, 2015 and 2016 events. The 2007 event is modelled to be approximately 0.4 m higher than the recorded at the Louth Park gauge. Cessnock Road at Testers Hollow was closed in 2007 for approximately two weeks due to flooding and remained closed for a further three weeks for repairs. This is similar to the simulated duration of inundation being approximately 9 days. In 2013 the road was closed for 8 days and the simulated duration of inundation is approximately 7 days. In 2015 the road was closed for 17 days and modelling indicates it was overtopped for approximately 9 days (although the road may have remained closed due to poor ground conditions or road damage). The road was closed for "several days" in 2016 and modelling indicates it was overtopped for approximately 4 days.

The Cessnock Road crossing in the vicinity of Fishery Creek has a higher level of flood immunity than that at Testers Hollow. The flood stage hydrographs for the historic events can be seen in Figure 3. The peak depth over the road and duration of inundation for each event can be seen in Table 3.

Table 3: Inundation of Cessnock Road at Fishery Creek for the historic flood events

Historic Flood Event	Modelled Peak Flood Level at Cessnock Road (mAHD)	Modelled Peak Flood Depth Over Cessnock Road (m)	Modelled Duration of Inundation of Cessnock Road (hours)
June 2007	6.69	0.74	127
March 2013	5.25	-	-
April 2015	6.53	0.58	119
January 2016	5.37	-	-

The road was modelled to be overtopped during the 2007 and 2015 floods, by approximately 0.6 m to 0.75 m. The duration of road inundation was approximately 5 days for both events.

3.5. Design Flood Events

Design flood events for the various mechanisms of flooding have been investigated at Testers Hollow. The full range of flood events have been modelled for both the local catchment and Wallis Creek flooding. The Hunter River only produces major flows into the Wallis Creek swamp areas in the 5% AEP and rarer events. An assessment of flood levels due to Wallis Creek flooding and Hunter River flooding indicates a very similar flood level at Testers Hollow for the 5% AEP event, for either 5% AEP Hunter River flooding (with 20% AEP Wallis/Swamp Creek flows), or for 5% Wallis/Swamp Creek flows alone. Hunter River flooding dominates for events rarer than the 5% AEP event, but is not relevant for more frequent inundation at Testers Hollow, and hence only the 5% AEP, 2% AEP, 1% AEP and PMF events have been run for Hunter River flooding.

A suite of flood maps for the existing flood behaviour due to Wallis Creek flooding is provided in Appendix B and Appendix C (respectively) for reference, including flood depth, velocity and hazard mapping for the full range of flood events.

3.5.1. Local Catchment and Wallis Creek Flooding

The stage hydrograph of flood levels on Cessnock Road at Testers Hollow due to local catchment and Wallis Creek flooding can be seen in Figure 4. It should be noted that only the peak flood levels for the Hunter River flooding have been provided on this graph. Further discussion on Hunter River flooding can be found in Section 3.5.2.

It can be seen from the stage hydrographs in Figure 4 that the immediate local catchment draining to Testers Hollow (west of the road) is not a significant flood mechanism, with both peak flood levels and duration of inundation being much less than Wallis Creek flooding for the same AEP. Even in the six hour storm event (the critical storm used to define local catchment flooding), flood levels on both sides of the road are still dominated by flooding from the Wallis Creek catchment rather than the local Testers Hollow catchment. In a previous investigation of road raising options (Reference 6), this flood mechanism was investigated and it was found that the total volume of rainfall runoff from this catchment (estimated using an XP-RAFTS hydrologic model using ARR 1987), would not fill the Testers Hollow storage area (with a fully blocked culvert) in a 1% AEP event. This was also confirmed using the current WBNM hydrologic modelling using ARR 2016.

Hence, the immediate local flooding is not considered to be a significant constraint in the assessment of road upgrade options. The potential flood impacts will be dominated by the Wallis Creek and Hunter River flooding. Any flood mitigation options that address Wallis Creek and Hunter River flooding will fulfil requirements for local flooding and hence local flooding does not require further consideration.

For Wallis Creek flooding, the road is overtopped in the 5% AEP event, with peak flood levels being very similar to the 5% AEP Hunter River flood. In events greater than this, up to the 1% AEP event, the water level does not vary as much as for Hunter River floods, with peak flood levels all within approximately 0.5 m of each other. The Wallis Creek PMF is the exception, with peak flood levels at approximately the 1% AEP Hunter River flood level. A summary of the peak flood levels, depths and duration of inundation of the road due to Wallis Creek flooding is shown in Table 4. The duration of inundation is quite long, with the PMF inundating Cessnock Road at Testers Hollow for over 9 days.

Table 4: Design Flood Inundation of Cessnock Road at Testers Hollow (Wallis Creek flooding)

Design Flood Event	Modelled Peak Flood Level at Cessnock Road (mAHD)	Modelled Peak Depth Over Cessnock Road (m)	Modelled Duration of Inundation of Cessnock Road (hours)[1]
20% AEP	4.50	-	-
5% AEP	5.91	1.34	86

2% AEP	6.28	1.71	108
1% AEP	6.40	1.83	139
PMF	9.62	5.05	225

Note 1: This is for the storm duration which produces the peak flood levels for Wallis Creek flooding

Design flood levels have also been analysed at the Fishery Creek crossing, since the overall flood immunity of the road depends on this crossing as well. The stage hydrographs at the Cessnock Road crossing of Fishery Creek due to Wallis Creek flooding can be seen in Figure 5. The results indicate that the Fishery Creek crossing has a much higher flood immunity than Testers Hollow, only just being overtopped in the 1% AEP Wallis Creek flood even. Again, the Hunter River flooding dominates the peak flood levels at this crossing. A summary of the peak flood levels, depths and duration of inundation of the road due to Wallis Creek flooding is provided in Table 5 below.

Table 5: Design Flood Inundation of Cessnock Road at Fishery Creek (Wallis Creek flooding)

Design Flood Event	Modelled Peak Flood Level at Cessnock Road (mAHD)	Modelled Peak Depth Over Cessnock Road (m)	Modelled Duration of Inundation of Cessnock Road (hours)[1]
20% AEP	4.28	-	-
5% AEP	5.12	-	-
2% AEP	5.58	-	-
1% AEP	6.30	0.35	37
PMF	9.61	3.66	143

Note 1: This is for the storm duration which produces the peak flood levels for Wallis Creek flooding

3.5.2. Hunter River Flooding

The Hunter River flooding is assumed to produce peak flood levels for the 5% AEP flood event and above. The flood study simulated flooding for a duration of 65 hours. The Hunter River hydrographs (sourced from an upstream flood model) have been extended for the current assessment. The duration of inundation due to Hunter River flooding is assumed to be dominated by the drainage characteristics of the Wallis Creek Swamp area (including the narrow channel of Wallis Creek and floodgates at the downstream end), once Hunter River water levels have dropped and there is no flow over Pitnacree Road and through Howes Lagoon. The peak flood levels and the drainage characteristics of the swamp can be seen in Figure 6 and Figure 7, for Cessnock Road at Testers Hollow and Fishery Creek, respectively. It should also be noted that the Hunter River flood is based on scaling the 1955 flood hydrograph and is representative of the temporal distribution of this one flood event.

The stage hydrograph of flood levels on Cessnock Road at Testers Hollow due to Hunter River flooding can be seen in Figure 6. There is a large variation in peak flood levels between the 2% AEP and PMF events, of approximately 4 m. The estimated duration of inundation is quite long, being between 5 and 11 days. A summary of the peak flood levels, depths and estimated duration of inundation of Cessnock Road due to Hunter River flooding at Testers Hollow is provided in Table 6 below.

Table 6: Design Flood Inundation of Cessnock Road at Testers Hollow (Hunter River flooding)

Design Flood Event	Modelled Peak Flood Level at Cessnock Road (mAHD)[1]	Modelled Peak Depth Over Cessnock Road (m)	Modelled Duration of Inundation of Cessnock Road (hours)[2]
5% AEP	5.95	1.38	127
2% AEP	7.69	3.05	210
1% AEP	9.73	5.08	248
PMF	11.71	7.12	259

Note 1: The modelled peak flood level from the original Hunter River model. The updated model that was run for this assessment generally produces slightly higher peak flood levels than the flood study model, by up to 0.2 m at Testers Hollow.

Note 2: Based on a scaling of the 1955 flood hydrograph extended and run in the updated Hunter River Model.

Design peak flood levels at the Fishery Creek crossing due to Hunter River flooding are similar to those at Testers Hollow for events larger than the 5% AEP. The stage hydrographs at the Cessnock Road crossing of Fishery Creek due to Hunter River flooding can be seen in Figure 7. The results indicate that the Fishery Creek crossing has a similar level of flood immunity to Testers Hollow for Hunter River Flooding, being inundated in the 5% AEP event, albeit to a lesser extent. Again, the Hunter River flooding dominates the peak flood levels at this crossing. A summary of the peak flood levels, depths and duration of inundation of the road due to Wallis Creek flooding is provided in Table 7 below.

Table 7: Design Flood Inundation of Cessnock Road at Fishery Creek (Hunter River flooding)

Design Flood Event	Modelled Peak Flood Level at Cessnock Road (mAHD)[1]	Modelled Peak Depth Over Cessnock Road (m)	Estimated Duration of Inundation of Cessnock Road (hours)[2]
5% AEP	6.78	0.83	25
2% AEP	7.69	1.74	108
1% AEP	9.73	3.78	150
PMF	11.76	5.81	165

Note 1: The modelled peak flood level from the original Hunter River model. The updated model that was run for this assessment produces slightly lower peak flood levels than the flood study model, by up to 0.2 m at the Fishery Creek crossing.

Note 2: Based on a scaling on the 1955 flood hydrograph extended and run in the updated Hunter River Model.

4. PROPOSED CONCEPT DESIGN

The proposed concept design (the proposal) seeks to reduce flood risk to traffic and improve access reliability along Cessnock Road. WMAwater developed an Options Report which outlined the existing flood immunity of the road and potential road upgrade options. Subsequently, Roads and Maritime Services selected a raised road level of 6.2 mAHD for the concept design (the proposal), coinciding with a 5% AEP flood immunity level (from both Wallis Creek and Hunter River flooding). The proposal will be located to the west of the existing road alignment, as shown in Figure 8. No water quality basins have been included for the flood assessment.

The proposal includes new culverts under the proposed road embankment, comprising three 1500 mm diameter pipes. One of these pipes is proposed to remain at the same invert level of the existing culvert (approximately RL 0.9 mAHD), with the remaining two being located approximately 0.6 m higher than this.

After the construction of the proposed road, the existing culvert under the existing embankment is to be removed and an open channel will be cut through the existing road embankment to enable free draining to the proposed culverts. The open channel has a base width of approximately 15m and minimum side batters of 1:4.

5. FLOOD IMPACT ASSESSMENT

5.1. Construction Phase

A number of construction activities have the potential to impact flooding. The inclusion of any temporary fill within the floodplain (e.g. stockpiles) could potentially cause an increase in flood levels (due to floodplain storage or conveyance considerations). Buildings, stockpiles and machineries located on flow paths also have the potential to cause flood impacts. Temporary crossings of watercourses may also be required during the construction and have the potential to impact on flooding. Portable buildings and other items not fixed on the site compounds have the potential to float and be carried away if affected by deep floodwaters, and may then become lodged and cause blockage of bridges and culverts further downstream. This could cause flood level impacts for areas upstream of the blockage. Loose materials stored within the floodplain have the potential to be mobilised during a flood, which can become a hazard during a flood, and may also contribute to blockage of hydraulic structures.

Construction phase impacts to flooding have not been modelled as part of the current assessment. Information regarding temporary compound sites including the stockpiling of material and assets is not currently available. Given the nature of the proposal, construction impacts are likely to be minor, and there are flood free sites available for the storage of construction plant and materials in the near vicinity of the site. Considerations for potential construction phase flood mitigation measures is provided in Section 6.1.

5.2. Operational Phase

The proposal features (including proposed road alignment, proposed culvert configuration and the proposed channel through the existing alignment) were included in both the Wallis Creek and Hunter River Flood Models to analyse potential changes in flood behaviour. Flood maps for the proposed conditions with Wallis Creek and Hunter River flooding are presented in Appendix D and Appendix E respectively, including flood depth, velocity and hazard mapping for the full range of flood events.

A flood impact assessment was undertaken by comparing these results with the existing conditions results. The changes in depth and duration of road inundation of Cessnock Road were assessed as well as the changes to peak flood levels, hazard and velocities. This assessment was undertaken for the 20% AEP, 5% AEP, 2% AEP, 1% AEP and PMF events. Flood impact maps showing the change in flood level and velocity are shown Appendix F and Appendix G for Wallis Creek and Hunter River flooding, respectively. The flood behaviour with the proposal generally remains similar, with some changes due to the raised embankment and enlarged culvert. A discussion of the potential operational phase impacts is provided in the following sections.

5.2.1. Depth and Duration of Inundation

The primary benefit for the road upgrade will be the reduction in road closure time during flood events. Using the modelling results, the benefit of the proposal is presented in Table 8.

Table 8: Depth and duration of inundation at Testers Hollow (Proposed Conditions)

Flood Event	Depth of Inundation (Change) [m]	Duration of Inundation (Change) [hours]
Historic Flood Events[1]		
June 2007	0.49 (-1.63)	120 (-95)
March 2013	NF[2] (-0.85)	NF[2] (-169)
April 2015	0.45 (-1.63)	106 (-102)
January 2016	NF[2] (-1.15)	NF[2] (-99)
Wallis Creek Flooding		
20% AEP	NF[2] (NF[2])	NF[2] (NF[2])
5% AEP	NF[2] (-1.34)	NF[2] (-86)
2% AEP	0.07 (-1.63)	6 (-102)
1% AEP	0.20 (-1.63)	32 (-107)
PMF	3.42 (-1.63)	135 (-90)
Hunter River Flooding		
5% AEP	NF[2] (-1.38)	NF[2] (-127)
2% AEP	1.70 (-1.63)	89 (-121)
1% AEP	3.58 (-1.63)	133 (-115)
PMF	5.58 (-1.63)	161 (-98)

Note 1: The historic flood events have not been modelled with the proposed concept design. The information presented here is estimated based on the existing conditions results.

Note 2: NF means the road is not flooded

Information on the performance of the proposal with the historic flood events has been provided based on the available model results for the design events. The proposal would have resulted in Cessnock Road at Testers Hollow being flood free in the March 2013 and January 2016 flood events, saving approximately 100 to 170 hours of road inundation time. The June 2007 and April 2015 flood events would have inundated the upgraded road, but to a depth of less than 0.5 m and reducing the time of inundation by approximately 100 hours for each of these floods.

The proposal results in Cessnock Road at Testers Hollow being flood free in the 5% AEP event due to both Wallis Creek and Hunter River flooding. There is a reduction in flood depth on the road of 1.63 m for events larger than this. The reduction in duration of inundation is between 85 and 130 hours across the range of events modelled, due to both Wallis Creek and Hunter River flooding. There is significant improvement to access with Wallis Creek flooding in events up to the 1% AEP, where the road is only flooded by 0.2 m, with the total time of inundation being

32 hours. The existing road is flooded by 1.83 m for a period of almost 6 days under the same event. The proposed road remains untrafficable in the Wallis Creek PMF event.

For Hunter River flooding, there is significant improvement to access with Hunter River flooding for the 5% AEP event. The existing road is flooded to a maximum depth of 1.38 m, with the total duration of inundation of over 5 days for the 5% AEP Hunter River flood event, while the proposed road is flood free. The proposed road, however, remains untrafficable in the 2% AEP Hunter River event and greater. The duration of inundation for these events decreases with the proposal, by approximately 4 to 5 days.

The area of Gillieston Heights becomes isolated when Cessnock Road at Testers Hollow and Fishery Creek is inundated, as evidenced during the 2015 flood event, when the town was isolated for over a week. The town is located along Cessnock Road, in between these two crossings and has a population of approximately 3,150 people (2016 census), with plans for further growth. The proposed raising of Cessnock Road at Testers Hollow results in improving the flood immunity of the road, so it would be just inundated (by less than 0.1 m) in a 2% AEP Wallis Creek event. The Fishery Creek crossing is not inundated in a 2% AEP event, and is cut off (depth of 0.35 m) in a 1% AEP Wallis Creek event. In a Hunter River flood event, the upgraded Testers Hollow crossing would have immunity for the 5% AEP event, but would be cut off in a 2% AEP event, while the Fishery Creek crossing would remain cut off in a 5% AEP event.

The average annual benefit in terms of inundation and duration of isolation was calculated using the design flood results (20%, 5%, 2%, 1% and PMF events only).. The Wallis Creek and Hunter River flood events were assumed fully independent for the purpose of the average annual duration calculations. Wallis Creek flooding generally occurs without a corresponding major flood on the Hunter River (as evidenced by each of the 2007, 2013, 2015 and 2016 flood events). Major floods on the Hunter River are more likely to be associated with some coincident Wallis Creek flooding, since they are produced by widespread regional rainfall events – however a Hunter River flood that is significant enough to overtop the Oakhampton floodway would not require significant local Wallis Creek flooding to inundate the road at Testers Hollow. Furthermore, these joint probabilities have already been taken into account in developing the design flood modelling. Therefore, full independence is a reasonable assumption for calculating the benefits of the proposal in terms of isolation reduction.

The results are presented in Table 9. There was assumed to be zero duration of inundation in the 20% AEP Wallis Creek event and 7% AEP Hunter River event for existing conditions. The AEP of the PMF was assumed to be 1 in 10^6 for Wallis Creek flooding and 1 in 10^5 for Hunter River. Duration of isolation was assumed to be when Cessnock Road is inundated at both Testers Hollow and Fishery Creek crossings.

Table 9: Average Annual Duration of Inundation and Isolation

Scenario	Average Annual Duration of Inundation at Testers Hollow (hrs)	Average Annual Duration of Isolation of Gillieston Heights (hrs)
Existing Conditions	23.5	6.2
Proposed Conditions	5.0	4.8
Change in Duration	-18.5	-1.4

It should be noted that the results presented here do not account for additional road closure times resulting from damage to the road. In the recent historic flood events, there were generally several days after inundation of the road receded that the road remained closed for repairs. This was not accounted for in the current assessment and only duration of inundation (flooding above the lowest road level) was assessed.

5.2.2. Flood Level Impact

The following considerations were relevant to the flood impact assessment:

- The proposal requires importation of fill into the Wallis Creek floodplain, reducing available flood storage and potentially increasing flood levels (storage considerations).
- The higher road embankment could potentially reduce conveyance of flows either from west to east or east to west (conveyance considerations), increasing local peak flood levels near the road. The flood storage area of Testers Hollow (to the west of Cessnock Road) is part of the wider Wallis Creek floodplain, however, it has been cut off by the Cessnock Road embankment. These conveyance considerations relate to maintaining floodplain connectivity between these two storage areas. That is, allowing both areas to act as one floodplain storage by allowing water to flow from one to the other.

These flood impacts were assessed by comparing modelling results of the proposed conditions to the existing conditions using the Wallis Creek Flood Model and Hunter River Flood Model. Flood impact maps can be seen in Figure F1 to Figure F5 for Wallis Creek flooding and Figure G1 to Figure G4 for Hunter River flooding.

The reduction in floodplain storage due to the proposed road embankment is not a concern for Testers Hollow. This was observed in the model simulations where the proposed road is overtopped (i.e. not causing a significant obstruction to flows). Due to the significant amount of floodplain storage that is available throughout the lower Wallis and Swamp/Fishery Creek catchment, the proposed road embankment has a negligible (±0.01 m) impact on flood levels. This can be seen in the impact maps for the 1% AEP and PMF Wallis Creek events in Figure F4 and Figure F5, and also the flood impact maps for the 2% AEP, 1% AEP and PMF Hunter River events in Figure G2, Figure G3 and Figure G4. The total volume of fill to RL 6.2 mAHD is approximately 1% of the total storage area available within Testers Hollow (west of the existing road embankment). Testers Hollow, in turn, is approximately 2% of the wider Wallis and Swamp/Fishery Creek floodplain storage area. Hence, the proportion of the entire Wallis and Swamp/Fishery Creek floodplain storage lost due to the proposal is minor, and therefore does not significantly increase flood levels.

In such circumstances, the NSW Floodplain Development Manual (Reference 7) requires consideration of how cumulative effects of similar development might affect flood levels over the long term. In this instance, it is unlikely that several similar projects will be undertaken. Furthermore, the benefits of the road raising accrue to the entire community without significant local adverse impact on flood levels. WMAwater therefore considers that the impacts resulting from importation of fill to raise the road are acceptable.

When considering the changes to peak flood levels due to the obstruction the road embankment causes to flows (floodplain connectivity), there are several scenarios to consider:

- Both existing and proposed embankments not overtopped
- Existing embankment overtopped, proposed embankment is not
- Both existing and proposed embankments overtopped
- Both existing and proposed embankments significantly overtopped

The impact of each scenario on peak flood levels is described below using the model results for each design flood event.

<u>Both existing and proposed embankments overtopped</u>

In the 20% AEP Wallis Creek flood event, the existing road embankment is not overtopped and flow into Testers Hollow is controlled by the existing culvert. Under existing conditions, the water level in Testers Hollow does not reach the level in the wider Wallis Creek flood storage area. The existing culvert does not have adequate capacity to transfer flow from the Wallis Creek floodplain into Testers Hollow at a rate that will allow the water level in Testers Hollow to reach the same water level as the wider floodplain before the water level across the floodplain starts to fall. With the proposed road embankment, flow into Testers Hollow is controlled by the proposed culverts. Since the proposed culverts have a larger capacity, more water can flow into Testers Hollow (to the west of the proposal). This increases the water level in Testers Hollow by approximately 0.22 m, allowing it to equalise with the wider Wallis Creek floodplain. The flood level in the Wallis Creek floodplain also reduces by approximately 0.04 m since more water is stored in Testers Hollow. This can be seen in Figure F1.

<u>Existing embankment overtopped, proposed embankment is not</u>

In the 5% AEP Wallis Creek flood event, the existing road embankment is overtopped and water flows across into Testers Hollow and equalises with flood levels across the wider Wallis Creek floodplain. With the proposed road embankment that is not overtopped, the flow into Testers Hollow is controlled by the proposed culverts. Since the culverts allow less flow than the overtopping flows across the existing embankment, there is a reduction in peak flood levels within Testers Hollow of approximately 0.11 m, as seen in Figure F2. Conversely, there is an increase in flood level within the Wallis Creek floodplain of approximately 0.01 m. This is the largest increase in flood level modelled across the Wallis Creek floodplain and extends from the Hunter Expressway in the south to Louth Park in the north. If the existing culvert size (1200 mm diameter) was retained, this impact would be slightly greater, since a smaller pipe would have a lower capacity and allow less water to be transferred into Testers Hollow.

In the Hunter River 5% AEP event, the existing road embankment is overtopped and the proposed road embankment would not be overtopped. The proposed culverts, however, allow water to enter Testers Hollow and equalise with the wider floodplain (as it does in existing conditions when it overtops the existing road). This is due to the long duration of the Hunter River flood. The flood impact maps for the 5% AEP Hunter River Flood can be seen in Figure G1.

Both existing and proposed embankments overtopped

In the 2% AEP Wallis Creek event, the proposed road would be overtopped by shallow water to a maximum of 0.07 m and for a total duration of only 6 hours. During this time, the water overtopping the road and flowing through the culvert are not sufficient to raise the water level in Testers Hollow to match the peak water level in the wider Wallis Creek storage area (as it does in existing conditions), and hence there is still a reduction in flood level observed within the Testers Hollow area to the west of the proposal (maximum reduction of 0.15 m). There is a negligible change in flood level in the wider Wallis Creek floodplain storage area, as seen in Figure F3.

Both existing and proposed embankments significantly overtopped

In Wallis Creek events larger than this, the proposed road would be substantially overtopped and there is negligible impact on flood levels since the obstruction to flows is minor (see Figure F4 and Figure F5).

For Hunter River floods greater than the 5% AEP event, both the existing and proposed embankments are significantly overtopped, and there would be no substantial change in peak flood levels across the floodplain. The flood impact maps with Hunter River flooding for the 2% AEP, 1% AEP and PMF events can be seen in Figure G2 to Figure G4.

5.2.3. Flood Velocity Impact

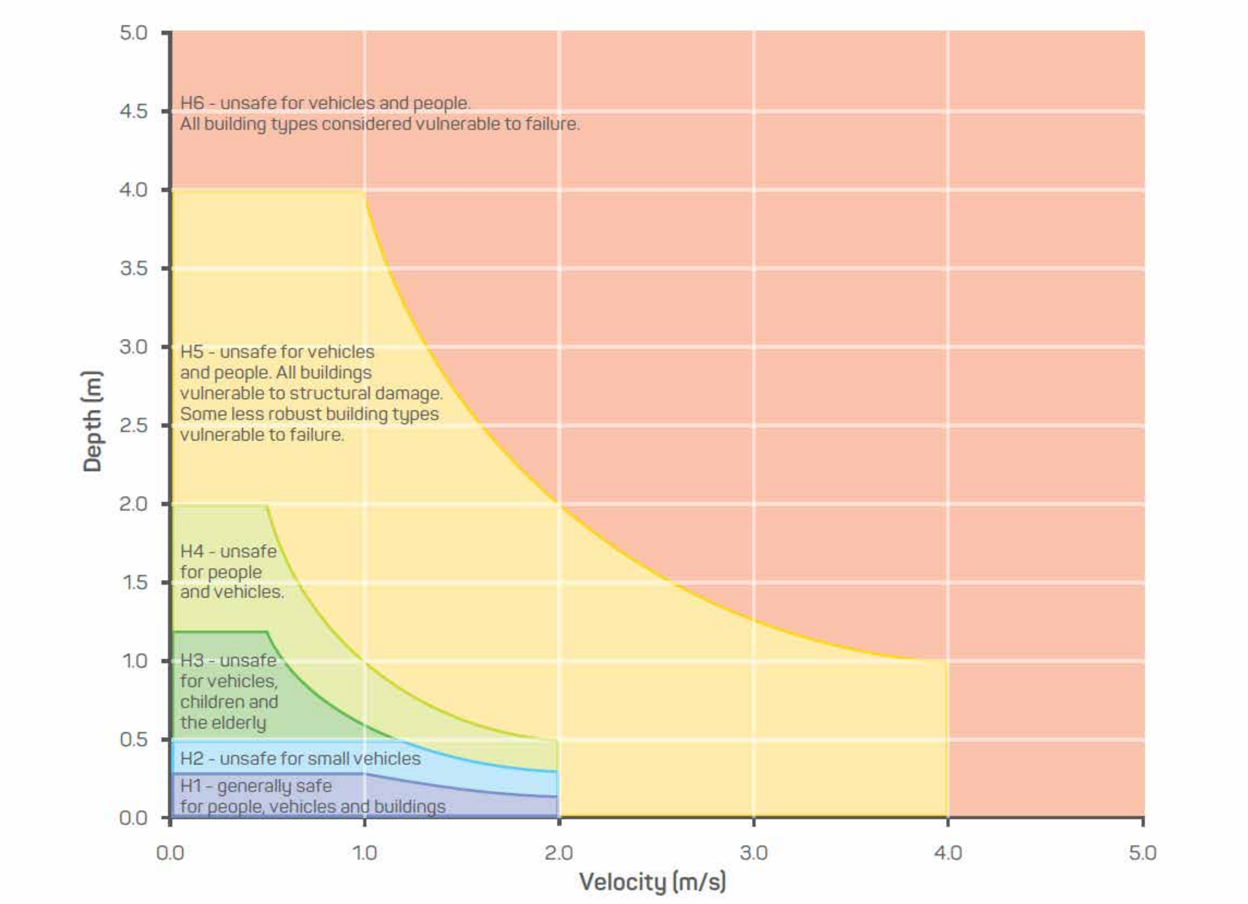
The change in peak velocity due to the proposal for Wallis Creek flooding can be seen in Figure F6 to Figure F10. With the proposal, there are increases in velocity at the inlet and outlet of the proposed culvert in the 20% AEP Wallis Creek flood event. These increases are approximately 0.2 m/s. In Wallis Creek flood events larger than this, there is generally a reduction in velocity in the vicinity of the proposal of up to 0.5 m/s, with a reduction in velocity over the existing embankment of approximately 2 m/s. Across the wider Wallis Creek floodplain, there are minimal changes in velocity, since the majority of the floodplain is a slow-moving flood storage area. In the PMF event there are some localised increases in velocity over the proposed road embankment as what was once a flood storage area becomes a weir as water overtops the proposed road.

The changes in peak velocity due to the proposal for Hunter River flooding can be seen in Figure G5 to Figure G8. In the 20% AEP event, there is a reduction in velocity over the existing road embankment of up to 3 m/s and some increases in velocity within Testers Hollow, generally up to approximately 0.2 m/s. In the 2% AEP event and greater, a similar pattern in flood level change can be seen, but with increases in peak velocity over the proposed road embankment as water overtops the proposed road that was once a flood storage area. Again, there are negligible changes in velocity across the wider Wallis Creek flood storage area.

5.2.1. Flood Hazard Impact

The flood hazard has been defined using the Australian Disaster Resilience Handbook Collection (2014). Handbook 7 of the collection deals with floods (Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia). The supporting guideline 7-3 (Reference 8) contains information relating to the categorisation of flood hazard based on velocity and depth of floodwater and its hazard to people, vehicles and buildings. A summary of this categorisation is provided in Diagram 1.

Diagram 1: General flood hazard vulnerability curves (Source: Reference 8)



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

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

The historic classification of hazard was generally based on the NSW Floodplain Development Manual 2005 (Reference 7). This defined two hydraulic hazard categories – high hazard and low hazard, plus a transition zone. The high hazard classification generally aligns with H4 and H5 of the Australian Disaster Resilience categories, while low hazard generally corresponds with H1 to H3.

Flood hazard maps using this categorisation are provided in Figure B11 to Figure B15 for existing conditions, and Figure C9 to Figure C12 for the proposed conditions. A comparison of the maps indicates that these is no change in flood hazard across the wider floodplain area. The only changes in flood hazard occur over the existing and proposed road embankments. A summary of the maximum flood hazard over the existing road and the proposed road for each flood event is outlined in Table 10. The flood hazard is removed for events up to the 5% AEP for both Wallis Creek and Hunter River flooding, since the proposed road is not flooded. The flood hazard is reduced significantly for Wallis Creek flooding in the 2% and 1% AEP events, and is lowered by one category in the PMF event. For Hunter River flooding, the flood hazard is lowered by one category in the 2% and 1% AEP events, with the PMF event remaining in the highest hazard category.

Table 10: Change in flood hazard over Cessnock Road

Flood Event	Maximum Existing Flood Hazard Category	Maximum Proposed Flood Hazard Category
Wallis Creek Flooding		
20% AEP	NF[1]	NF[1]
5% AEP	H5	NF[1]
2% AEP	H5	H1
1% AEP	H5	H1
PMF	H6	H5
Hunter River Flooding		
5% AEP	H5	NF[1]
2% AEP	H5	H4
1% AEP	H6	H5
PMF	H6	H6

Note 1: NF means the road is not flooded

5.2.2. Floodplain Connectivity

As discussed in Section 5.2.2, there are changes in flood level on the western side of the embankment from the existing conditions, when the proposed road is not overtopped due to Wallis Creek flooding.

Under existing conditions, lack of floodplain connectivity is only an issue in the 20% AEP Wallis

Creek flood event, since this is the only modelled event to not overtop the existing road. With the proposal, the larger culverts facilitate floodplain connectivity that the existing culvert restricts in this event. This is demonstrated in the graph shown in Figure 9. The figure shows the water level on each side of the road embankment as well as the flow and velocity through the culvert, for both existing and proposed conditions. The positive axis indicates flow from west to east (i.e. from Testers Hollow into Wallis Creek). It can be seen that there is initially positive flow in the culvert as it drains Testers Hollow in the early stages of the storm. This quickly reverses as Wallis Creek begins to flood and the backwater causes water to flow into Testers Hollow. This flow into Testers Hollow is the source of the largest flows through the culvert. The flow through the proposed culvert is approximately twice that of the existing culvert and the water level on the western side of the embankment equalises with the eastern side of the embankment at the peak of the flood, whereas in the existing conditions, this does not occur. The velocity through the proposed culvert is also less than the existing conditions, being within ±1.5 m/s.

In the 5% AEP Wallis Creek flood event, the existing road is overtopped and hence floodplain connectivity is not an issue. In the proposed conditions, however, the high road embankment means that floodplain connectivity is controlled by the proposed culverts. Figure 10 shows the performance of the proposed culvert and the water levels on each side of the culvert. The peak velocities through the culverts, however, remain less than the existing culvert.

In the 2% AEP Wallis Creek flood event, the proposed road is just overtopped. This can be seen in Figure 11. The peak flow from Wallis Creek into Testers Hollow through the proposed culvert reaches 15 m^3/s, although the peak velocity remains less than the existing culvert, being less than 3 m/s.

Graphs for the 1% AEP and PMF Wallis Creek Flood Events can also be seen in Figure 12 and Figure 13. In these events, the flood behaviour is similar to the existing case, whereby the local Testers Hollow catchment begins to drain through the culvert before backwater from Wallis Creek inundates Testers Hollow via the culvert and overtopping the road. Once the peak flood level is reached on both sides of the road embankment, water begins to drain from Testers Hollow back into Wallis Creek as the water level in the wider floodplain reduces.

In the Hunter River flood events, it is only the 5% AEP event that does not overtop the proposal, and hence there is a notable difference in the flood behaviour to the existing conditions. This can be seen in Figure 14. There is no local catchment included in the model draining from Testers Hollow to Wallis Creek, so it is only the conveyance of backwater through the culvert to fill the Testers Hollow storage area, and the subsequent draining of this area that can be seen. This occurs twice due to the double peak in the assumed flood hydrograph. The largest surge of water into Testers Hollow occurs during the first peak, where the flow through the proposed culvert reaches almost 19 m^3/s, although the velocity through the proposed culvert is less than the existing culvert, reaching approximately 3.5 m/s. When the existing road is currently overtopped, there is negligible flow through the culvert, while there are substantial flows through the proposed culvert in order to maintain floodplain connectivity. Despite the proposal not being overtopped, the flood level in Testers Hollow equalises with the wider floodplain. The “impacts” mapped for this event are considered to be a product of modelling assumptions rather than a real change in flood behaviour.

In the 2% AEP to PMF Hunter River flood events, there is negligible change in flood behaviour when both the existing road and proposal are overtopped, as shown in Figure 15 to Figure 17. The water levels on each side of the embankment are consistent and there is no discernible flow through the culverts. On the rising and falling limbs of the flood, however, there are some changes to flood behaviour with the proposal. Under existing conditions, there is initially flow through the culvert into Testers Hollow, which lasts until the existing road is overtopped. Under proposed conditions, there is a much larger flow, exceeding 20 m^3/s and this is sustained for a longer period of time, until the proposed road is overtopped. The velocity through the proposed culvert, however, is generally lower than the existing culvert, being less than 5 m/s. Flow through the proposed culvert commences again sooner, as the water level recedes to below the top of the road. This flow is generally much lower than the rising limb of the flood, as the difference in water level between the eastern and western sides of the embankment are smaller as floodwaters slowly recede.

6. SAFEGUARDS AND MANAGEMENT MEASURES

6.1. Construction Phase

Details of construction staging and compound site locations have not been provided at this stage. The following considerations are given with regards to potential safeguards and management measures for the construction phase:

- A key consideration will be management of the waterlogged area of Testers Hollow that is to be built upon. Dewatering activities will need to be undertaken.
- The crossing of the Testers Hollow flow path will require management to ensure that drainage of the Testers Hollow area to Wallis Creek is maintained.
- Compound and stockpile sites should be located outside the floodplain (at least above the 5% AEP Hunter River flood level) to minimise potential flood impacts, erosion of stockpiles and damage to temporary buildings and plant.
- A Soil and Water Management Plan (SWMP) would be developed in accordance with *Managing Urban Stormwater: Soils and Construction Volume 1* (Reference 9). The SWMP would document appropriate erosion and sediment control measures to be implemented during the construction phase to minimise the sediment that could be transported into the Testers Hollow or Wallis Creek swamp areas. The SWMP should outline appropriate diversions of overland flow for construction and compound areas, including the management of the Testers Hollow flow path to Wallis Creek.
- It is also recommended that a Flood Management Plan be prepared as part of the delivery phase to document an action plan for the construction site in response to a potential flood event from either Wallis Creek or Hunter River flooding. If a flood event occurs during construction, much of the work area will be inundated and may take weeks to drain.

6.2. Operational Phase

The proposal will have minimal impact on flood behaviour during the operational phase. The proposal includes a new culvert structure (3 x 1500 mm diameter pipes) under the new embankment. The primary benefit of the upgraded culvert structure would be to minimise damage to the road caused by overtopping, as it would equalise flood levels on either side of the road embankment prior to overtopping occurring. There would also be benefits relating to mitigation of changes to flood levels and velocities..

If the existing culvert size (1 x 1200 mm) were to be retained through the proposed embankment, there would be a significantly greater risk of damage and embankment instability (and possibly failure) resulting from overtopping flows across the embankment in large flood events. There would also be greater impacts to peak flood levels and increases in peak culvert velocities. No additional flood mitigation measures are proposed for the operational phase of the proposal.

Given the high conveyance of flows through the proposed culvert, scour protection measures should be considered at both the inlet and outlet of the culvert. Culvert velocities reach a maximum of 4.8 m/s, which could potentially scour surrounding soil at the inlet and/or outlet. Scour protection measures should also be considered along the channel that is to be cut through the existing road embankment. Velocities along the channel are only modelled to reach a maximum of approximately 0.5 m/s, however, consideration should be given to the channel lining (for example grass or rock) to prevent soil erosion.

7. CONCLUSIONS

Roads and Maritime Services is proposing to upgrade Cessnock Road at Testers Hollow to reduce flood risk to traffic and improve access reliability along the road. Cessnock Road can be inundated from the local catchment draining Wallis and Swamp-Fishery Creeks, and also regional flooding from the Hunter River. These flood mechanisms have been investigated using two flood models – one simulating inundation due to the Hunter River (from the Hunter River: Branxton to Green Rocks Flood Study, Reference 1), and one simulating local catchment runoff from Wallis and Swamp/Fishery Creeks (from the Wallis and Swamp Fishery Creek Flood Study, Reference 3).

The historic flood events of June 2007, March 2013, April 2015 and January 2016 were simulated using the Wallis Creek Flood Model. Each of these events inundated Cessnock Road at Testers Hollow. The 2007 and 2015 events were the largest, simulated to inundate the road to a depth of approximately 2 m and lasting approximately 8 days.

The design flood events for the immediate local catchment draining to Testers Hollow (west of the road) were investigated, but it was found that these events were not a concern for road inundation, since Wallis Creek flooding dominates up to the 5% AEP event, and Hunter River flooding dominates in the 5% AEP event and greater. This assessment focussed on flood behaviour for the Wallis Creek and Hunter River flood mechanisms. The existing flood behaviour has been defined at both the Testers Hollow and Fishery Creek crossings of Cessnock Road, including flood depths, velocities, hazard and duration of inundation.

Roads and Maritime Services propose to construct a new road embankment to the west of the existing embankment at Testers Hollow. The proposed road has a finished road level of 6.2 mAHD, approximately 1.6 m higher than the existing road embankment, with new culverts proposed under the road. The proposal has been included in the two flood models to simulate the flood behaviour with the development.

Although no details regarding construction staging or compound sites is currently available, the potential construction phase impacts are expected to be minor. The operational phase of the proposal has the potential to cause flooding impacts which have been investigated using the flood models. This report has identified the potential flood impacts of the current concept design on flood levels, velocities and hazard across the floodplain as well as the improvement to flood depths and duration of inundation of Cessnock Road at Testers Hollow.

The proposed road has a flood immunity up to the 5% AEP event for both Wallis Creek and Hunter River flooding. In events greater than this, the depth and duration of flooding is reduced substantially. In the Wallis Creek 1% AEP event, the road is only inundated by approximately 0.2 m, with a reduction in the duration of inundation of approximately 4 days. In the 2% AEP flood event and greater for the Hunter River, the road is still not trafficable, however, the duration of inundation is reduced by approximately 5 days. The average annual duration of inundation would be reduced from 23.5 hours to 5 hours and the average annual duration of isolation of Gillieston Heights would be reduced from 6.2 hours to 4.8 hours.

There are some changes to peak flood levels in both Testers Hollow (to the west of the proposal) and the Wallis Creek floodplain (to the east of the proposal). These changes are not considered to be adverse, given the nature of the floodplain and land use in these areas.

The changes to velocity are not considered to be adverse. There are minimal changes to velocity across the wider Wallis Creek floodplain (which acts as a flood storage area), and some minor changes within Testers Hollow. The notable changes to velocity occur over the existing and proposed road embankments.

The changes to flood hazard are minor across the wider floodplain. The major changes occur over the existing and proposed road embankments, where the flood hazard over the new road embankment is improved or remains the same as the existing road embankment. There is significant improvement to flood hazard for road users, particularly for the Wallis Creek flood events.

The most significant change to flood behaviour is in floodplain connectivity considerations. The movement of water into and out of Testers Hollow is controlled by the size of the culvert under the embankment, the overtopping level of the embankment and the relative water levels on either side of the embankment. The proposed larger culverts have greater capacity than the existing drainage, facilitating greater floodplain connectivity and lower peak velocity through the culvert.

Potential safeguards and management measures to be investigated at the detailed design stage for the construction phase include the following:

- Management of waterlogged areas of Testers Hollow during construction
- Ensure drainage flow paths from Testers Hollow to Wallis Creek are maintained
- Compound and stockpile sites to be located outside the floodplain (at least above the 5% AEP Hunter River flood level)
- Development of a Soil and Water Management Plan
- Development of a Flood Management Plan

Potential safeguards and management measures to be investigated at the detailed design stage for the operational phase include scour protection at the inlet and outlet of the proposed culvert, as well as consideration of lining the proposed channel to be cut through the existing embankment.

