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

Table B1: BoM 2016 Rainfall Depths – City Catchment

Duration (min)	Annual Exceedance Probability (AEP)						
	63.20%	50%	20%	10%	5%	2%	1%
5	5.7	6.5	9.2	11	12.8	15.3	17.3
10	8.6	9.9	13.9	16.7	19.7	23.5	26.5
15	10.6	12.1	17.1	20.6	24.1	28.8	32.5
30	14.2	16.2	22.8	27.5	32.1	38.4	43.4
60	17.9	20.4	28.6	34.4	40.1	47.8	53.9
120	22	25	34.8	41.4	48.2	57.4	64.6
180	24.5	27.9	38.4	45.9	53.4	63.3	71.1
360	29.7	33.6	45.9	54.5	63	74.4	83.4
720	36	40.4	54.8	64.8	74.6	88.2	98.8
1440	43.4	48.7	65.3	76.8	88.3	104.4	116.9
2880	51.4	57.6	76.8	90.2	103.7	121.9	136.3
4320	56.2	62.9	83.5	97.9	112.3	132.5	147.6

Table B2: BoM 2016 Rainfall Depths – East Catchment

Duration (min)	Annual Exceedance Probability (AEP)						
	63.20%	50%	20%	10%	5%	2%	1%
5	5.8	6.6	9.3	11.1	12.9	15.4	17.3
10	8.8	10.1	14.1	16.8	19.7	23.5	26.5
15	10.8	12.3	17.3	20.8	24.2	29	32.5
30	14.4	16.5	23.1	27.7	32.3	38.5	43.4
60	18.3	20.8	29	34.7	40.4	48.1	54.1
120	22.4	25.6	35.2	42	48.8	58	65.2
180	25.2	28.6	39.3	46.8	54	64.2	72
360	30.7	34.6	47.1	55.8	64.2	76.2	85.2
720	37.4	41.9	56.5	66.7	76.9	90.7	101.6
1440	45.4	50.6	67.7	79.4	91.4	107.8	120.5
2880	53.8	60	79.7	93.6	107.5	126.2	140.6
4320	58.9	65.7	87.1	102.2	116.6	136.8	151.9

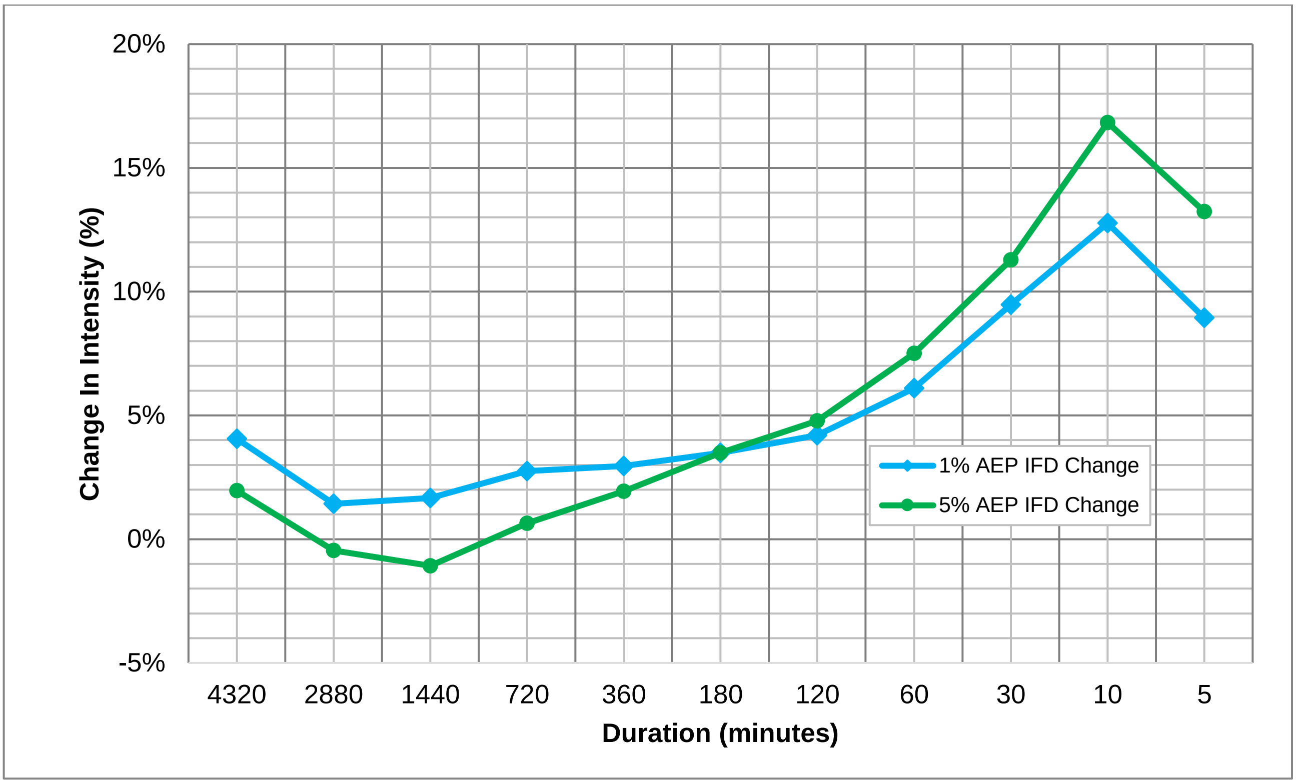
Table B3: BoM 2016 Rainfall Depths – Lake Albert Catchment

Duration (min)	Annual Exceedance Probability (AEP)						
	63.20%	50%	20%	10%	5%	2%	1%
5	5.7	6.6	9.2	11	12.8	15.3	17.3
10	8.7	10	14	16.8	19.7	23.5	26.5
15	10.7	12.2	17.2	20.6	24.1	28.8	32.5
30	14.3	16.3	22.9	27.5	32.1	38.4	43.3
60	18	20.6	28.8	34.5	40.1	47.9	53.9
120	22.2	25.2	34.8	41.6	48.4	57.4	64.6
180	24.8	28.1	38.7	46.2	53.4	63.3	71.1
360	30.1	33.9	46.3	54.8	63.6	75	84
720	36.5	40.9	55.2	65.2	75.1	88.7	99.2
1440	43.9	49.2	66	77.52	89.04	104.88	117.36
2880	52.3	58.1	77.8	91.2	104.2	122.9	137.3
4320	56.9	63.5	84.2	99.4	113.0	133.2	148.3

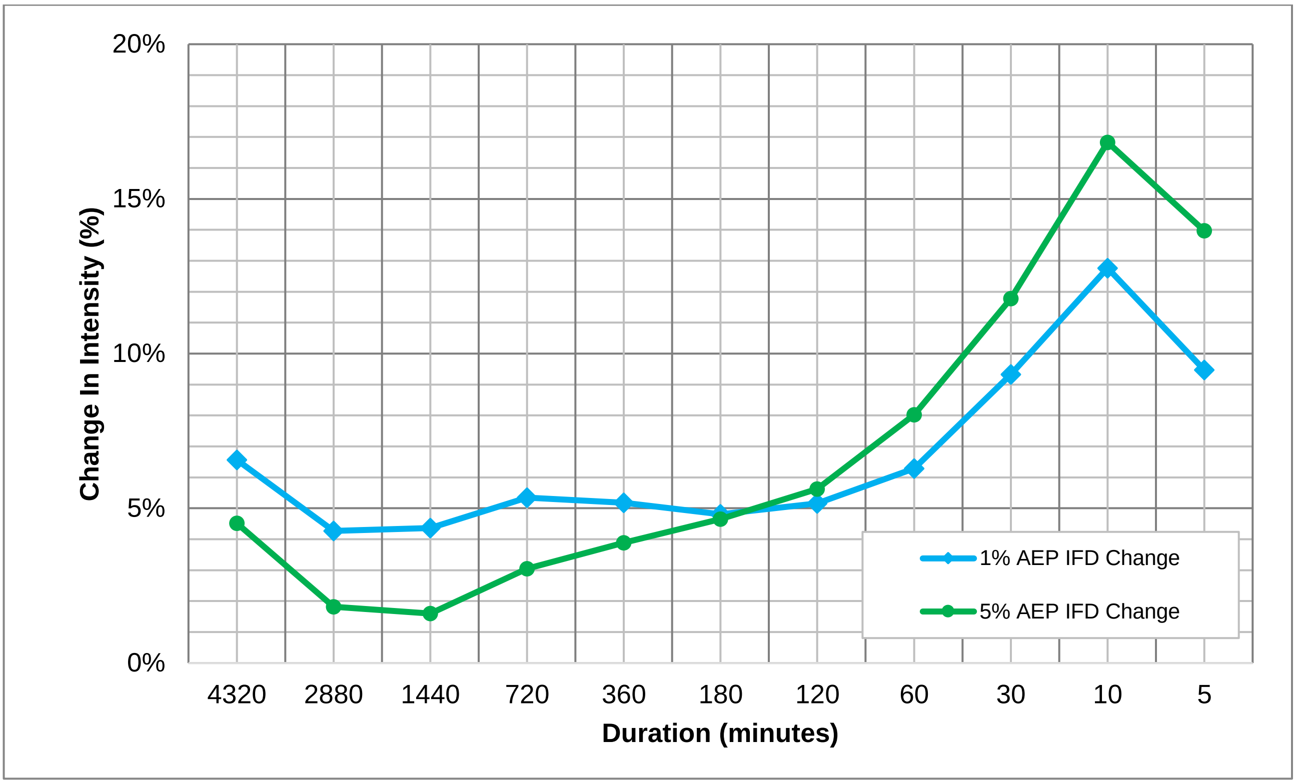
Table B4: BoM 2016 Rainfall Depths – North Catchment

