Table 19 Floodplain Risk Management Plan (Part 2 of 2)

Property Modification Measures									
Option ID	**Option**	**Description**	**Benefits**	**Concerns**	**Responsibility**	**Funding**	**Cost**	**B/C Ratio**	**Priority**
PM01	Voluntary House Raising and Voluntary Purchase Feasibility Study	Feasibility study to investigate the suitability of a voluntary house raising scheme to reduce property damages to dwellings in low flood hazard areas of Gundagai.	Reduction in frequency of over-floor inundation of dwellings in low hazard areas, and associated cost savings and reduction in stress/trauma/ cleanup requirements.	Not all eligible dwellings may be suitable to raise and may require alternative approaches. VHR schemes take time and residents may be impatient, or unwilling to participate.	Council	Eligible for OEH funding	$50k	~1.4	High
PM03	Flood Proofing Measures for Commercial Properties	Implement temporary flood barriers, or wet proofing measures, to commercial premises in flood affected areas (e.g. Sheridan Lane and Sheridan Street)	Significantly reduce commercial property damages, and associated stress and trauma. Reduce burden on the SES to help businesses prepare for floods, and decrease recovery times following	Staff to be regularly trained in the installation of temporary flood proofing measures. Implementation of measures at the time of construction may be considered onerous by developers.	Individual business owners	N/A	TBD (varies depending on product)	>>1	High
PM04	Revision of Flood Planning Level and Flood Planning Area	Council to adopt a Flood Planning Level of 1% AEP + 0.5 m freeboard in areas affected by mainstream flooding, and 0.3m freeboard in overland flow	The higher FPL will improve the level of protection for new developments, while the FPA will provide clear guidance on the properties subject to flood related	A planning proposal is required to amend the LEP and implement the new FPL and FPA. Some residents may oppose the higher FPL as it may be considered more	Council	N/A	Minimal	N/A	High
PM05	Inclusion of Flood Related Information on Section 10.7(2) and (5) Planning Certificates	Council to provide flood information from the Gundagai Flood Study to property owners via planning certificates.	Improve the flood awareness of property owners in Gundagai, and ensure flood related development controls are applied where necessary.	Provision of data may be considered onerous for Council staff.	Council	N/A	Minimal	N/A	High
PM06	Inclusion of Flood Related Development Controls in Development Control Plan	When the new Cootamundra - Gundagai DCP is drafted it is recommended that flood related development controls are included. Engagement of a specialist planning consultant to provide advice and guidance is recommended.	Objectives of the Gundagai LEP (Clause 6.3) to be supported by the appropriate application of flood related development controls.	Development controls may be considered onerous by developers.	Council	N/A	Estimated at $30k for specialist planning consultant	N/A	Medium
Flood Modification Measures									
FM10	Install flap valve on Gundagai McDonalds carpark culvert	A flap valve is to be installed at the western end of the culvert that drains the McDonalds carpark through the Hume Highway embankment.	Prevent backflow of the culvert during flood events, reducing flood risk to the carpark and the burden on the SES/Council to respond to inundation.	Minor cost to purchase and install valve, inclusion in routine maintenance schedule to ensure proper function.	Council	N/A	<$3k	N/A	High
FM09	Vegetation Management	Continue routine riparian vegetation management.	Ensure density of vegetation in riparian areas does not increase and affect flood levels in Gundagai.	Vegetation management must be done in line with NSW bidiversity legislation.	Council	N/A	As per existing schedule	N/A	Low

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6. **Murrumbidgee River at Gundagai: Flood Frequency Studies (Ref 78/13149)**
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7 **Murrumbidgee River Flooding - Data Collection - March 2012 – Draft Report**
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10. **Floodplain Risk Management Guideline – Residential Flood Damages**
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Howells, L., McLuckie, D., Collings, G. and Lawson, N.
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Thomas C, Golaszewski R, Honour W

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Floodplain Management Authorities of NSW 50th Annual Conference

13. NSW Office of Environment and Heritage
Floodplain Management Program
Guidelines for voluntary house raising schemes
February 2013

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15. **Gundagai Local Flood Plan** – a Subplan of the Gundagai Local Disaster Plan (DISPLAN) July 2008.

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16. **Revised Murrumbidgee River at Wagga Wagga Floodplain Risk Management Study and Plan**
Wagga Wagga City Council, March 2018

COOTAMUNDRA GUNDAGAI
REGIONAL COUNCIL

GUNDAGAI FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
FINAL REPORT

VOLUME 2

LIST OF FIGURES

APPENDIX F: FLOODPLAIN RISK MITIGATION OPTION IMPACT MAPS

DECEMBER 2018

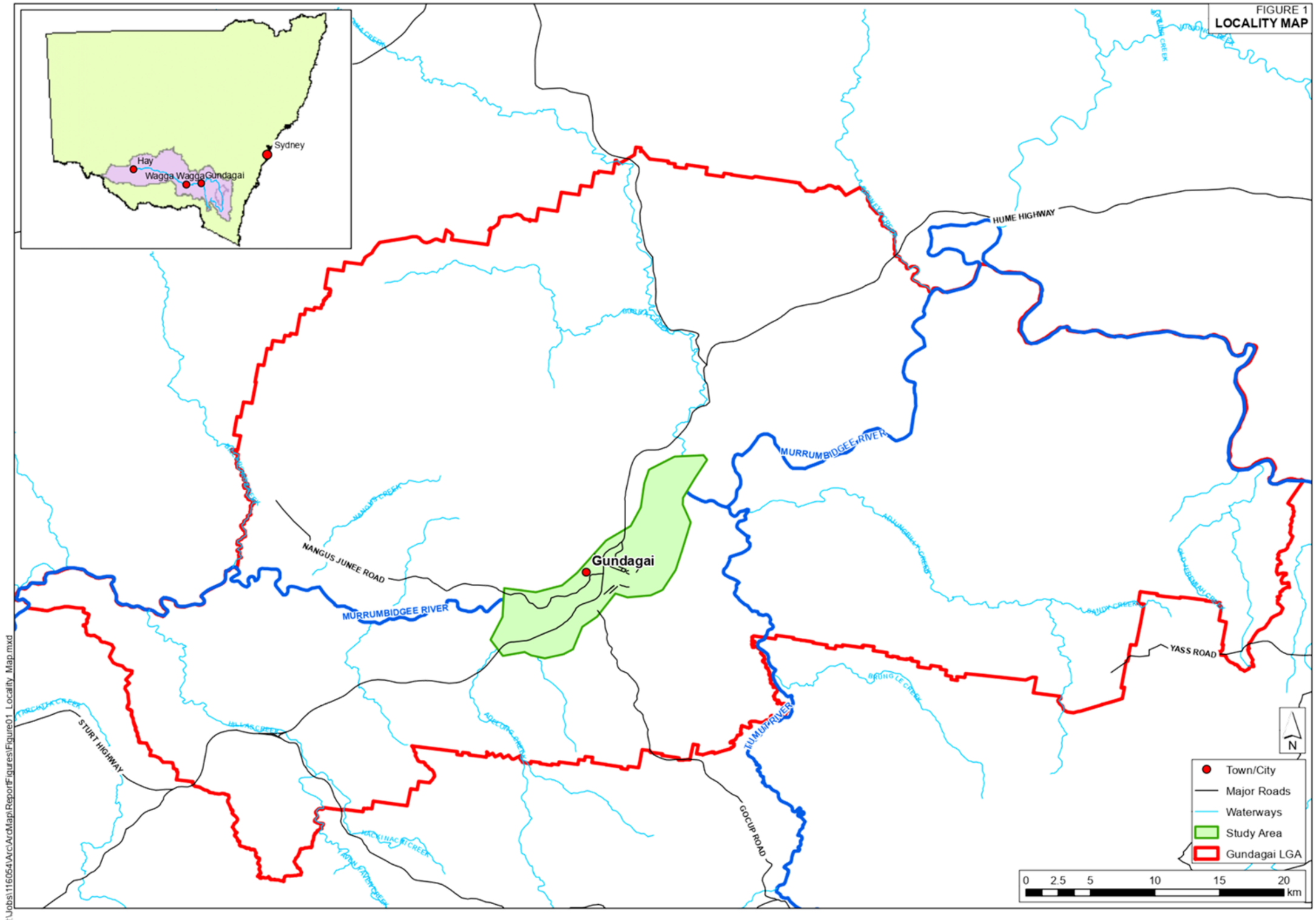
FIGURE 1
LOCALITY MAP
Sydney
Hay
Wagga Wagga
Gundagai
HUME HIGHWAY
MURRUMBIDGEE RIVER
NANGUS JUNEE ROAD
Gundagai
MURRUMBIDGEE RIVER
YASS ROAD
STURT HIGHWAY
GOCUP ROAD
TUMUT RIVER
N
Town/City
Major Roads
Waterways
Study Area
Gundagai LGA
0 2.5 5 10 15 20
km
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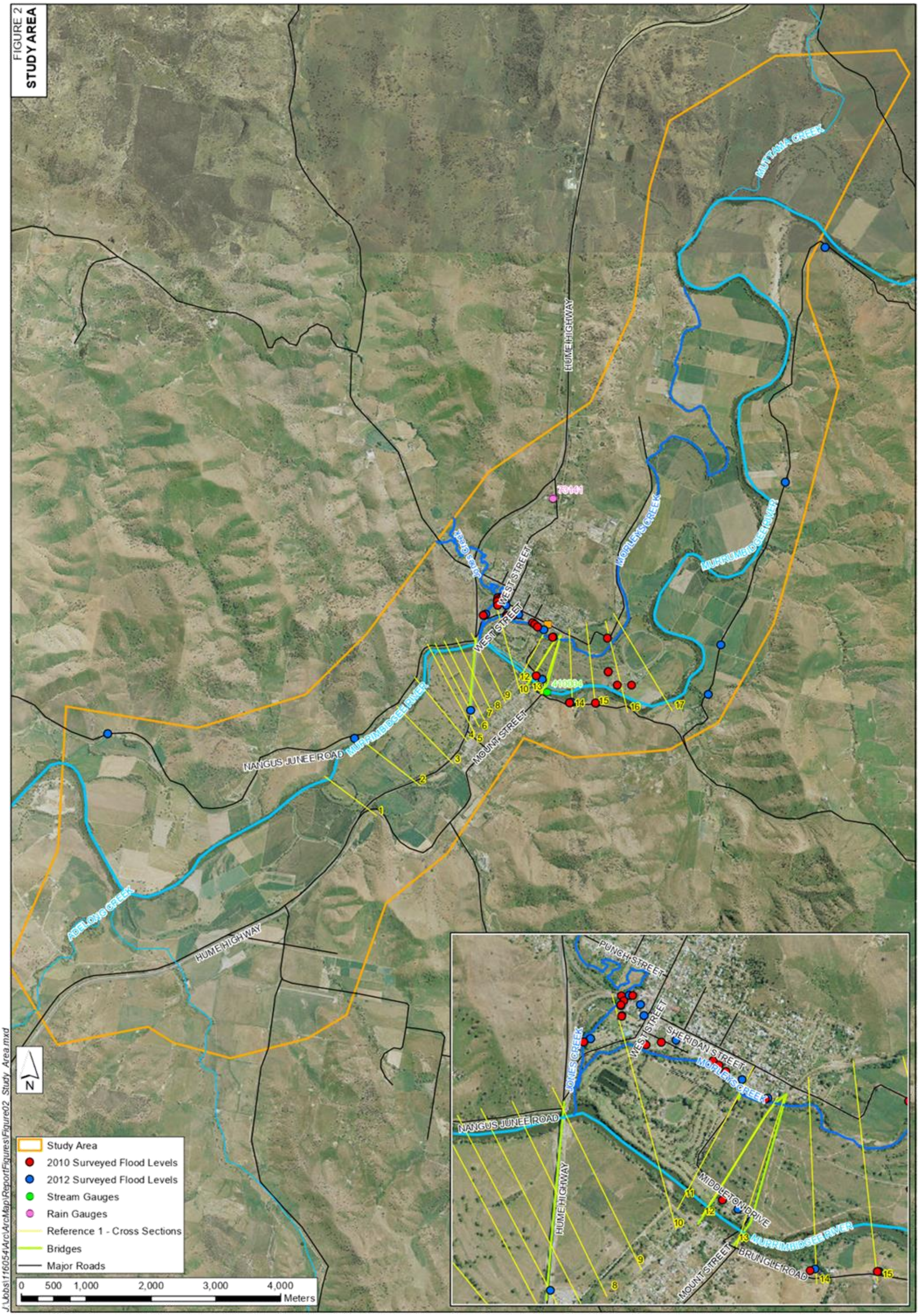
FIGURE 2
STUDY AREA
MUTTAMA CREEK
HUME HIGHWAY
79141
JONES CREEK
WEST STREET
WEST STREET
MOPLEYS CREEK
MURRUMBIDGEE RIVER
12
13
10
410394
9
8
7
6
4
5
3
2
1
14
15
16
17
MURRUMBIDGEE RIVER
NANGUS JUNEE ROAD
MOUNT STREET
ADELONG CREEK
HUME HIGHWAY
PUNCH STREET
WEST STREET
SHERIDAN STREET
JONES CREEK
MOPLEYS CREEK
NANGUS JUNEE ROAD
HUME HIGHWAY
MIDDLETON DRIVE
MURRUMBIDGEE RIVER
BRUNGLE ROAD
MOUNT STREET
11
12
10
13
9
8
14
15
N
Study Area
2010 Surveyed Flood Levels
2012 Surveyed Flood Levels
Stream Gauges
Rain Gauges
Reference 1 - Cross Sections
Bridges
Major Roads
0 500 1,000 2,000 3,000 4,000
Meters
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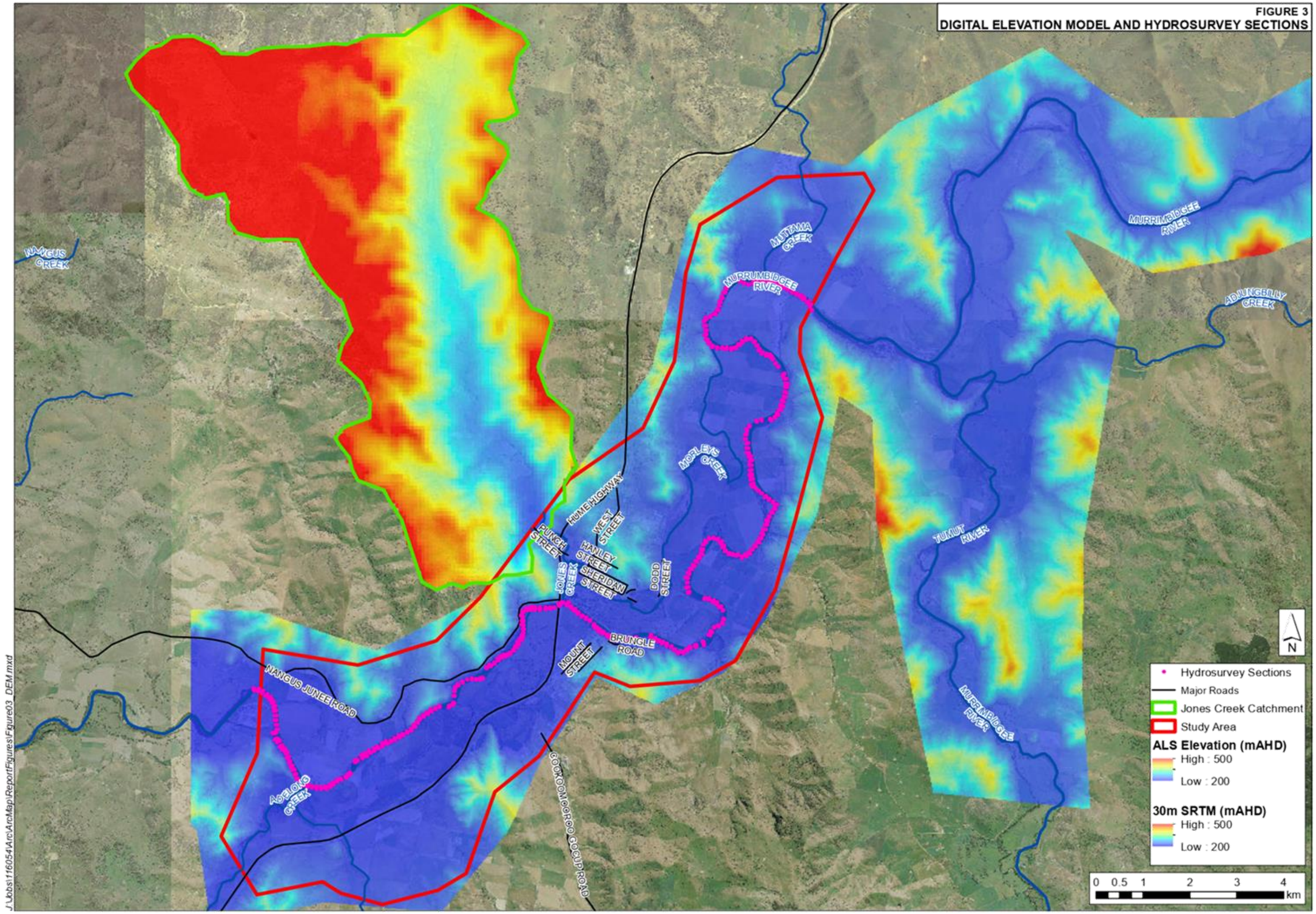
FIGURE 3
DIGITAL ELEVATION MODEL AND HYDROSURVEY SECTIONS
NANGUS CREEK
MUTAMA CREEK
MURRUMBIDGEE RIVER
MURRUMBIDGEE RIVER
ADJUNGBILLY CREEK
MOPLEYS CREEK
HUME HIGHWAY
WEST STREET
PUNCH STREET
JONES CREEK
HANLEY STREET
SHERIDAN STREET
DODD STREET
BRUNGLE ROAD
MOUNT STREET
NANGUS JUNEE ROAD
ADELONG CREEK
COOKOOMOOROO COOLUP ROAD
TUMUT RIVER
MURRUMBIDGEE RIVER
N
Hydrosurvey Sections
Major Roads
Jones Creek Catchment
Study Area
ALS Elevation (mAHD)
High : 500
Low : 200
30m SRTM (mAHD)
High : 500
Low : 200
0 0.5 1 2 3 4
km
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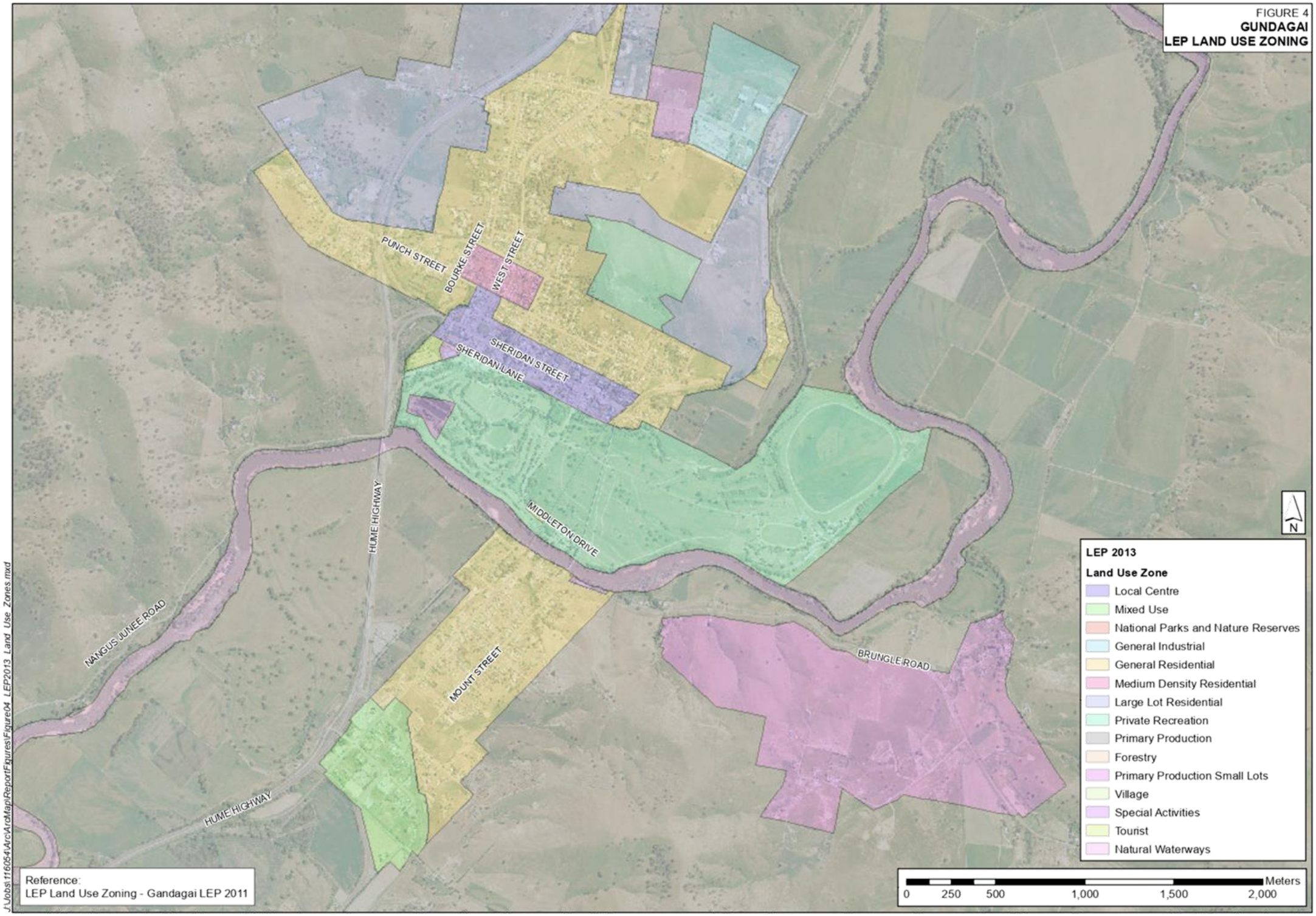
FIGURE 4
GUNDAGAI
LEP LAND USE ZONING
PUNCH STREET
BOURKE STREET
WEST STREET
SHERIDAN STREET
SHERIDAN LANE
HUME HIGHWAY
MIDDLETON DRIVE
NANGUS JUNEE ROAD
MOUNT STREET
BRUNGLE ROAD
HUME HIGHWAY
N
LEP 2013
Land Use Zone
Local Centre
Mixed Use
National Parks and Nature Reserves
General Industrial
General Residential
Medium Density Residential
Large Lot Residential
Private Recreation
Primary Production
Forestry
Primary Production Small Lots
Village
Special Activities
Tourist
Natural Waterways
Reference:
LEP Land Use Zoning - Gandagai LEP 2011
0 250 500 1,000 1,500 2,000 Meters
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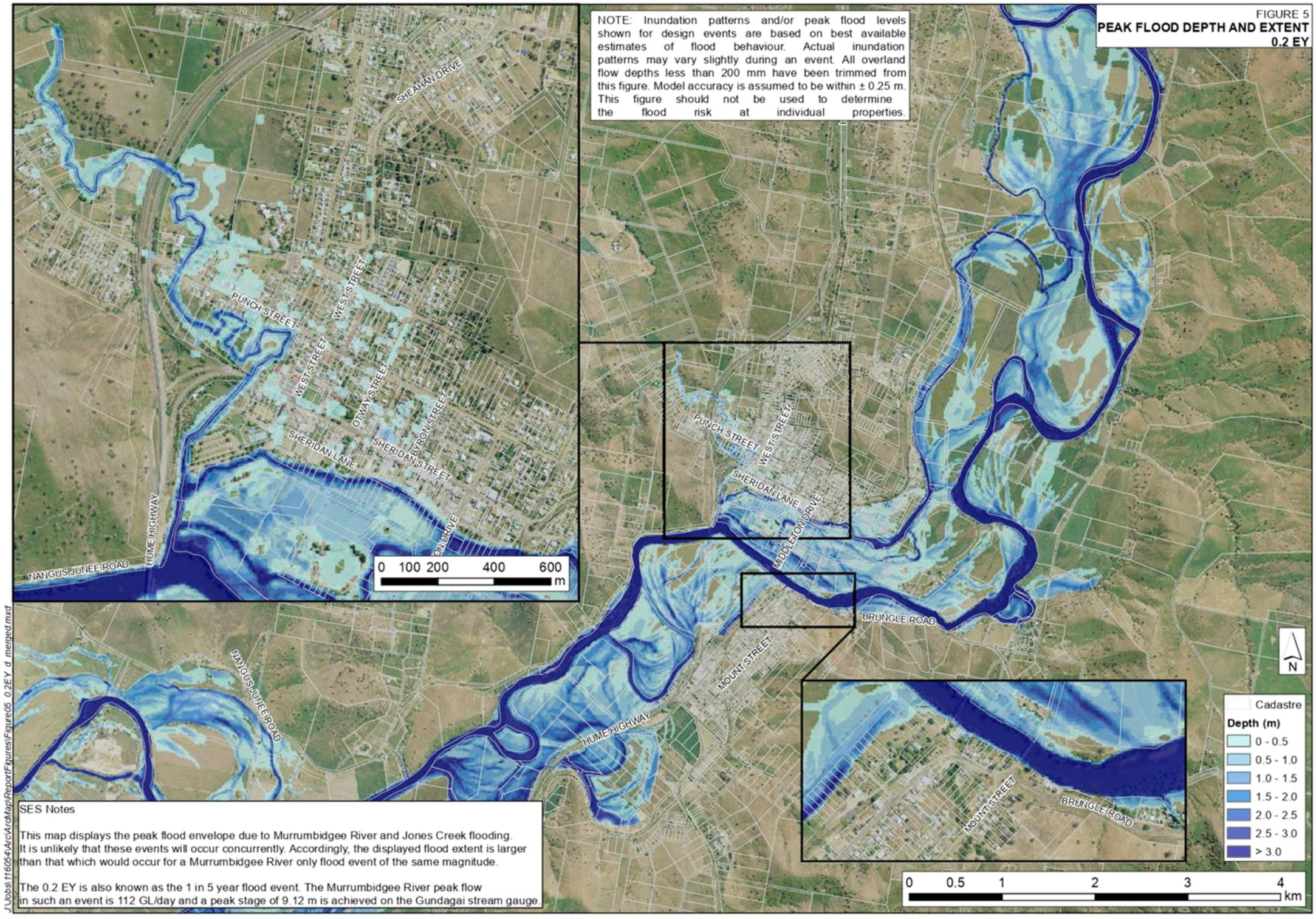
FIGURE 5
PEAK FLOOD DEPTH AND EXTENT
0.2 EY
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
OTWAY STREET
BYRON STREET
SHERIDAN LANE
SHERIDAN STREET
HUME HIGHWAY
NANGUS JUNEE ROAD
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
0 100 200 400 600 m
0 0.5 1 2 3 4 km
N
Cadastre
Depth (m)
0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
> 3.0
SES Notes
This map displays the peak flood envelope due to Murrumbidgee River and Jones Creek flooding. It is unlikely that these events will occur concurrently. Accordingly, the displayed flood extent is larger than that which would occur for a Murrumbidgee River only flood event of the same magnitude.
The 0.2 EY is also known as the 1 in 5 year flood event. The Murrumbidgee River peak flow in such an event is 112 GL/day and a peak stage of 9.12 m is achieved on the Gundagai stream gauge.
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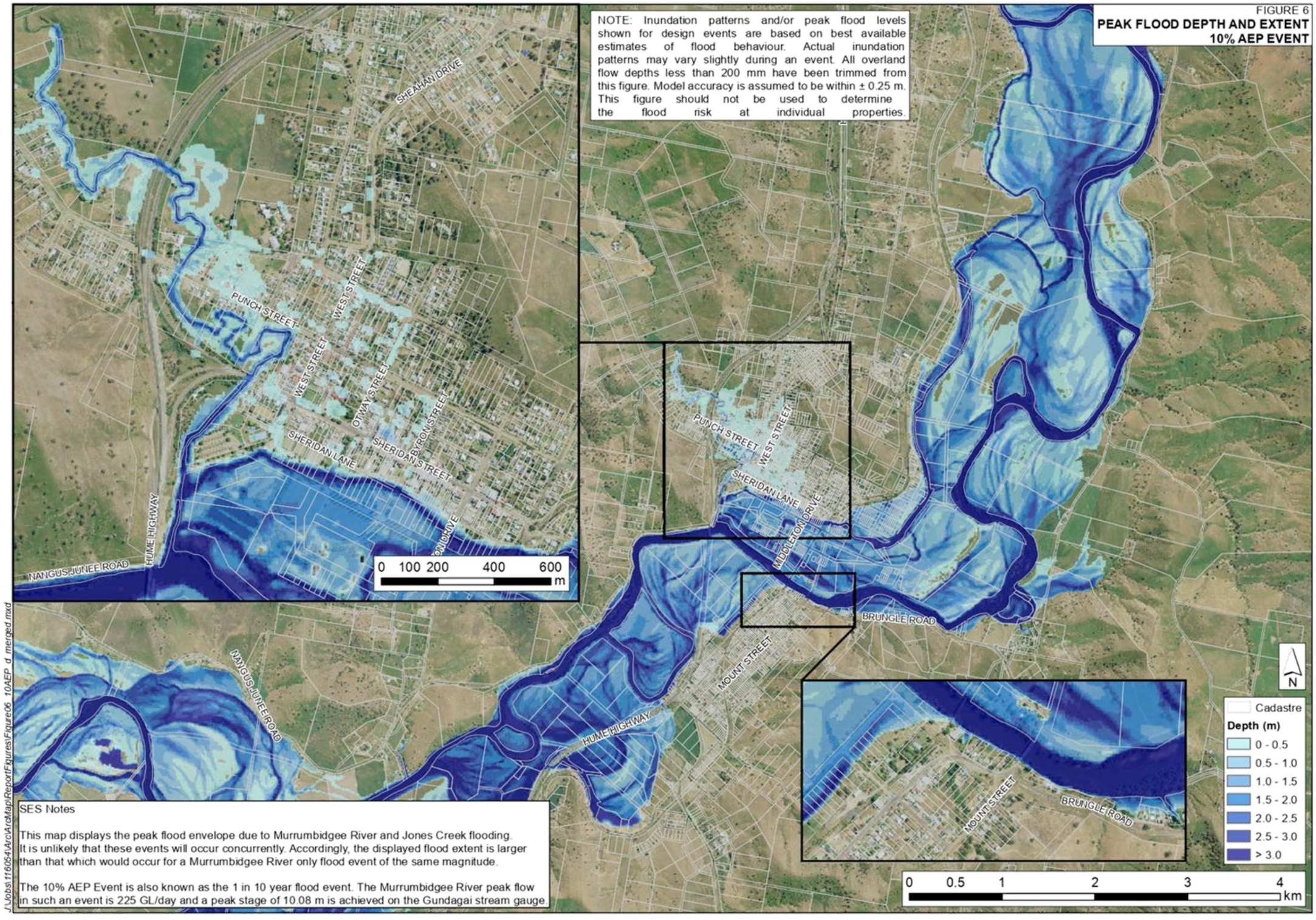
FIGURE 6
PEAK FLOOD DEPTH AND EXTENT
10% AEP EVENT
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
OTWAY STREET
BYRON STREET
SHERIDAN LANE
SHERIDAN STREET
HUME HIGHWAY
NANGUS JUNEE ROAD
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
0 100 200 400 600 m
0 0.5 1 2 3 4 km
N
Cadastre
Depth (m)
0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
> 3.0
SES Notes
This map displays the peak flood envelope due to Murrumbidgee River and Jones Creek flooding. It is unlikely that these events will occur concurrently. Accordingly, the displayed flood extent is larger than that which would occur for a Murrumbidgee River only flood event of the same magnitude.
The 10% AEP Event is also known as the 1 in 10 year flood event. The Murrumbidgee River peak flow in such an event is 225 GL/day and a peak stage of 10.08 m is achieved on the Gundagai stream gauge.
J:\Jobs\116054\ArcMap\ReportFigures\Figure06_10AEP_d_merged.mxd