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Figures

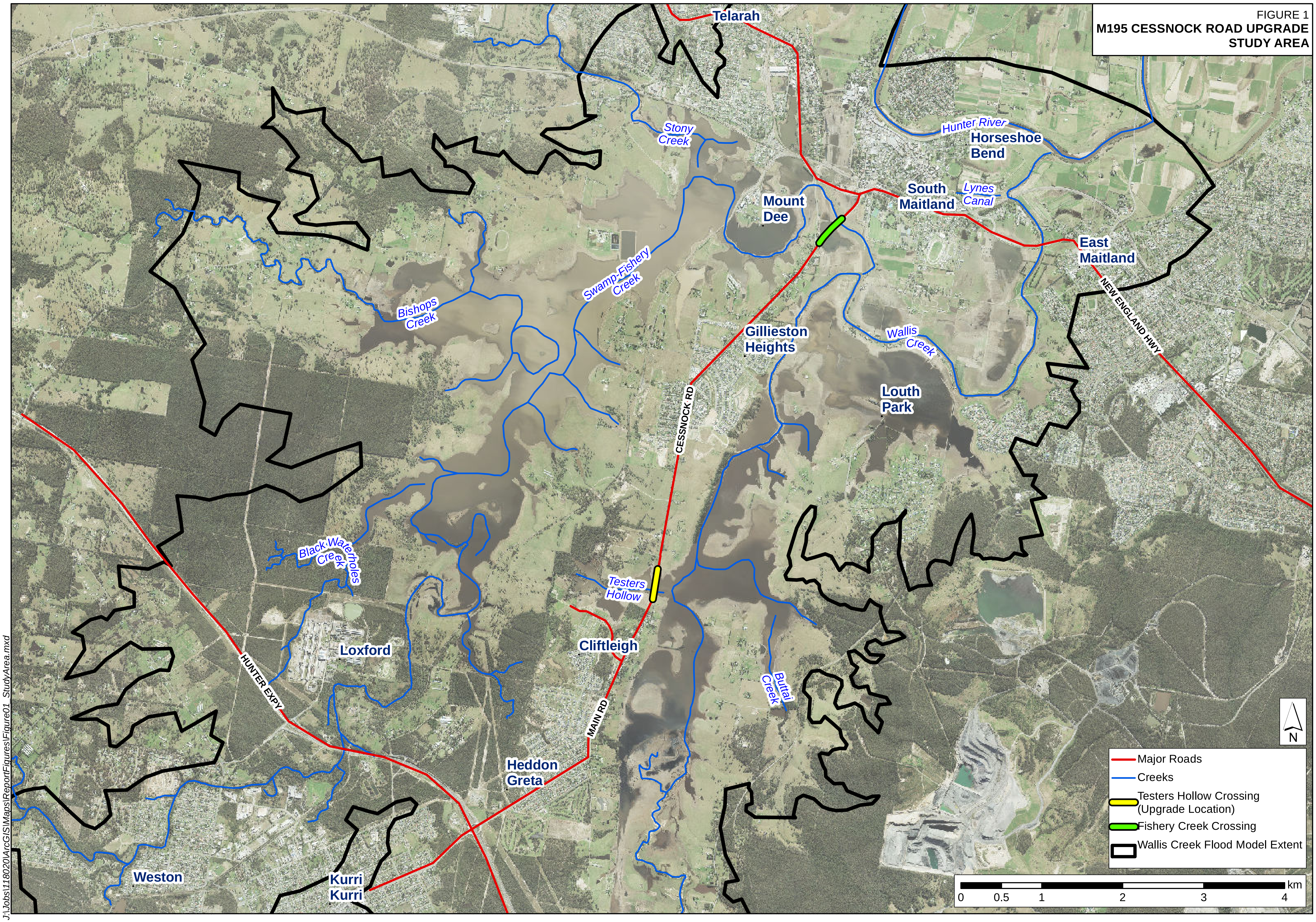
FIGURE 1
M195 CESSNOCK ROAD UPGRADE
STUDY AREA
Telarah
Stony Creek
Hunter River
Horseshoe Bend
South Maitland
Lynes Canal
Mount Dee
East Maitland
NEW ENGLAND HWY
Swamp-Fishery Creek
Bishops Creek
Gillieston Heights
Wallis Creek
Louth Park
CESSNOCK RD
Black Waterholes Creek
Testers Hollow
Cliftleigh
Loxford
HUNTER EXPY
Buttai Creek
MAIN RD
Heddon Greta
Weston
Kurri Kurri
N
Major Roads
Creeks
Testers Hollow Crossing (Upgrade Location)
Fishery Creek Crossing
Wallis Creek Flood Model Extent
0 0.5 1 2 3 4 km
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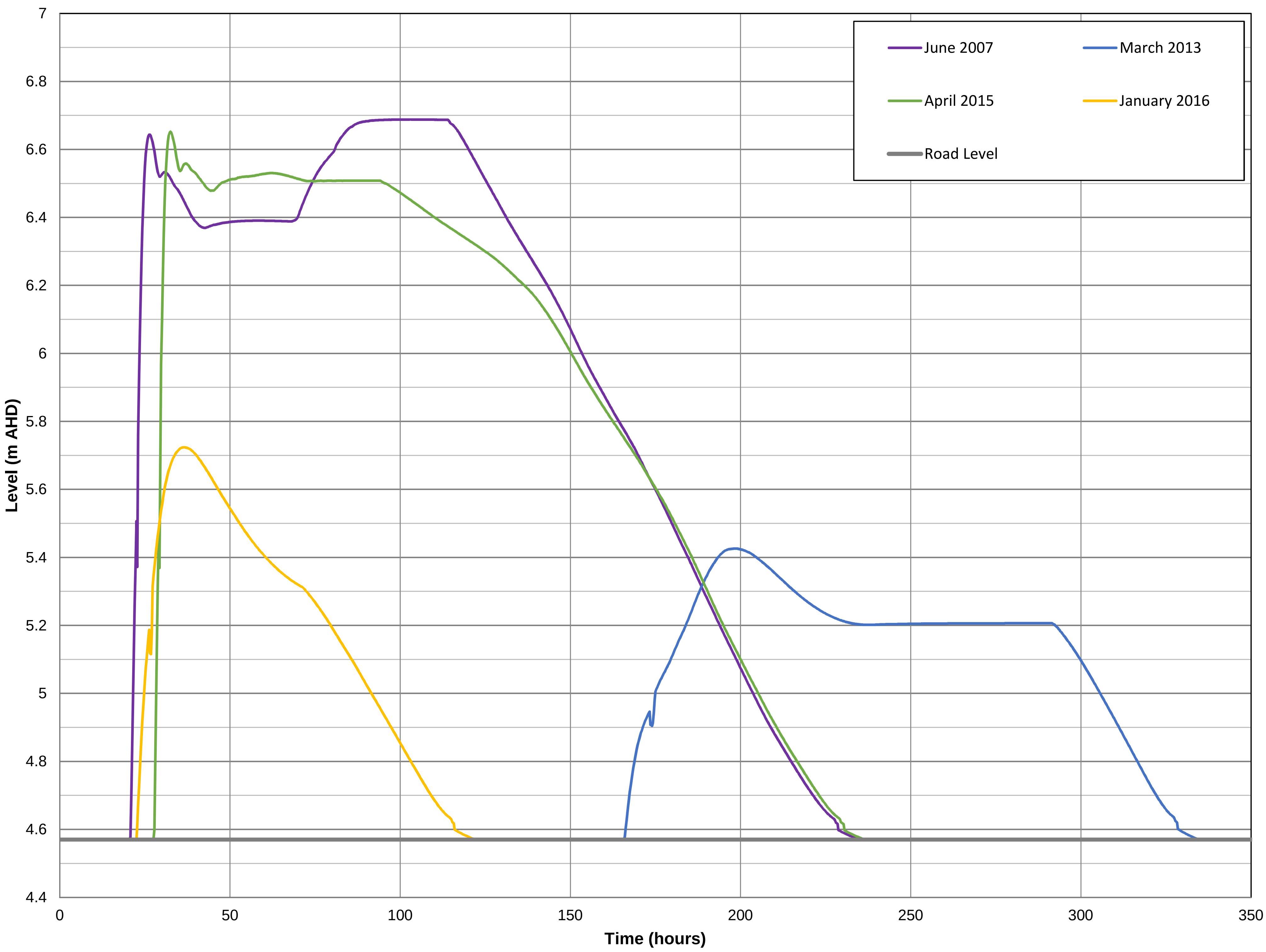

FIGURE 2
STAGE HYDROGRAPH
CESSNOCK ROAD AT TESTERS HOLLOW
HISTORIC STORMS

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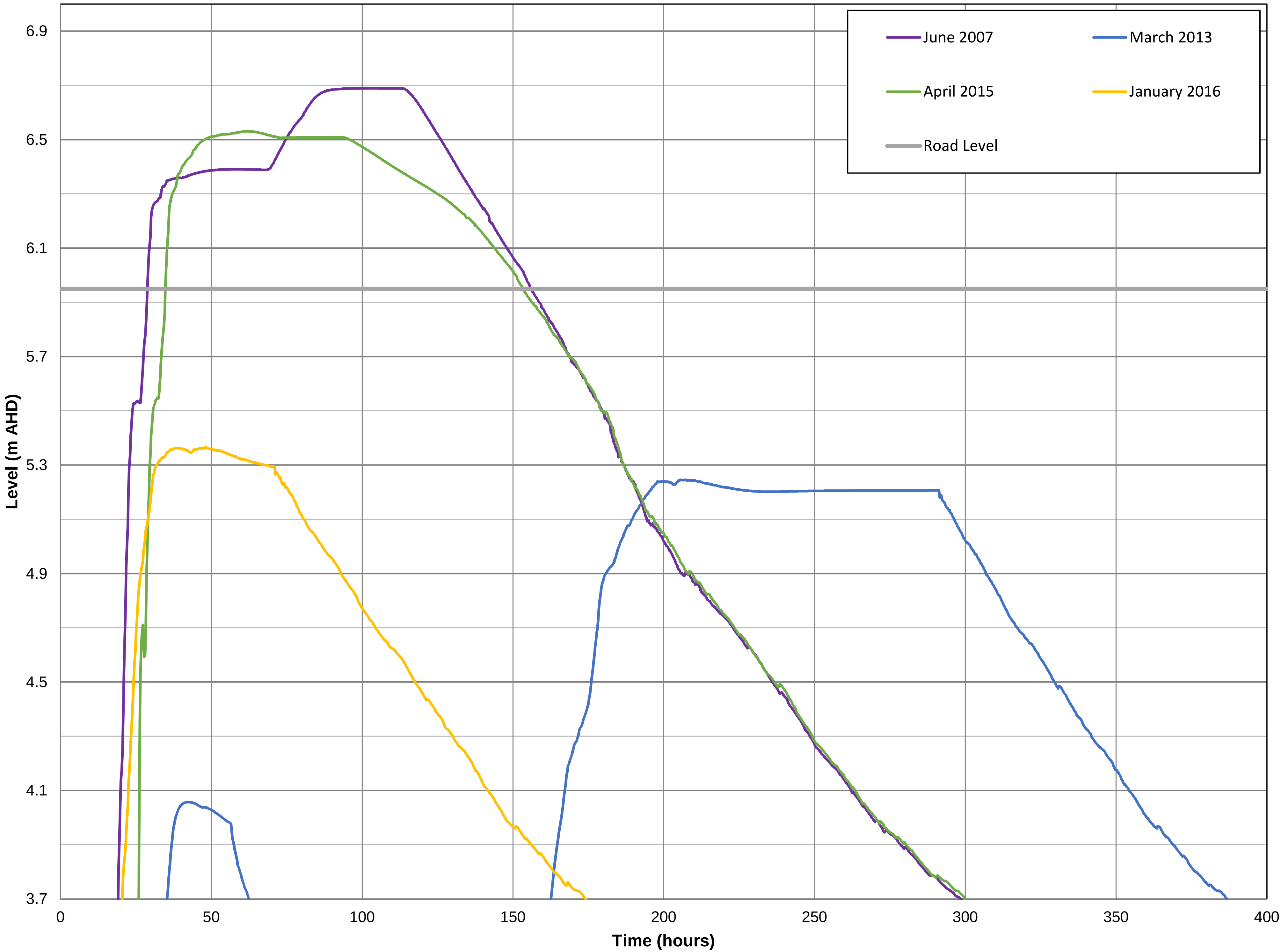

FIGURE 3
STAGE HYDROGRAPH
CESSNOCK ROAD AT FISHERY CREEK
HISTORIC STORMS

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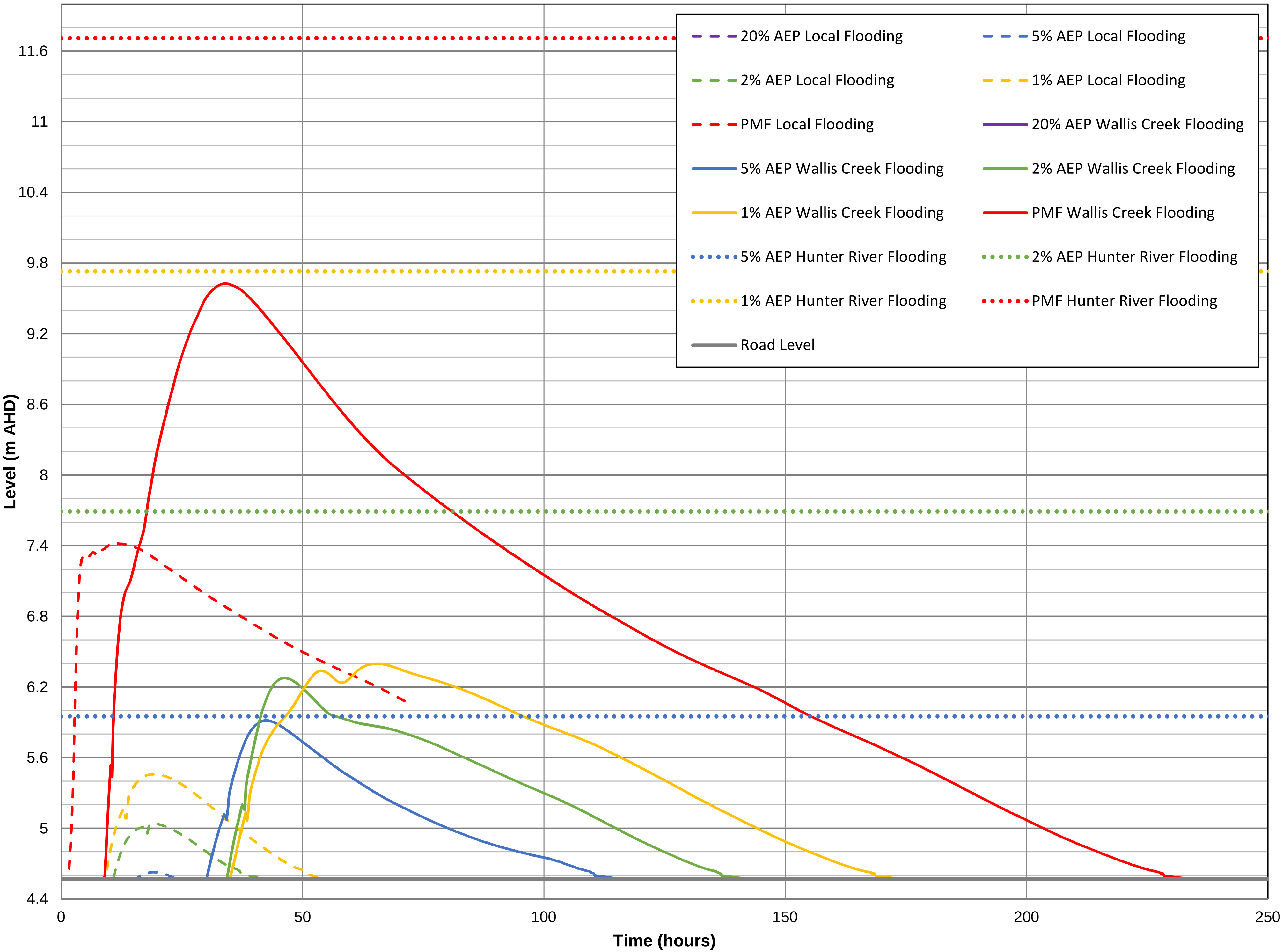

FIGURE 4
STAGE HYDROGRAPH
CESSNOCK ROAD AT TESTERS HOLLOW
LOCAL CATCHMENT AND WALLIS CREEK DESIGN STORMS

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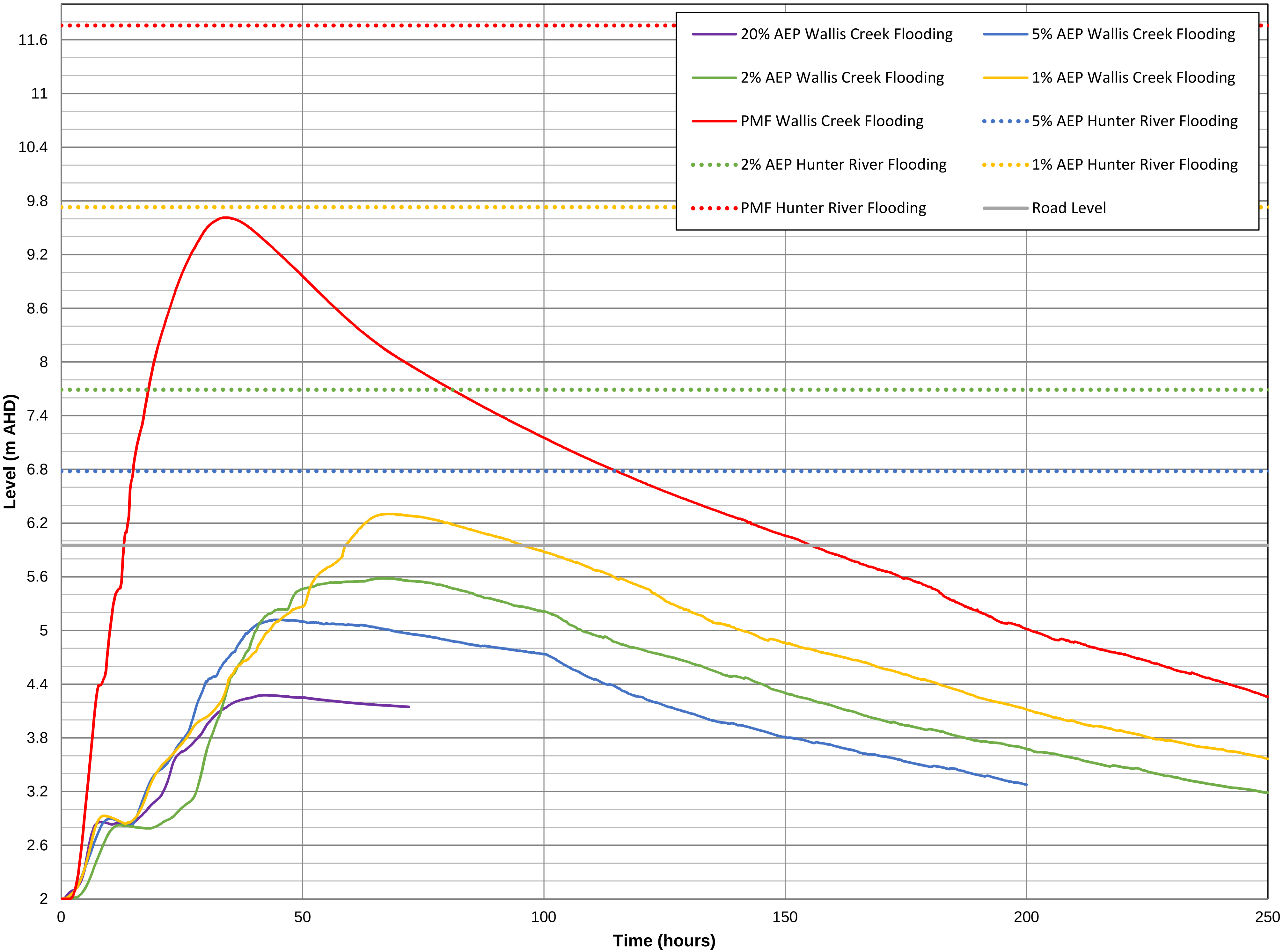

FIGURE 5
STAGE HYDROGRAPH
CESSNOCK ROAD AT FISHERY CREEK
WALLIS CREEK DESIGN STORMS

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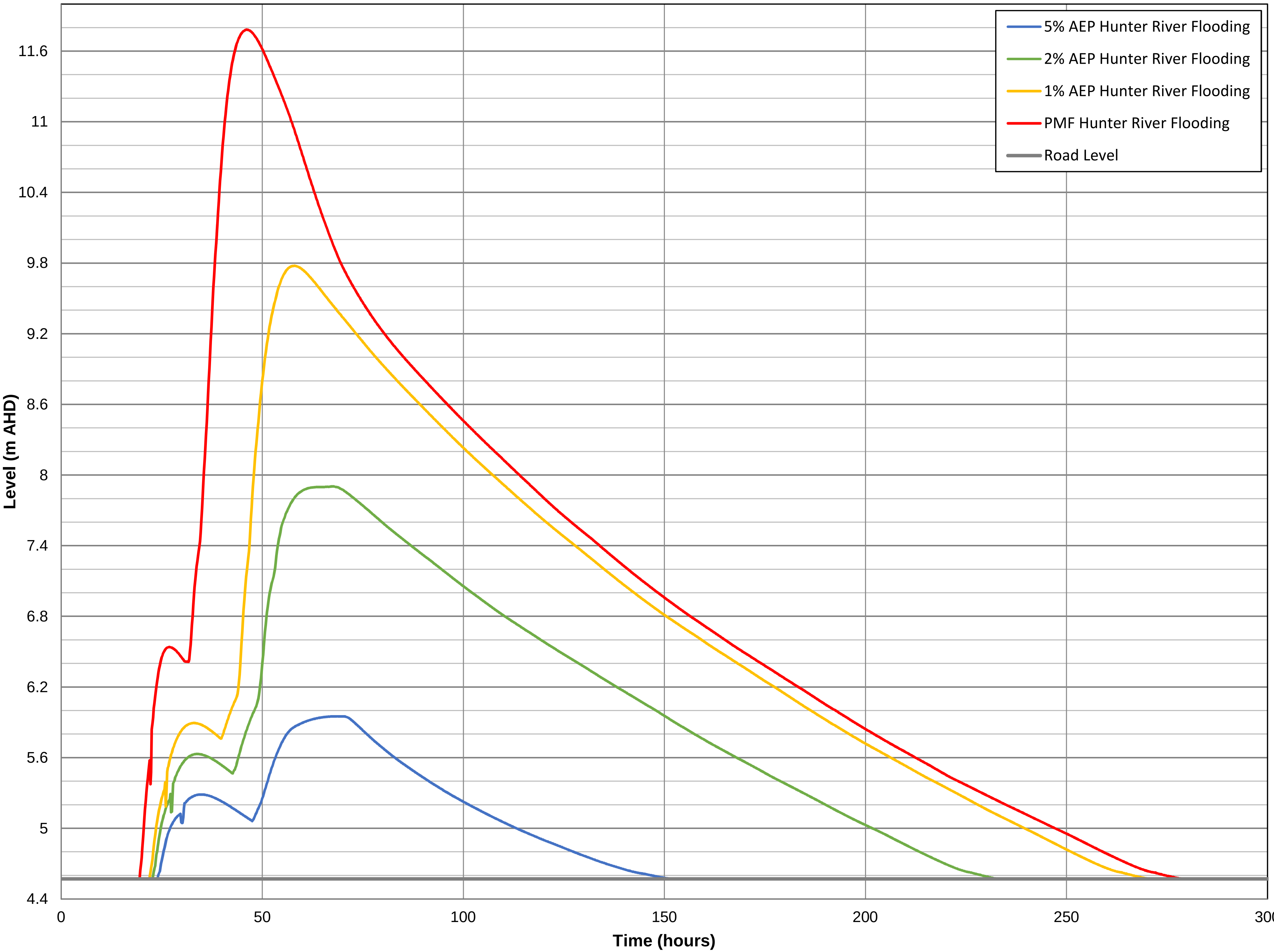

FIGURE 6

STAGE HYDROGRAPH
CESSNOCK ROAD AT TESTERS HOLLOW
HUNTER RIVER DESIGN STORMS

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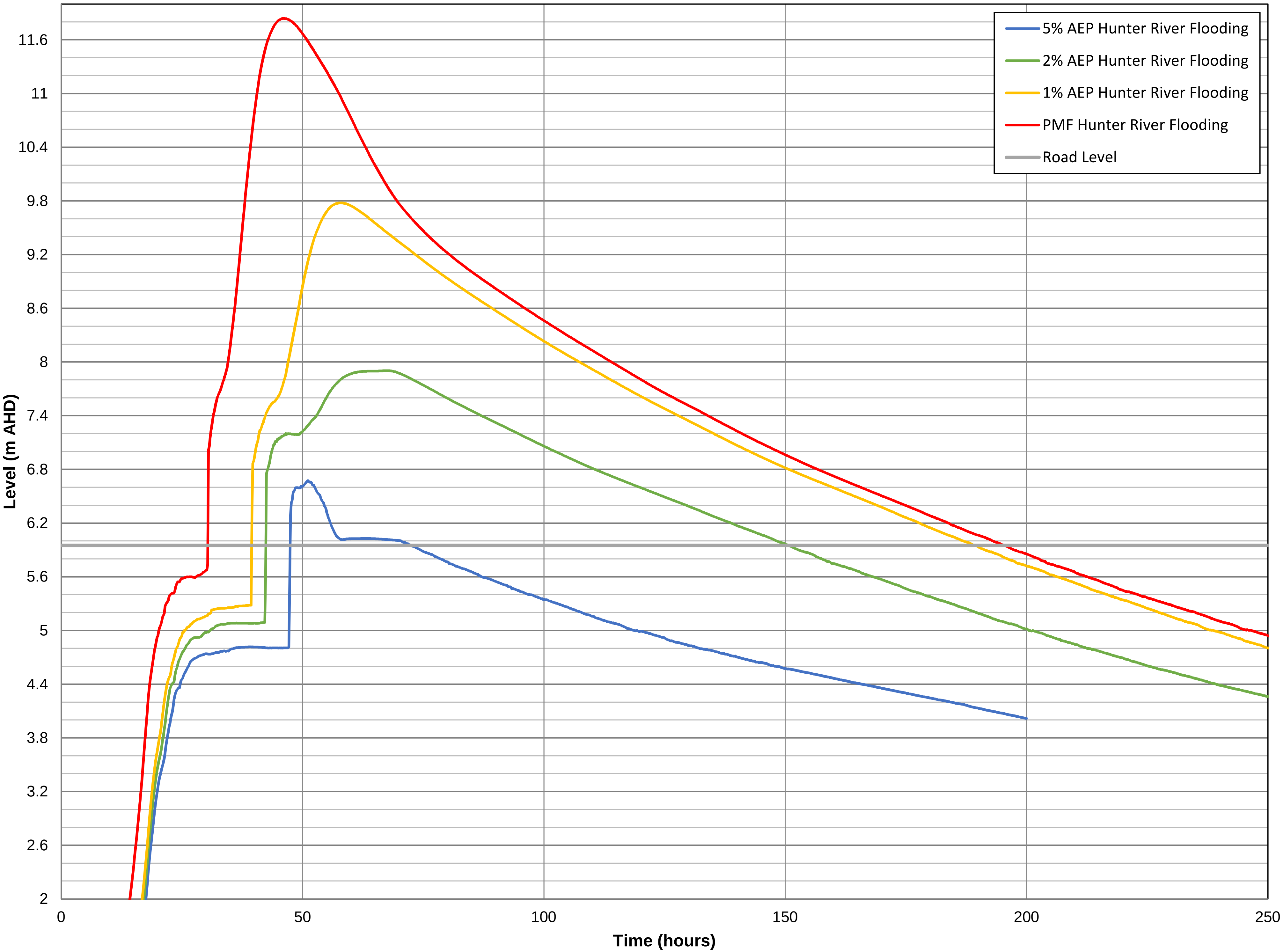

FIGURE 7

STAGE HYDROGRAPH
CESSNOCK ROAD AT FISHERY CREEK
HUNTER RIVER DESIGN STORMS


FIGURE 8
M195 CESSNOCK ROAD UPGRADE
THE PROPOSAL
Testers Hollow
Wallis Creek
N
Creeks
Proposal Concept Design
0
50
100
200
300
m
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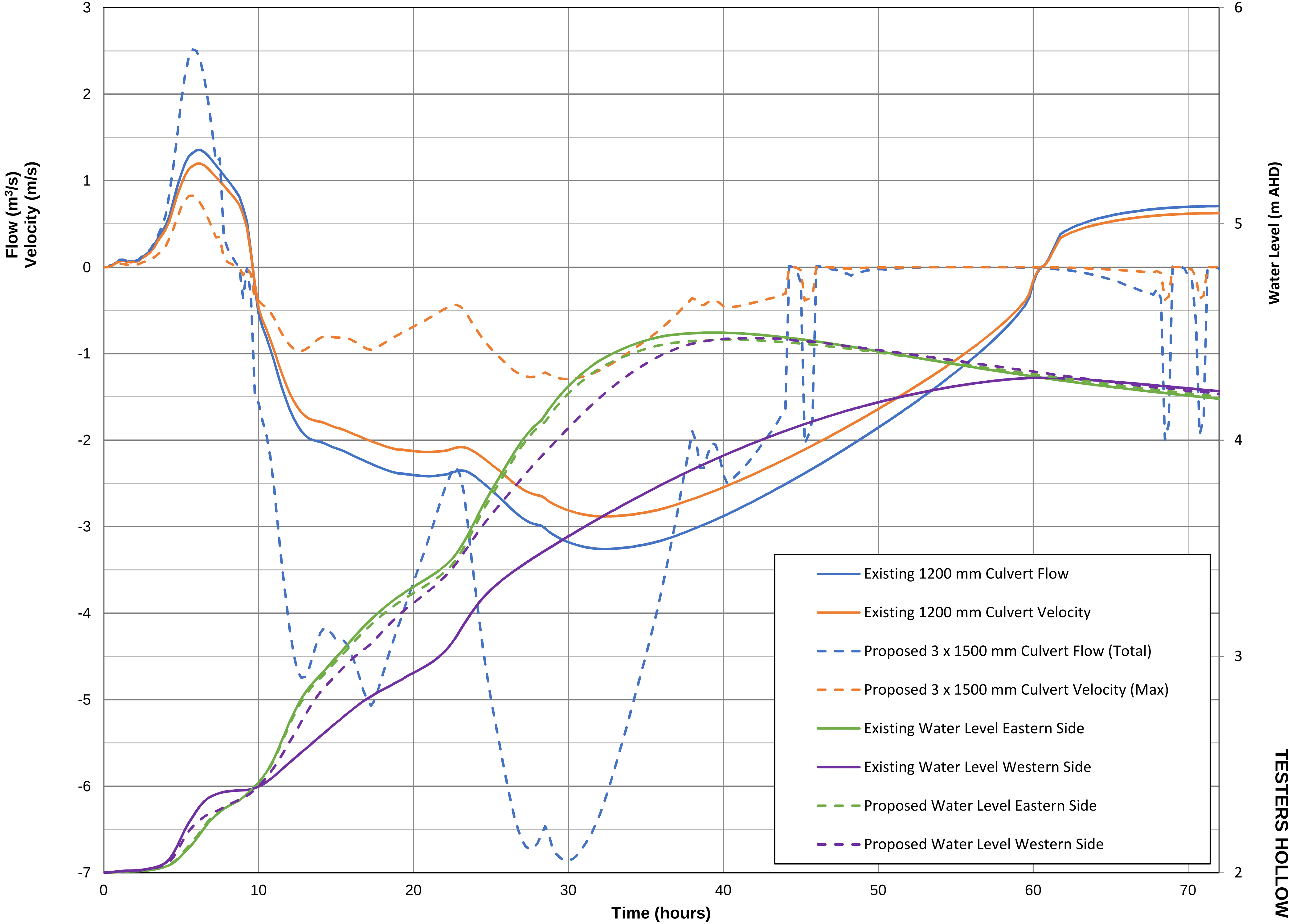

FIGURE 9

TIME SERIES GRAPH OF WALLIS CREEK 20% AEP EVENT
EXISTING CONDITIONS AND CONCEPT DESIGN
TESTERS HOLLOW

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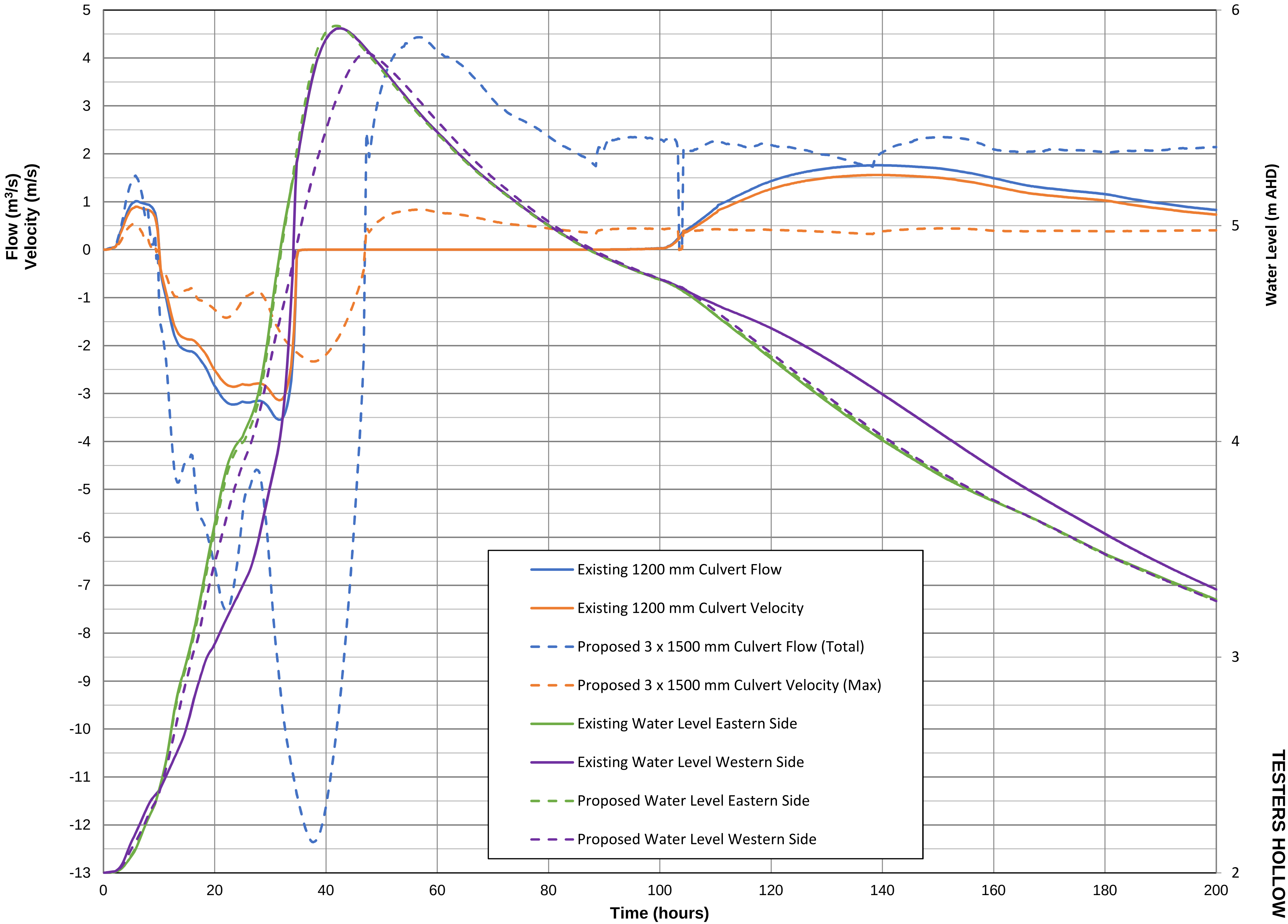

FIGURE 10

TIME SERIES GRAPH OF WALLIS CREEK 5% AEP EVENT
EXISTING CONDITIONS AND CONCEPT DESIGN
TESTERS HOLLOW

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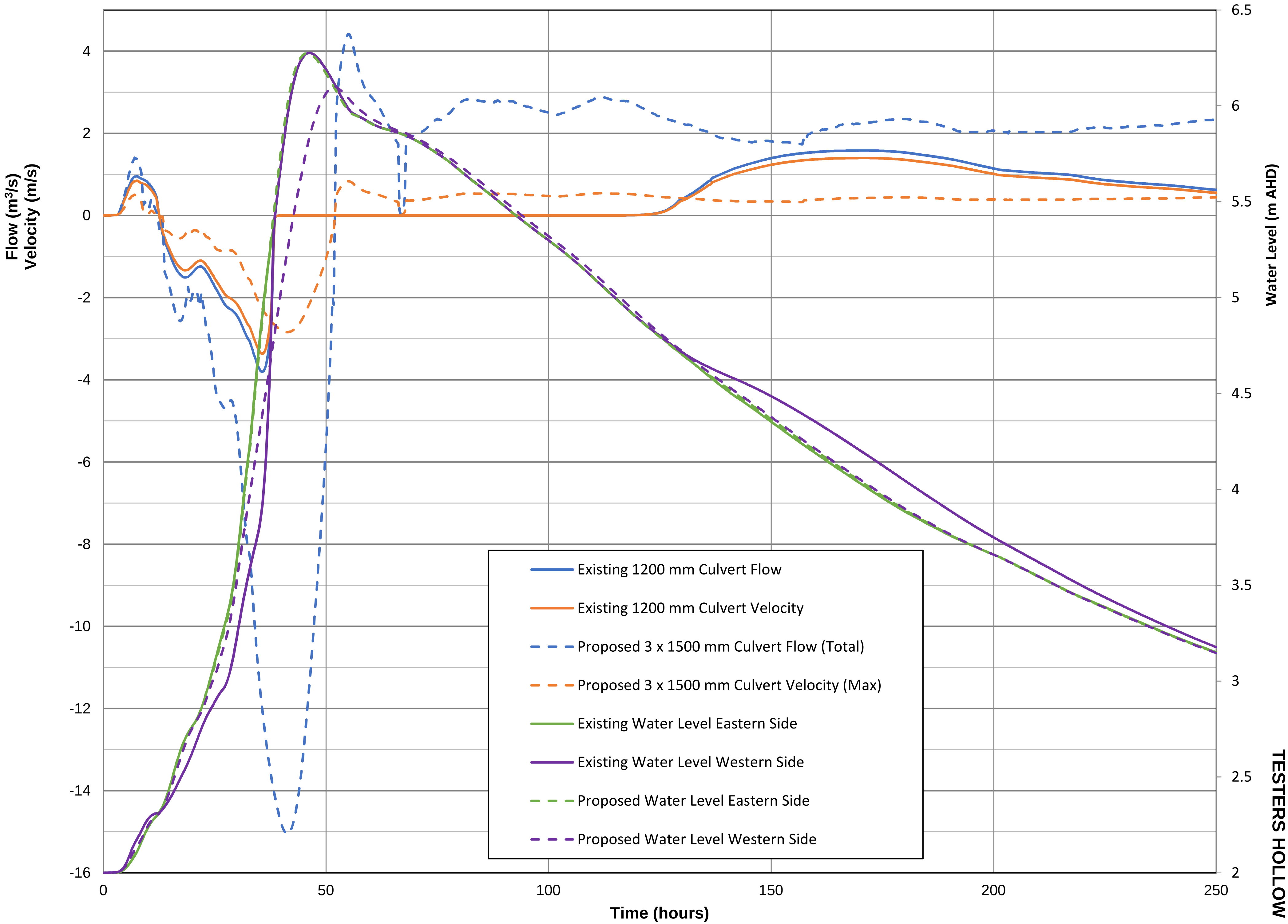

FIGURE 11
TIME SERIES GRAPH OF WALLIS CREEK 2% AEP EVENT
EXISTING CONDITIONS AND CONCEPT DESIGN
TESTERS HOLLOW

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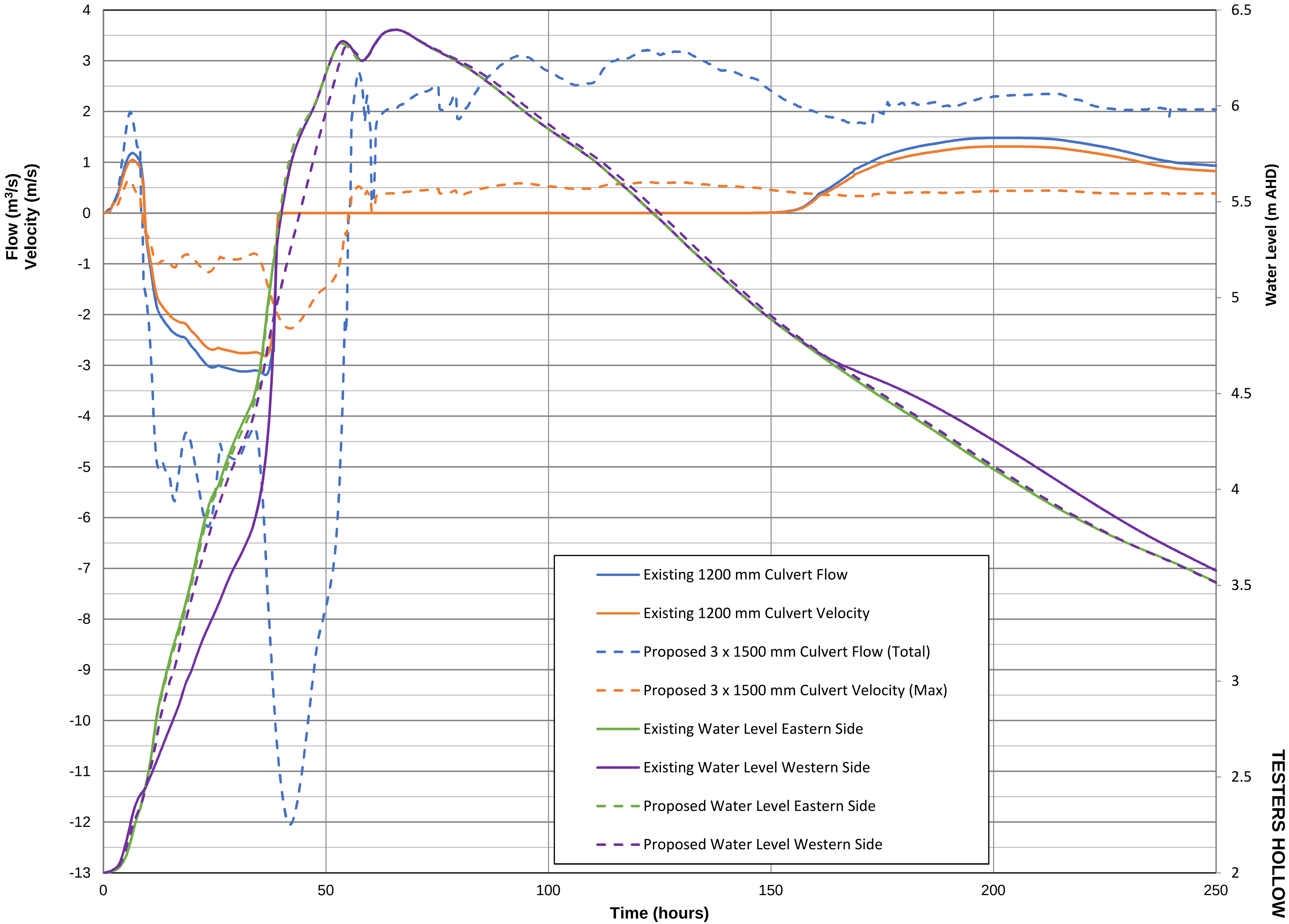

FIGURE 12
TIME SERIES GRAPH OF WALLIS CREEK 1% AEP EVENT
EXISTING CONDITIONS AND CONCEPT DESIGN
TESTERS HOLLOW

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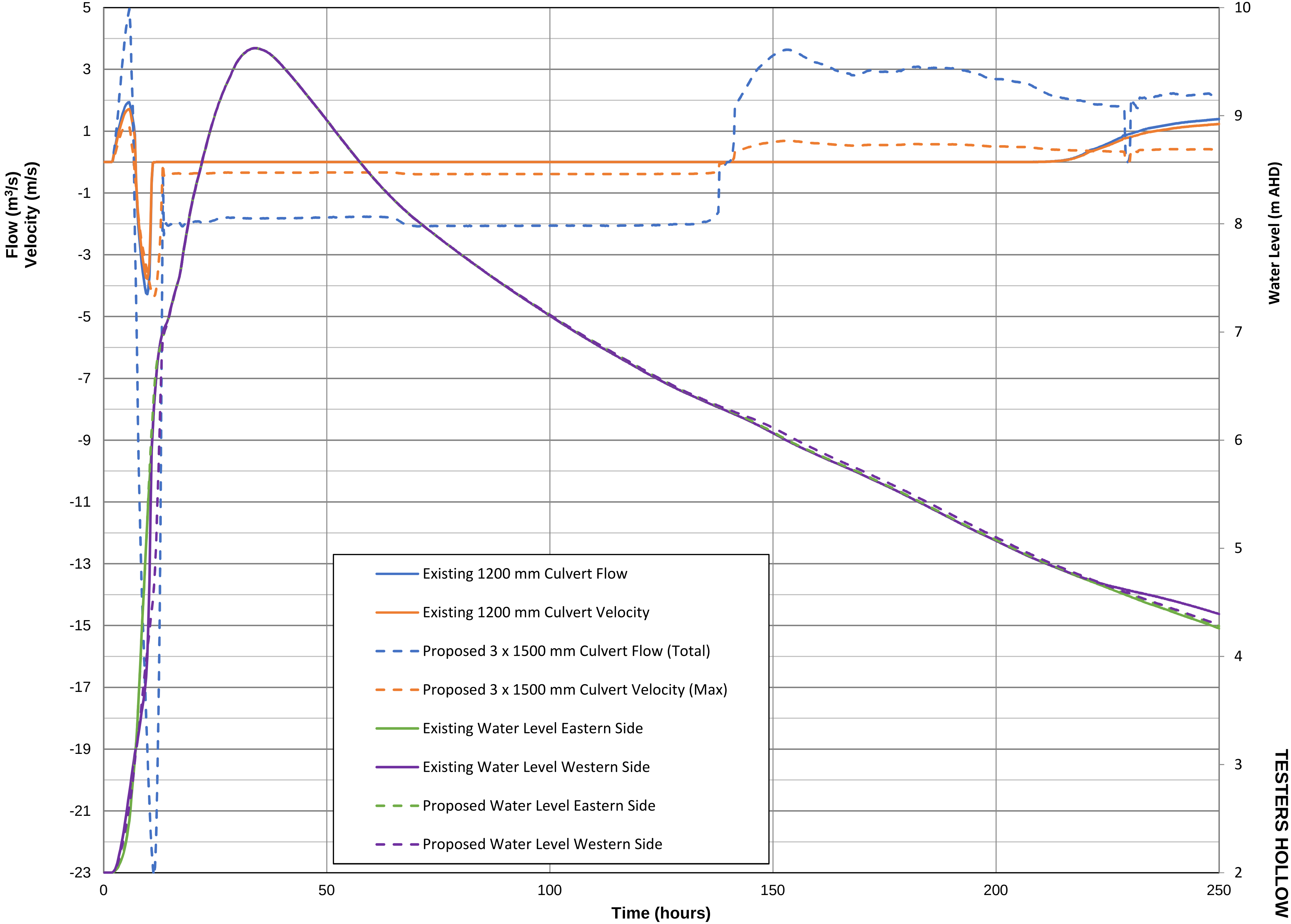

FIGURE 13
TIME SERIES GRAPH OF WALLIS CREEK PMF EVENT
EXISTING CONDITIONS AND CONCEPT DESIGN
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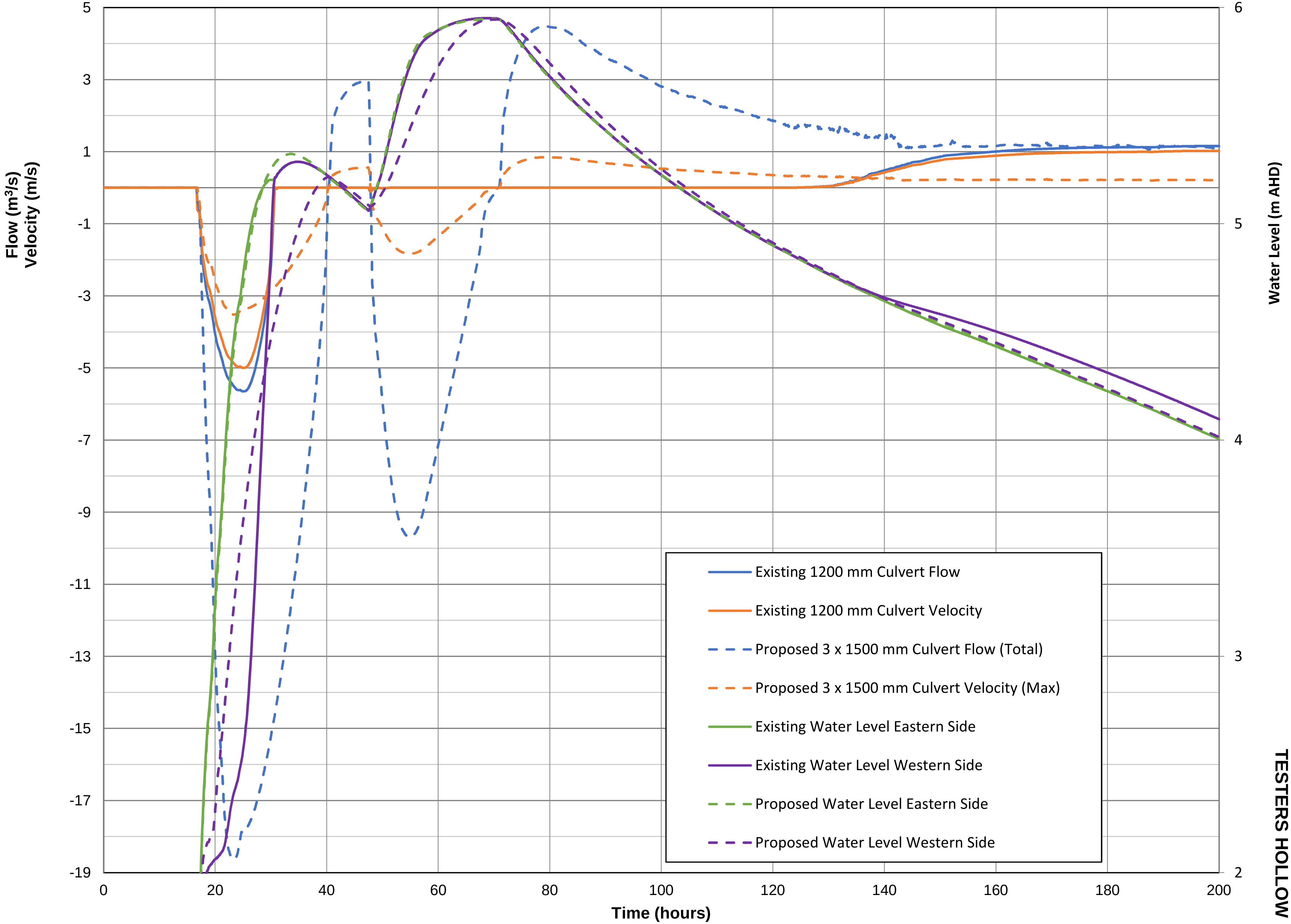