Duration (min)	Annual Exceedance Probability (AEP)						
	63.20%	50%	20%	10%	5%	2%	1%
5	5.6	6.4	9	10.8	12.7	15.1	17.1
10	8.5	9.8	13.8	16.6	19.3	23.2	26.2
15	10.5	12	16.9	20.3	23.8	28.5	32.3
30	14	16	22.5	27.1	31.7	38	42.9
60	17.6	20.2	28.3	34	39.7	47.4	53.4
120	21.6	24.6	34.4	41.2	48	57	64.2
180	24.3	27.6	38.4	45.6	53.1	63.3	71.1
360	29.5	33.3	45.7	54.4	63	75	84
720	35.8	40.3	54.7	64.8	75	88.9	99.8
1440	43.2	48.5	65.3	77	88.8	105.1	117.8
2880	51.4	57.1	76.8	90.2	103.7	122.4	136.8
4320	55.9	62.4	83.5	97.9	112.3	132.5	147.6

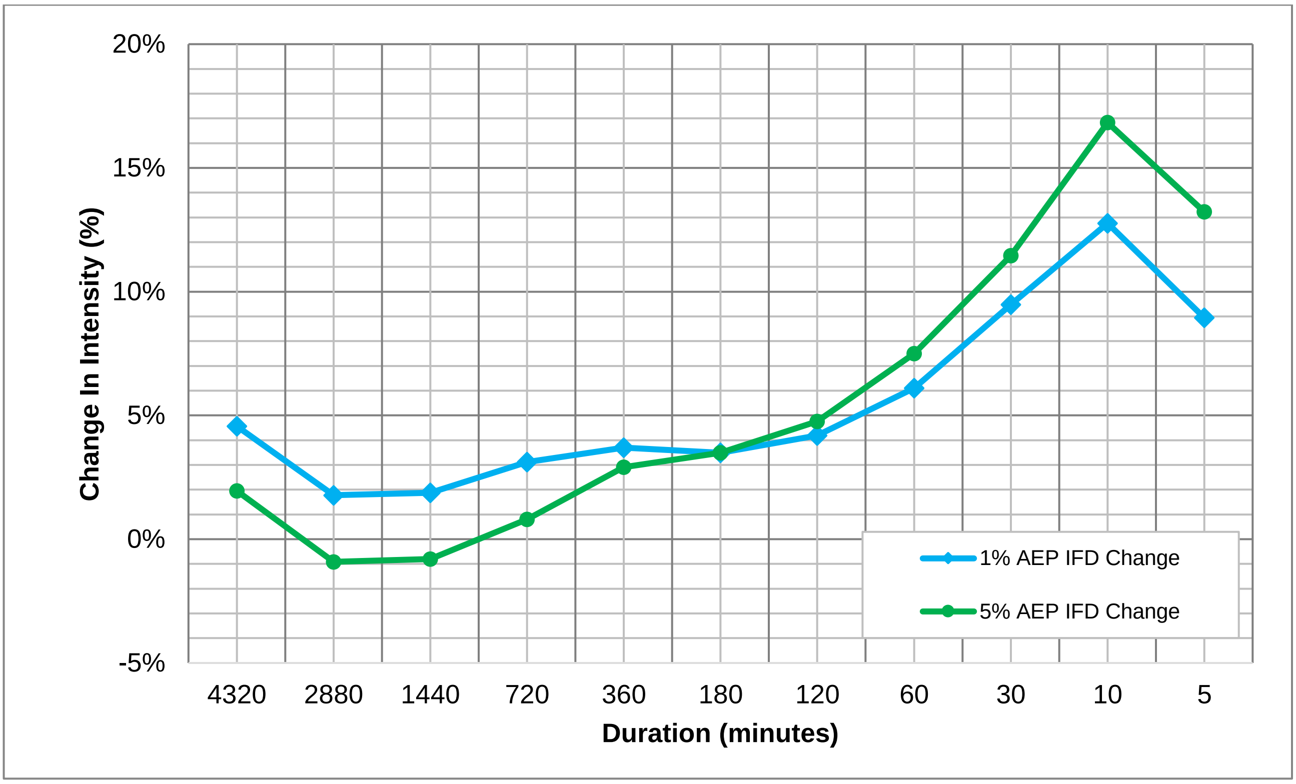
Graph B1: Change in Intensity for 1% AEP and 5 % AEP IFD 2016 v 1987 ARR – City Catchment



Graph B2: Change in Intensity for 1% AEP and 5 % AEP IFD 2016 v 1987 ARR – East Catchment



Graph B3: Change in Intensity for 1% AEP and 5 % AEP IFD 2016 v 1987 ARR – Lake Albert Catchment



Graph B4: Change in Intensity for 1% AEP and 5 % AEP IFD 2016 v 1987 ARR – North Catchment