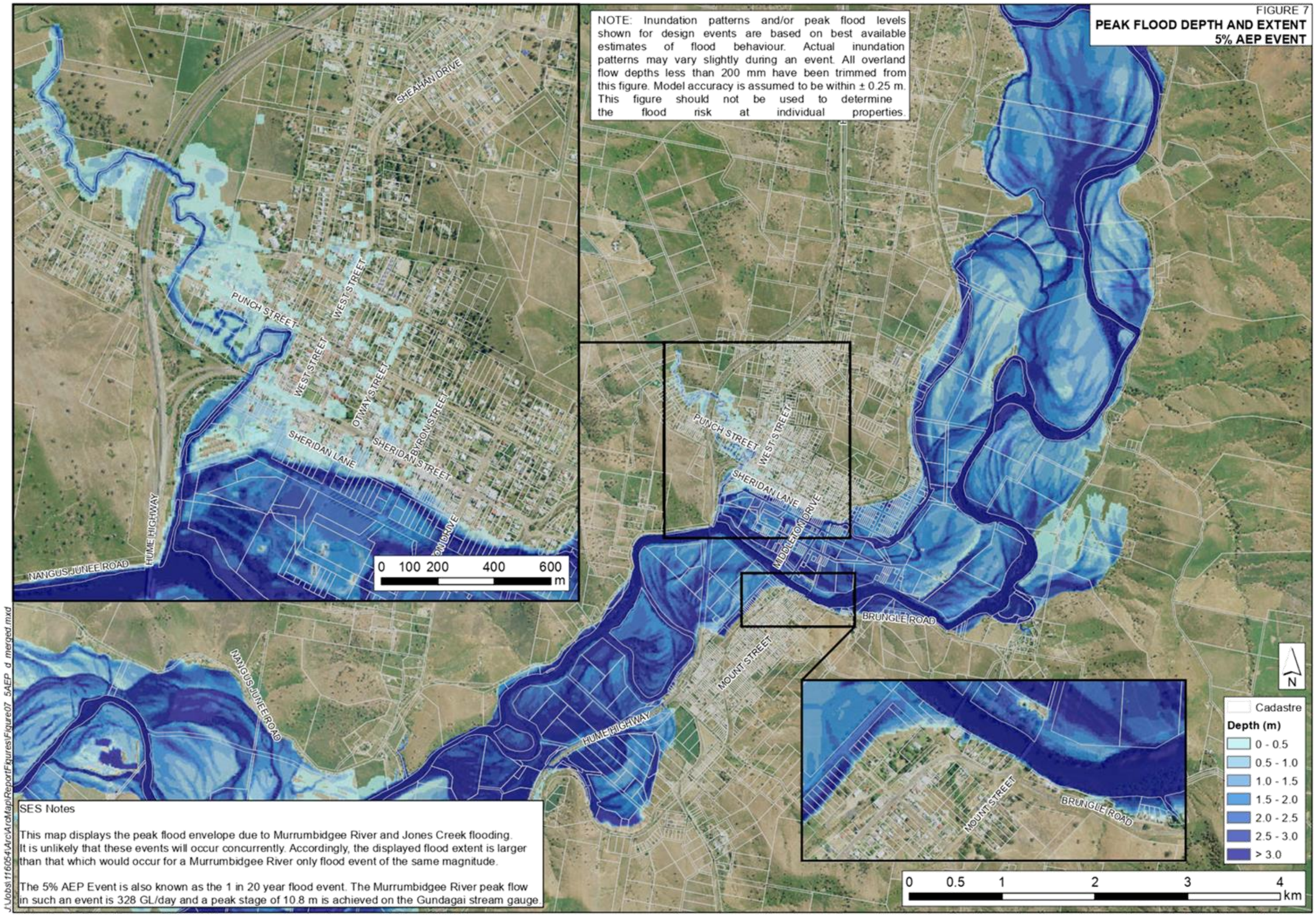
FIGURE 7
PEAK FLOOD DEPTH AND EXTENT
5% AEP EVENT
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
OTWAY STREET
BYRON STREET
SHERIDAN LANE
SHERIDAN STREET
HUME HIGHWAY
NANGUS JUNEE ROAD
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
0 100 200 400 600 m
0 0.5 1 2 3 4 km
N
Cadastre
Depth (m)
0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
> 3.0
SES Notes
This map displays the peak flood envelope due to Murrumbidgee River and Jones Creek flooding. It is unlikely that these events will occur concurrently. Accordingly, the displayed flood extent is larger than that which would occur for a Murrumbidgee River only flood event of the same magnitude.
The 5% AEP Event is also known as the 1 in 20 year flood event. The Murrumbidgee River peak flow in such an event is 328 GL/day and a peak stage of 10.8 m is achieved on the Gundagai stream gauge.
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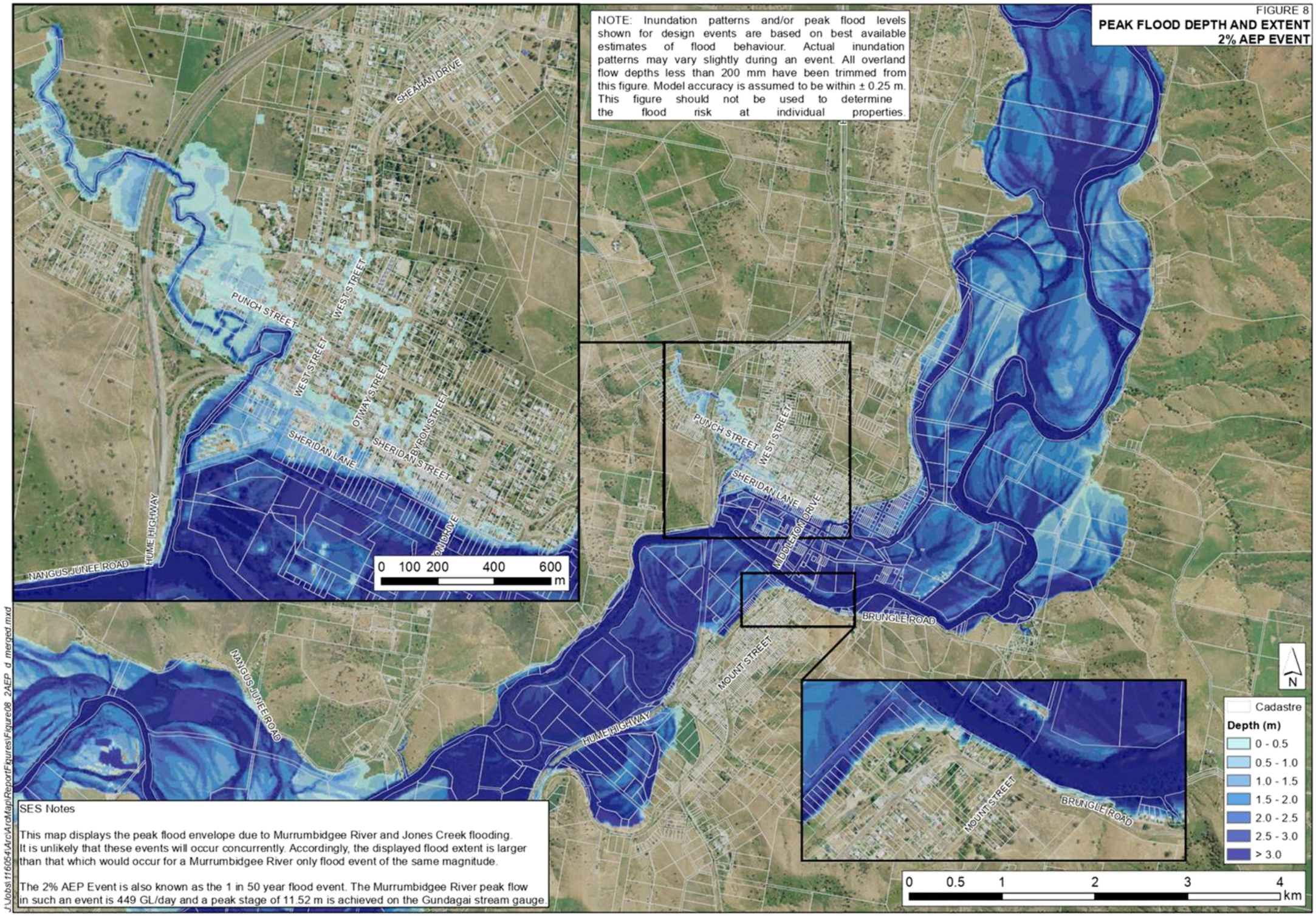
FIGURE 8
PEAK FLOOD DEPTH AND EXTENT
2% AEP EVENT
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
OTWAY STREET
BYRON STREET
SHERIDAN LANE
HUME HIGHWAY
NANGUS JUNEE ROAD
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
0 100 200 400 600 m
0 0.5 1 2 3 4 km
N
Cadastre
Depth (m)
0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
> 3.0
SES Notes
This map displays the peak flood envelope due to Murrumbidgee River and Jones Creek flooding. It is unlikely that these events will occur concurrently. Accordingly, the displayed flood extent is larger than that which would occur for a Murrumbidgee River only flood event of the same magnitude.
The 2% AEP Event is also known as the 1 in 50 year flood event. The Murrumbidgee River peak flow in such an event is 449 GL/day and a peak stage of 11.52 m is achieved on the Gundagai stream gauge.
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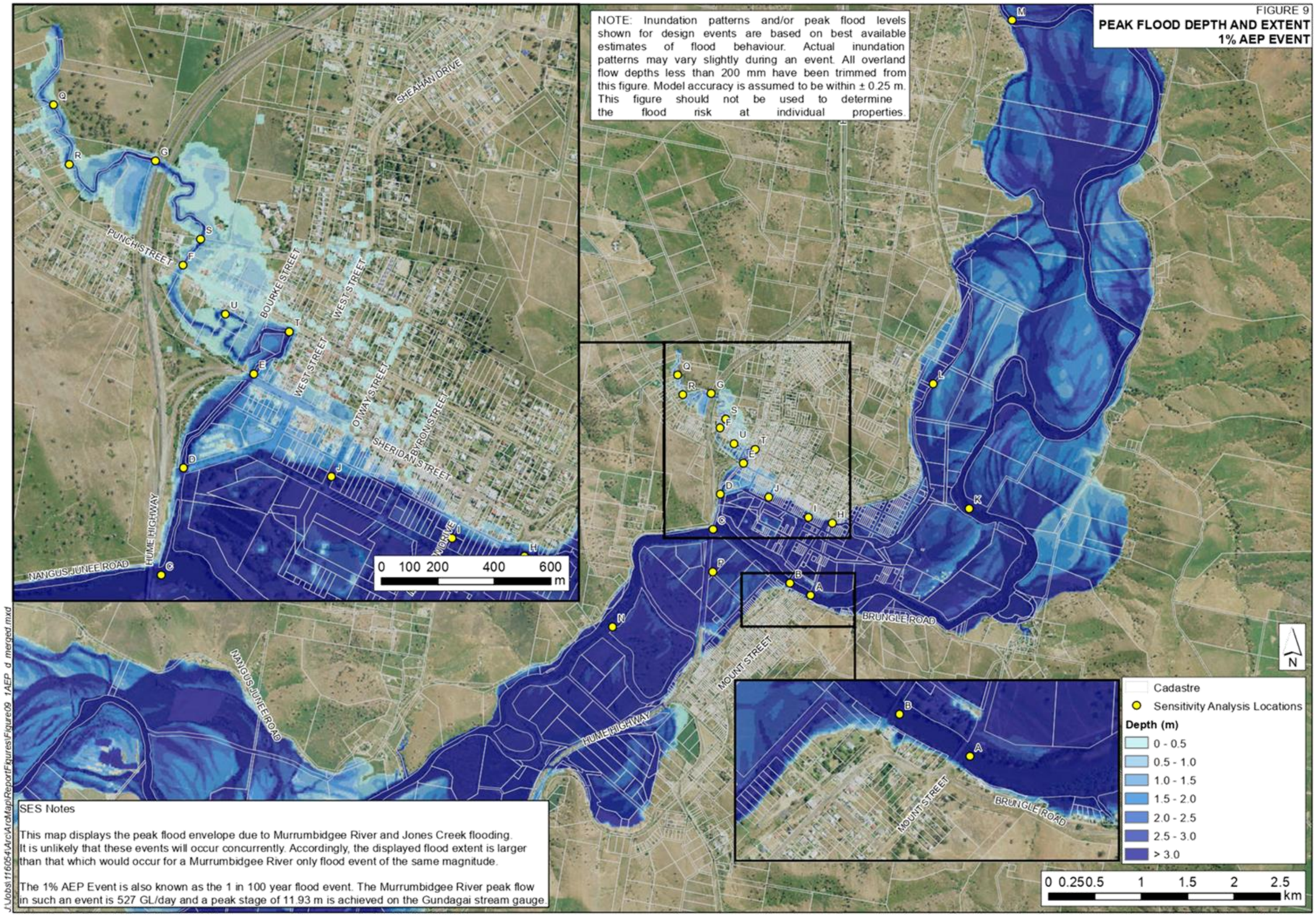
FIGURE 9
PEAK FLOOD DEPTH AND EXTENT
1% AEP EVENT
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
BOURKE STREET
WEST STREET
OTWAY STREET
SHERIDAN STREET
BYRON STREET
HUME HIGHWAY
NANGUS JUNEE ROAD
MOUNT STREET
BRUNGLE ROAD
0 100 200 400 600 m
0 0.250.5 1 1.5 2 2.5 km
N
Cadastre
Sensitivity Analysis Locations
Depth (m)
0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
> 3.0
SES Notes
This map displays the peak flood envelope due to Murrumbidgee River and Jones Creek flooding. It is unlikely that these events will occur concurrently. Accordingly, the displayed flood extent is larger than that which would occur for a Murrumbidgee River only flood event of the same magnitude.
The 1% AEP Event is also known as the 1 in 100 year flood event. The Murrumbidgee River peak flow in such an event is 527 GL/day and a peak stage of 11.93 m is achieved on the Gundagai stream gauge.
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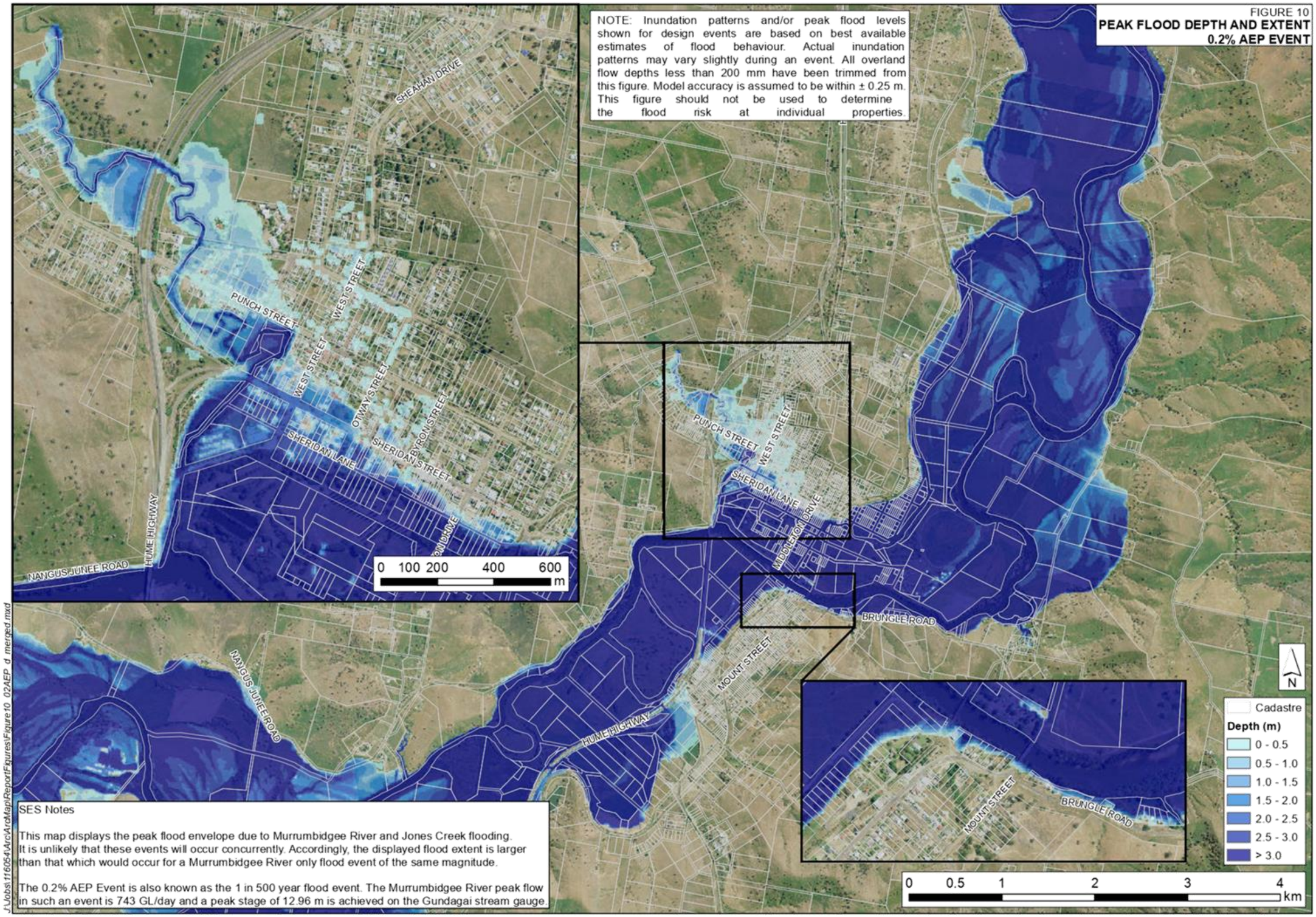
FIGURE 10
PEAK FLOOD DEPTH AND EXTENT
0.2% AEP EVENT
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
OTWAY STREET
BYRON STREET
SHERIDAN LANE
SHERIDAN STREET
HUME HIGHWAY
NANGUS JUNEE ROAD
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
0 100 200 400 600 m
0 0.5 1 2 3 4 km
N
Cadastre
Depth (m)
0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
> 3.0
SES Notes
This map displays the peak flood envelope due to Murrumbidgee River and Jones Creek flooding. It is unlikely that these events will occur concurrently. Accordingly, the displayed flood extent is larger than that which would occur for a Murrumbidgee River only flood event of the same magnitude.
The 0.2% AEP Event is also known as the 1 in 500 year flood event. The Murrumbidgee River peak flow in such an event is 743 GL/day and a peak stage of 12.96 m is achieved on the Gundagai stream gauge.
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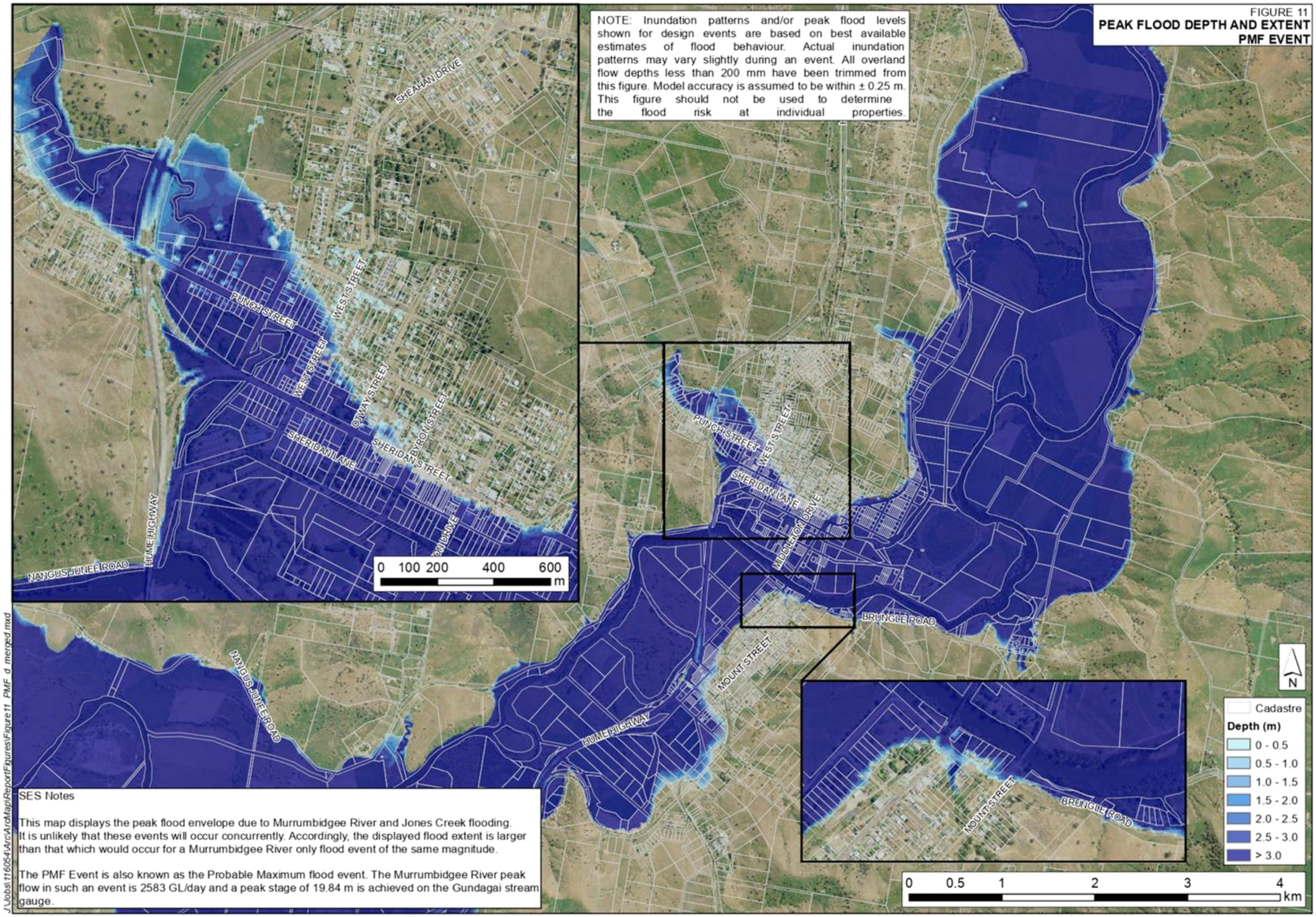
FIGURE 11
PEAK FLOOD DEPTH AND EXTENT
PMF EVENT
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
OTWAY STREET
BYRON STREET
SHERIDAN LANE
SHERIDAN STREET
HUME HIGHWAY
NANGUS JUNEE ROAD
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
0 100 200 400 600 m
0 0.5 1 2 3 4 km
N
Cadastre
Depth (m)
0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
> 3.0
SES Notes
This map displays the peak flood envelope due to Murrumbidgee River and Jones Creek flooding. It is unlikely that these events will occur concurrently. Accordingly, the displayed flood extent is larger than that which would occur for a Murrumbidgee River only flood event of the same magnitude.
The PMF Event is also known as the Probable Maximum flood event. The Murrumbidgee River peak flow in such an event is 2583 GL/day and a peak stage of 19.84 m is achieved on the Gundagai stream gauge.
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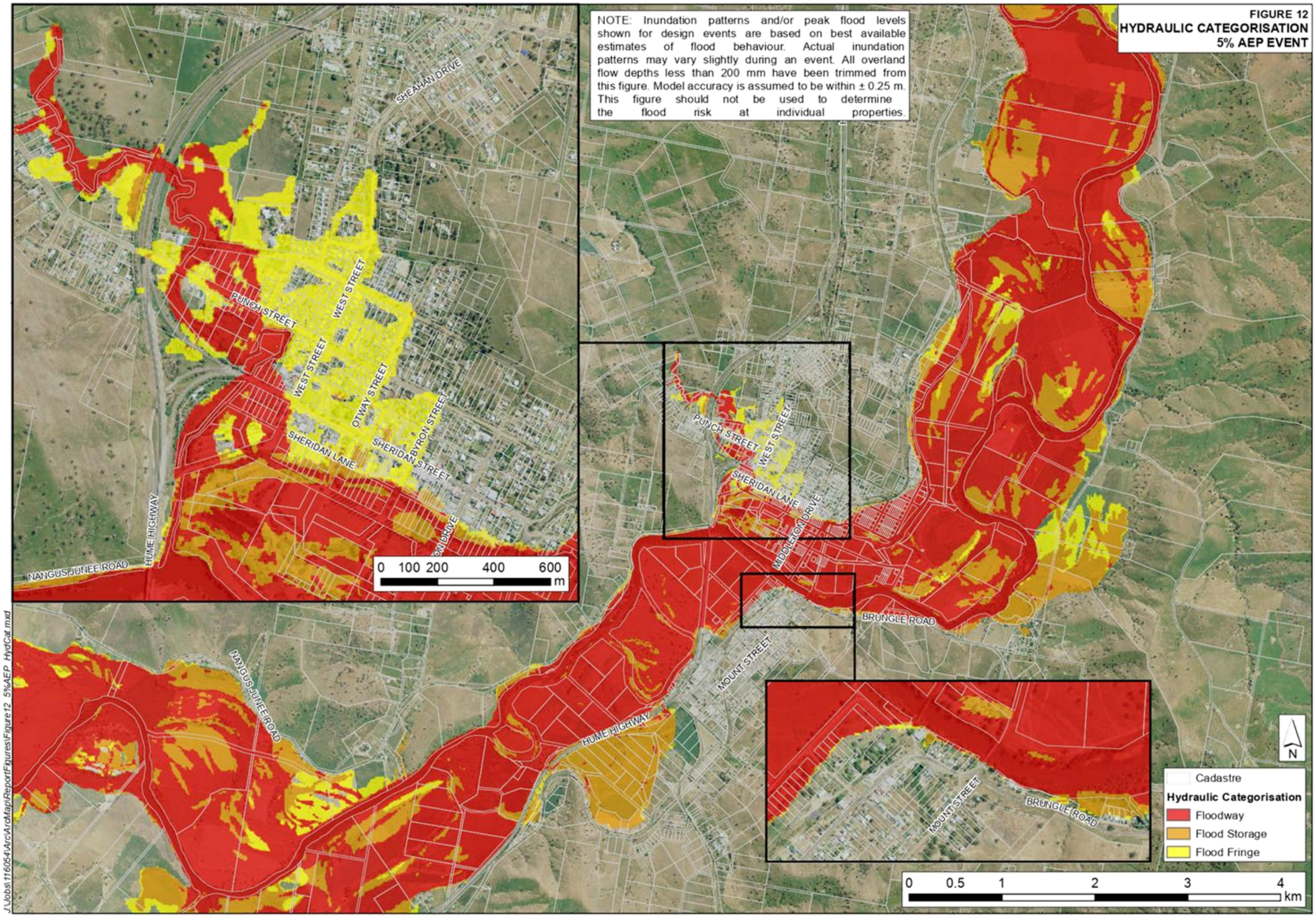
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
FIGURE 12
HYDRAULIC CATEGORISATION
5% AEP EVENT
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
WEST STREET
OTWAY STREET
SHERIDAN LANE
SHERIDAN BYRON STREET
HUME HIGHWAY
NANGUS JUNEE ROAD
0 100 200 400 600 m
PUNCH STREET
WEST STREET
SHERIDAN LANE
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
NANGUS JUNEE ROAD
HUME HIGHWAY
MOUNT STREET
BRUNGLE ROAD
N
Cadastre
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0 0.5 1 2 3 4 km
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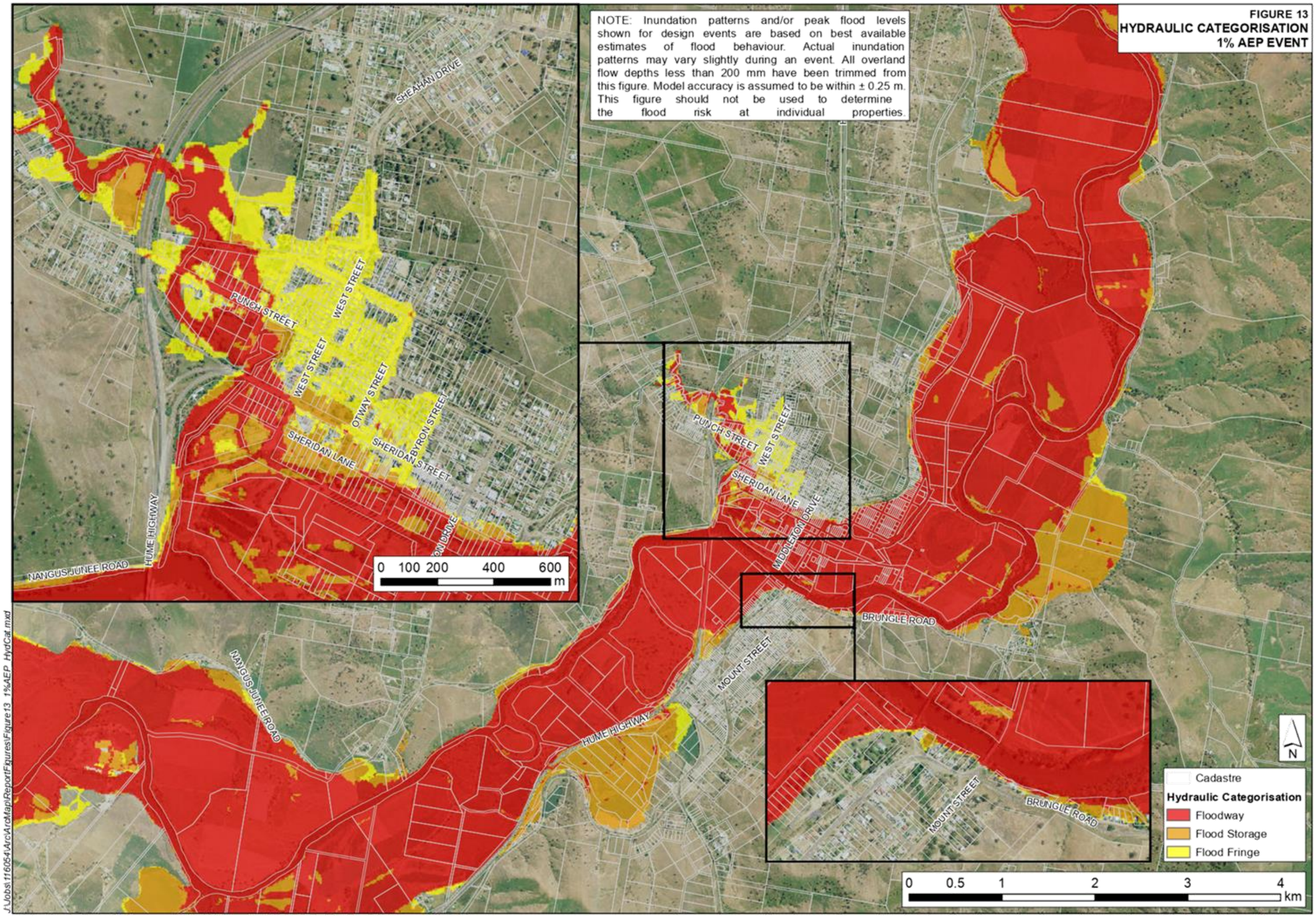
FIGURE 13
HYDRAULIC CATEGORISATION
1% AEP EVENT
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
OTWAY STREET
BYRON STREET
SHERIDAN LANE
NANGUS JUNEE ROAD
HUME HIGHWAY
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
0 100 200 400 600 m
0 0.5 1 2 3 4 km
N
Cadastre
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
J:\Jobs\116054\ArcAreMap\ReportFigures\Figure 13 1%AEP HydCat.mxd