FIGURE 14
TIME SERIES GRAPH OF HUNTER RIVER 5% AEP EVENT
EXISTING CONDITIONS AND CONCEPT DESIGN
TESTERS HOLLOW

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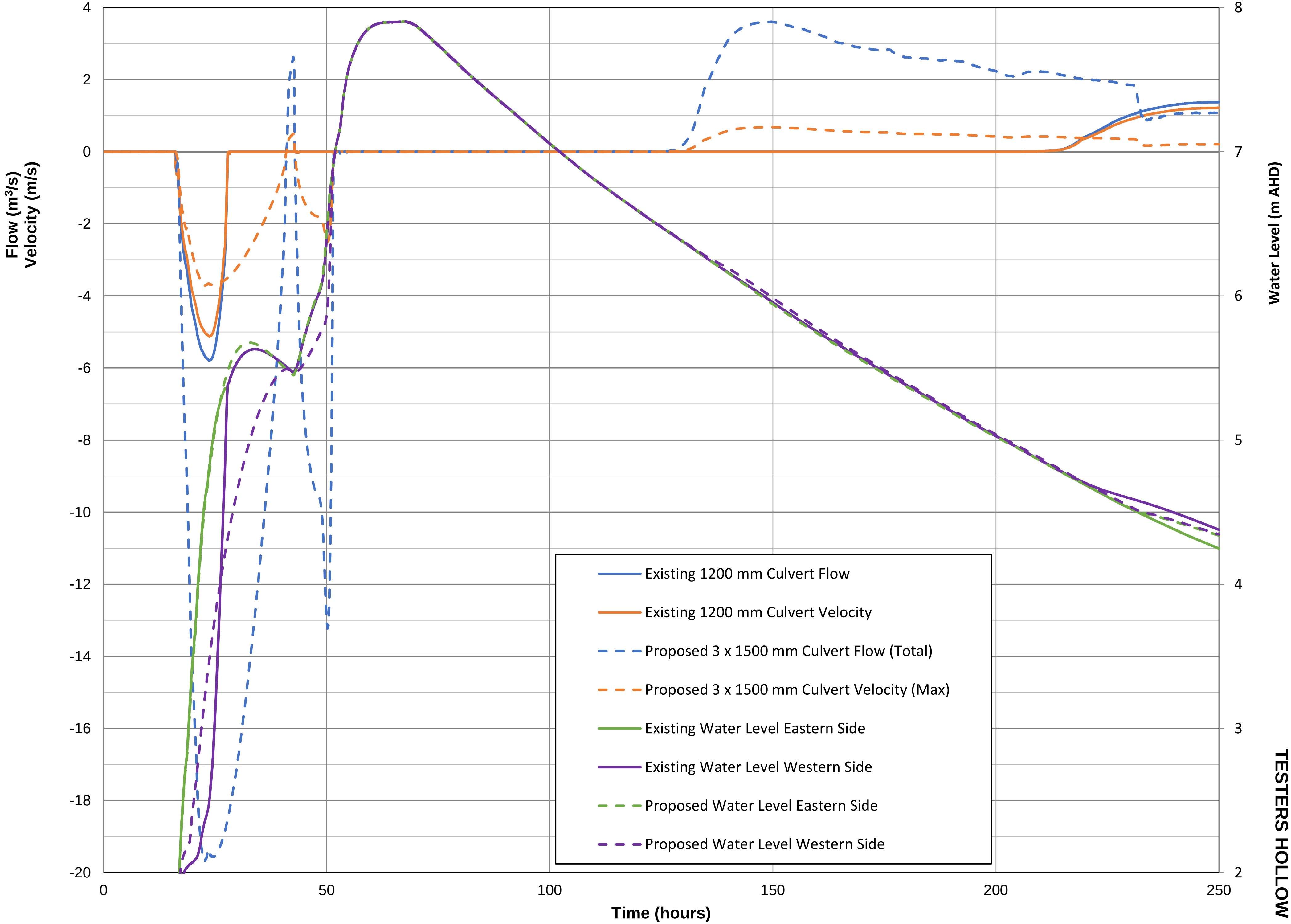

FIGURE 15
TIME SERIES GRAPH OF HUNTER RIVER 2% AEP EVENT
EXISTING CONDITIONS AND CONCEPT DESIGN
TESTERS HOLLOW

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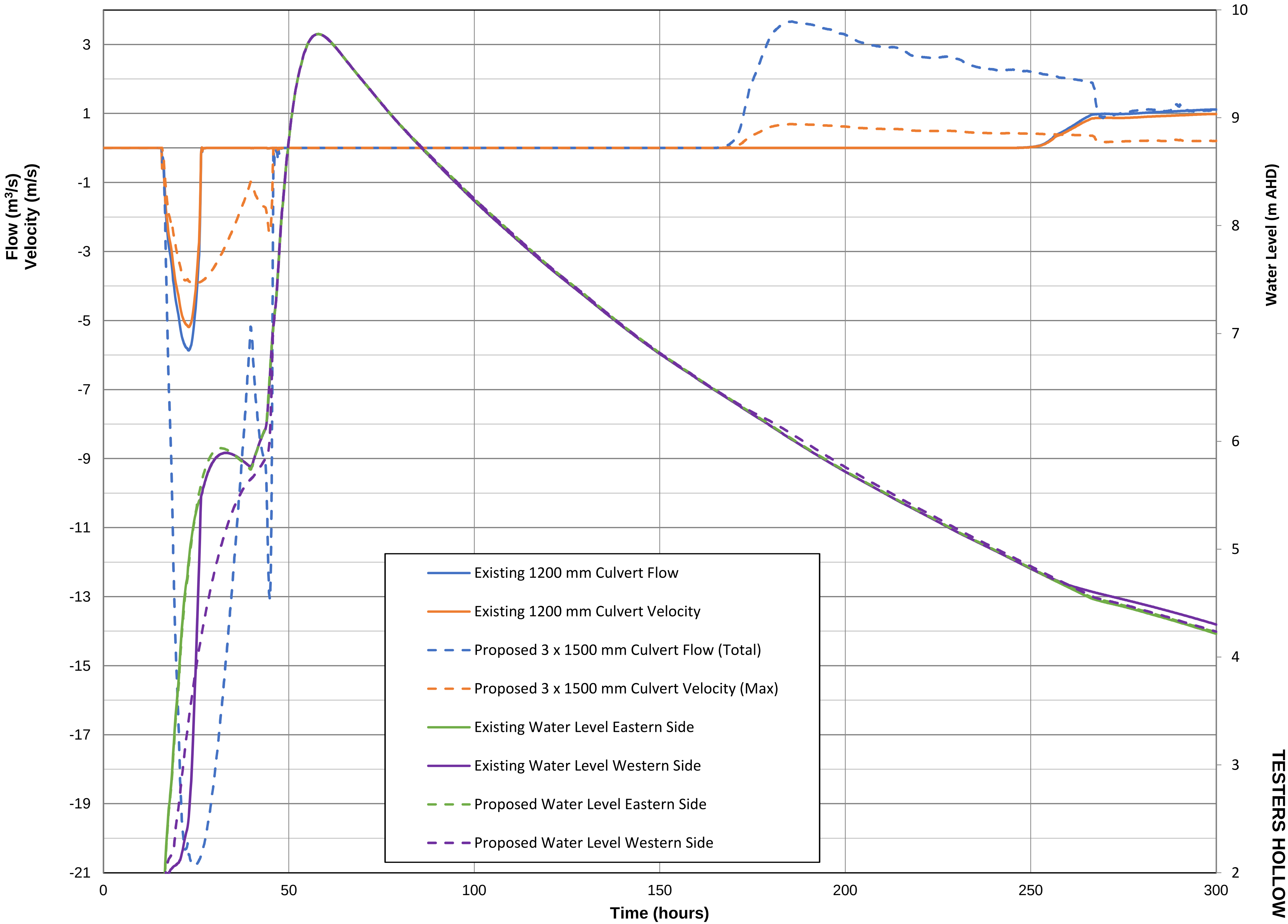

FIGURE 16
TIME SERIES GRAPH OF HUNTER RIVER 1% AEP EVENT
EXISTING CONDITIONS AND CONCEPT DESIGN
TESTERS HOLLOW

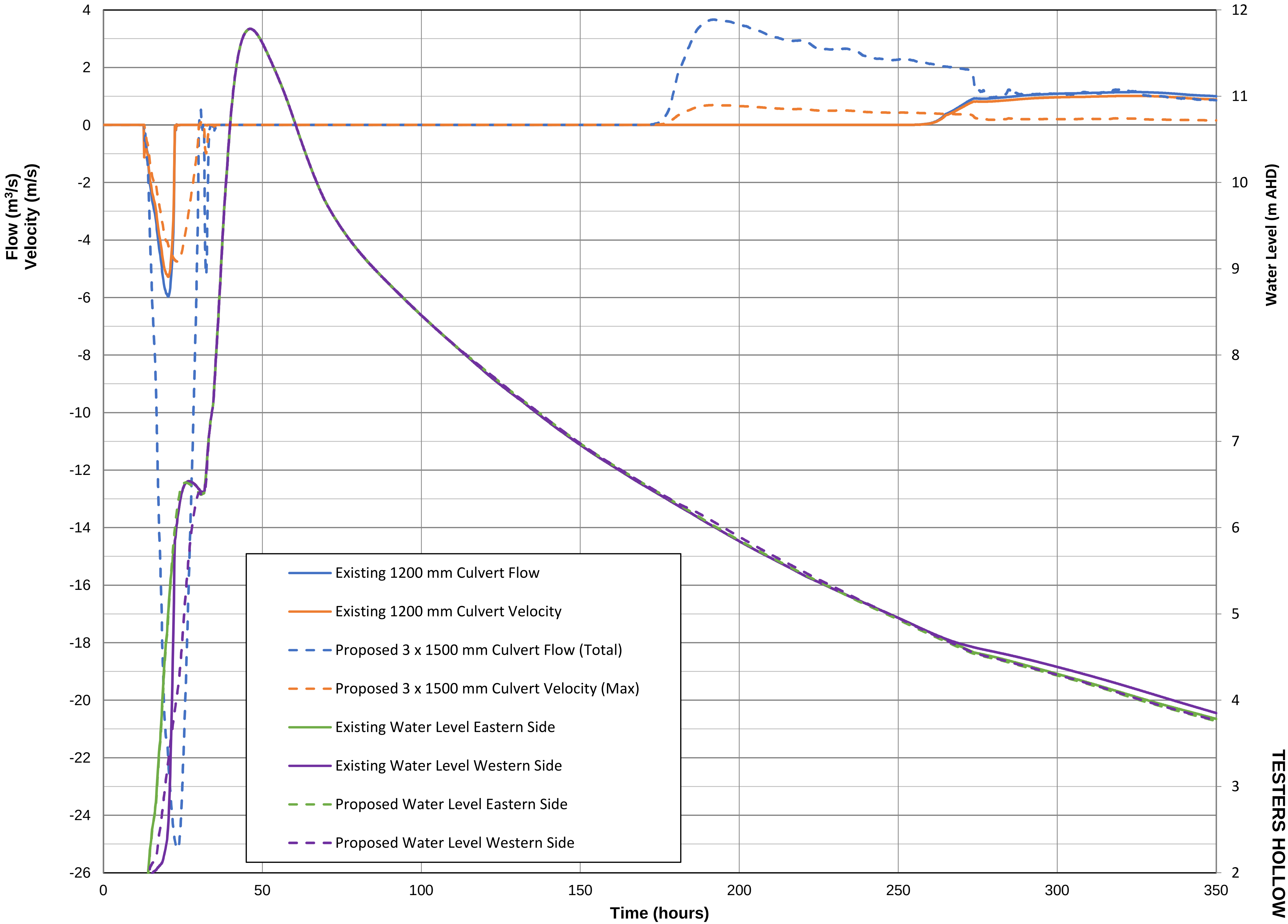

FIGURE 17

TIME SERIES GRAPH OF HUNTER RIVER PMF EVENT
EXISTING CONDITIONS AND CONCEPT DESIGN
TESTERS HOLLOW

Appendix A

APPENDIX A. GLOSSARY

Based on the Floodplain Development Manual (April 2005 edition)

acid sulfate soils — Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.

Annual Exceedance Probability (AEP) — The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).

Areal Reduction Factor — The ration between the design values of areal average rainfall and point rainfall, computed for the same duration and AEP. This allows for the fact that larger catchments are less likely than smaller catchments to experience higher intensity storms simultaneously over the whole catchment area.

Australian Height Datum (AHD) — A common national surface level datum approximately corresponding to mean sea level.

Average Annual Damage (AAD) — Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.

Average Recurrence Interval (ARI) — The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.

caravan and moveable home parks — Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.

catchment — The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.

consent authority — The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.

development — Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act).

infill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development.

	new development: refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.

flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees,

the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

flood storage areas Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

floodway areas Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.

freeboard Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.

habitable room **in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.

in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

hazard A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.

hydraulics Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

hydrograph A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.

hydrology Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

local overland flooding Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

local drainage Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

mainstream flooding Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

$ the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or

$ water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

$ major overland flow paths through developed areas outside of defined drainage reserves; and/or

$ the potential to affect a number of buildings along the major flow path.

mathematical/computer models
The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach
The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding
Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures
Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge
The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF)
The PMF is 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. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to Awater level@. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
TUFLOW	A hydraulic modelling software package capable of simulating free surface water flow in both 1D and 2D.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
WBNM	Watershed Bounded Network Model – a hydrologic modelling software package that simulates rainfall and runoff processes to determine flood hydrographs.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

APPENDIX B. EXISTING CONDITIONS FLOOD MAPS FOR WALLIS CREEK FLOODING

Appendix B

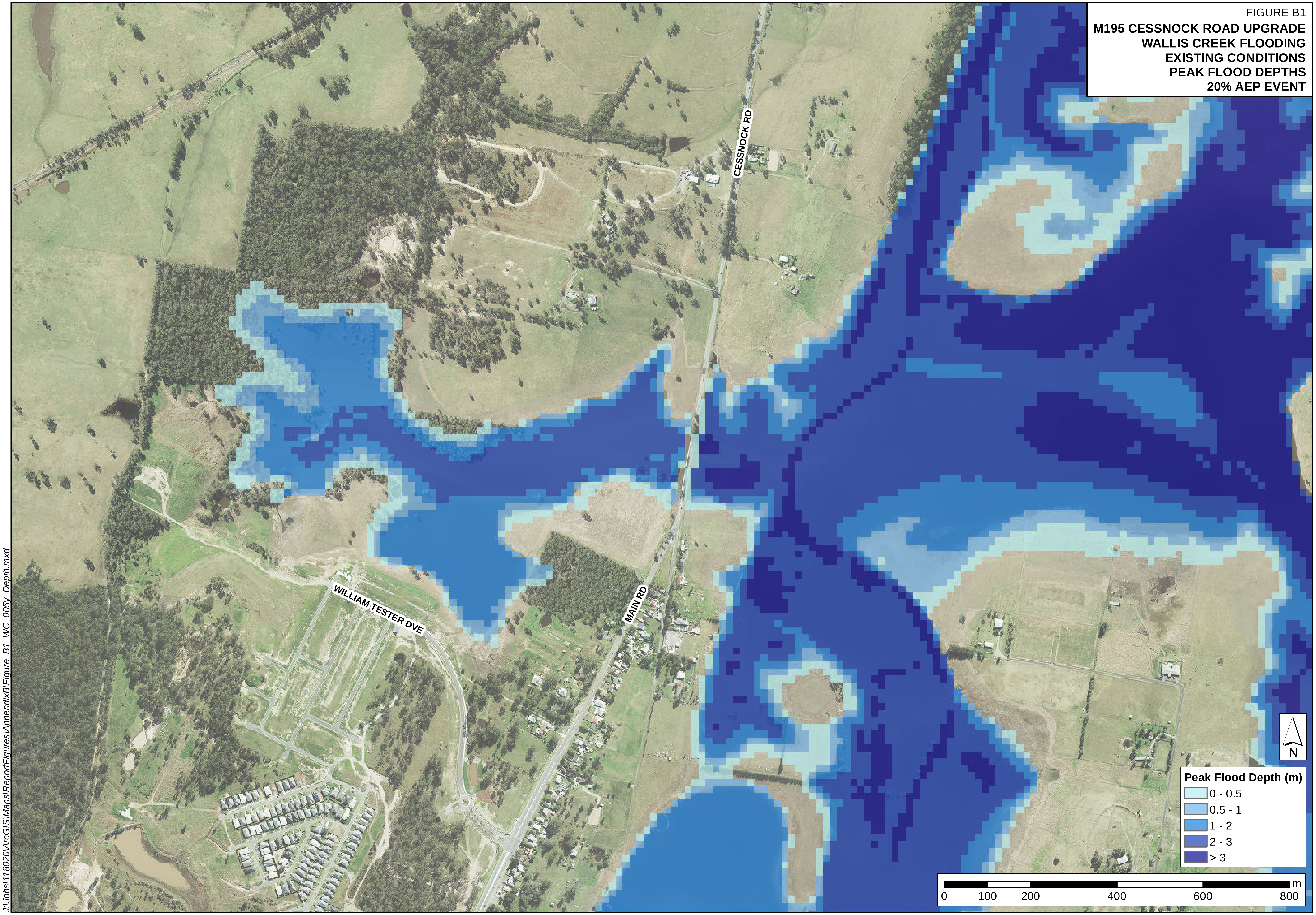
FIGURE B1
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
EXISTING CONDITIONS
PEAK FLOOD DEPTHS
20% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Flood Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 3
> 3
0 100 200 400 600 800 m
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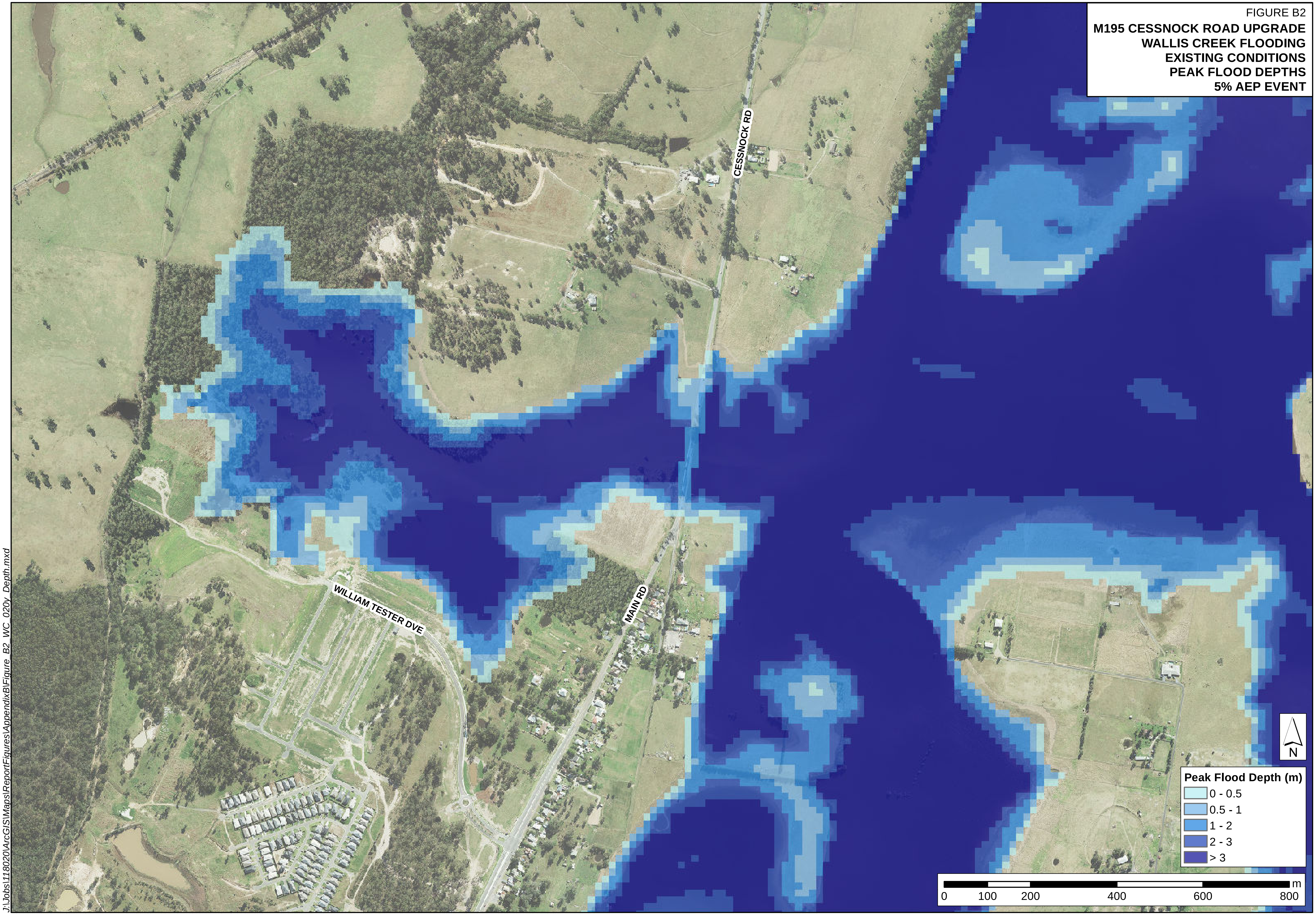
FIGURE B2
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
EXISTING CONDITIONS
PEAK FLOOD DEPTHS
5% AEP EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Peak Flood Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 3
> 3
0 100 200 400 600 800 m
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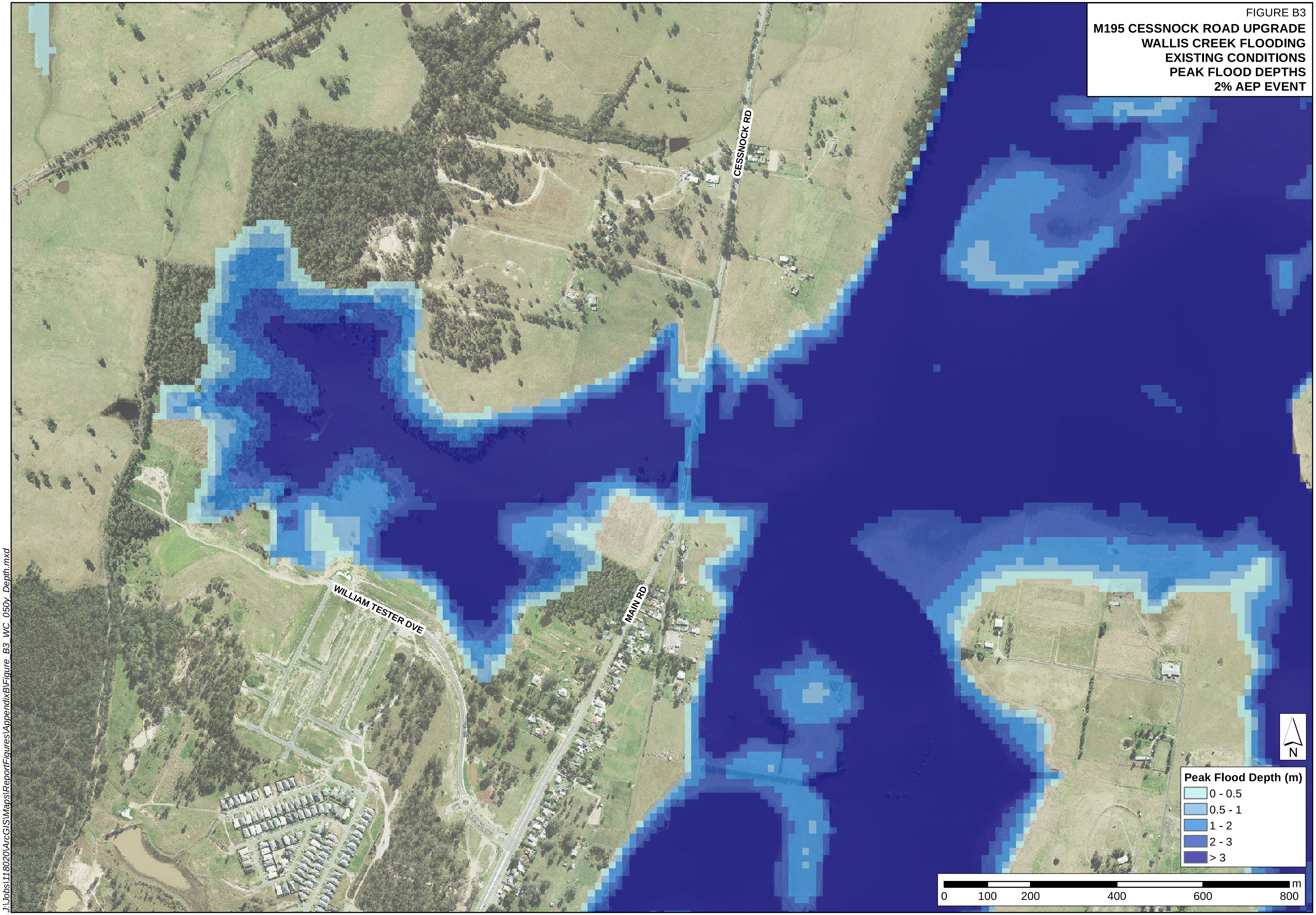

FIGURE B3
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
EXISTING CONDITIONS
PEAK FLOOD DEPTHS
2% AEP EVENT

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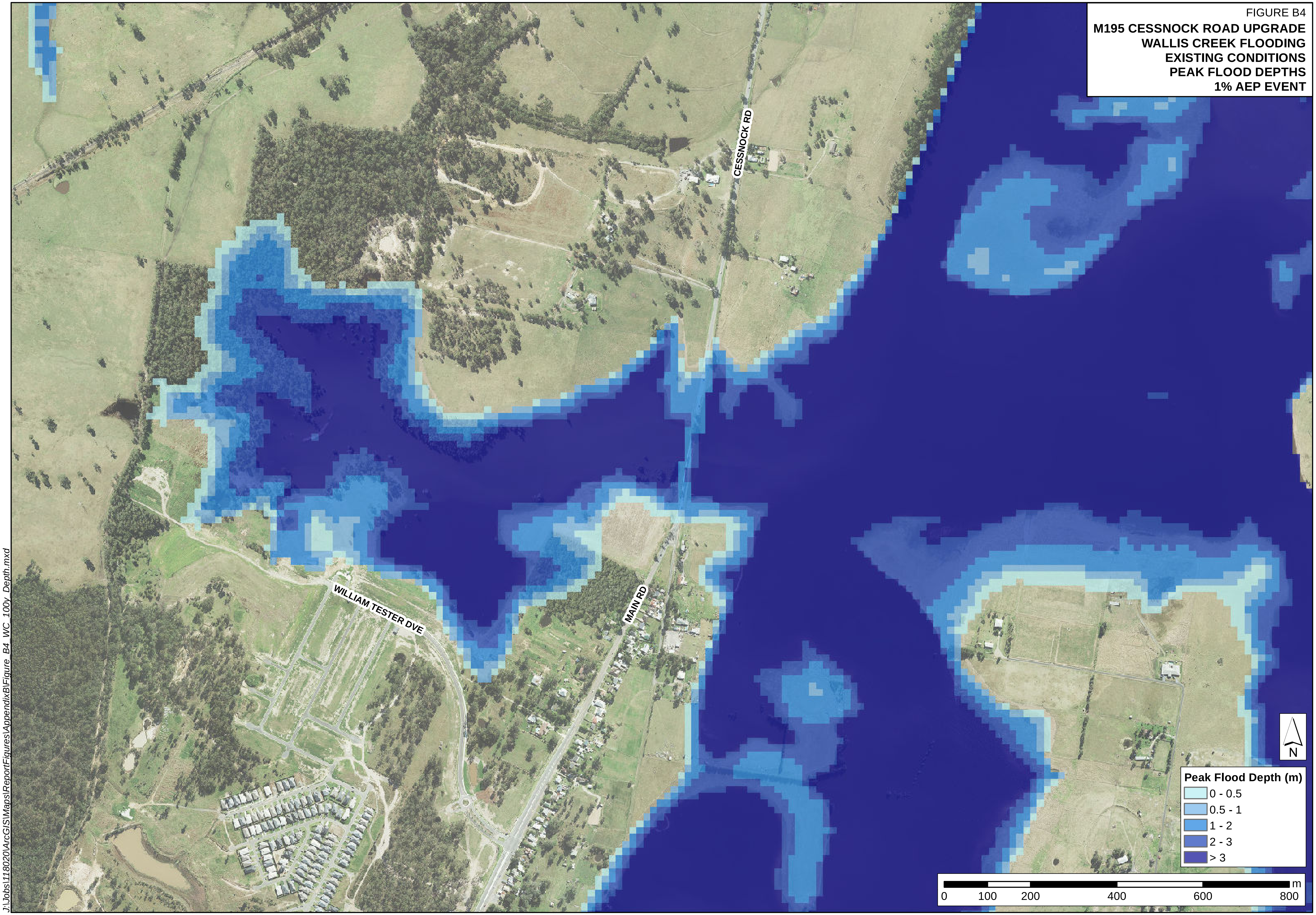

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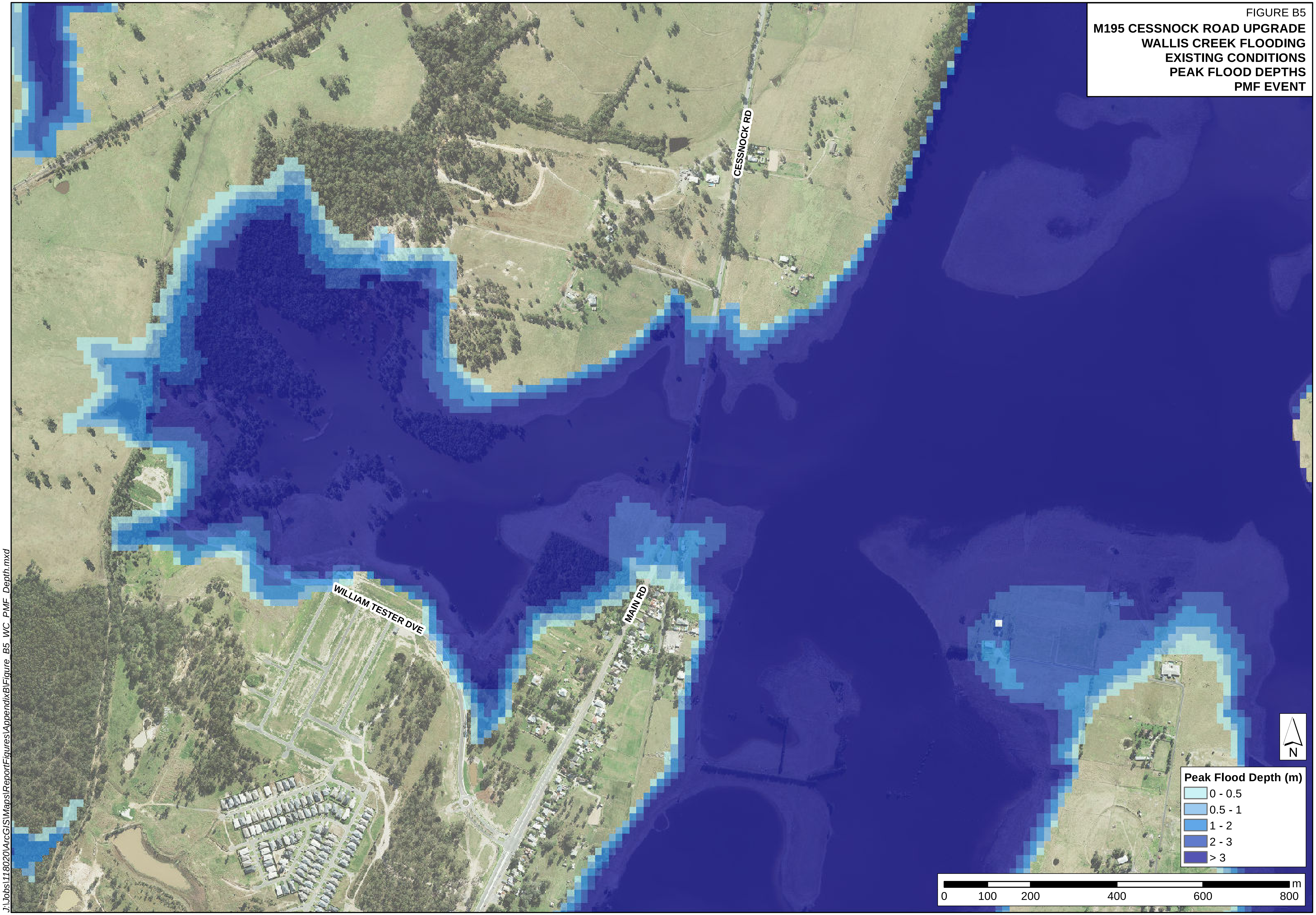
FIGURE B5
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
EXISTING CONDITIONS
PEAK FLOOD DEPTHS
PMF EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Peak Flood Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 3
> 3
0 100 200 400 600 800 m
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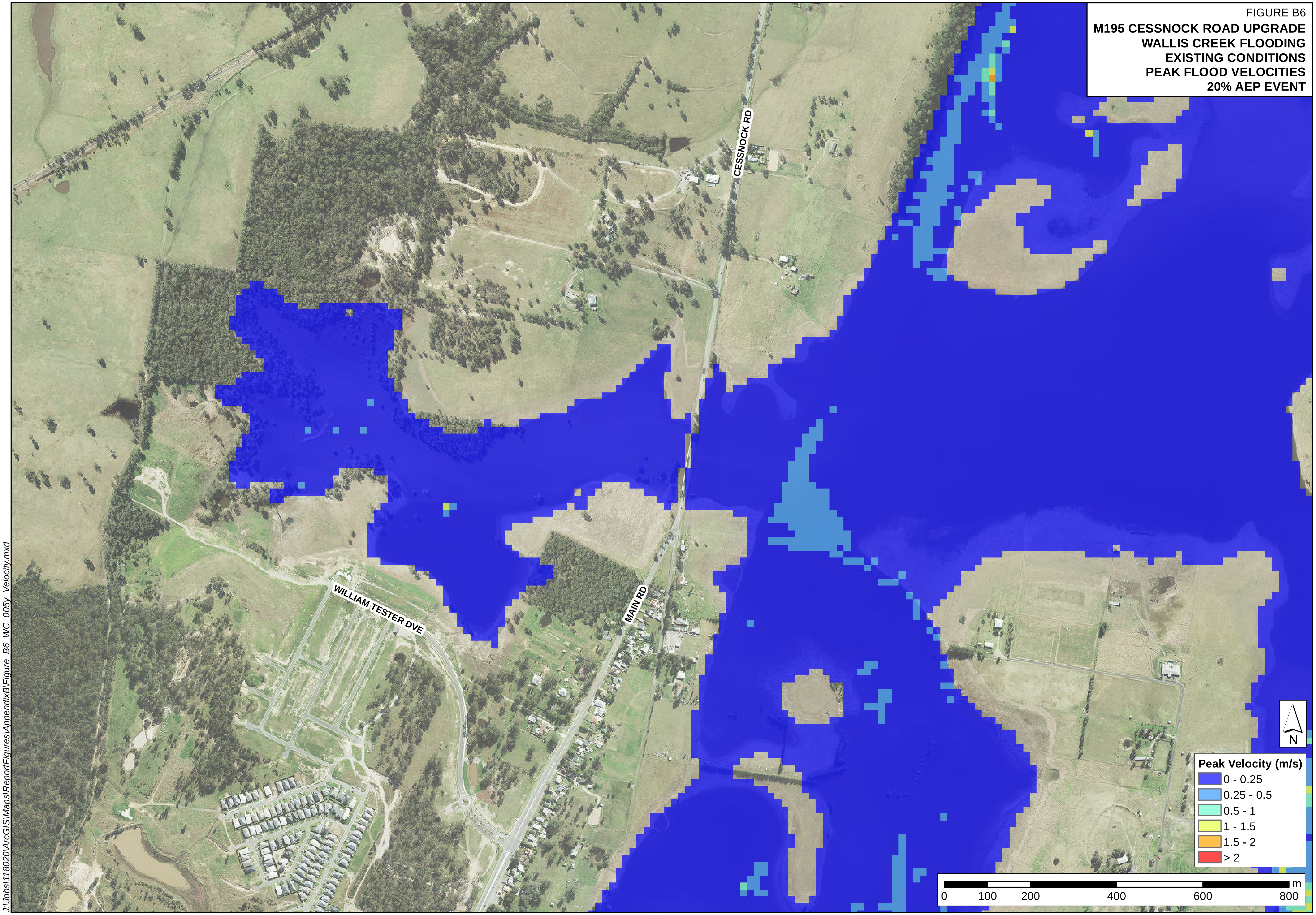

FIGURE B6

M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
EXISTING CONDITIONS
PEAK FLOOD VELOCITIES
20% AEP EVENT

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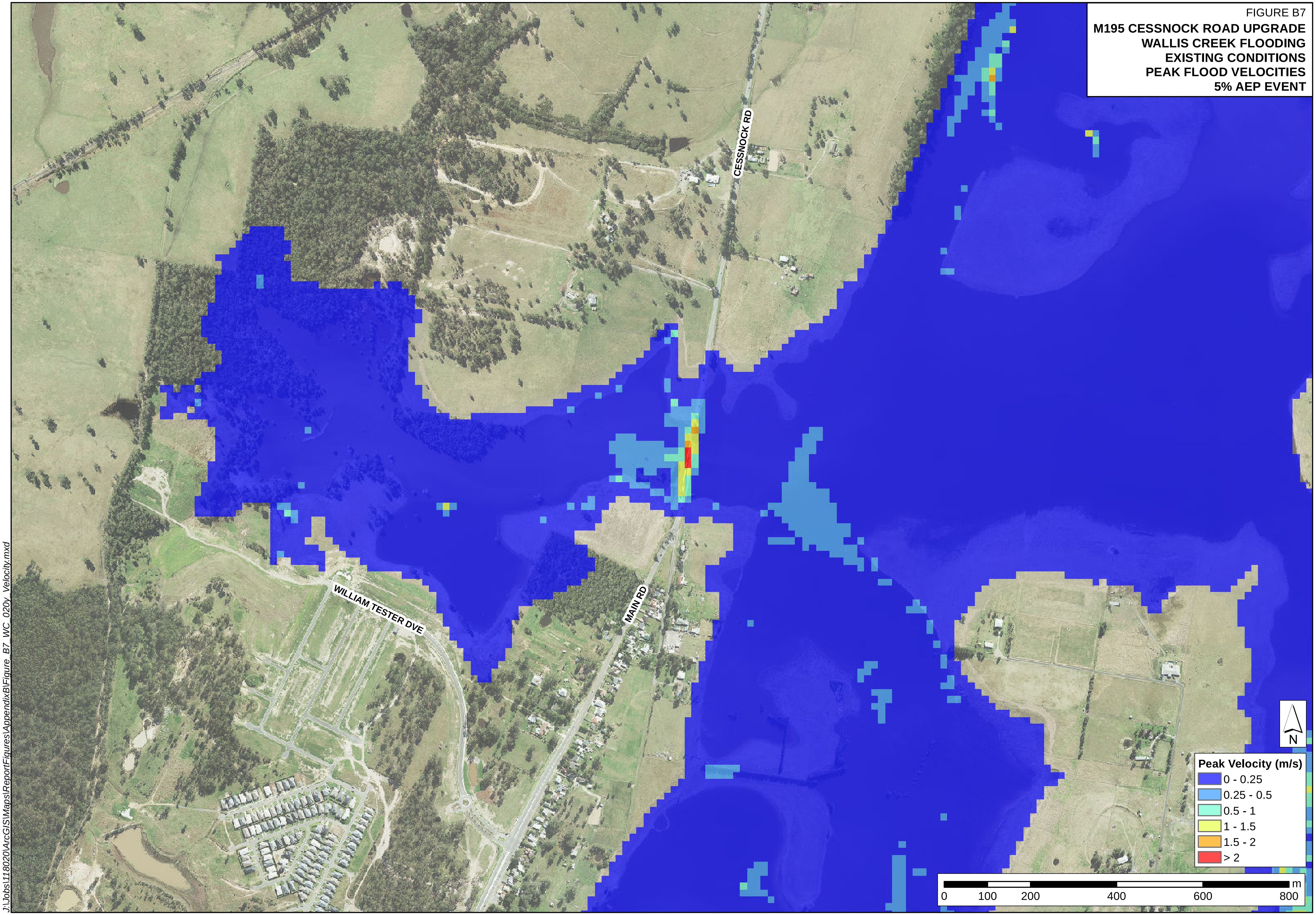

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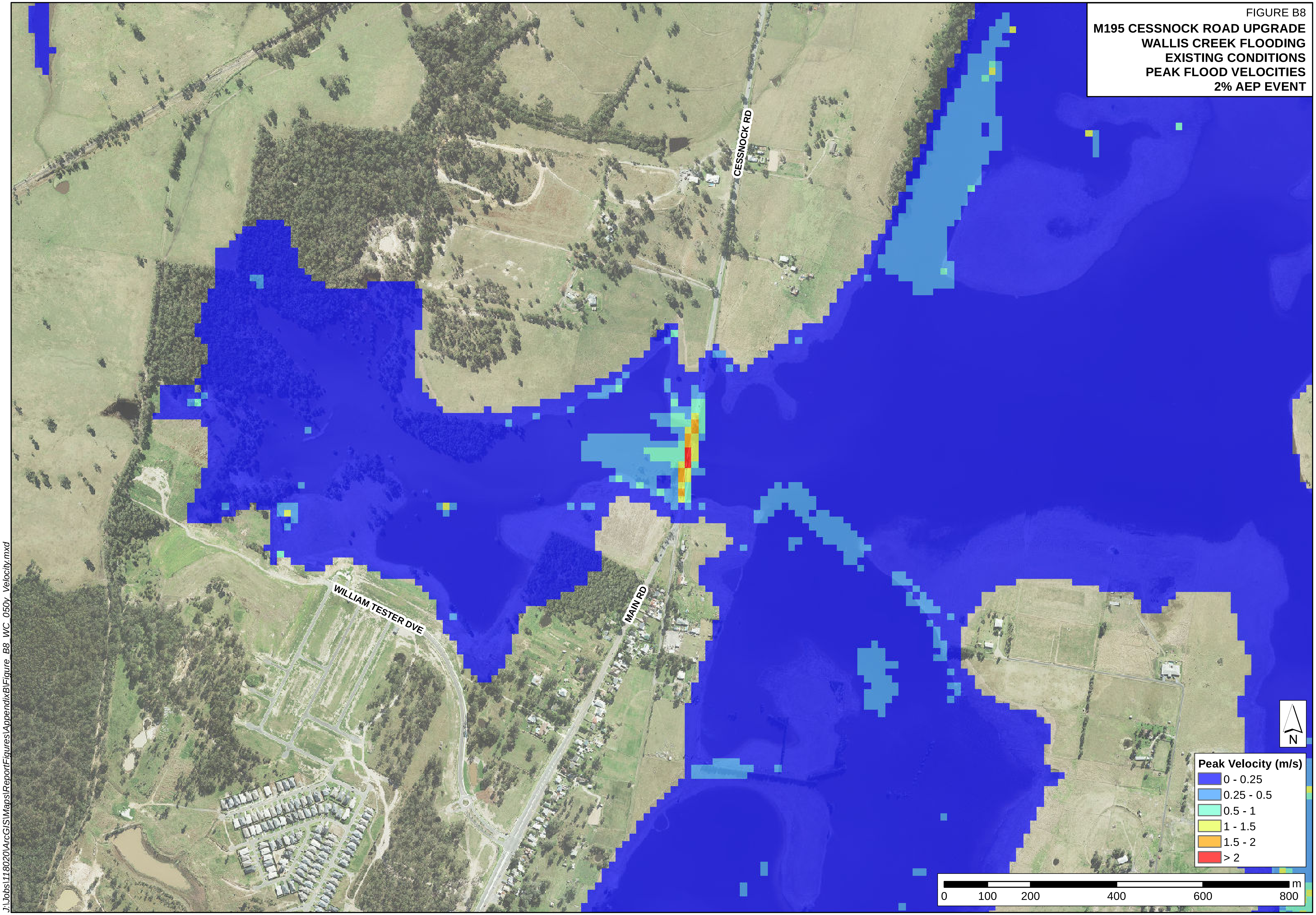