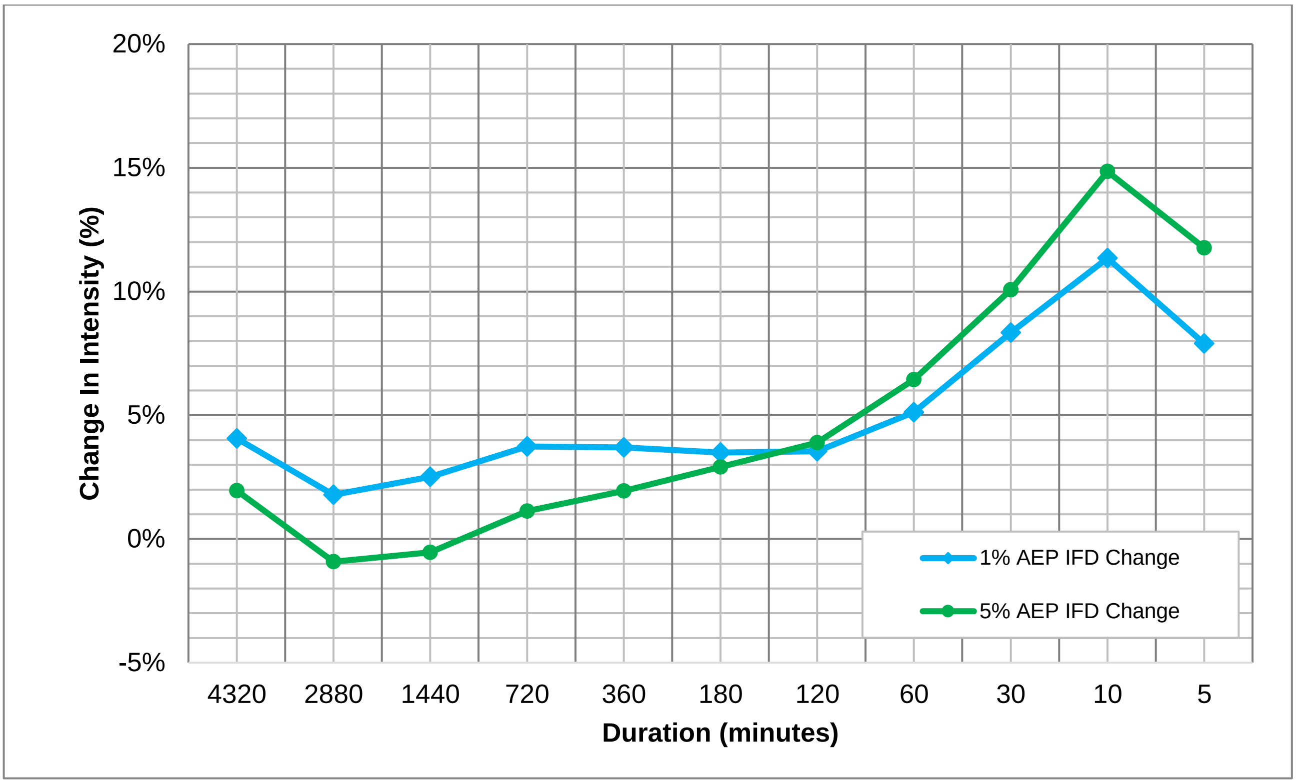


Table B5: Median Pre-Burst Depth Value – City Catchment

Duration (min)	Annual Exceedance Probability (AEP)					
	50%	20%	10%	5%	2%	1%
60	1.7	1.5	1.4	1.2	0.8	0.5
90	2.5	1.7	1.1	0.6	0.6	0.6
120	4.3	3.2	2.5	1.8	0.8	0.1
180	3.1	3.1	3.1	3.1	1.8	0.8
360	2.0	1.1	0.6	0.1	1.3	2.2
720	0.0	0.8	1.4	1.9	2.8	3.4
1080	0.0	0.4	0.6	0.9	2.0	2.9
1440	0.0	0.1	0.1	0.2	0.5	0.8
2160	0.0	0.0	0.0	0.0	0.0	0.0
2880	0.0	0.0	0.0	0.0	0.0	0.0
4320	0.0	0.0	0.0	0.0	0.0	0.0

Table B6: Median Pre-Burst Depth Value – East Catchment

Duration (min)	Annual Exceedance Probability (AEP)					
	50%	20%	10%	5%	2%	1%
60	1.9	1.5	1.3	1.0	0.7	0.5
90	4.5	2.9	1.9	0.9	0.7	0.5
120	4.7	3.0	1.9	0.9	0.4	0.1
180	3.1	2.8	2.6	2.4	1.6	1.0
360	3.0	1.8	0.9	0.2	1.5	2.5
720	0.1	1.0	1.6	2.1	4.7	6.7
1080	0.0	0.3	0.5	0.7	2.8	4.4
1440	0.0	0.2	0.3	0.4	0.7	1.0
2160	0.0	0.0	0.0	0.0	0.0	0.0
2880	0.0	0.0	0.0	0.0	0.0	0.0
4320	0.0	0.0	0.0	0.0	0.0	0.0

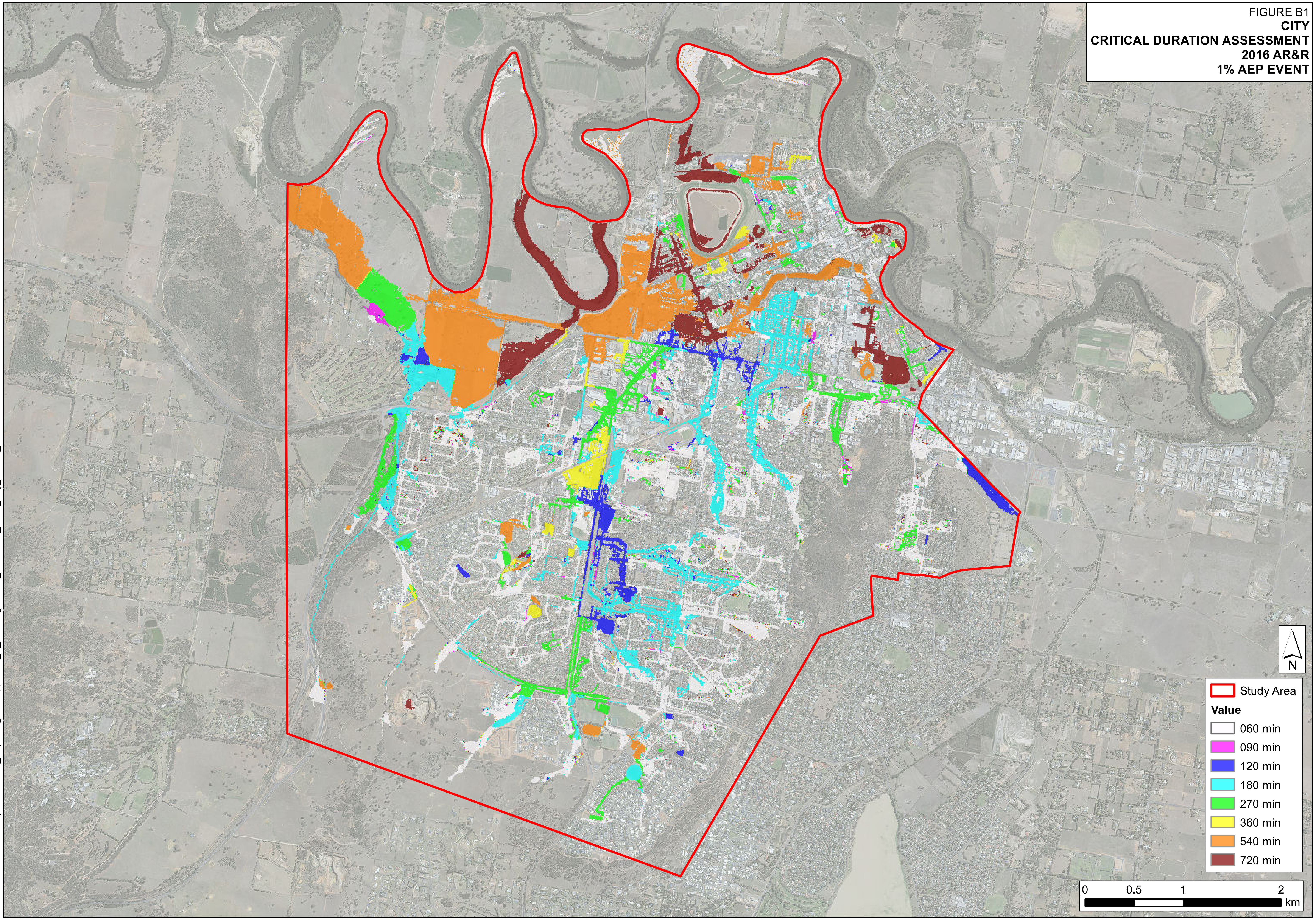
Table B7: Median Pre-Burst Depth Value – Lake Albert Catchment

Duration (min)	Annual Exceedance Probability (AEP)					
	50%	20%	10%	5%	2%	1%
60	1.9	1.5	1.3	1.0	0.7	0.5
90	4.5	2.9	1.9	0.9	0.7	0.5
120	4.7	3.0	1.9	0.9	0.4	0.1
180	3.1	2.8	2.6	2.4	1.6	1.0
360	3.0	1.8	0.9	0.2	1.5	2.5
720	0.1	1.0	1.6	2.1	4.7	6.7
1080	0.0	0.3	0.5	0.7	2.8	4.4
1440	0.0	0.2	0.3	0.4	0.7	1.0
2160	0.0	0.0	0.0	0.0	0.0	0.0
2880	0.0	0.0	0.0	0.0	0.0	0.0
4320	0.0	0.0	0.0	0.0	0.0	0.0