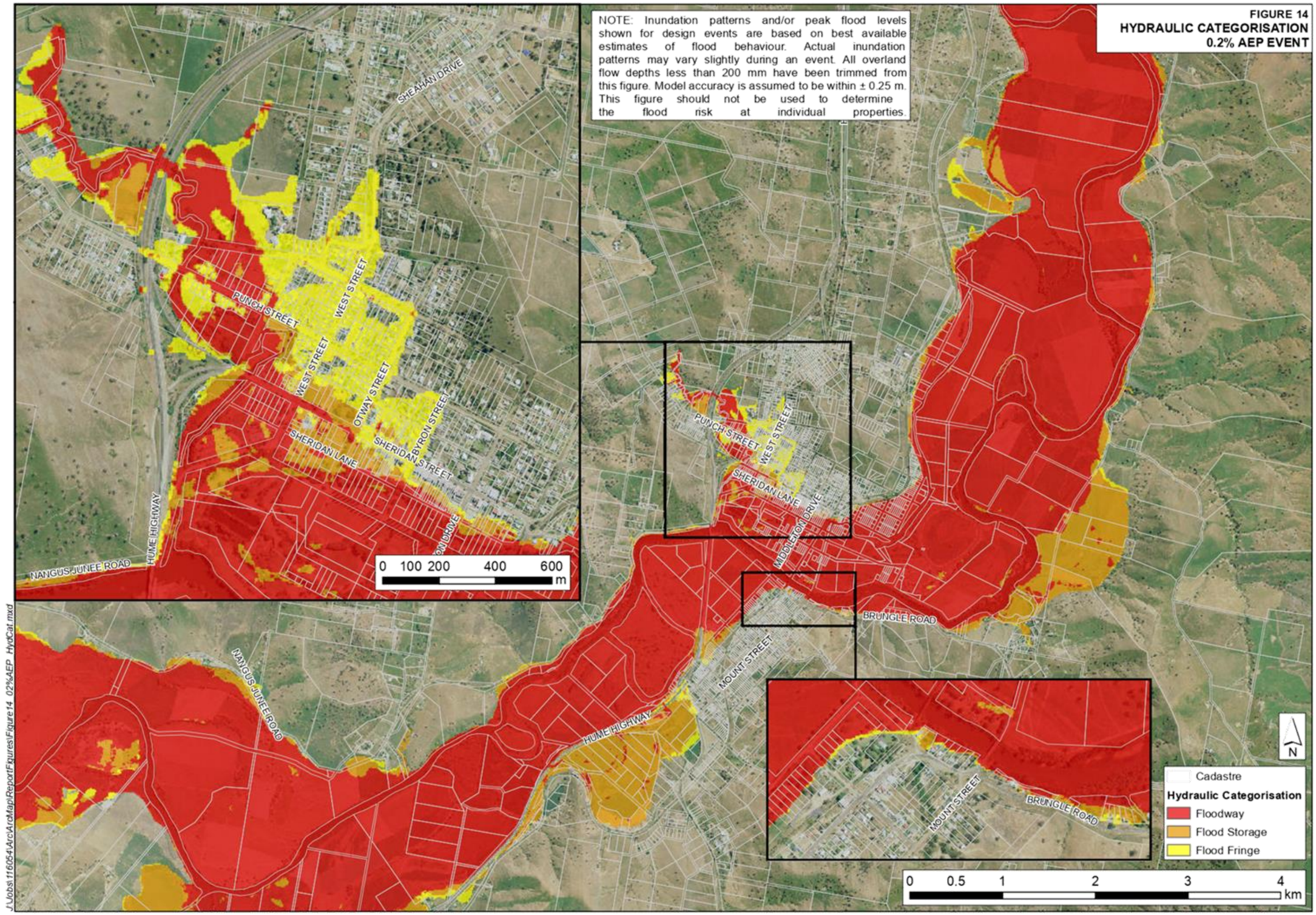
FIGURE 14
HYDRAULIC CATEGORISATION
0.2% AEP EVENT
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
OTWAY STREET
BYRON STREET
SHERIDAN LANE
SHERIDAN STREET
HUME HIGHWAY
NANGUS JUNEE ROAD
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
0 100 200 400 600 m
0 0.5 1 2 3 4 km
N
Cadastre
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
J:\Jobs\116054\ArcArcMap\ReportFigures\Figure 14 02%AEP HydCat.mxd

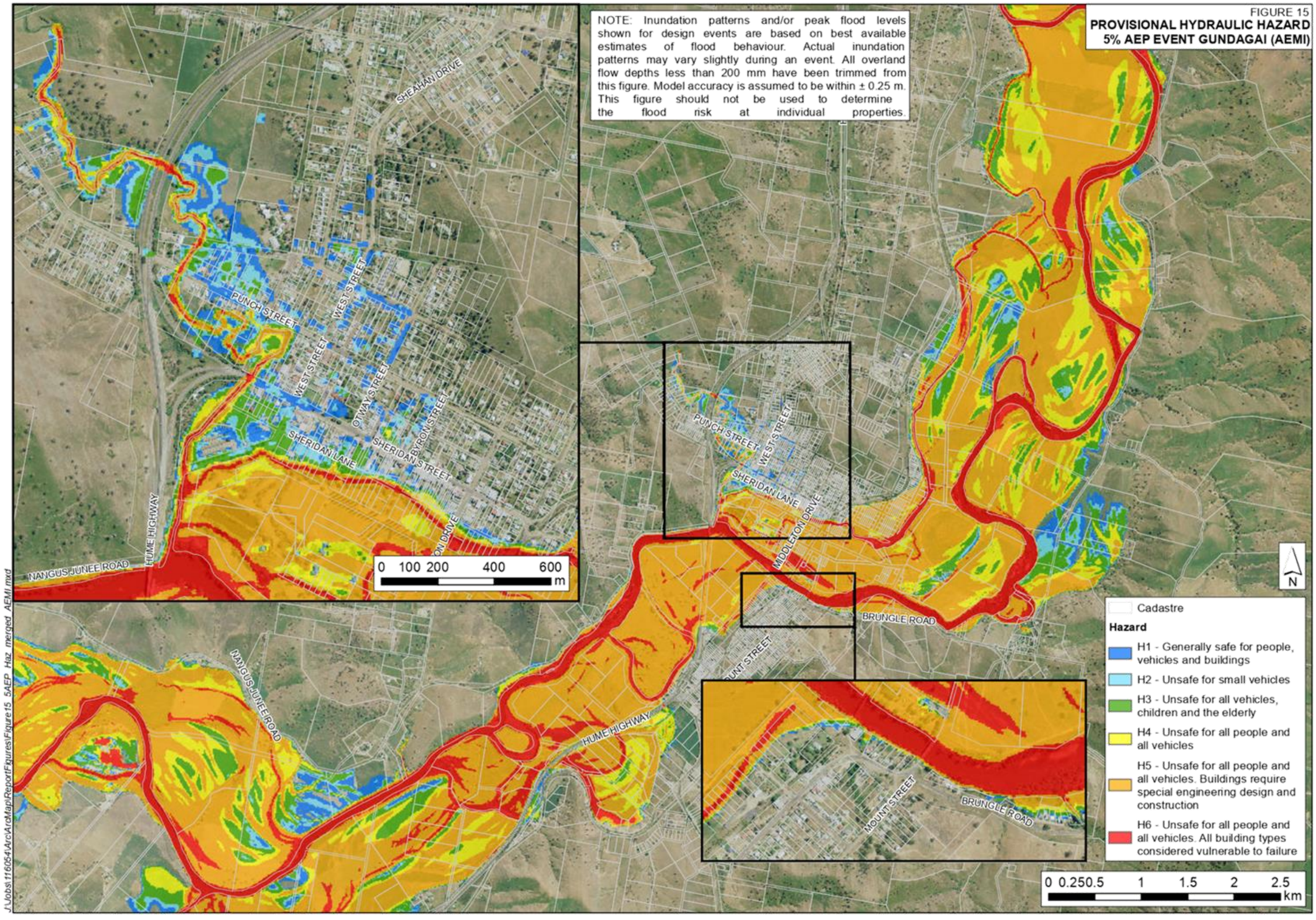
FIGURE 15
PROVISIONAL HYDRAULIC HAZARD
5% AEP EVENT GUNDAGAI (AEMI)
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
OTWAY STREET
BYRON STREET
SHERIDAN LANE
SHERIDAN STREET
HUME HIGHWAY
NANGUS-JUNEE ROAD
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
0 100 200 400 600 m
0 0.250.5 1 1.5 2 2.5 km
N
Cadastre
Hazard
H1 - Generally safe for people, vehicles 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. Buildings require special engineering design and construction
H6 - Unsafe for all people and all vehicles. All building types considered vulnerable to failure
J:\Jobs\116054\ArcMap\ReportFigures\Figure15_5AEP_Haz_merged_AEMI.mxd

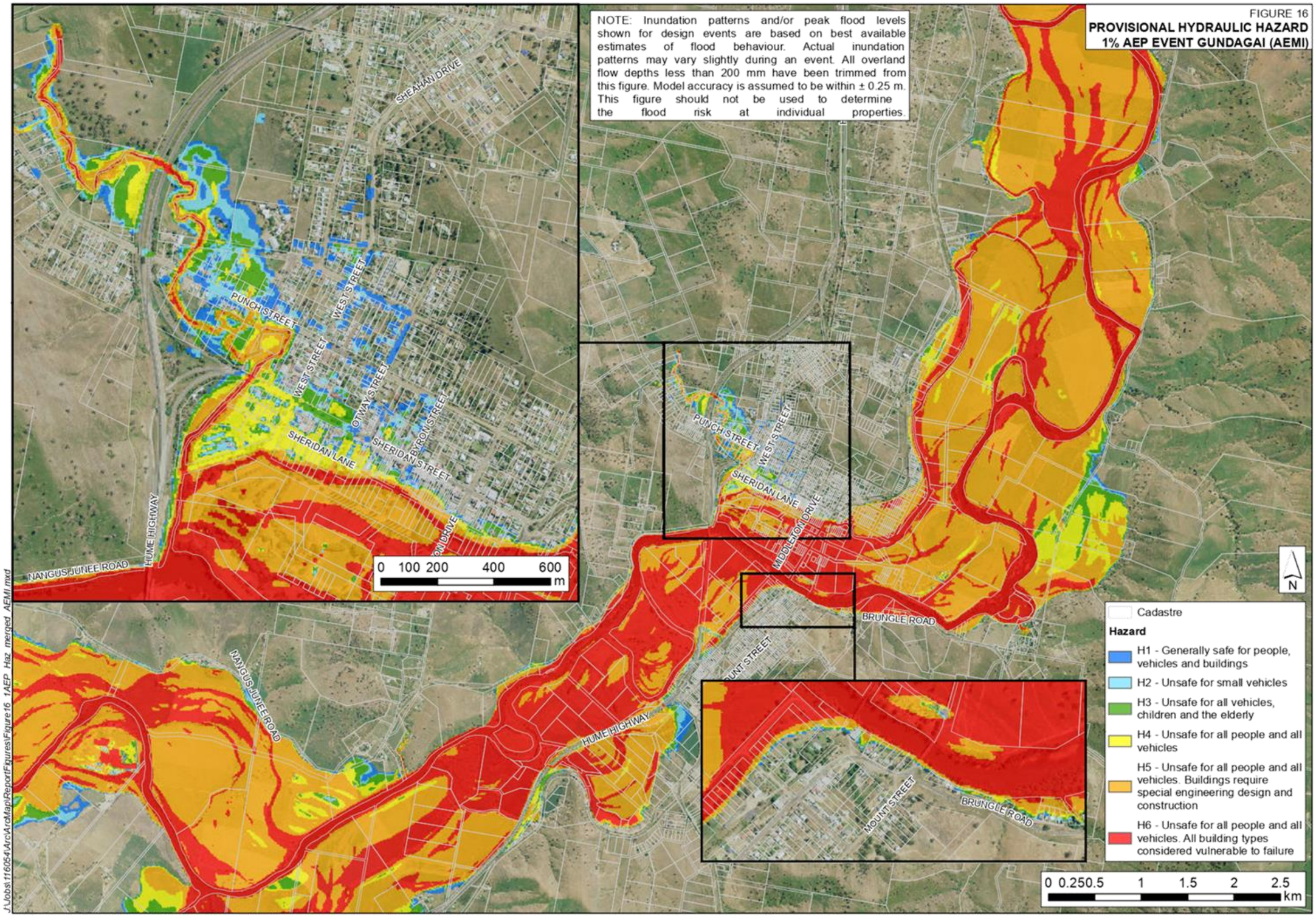
FIGURE 16
PROVISIONAL HYDRAULIC HAZARD
1% AEP EVENT GUNDAGAI (AEMI)
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
OTWAY STREET
BYRON STREET
SHERIDAN LANE
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
HUME HIGHWAY
NANGUS JUNEE ROAD
0 100 200 400 600 m
0 0.250.5 1 1.5 2 2.5 km
N
Cadastre
Hazard
H1 - Generally safe for people, vehicles 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. Buildings require special engineering design and construction
H6 - Unsafe for all people and all vehicles. All building types considered vulnerable to failure
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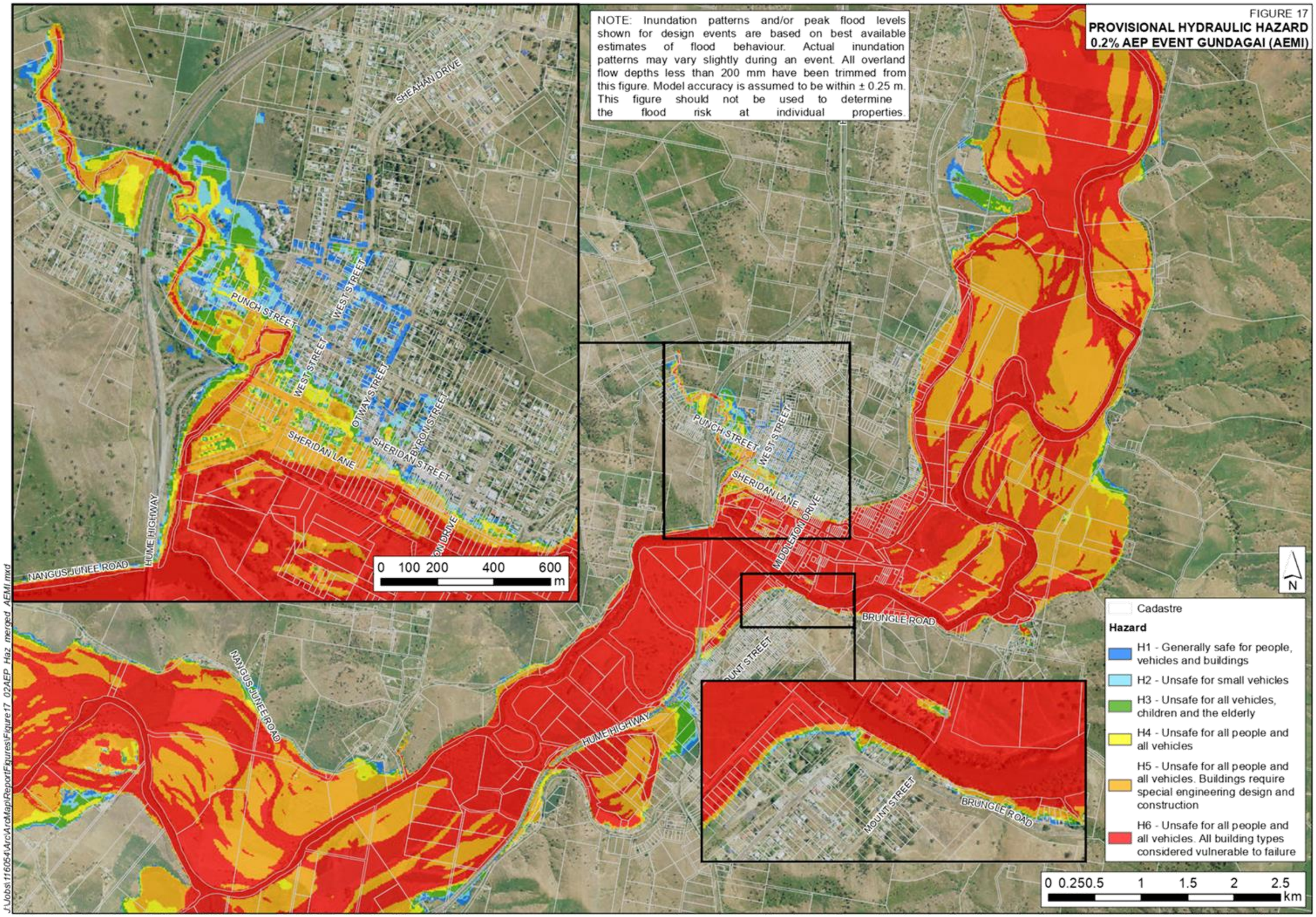


FIGURE 17
PROVISIONAL HYDRAULIC HAZARD
0.2% AEP EVENT GUNDAGAI (AEMI)
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. All overland flow depths less than 200 mm have been trimmed from this figure. Model accuracy is assumed to be within ± 0.25 m. This figure should not be used to determine the flood risk at individual properties.
SHEAHAN DRIVE
PUNCH STREET
WEST STREET
OTWAY STREET
SHERIDAN LANE
SHERIDAN STREET
BYRON STREET
HUME HIGHWAY
NANGUS JUNEE ROAD
MIDDLETON DRIVE
BRUNGLE ROAD
MOUNT STREET
0 100 200 400 600 m
0 0.250.5 1 1.5 2 2.5 km
N
Cadastre
Hazard
H1 - Generally safe for people, vehicles 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. Buildings require special engineering design and construction
H6 - Unsafe for all people and all vehicles. All building types considered vulnerable to failure
J:\Jobs\116054\ArcMap\ReportFigures\Figure17_02AEP_Haz_merged_AEMI.mxd

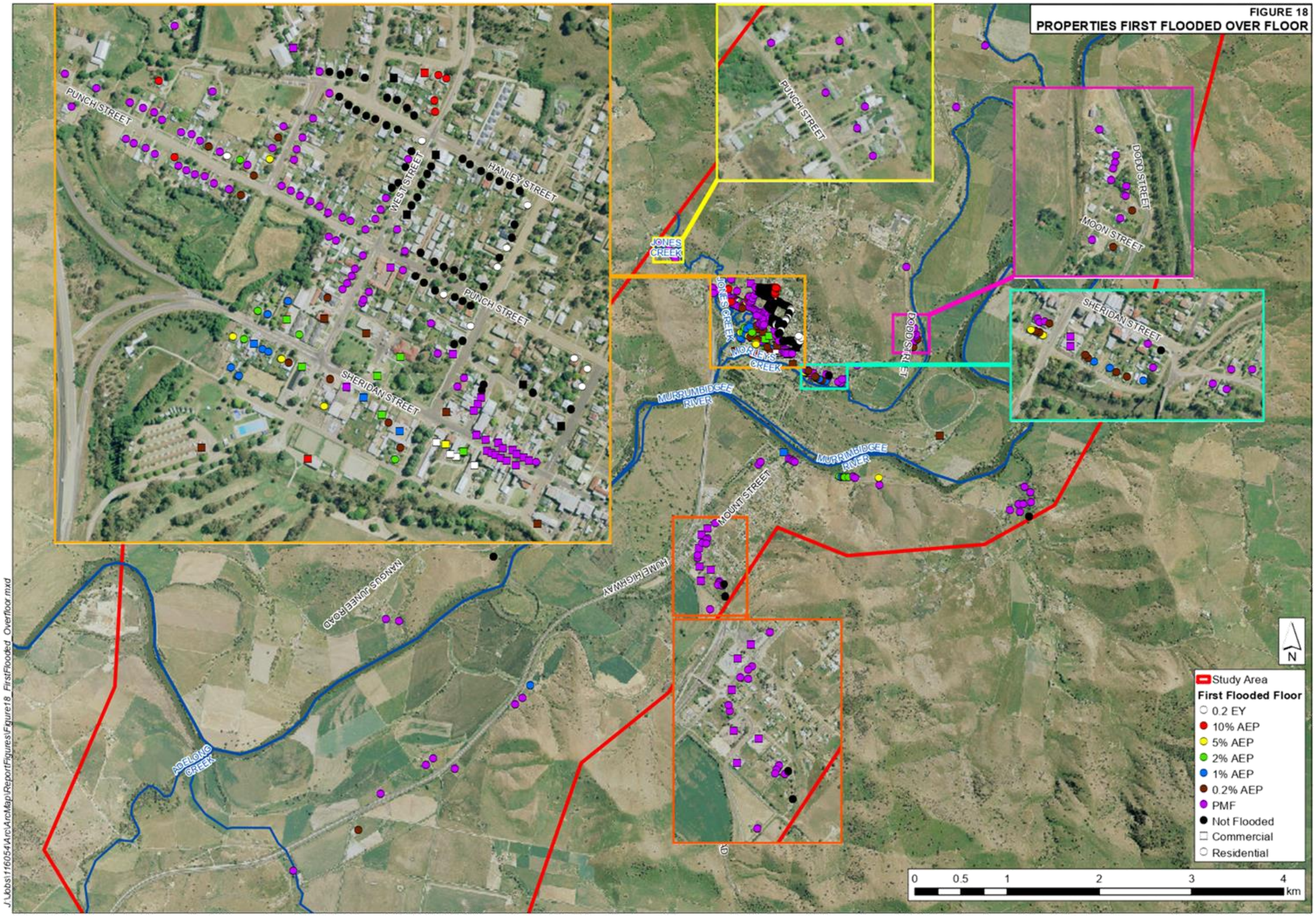


FIGURE 18
PROPERTIES FIRST FLOODED OVER FLOOR
PUNCH STREET
WEST STREET
HANLEY STREET
PUNCH STREET
SHERIDAN STREET
JONES CREEK
JONES CREEK
MORLEYS CREEK
DODD STREET
MOON STREET
SHERIDAN STREET
MURRUMBIDGEE RIVER
MURRUMBIDGEE RIVER
MOUNT STREET
NANGUS JUNEE ROAD
HUME HIGHWAY
ADELONG CREEK
N
Study Area
First Flooded Floor
0.2 EY
10% AEP
5% AEP
2% AEP
1% AEP
0.2% AEP
PMF
Not Flooded
Commercial
Residential
0 0.5 1 2 3 4
km
J:\Jobs\116054\ArcMap\ReportFigures\Figure18_FirstFlooded_Overfloor.mxd

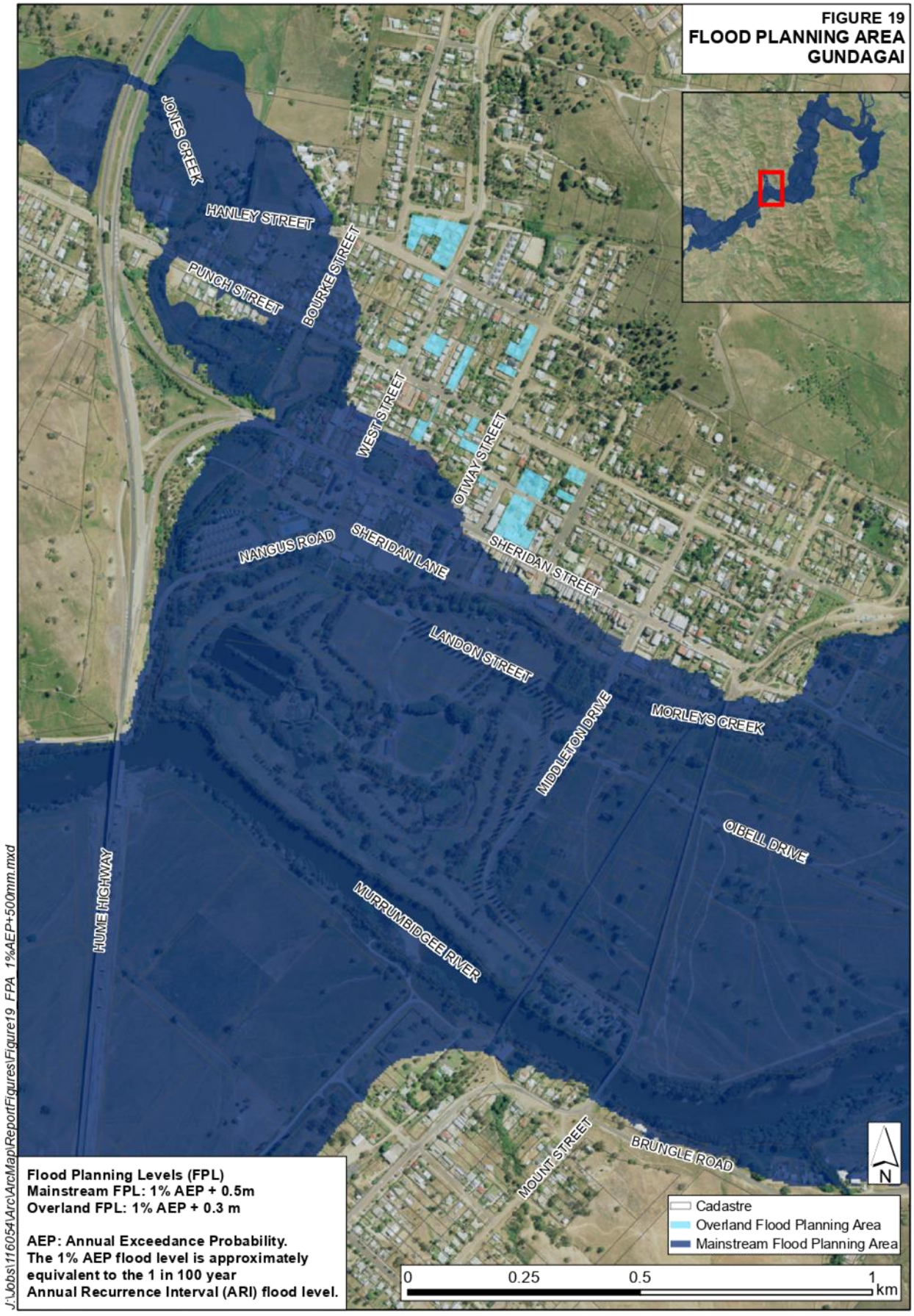


FIGURE 19
FLOOD PLANNING AREA
GUNDAGAI
JONES CREEK
HANLEY STREET
PUNCH STREET
BOURKE STREET
WEST STREET
OTWAY STREET
NANGUS ROAD
SHERIDAN LANE
SHERIDAN STREET
LANDON STREET
MIDDLETON DRIVE
MORLEYS CREEK
OIBELL DRIVE
HUME HIGHWAY
MURRUMBIDGEE RIVER
MOUNT STREET
BRUNGLE ROAD
N
Cadastre
Overland Flood Planning Area
Mainstream Flood Planning Area
0
0.25
0.5
1
km
Flood Planning Levels (FPL)
Mainstream FPL: 1% AEP + 0.5m
Overland FPL: 1% AEP + 0.3 m
AEP: Annual Exceedance Probability.
The 1% AEP flood level is approximately equivalent to the 1 in 100 year
Annual Recurrence Interval (ARI) flood level.
J:\Jobs\116054\ArcMap\ReportFigures\Figure19_FPA_1%AEP+500mm.mxd