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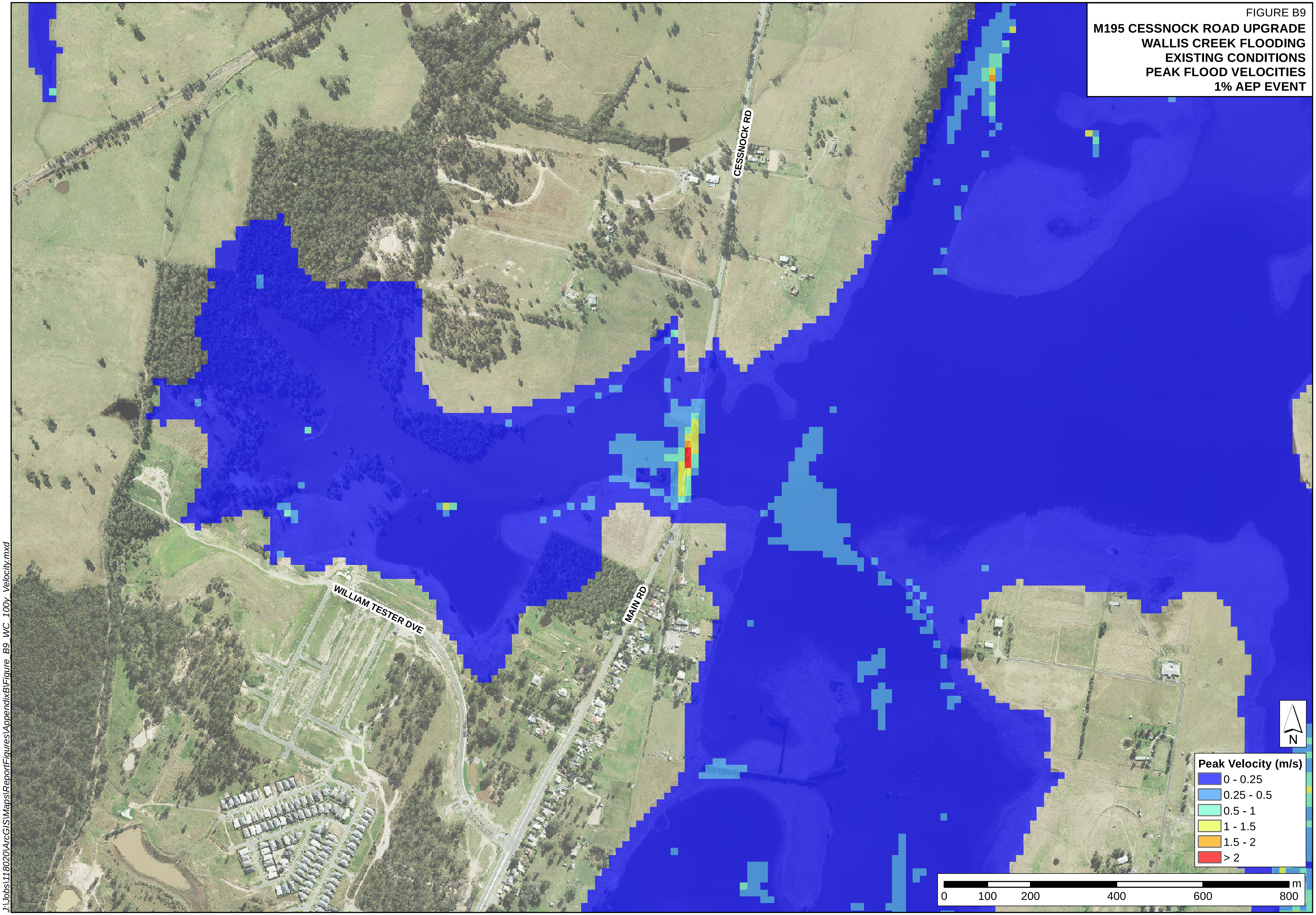

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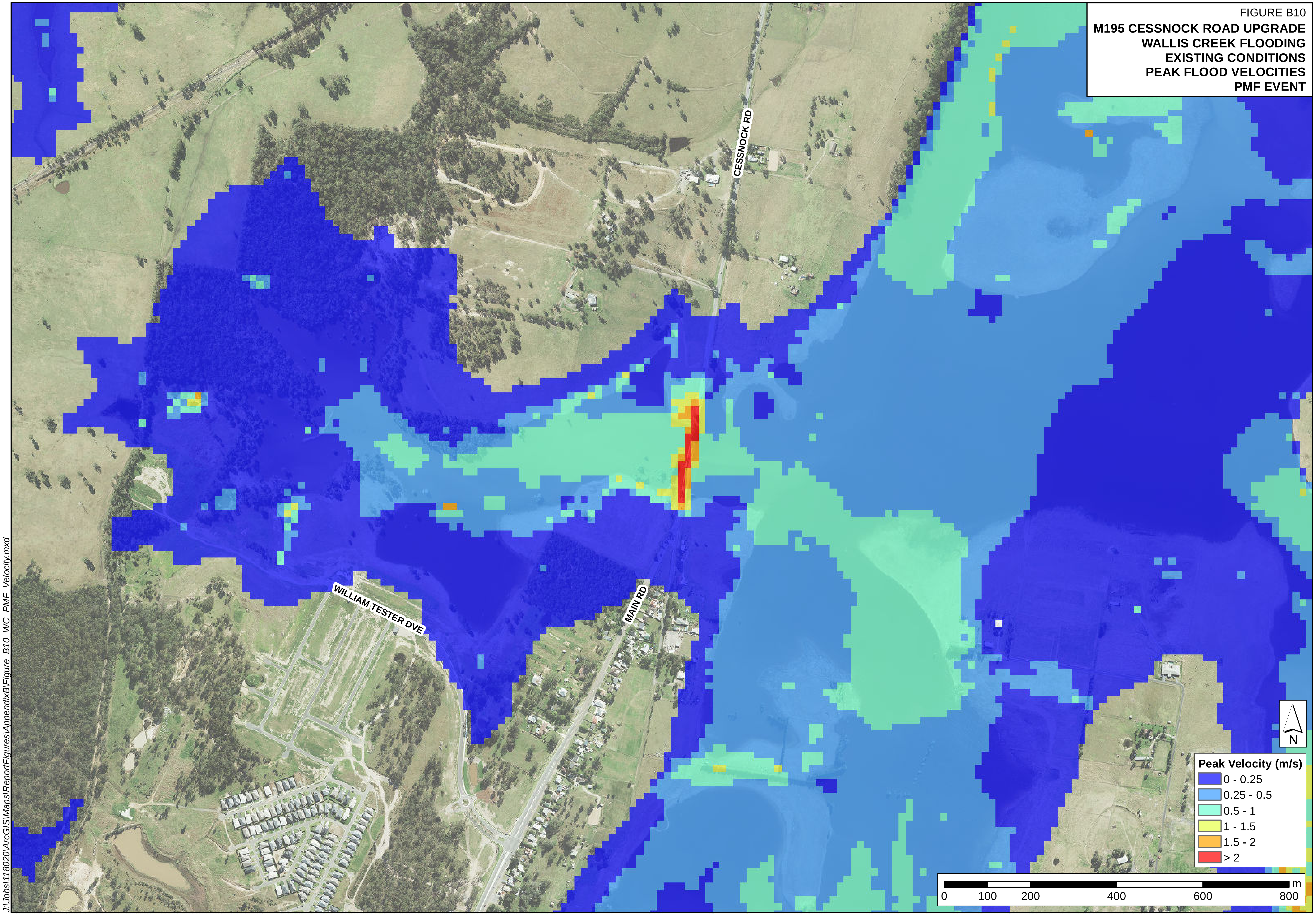
FIGURE B10
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
EXISTING CONDITIONS
PEAK FLOOD VELOCITIES
PMF EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Peak Velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
> 2
m
0
100
200
400
600
800
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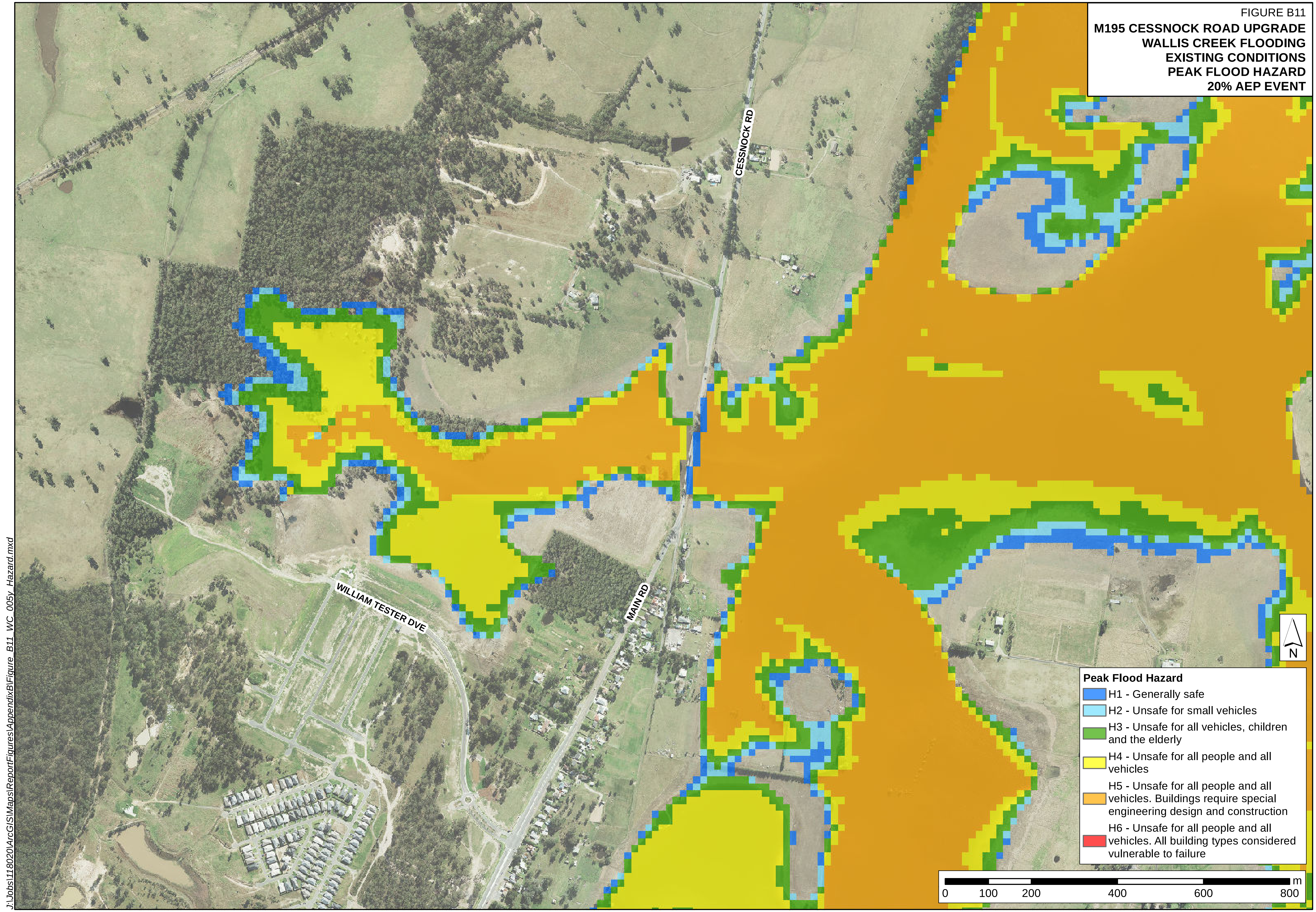
FIGURE B11
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
EXISTING CONDITIONS
PEAK FLOOD HAZARD
20% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Flood Hazard
H1 - Generally safe
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unsafe for all people and all vehicles. All building types considered vulnerable to failure
0 100 200 400 600 800 m
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixB\Figure_B11_WC_005y_Hazard.mxd

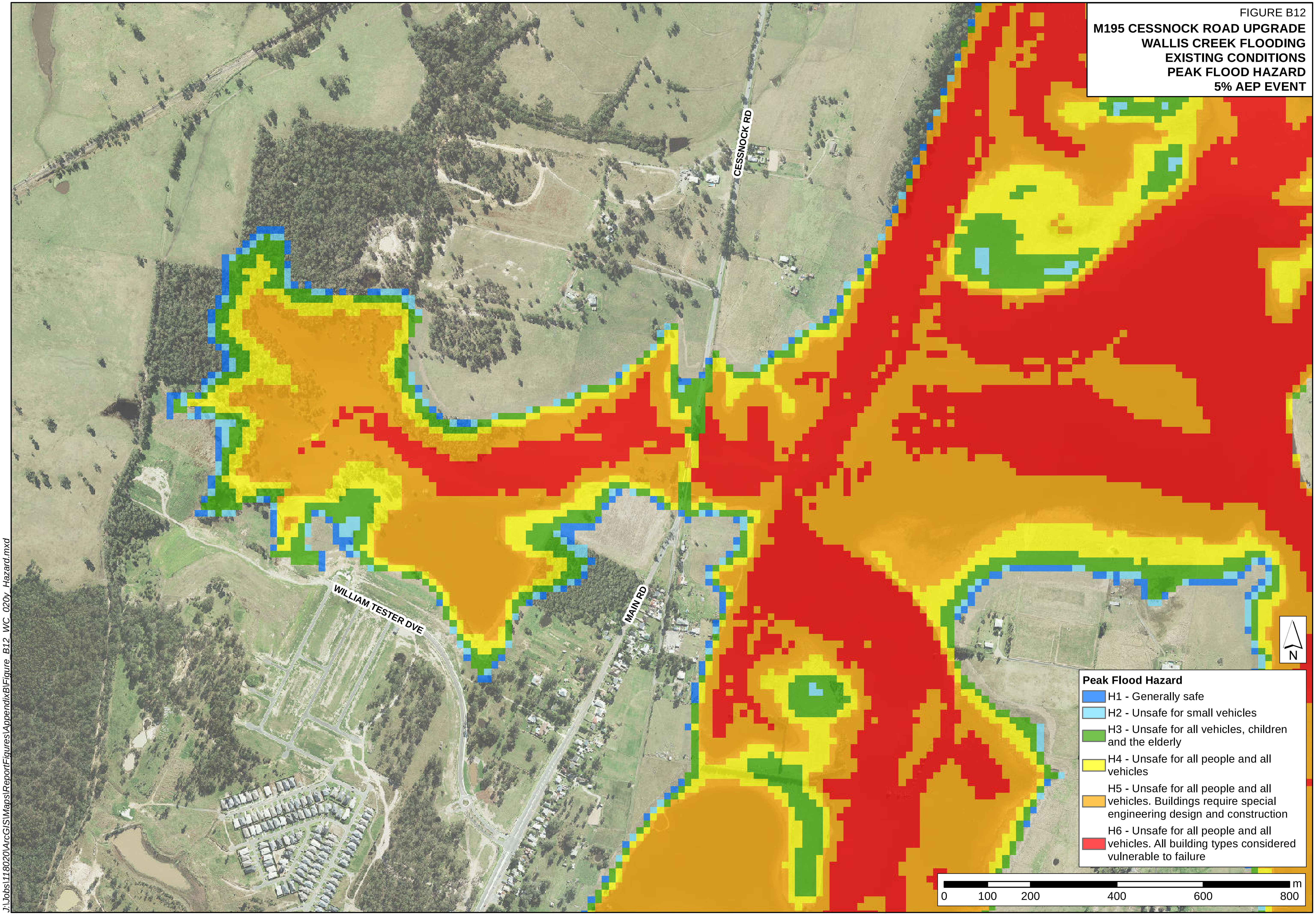

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FIGURE B13

M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
EXISTING CONDITIONS
PEAK FLOOD HAZARD
2% AEP EVENT

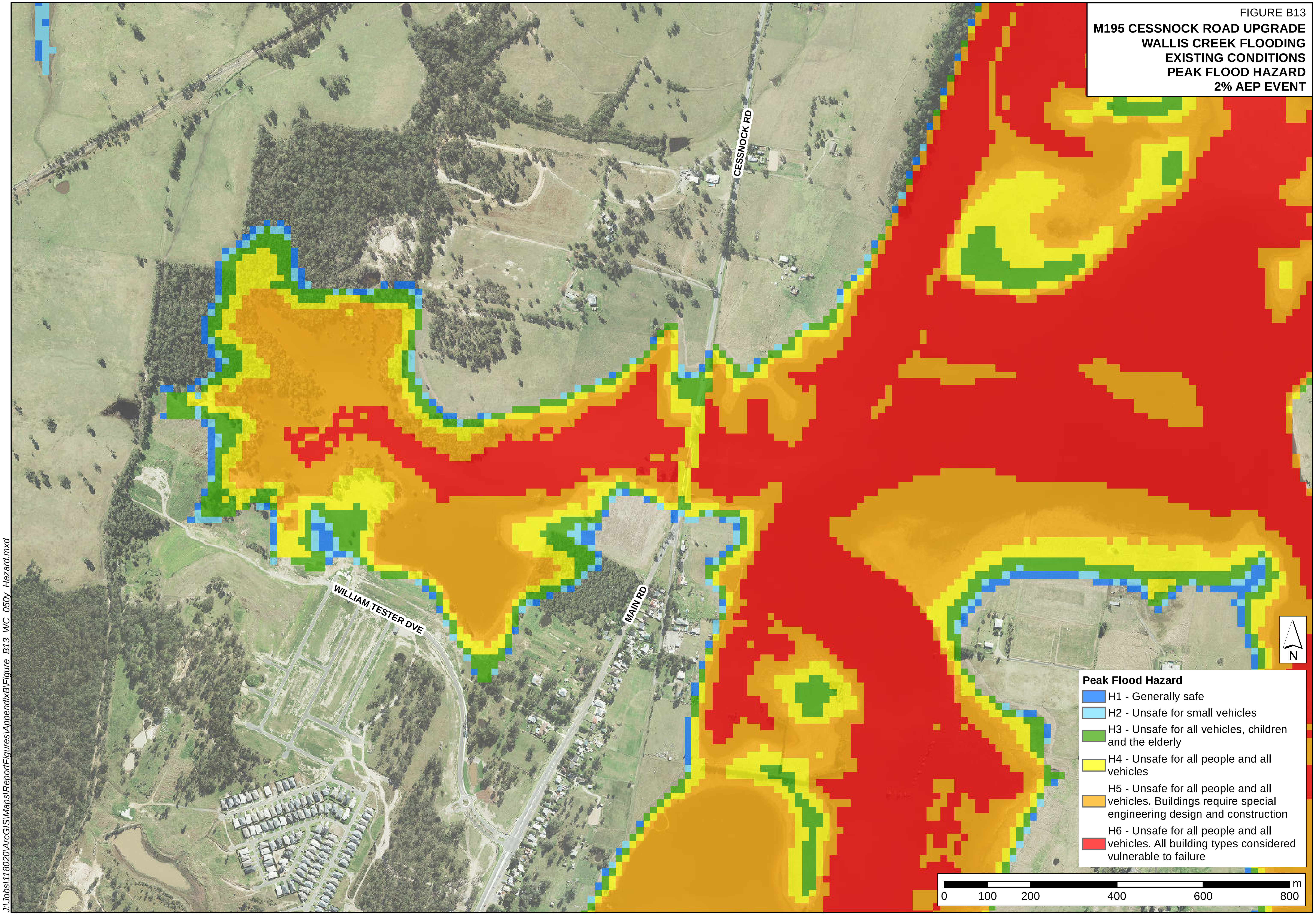

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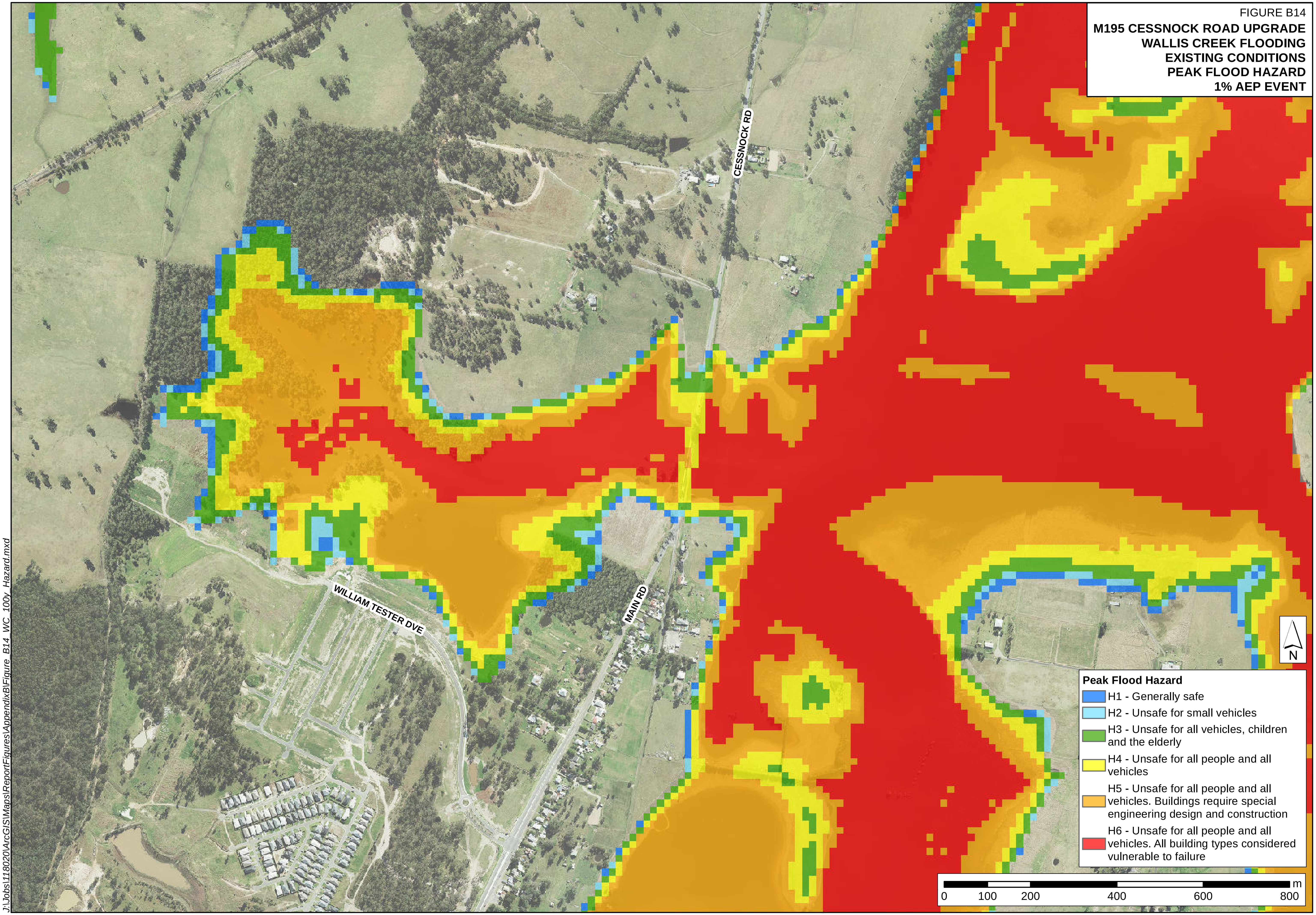
FIGURE B14

M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
EXISTING CONDITIONS
PEAK FLOOD HAZARD
1% AEP EVENT



Peak Flood Hazard

- H1 - Generally safe
- H2 - Unsafe for small vehicles
- H3 - Unsafe for all vehicles, children and the elderly
- H4 - Unsafe for all people and all vehicles
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
- H6 - Unsafe for all people and all vehicles. All building types considered vulnerable to failure

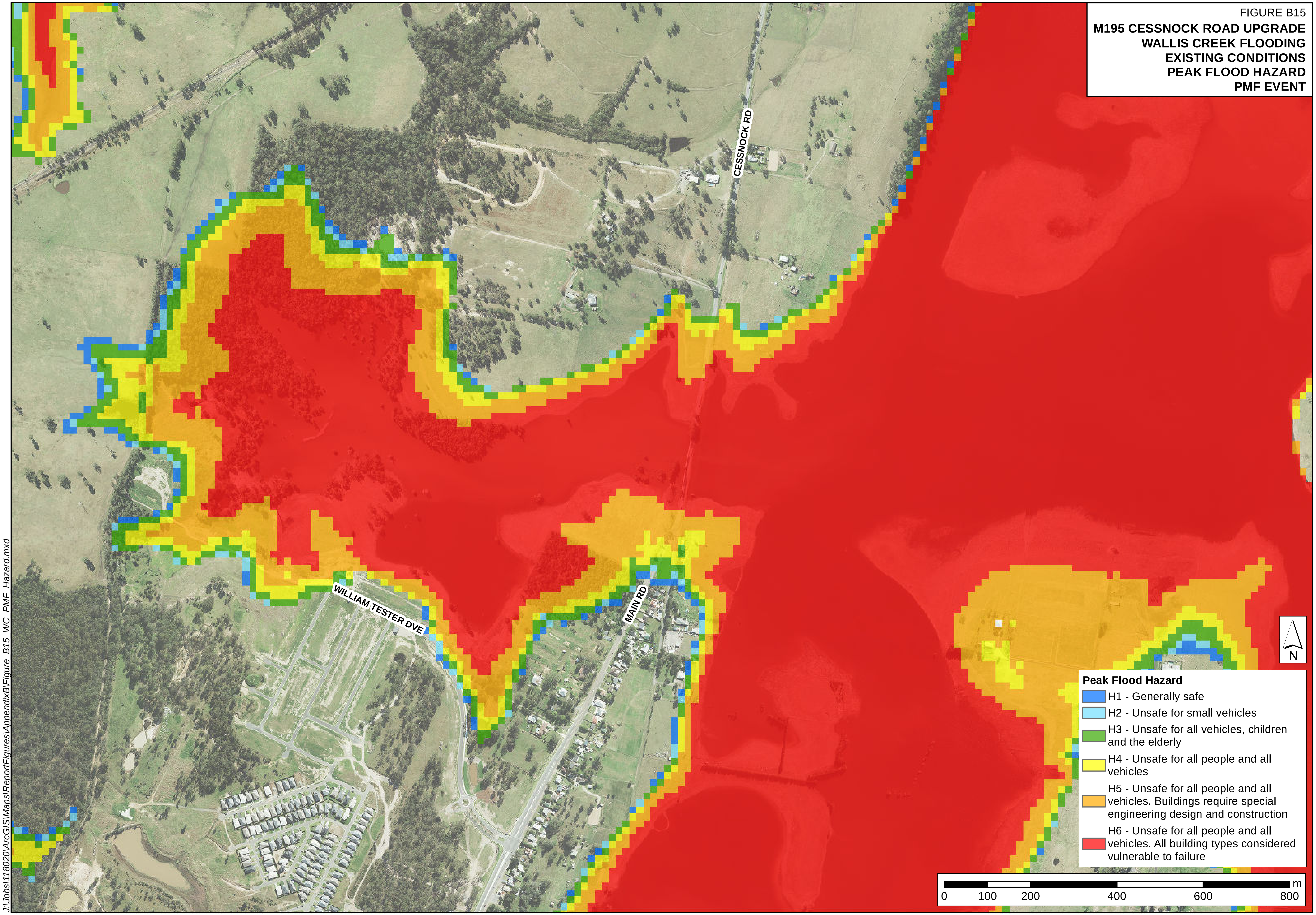
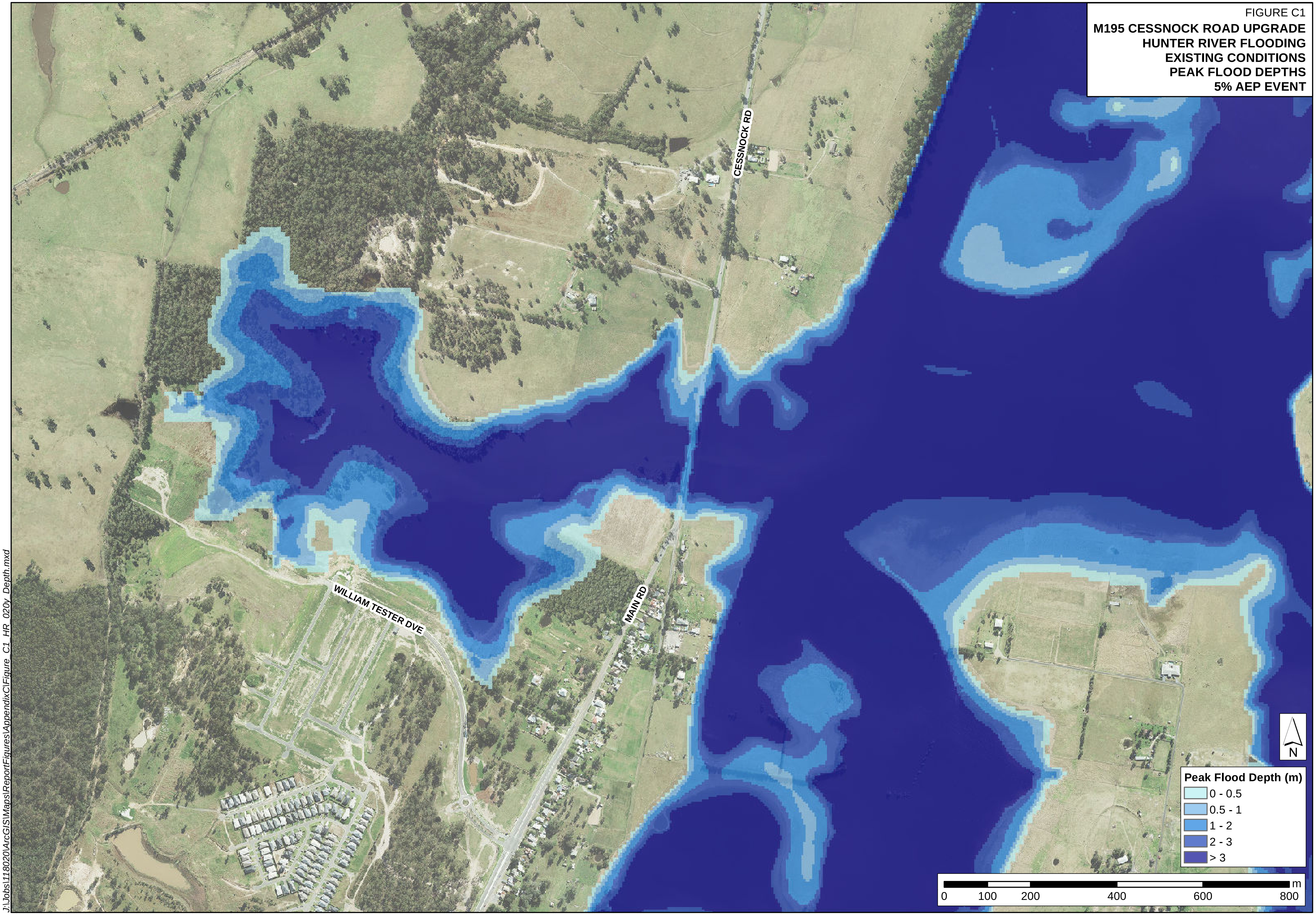


FIGURE B15
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
EXISTING CONDITIONS
PEAK FLOOD HAZARD
PMF EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Peak Flood Hazard
H1 - Generally safe
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unsafe for all people and all vehicles. All building types considered vulnerable to failure
0
100
200
400
600
800
m
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixB\Figure_B15_WC_PMF_Hazard.mxd

APPENDIX C. EXISTING CONDITIONS FLOOD MAPS FOR HUNTER RIVER FLOODING

FIGURE C1

M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
EXISTING CONDITIONS
PEAK FLOOD DEPTHS
5% AEP EVENT



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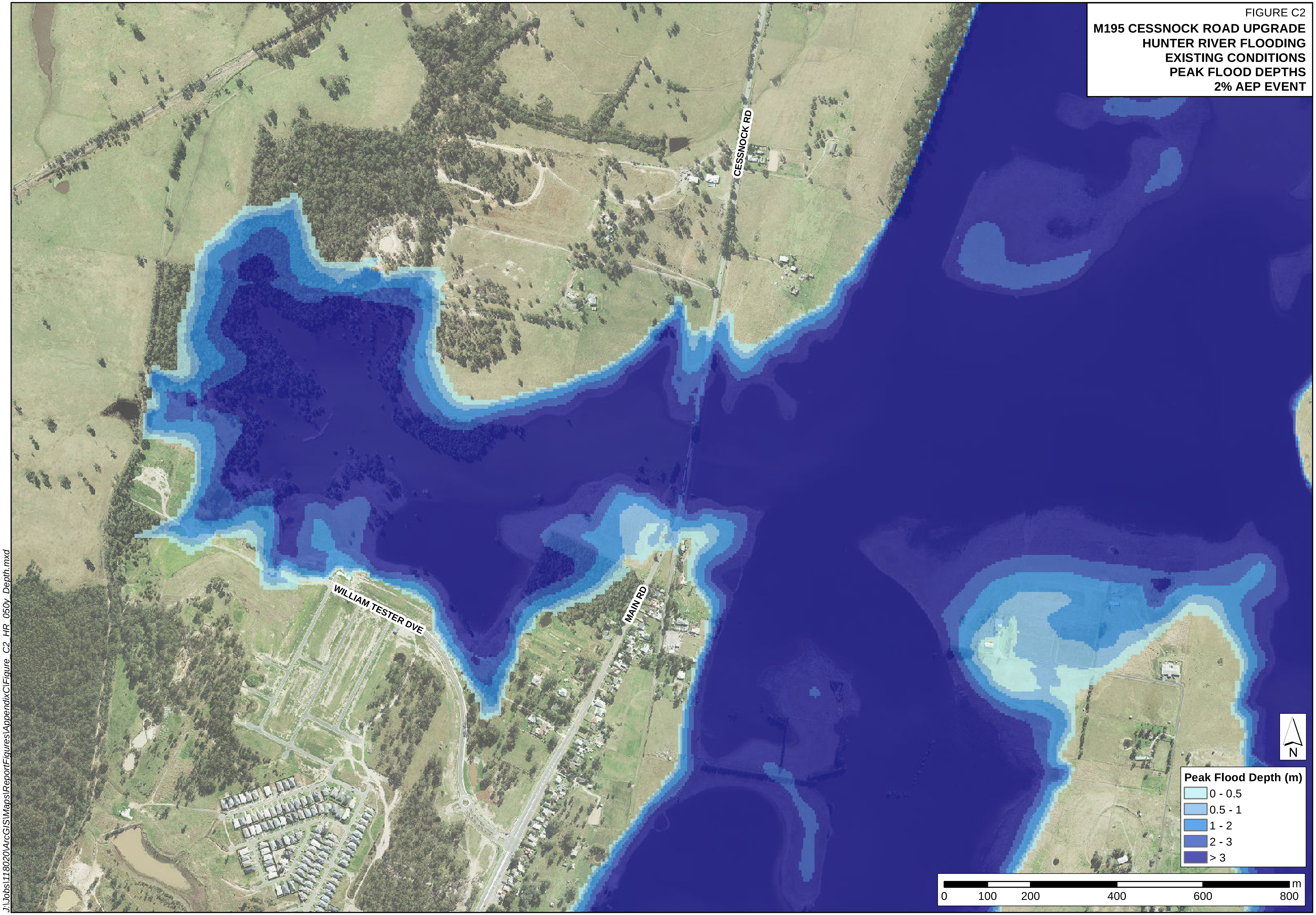

FIGURE C2
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
EXISTING CONDITIONS
PEAK FLOOD DEPTHS
2% AEP EVENT

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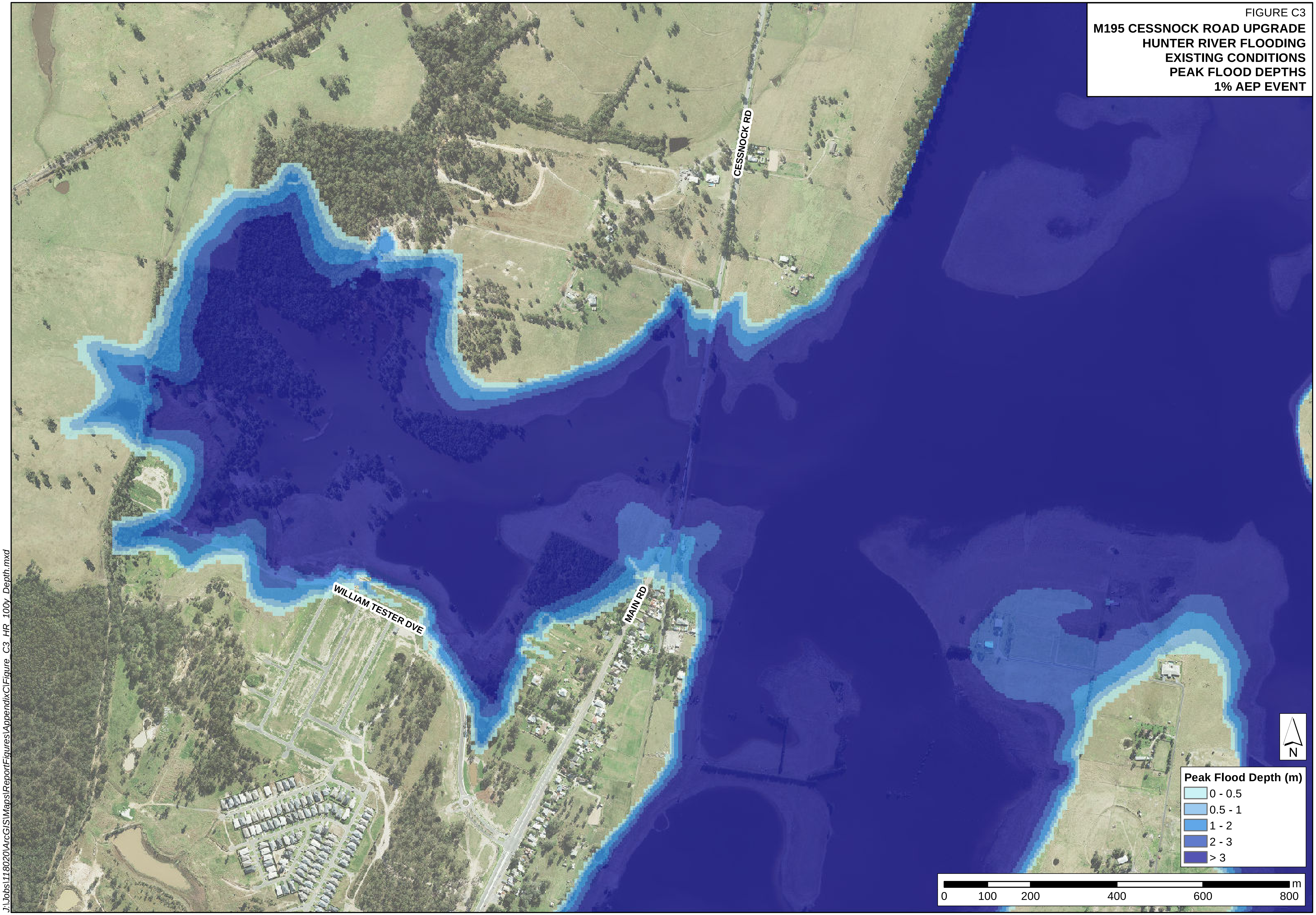
FIGURE C3
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
EXISTING CONDITIONS
PEAK FLOOD DEPTHS
1% AEP EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Peak Flood Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 3
> 3
0
100
200
400
600
800
m
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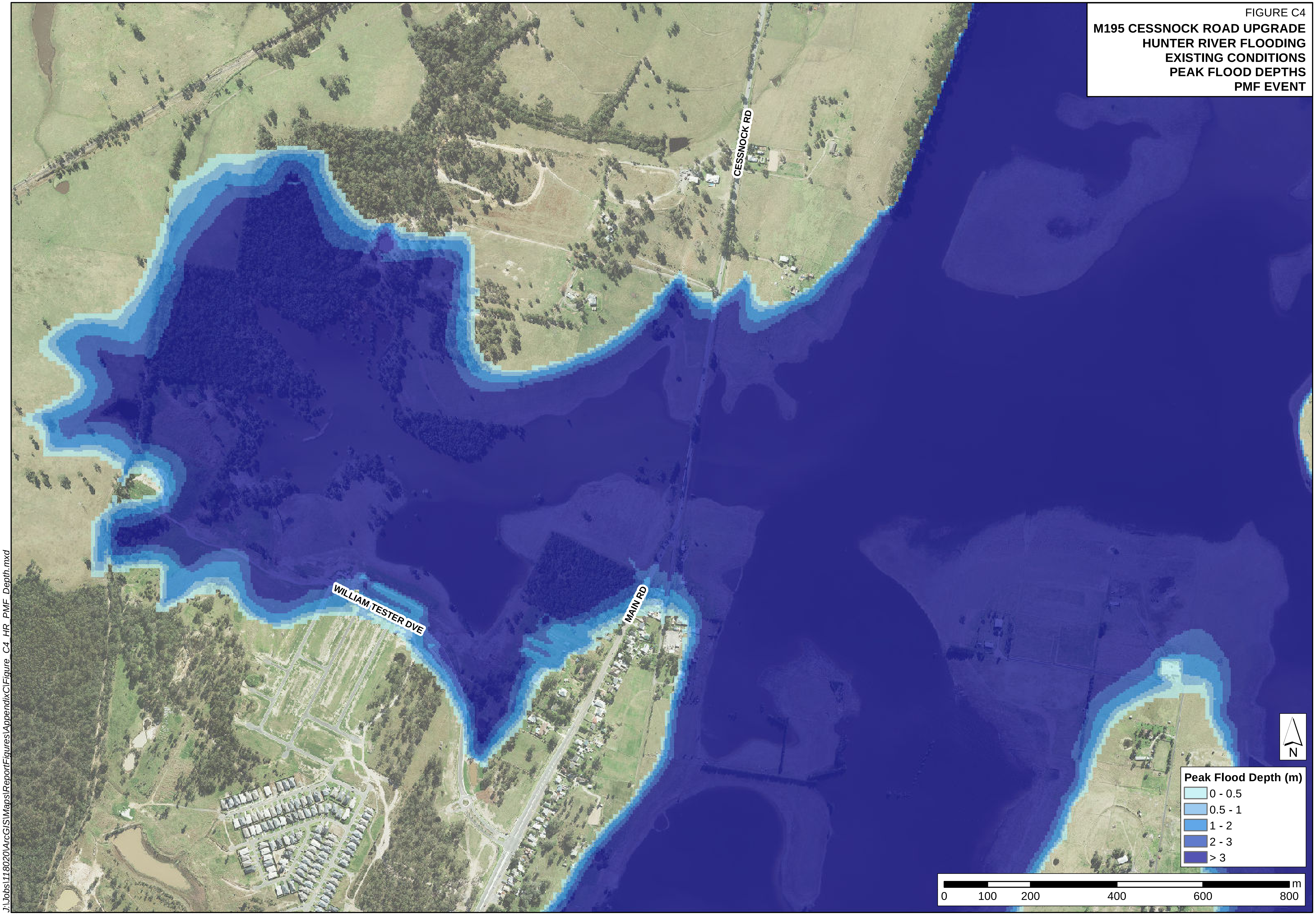
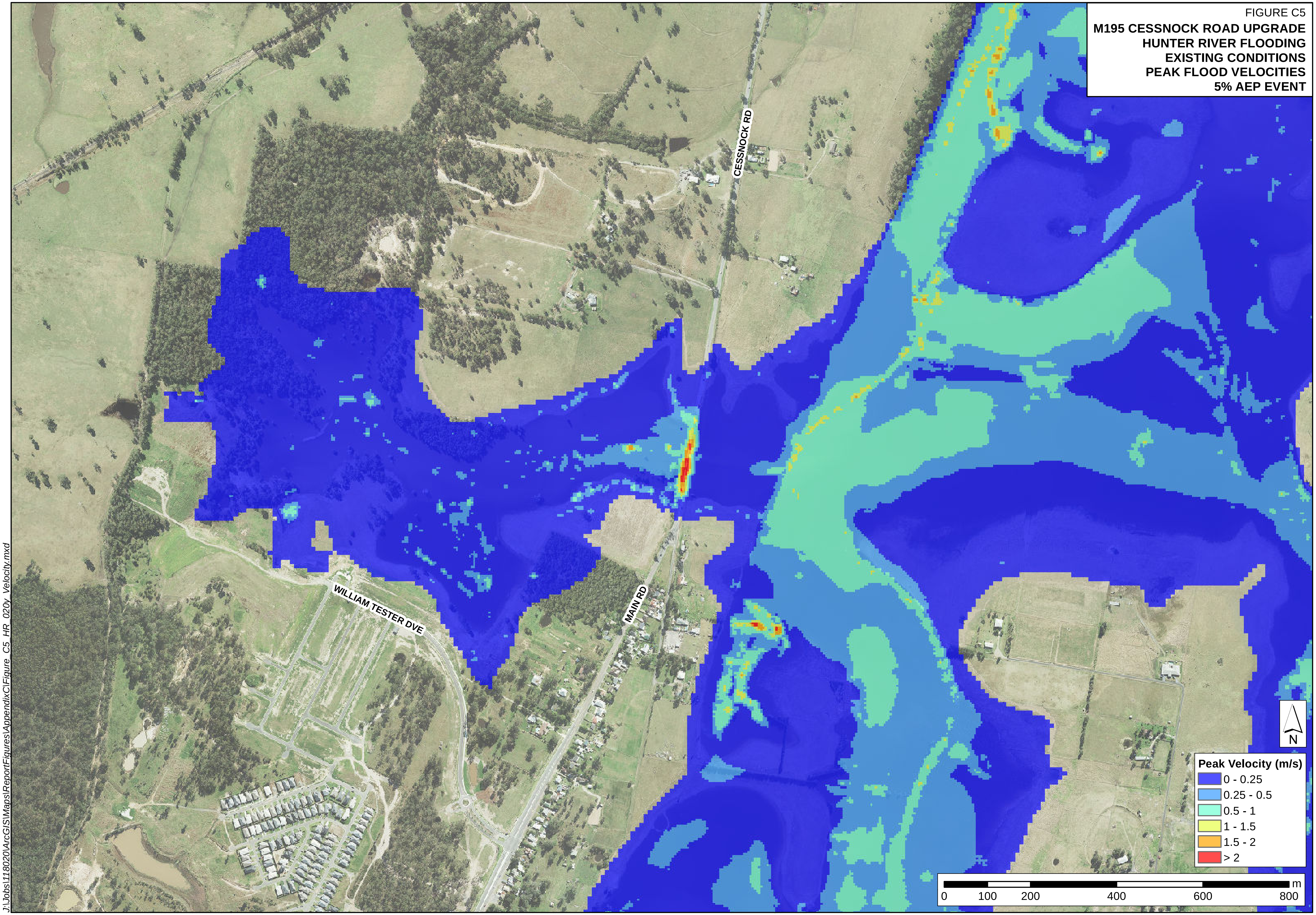