Table B8: Median Pre-Burst Depth Value – North Catchment

Duration (min)	Annual Exceedance Probability (AEP)					
	50%	20%	10%	5%	2%	1%
60	1.8	1.6	1.5	1.4	0.9	0.5
90	2.8	1.9	1.3	0.7	0.6	0.5
120	4.4	3.2	2.5	1.7	0.8	0.1
180	3.0	2.9	2.8	2.8	1.6	0.7
360	2.2	1.3	0.7	0.1	1.2	2.1
720	0.1	1.0	1.5	2.1	4.0	5.4
1080	0.0	0.3	0.5	0.6	2.5	3.8
1440	0.0	0.2	0.3	0.4	0.6	0.8
2160	0.0	0.0	0.0	0.0	0.0	0.0
2880	0.0	0.0	0.0	0.0	0.0	0.0
4320	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE B1
CITY
CRITICAL DURATION ASSESSMENT
2016 AR&R
1% AEP EVENT



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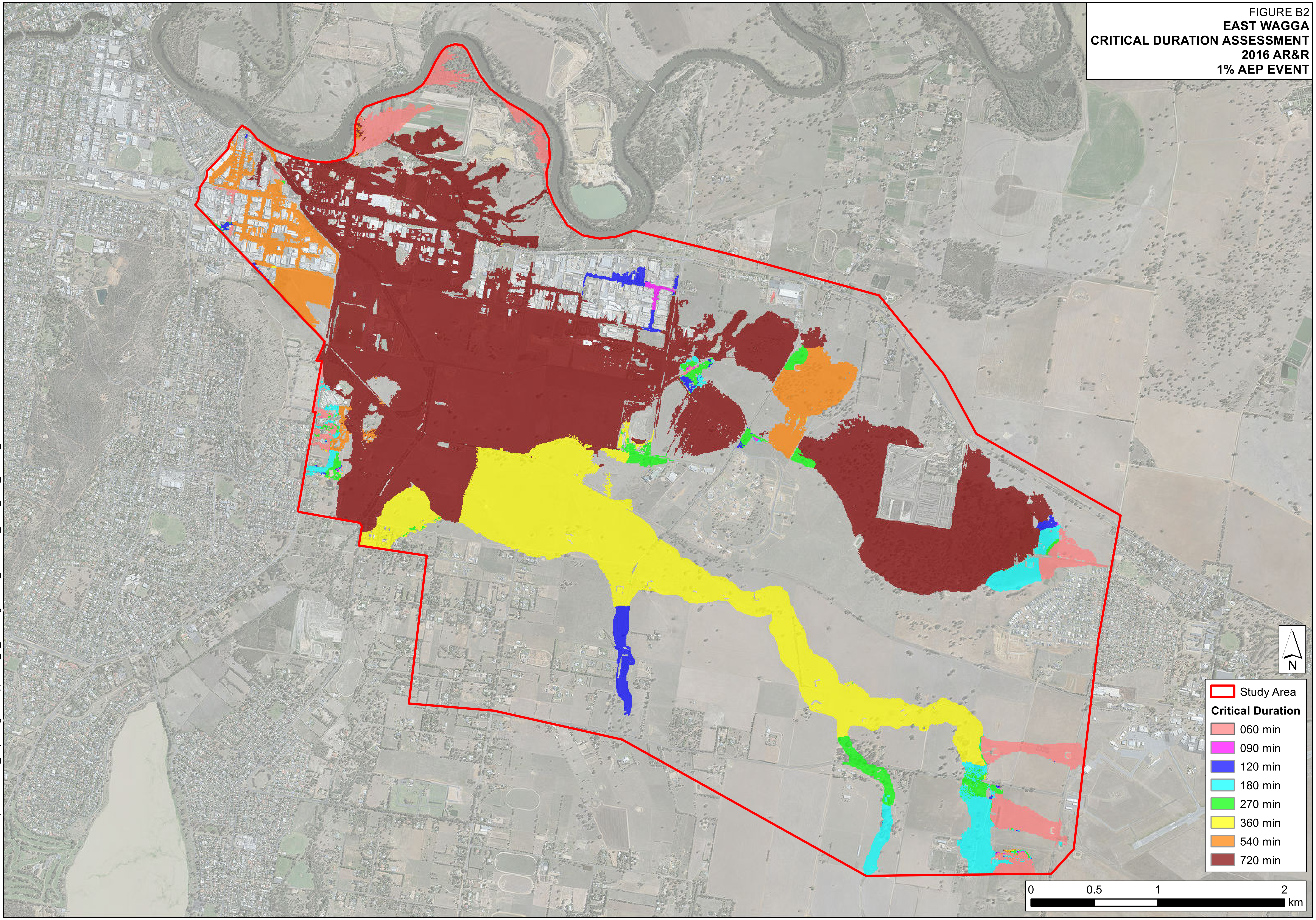
FIGURE B2
EAST WAGGA
CRITICAL DURATION ASSESSMENT
2016 AR&R
1% AEP EVENT
N
Study Area
Critical Duration
060 min
090 min
120 min
180 min
270 min
360 min
540 min
720 min
0
0.5
1
2
km
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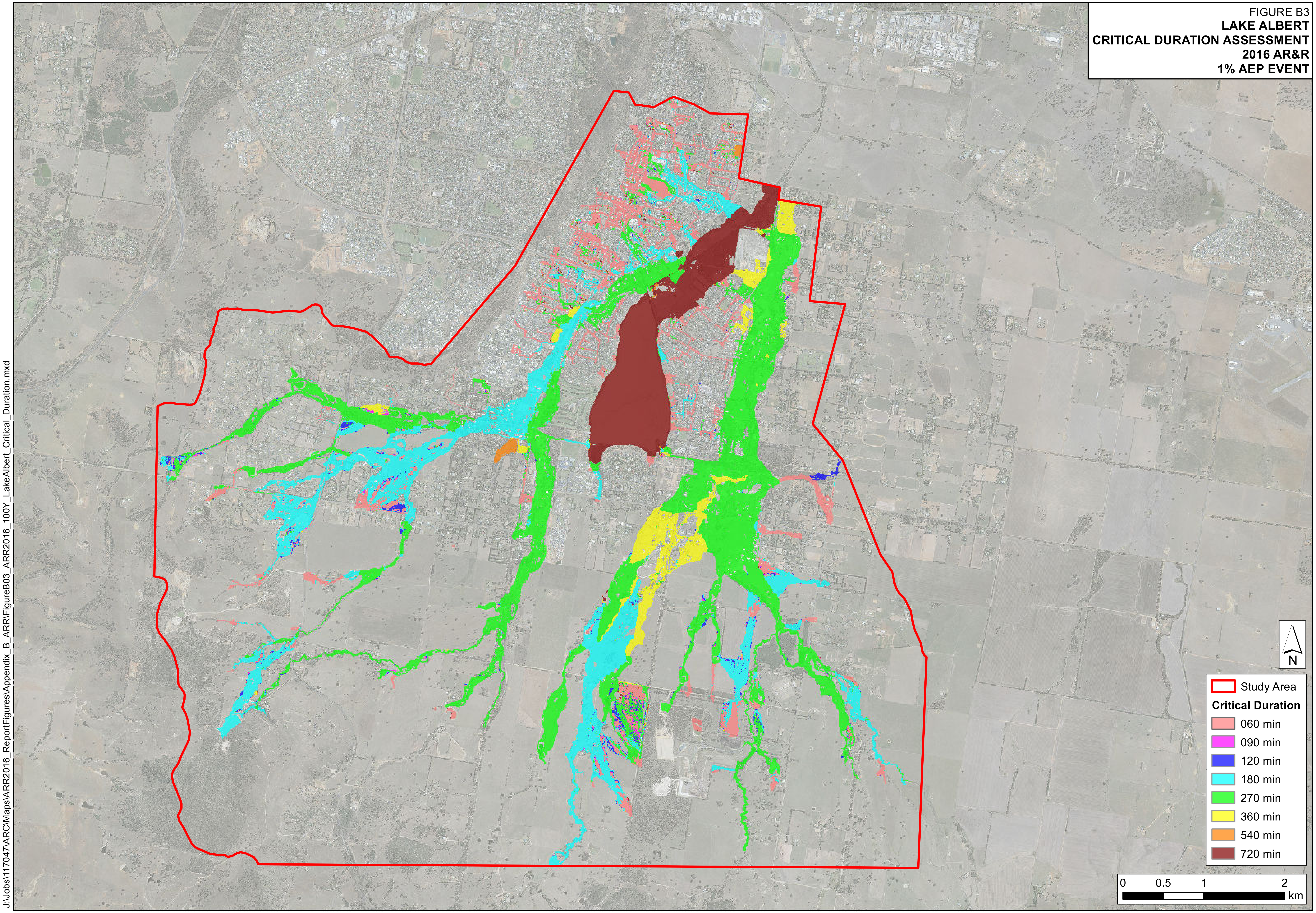
FIGURE B3
LAKE ALBERT
CRITICAL DURATION ASSESSMENT
2016 AR&R
1% AEP EVENT
N
Study Area
Critical Duration
060 min
090 min
120 min
180 min
270 min
360 min
540 min
720 min
0
0.5
1
2
km
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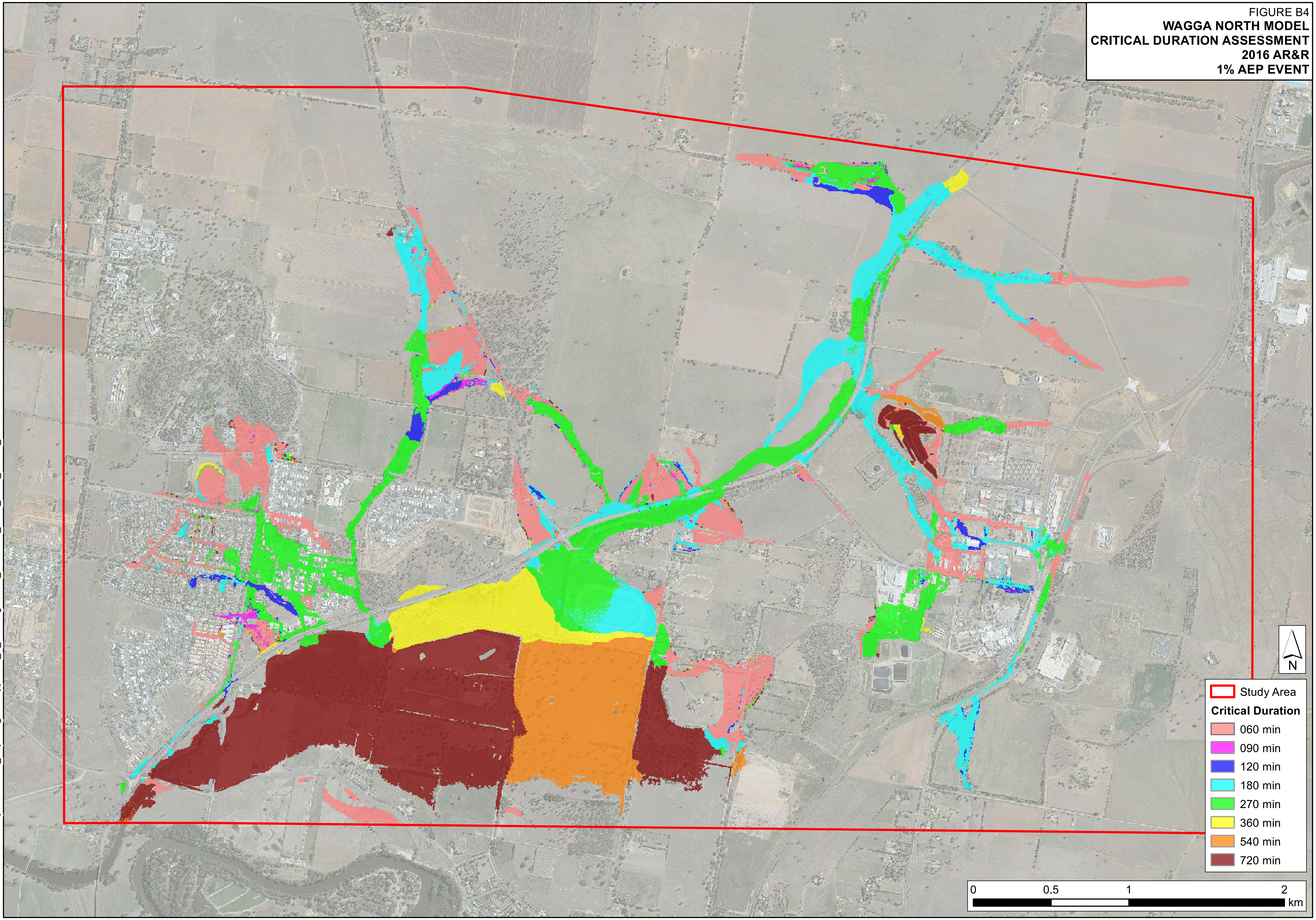
FIGURE B4
WAGGA NORTH MODEL
CRITICAL DURATION ASSESSMENT
2016 AR&R
1% AEP EVENT