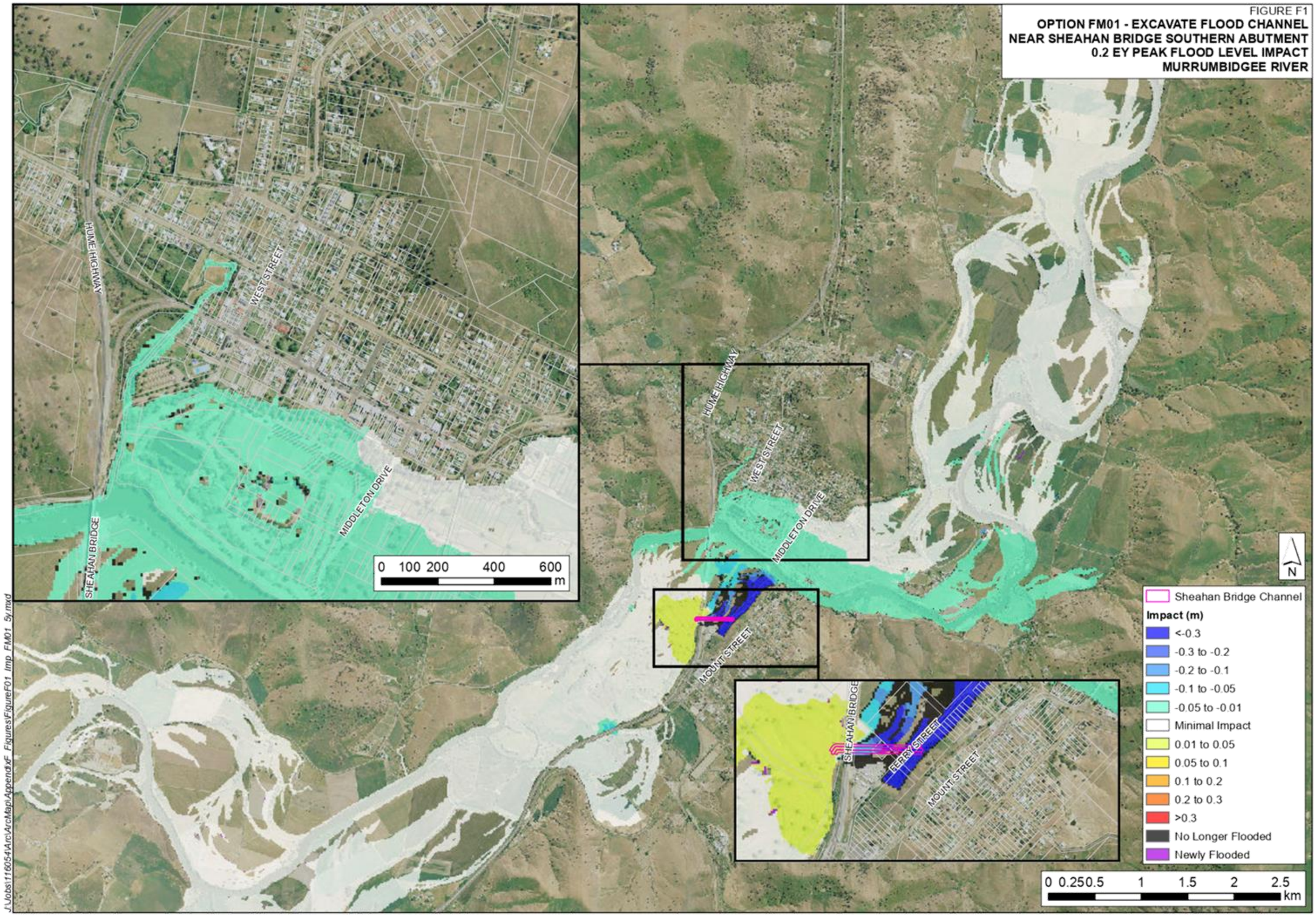


FIGURE F1
OPTION FM01 - EXCAVATE FLOOD CHANNEL
NEAR SHEAHAN BRIDGE SOUTHERN ABUTMENT
0.2 EY PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
HUME HIGHWAY
WEST STREET
MIDDLETON DRIVE
SHEAHAN BRIDGE
MOUNT STREET
FERRY STREET
0 100 200 400 600 m
0 0.250.5 1 1.5 2 2.5 km
N
Sheahan Bridge Channel
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
J:\Jobs\116054\ArcMap\Appendix\F_Figures\FigureF01_Imp_FM01_5y.mxd

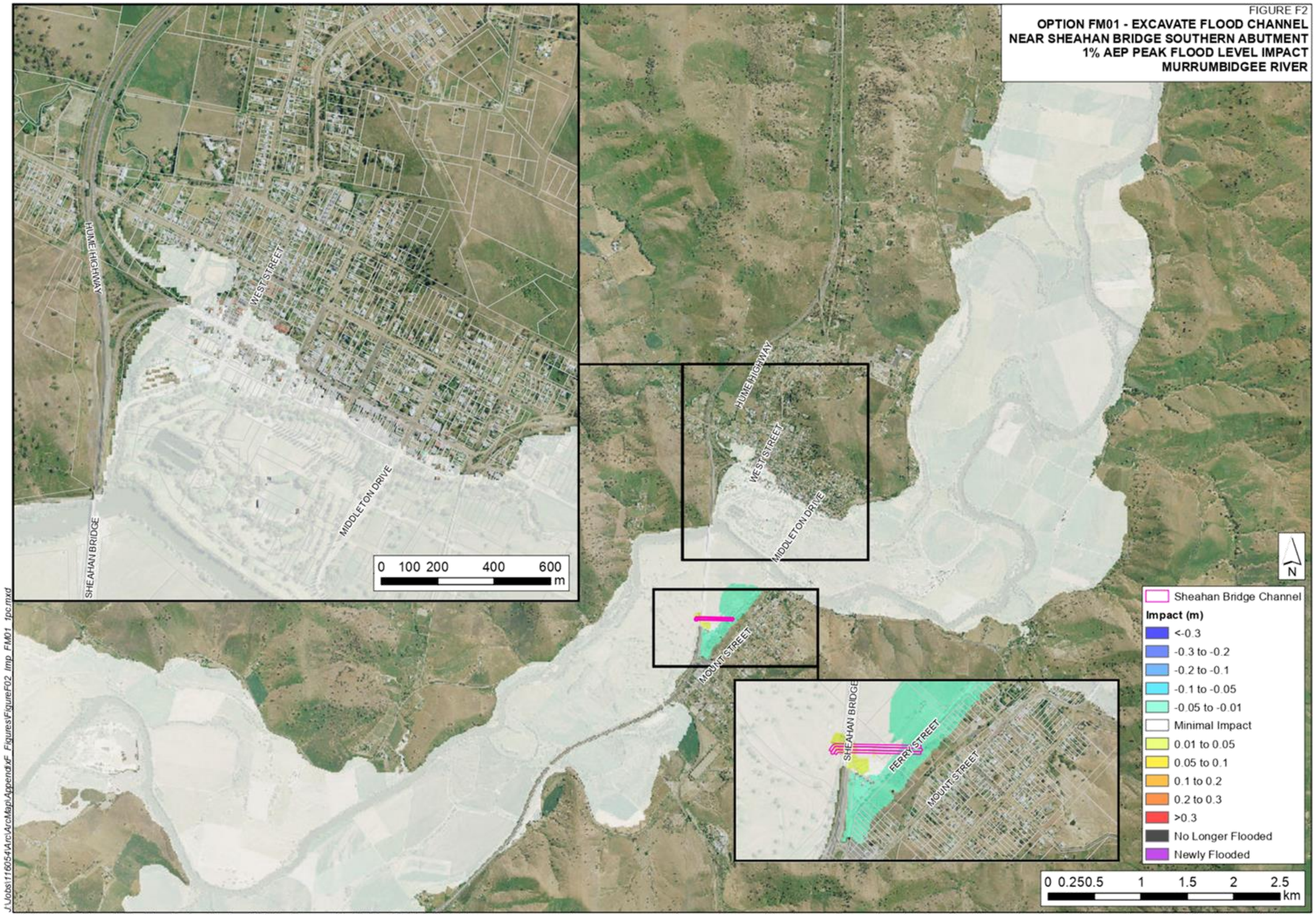


FIGURE F2
OPTION FM01 - EXCAVATE FLOOD CHANNEL
NEAR SHEAHAN BRIDGE SOUTHERN ABUTMENT
1% AEP PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
HUME HIGHWAY
WEST STREET
MIDDLETON DRIVE
SHEAHAN BRIDGE
MOUNT STREET
FERRY STREET
0 100 200 400 600 m
N
Sheahan Bridge Channel
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.250.5 1 1.5 2 2.5 km
J:\Jobs\116054\ArcMap\Append\xF_Figures\FigureF02_Imp_FM01_1pc.mxd

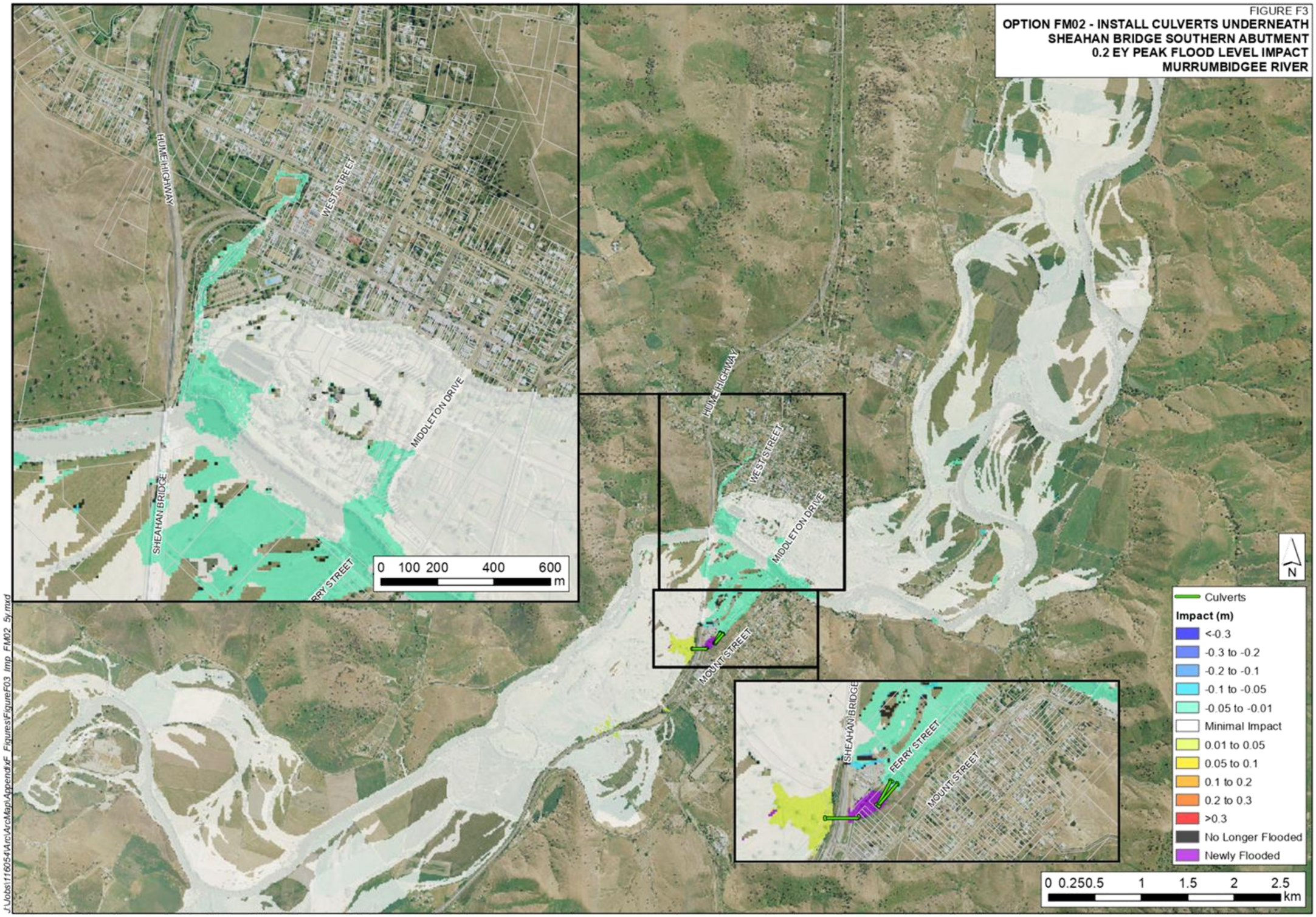


FIGURE F3
OPTION FM02 - INSTALL CULVERTS UNDERNEATH SHEAHAN BRIDGE SOUTHERN ABUTMENT
0.2 EY PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
HUME HIGHWAY
WEST STREET
MIDDLETON DRIVE
SHEAHAN BRIDGE
FERRY STREET
MOUNT STREET
0 100 200 400 600 m
0 0.250.5 1 1.5 2 2.5 km
N
Culverts
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
J:\Jobs\116054\Arc\ArcMap\Appendix F_Figures\FigureF03_Imp_FM02_5y.mxd

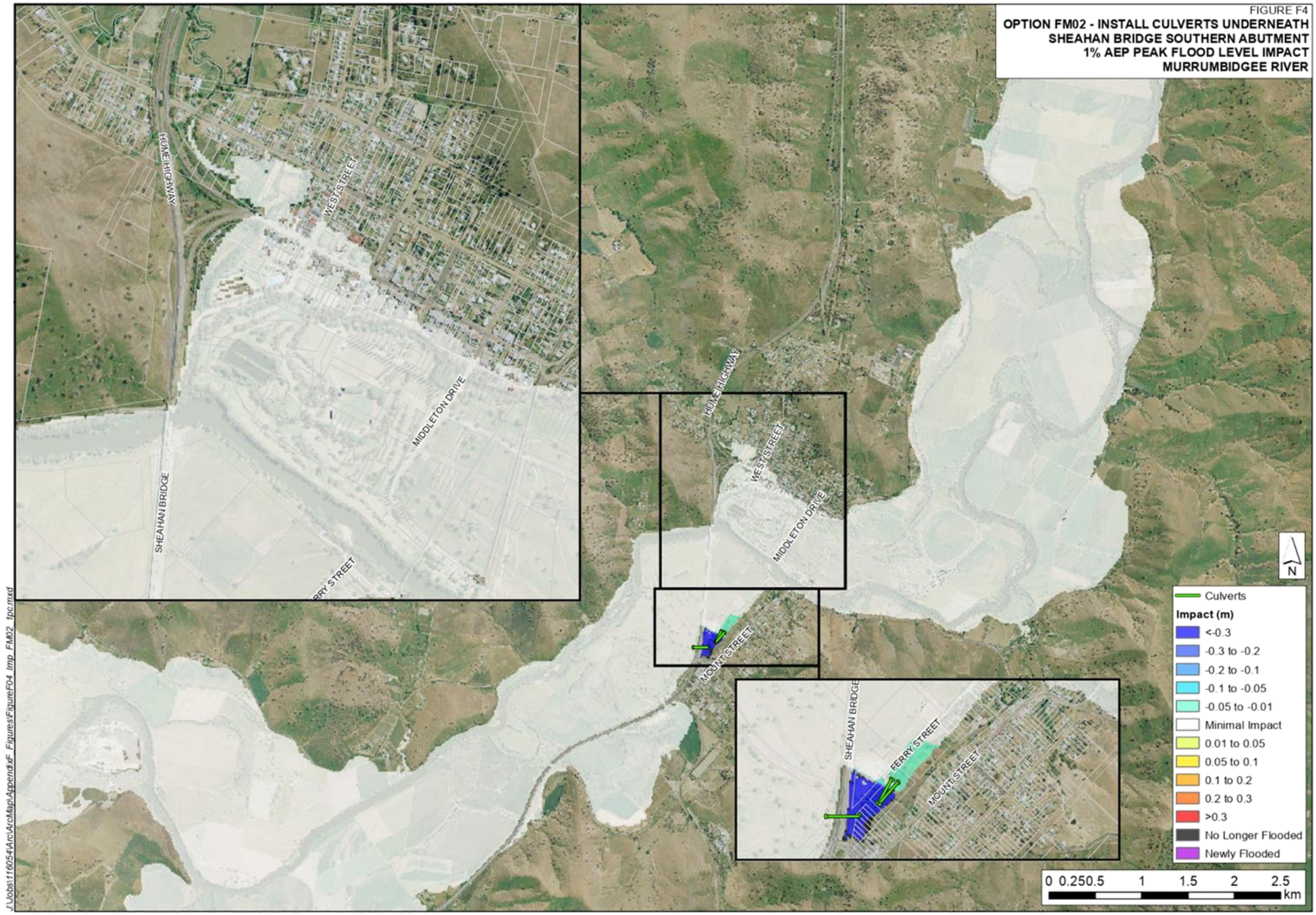


FIGURE F4
OPTION FM02 - INSTALL CULVERTS UNDERNEATH SHEAHAN BRIDGE SOUTHERN ABUTMENT
1% AEP PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
HUME HIGHWAY
WEST STREET
MIDDLETON DRIVE
SHEAHAN BRIDGE
FERRY STREET
MOUNT STREET
N
Culverts
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.250.5 1 1.5 2 2.5
km
J:\Jobs\116054\Arc\ArcMap\Appendix F_Figures\FigureF04_Imp_FM02_1pc.mxd

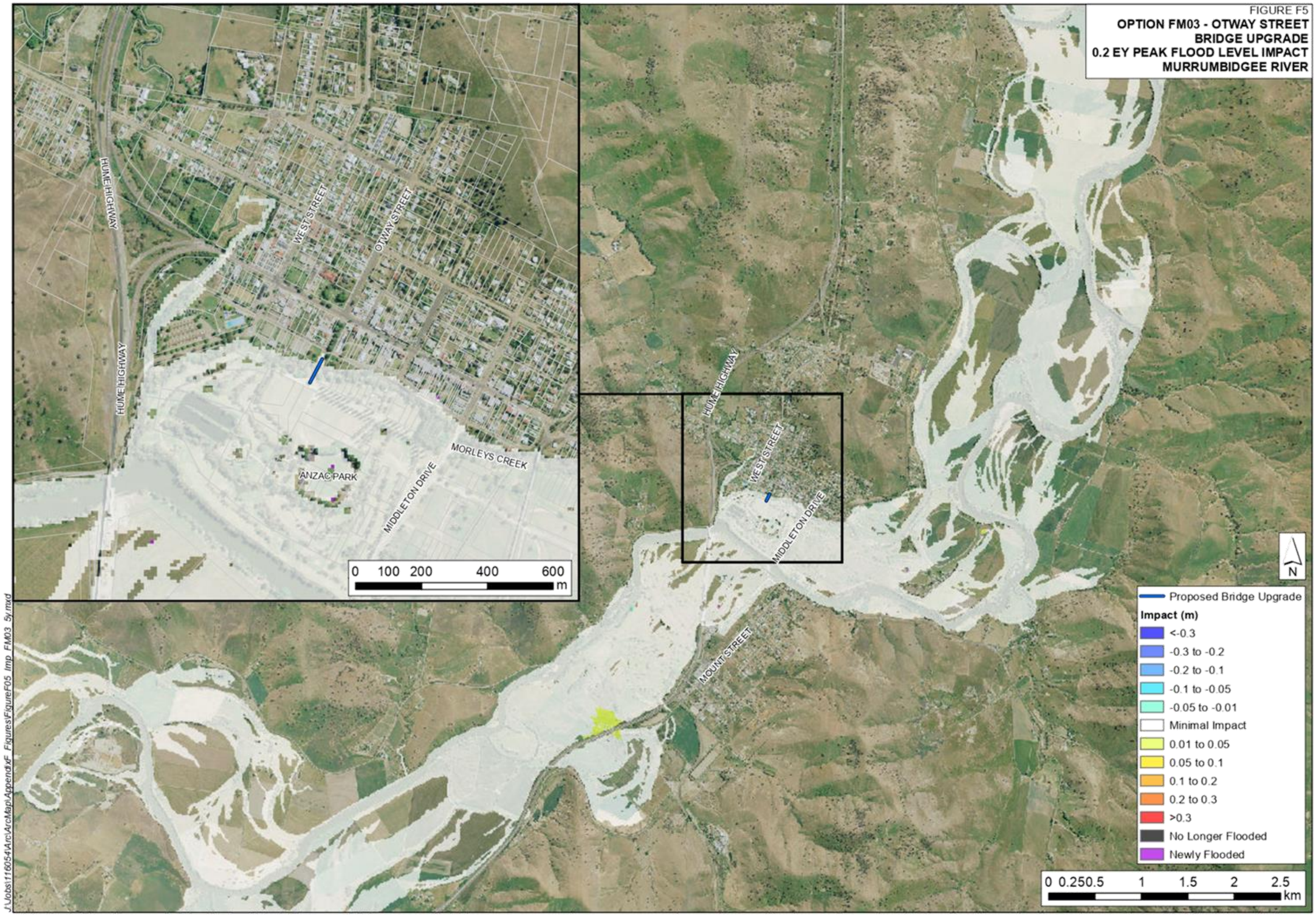


FIGURE F5
OPTION FM03 - OTWAY STREET
BRIDGE UPGRADE
0.2 EY PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
HUME HIGHWAY
WEST STREET
OTWAY STREET
ANZAC PARK
MORLEYS CREEK
MIDDLETON DRIVE
MOUNT STREET
0 100 200 400 600 m
0 0.250.5 1 1.5 2 2.5 km
N
Proposed Bridge Upgrade
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
J:\Jobs\116054\Arc\ArcMap\Appendix\F_Figures\FigureF05_Imp_FM03_5y.mxd

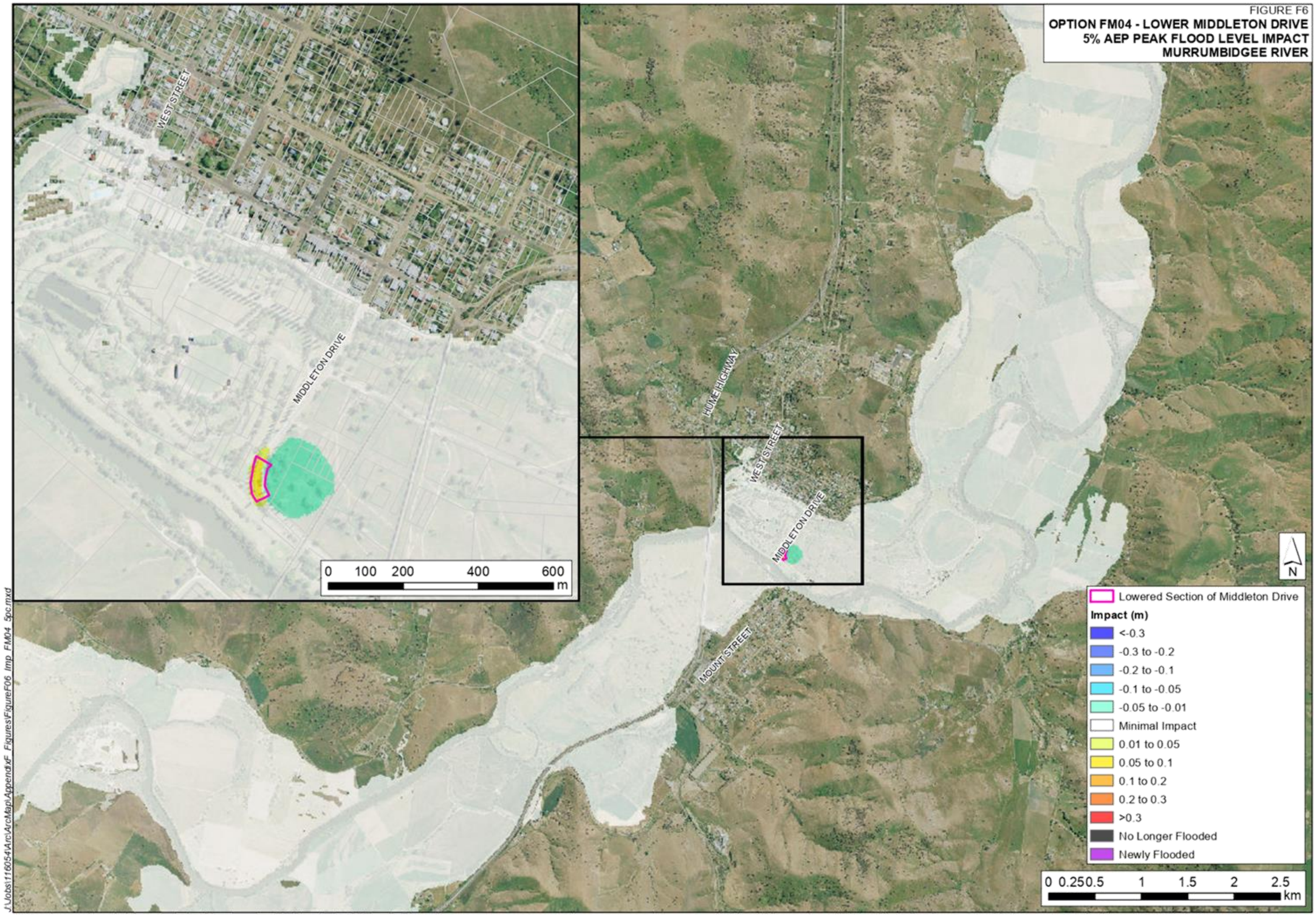


FIGURE F6
OPTION FM04 - LOWER MIDDLETON DRIVE
5% AEP PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
WEST STREET
MIDDLETON DRIVE
HUME HIGHWAY
MOUNT STREET
0 100 200 400 600 m
0 0.250.5 1 1.5 2 2.5 km
N
Lowered Section of Middleton Drive
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
J:\Jobs\116054\Arc\ArcMap\Appendix\F_Figures\FigureF06_Imp_FM04_5pc.mxd

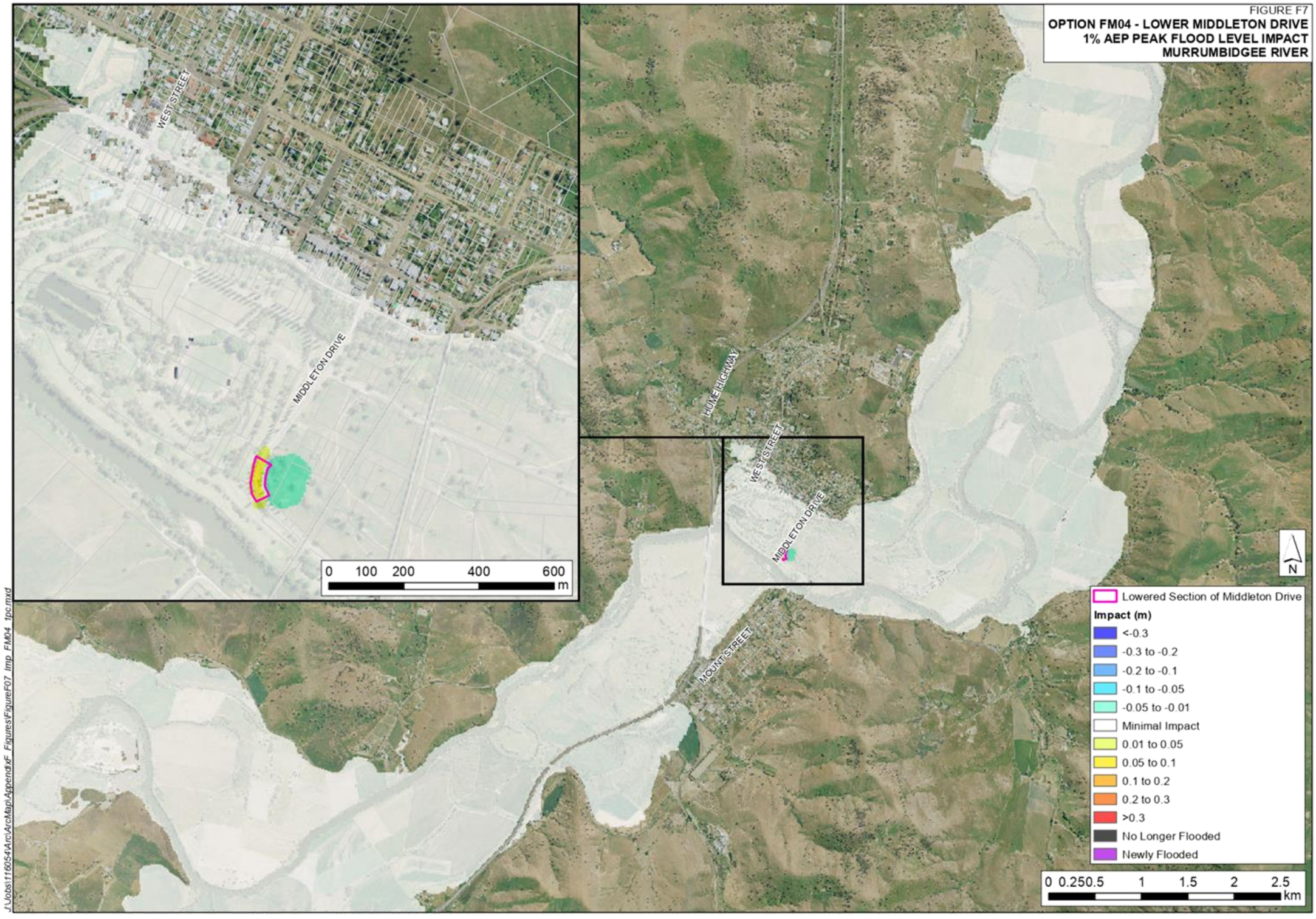


FIGURE F7
OPTION FM04 - LOWER MIDDLETON DRIVE
1% AEP PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
WEST STREET
MIDDLETON DRIVE
HUME HIGHWAY
MOUNT STREET
0 100 200 400 600 m
0 0.250.5 1 1.5 2 2.5 km
N
Lowered Section of Middleton Drive
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
J:\Jobs\116054\ArcGIS\ArcMap\Appendix F_Figures\FigureF07_Imp_FM04_1pc.mxd