FIGURE C4
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
EXISTING CONDITIONS
PEAK FLOOD DEPTHS
PMF EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Peak Flood Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 3
> 3
m
0
100
200
400
600
800
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixC\Figure_C4_HR_PMF_Depth.mxd



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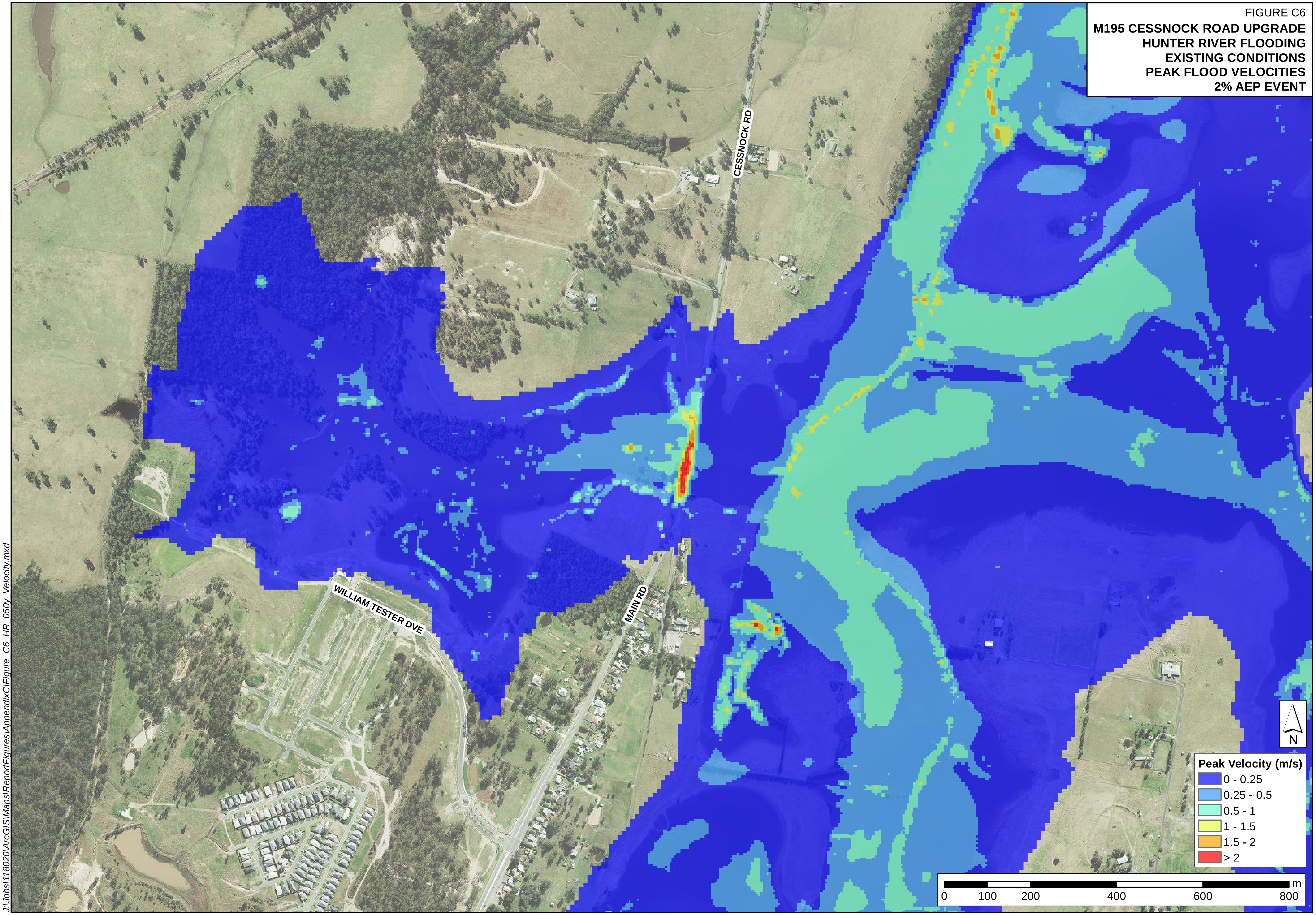

FIGURE C6

M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
EXISTING CONDITIONS
PEAK FLOOD VELOCITIES
2% AEP EVENT

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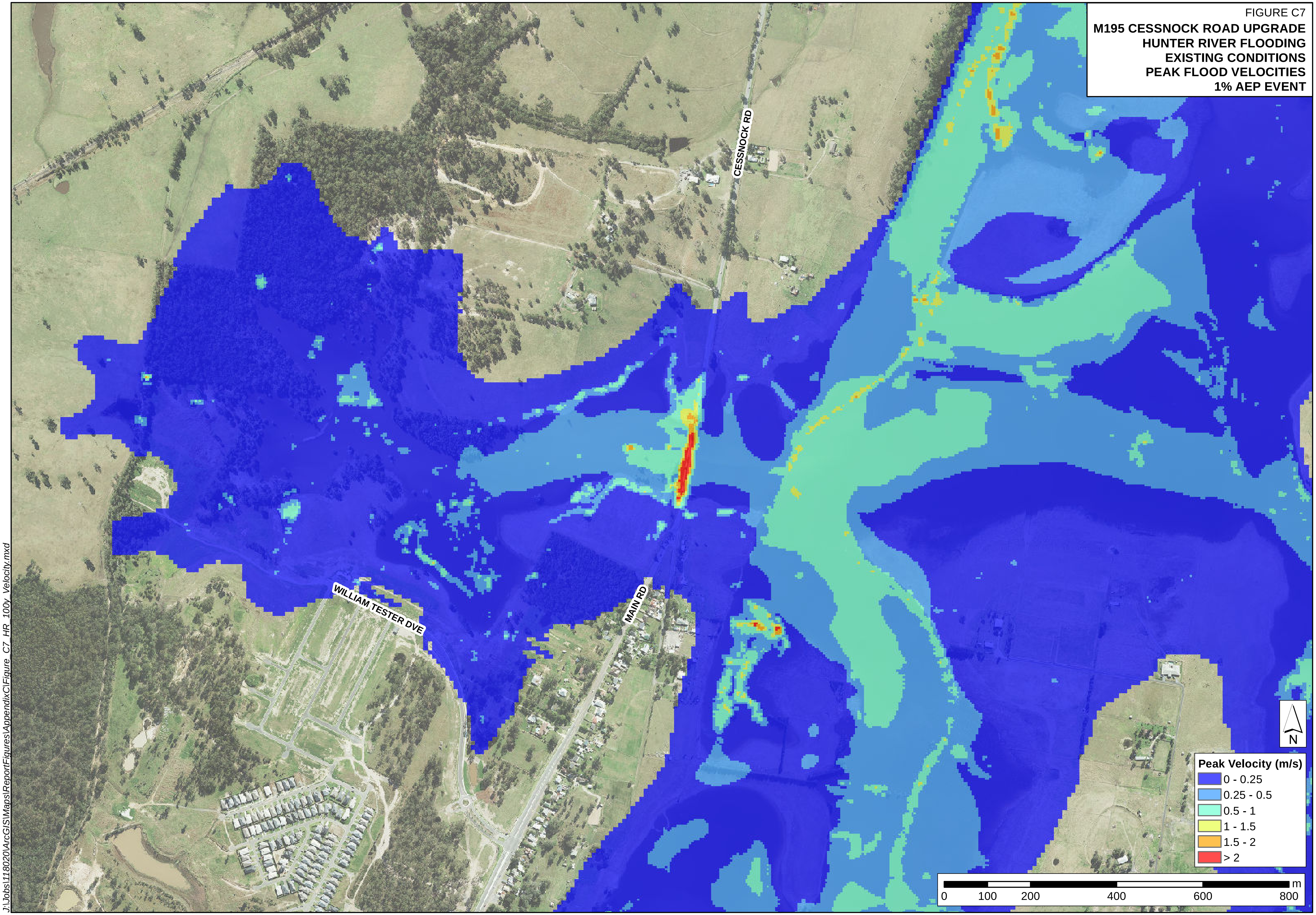

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FIGURE C8

M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
EXISTING CONDITIONS
PEAK FLOOD VELOCITIES
PMF EVENT

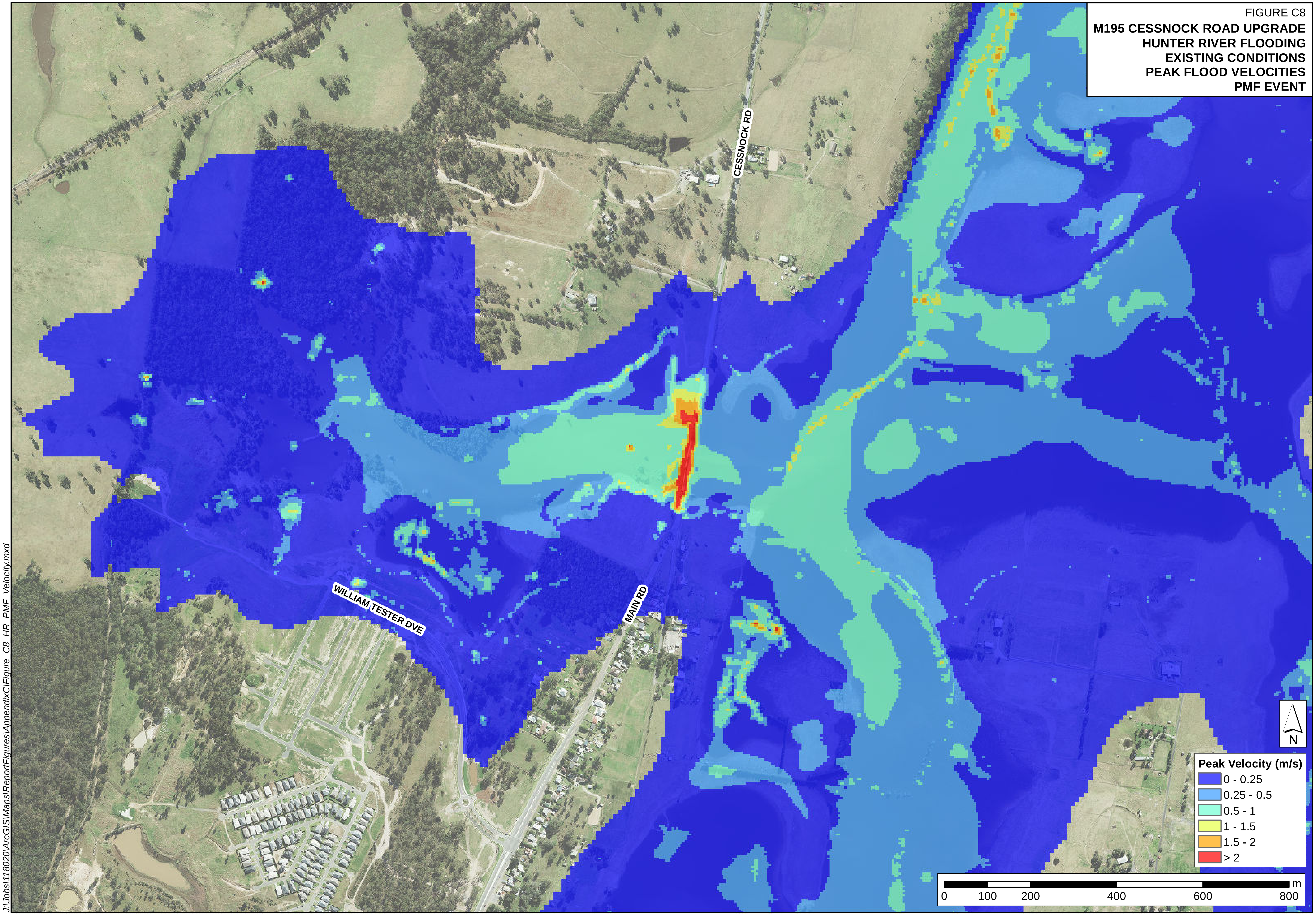

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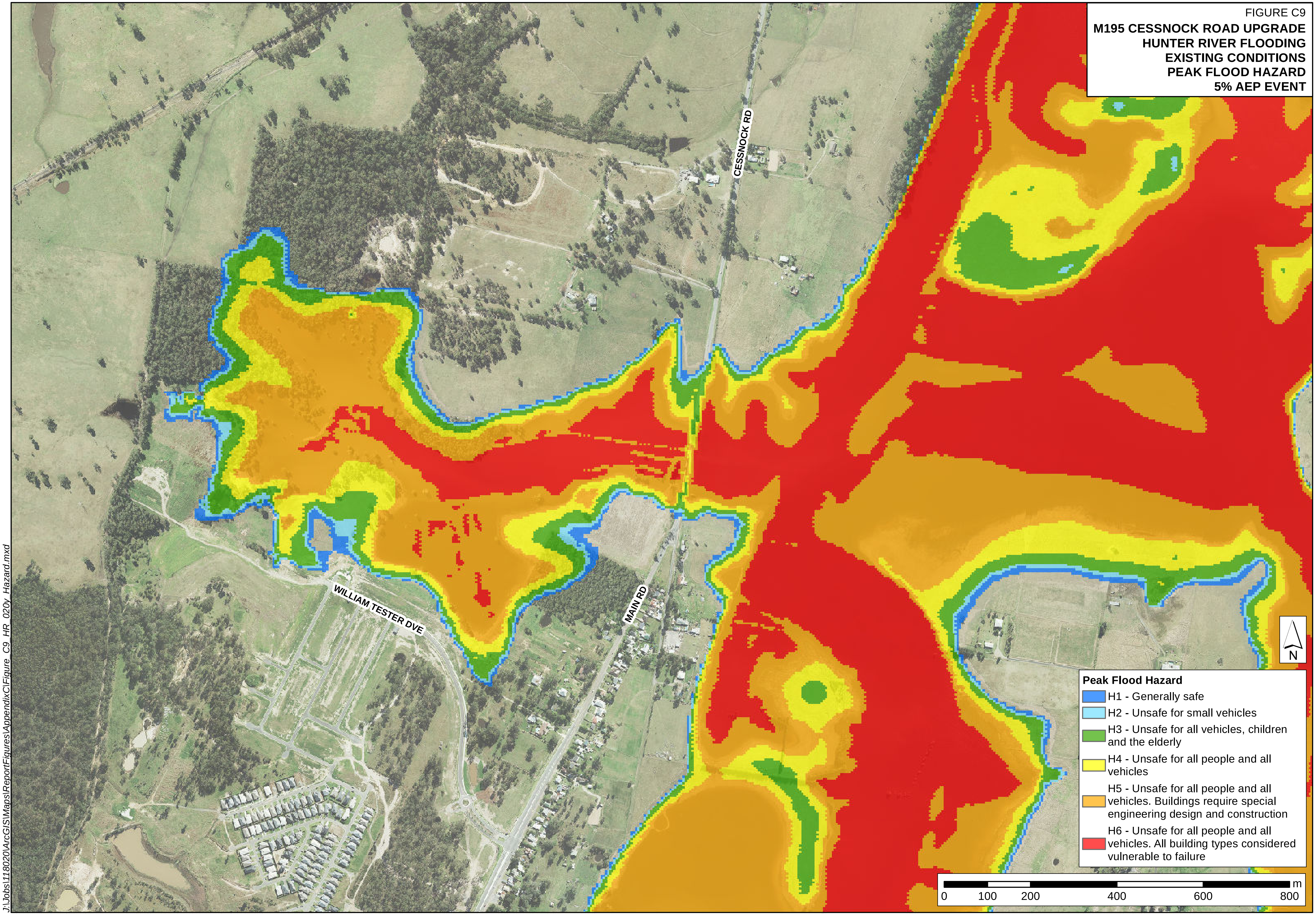
FIGURE C9
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
EXISTING CONDITIONS
PEAK FLOOD HAZARD
5% AEP EVENT



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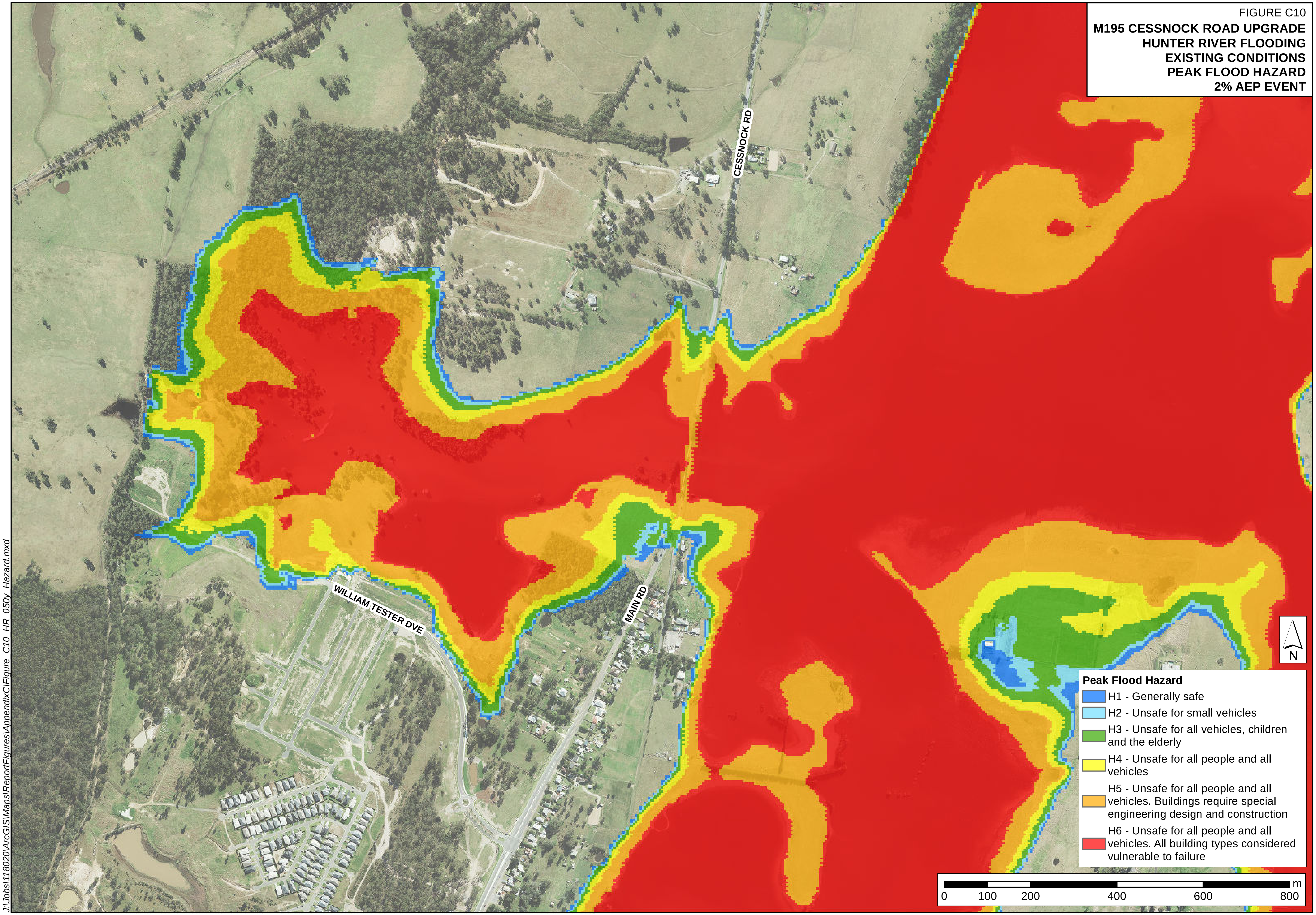

FIGURE C10
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
EXISTING CONDITIONS
PEAK FLOOD HAZARD
2% AEP EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Peak Flood Hazard
H1 - Generally safe
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unsafe for all people and all vehicles. All building types considered vulnerable to failure
0 100 200 400 600 800 m
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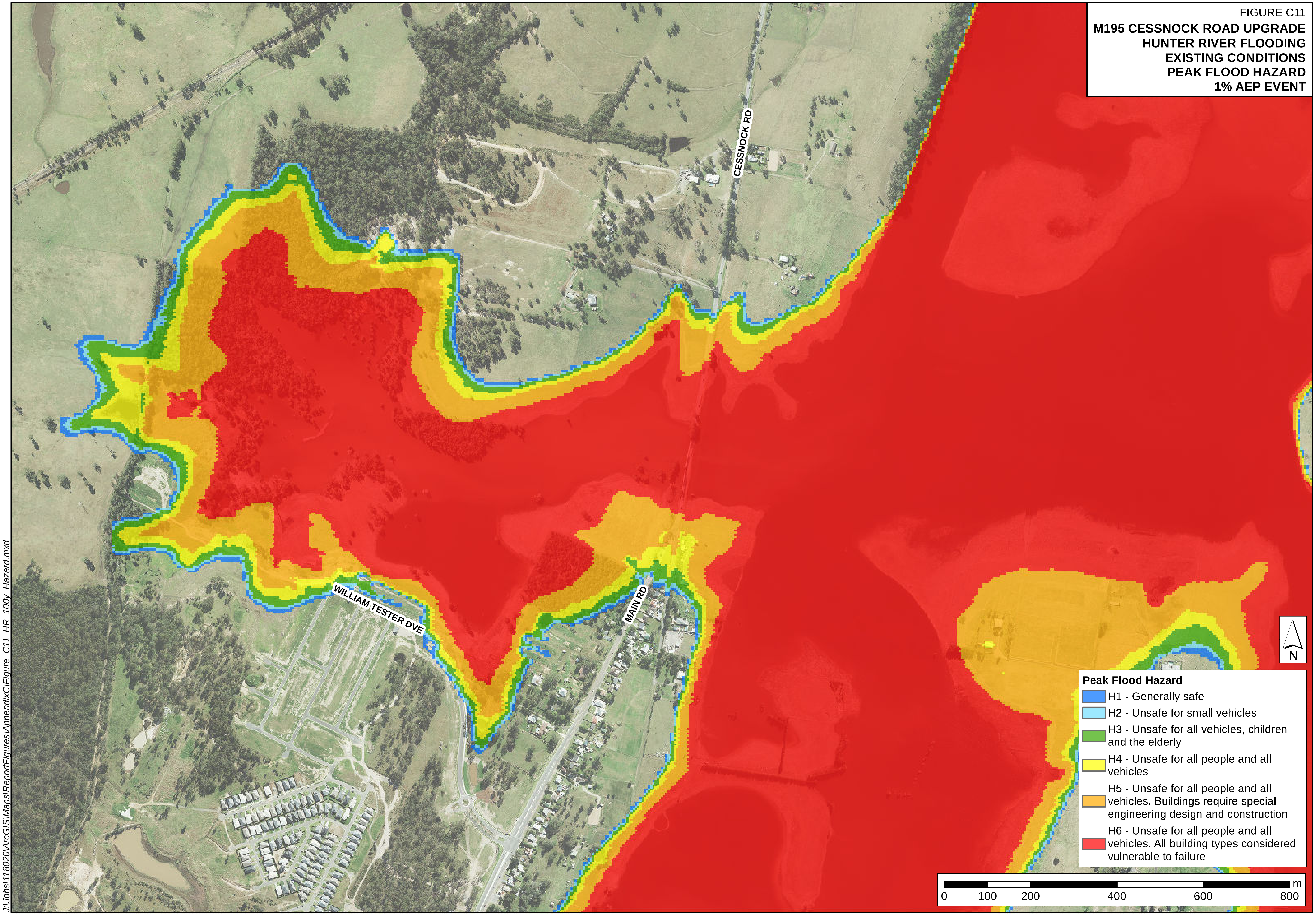

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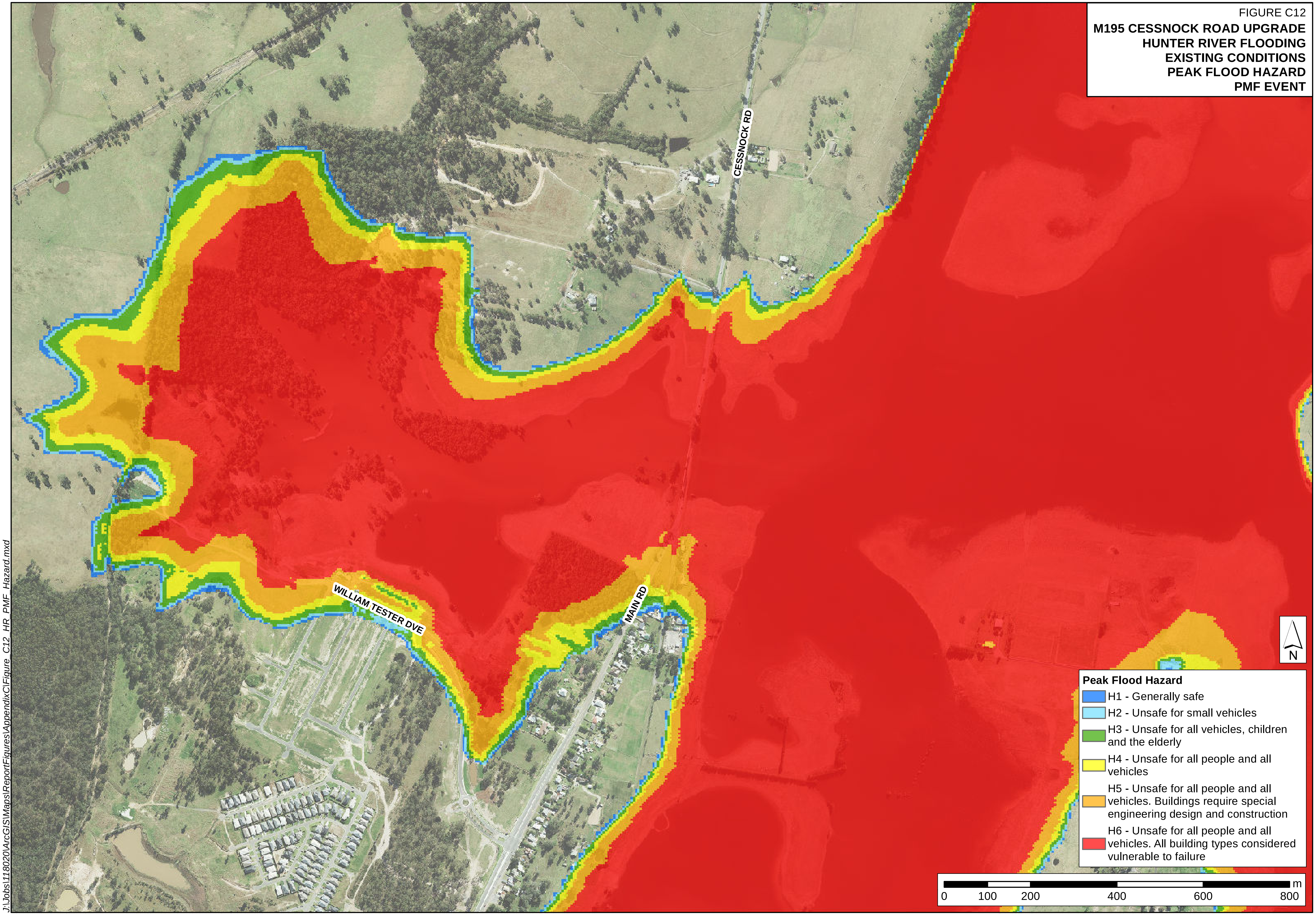
FIGURE C12

M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
EXISTING CONDITIONS
PEAK FLOOD HAZARD
PMF EVENT



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APPENDIX D. PROPOSED CONDITIONS FLOOD MAPS FOR WALLIS CREEK FLOODING

Appendix D

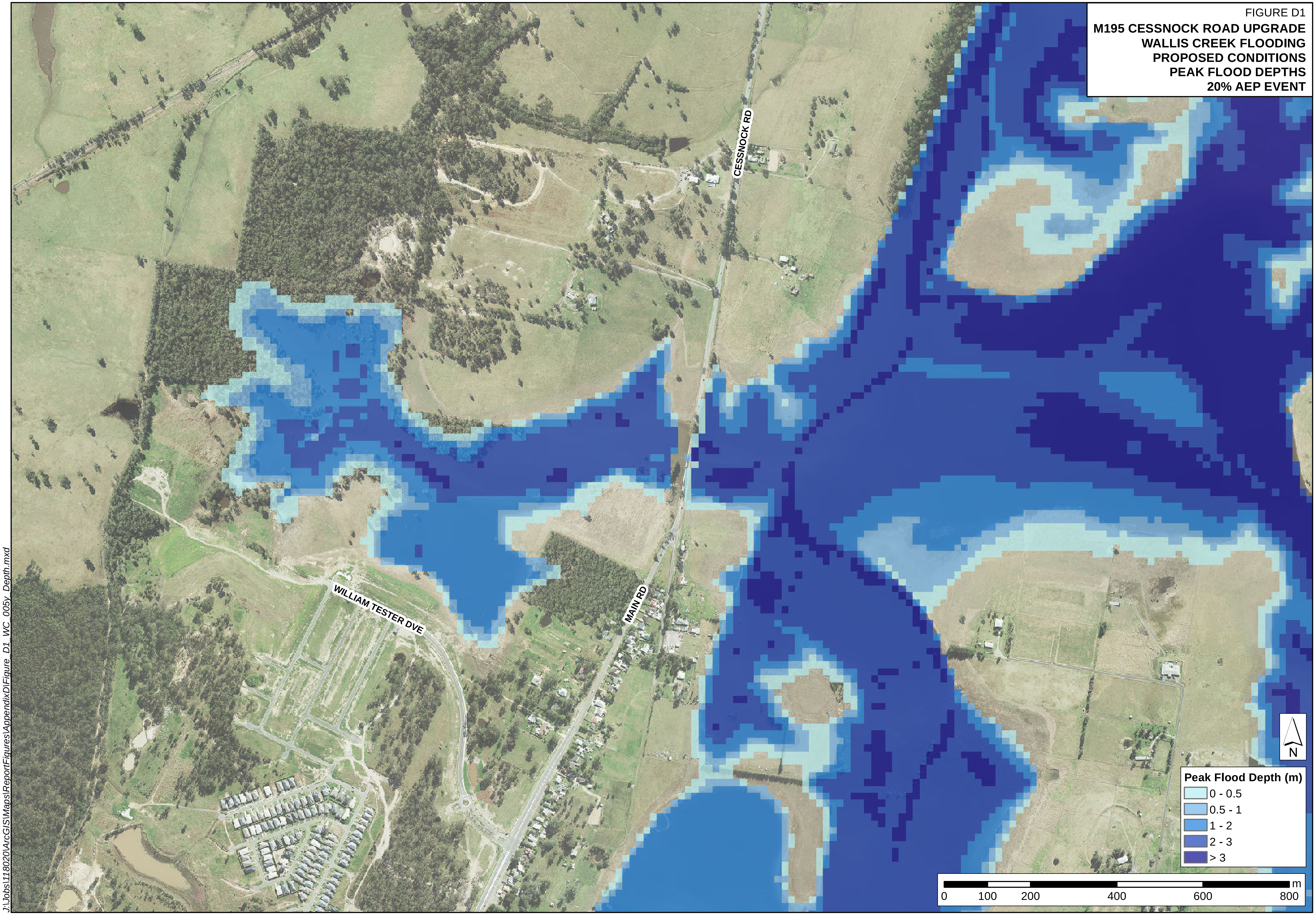
FIGURE D1
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD DEPTHS
20% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Flood Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 3
> 3
m
0
100
200
400
600
800
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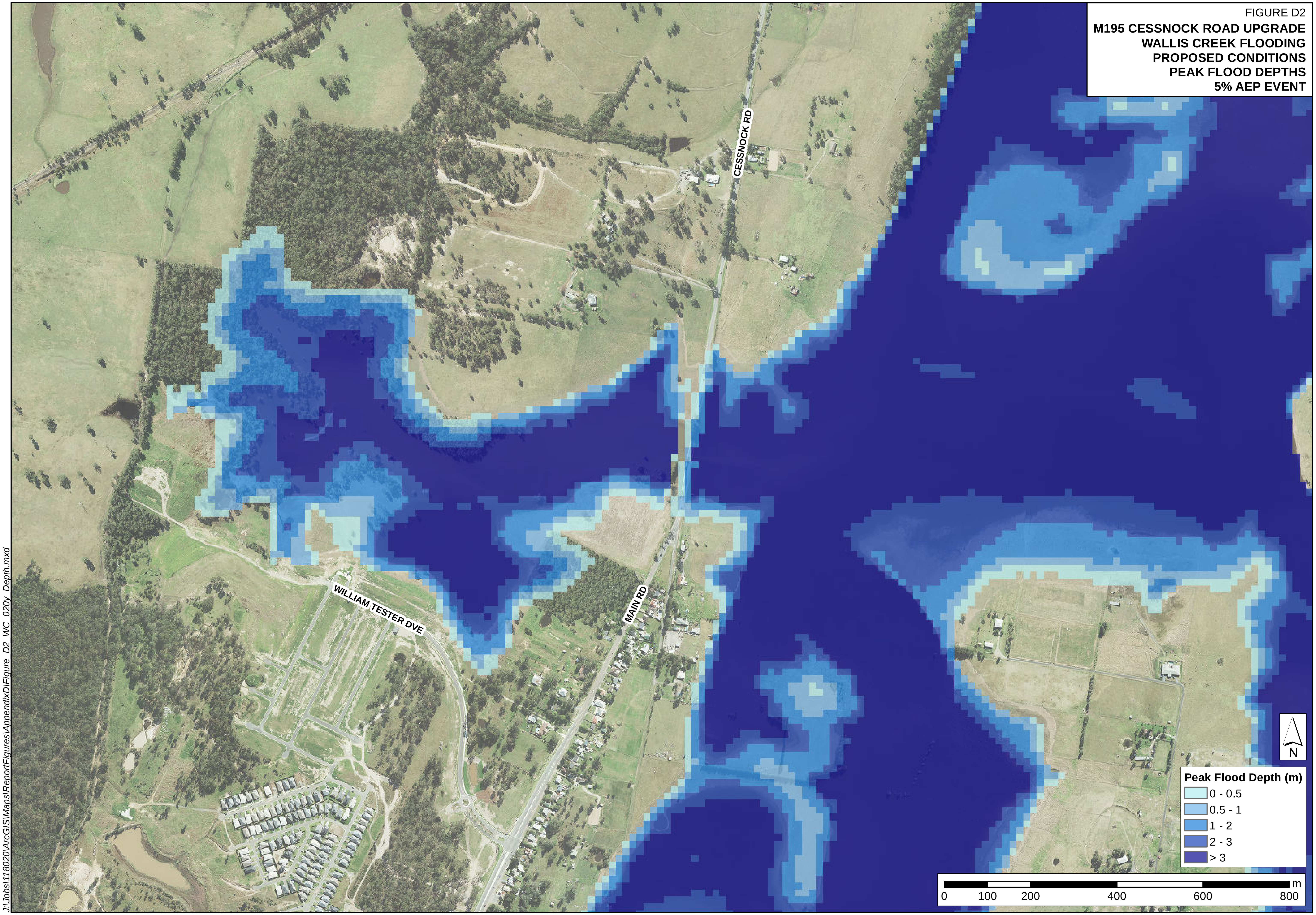
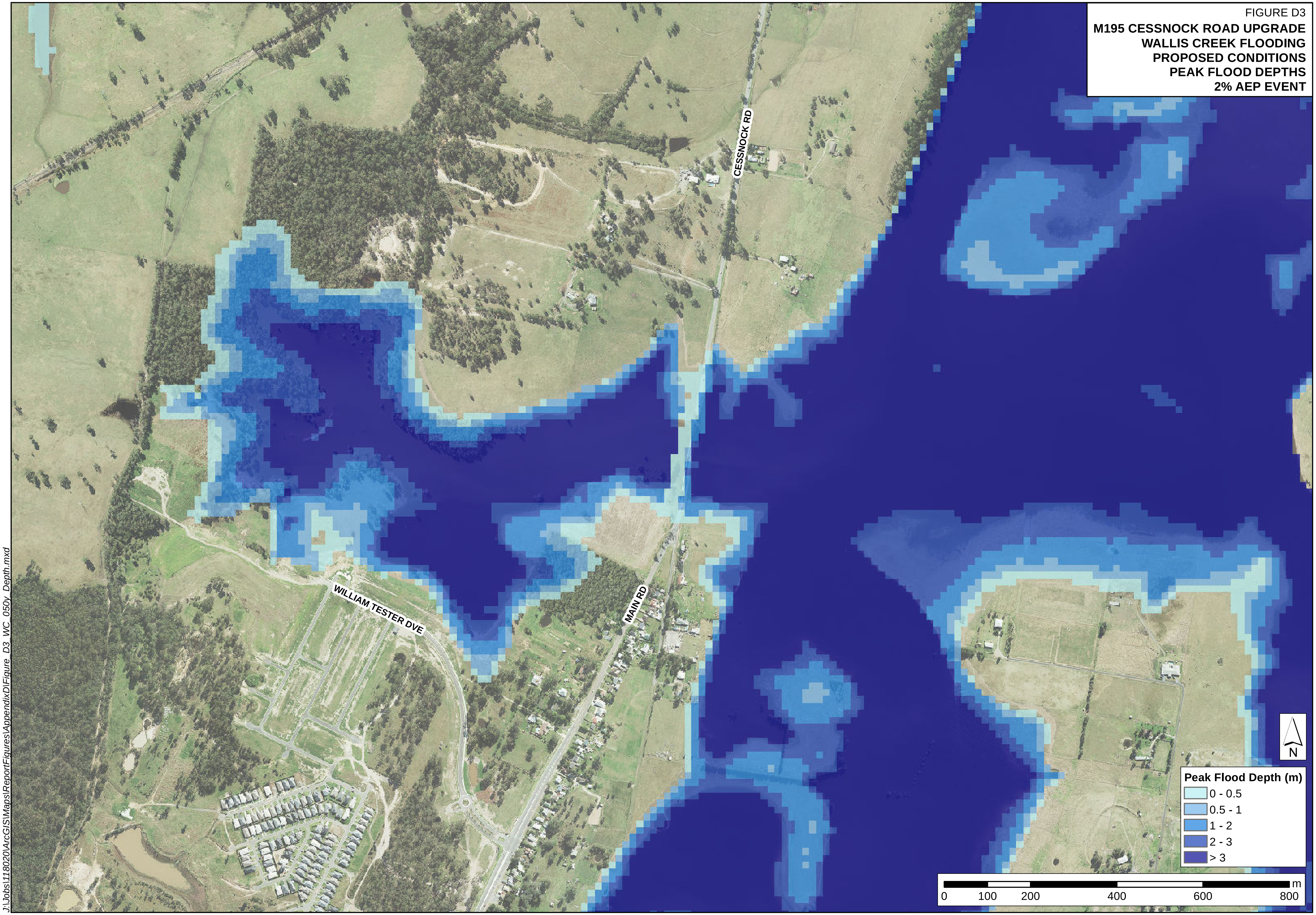


FIGURE D2
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD DEPTHS
5% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Flood Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 3
> 3
0
100
200
400
600
800
m
J:\Jobs\118020\ArcGIS\Maps\Report\Figures\Appendix\D\Figure_D2_WC_020y_Depth.mxd

FIGURE D3
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD DEPTHS
2% AEP EVENT



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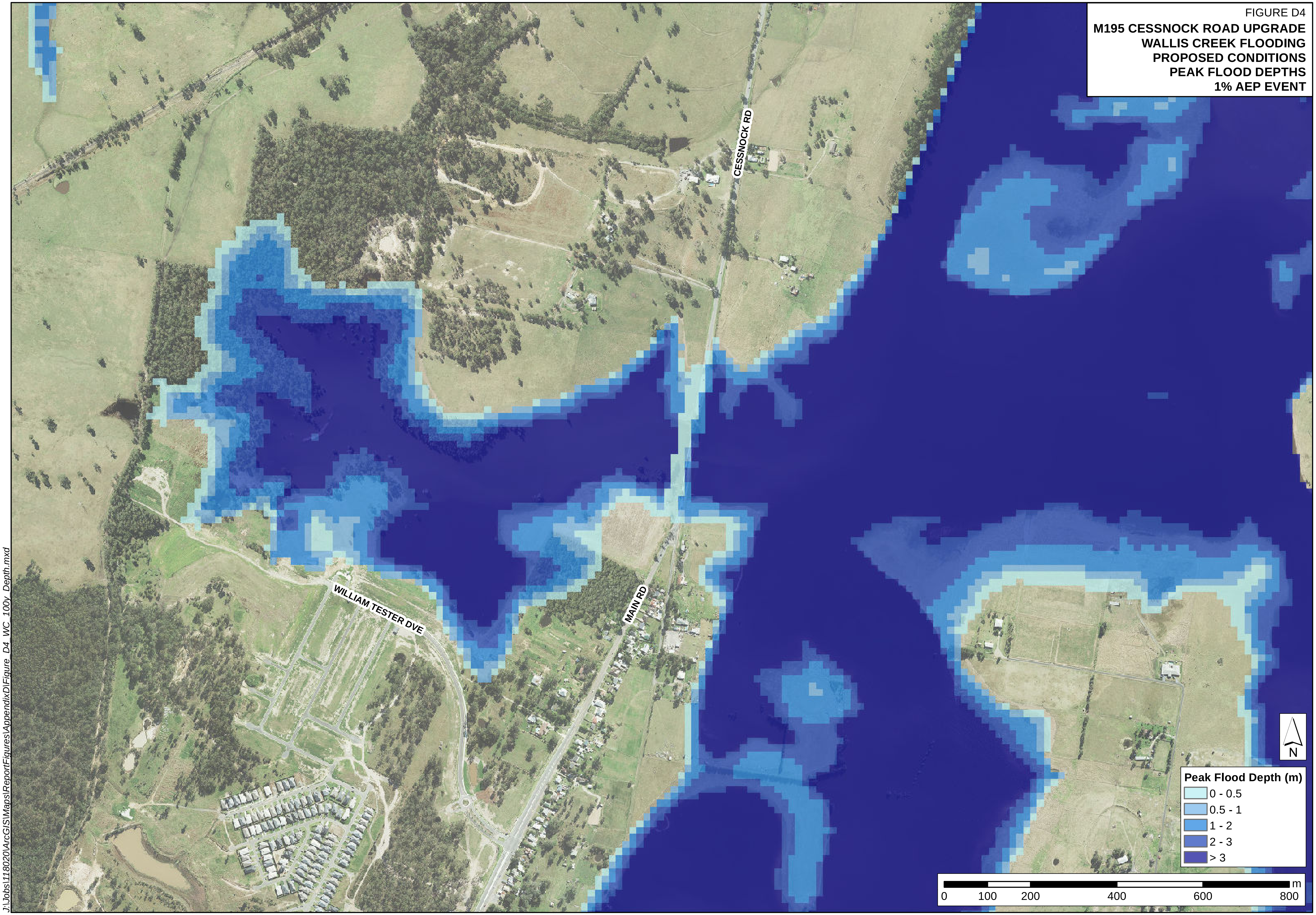