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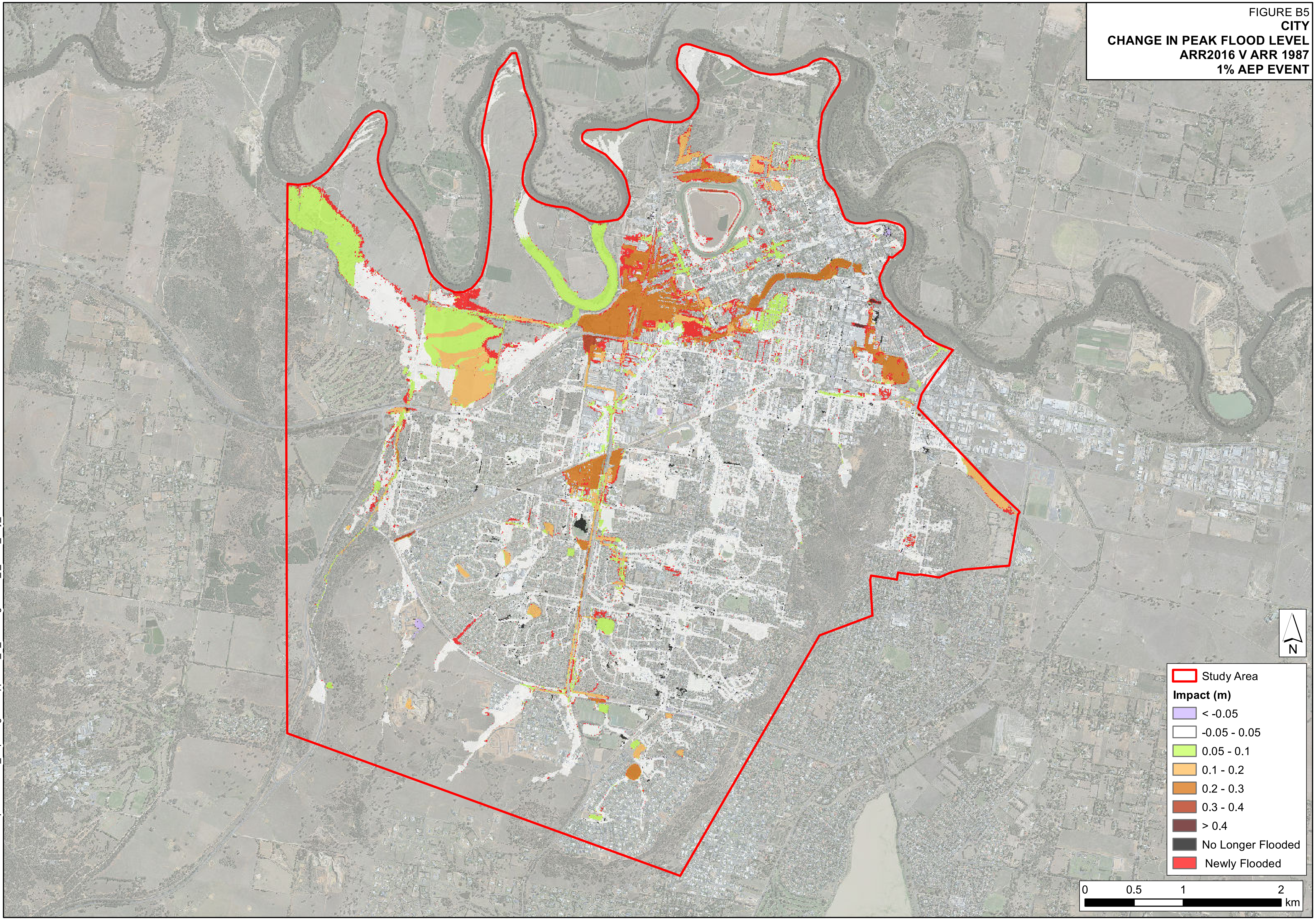