FIGURE F8
OPTION FM05 - INSTALL CULVERT THROUGH MIDDLETON DRIVE
0.2 EY PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
WEST STREET
MIDDLETON DRIVE
4 x 2.4 m x 0.6 m BC
HUME HIGHWAY
MOUNT STREET
0 100 200 400 600 m
N
Proposed Culvert
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.250.5 1 1.5 2 2.5 km
J:\Jobs\116054\ArcMap\Appendix F Figures\FigureF08_Imp_FM05_5y.mxd

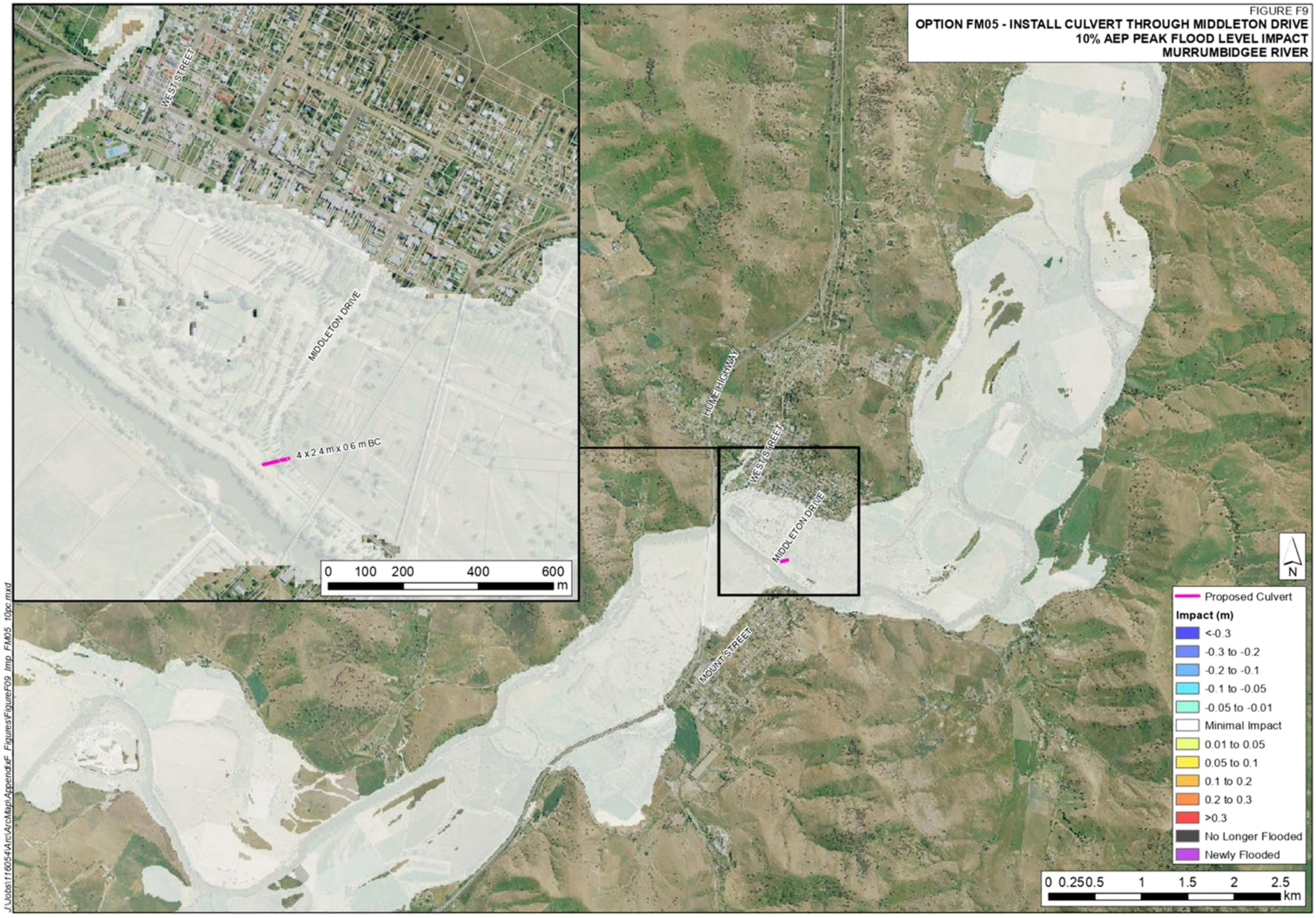
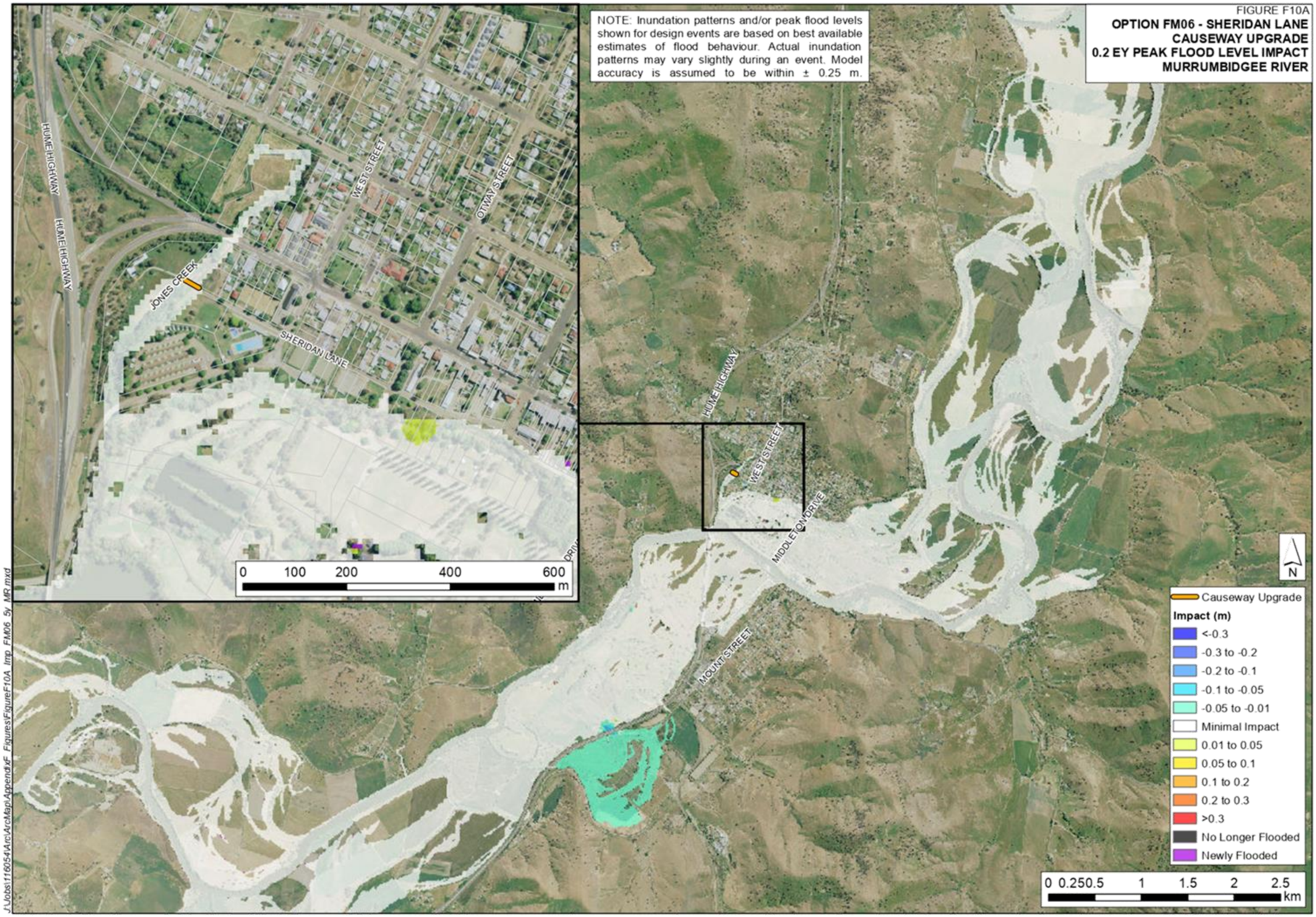


FIGURE F9
OPTION FM05 - INSTALL CULVERT THROUGH MIDDLETON DRIVE
10% AEP PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
WEST STREET
MIDDLETON DRIVE
4 x 2.4 m x 0.6 m BC
0 100 200 400 600 m
HUME HIGHWAY
WEST STREET
MIDDLETON DRIVE
MOUNT STREET
N
Proposed Culvert
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.250.5 1 1.5 2 2.5 km
J:\Jobs\116054\Arc\ArcMap\Appendix\F_Figures\FigureF09_Imp_FM05_10pc.mxd


NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. Model accuracy is assumed to be within ± 0.25 m.
FIGURE F10A
OPTION FM06 - SHERIDAN LANE CAUSEWAY UPGRADE
0.2 EY PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
HUME HIGHWAY
HUME HIGHWAY
JONES CREEK
SHERIDAN LANE
WEST STREET
OTWAY STREET
MIDDLETON DRIVE
MOUNT STREET
0 100 200 400 600 m
N
Causeway Upgrade
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.250.5 1 1.5 2 2.5 km
J:\Jobs\116054\Arc\ArcMap\Appendix\F_Figures\FigureF10A_Imp_FM06_5y_MR.mxd

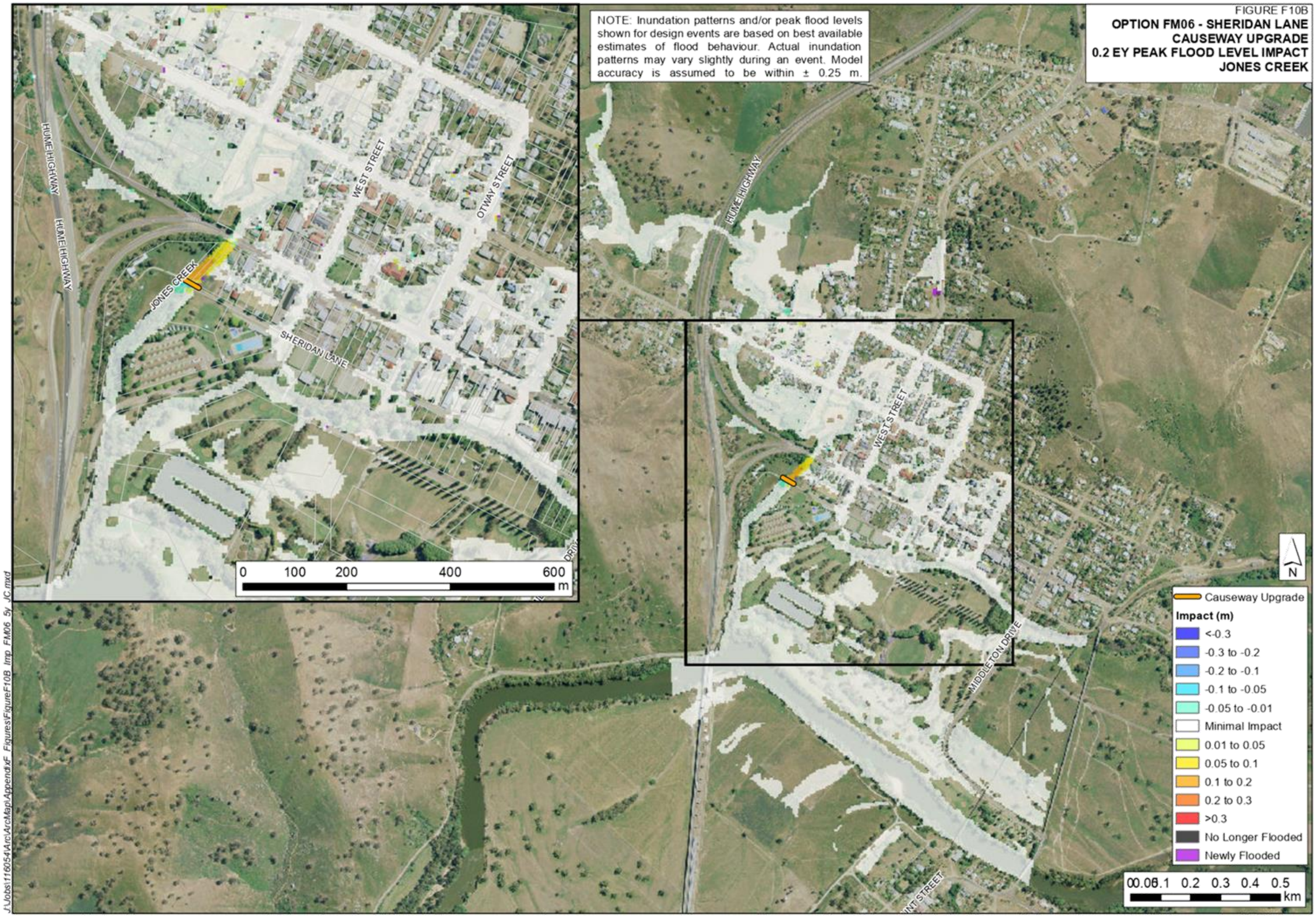


FIGURE F10B
OPTION FM06 - SHERIDAN LANE CAUSEWAY UPGRADE
0.2 EY PEAK FLOOD LEVEL IMPACT
JONES CREEK
NOTE: Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour. Actual inundation patterns may vary slightly during an event. Model accuracy is assumed to be within ± 0.25 m.
HUME HIGHWAY
WEST STREET
OTWAY STREET
JONES CREEK
SHERIDAN LANE
MIDDLETON DRIVE
0 100 200 400 600 m
N
Causeway Upgrade
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.05 0.1 0.2 0.3 0.4 0.5 km
J:\Jobs\116054\Arc\ArcMap\Appendix\F_Figures\FigureF10B_Imp_FM06_5y_JC.mxd

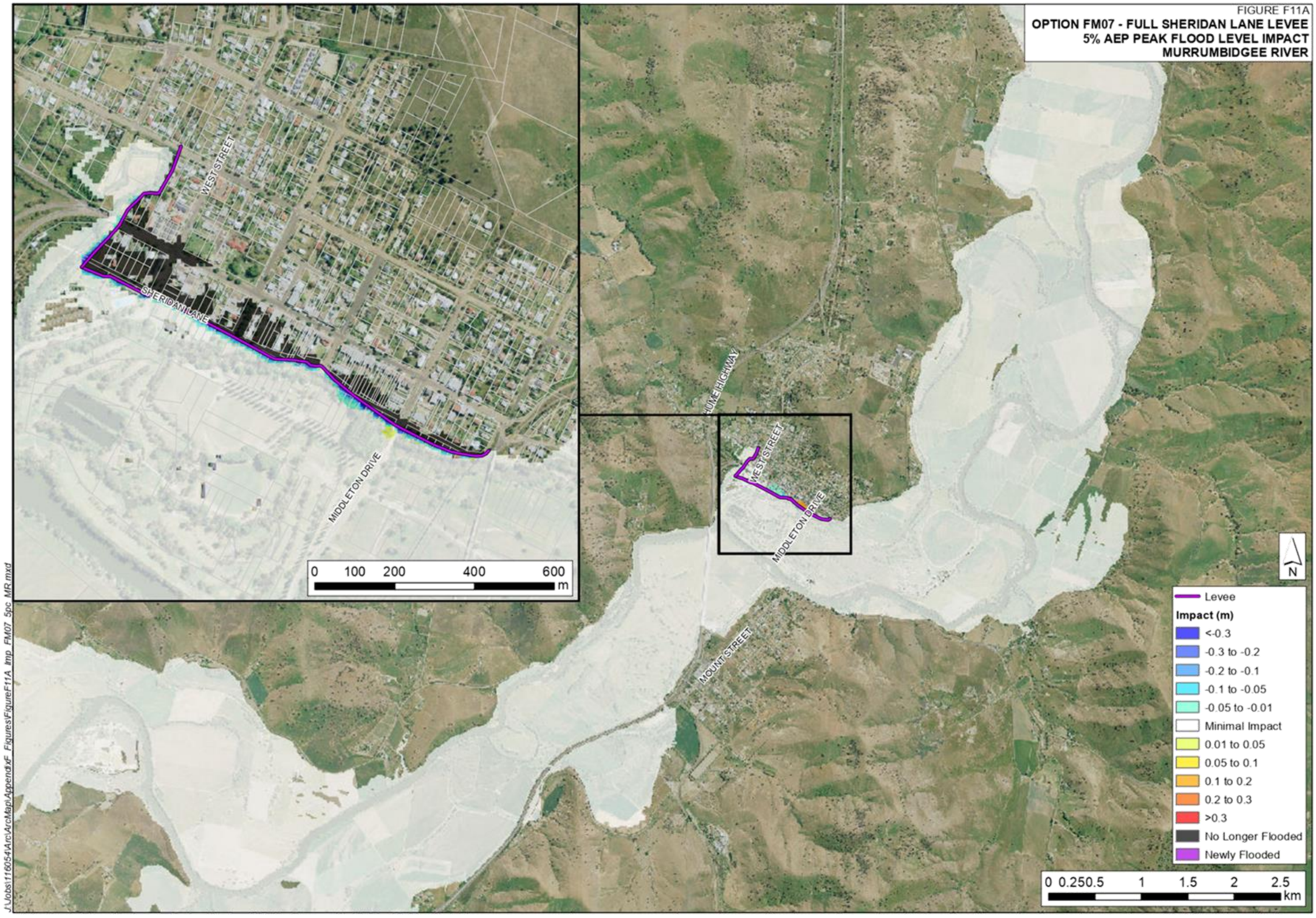


FIGURE F11A
OPTION FM07 - FULL SHERIDAN LANE LEVEE
5% AEP PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
WEST STREET
SHERIDAN LANE
MIDDLETON DRIVE
HUME HIGHWAY
MOUNT STREET
0 100 200 400 600 m
0 0.250.5 1 1.5 2 2.5 km
N
Levee
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
J:\Jobs\116054\ArcMap\Appendix F_Figures\FigureF11A_Imp_FM07_5pc_MR.mxd