FIGURE D4
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD DEPTHS
1% AEP EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Peak Flood Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 3
> 3
m
0
100
200
400
600
800
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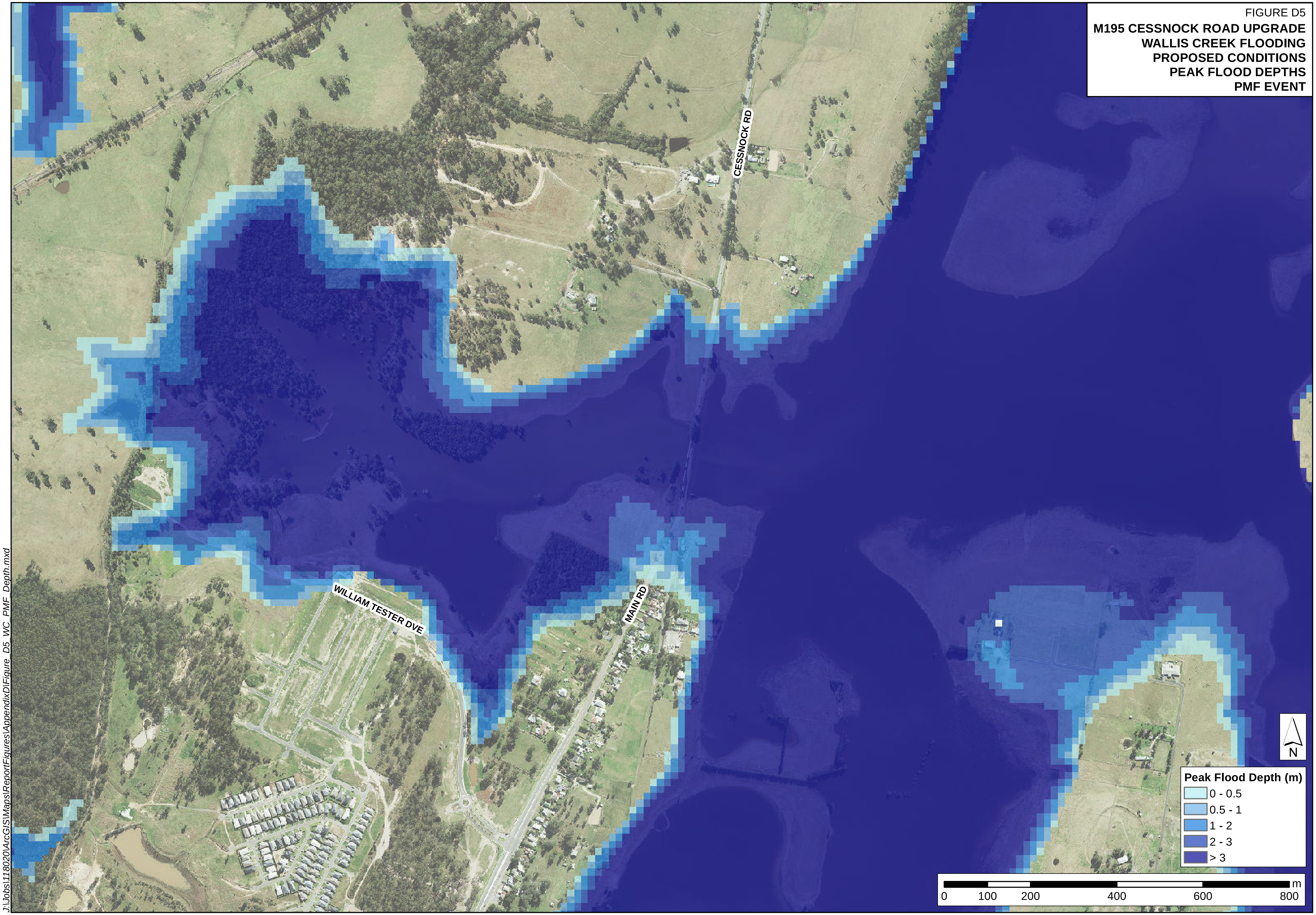


FIGURE D5
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD DEPTHS
PMF EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Peak Flood Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 3
> 3
m
0
100
200
400
600
800
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixD\Figure_D5_WC_PMF_Depth.mxd

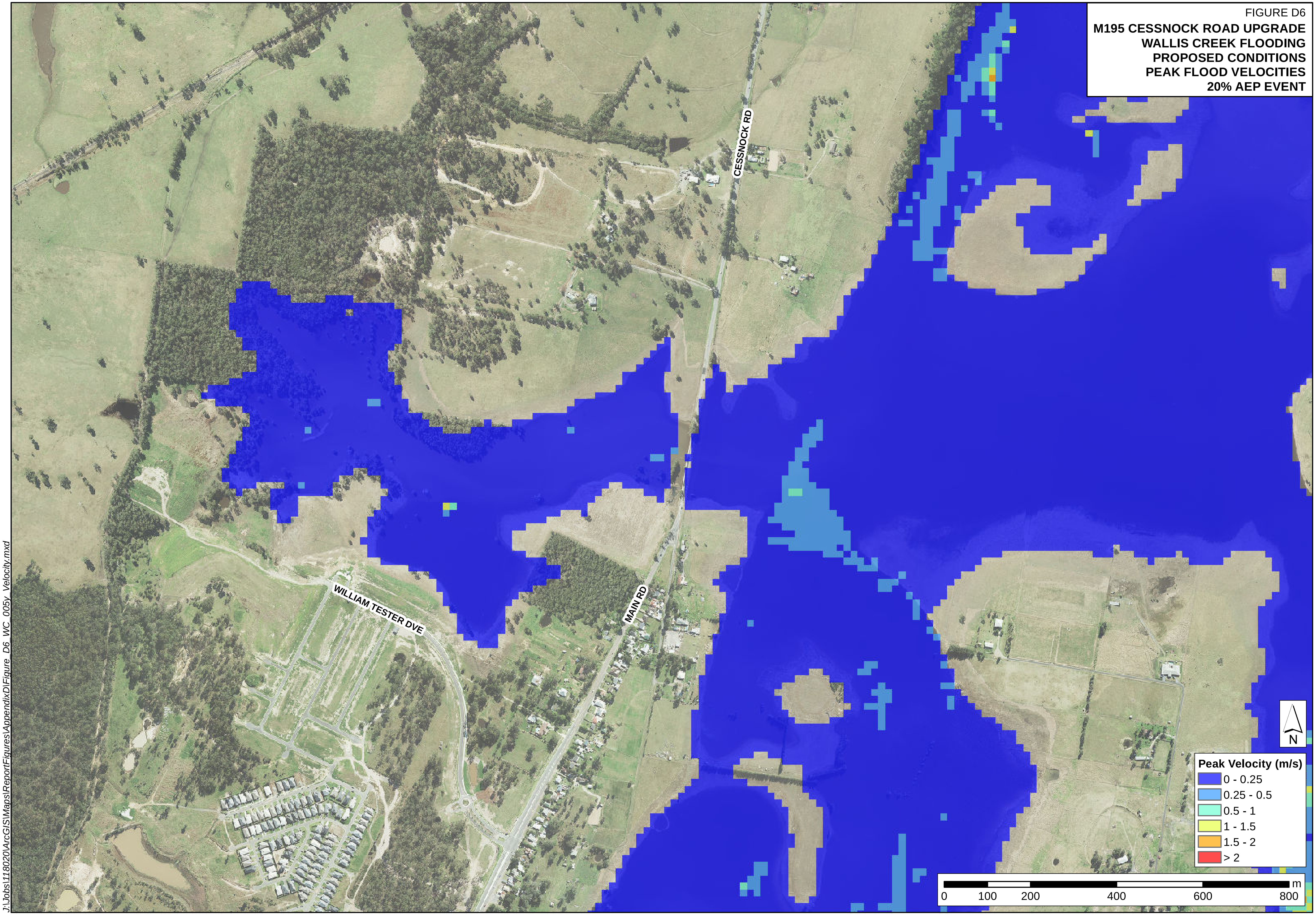


FIGURE D6
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD VELOCITIES
20% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
> 2
m
0
100
200
400
600
800
J:\Jobs\118020\ArcGIS\Maps\Report\Figures\AppendixD\Figure_D6_WC_005y_Velocity.mxd

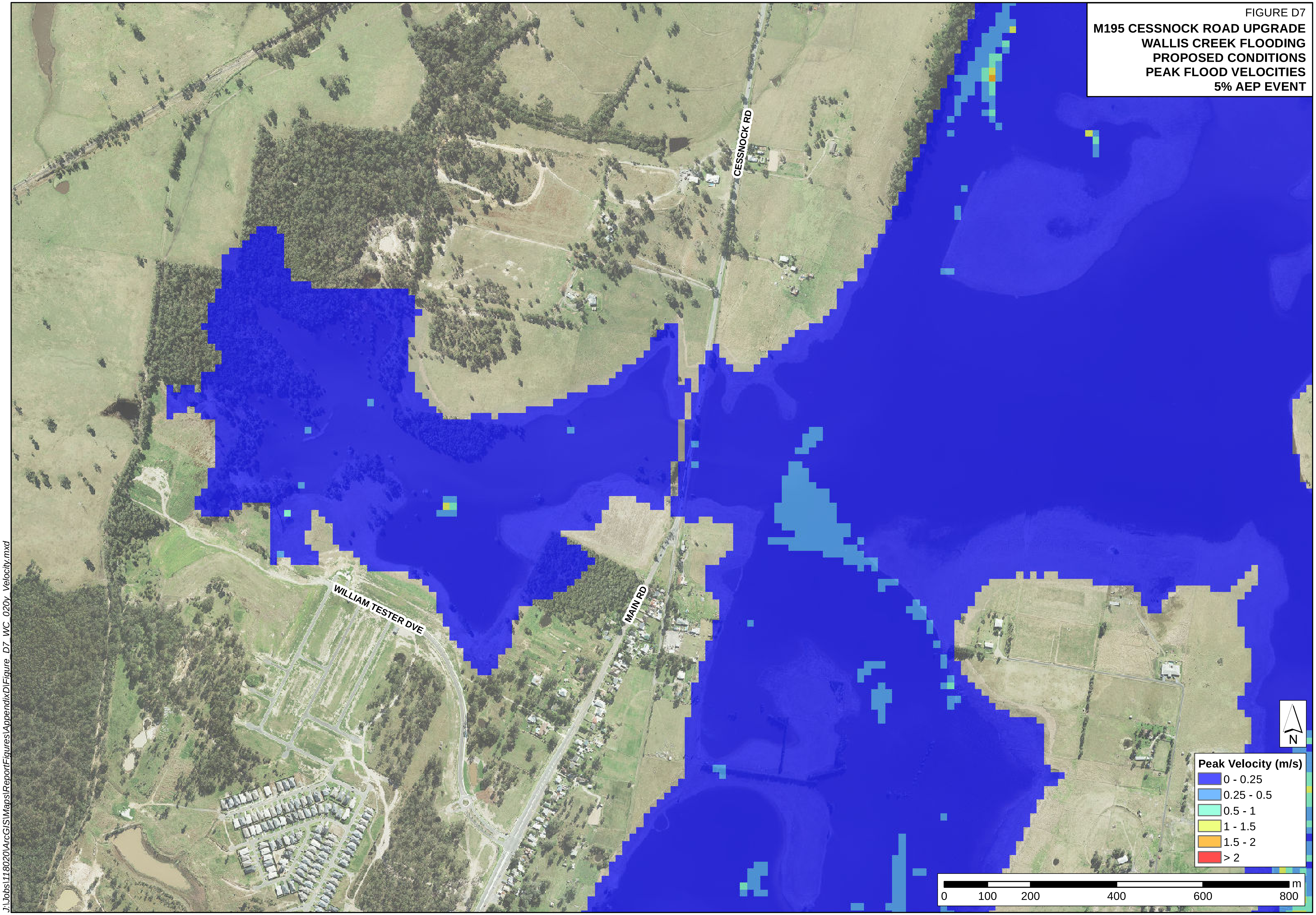
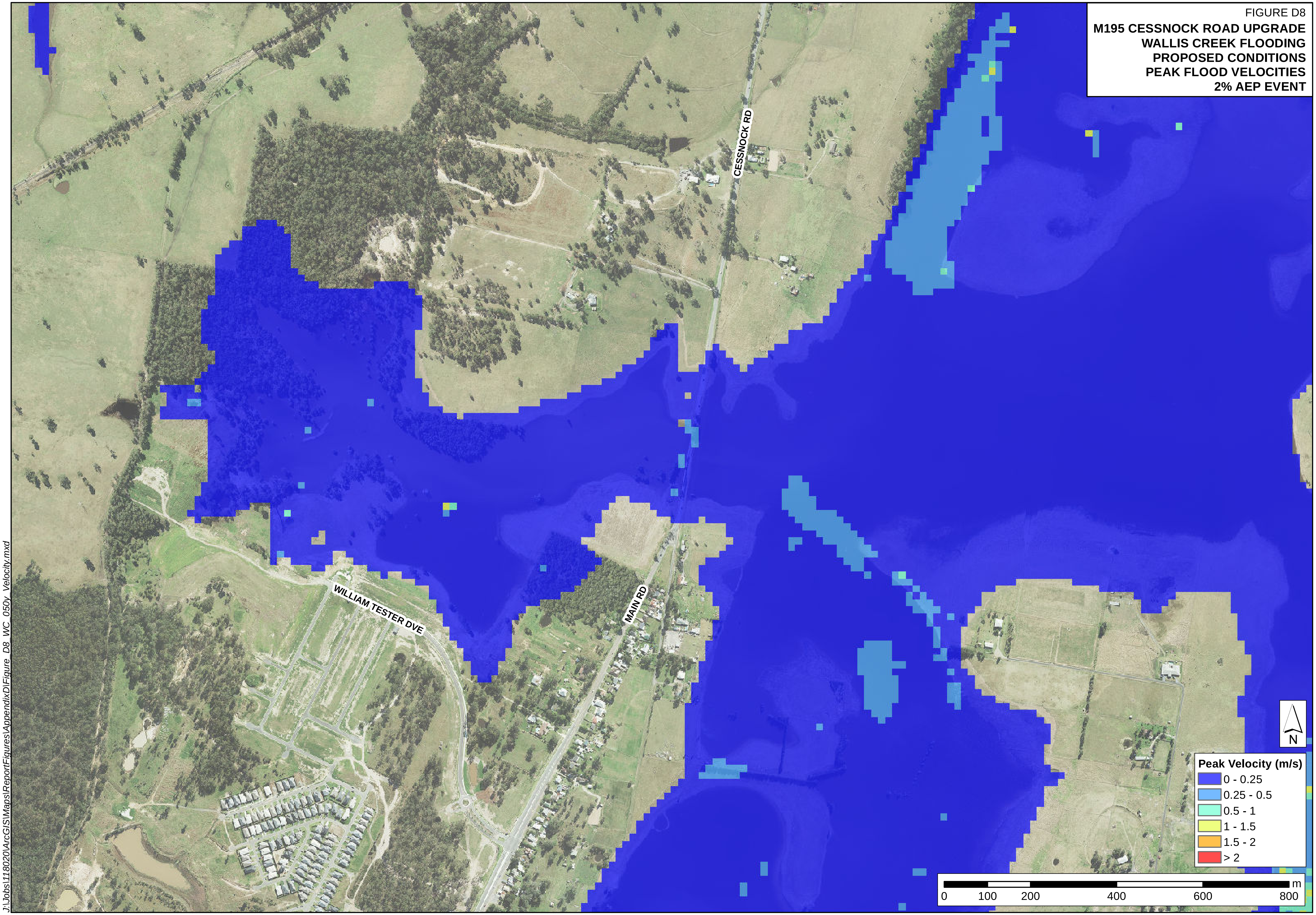


FIGURE D7
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD VELOCITIES
5% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
> 2
0
100
200
400
600
800
m
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixD\Figure_D7_WC_020y_Velocity.mxd

FIGURE D8
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD VELOCITIES
2% AEP EVENT



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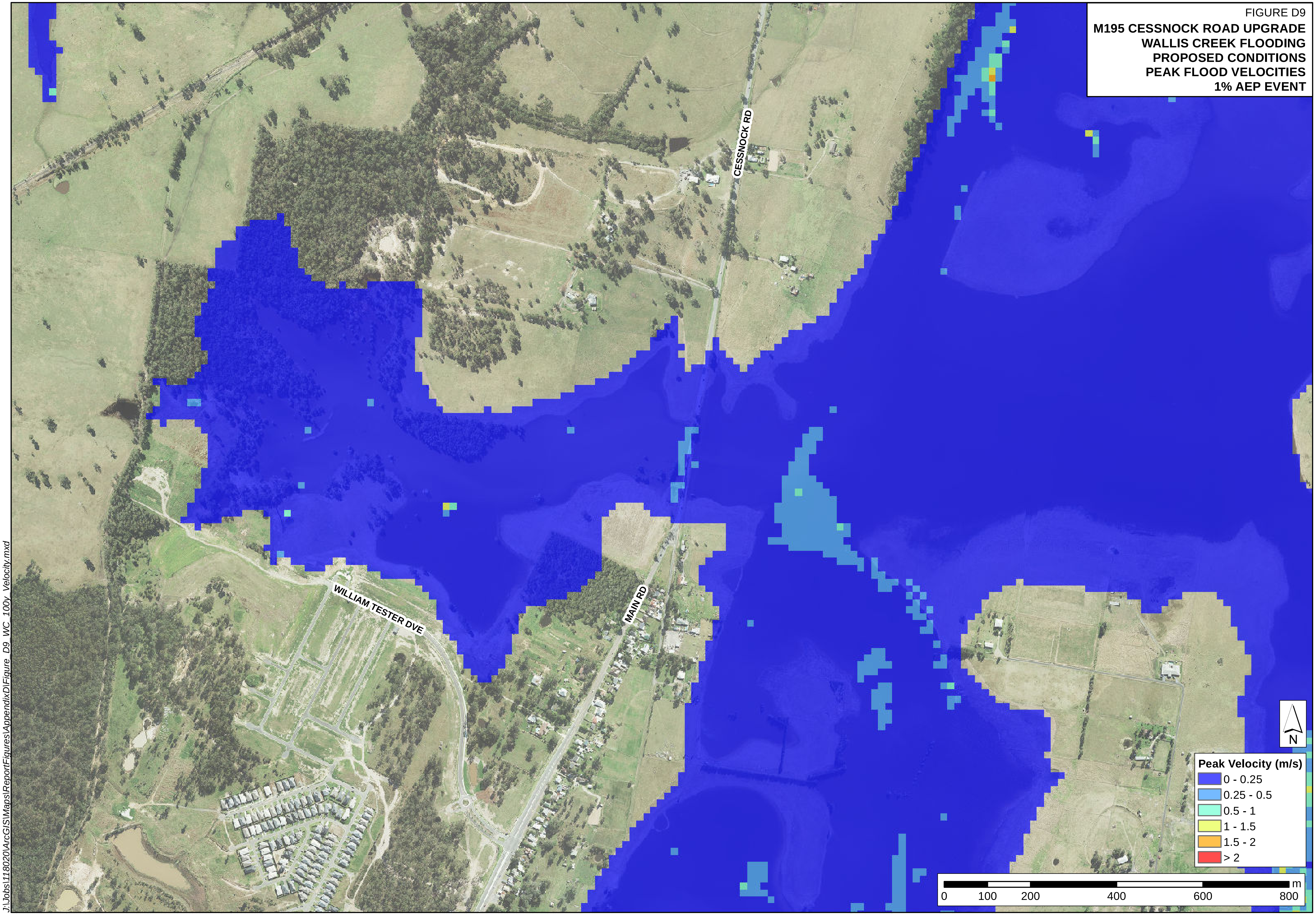


FIGURE D9
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD VELOCITIES
1% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
> 2
0
100
200
400
600
800
m
J:\Jobs\118020\ArcGIS\Maps\Report\Figures\AppendixD\Figure_D9_WC_100y_Velocity.mxd

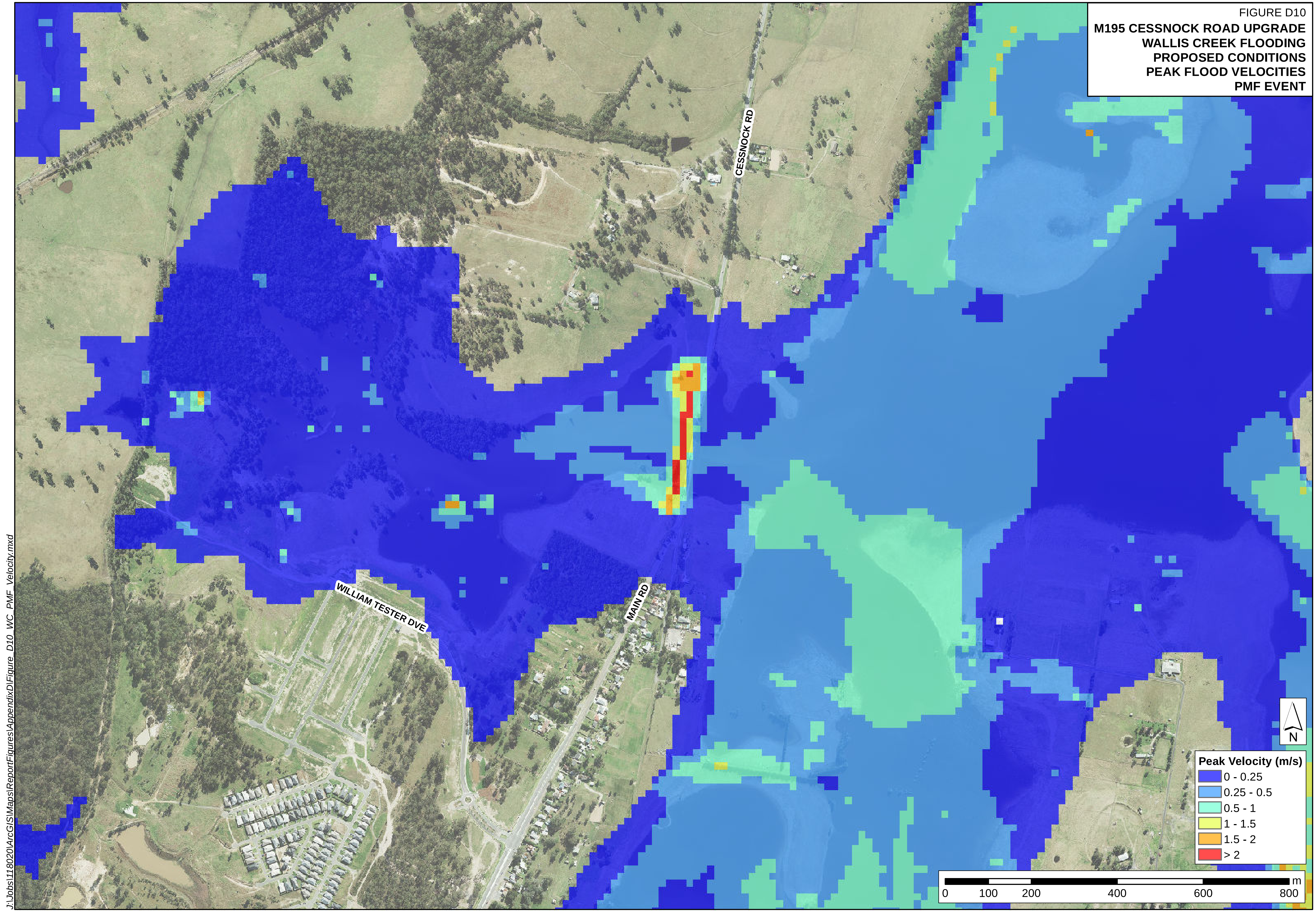
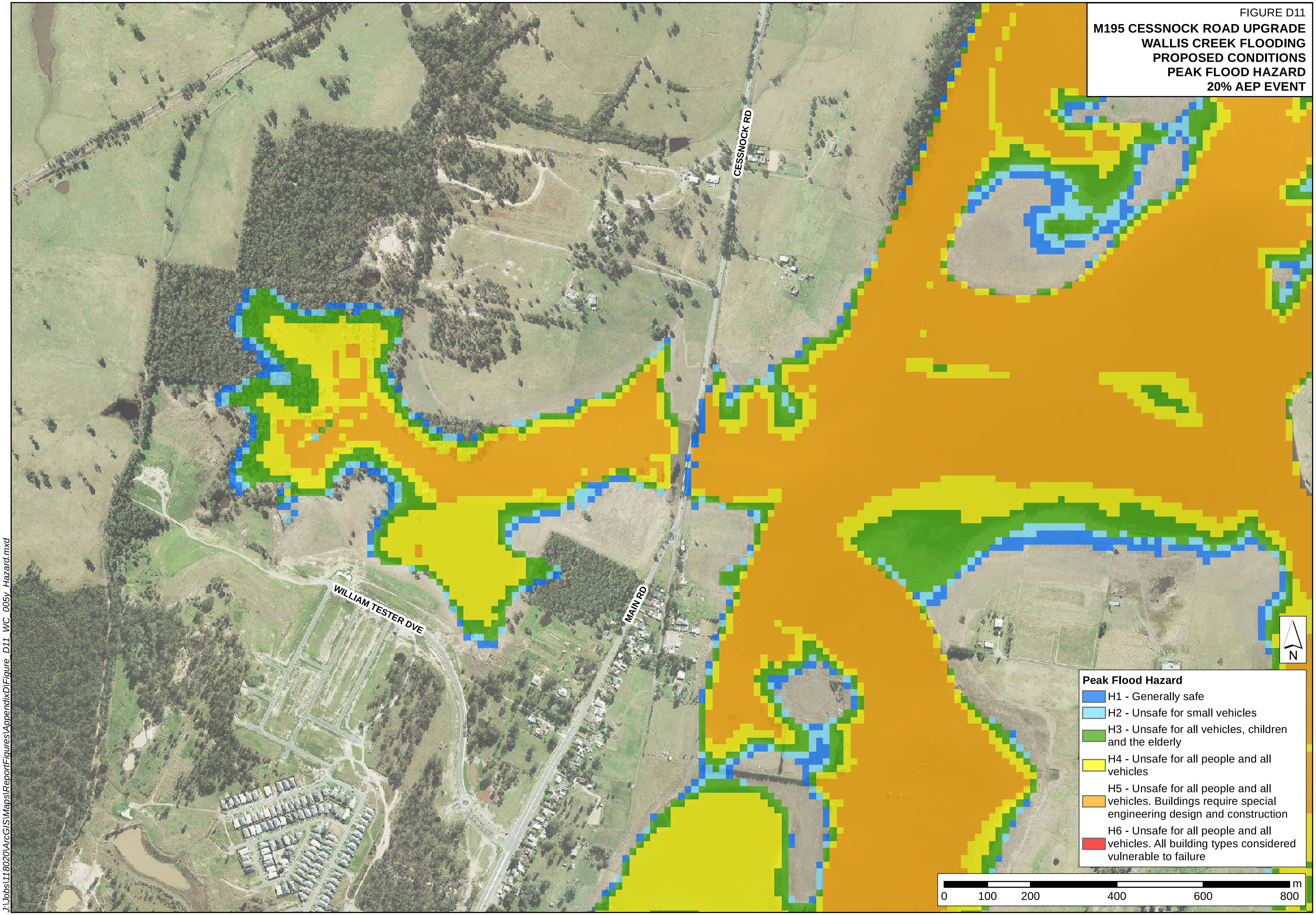


FIGURE D10
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD VELOCITIES
PMF EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
> 2
0 100 200 400 600 800 m
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixD\Figure_D10_WC_PMF_Velocity.mxd



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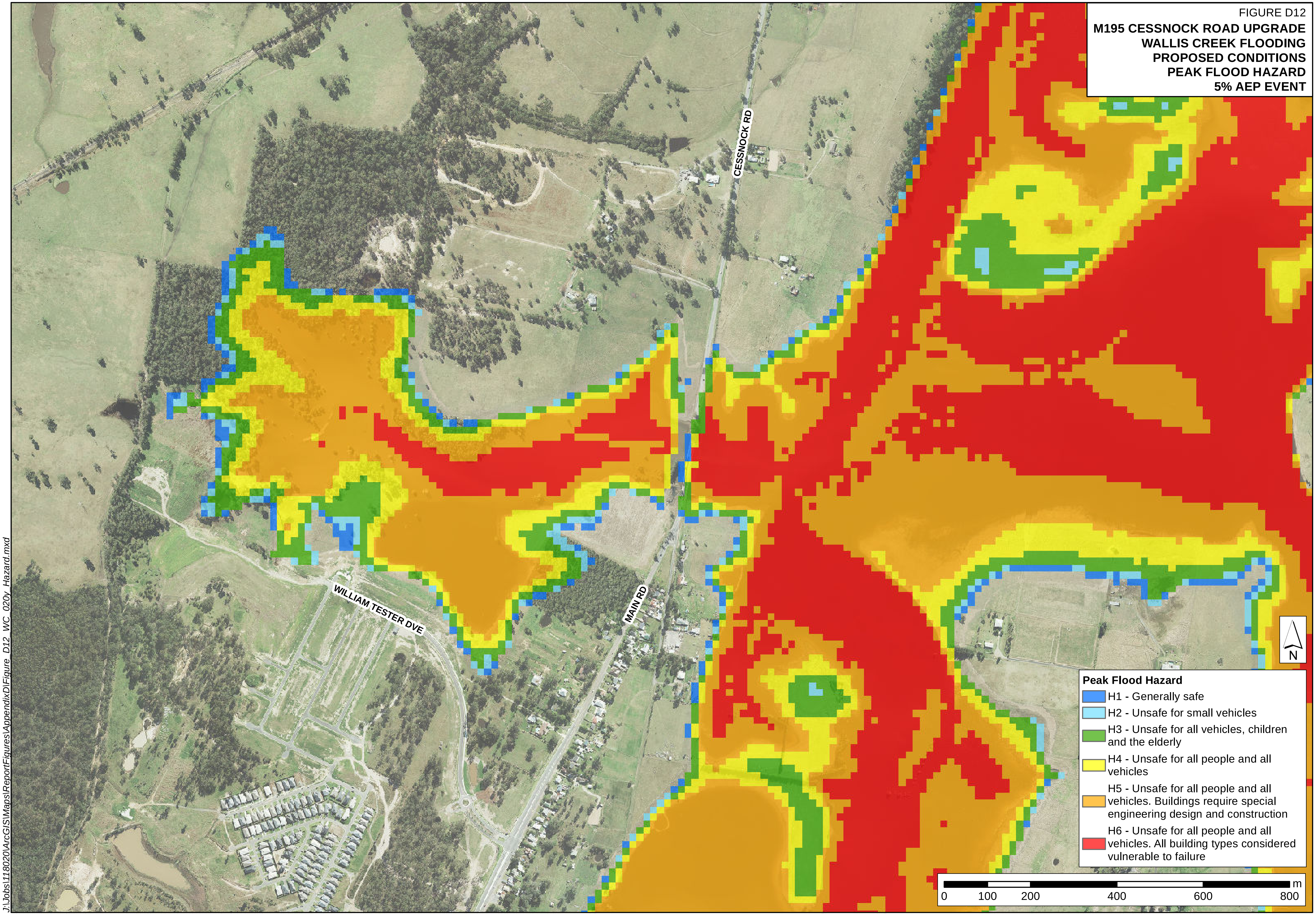
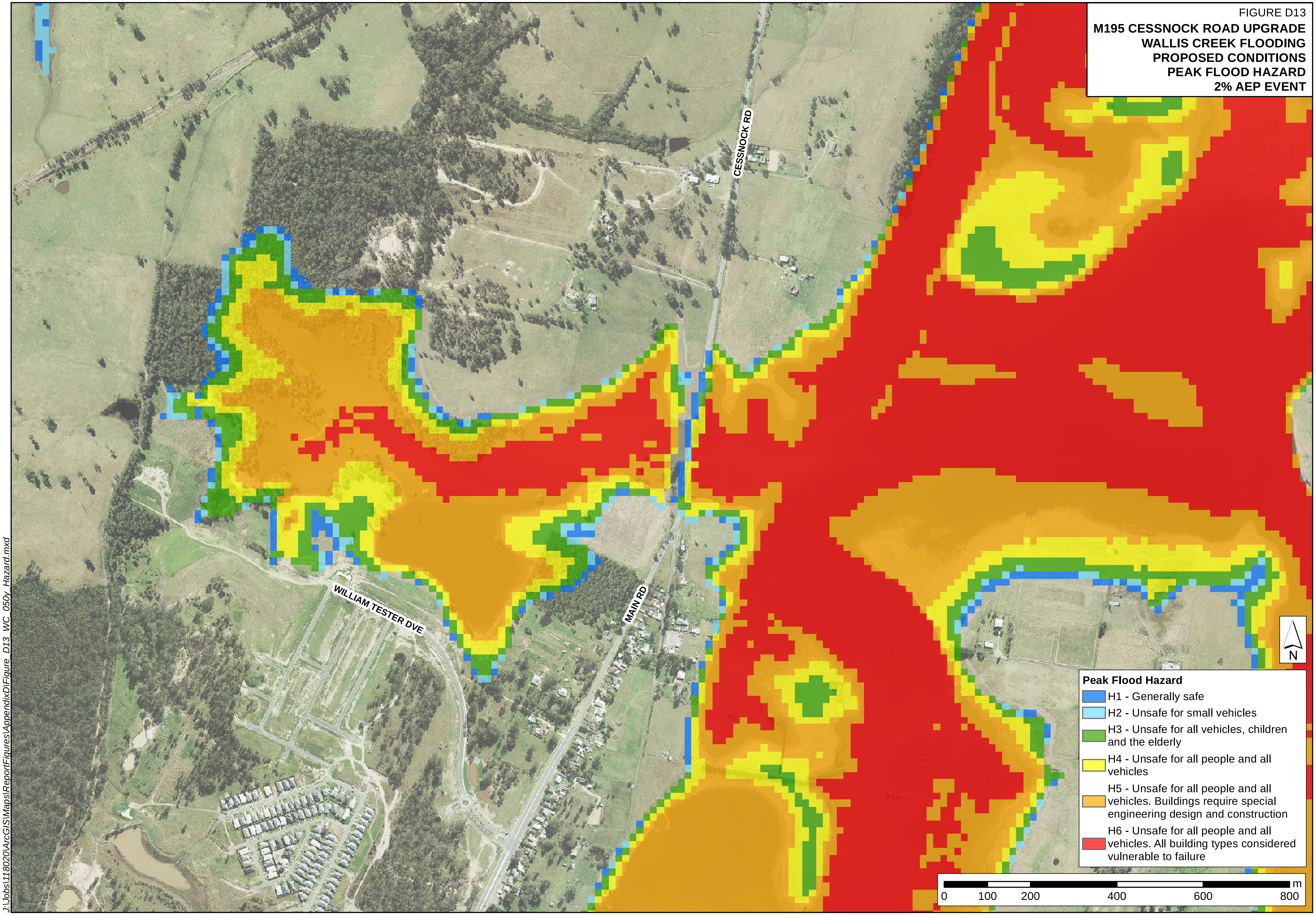


FIGURE D12
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD HAZARD
5% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Flood Hazard
H1 - Generally safe
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unsafe for all people and all vehicles. All building types considered vulnerable to failure
0 100 200 400 600 800 m
J:\Jobs\118020\ArcGIS\Maps\Report\Figures\AppendixD\Figure_D12_WC_020y_Hazard.mxd

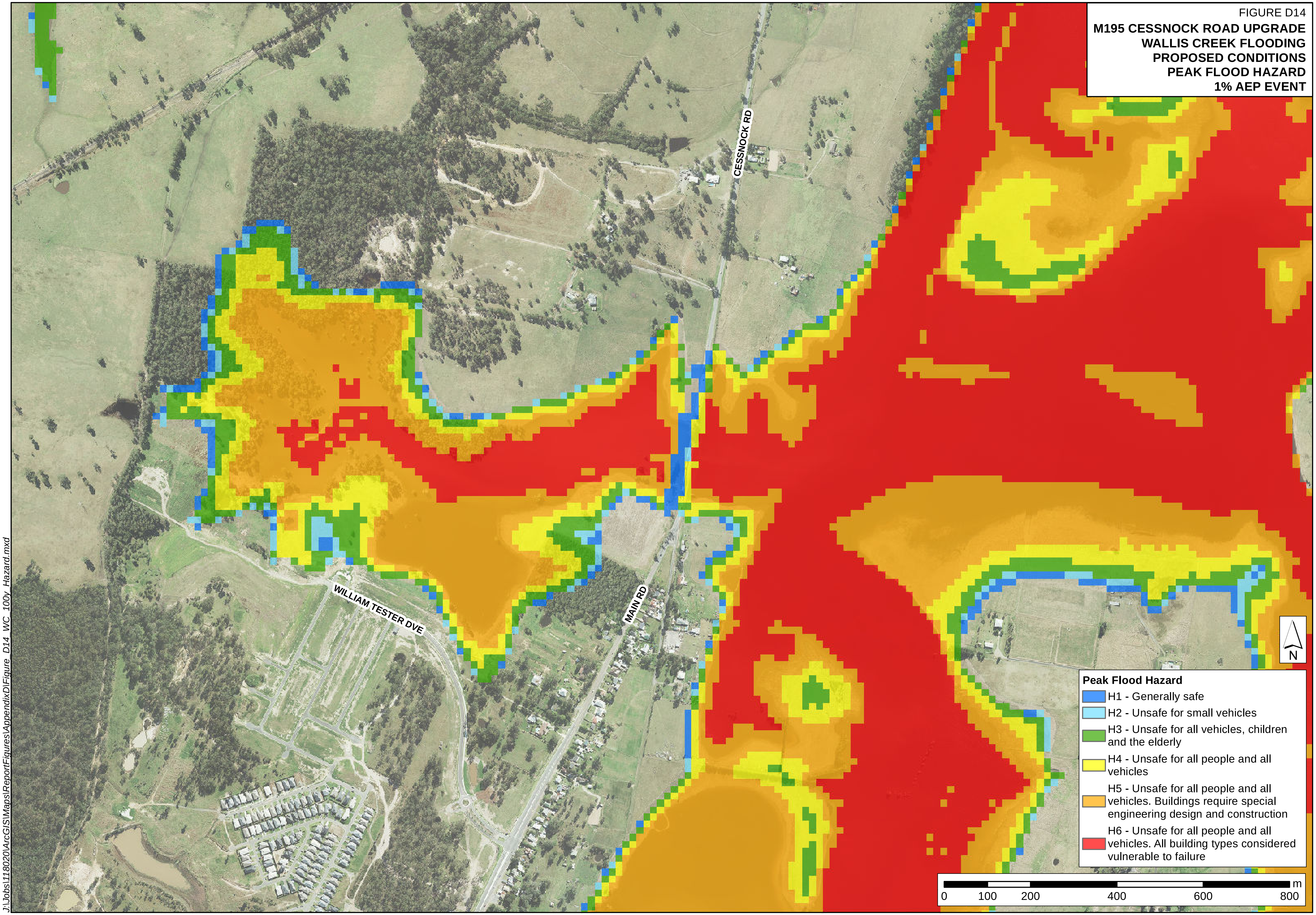
FIGURE D13
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD HAZARD
2% AEP EVENT



J:\Jobs\118020\ArcGIS\Maps\Report\Figures\AppendixD\Figure_D13_WC_050y_Hazard.mxd

FIGURE D14

M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
PEAK FLOOD HAZARD
1% AEP EVENT



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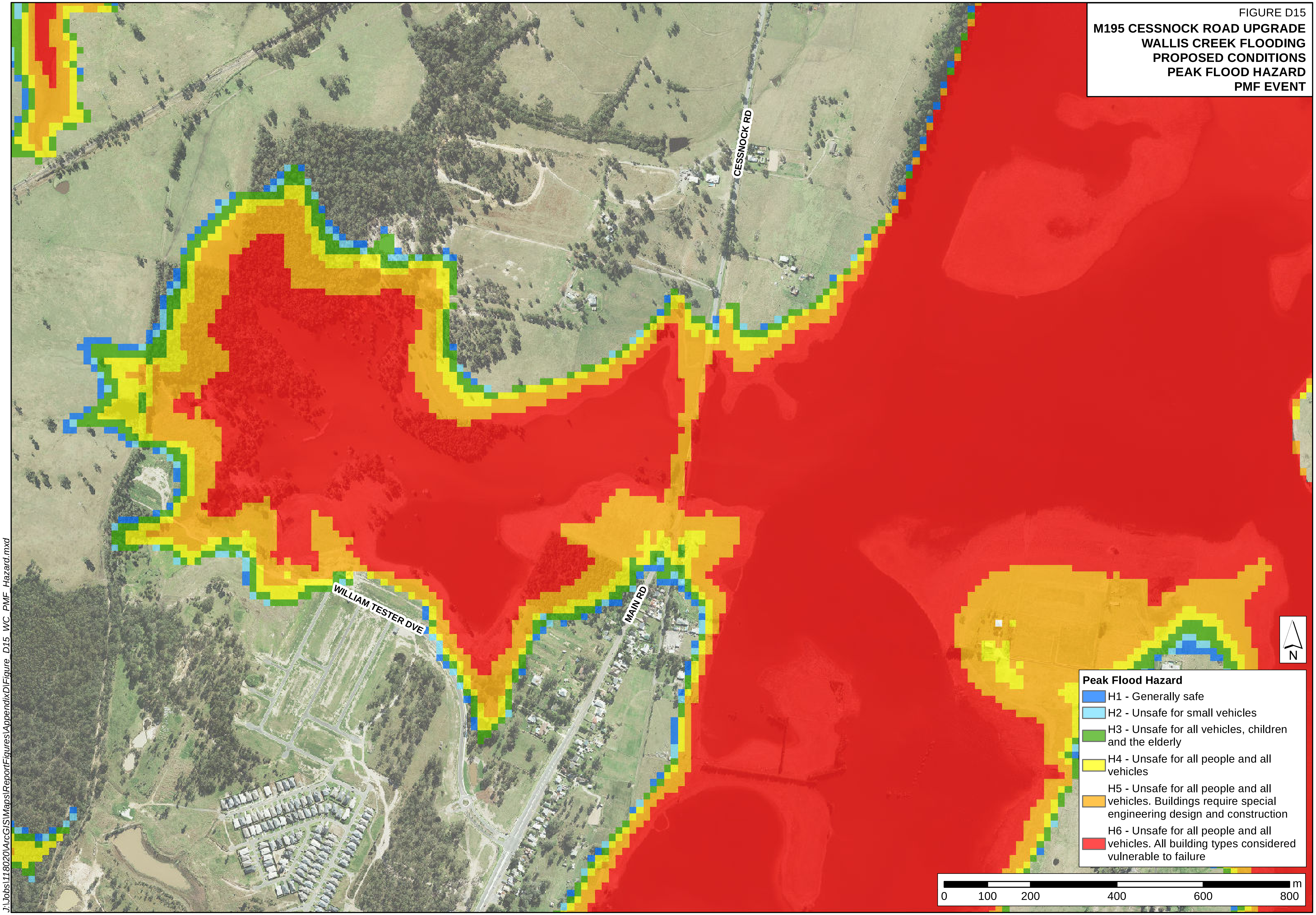
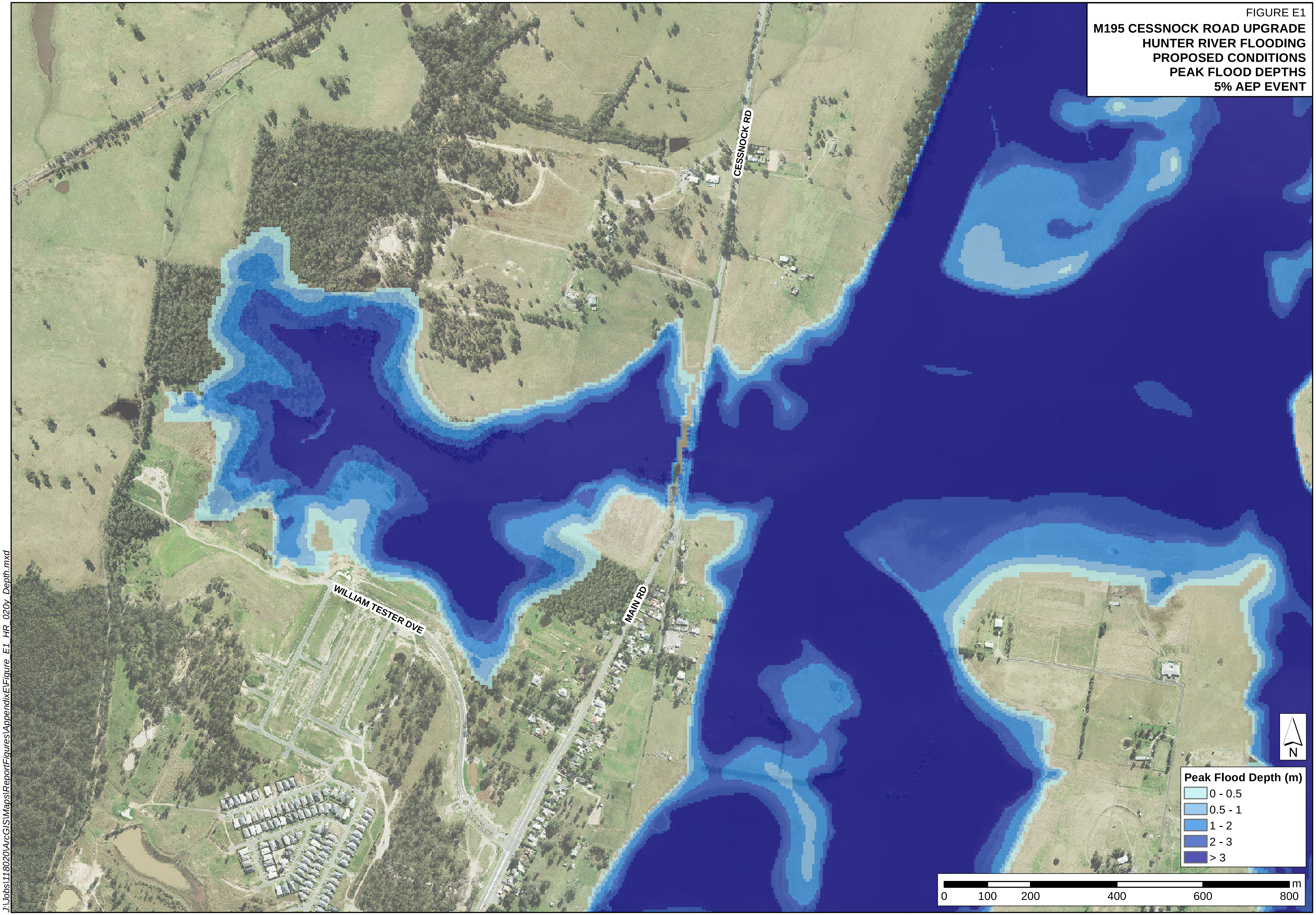