FIGURE B5
CITY
CHANGE IN PEAK FLOOD LEVEL
ARR2016 V ARR 1987
1% AEP EVENT

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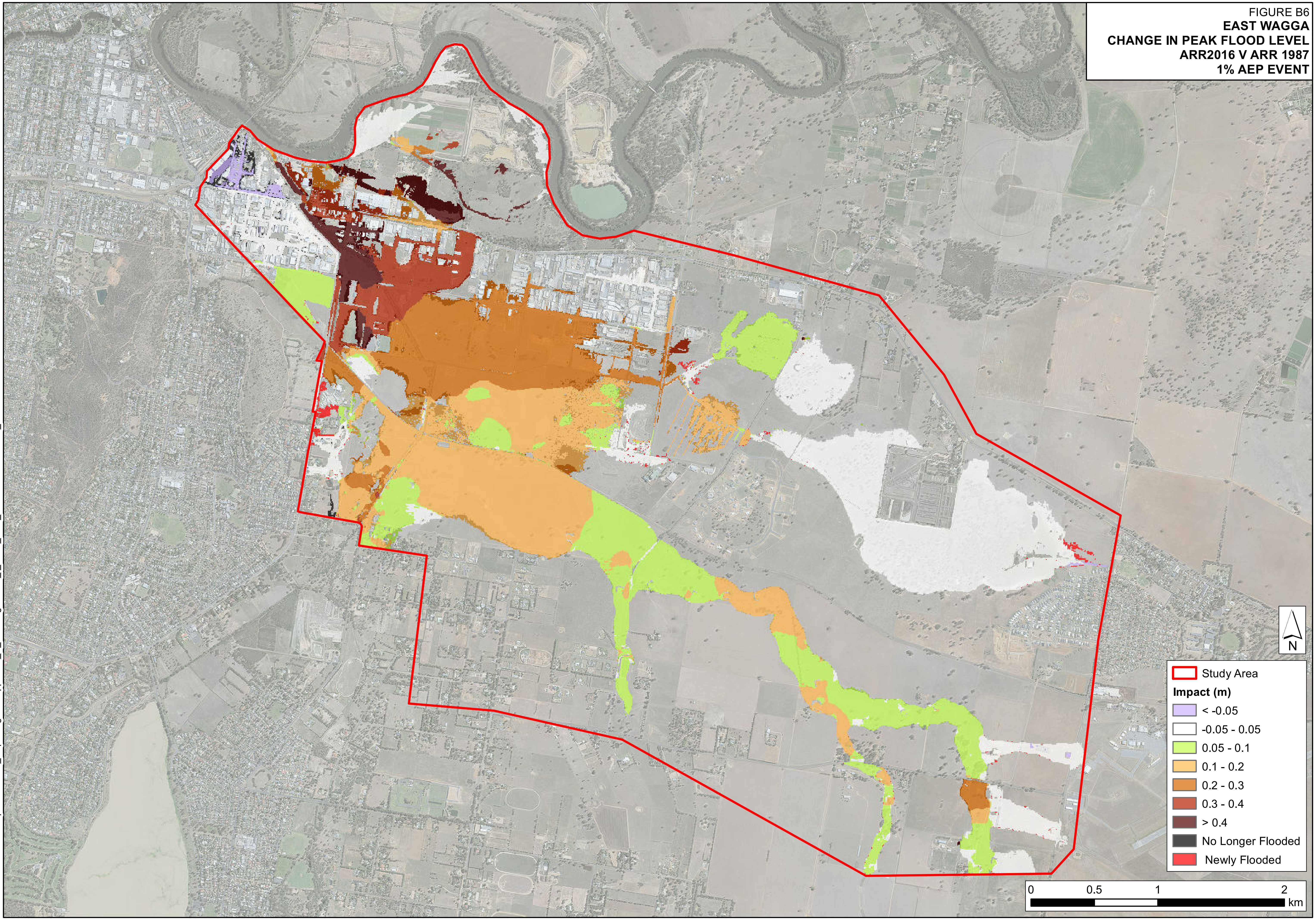