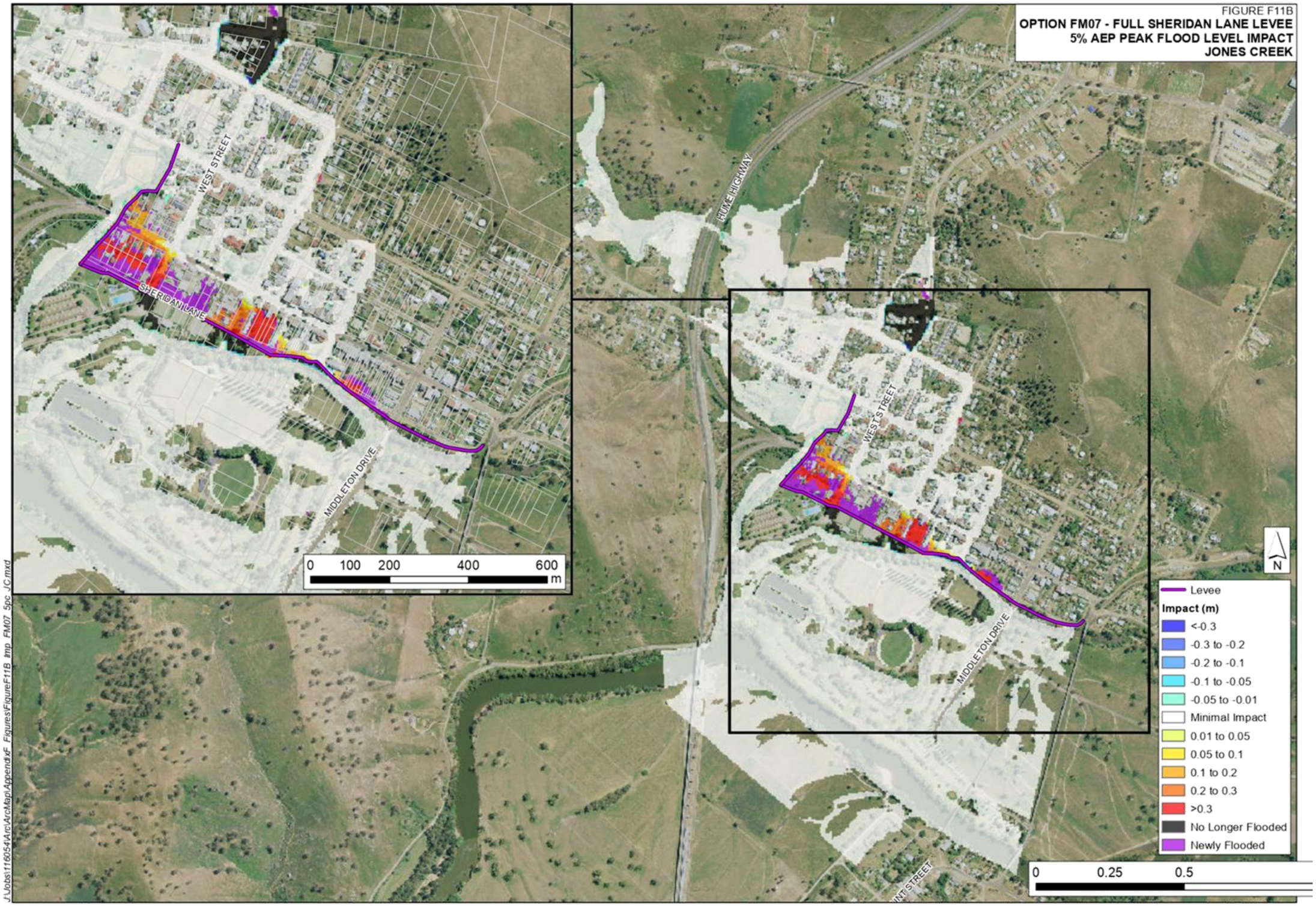


FIGURE F11B
OPTION FM07 - FULL SHERIDAN LANE LEVEE
5% AEP PEAK FLOOD LEVEL IMPACT
JONES CREEK
WEST STREET
SHERIDAN LANE
MIDDLETON DRIVE
HUME HIGHWAY
0 100 200 400 600
m
N
Levee
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.25 0.5
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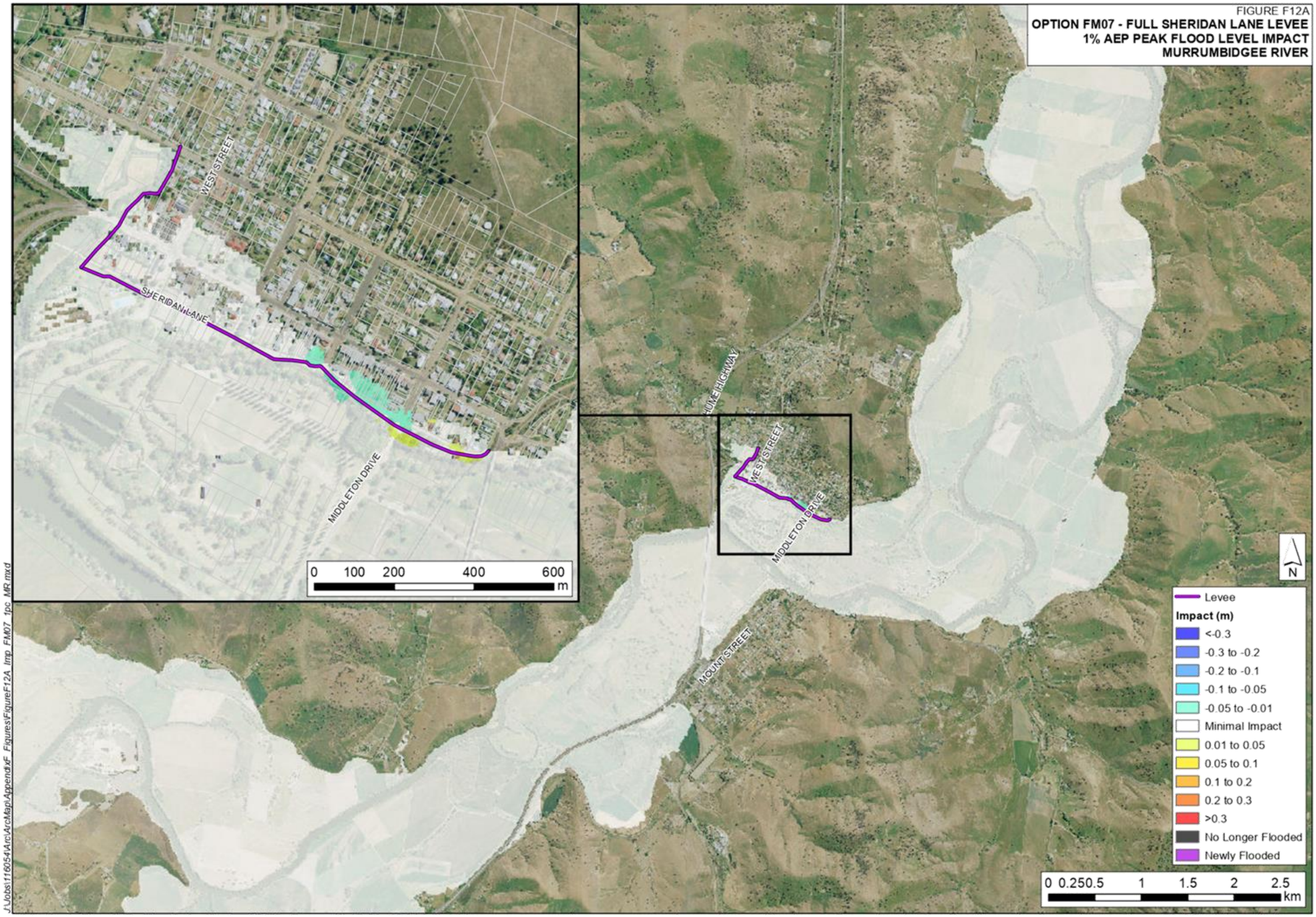
FIGURE F12A
OPTION FM07 - FULL SHERIDAN LANE LEVEE
1% AEP PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
WEST STREET
SHERIDAN LANE
MIDDLETON DRIVE
HUME HIGHWAY
MOUNT STREET
0 100 200 400 600 m
N
Levee
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.250.5 1 1.5 2 2.5 km
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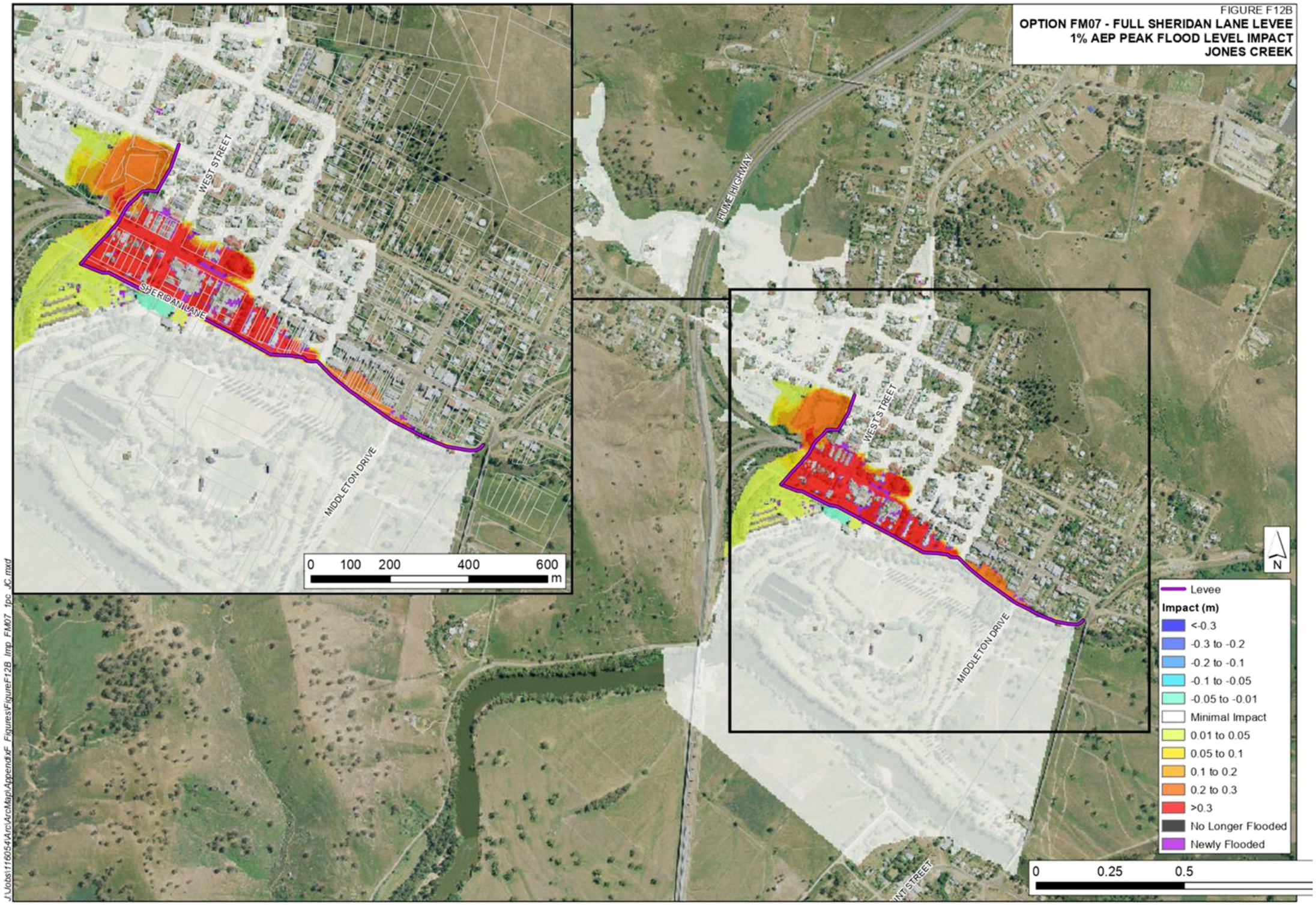
FIGURE F12B
OPTION FM07 - FULL SHERIDAN LANE LEVEE
1% AEP PEAK FLOOD LEVEL IMPACT
JONES CREEK
WEST STREET
HUME HIGHWAY
SHERIDAN LANE
MIDDLETON DRIVE
0 100 200 400 600 m
N
Levee
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.25 0.5
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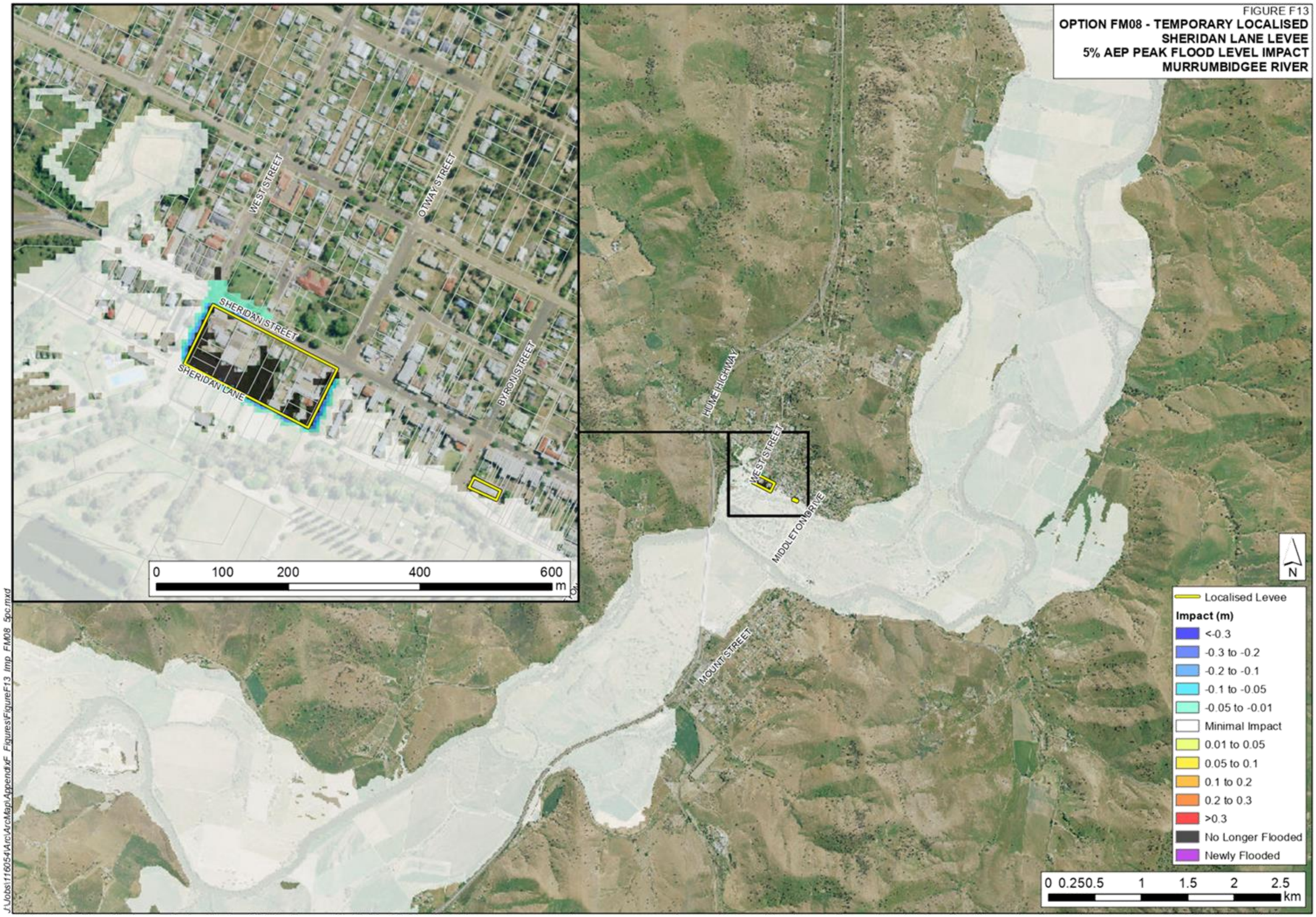
FIGURE F13
OPTION FM08 - TEMPORARY LOCALISED SHERIDAN LANE LEVEE
5% AEP PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
WEST STREET
OTWAY STREET
BYRON STREET
SHERIDAN STREET
SHERIDAN LANE
HUME HIGHWAY
MIDDLETON DRIVE
MOUNT STREET
0 100 200 400 600 m
N
Localised Levee
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.250.5 1 1.5 2 2.5 km
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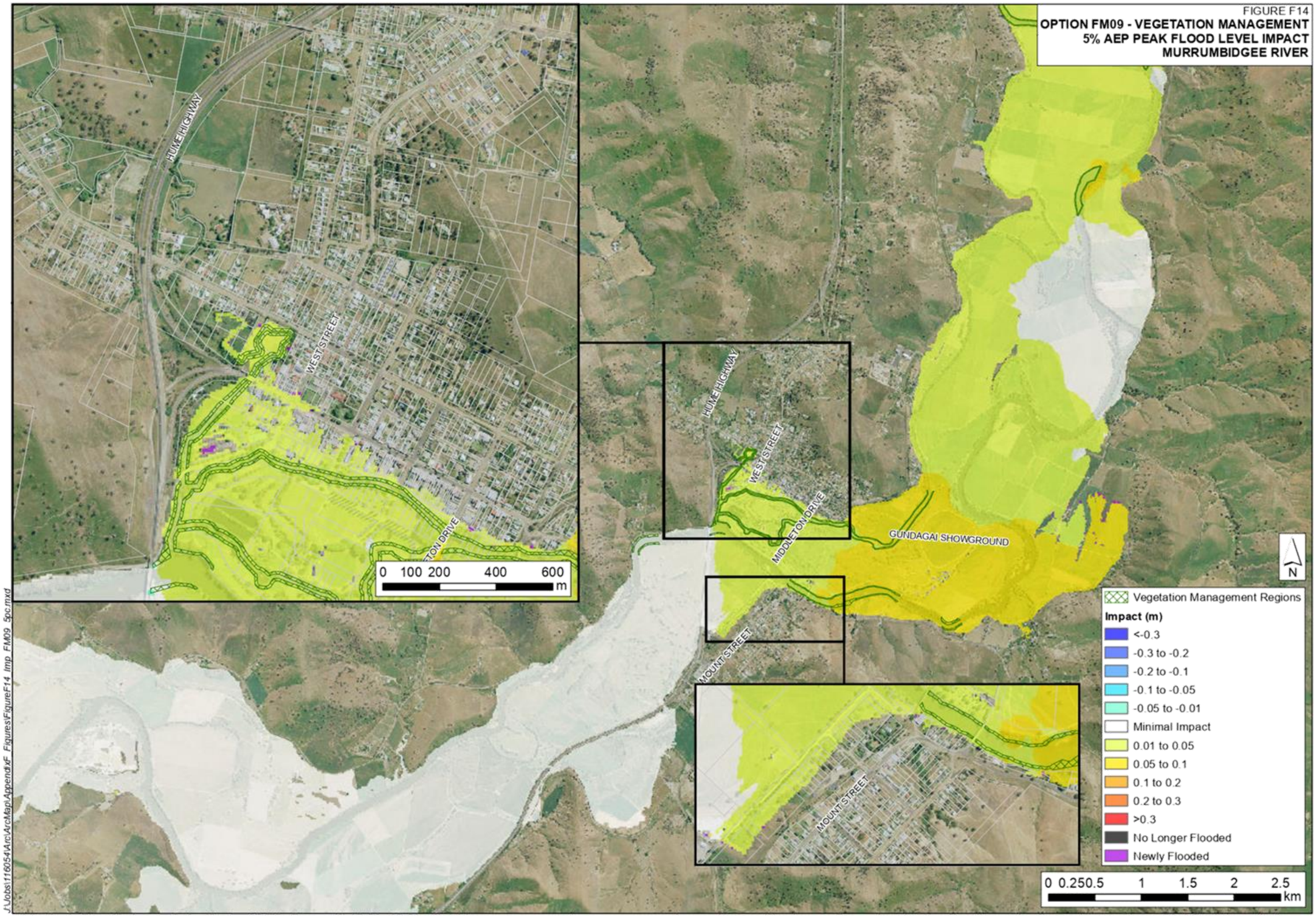
FIGURE F14
OPTION FM09 - VEGETATION MANAGEMENT
5% AEP PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
HUME HIGHWAY
WEST STREET
MIDDLETON DRIVE
GUNDAGAI SHOWGROUND
MOUNT STREET
0 100 200 400 600 m
N
Vegetation Management Regions
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.250.5 1 1.5 2 2.5 km
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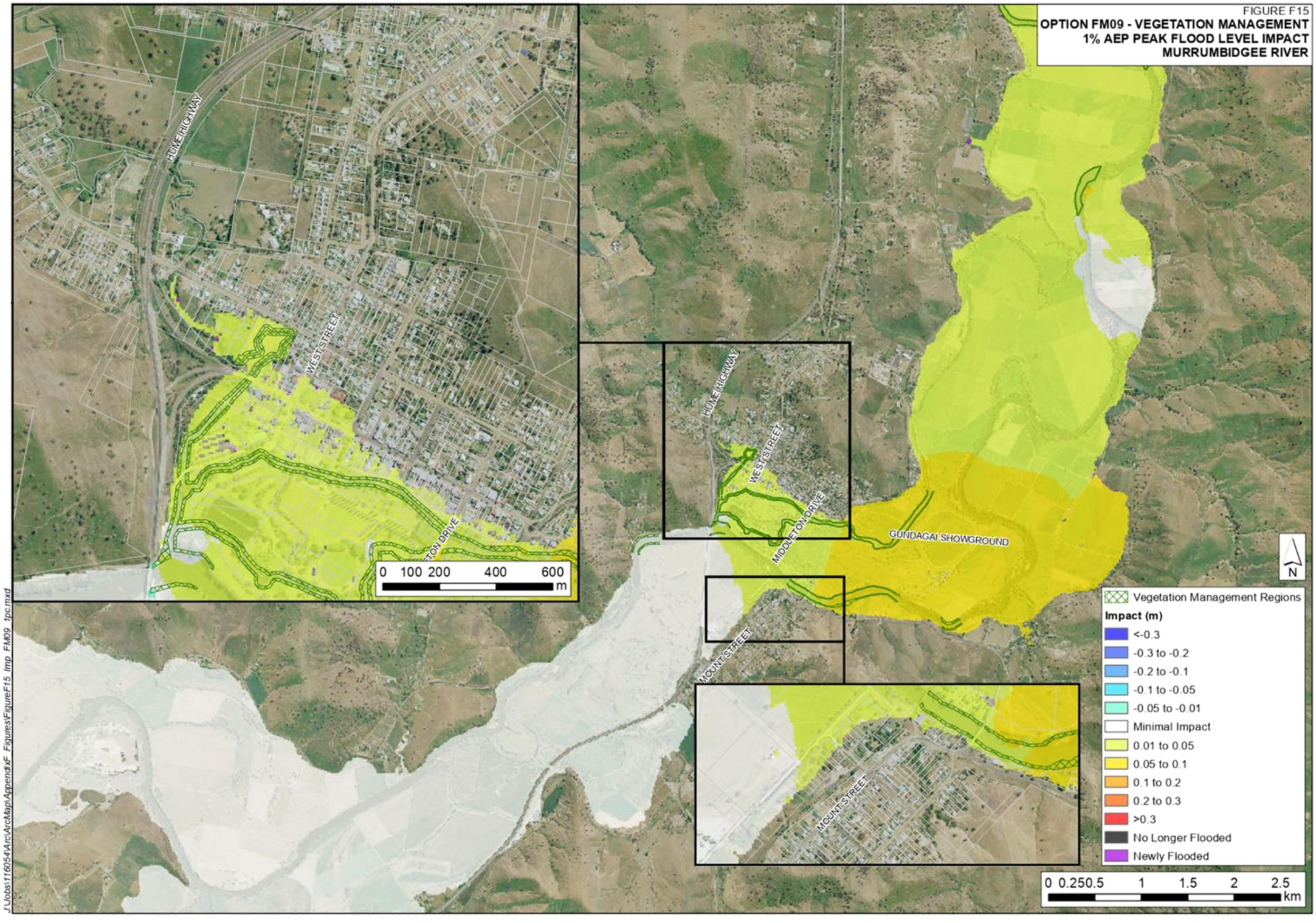
FIGURE F15
OPTION FM09 - VEGETATION MANAGEMENT
1% AEP PEAK FLOOD LEVEL IMPACT
MURRUMBIDGEE RIVER
HUME HIGHWAY
WEST STREET
MIDDLETON DRIVE
GUNDAGAI SHOWGROUND
MOUNT STREET
0 100 200 400 600
m
N
Vegetation Management Regions
Impact (m)
<-0.3
-0.3 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
Minimal Impact
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.3
>0.3
No Longer Flooded
Newly Flooded
0 0.250.5 1 1.5 2 2.5
km
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Appendix A

Appendix A: Glossary

Taken from 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).
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)	FPLs 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 States 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 A water 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.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.


Appendix B

Gundagai
Floodplain Risk Management Study & Plan

COOTAMUNDRA-GUNDAGAI REGIONAL COUNCIL

Council is currently undertaking a Floodplain Risk Management Study and Plan to investigate ways to manage flooding in Gundagai. This questionnaire gives you an opportunity to make suggestions or note key problem areas where flood risk could be reduced. Some examples of flood mitigation strategies are described below to help you complete this questionnaire.

DRAINS AND CHANNELS increase the rate at which water is removed from a flood affected area. These structures are often situated in existing flow paths and are generally earthen or concrete lined.

RETENTION BASINS are areas (such as playing fields) that store water and release it at a lower, more controlled rate to reduce downstream flood levels. Generally more suited to smaller, urban catchments.

LEVEES are used to exclude flood water from flood prone areas. Levees are often constructed from earth embankments, concrete walls or sheet piles.

CULVERTS AND BRIDGES allow water to flow under roads, train tracks or similar obstructions. It can often be beneficial to increase the conveyance capacity of existing culverts, or install new culverts to decrease upstream water levels, however the downstream impacts must also be taken into account.

VOLUNTARY HOUSE RAISING has been widely used throughout NSW to significantly reduce flooding of habitable floors particularly in lower flood hazard areas. Suitable houses are raised above the Flood Planning Level, to protect and reduce damages.

VOLUNTARY PURCHASE involves the acquisition of flood affected properties situated in high hazard areas, and demolition of the residence to remove it from the floodplain. The floodplain is then reserved for a more appropriate land use.

FLOOD RESPONSE MEASURES
Include improvements to flood warning systems and alerts, road upgrades to improve local evacuation routes and community education and awareness programs. These options are best implemented in conjunction with the SES and local community groups.

SMART PLANNING POLICIES can help reduce risk to residents, existing and new developments across the wider floodplain. These can include improvements to the Local Environment Plan (LEP) and Development Control Plan (DCP).

Please complete and return this questionnaire to:

Cootamundra – Gundagai Regional Council

255 Sheridan Street,

Gundagai NSW 2722

DUE DATE: Wednesday 4th April

Please make sure all surveys are returned before this date or they may not be counted.

Alternatively, you can access an online version of this survey at:

https://www.surveymonkey.com/r/gundagai

If you have additional information you would like to make available for the Study or further comments, please attach them to your questionnaire response or alternatively email to the contacts on Page 4.

Gundagai
Floodplain Risk Management Study & Plan

COOTAMUNDRA-GUNDAGAI REGIONAL COUNCIL

Please complete this questionnaire and return to council. Please make sure all surveys are returned before Wednesday 4th April 2018 or they may not be counted.

1. Your Details
(Please note your contact details are optional, will be held confidential and will only be used to contact you for more information regarding this study)

Name:

Address:

Telephone:

Email:

2. How long have you lived in this area?

☐ Years ☐ Months

3. Can we contact you directly for more information?

☐ Yes ☐ No

If 'Yes', what method of contact would you prefer? e.g. telephone, Email etc.

4. Do you think something should be done to reduce flood risk in Gundagai due to the Murrumbidgee River and Jones Creek?

☐ Yes ☐ No ☐ Don't Know

5. Please describe the location/s where you think flood risk should be considered:

Please name nearest street and cross street and other useful information to identify the location of flood risk, and type of problem that occurs.

7. If eligible, would you be interested in a Voluntary Purchase scheme?

☐ Yes ☐ No

8. If eligible, would you be interested in a Voluntary House Raising scheme?

☐ Yes ☐ No

Please note that Questions 6. and 7. are only to obtain an indication of the level of community interest in these schemes. It does not mean your property is flood prone and/or appropriate for these options. Eligibility for VP and VHR are based on the severity of flood hazard. Please feel free to comment generally on VP and VHR schemes below.

9. Do you have any of your own ideas to reduce flood risk?

☐ Yes ☐ No

If 'Yes' can you please describe the location of where you think flood risk could be improved (please provide nearest crossroads or known landmarks). A number of pre defined options are presented on the next page that may help with your comments.

Gundagai
Floodplain Risk Management Study & Plan

As a local resident who may have witnessed flooding, you may have your own ideas about how to reduce flood risks. Which of the following management options would you prefer for Gundagai (1 = least preferred, 5 = most preferred)? See the front page for descriptions of the mitigation options.

10. Potential Options	Preference
Retarding or detention basins (these temporarily hold water and reduce peak flood flows) - Suggested location/other comments:	1 2 3 4 5
Improved flood flow paths such as channels and drains - Suggested location/other comments:	1 2 3 4 5
Culvert/bridge enlarging - Suggested location/other comments:.	1 2 3 4 5
Pit and pipe upgrades - Suggested location/other comments:	1 2 3 4 5
Levee banks or flood walls - Suggested location/other comments:	1 2 3 4 5
Strategic planning and flood related development controls - Suggested location/other comments:	1 2 3 4 5
Education of the community, providing greater awareness of potential hazards - Suggested location/other comments:	1 2 3 4 5
Flood forecasting, flood warnings, evacuation planning and emergency response measures - Suggested location/other comments:	1 2 3 4 5

Contacts

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Cootamundra Gundagai Regional Council
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Tel: 02 6944 0200

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WMAwater
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Tel: 02 9299 2855


Appendix C

APPENDIX C. FLOOD DAMAGES ASSESSMENT

PAGE

LIST OF FIGURES

C.1. BACKGROUND

C.1.1. Introduction

A flood damages assessment has been undertaken to determine the economic costs of flooding in Gundagai due to both the Murrumbidgee River, and overland flooding in the Jones Creek catchment. This appendix describes the factors that contribute to flood damages, and the methodology used to undertake the damages assessment for the Gundagai Floodplain Risk Management Study & Plan (FRMS&P).

The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding;
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such failure of services (e.g sewage treatment plant) or flood borne debris;
- The types of development, assets and infrastructure affected and their building materials or construction type.

The quantification of flood damages is an important part of the floodplain risk management process and is typically focused on the direct, tangible damages (described below) relating to property development. Flood damages assessments typically do not capture other tangible or intangible damages. As a result, while the damages assessment is useful to get a "feel" for the magnitude of the flood problem, it is of limited value for absolute economic evaluation, or for determining overall viability of a mitigation option. The damages assessment however forms a useful basis of comparison to assess the relative economic merits of mitigation measures, in which their benefits (reduction in tangible property damages) are compared to the cost of implementation.

C.1.2. Flood Damage Categories

The Floodplain Development Manual (Reference 1) broadly categorises flood damages as either tangible or intangible.

Tangible Damages:

- Financial in nature and can be readily measured in monetary terms, and include:
    - Damage or loss caused by floodwaters wetting goods and possessions (direct damages); and
    - Loss of wages and extra outlays incurred during clean-up operations and in the post-flood recovery period (indirect damages)

Intangible Damages:

- Intangible damages are difficult, if not impossible to quantify in financial terms, and may include:

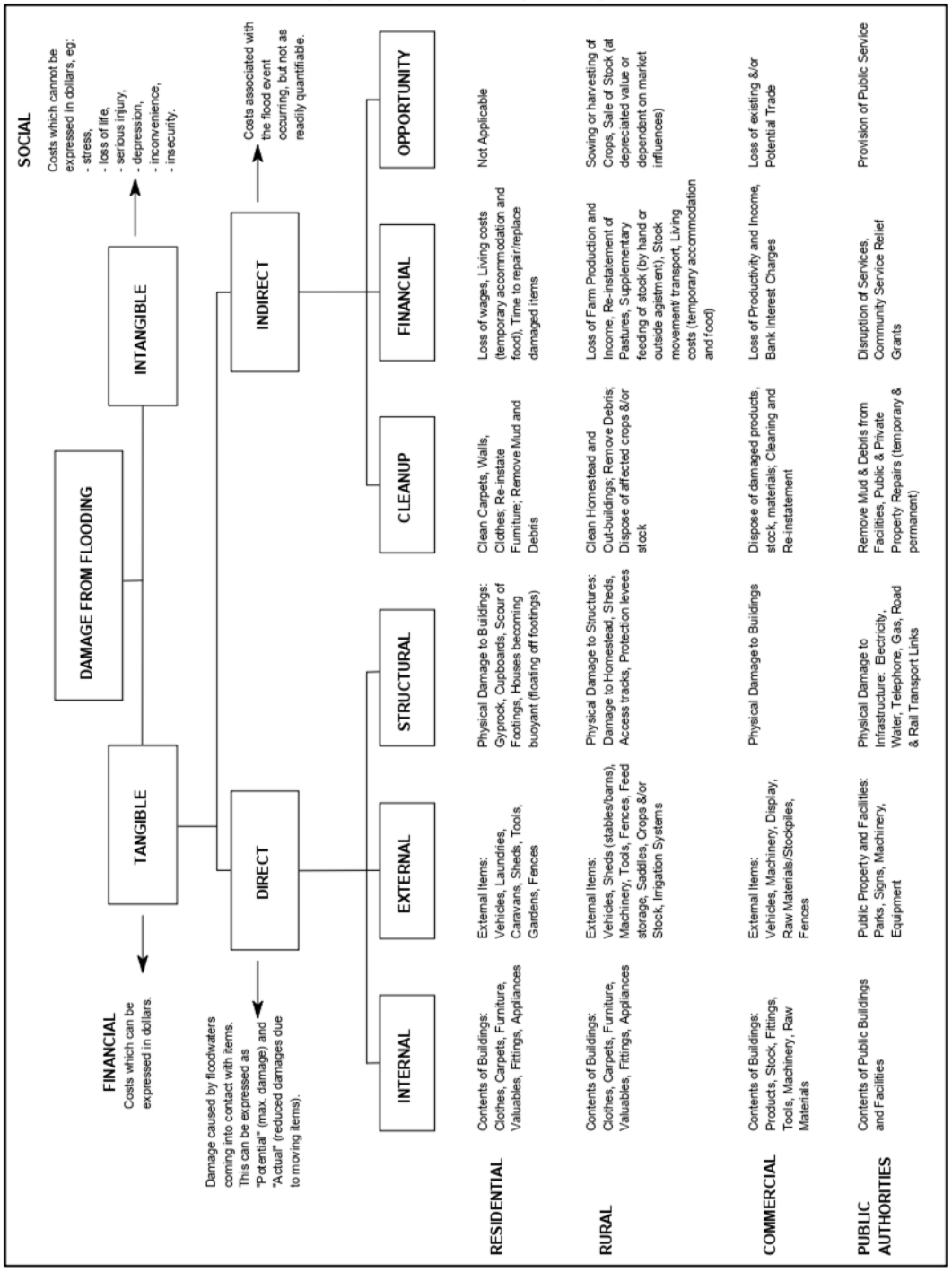
- increased levels of emotional stress and mental and physical illness caused by the flood episode;
- Sense of loss and despondency caused by the destruction of memorabilia (family photographs and documents) or loss of pets;
- Stress caused by additional (and at times quite large) financial outlays to replace flood damaged possessions; and
- Stress caused by family disruption – including for example temporary accommodation, attend different schools, increased distances or time to travel to work.

Tangible damages can be further classified as direct or indirect, presented in Diagram 1. Direct damages are those caused by floodwaters wetting goods and possessions, thereby either damaging them irreparably or reducing their value. Indirect damages are the additional financial losses caused by the flood, including for example:

- the extra cost of food and accommodation for evacuees;
- loss of wages by employees;
- loss of actual and prospective production or sales by flood-affected commercial and industrial establishments; and
- Opportunity cost to the public caused by the closure or limited operation of public facilities.

Intangible and indirect tangible damages are not considered in this damages assessment, however are evaluated for shortlisted flood risk mitigation options via a multi-criteria matrix assessment.

Diagram 1 Flood Damage Categories



C.2. QUANTIFICATION OF DAMAGES

C.2.1. Floor Level Data

To undertake the flood damages assessment, floor level data is required. Hydrographic and Cadastral Survey Pty Ltd were engaged in July 2014 to undertake a floor level survey for properties estimated to be located within the Murrumbidgee River 1% AEP flood extent. The survey included floor level data for 81 residential properties, 11 commercial premises (generally shops along Sheridan Street/ Sheridan Lane), 9 public facilities (such as the Gundagai District Services Club and Sports Club and a number of motels) and 1 industrial property.

For each property, the survey also captured the following descriptors:

- Estimate regarding whether the ground floor was habitable;
- Indication of house size (small, medium or large);
- Floor Construction (pier, slab or other);
- Wall construction (Brick, stone or rendered, clad, or mixed)
- Type (residential, commercial, industrial, public)
- Name and Nature of Use/Business (non-residential buildings only)

For properties outside this extent (but within the Murrumbidgee River PMF extent) and within the Jones Creek floodplain, detailed survey was not obtained due to the high incremental cost of obtaining these levels, and the limited value this data adds to the assessment. Instead, floor levels of the remaining 149 properties were estimated using visual inspection and available LiDAR data. The total number and type of properties included in the assessment (either surveyed or estimated) is provided in Table 1.

Table 1 Properties included in the damages assessment

Property Type	Total Count
Residential	199
Commercial	42
Industrial	1
Public	9
Total	**251**

One of the limitations associated with the floor level data is that the recorded level only represents the level that could be seen from the street frontage. It is acknowledged that properties may have different floor levels throughout the building, however these have not been captured.

C.2.2. Flood Levels and Depth of Flooding Calculations

The damages assessment is based on relating the depth of property inundation to a monetary amount. This section describes how the depth at each property is derived, while Section C.2.3 describes the process of determining financial losses.

Available floor levels, ground levels and peak flood levels were analysed to identify a representative depth for each property. Floor levels were adopted from the survey and estimation techniques described in Section C.2.1. For surveyed properties, ground levels were taken directly

from the survey. For estimated properties, a ground level was extracted from the digital elevation model (refer to Section 2.1 of the main report) at the same location as the floor level was estimated (usually at or close to the front door). The peak flood level for each design flood event was then extracted from the model results for the same location.

It is noted the approach is somewhat limited in that it does not necessarily account for variations in water level across a property. However, it is considered appropriate for the purpose of the damages assessment to provide a representation of damages across the study area rather than detailed damages for individual properties, to allow for the comparison of mitigation options.

C.2.3. Property Damage Analysis

The assessment is based on damage curves that relate the depth of flooding on a property to the potential tangible damage cost within the property. While it would be ideal to prepare damage curves for the individual catchment, damage data is generally not readily available and can be a costly exercise to obtain. To address this, NSW Office of Environment and Heritage (OEH) has carried out research and prepared a methodology (Reference 2) to develop damage curves based on state-wide historical data. The methodology is applicable for residential properties, and with some adjustment, can be applied to commercial or industrial properties.

C.2.3.1. Residential Damages

As described in Reference 2, a number of considerations are required to develop the residential damage curves, including, for example:

- Average value of contents;
- Contents damage repair limitation factor (on average damages are lower for short duration events compared to longer duration);
- Level of community flood awareness;
- Effective warning time (and ability of residents to relocate valuables);
- Typical table/bench height;
- External damage (to gardens, garages etc);
- Structural damage to the property;
- Clean up costs; and
- Additional costs during the recovery period, e.g. alternate accommodation.