J:\Jobs\118020\ArcGIS\Maps\Report\Figures\AppendixD\Figure_D15_WC_PMF_Hazard.mxd

APPENDIX E. PROPOSED CONDITIONS FLOOD MAPS FOR HUNTER RIVER FLOODING



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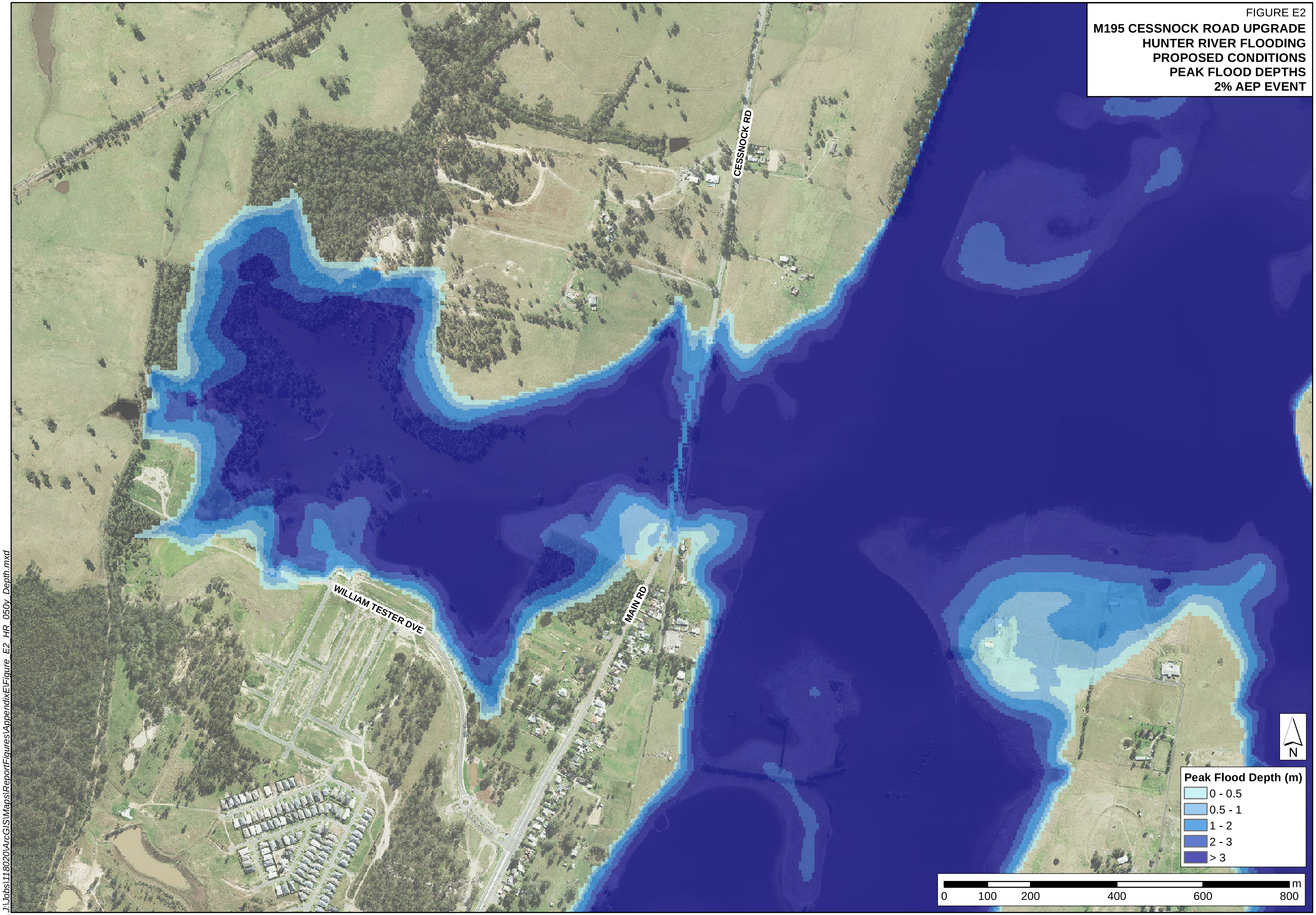
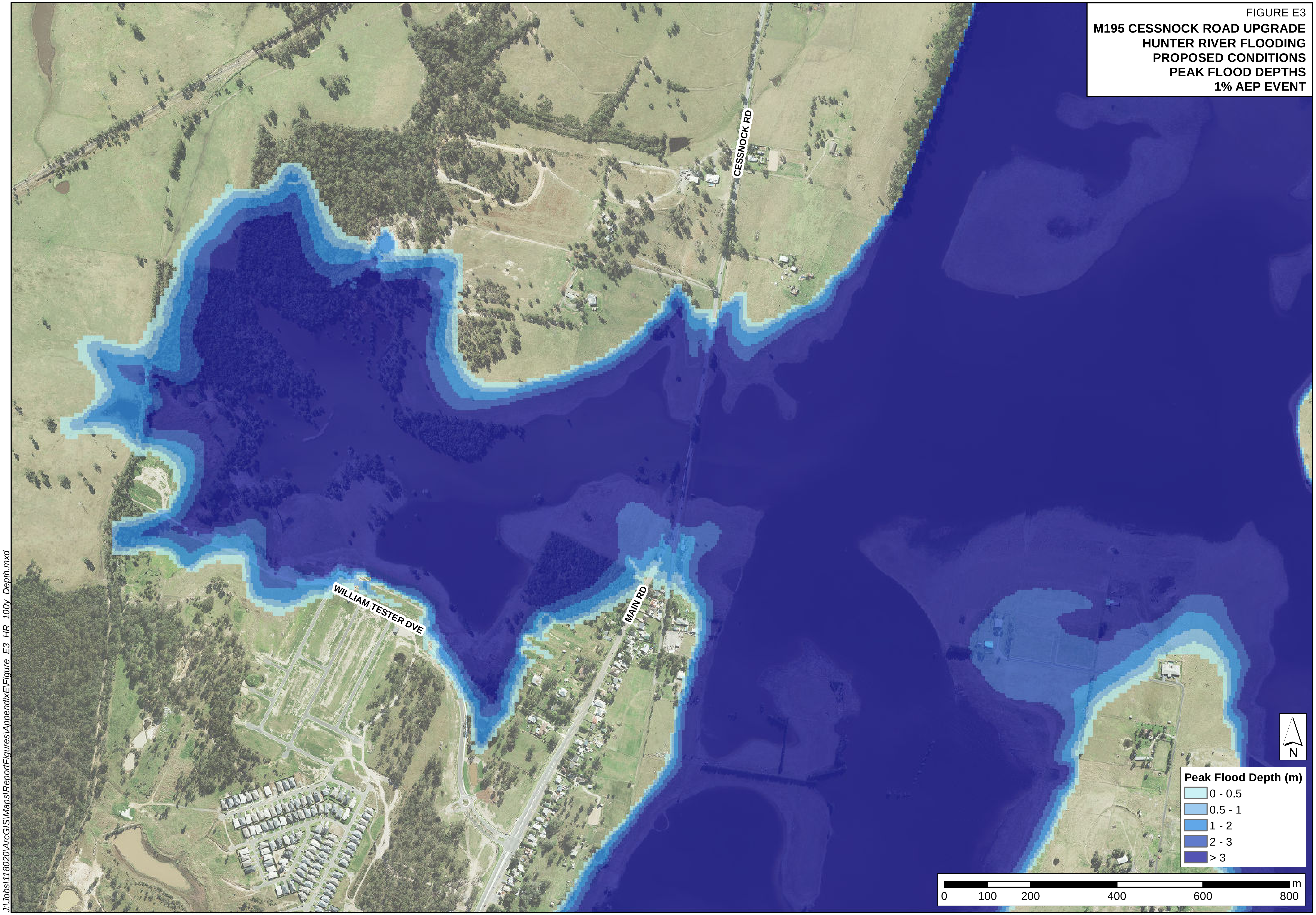


FIGURE E2
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
PEAK FLOOD DEPTHS
2% AEP EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Peak Flood Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 3
> 3
0
100
200
400
600
800
m
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixE\Figure_E2_HR_050y_Depth.mxd



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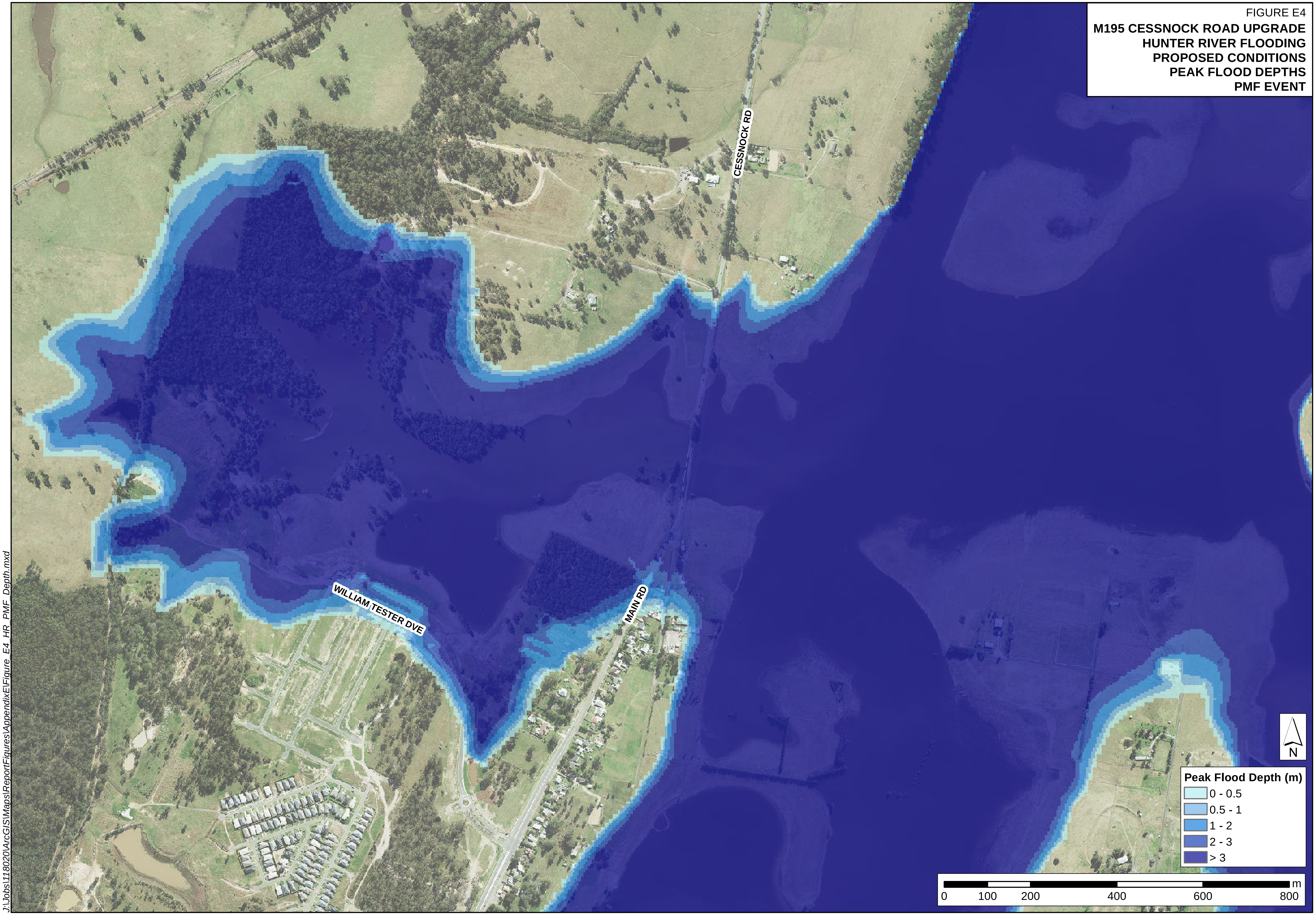


FIGURE E4
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
PEAK FLOOD DEPTHS
PMF EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Peak Flood Depth (m)
0 - 0.5
0.5 - 1
1 - 2
2 - 3
> 3
m
0
100
200
400
600
800
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixE\Figure_E4_HR_PMF_Depth.mxd

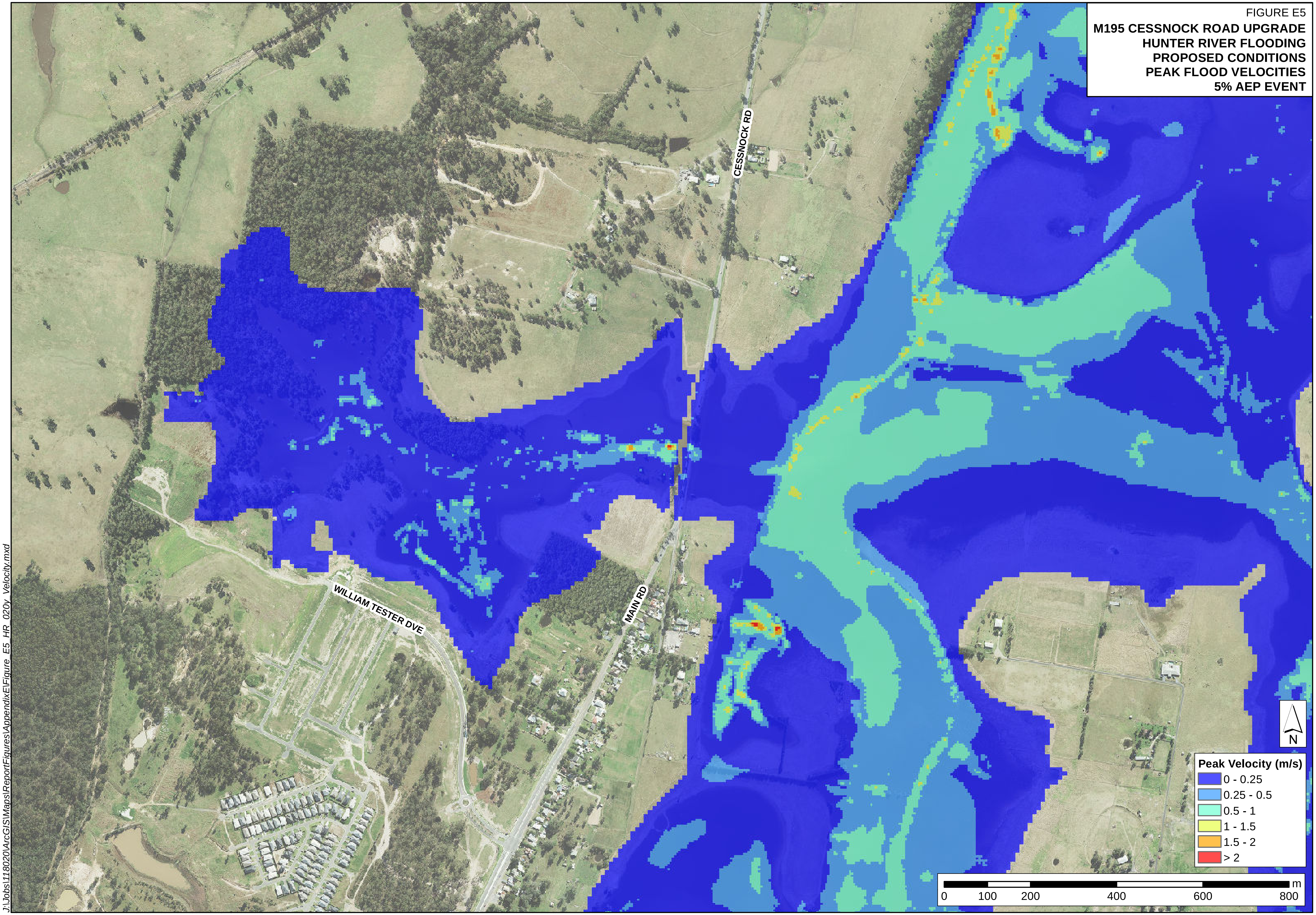
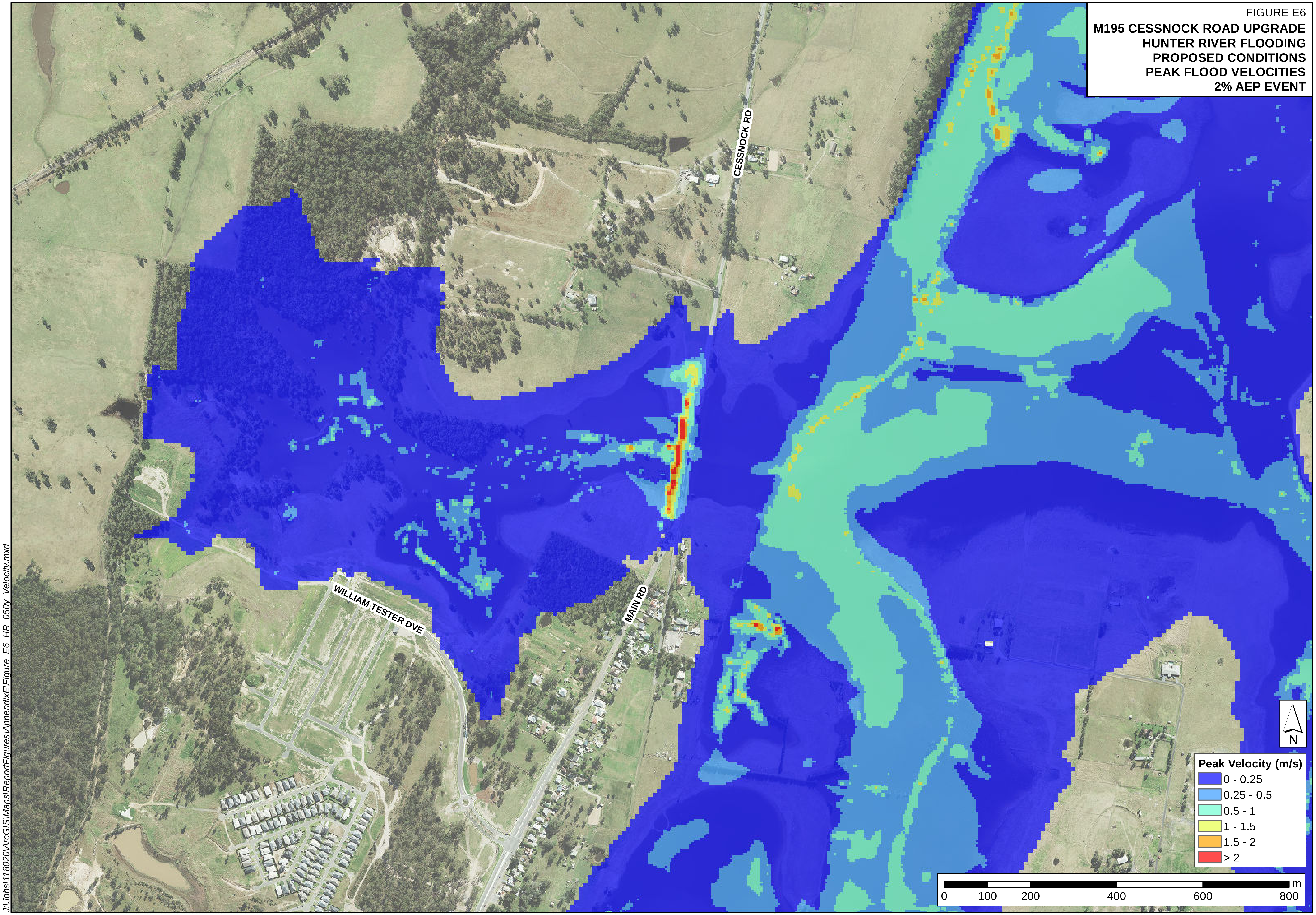


FIGURE E5
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
PEAK FLOOD VELOCITIES
5% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
> 2
m
0
100
200
400
600
800
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixE\Figure_E5_HR_020y_Velocity.mxd

FIGURE E6

M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
PEAK FLOOD VELOCITIES
2% AEP EVENT



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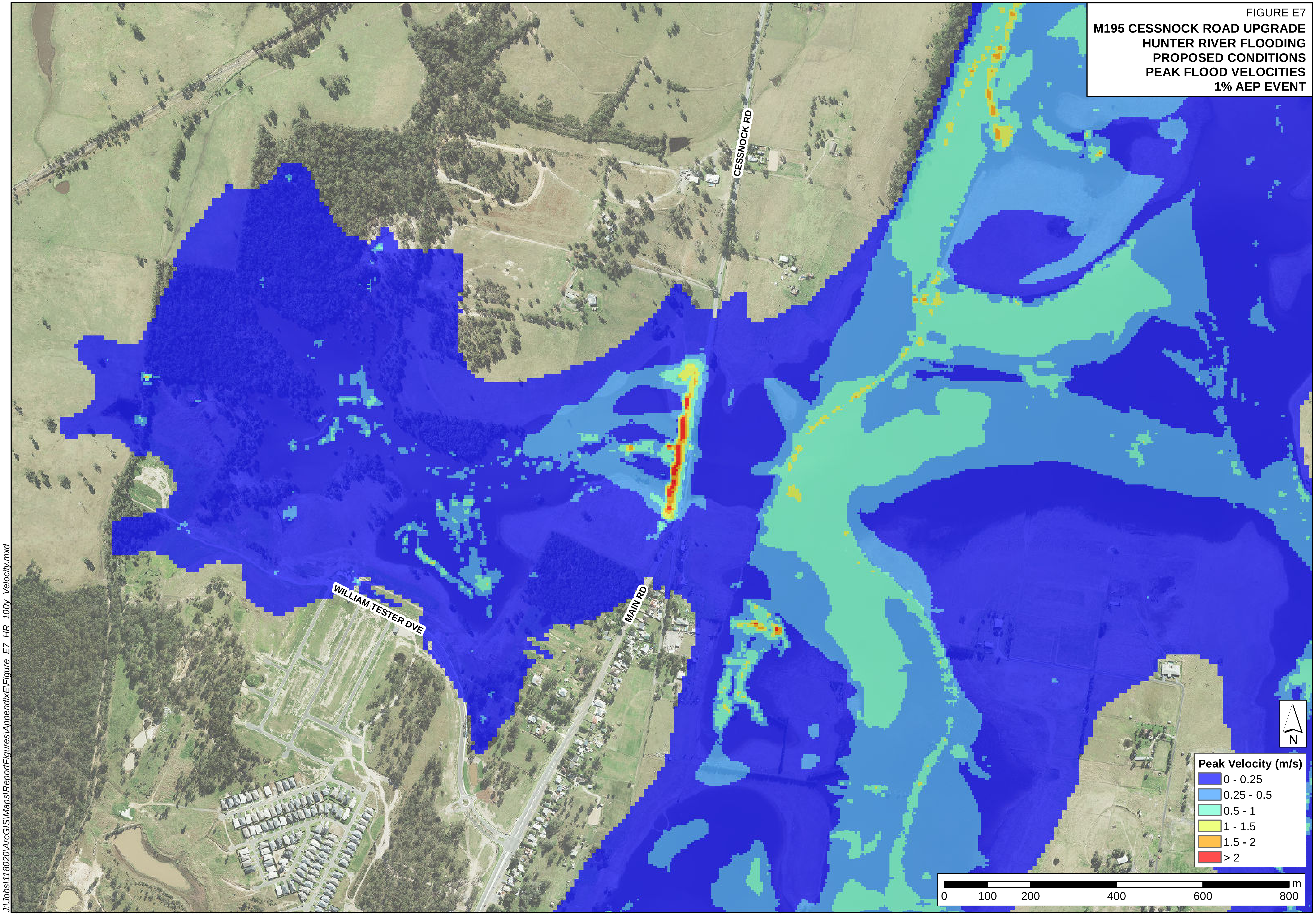
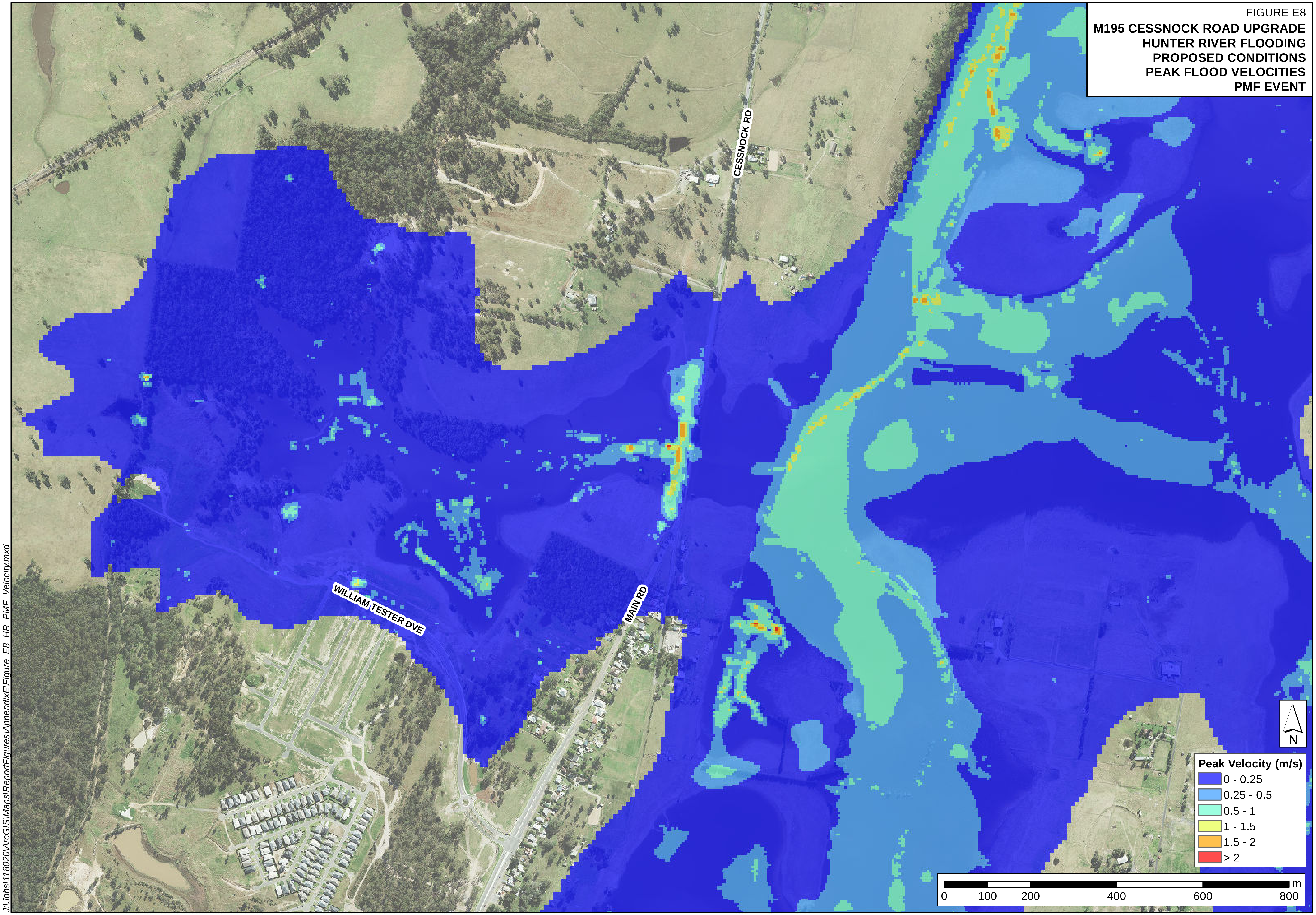


FIGURE E7
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
PEAK FLOOD VELOCITIES
1% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Velocity (m/s)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 1.5
1.5 - 2
> 2
0
100
200
400
600
800
m
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixE\Figure_E7_HR_100y_Velocity.mxd



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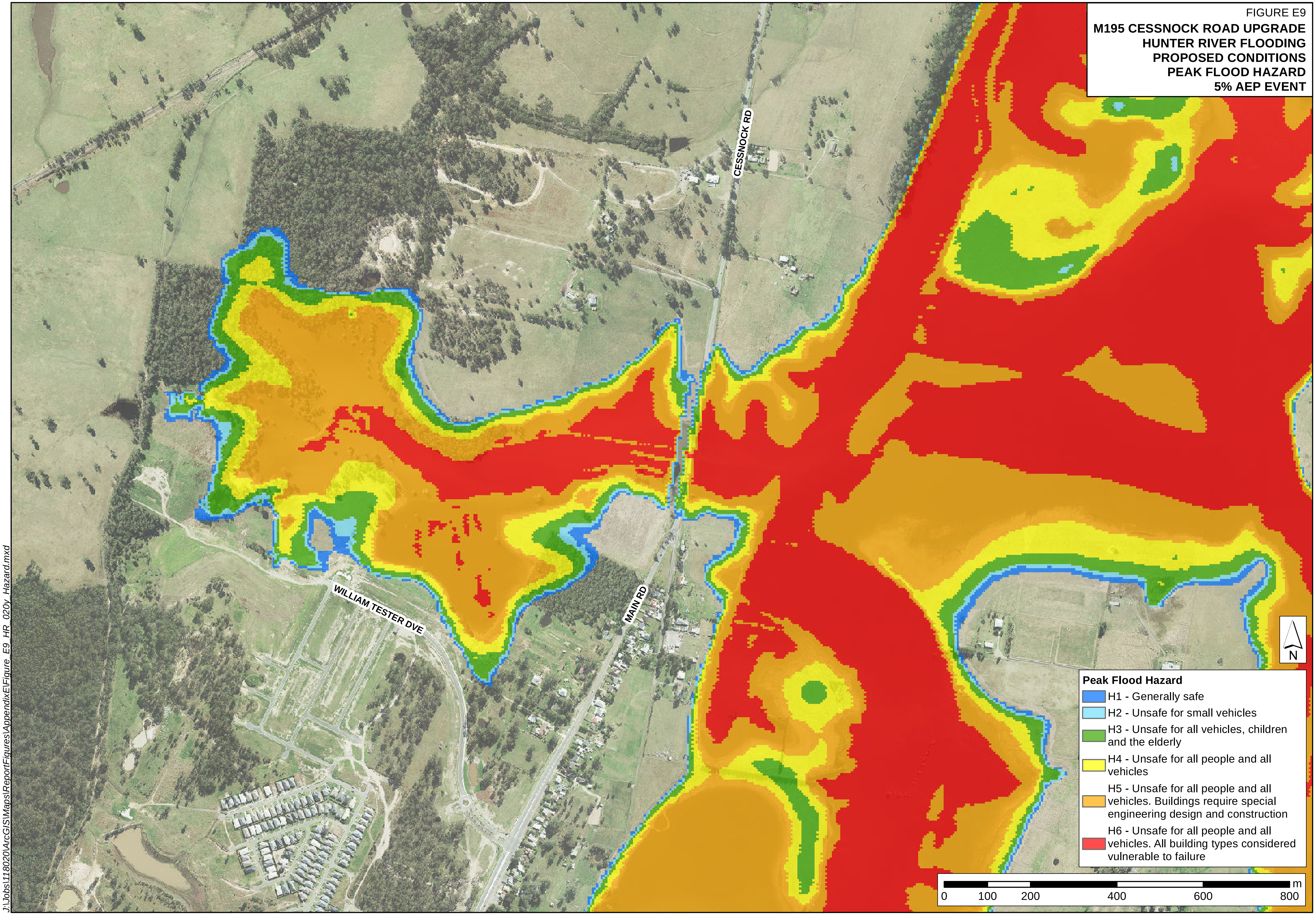
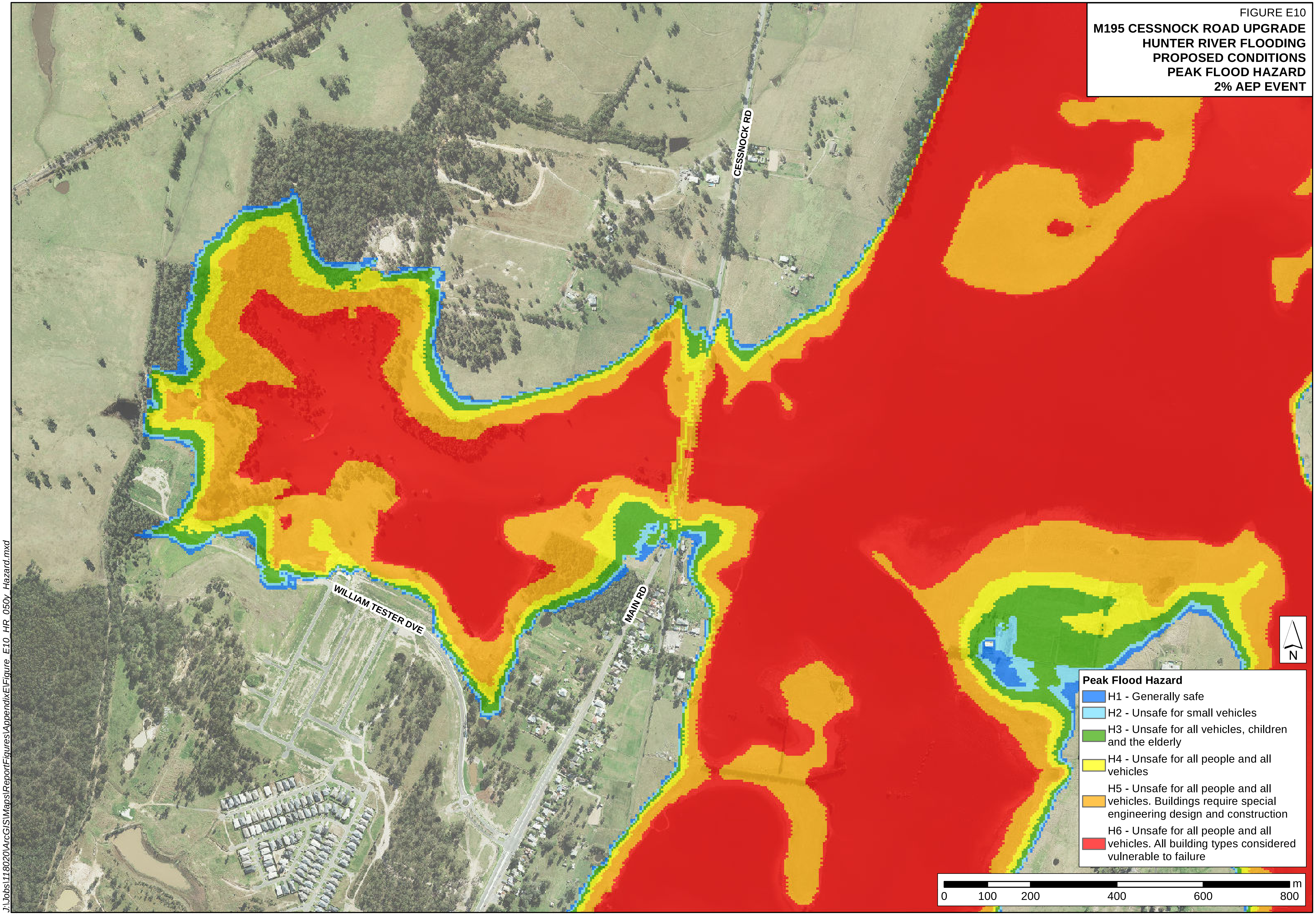


FIGURE E9
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
PEAK FLOOD HAZARD
5% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Peak Flood Hazard
H1 - Generally safe
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unsafe for all people and all vehicles. All building types considered vulnerable to failure
0 100 200 400 600 800 m
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixE\Figure_E9_HR_020y_Hazard.mxd

FIGURE E10

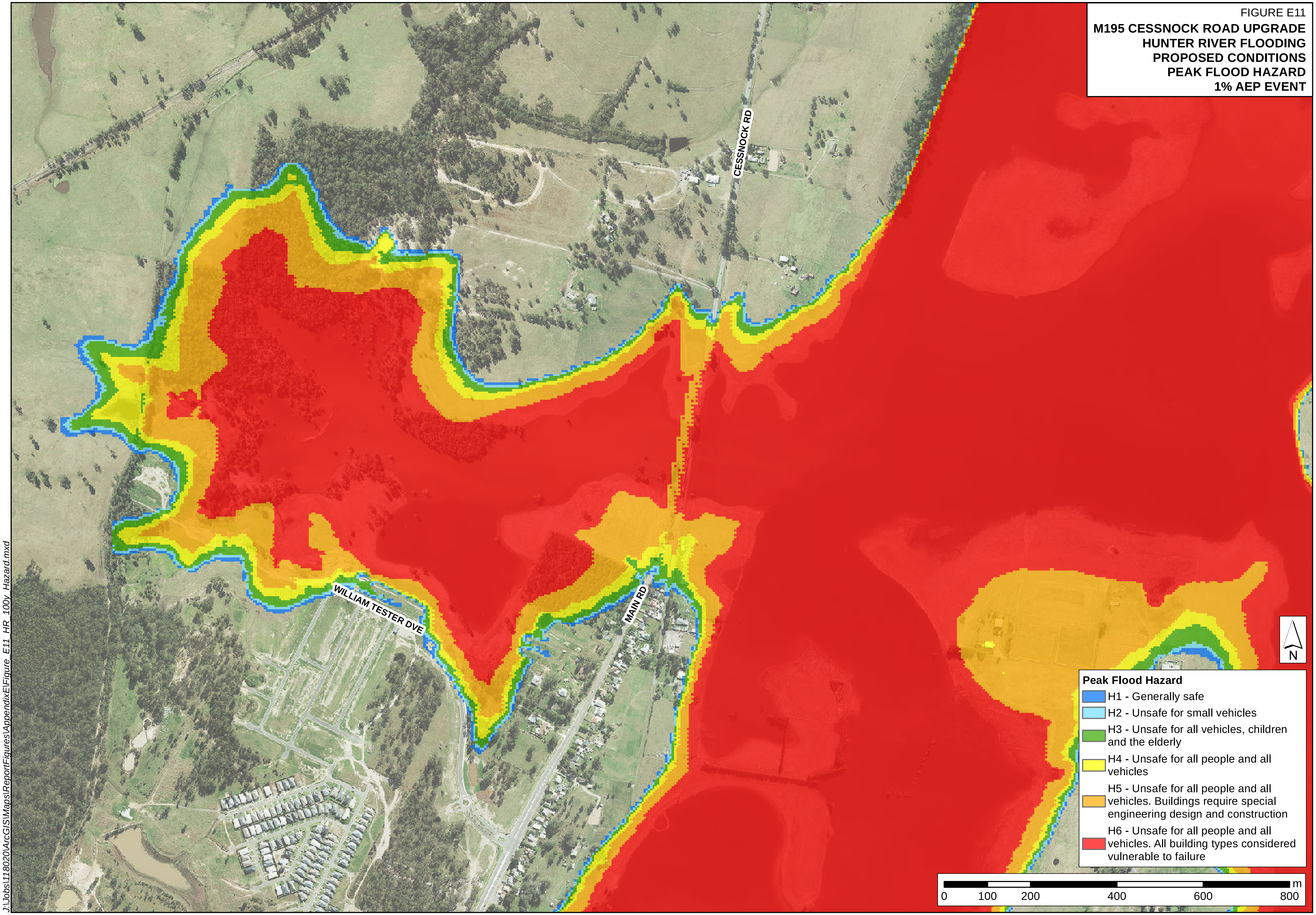
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
PEAK FLOOD HAZARD
2% AEP EVENT



J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixE\Figure_E10_HR_050y_Hazard.mxd

FIGURE E11

M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
PEAK FLOOD HAZARD
1% AEP EVENT



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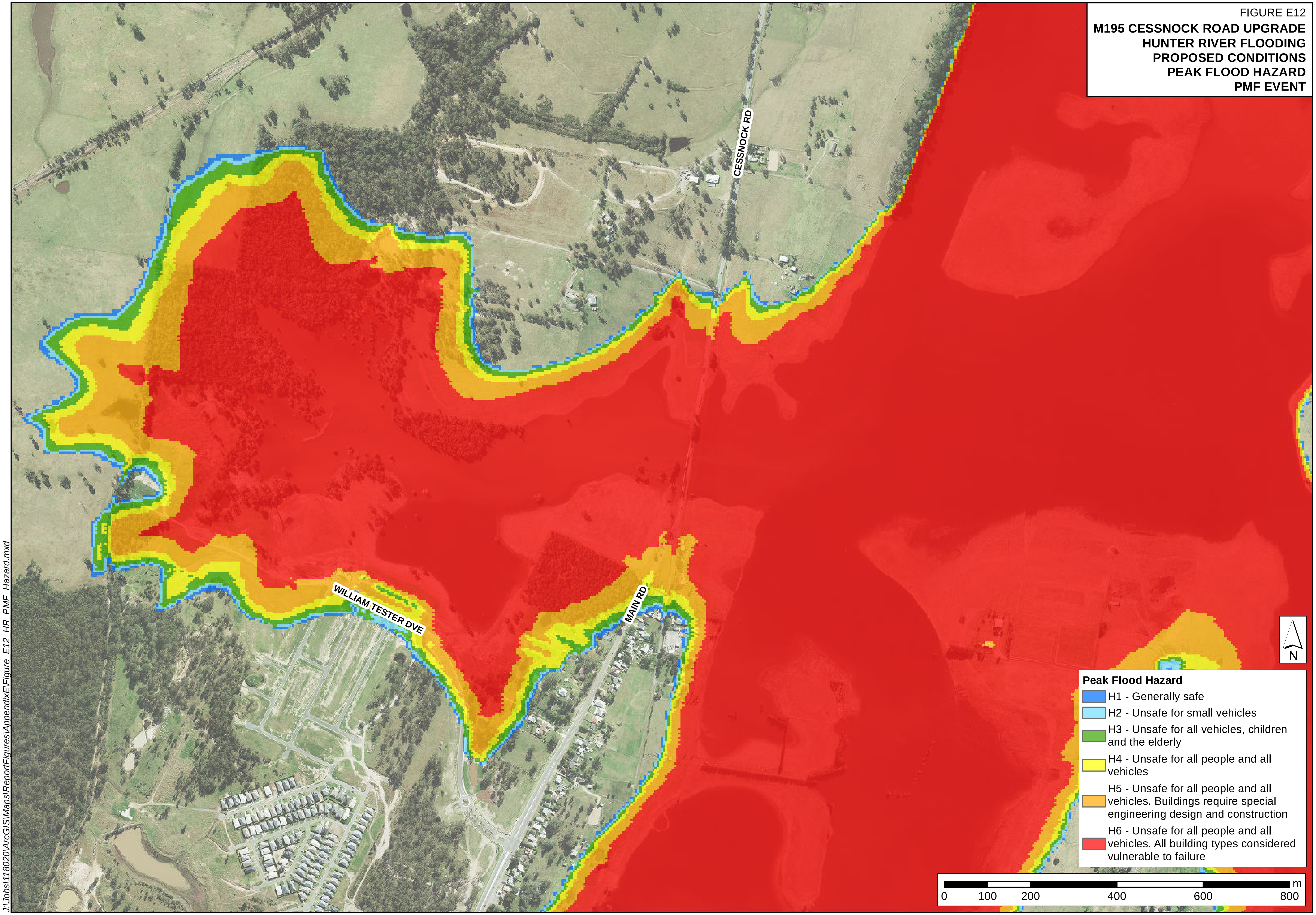

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APPENDIX F. FLOOD IMPACT MAPS FOR WALLIS CREEK FLOODING

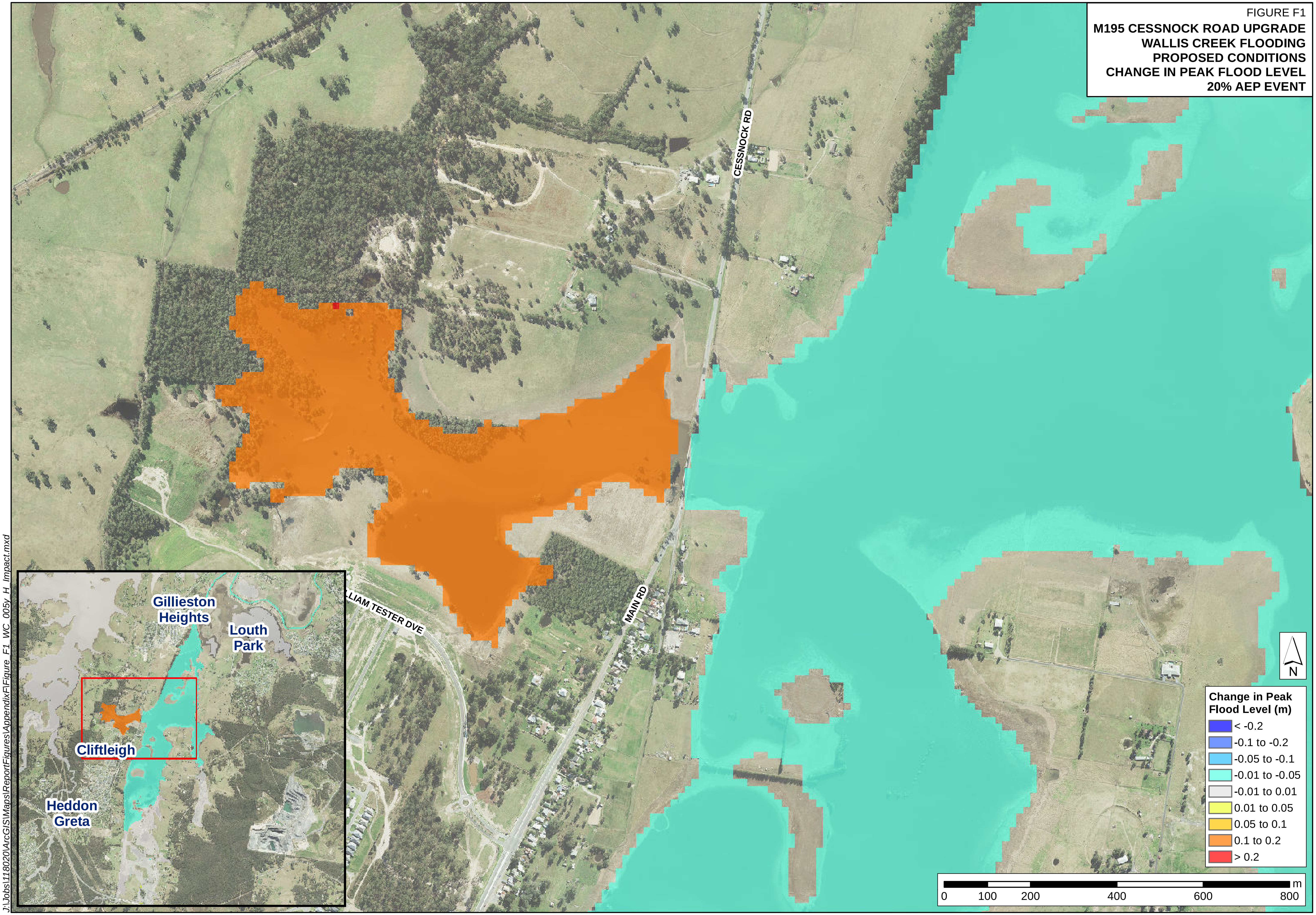


FIGURE F1
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD LEVEL
20% AEP EVENT
CESSNOCK RD
MAIN RD
LLIAM TESTER DVE
Gillieston Heights
Louth Park
Cliftleigh
Heddon Greta
N
Change in Peak Flood Level (m)
< -0.2
-0.1 to -0.2
-0.05 to -0.1
-0.01 to -0.05
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
> 0.2
0 100 200 400 600 800 m
J:\Jobs\118020\ArcGIS\Maps\Report\Figures\AppendixF\Figure_F1_WC_005y_H_Impact.mxd