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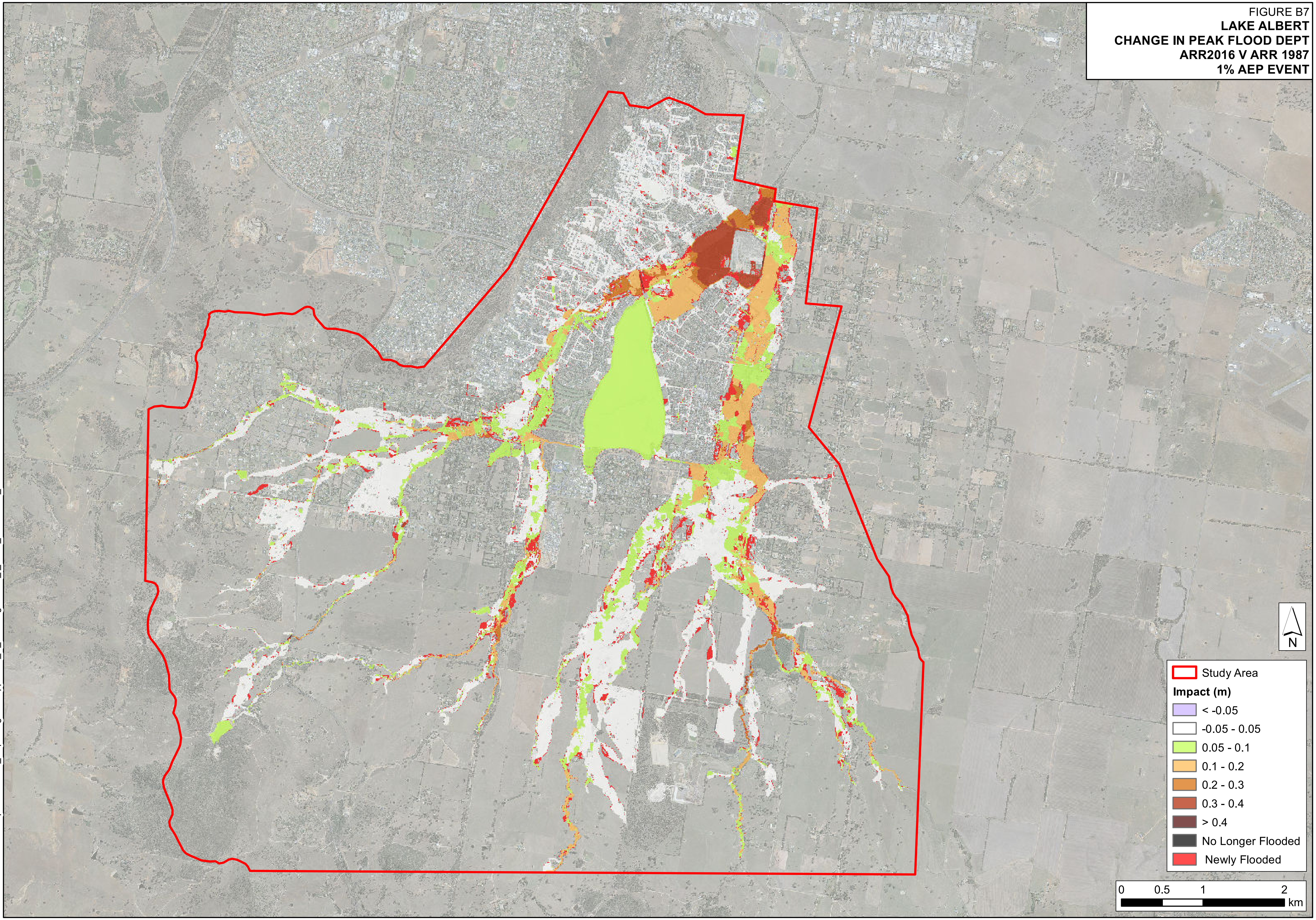
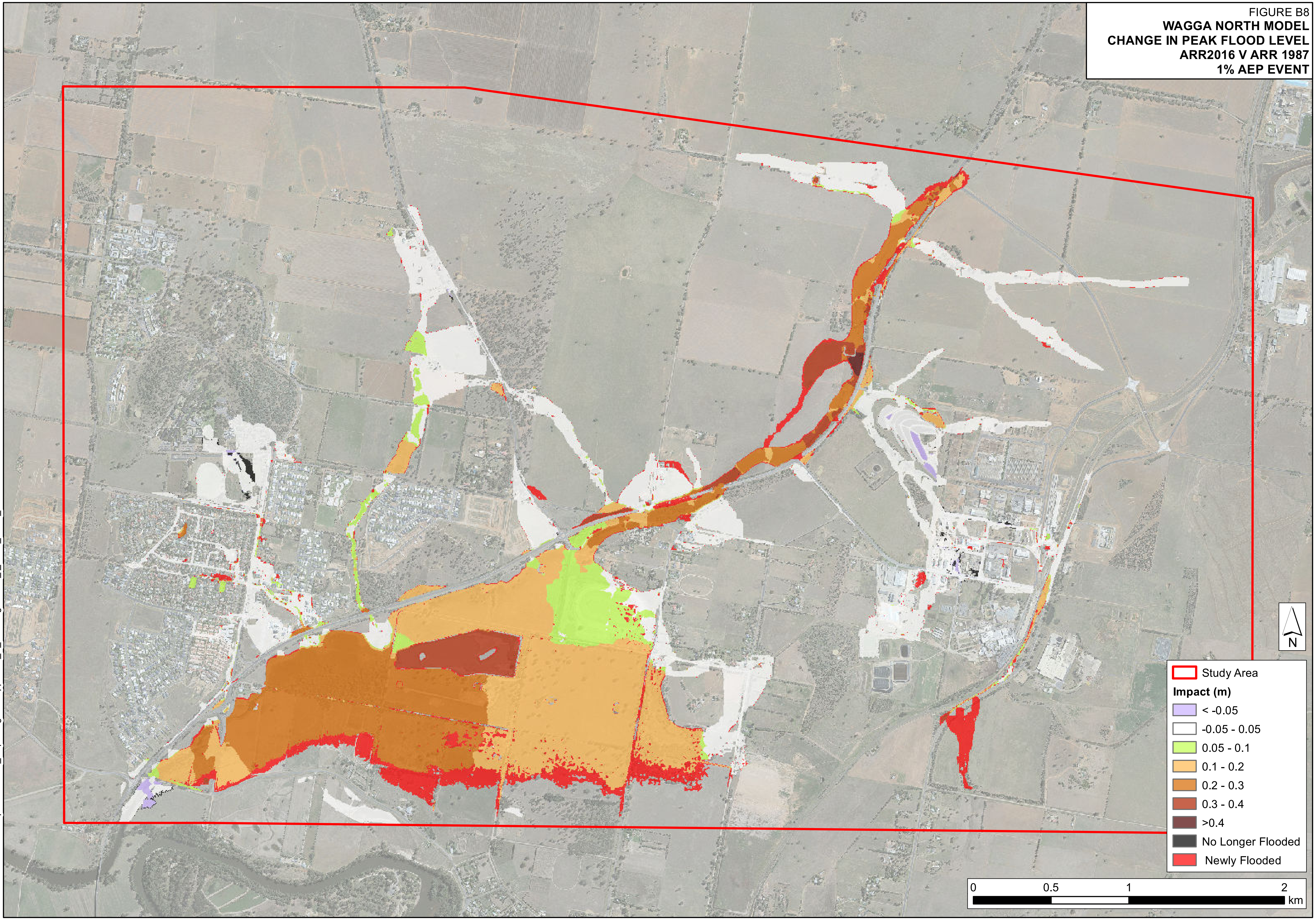


FIGURE B7
LAKE ALBERT
CHANGE IN PEAK FLOOD DEPT
ARR2016 V ARR 1987
1% AEP EVENT
N
Study Area
Impact (m)
< -0.05
-0.05 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
> 0.4
No Longer Flooded
Newly Flooded
0
0.5
1
2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB07_I_100Y_LakeAlbert_ARR2016VARR1987.mxd

FIGURE B8
WAGGA NORTH MODEL
CHANGE IN PEAK FLOOD LEVEL
ARR2016 V ARR 1987
1% AEP EVENT



J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB08_I_100Y_North_ARR2016VARR1987.mxd