These factors have not been assessed individually in this study, rather have contributed to the development of the OEH residential flood damage curve, which has been applied in this damage assessment. Chart 1 shows the components that make up a damage curve for a residential house (on a slab, or "low set"). The curves used for all residential property types are shown in Chart 2. The curves differentiate damages for dwellings with the lowest habitable floor close to ground level (e.g. on a slab), and "high set" which may refer to properties constructed on piers. Damages for two story dwellings are calculated separately, as some allowance is made for possessions to be stored on the second level. As shown in Chart 2, damages for lower flood depths are therefore lower in comparison to one-story dwellings, while there is a marked jump in damages when depths reach 2.5 m, as a result of inundation of the second story occurring.

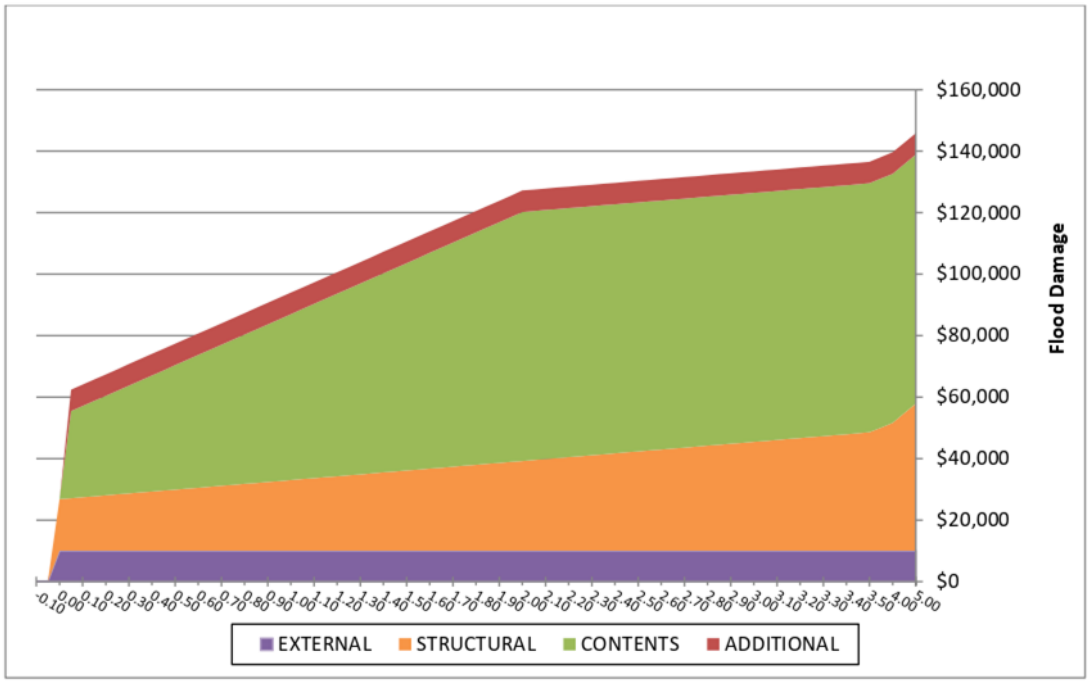


Chart 1 Residential Damage Curve (House on a slab)

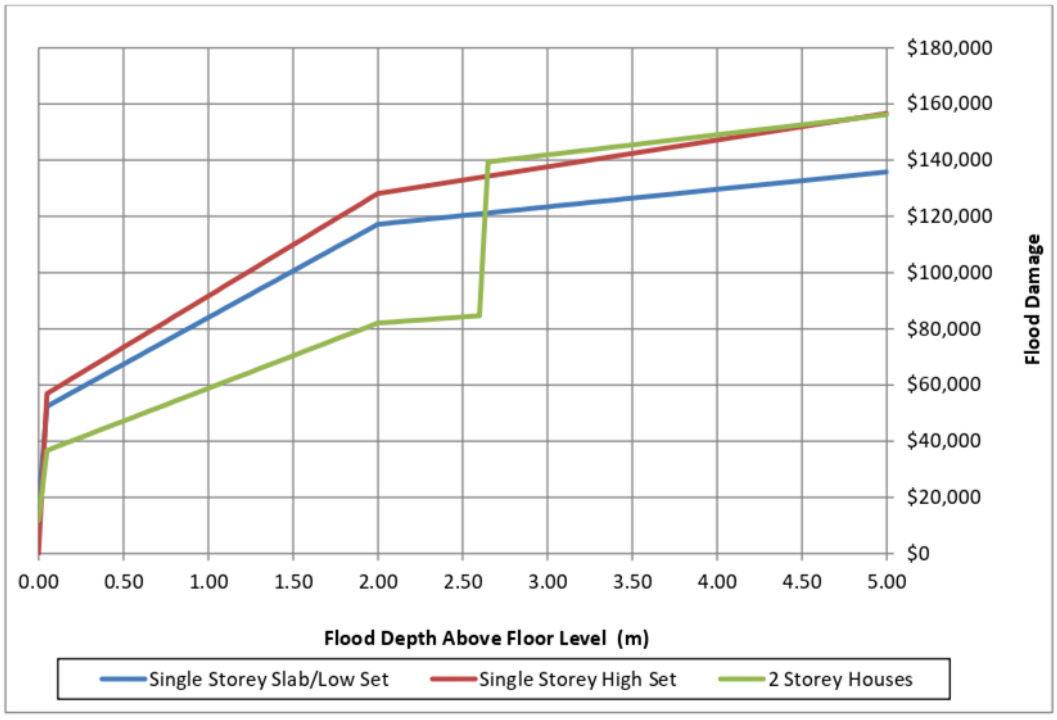
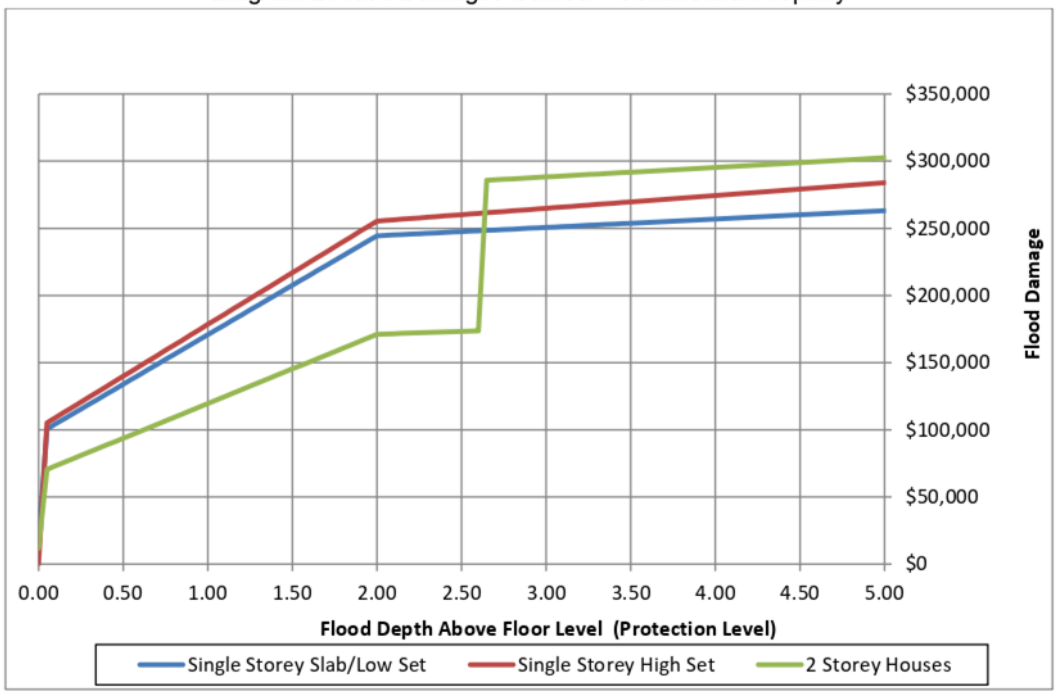


Chart 2 Residential Damage Curves

C.2.3.2. Commercial Damages

Commercial and industrial damages are typically higher than residential damages due to the potential value of stock and premises that may be damaged, and the ongoing losses of income as damages are repaired and days of business lost before operation can recommence. It is noted also that commercial damages can be highly variable and dependent on the nature of flooding, type of business, and any operational plans in place to minimise damage (e.g. relocation of stock). As a result it is difficult to make an estimate of total commercial damage. A method is adopted in which the residential damage curves are scaled up and applied to commercial properties. To adjust the residential curve for use in the commercial damages assessment, the average contents damages for a business was estimated to be $150,000 (compared to $60,000 for a dwelling).

Diagram 2 Flood Damages Curves – Commercial Property



C.2.4. Expressing Flood Damages

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. This approach means that smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods. For the calculation of AAD for Gundagai, the 0.2 EY event was the smallest (most frequent) flood event modelled. it was assumed that there are no flood damages incurred in events more frequent than the 0.2 EY flood event, as the riverine flood extent is largely confined to the main river channel, and that out-of-bank flow from Morleys Creek is unlikely to cause damage to properties aside from potentially some sporting amenities on the Gundagai Commons. Overland flooding in the Jones Creek catchment is also relatively minimal in this size event.

C.3. RESULTS

C.3.1. Overview

The damage assessment results presented in the main report (Section 3.5.2) are based on an 'envelope' of Jones Creek overland flooding and riverine flooding from the Murrumbidgee River. The envelope takes the higher of the two flood levels (that is, overland or riverine), at each model grid cell, and has been used to give an overview of the total flood damages that occur in Gundagai. However, it is useful to look at the two flooding mechanisms separately to understand the relative costs that are incurred by flooding in each system. As such, this appendix presents the flood damages due to each system separately.

C.3.2. Jones Creek Damages

The flood damages assessment results for Jones Creek are provided in Table 2 to Table 4 below. The results indicate that relatively frequent flood events, especially the 10% AEP and 0.2 EY events, constitute over a third of the residential average annual damages (AAD), and over half of the non-residential AAD. It is also notable that many more properties are subject to external inundation (e.g. through rear or front yards) than over floor inundation, indicating that flow is relatively shallow compared to the height of floor levels. This is typical of overland flow flood affectation driven by excess runoff from local rainfall.

Table 2 Residential Flood Damages (Jones Creek)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	41	10	$ 801,728	30	$ 19,554
10% AEP	47	16	$ 1,324,544	27	$ 28,182
5% AEP	53	17	$ 1,509,921	18	$ 28,489
2% AEP	58	18	$ 1,619,686	12	$ 27,926
1% AEP	63	24	$ 2,067,062	5	$ 32,811
0.2% AEP	74	40	$ 3,596,856	6	$ 48,606
PMF	122	95	$ 10,617,530	4	$ 87,029
Average Annual Damages (AAD)			**$ 399,611**		**$ 3,276**

Table 3 Non-Residential Flood Damages (Jones Creek)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	11	4	$ 453,606	31	$ 41,237
10% AEP	12	5	$ 722,125	27	$ 60,177
5% AEP	12	5	$ 729,661	16	$ 60,805
2% AEP	11	5	$ 729,136	10	$ 66,285
1% AEP	15	6	$ 933,317	4	$ 62,221
0.2% AEP	26	18	$ 3,495,236	8	$ 134,432
PMF	30	24	$ 5,833,581	4	$ 194,453
Average Annual Damages (AAD)			**$ 220,313**		**$ 7,344**

Table 4 Combined Residential and Non-Residential Flood Damages (Jones Creek)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	52	14	$ 1,255,333	30	$ 24,141
10% AEP	59	21	$ 2,046,669	27	$ 34,689
5% AEP	65	22	$ 2,239,582	17	$ 34,455
2% AEP	69	23	$ 2,348,822	11	$ 34,041
1% AEP	78	30	$ 3,000,379	4	$ 38,466
0.2% AEP	100	58	$ 7,092,092	7	$ 70,921
PMF	152	119	$ 16,451,111	4	$ 108,231
Average Annual Damages (AAD)			**$ 619,924**		**$ 4,078**

[1]'No. Properties Affected': there is flooding above ground level within the property boundary (i.e. the lot)
[2]'No. Flooded above floor level': there is flooding above the surveyed or estimated floor level of the house.

C.3.3. Murrumbidgee River Damages

This section presents the results of the flood damages assessment due *only* to riverine flooding from the Murrumbidgee River. These results assume no flooding is occurring in the Jones Creek local catchment concurrently.

Table 5 Residential Damages (Murrumbidgee River)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	0	0	$ -	0	$ -
10% AEP	0	0	$ -	0	$ -
5% AEP	8	6	$ 422,948	10	$ 52,869
2% AEP	16	13	$ 1,109,773	22	$ 69,361
1% AEP	24	23	$ 2,125,039	15	$ 88,543
0.2% AEP	43	40	$ 4,748,502	26	$ 110,430
PMF	177	170	$ 23,380,104	27	$ 132,091
Average Annual Damages (AAD)			**$ 105,221**		**$ 594**

Table 6 Non- Residential Flood Damages (Murrumbidgee River)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	0	0	$ -	0	$ -
10% AEP	2	1	$ 167,364	6	$ 83,682
5% AEP	7	5	$ 843,178	18	$ 120,454
2% AEP	12	11	$ 1,737,062	28	$ 144,755
1% AEP	16	15	$ 2,666,521	16	$ 166,658
0.2% AEP	20	20	$ 4,539,128	21	$ 226,956
PMF	51	51	$ 12,644,733	12	$ 247,936
Average Annual Damages (AAD)			**$ 140,274**		**$ 2,750**

Table 7 Combined Residential and Non-Residential Flood Damages (Murrumbidgee River)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Combined Damages	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	0	0	$ -	0	$ -
10% AEP	2	1	$ 167,364	3	$ 83,682
5% AEP	15	11	$ 1,266,127	15	$ 84,408
2% AEP	28	24	$ 2,846,836	25	$ 101,673
1% AEP	40	38	$ 4,791,561	16	$ 119,789
0.2% AEP	63	60	$ 9,287,630	23	$ 147,423
PMF	228	221	$ 36,024,837	18	$ 158,004
Average Annual Damages (AAD)			**$ 245,495**		**$ 1,077**

[1]*'No. Properties Affected': there is flooding above ground level within the property boundary (i.e. the lot)*
[2]*'No. Flooded above floor level': there is flooding above the surveyed or estimated floor level of the house.*

C.3.4. Discussion of Results

C.3.4.1. Total Flood Damages

The total damages in each event for both overland and riverine flooding are shown in Chart 3 below. The chart displays how for very rare events the damages due to riverine flooding are far higher than for overland flooding. At the other end of the spectrum, in frequent events, such as the 10% AEP and 0.2 EY, the total damages due to overland flooding in the Jones Creek catchment are significantly higher than those due to riverine flooding. In the 0.2 EY and 10% AEP event, no residential properties are noted to be affected by riverine flooding. This is due to the floodplain being contained between Morleys Creek and the river channel itself, affecting only the (largely vacant) land between the two watercourses.

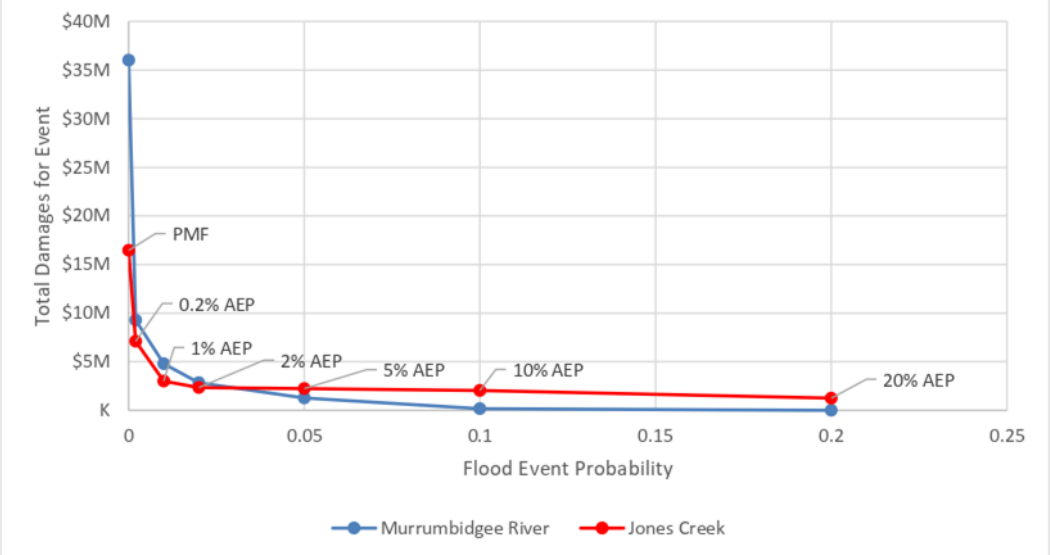


Chart 3 Total Flood Damages (Combined residential and non residential)

C.3.4.2. Annual Average Damages

The Annual Average Damages (AAD) for overland flooding and riverine flooding are identified in the previous results tables and summarised in Table 8 below.

Table 8 Average Annual Damages in Gundagai

	Jones Creek Catchment (Overland)	Murrumbidgee River (Riverine)
Residential	$399,600	$105,200
Non-Residential	$220,300	$140,300
Combined	$619,900	$245,500

As indicated in Chart 4, residential damages due to overland flooding in the Jones Creek catchment contribute the highest proportion to the Average Annual Damages, when looking at the two flooding mechanisms separately. This is a result of overland flow affecting properties in frequent events, whereas riverine flooding does not affect many properties until events around the 5% AEP level and greater.

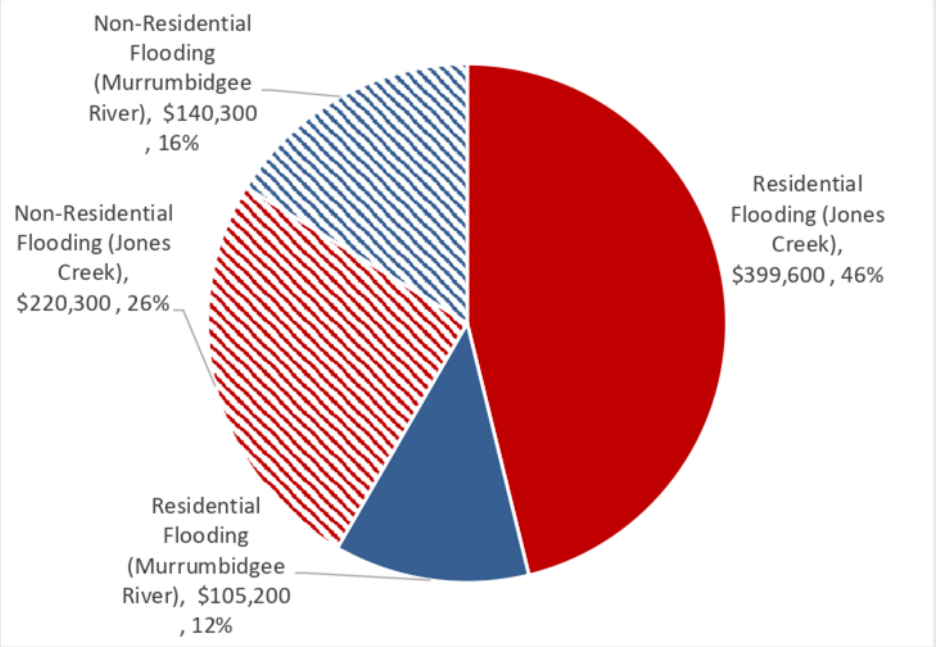


Chart 4 Average Annual Damages in Gundagai

Note: some properties are affected by both riverine and overland flooding. The analysis presented in this appendix assumes riverine and overland flooding do not occur concurrently, while the results presented in the main report reflect "enveloped" peak flood levels of both the Murrumbidgee River and Jones Creek local catchment.

C.3.4.3. Property Affectation

Another useful output from the flood damages assessment is the identification of the event in which a dwelling (or commercial premise) is first inundated above floor level. This information can be used to identify properties that are frequently affected internally and that may be eligible for Voluntary House Raising (see Appendix G), or to identify hotspots where other mitigation strategies should be targeted.

Figure C 1 shows the frequency of overfloor flood affectation due to Murrumbidgee River flooding, and the inset figure shows the same for overland flow in the Jones Creek catchment, assuming the two systems are not flooding concurrently. The coloured dots on each property indicate the event in which commercial (square icons) and residential properties (circular icons) are first affected over floor, thereby giving an indication of frequently affected properties. The results are consistent with the total damages results reported in Section C.3, showing that in the Jones Creek catchment a number of properties are affected by overland flow in the 0.2 EY and 10% AEP events that would not be affected by riverine flooding until a much rarer event. It is notable also that the majority of properties in the floodplain are not affected over floor until an event rarer than the 0.2 AEP event. This is a testament to sensible land use planning after the catastrophic flood of 1852, following which the town was relocated on higher ground.

C.4. INTANGIBLE FLOOD DAMAGES

The intangible damages associated with flooding are inherently more difficult to quantify than tangible damages. In addition to the direct and indirect tangible damages, additional costs/damages are experienced by residents affected by flooding, such as ongoing stress and anxiety, loss of life, injury etc. It is difficult to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to substantially greater than the tangible damages) and depend on a range of factors including the size of flood, the individuals affected, community preparedness, etc. However, it is important that intangible damages are not overlooked when considering the impacts of flooding on a community. An overview of the types of intangible damages likely to occur from Murrumbidgee River and Jones Creek floods in Gundagai is discussed below.

Isolation

Isolation (the ability to freely exit and enter a property, or escape a flooded area) during flood events will become a significant factor for rural residents. Often there is a high level of community support and spirit, which can to some extent negate the effects of isolation and can assist in a flood. Extended periods between floods can lead to some residents being unprepared for long periods of isolation, and highlights the need for community education between flood events. Isolation is also of significant concern if a medical emergency arises during a flood, or any other assistance is required by residents who may choose to ignore evacuation orders. Disconnection from utilities such as clean water, sewerage and power can exacerbate the risks of being isolated for extended periods. The relatively long warning time available in Gundagai goes some way to helping residents safely prepare and evacuate before becoming stranded, though it is acknowledged that not all residents will receive or heed warnings and isolation may still be an issue for both residents who elect to not evacuate and those who offer assistance to them during the flood.

Population Demographics

Analysis of the 2016 Census data indicates that there are some features of the population demographics of the community in Gundagai that may contribute to additional intangible damages, particularly community resilience. For example, the proportion of residents aged over 60 years is 27.0% compared to 16.2% for the whole of NSW. Elderly residents may have more difficulty evacuating or recovering from a flood event, however many of these residents are likely to have experienced at least one flood in Gundagai and may be better prepared for the challenges that come with a flood.

While some households in flood-liable communities enjoy high incomes, many people living in vulnerable communities are living on incomes that are significantly lower than the NSW average. For example, the median weekly income for households in Gundagai is $1,022 compared to $1,486 for NSW.

These age and income statistics indicate the possibility that flood-liable communities may be less able to adapt to change and less flood resilient therefore requiring local adaptation plans that acknowledge and respond to specific local challenges. Well-developed emergency

preparedness, response and recovery programs are especially important in providing assistance to vulnerable residents.

Stress

In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, loss of work, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and its associated damage. The extent of the stress depends on the individual. In Gundagai, the majority of the population is situated outside the floodplain, and many residents would have experienced recent flood events in Gundagai (2010, 2012). However, a number of residents and business owners located within the floodplain (especially Sheridan Lane) may be affected by stress during and following a flood, and the importance of support during these times should not be underestimated.

Risk to Life and Injury

During any flood event there is the potential for injury as well as loss of life. Community safety during a flood can be impacted by several factors including:

- Availability of safe access routes;
- Willingness and ability of residents to obey evacuation orders;
- Effective warning time;
- The number of properties and access routes affected by high hazard flooding;
- The duration of inundation and potential for isolation;
- The proportion of aged residents living in flood affected properties.

Due to the difficulty quantifying these factors, and in the absence of a methodology to do so, intangible flood damages have not been included in the damages assessment described in this appendix. Analysis of intangible damages will instead be captured via a multi-criteria matrix assessment for each flood risk mitigation option investigated in this Study.

C.5. LIMITATIONS

Given the variability of flood behaviour and range of property and content values, the total likely damages in any given flood event is useful to get an indication of the magnitude of the flood problem, however it is of little value for absolute economic evaluation. Nevertheless, damages estimates are appropriate to inform and compare the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision making process.

Aside from property damages, significant tangible costs can be expected for Gundagai that were not included in the flood damages assessment due to the lack of suitable data and established methodology. These costs include:

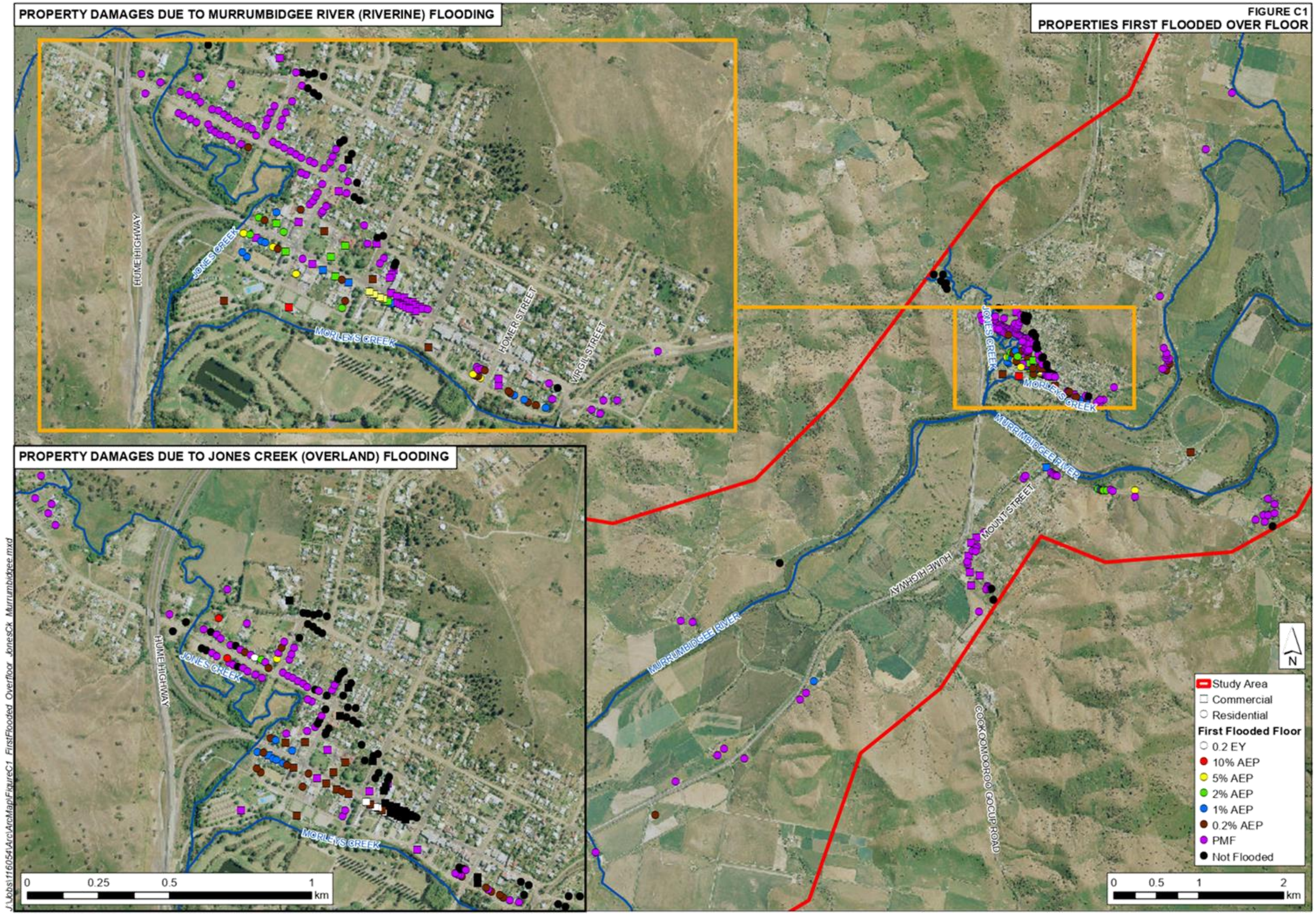
- inundation of properties for which floor level data were not obtained, such as rural/agricultural homesteads;
- loss of livestock and crops;
- other agricultural damages such as erosion of arable land and damage to equipment/fences;
- damage to public infrastructure such as roads, railways and power lines. Council noted combined damages costing around $17M to roads and related infrastructure following the 2010 and 2012 events;
- damage to public amenities such as toilets, parks and gardens, footpaths and cycleways; and
- costs of emergency management operations, such as helicopter rescue and evacuation centres.

As described in Section C.5, it is not possible to include intangible damages in this flood damages assessment. Such damages, including stress, risk to life and isolation, are incorporated into the mitigation option assessment through a multi-criteria matrix assessment.

APPENDIX C REFERENCES

1. NSW Government
Floodplain Development Manual
April 2005

2. Department of Environment and Climate Change
Floodplain Risk Management Guideline – Residential Flood Damages
NSW State Government, October 2007


PROPERTY DAMAGES DUE TO MURRUMBIDGEE RIVER (RIVERINE) FLOODING
PROPERTY DAMAGES DUE TO JONES CREEK (OVERLAND) FLOODING
FIGURE C1
PROPERTIES FIRST FLOODED OVER FLOOR
HUME HIGHWAY
JONES CREEK
MORLEYS CREEK
HOMER STREET
VIRGIL STREET
MURRUMBIDGEE RIVER
MOUNT STREET
COOKSCAMOOROO COCUP ROAD
Study Area
Commercial
Residential
First Flooded Floor
0.2 EY
10% AEP
5% AEP
2% AEP
1% AEP
0.2% AEP
PMF
Not Flooded
N
0 0.25 0.5 1 km
0 0.5 1 2 km
J:\Jobs\116054\ArcMap\FigureC1_FirstFlooded_Overfloor_JonesCk_Murrumbidgee.mxd


Appendix D

APPENDIX D. PLANNING AND POLICY REVIEW

PAGE

D.1. Introduction

It is important to understand the national and state legislation to ensure proposed floodplain risk management measures are in keeping with national, state and local statutory requirements. This appendix describes the national and state legislative instruments that influence planning, specifically in relation to flood risk, at the local government level. Local planning instruments relating to flood risk in Gundagai are described in Section 5.1 of the main report.