FIGURE F2

M195 CESSNOCK ROAD UPGRADE WALLIS CREEK FLOODING PROPOSED CONDITIONS CHANGE IN PEAK FLOOD LEVEL 5% AEP EVENT

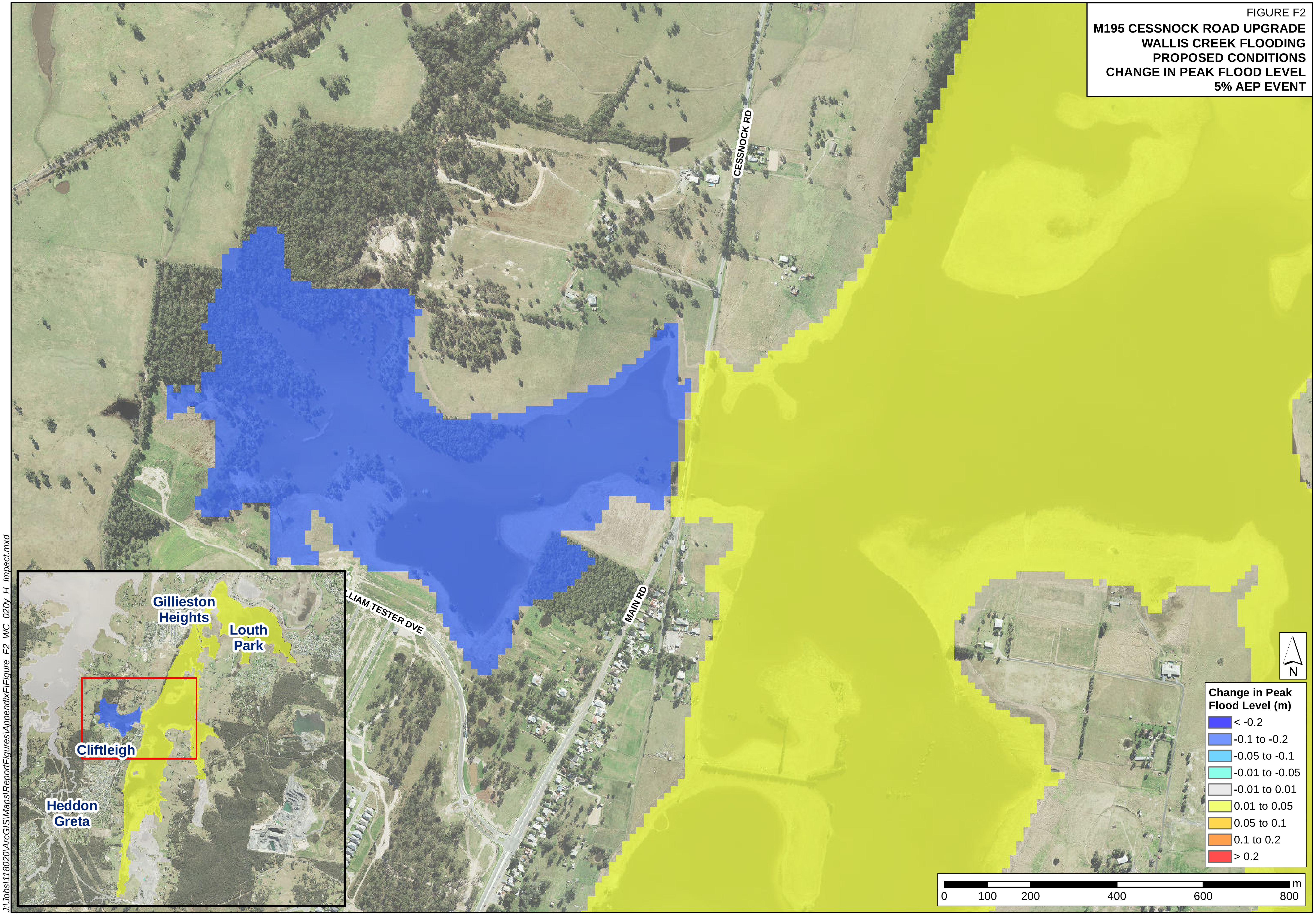
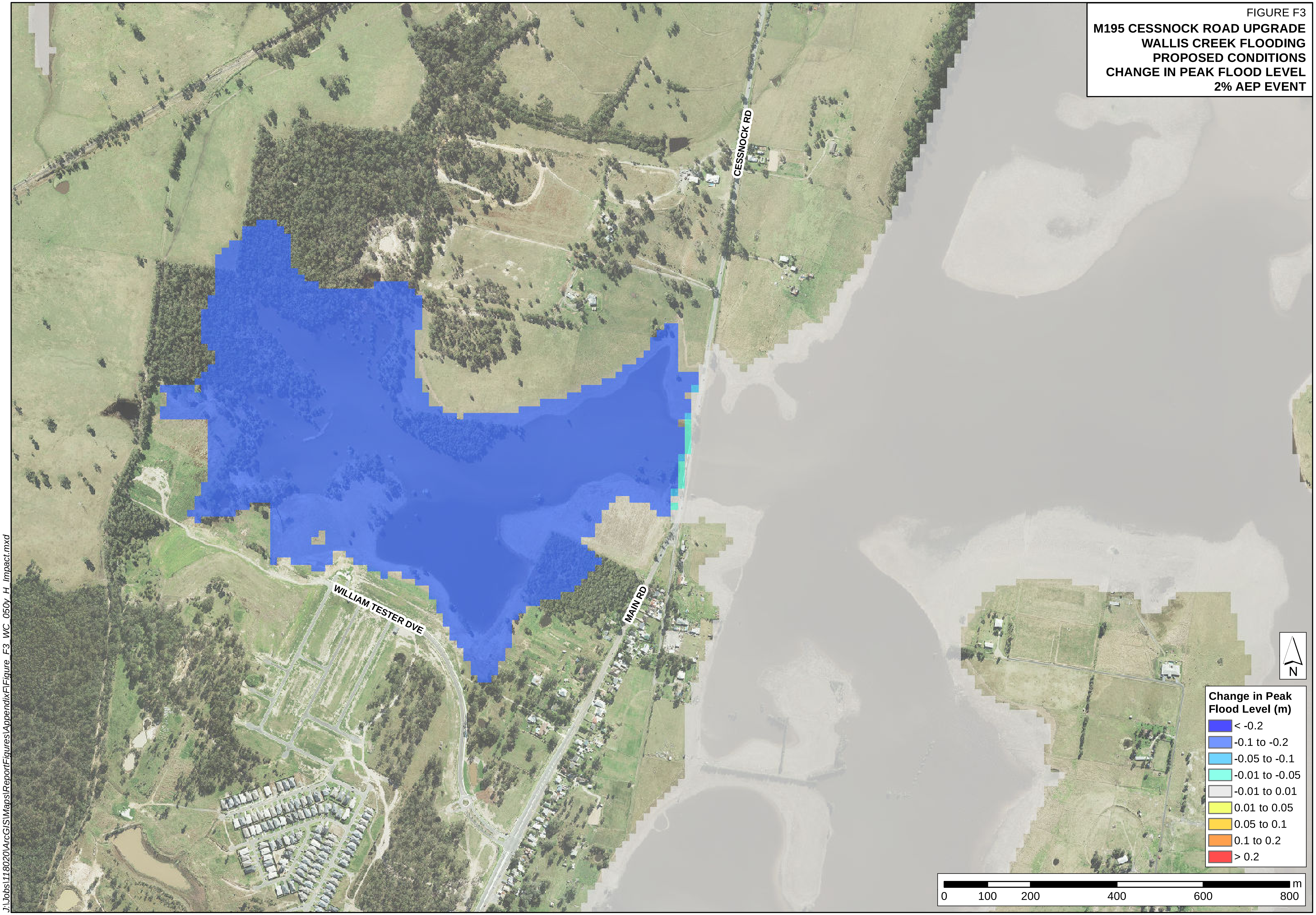


FIGURE F3

M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD LEVEL
2% AEP EVENT



J:\Jobs\118020\ArcGIS\Maps\Report\Figures\AppendixF\Figure_F3_WC_050y_H_Impact.mxd

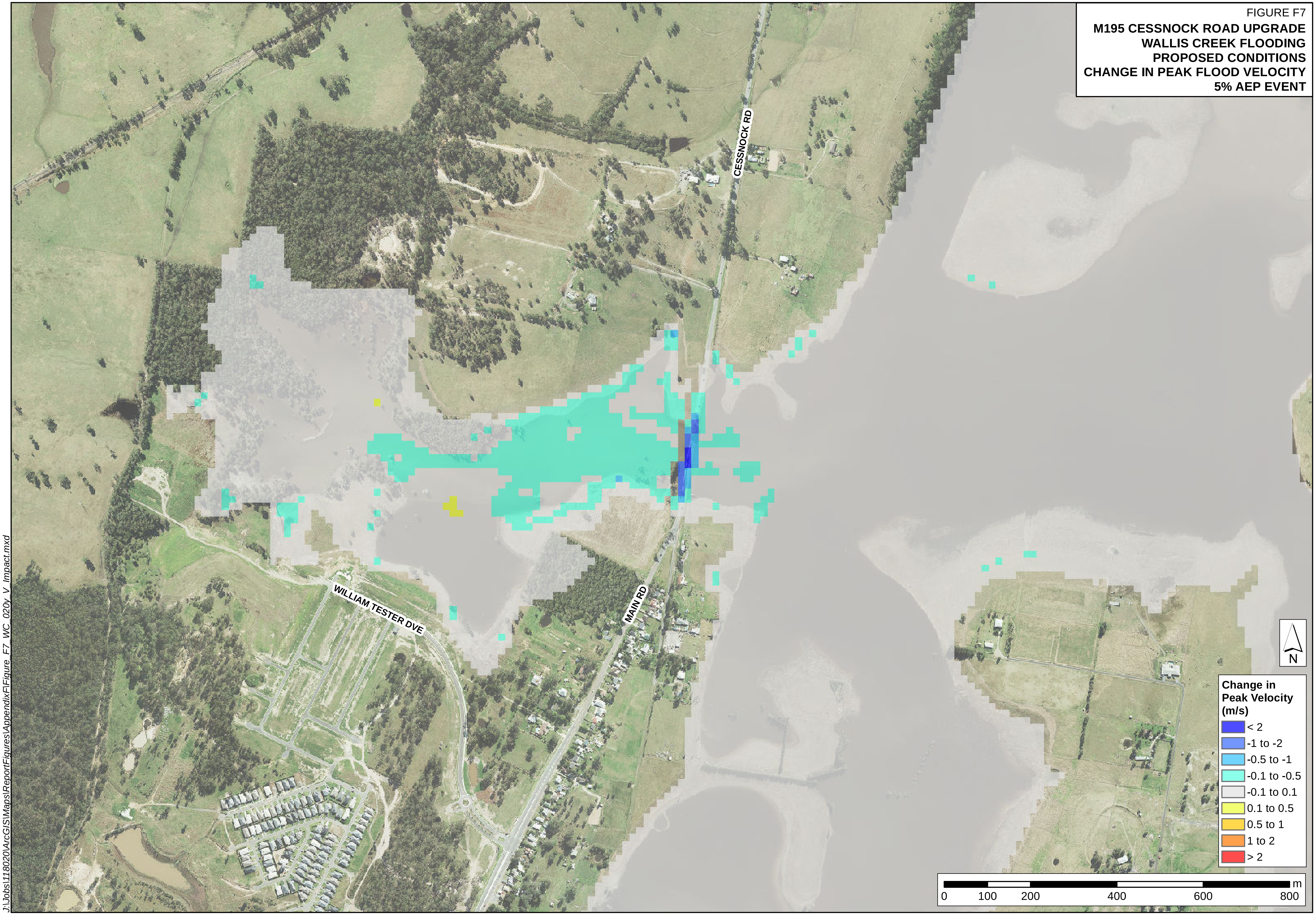

FIGURE F4
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD LEVEL
1% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Change in Peak Flood Level (m)
< -0.2
-0.1 to -0.2
-0.05 to -0.1
-0.01 to -0.05
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
> 0.2
m
0
100
200
400
600
800
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixF\Figure_F4_WC_100y_H_Impact.mxd

FIGURE F5
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD LEVEL
PMF EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Change in Peak Flood Level (m)
< -0.2
-0.1 to -0.2
-0.05 to -0.1
-0.01 to -0.05
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
> 0.2
0
100
200
400
600
800
m
J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixF\Figure_F5_WC_PMF_H_Impact.mxd

J:\Jobs\118020\ArcGIS\Maps\Report\Figures\AppendixF\Figure_F6_WC_005y_V_Impact.mxd

FIGURE F7

M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD VELOCITY
5% AEP EVENT



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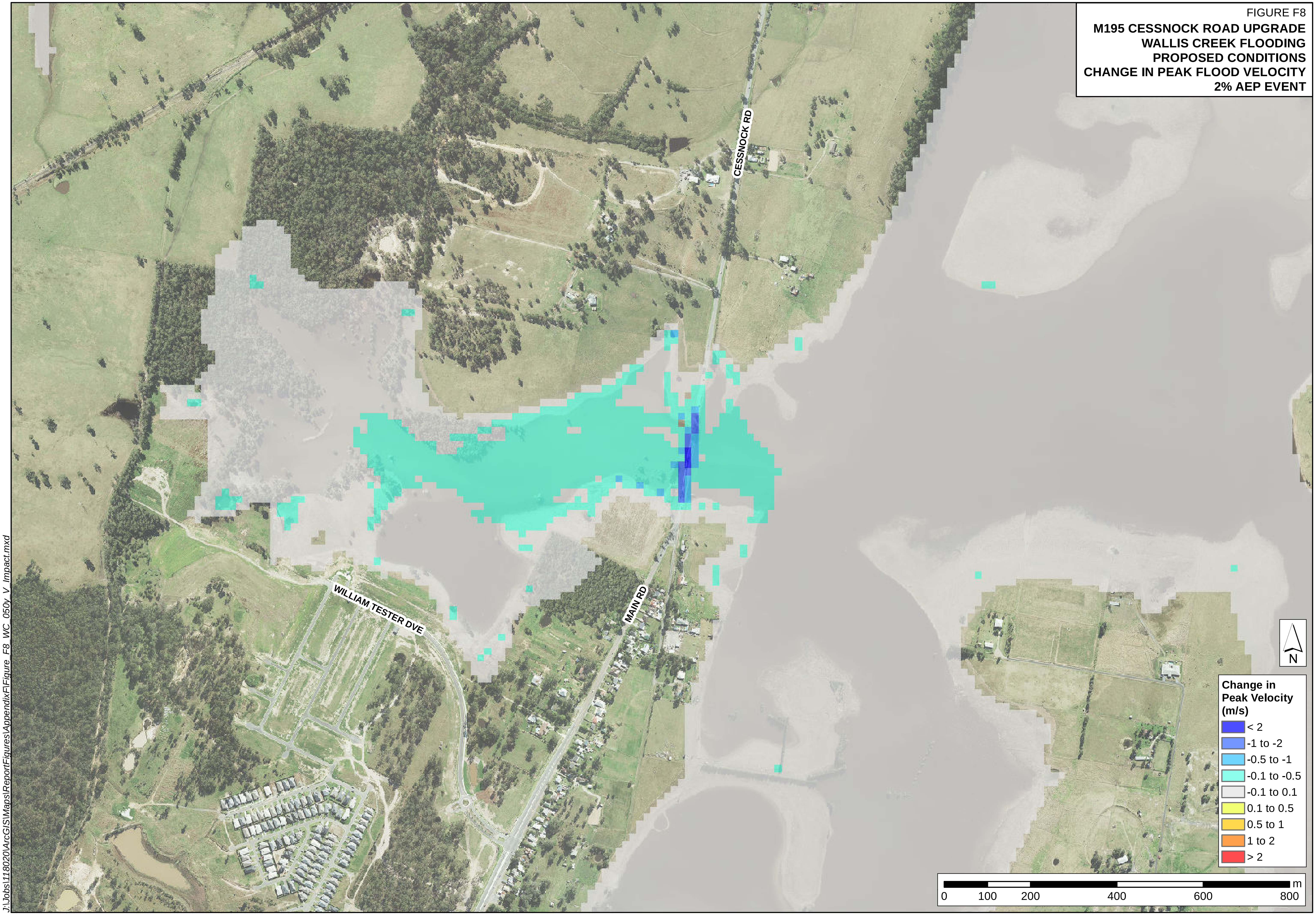

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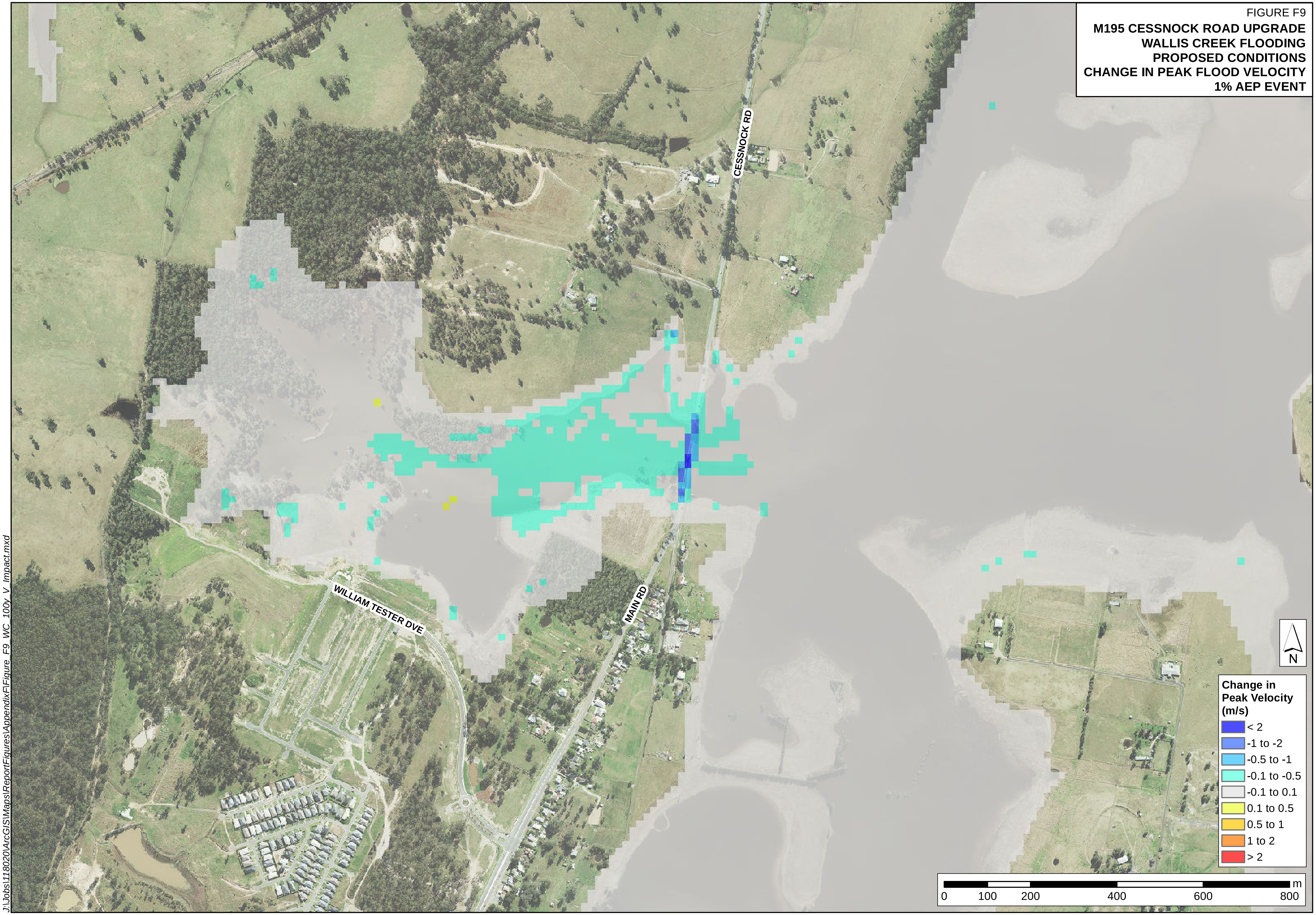
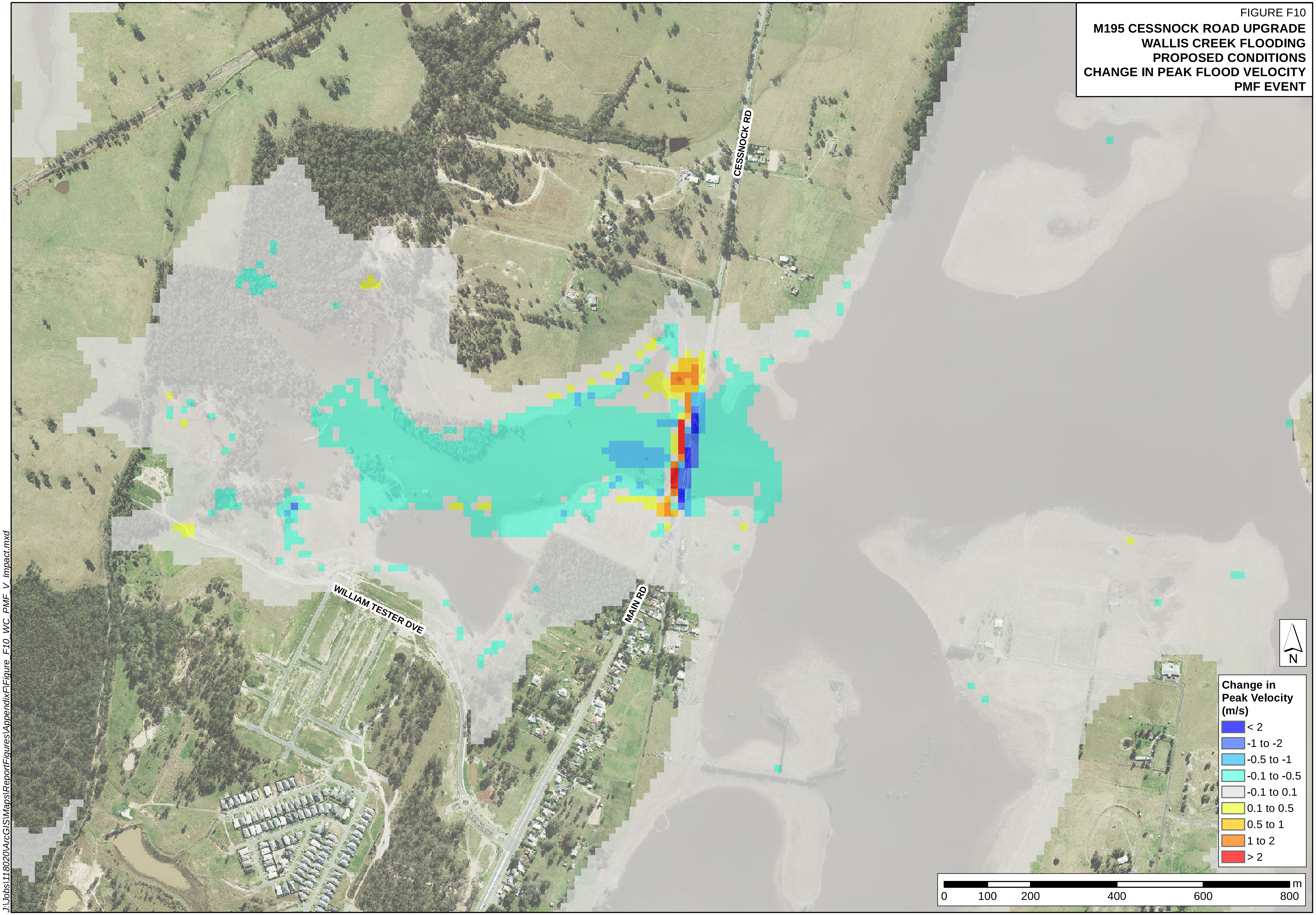


FIGURE F9
M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD VELOCITY
1% AEP EVENT
CESSNOCK RD
MAIN RD
WILLIAM TESTER DVE
N
Change in Peak Velocity (m/s)
< 2
-1 to -2
-0.5 to -1
-0.1 to -0.5
-0.1 to 0.1
0.1 to 0.5
0.5 to 1
1 to 2
> 2
0 100 200 400 600 800 m
J:\Jobs\118020\ArcGIS\Maps\Report\Figures\AppendixF\Figure_F9_WC_100y_V_Impact.mxd

FIGURE F10

M195 CESSNOCK ROAD UPGRADE
WALLIS CREEK FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD VELOCITY
PMF EVENT



J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixF\Figure_F10_WC_PMF_V_Impact.mxd

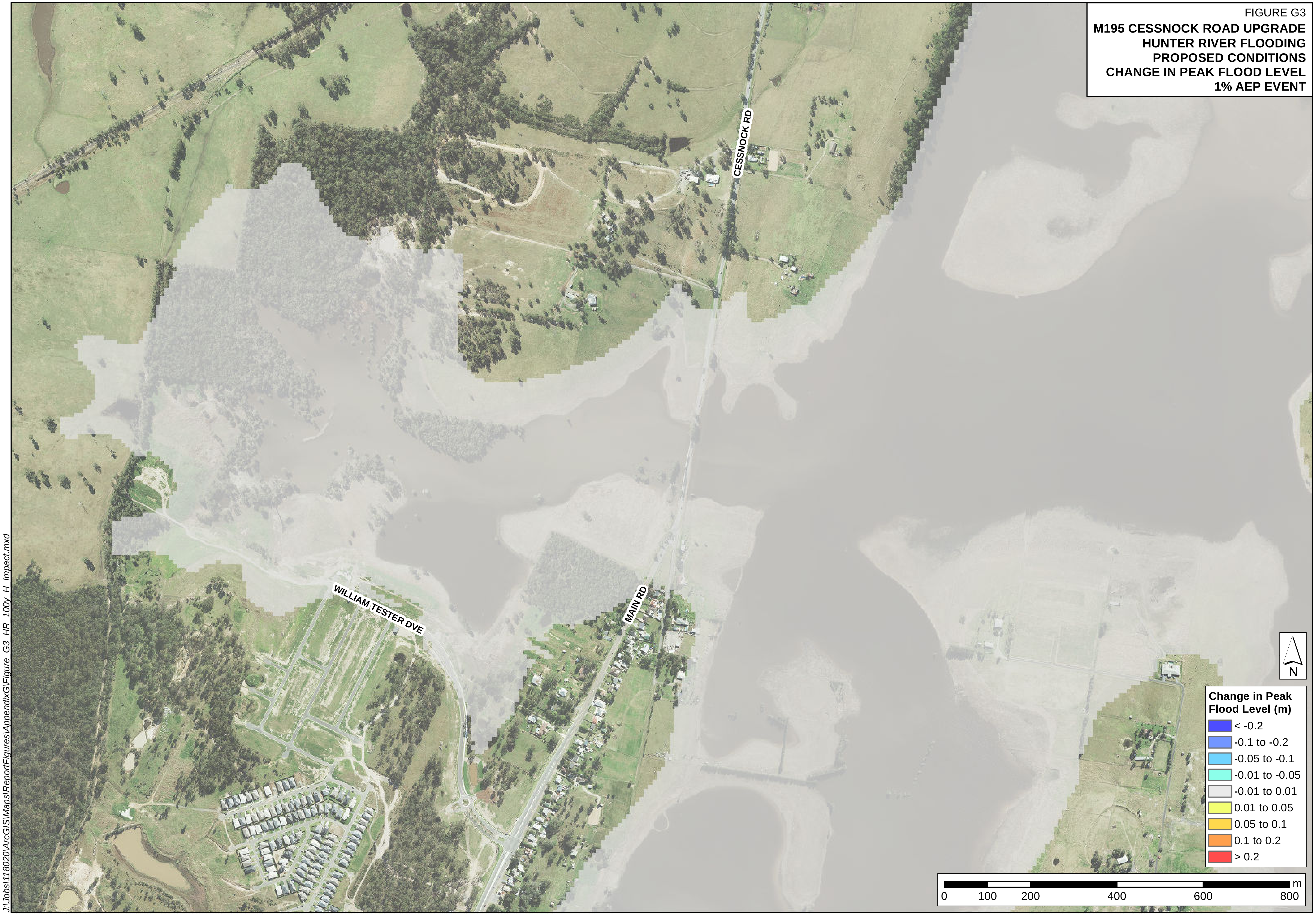
APPENDIX G. FLOOD IMPACT MAPS FOR HUNTER RIVER FLOODING

FIGURE G1

M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD LEVEL
5% AEP EVENT

J:\Jobs\118020\ArcGIS\Maps\Report\Figures\Appendix\G\Figure_G1_HR_020y_H_Impact.mxd


FIGURE G2
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD LEVEL
2% AEP EVENT
CESSNOCK RD
WILLIAM TESTER DVE
MAIN RD
N
Change in Peak Flood Level (m)
< -0.2
-0.1 to -0.2
-0.05 to -0.1
-0.01 to -0.05
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
> 0.2
m
0
100
200
400
600
800
J:\Jobs\118020\ArcGIS\Maps\Report\Figures\AppendixG\Figure_G2_HR_050y_H_Impact.mxd



J:\Jobs\118020\ArcGIS\Maps\Report\Figures\AppendixG\Figure_G3_HR_100y_H_Impact.mxd

FIGURE G4

M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD LEVEL
PMF EVENT

J:\Jobs\118020\ArcGIS\Maps\ReportFigures\AppendixG\Figure_G4_HR_PMF_H_Impact.mxd

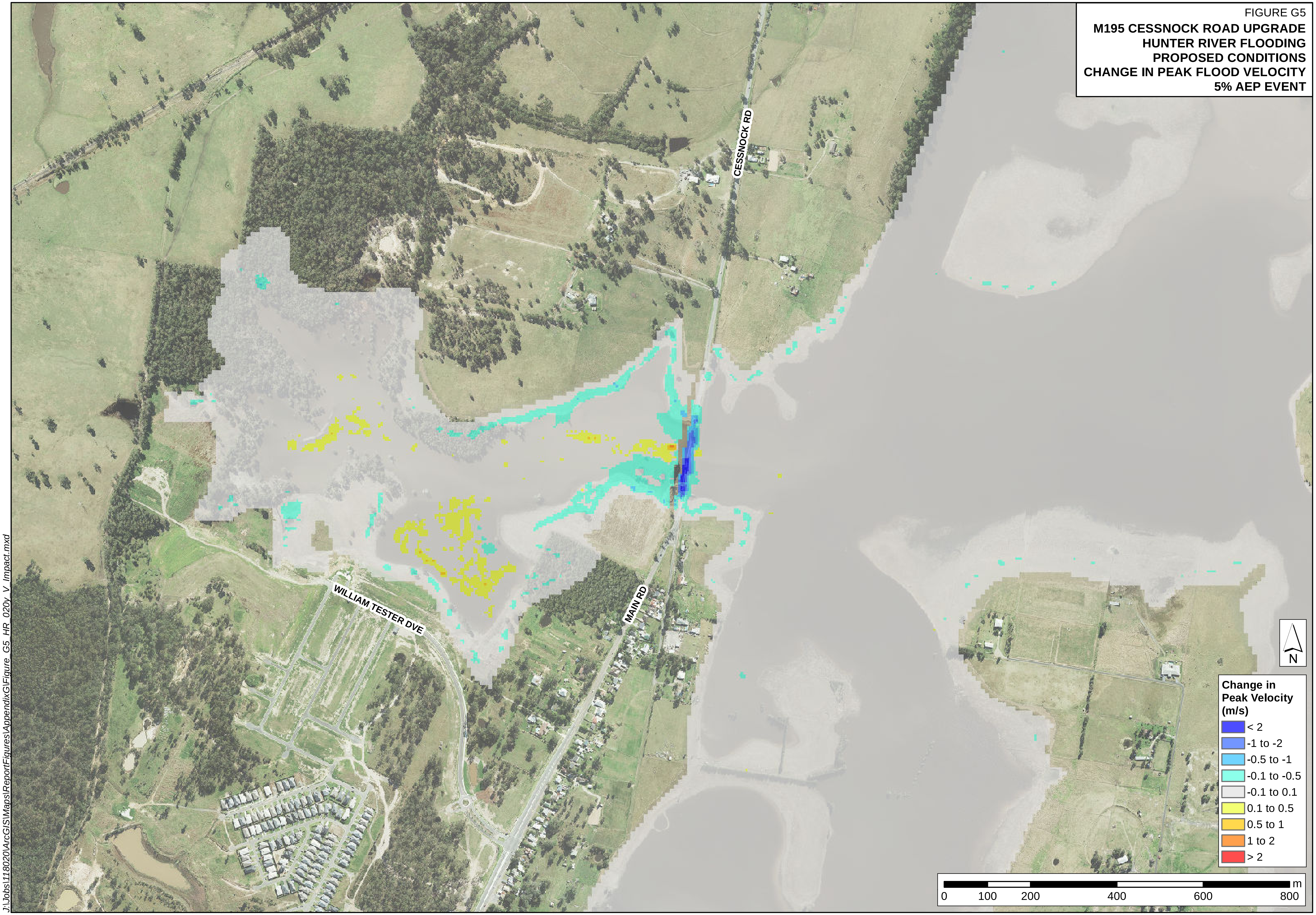


FIGURE G5
M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD VELOCITY
5% AEP EVENT

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FIGURE G6

M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD VELOCITY
2% AEP EVENT

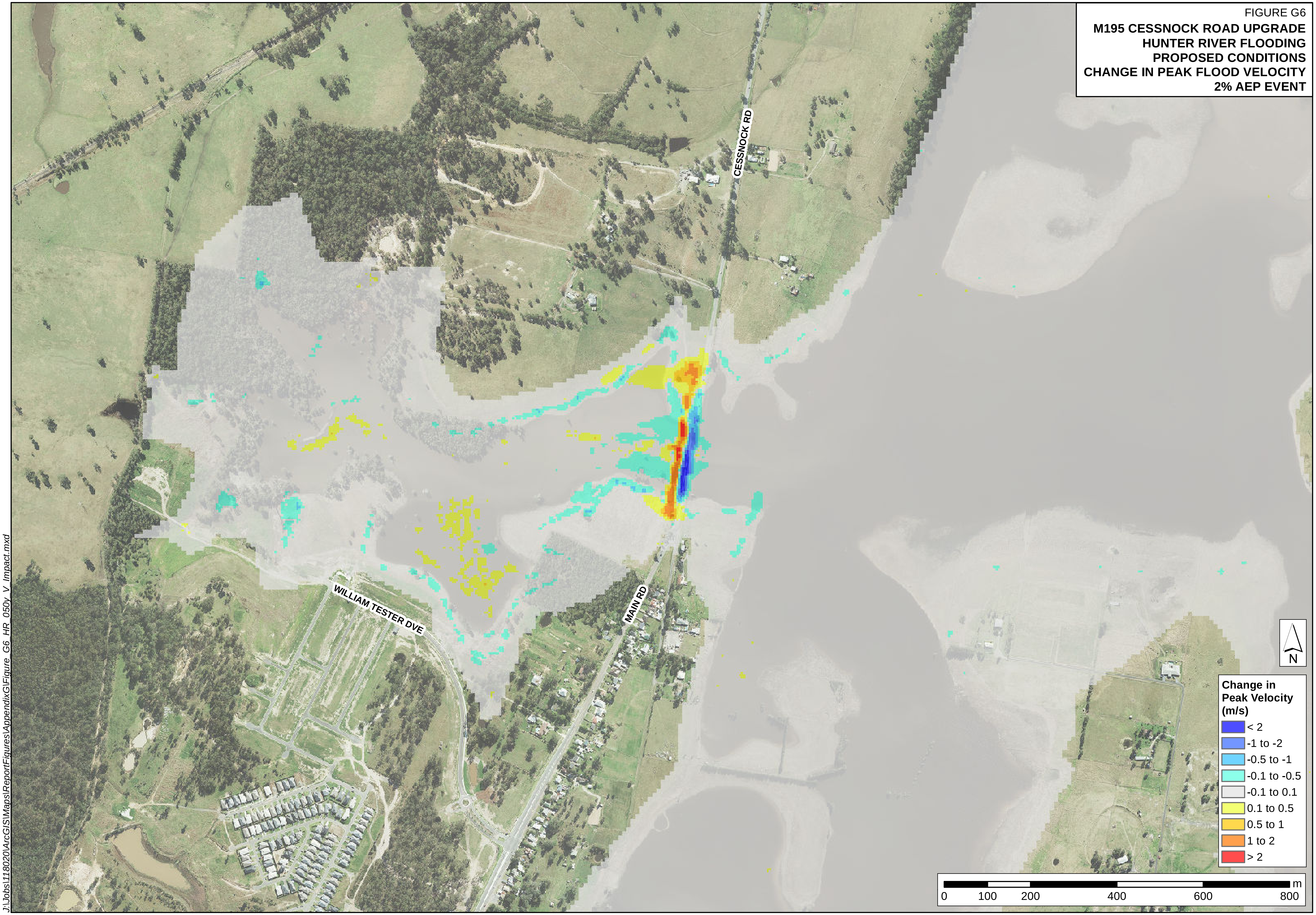

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FIGURE G7

M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD VELOCITY
1% AEP EVENT

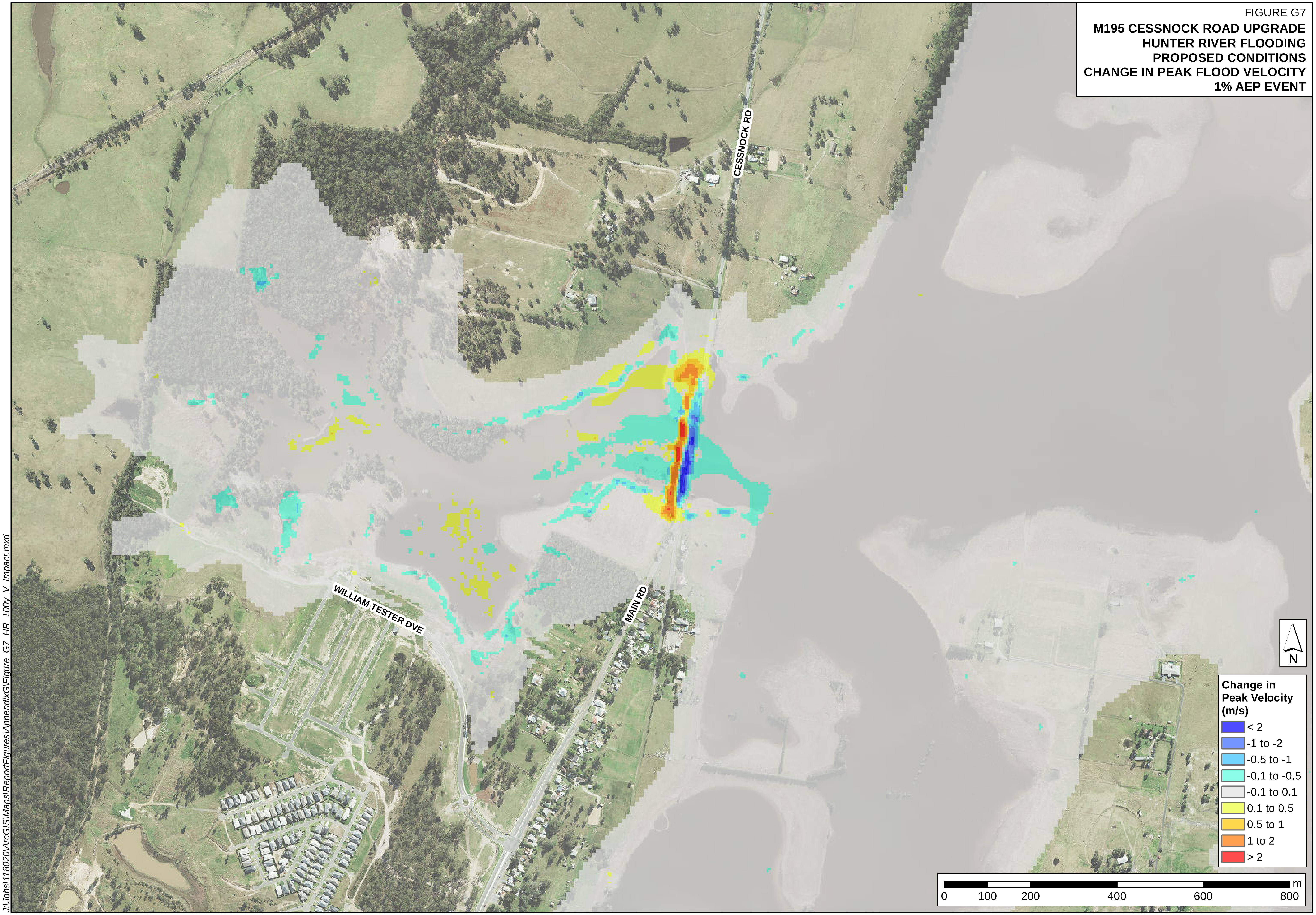

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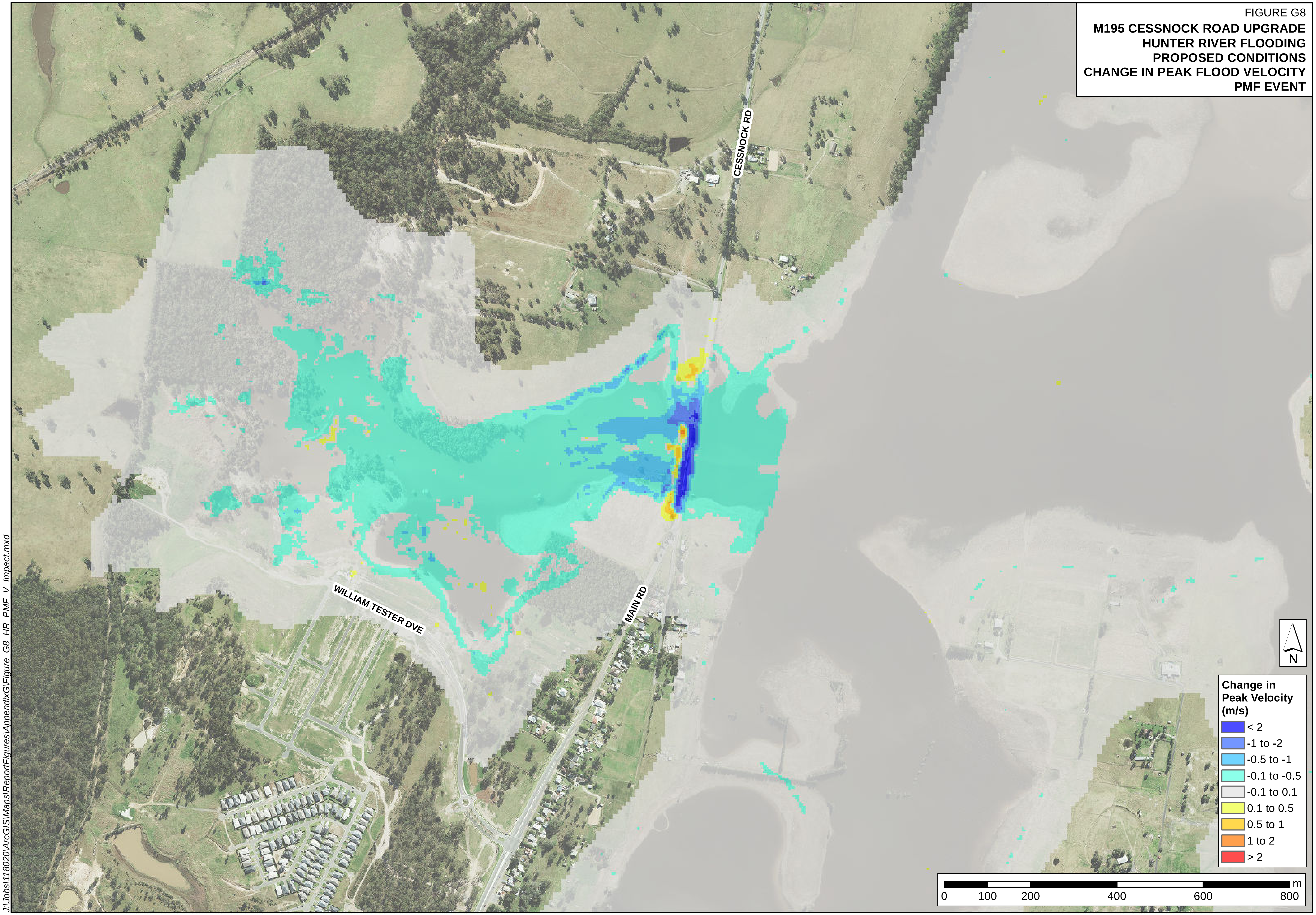
FIGURE G8

M195 CESSNOCK ROAD UPGRADE
HUNTER RIVER FLOODING
PROPOSED CONDITIONS
CHANGE IN PEAK FLOOD VELOCITY
PMF EVENT



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