It is noted that the policies presented and summarised in this Appendix were in force at the time of writing, and that this document may not remain current as policies are amended (or repealed) over the years.

D.2. National Provisions – Building Code of Australia

The Building Code of Australia (BCA) is part of the National Construction Code (NCC) Series, an initiative of the Council of Australian Governments (COAG) developed to incorporate all on-site construction requirements into a single code. The BCA is produced and maintained by the Australian Building Codes Board on behalf of the Australian Government and each State and Territory Government.

The BCA is a uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia. The goals of the BCA are to enable the achievement and maintenance of acceptable standards of structural sufficiency, safety, health and amenity for the benefit of the community now and in the future.

The BCA contains requirements to ensure new buildings and structures and, subject to State and Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse during a flood when subjected to flood actions resulting from the 'defined flood event'. The 'Defined flood event' (DFE) is "*the flood event selected for the management of flood hazard for the location of specific development as determined by the appropriate authority.*" In NSW this is typically the 1% AEP event.

Flood hazard areas are identified by the relevant State/Territory or Local Government authority (such as via a Floodplain Risk Management Study). The BCA is produced and maintained by the Australian Building Codes Board and given legal effect through the *Building Act 1975,* which in turn is given legal effect by building regulatory legislation in each State and Territory. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must, therefore, be read in conjunction with that legislation.

The BCA provides general requirements for measures to keep water out of the building structure and foundations, such as setting minimum heights above ground, and minimum paved apron requirements graded to direct runoff away from the building. Additional requirements for buildings in flood hazard areas, consistent with the objectives of the BCA, primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event.

D.3. State Provisions – NSW Environmental Planning and Assessment Act 1979

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling the impact of development. Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. The policies and guidelines described in this Section fall under the EP&A Act. The objects of the Act are set out below:

Environmental Planning and Assessment Act 1979 No 203

1.3 Objects of Act

The objects of this Act are as follows:

(a) to promote the social and economic welfare of the community and a better environment by the proper management, development and conservation of the State's natural and other resources,

(b) to facilitate ecologically sustainable development by integrating relevant economic, environmental and social considerations in decision-making about environmental planning and assessment,

(c) to promote the orderly and economic use and development of land,

(d) to promote the delivery and maintenance of affordable housing,

(e) to protect the environment, including the conservation of threatened and other species of native animals and plants, ecological communities and their habitats,

(f) to promote the sustainable management of built and cultural heritage (including Aboriginal cultural heritage),

(g) to promote good design and amenity of the built environment,

(h) to promote the proper construction and maintenance of buildings, including the protection of the health and safety of their occupants,

(i) to promote the sharing of the responsibility for environmental planning and assessment between the different levels of government in the State,

(j) to provide increased opportunity for community participation in environmental planning and assessment.

D.3.1. Ministerial Direction 4.3

Direction 4.3 was one in a list of directions issued on the 1st July 2009. The directions were issued by the Minister for Planning to relevant planning authorities under section 117(2) of the *Environmental Planning and Assessment Act 1979*. Each of the directions apply to planning proposals lodged within the Department of Planning on or after the date the particular direction was issued. Direction 4 pertains to "Hazard and Risk", with Direction 4.3 relating specifically to Flood Prone Land. Direction 4.3 is provided below:

Objectives

(1) The objectives of this direction are:

(a) to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and

(b) to ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

Clause (3) of Direction 4.3 states:

(3) This direction applies when a relevant planning authority prepares a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.

Clauses (4)-(9) of Direction 4.3 state:

(4) A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).

(5) A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.

(6) A planning proposal must not contain provisions that apply to the flood planning areas which:

(a) permit development in floodway areas,
(b) permit development that will result in significant flood impacts to other properties,
(c) permit a significant increase in the development of that land,
(d) are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or
(e) permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.

(7) A planning proposal must not impose flood related development controls above the residential flood planning level for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

(8) For the purposes of a planning proposal, a relevant planning authority must not determine a flood planning level that is inconsistent with the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas) unless a relevant planning authority provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

(9) A planning proposal may be inconsistent with this direction only if the relevant planning authority can satisfy the Director-General (or an officer of the Department nominated by the Director-General) that:

(a) the planning proposal is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or

(b) the provisions of the planning proposal that are inconsistent are of minor significance.

Note: "Flood planning area", "flood planning level", "flood prone land" and floodway area" have the same meaning as in the Floodplain Development Manual 2005.

D.3.2. NSW Flood Prone Land Policy

The primary objectives of the NSW Government's Flood Prone Land Policy are:

(a) to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and

(b) to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Floodplain Development Manual 2005 (the Manual), relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy. Section 733 of the Local Government Act 1993 provides councils and statutory indemnity for decisions made and information provided in good faith from the outcomes of the management process (undertaken in accordance with the Manual).

The Manual outlines a merits approach based on floodplain management and recognises differences between urban and rural floodplain issues. At the strategic level, this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk.

D.3.3. Planning Circular PS 07-003

Planning Circular PS 07-003 (31 January 2007) provides advice on a package of changes concerning flood-related development controls for land above the 1-in-100 year flood and up to the Probable Maximum Flood (PMF). These areas are sometimes known as low flood risk areas. The package includes:

- an amendment to the EP&A Regulation 2000;
- Revised ministerial direction regarding flood prone land (issued under section 117 of the EP&A Act 1979); and
- A new Guideline concerning flood related development controls in low flood risk areas.

The changes follow community concern over notations about low flooding risk being included on Section 149 Planning Certificates *[now known as Section 10.7 Planning Certificates]* and the appropriate development controls that should apply to residential development in low flood risk areas.

The new Guideline notes that *"unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land above the residential flood planning level (FPL) (low flood risk areas)."*

The circular goes on to note: *"However the Guideline does acknowledge that controls may need to apply to critical infrastructure (such as hospitals) and consideration given to evacuation routes and vulnerable developments (like nursing homes) in areas above the 100 year flood."*

In Planning Circular PS 07-003 it is noted that: *"Section 733 of the* Local Government Act 1993 *(the LG Act) protects councils from liability if they have followed the requirements of the Manual. The Minister has notified that the Guideline should be considered in conjunction with the Manual under section 733(4) and (5) of that Act. Councils will need to follow both the Manual and the Guideline to gain the protection given by section 733 of the LG Act".*

D.3.4. Section 10.7 Planning Certificates

Formerly known as Section 149 Planning Certificates, Section 10.7 Planning Certificates describe how a property may be used and the controls on development applicable to that property. The Planning Certificate is issued under Section 10.7 of the Environmental Planning and Assessment Act 1979.

When land is bought or sold, the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2010 requires that a Section 10.7 Planning Certificate be attached to the contract of sale for the land.

Section 10.7 of the EP&A Act states:

> *(1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a planning certificate) with respect to any land within the area of the council.*

(2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected with this or any other Act or otherwise).

(3) (Repealed)

(4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.

(5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.

(6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.

(7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.

The Environmental Planning and Assessment Regulation 2000, Schedule 4 specifies the information to be disclosed on a Section 10.7 (2) Planning Certificate. In particular Schedule 4, 7A refers to flood related development control information and requires Councils to provide the following information:

1) *Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.*

2) *Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.*

3) *Words and expressions in this clause have the same meanings as in the Standard Instrument.*

Section 10.7 (2) and (5) certificates contain the information prescribed in Schedule 4 described above and additional information relating to the property. In a flooding context, additional information may include notations on flood hazard, percentage of the lot affected by flooding, or peak flood depths and levels on the property.

D.3.5. State Environmental Planning Policy (Exempt and Complying Development Codes (2008))

The aims of State Environmental Planning Policy (Exempt and Complying Development) 2008 are presented below.

This Policy aims to provide streamlined assessment processes for development that complies with specified development standards by:

(a) providing exempt and complying development codes that have State-wide application, and

(b) identifying, in the exempt development codes, types of development that are of minimal environmental impact that may be carried out without the need for development consent, and

(c) identifying, in the complying development codes, types of complying development that may be carried out in accordance with a complying development certificate as defined in the Act, and

(d) enabling the progressive extension of the types of development in this Policy, and

(e) providing transitional arrangements for the introduction of the State-wide codes, including the amendment of other environmental planning instruments.

D.3.5.1. State Environmental Planning Policy (Exempt and Complying Development Codes) Amendment (Housing Code) 2017

Part 3 of the SEPP relates to the *"Housing Code"*. This section replaces the former *"General Housing Code"*, which was repealed in June 2017. Part 3 is divided into 5 "Divisions", with Division 2 containing General standards relating to land type. Part 3.5 specifically relates to Complying Development on flood control lots.

Section 3.5 is reproduced below.

3.5 Complying development on flood control lots

1) Development under this code must not be carried out on any part of a flood control lot, other than a part of the lot that the council or a professional engineer who specialises in hydraulic engineering has certified, for the purposes of the issue of the relevant complying development certificate, as not being any of the following:
   a) a flood storage area,
   b) a floodway area,
   c) a flow path,
   d) a high hazard area,
   e) a high risk area.

2) If complying development under this code is carried out on any part of a flood control lot, the following development standards also apply in addition to any other development standards:

a) *if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,*
b) *any part of the dwelling house or any attached development or detached development that is erected at or below the flood planning level is constructed of flood compatible material,*
c) *any part of the dwelling house and any attached development or detached development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level),*
d) *the development must not result in increased flooding elsewhere in the floodplain,*
e) *the lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of the dwelling house,*
f) *vehicular access to the dwelling house will not be inundated by water to a level of more than 0.3m during a 1:100 ARI (average recurrent interval) flood event,*
g) *the lot must not have any open car parking spaces or carports lower than the level of a 1:20 ARI (average recurrent interval) flood event.*

3) *The requirements under subclause (2) (c) and (d) are satisfied if a joint report by a professional engineer specialising in hydraulic engineering and a professional engineer specialising in civil engineering states that the requirements are satisfied.*

4) *A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual, unless it is otherwise defined in this Policy.*

5) *In this clause:*
flood compatible material *means building materials and surface finishes capable of withstanding prolonged immersion in water.*

flood planning level *means:*
(a) the flood planning level adopted by a local environmental plan applying to the lot, or
(b) if a flood planning level is not adopted by a local environmental plan applying to the lot, the flood planning level adopted in a development control plan by the relevant council for the lot.

Floodplain Development Manual *means the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005.*

flow path *means a flow path identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

high hazard area *means a high hazard area identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

D.3.5.2. Rural Housing Code

Part 3A of the SEPP contains the *"Rural Housing Code"*, which applies to development that is specified in clauses 3A.2–3A.5 on lots in Zones RU1, RU2, RU3, RU4, RU6 and R5. Section 3A.38 contains "Complying development on flood control lots". The standards contained in this section are the same as those in Clause 3.5 provided in Section D.3.5.1, with the exception of Clause 2 (c) which states:

> *2 (c) any part of the dwelling house or any ancillary development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level)*


Appendix E

APPENDIX E. FREEBOARD ASSESSMENT

PAGE

Attachment A: BoM Wind Speed and Direction Data for Gundagai (Nangus Road)

E.1. EXECUTIVE SUMMARY

Planning measures (such as flood planning levels) and mitigation works are often designed based on a level of protection or capacity for a particular design flood event, such as the 1% AEP event. To provide reasonable certainty that this level is achieved, a freeboard is added to the selected design flood level. Freeboard is a factor of safety and can be different for flood planning levels and mitigation works due to the components applicable to each. The following components are generally included in the derivation of freeboard:

- Uncertainties in flood level estimates (due to ground survey, design flow accuracy, structure blockage);
- Local variations (surge) in flood level;
- Wind, wave action and surge;
- Changes in the catchment and design estimates over time resulting from climate change, development etc;
- Post construction settlement (for mitigation works); and
- Surface erosion, defects or shrinkage (for mitigation works).

This appendix assesses the freeboard requirements for residential Flood Planning Levels in Gundagai based on mainstream flooding from the Murrumbidgee River and Jones Creek. The assessment has not considered freeboard for mitigation works, which would additionally incorporate allowance for settlement, erosion and other defects. The results of the freeboard assessment are summarised in Table 1. Discussion of how each factor is calculated is provided in the subsequent sections of this document, as referenced in Table 1.

The assessment found that the minimum appropriate freeboard for flood planning levels for properties affected by mainstream flooding in Gundagai is at least 0.5 m.

Table 1 Gundagai Freeboard Assessment Results

	Jones Creek			Murrumbidgee River			Reference
	(A)	(B)	(A x B)	(C)	(D)	(C x D)	
Component	Allowance (m)	Probability	Final Jones Creek Component (m)	Allowance (m)	Probability	Final Murrumbidgee River Component (m)	
Uncertainties in Estimated Flood Levels	0.1	1	0.1	0.2	1	0.2	E.2.1
Local Water Surge	0.4	0.5	0.20	0.12	0.5	0.06	E.2.2
Wave Action	0.2	0.5	0.1	0.17	0.5	0.085	E.2.3
Climate Change	0.1	1	0.1	0.25	1	0.25	E.2.4
Total			**0.50**			**0.60**	

E.2. DETERMINATION OF FREEBOARD COMPONENTS

Flood planning levels (FPLs) are an important tool in the management of flood risk. They are derived from a combination of a flood event (either an historic event or a design AEP event), and a freeboard (Reference 1). This section seeks to identify and subsequently quantify the various components making up freeboard as they apply to flood planning levels.

E.2.1. Uncertainties in Estimated Flood Levels

E.2.1.1. Discussion

The determination of design flood levels comprises a number of factors and parameters, each containing a degree of uncertainty. These factors may include:

- How well the theoretical ARI-Discharge curve fits known flood events, and if it has changed since an historic event;
- Availability of detailed survey and other topographic data;
- Reliability of historical flood data; and
- Estimated parameters including afflux, surface roughness, evapotranspiration, rainfall patterns etc.

These uncertainties can have localised or cumulative effects on the accuracy of hydrologic and hydraulic modelling, and hence, the resulting design flood levels produced. A component of the freeboard accounts for this uncertainty in the design flood levels.

E.2.1.2. Component Determination

Uncertainties in flood level estimates can be approximated through an analysis of the sensitivity of design flood levels to changes in various modelling assumptions. A sensitivity analysis was undertaken as part of the *Gundagai Flood Study* (Reference 3), which assessed the Murrumbidgee River flood model's sensitivity to factors including hydraulic roughness, flow and volume estimates, grid cell size and upstream attenuation. The sensitivity of modelled Jones Creek flood behaviour to rainfall estimates, hydraulic roughness, lag, culvert blockage and initial and continuing losses was also assessed. The model's sensitivity to these factors has been used to inform this freeboard component, as described in Table 33 and Table 34 in the *Gundagai Flood Study* (Reference 3). The resulting average increase in peak flood level, as determined in the original assessment (Reference 3), is applied as the appropriate freeboard component. Results are presented in Table 2.

Table 2 Uncertainties in Estimated Flood Levels - Freeboard Components

Mechanism	Freeboard Component (m)
Murrumbidgee River	0.2
Jones Creek	0.1

E.2.2. Local Water Surge

E.2.2.1. Discussion

Local flood water levels can be higher than the general flood level due to local blockages or obstructions in the floodplain, or, for mitigation works, if the levee alignment is oblique to the direction of the flow. Local surge can also be generated by trucks or boats passing through floodwaters. Some examples of local surge are shown below.

E.2.2.2. Component Determination

Results of flood modelling can be used to understand the sensitivity of design flood levels to the influences that cause local surge. The impacts of blockage were considered as part of the sensitivity analysis undertaken in Reference 3, and this level of sensitivity has been used to derive the freeboard component related to local surge. The sensitivity assessment applied a blockage factor of 50% to bridges in the Murrumbidgee River and Jones Creek models.

A comparison of results in the blockage case and the design case indicated that the Murrumbidgee River is most sensitive to blockage at the Middleton Drive bridge, where flood levels increase locally by approximately 0.12 m. Local flood level increases at this location are likely to affect properties along Brungle Road. In terms of the Jones Creek catchment, blocking structures across the creek at Sheridan Street and Punch Street was shown to cause local increases in peak flood levels in the order of 0.3 m. Flood levels upstream of the Hume Highway bridge however are significantly more sensitive, increasing by over a metre due to blockage in the Jones Creek bridge crossing. This level of increase would impact on properties on Burra Road west of the Hume Highway. It is noted however that the increase of over 1.0 m is not representative of the broader Jones Creek catchment, and would therefore not be appropriate to apply as the Jones Creek freeboard component for local surge. Instead, a freeboard component of 0.4 m is considered appropriate. The results are presented in Table 3.

Table 3 Local Water Surge - Freeboard Components

Mechanism	Freeboard Component (m)
Murrumbidgee River	0.12
Jones Creek	0.4

E.2.3. Wave Action

E.2.3.1. Discussion

Increases in water level as a result of wave action are not determined in floodplain modelling. Wind-induced waves across fetches of open water are important to consider in the wide floodplains of the Murrumbidgee River or areas of high wind speeds, that is towns in valleys such as Gundagai. Design wave actions are a product of:

- Fetch – the distance the wave is assumed to travel;
- Wind speed and direction;
- Wave Height;
- Wind Set-up, and
- Wave Run-up – when a wave reaches a sloping embankment (e.g. levee) it will break on the embankment and run up the slope. Run-up would not apply to flood planning levels.

E.2.3.2. Component Determination

For this freeboard assessment 'wave action' is assumed to mean the surface waves generated by wind across the water surface. The wave height is a product of the windspeed in the direction of the fetch, and the fetch distance across which the wind travels. These factors are described below.

Effective Fetch

Fetch describes the length of the water surface along which waves are generated. While waves can be generated across whichever direction the wind is blowing, only the direction that would direct waves onto properties in Gundagai is considered for this assessment. In Gundagai, the Murrumbidgee River fetch direction is approximately north-south across the Murrumbidgee River, perpendicular to Sheridan Lane. In a 1% AEP event, the Murrumbidgee River fetch is approximately one kilometre. The Jones Creek fetch is taken as east-west to account for waves generated by westerly winds towards properties, and is estimated to be approximately 300 m in a 1% AEP event.

Windspeed

Windspeed and direction data has been obtained from the Bureau of Meteorology (BoM) taken at Gundagai, Nangus Road (Site No. 073141), and is presented in Attachment A. For wind setup in a Murrumbidgee River flood event, the wind direction is taken as southerly, while for Jones Creek flooding, westerly wind would cause the most significant waves propagating towards properties. Wind speeds in each of the fetch directions are summarised in Table 4.

The "significant wave height", H_s, in metres, is derived by combining the fetch (in metres) and the windspeed (in m/s). For this freeboard assessment, the relationship has been derived from the chart presented in Diagram 1, taken from Reference 6, with the results presented in Table 4. The Wave Action freeboard component is taken as the Significant Height derived in this assessment.

Diagram 1 Simplified relationship between fetch length, wind speed and significant wave height (Reference 6)

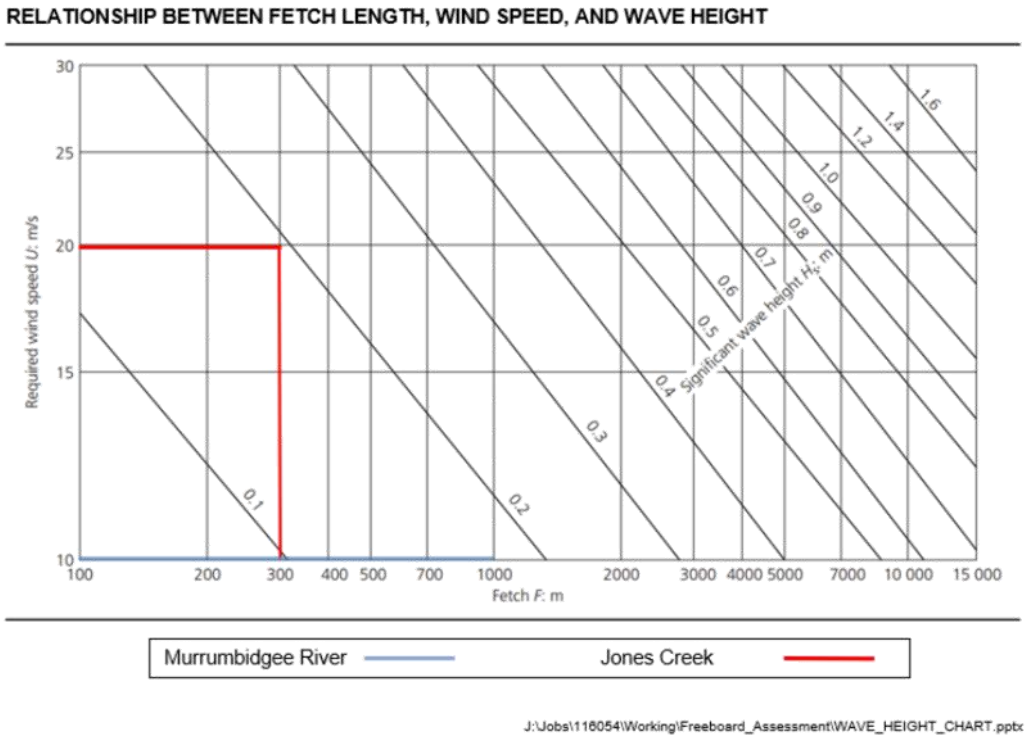


Table 4 Fetch, Wind speed, and wave height freeboard component

Mechanism	Fetch Direction	Wind speed (m/s)	Fetch (m)	Wave Height Freeboard Component
Murrumbidgee River	South to north	10	1000	0.17
Jones Creek	West to east	20	300	0.20

E.2.4. Climate Change

E.2.4.1. Discussion

The Floodplain Development Manual (Reference 1) indicates that climate change should be considered in the development and implementation of floodplain risk management works, to ensure that the level of protection can be maintained under future conditions. The impacts of climate change on flood-producing rainfall events will have a flow on effect on flood behaviour. This may result in key flood levels being reached more frequently. The freeboard allowance required to cater for climate change is greatly affected by the uncertainties in future climate model projections, and is therefore somewhat of an estimation, though is considered appropriate for the purpose of this assessment.

E.2.4.2. Component Determination

The potential impacts of climate change, and the flood model's sensitivity to these impacts were assessed as part of the *Gundagai Flood Study* (Reference 3). The sensitivity of riverine flooding was assessed by varying Murrumbidgee River flows by 10%. An increase in flow of 10% yielded an average increase in peak flood levels (in the 1% AEP event) of 0.25 m. Jones Creek flooding is controlled by rainfall, and as such the Flood Study (Reference 3) assessed the sensitivity of the Jones Creek model by varying the rainfall intensity. Results showed that, for an increase in rainfall of 10%, the peak flood levels would increase by 0.06 m on average. In parts of the Jones Creek catchment adjacent to properties (particularly Punch Street), variations of up to 0.15 m were noted. Therefore, a freeboard component of 0.1 m for climate change is considered appropriate. These components are summarised in Table 5.

Table 5 Climate Change Freeboard Component

Mechanism	Freeboard Component (m)
Murrumbidgee River	0.25
Jones Creek	0.10

E.3. JOINT PROBABILITY ANALYSIS

Joint probability analyses are used to address the chance of two or more conditions occurring at the same time. The analysis recognises that design flood characteristics could result from a variety of combinations of flood-producing factors, and that in reality not all freeboard components would occur concurrently. Assigning probability factors to each component is therefore undertaken to determine the appropriate design freeboard.

The following probability factors have been assigned in this freeboard assessment, and have been based on those applied in Reference 4:

Freeboard Component	Probability Factor
Uncertainties in Flood Levels	1
Local Water Surge	0.5
Wave Action	0.5
Climate Change	1

E.4. CONCLUSION

A freeboard assessment has been undertaken to determine the appropriate freeboard for residential flood planning levels in Gundagai. The assessment sought to quantify the following factors that can lead to flood levels being higher than the modelled estimates:

- Uncertainties in estimated flood levels;
- Local water surge;
- Wave action; and
- Climate change.

A summary of the freeboard assessment is presented in Table 6.

Table 6 Gundagai Freeboard Assessment Results

	Jones Creek			Murrumbidgee River			Reference
	(A)	(B)	(A x B)	(C)	(D)	(C x D)	
Component	Allowance (m)	Probability	Final Jones Creek Component (m)	Allowance (m)	Probability	Final Murrumbidgee River Component (m)	
Uncertainties in Estimated Flood Levels	0.1	1	0.1	0.2	1	0.2	E.2.1
Local Water Surge	0.4	0.5	0.20	0.12	0.5	0.06	E.2.2
Wave Action	0.2	0.5	0.1	0.17	0.5	0.085	E.2.3
Climate Change	0.1	1	0.1	0.25	1	0.25	E.2.4
Total			**0.50**			**0.60**	

Considering the above factors and likelihood of concurrence, a minimum freeboard of 0.5 m is deemed appropriate for flood planning levels in Gundagai. The appropriate flood planning level (FPL) for residential development in Gundagai is therefore the 1% AEP level plus 0.5 m freeboard. The Flood Planning Area is, as defined in the Floodplain Development Manual (Reference 1), is the area of land below the FPL. Given the relatively steep topography in Gundagai, adding 0.5 m freeboard to the 1% AEP level does not extend the FPA significantly, in fact no additional properties are captured in the revised FPA. However, the higher FPL will mean that when properties in the FPA are redeveloped (or raised via a voluntary house raising scheme), they will have a higher level of flood protection, thereby reducing flood damages.

Adopting a freeboard of 0.5m will also be consistent with State Government recommendations.

E.5. REFERENCES

1. NSW Government
Floodplain Development Manual
April 2005

2. Department of Environment and Climate Change
Floodplain Risk Management Guideline – Residential Flood Damages
NSW State Government, October 2007

WMAwater
3. **Gundagai Flood Study**
Cootamundra – Gundagai Regional Council, March 2018

4. NSW Department of Public Works
Wagga Wagga Levee upgrade
Flood Freeboard
Report No. DC 10096
November 2010

5. Sinclair Knight Merz
Deniliquin Flood Protection Levee Study
July, 1997.

6. Institute of Civil Engineers
Floods and Reservoir Safety
1996


Attachment A

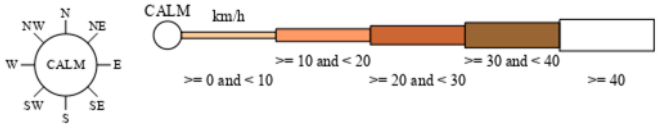
Rose of Wind direction versus Wind speed in km/h (10 May 1995 to 09 Aug 2018)

Custom times selected, refer to attached note for details

GUNDAGAI (NANGUS RD)

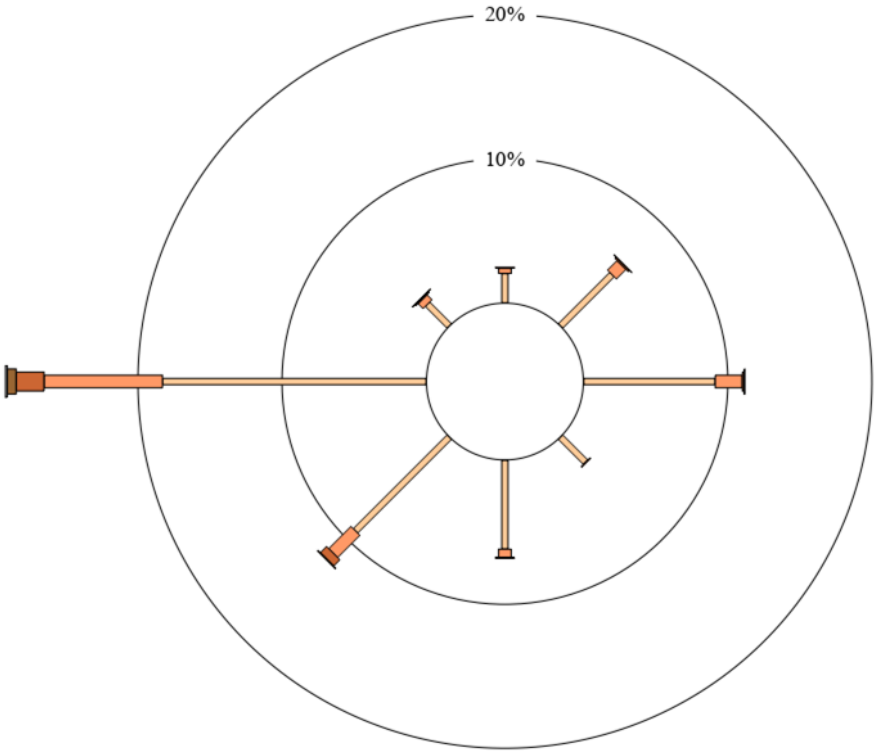
Site No: 073141 • Opened May 1995 • Still Open • Latitude: -35.064° • Longitude: 148.0986° • Elevation 225m

An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.



3 pm
6969 Total Observations

Calm 27%



Wind directions are divided into eight compass directions. The circles around the image represent the various percentages of occurrence of the winds. For example, if the branch to the west just reaches the 10% ring it means a frequency of 10% blowing from that direction. The scale factor can be ignored when interpreting these wind roses.
An observed wind speed which falls precisely on the boundary between two divisions will be included in the lower range (eg 10km/h is included in the 1-10 km/h range).
Calm has no direction. An asterisk(*) indicate that calm is less than 1%.
Only quality controlled data have been used.

Note copied from http://www.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/windrose_selector.cgi?period=Annual&type=9&location=72150&Submit=Get+Rose