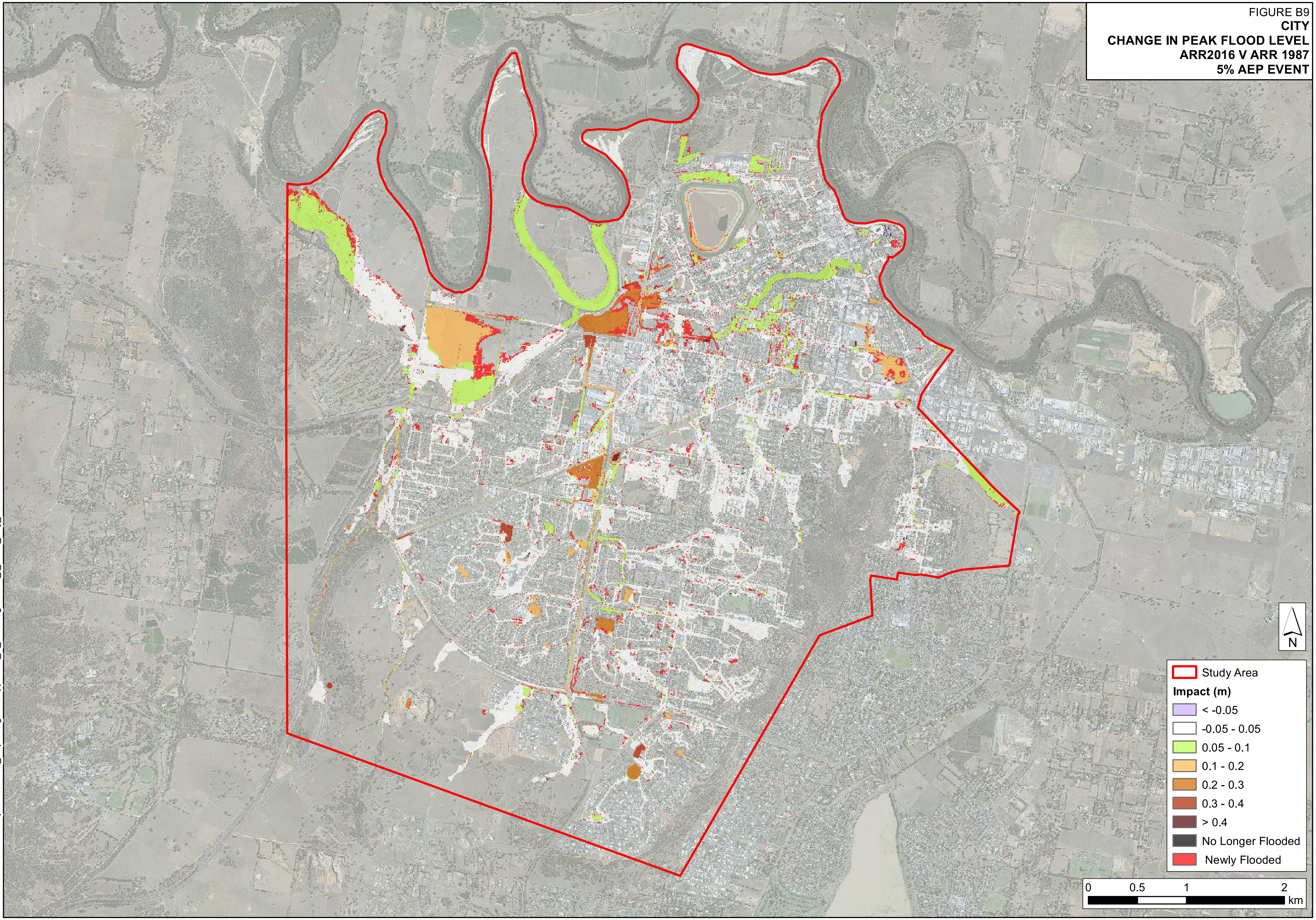
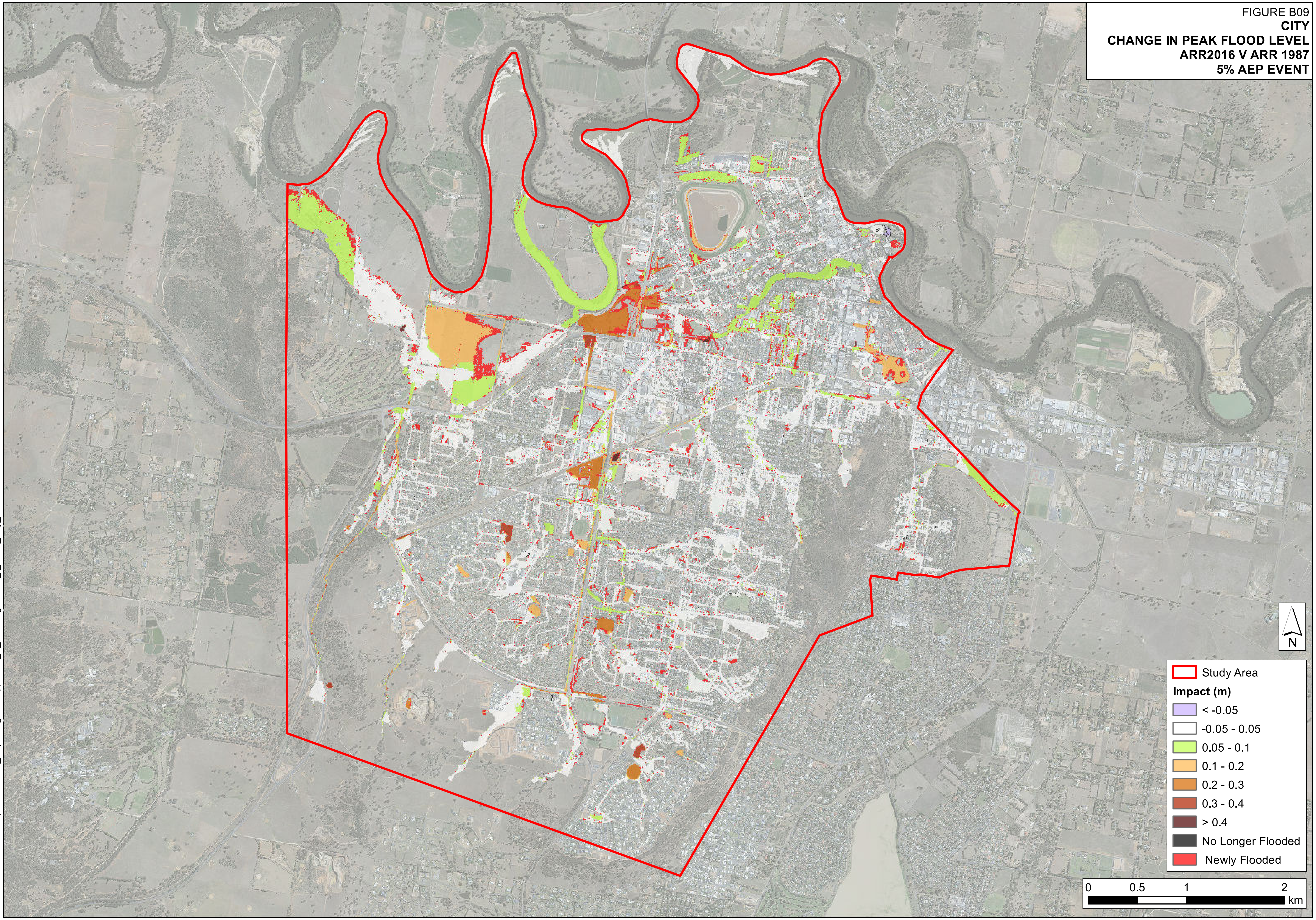


FIGURE B9
CITY
CHANGE IN PEAK FLOOD LEVEL
ARR2016 V ARR 1987
5% AEP EVENT
N
Study Area
Impact (m)
< -0.05
-0.05 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
> 0.4
No Longer Flooded
Newly Flooded
0
0.5
1
2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB09_I_020Y_City_ARR2016VARR1987.mxd



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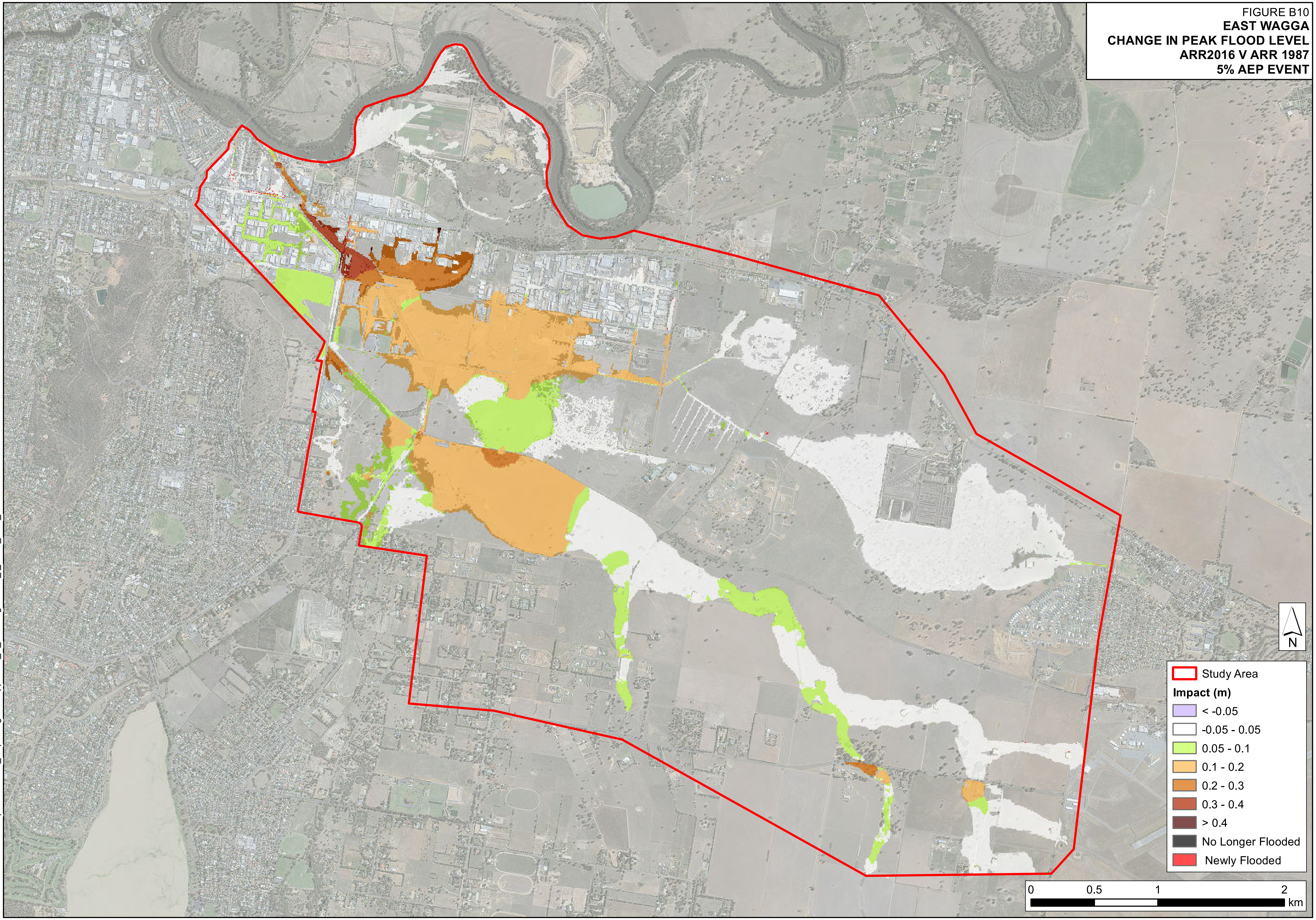
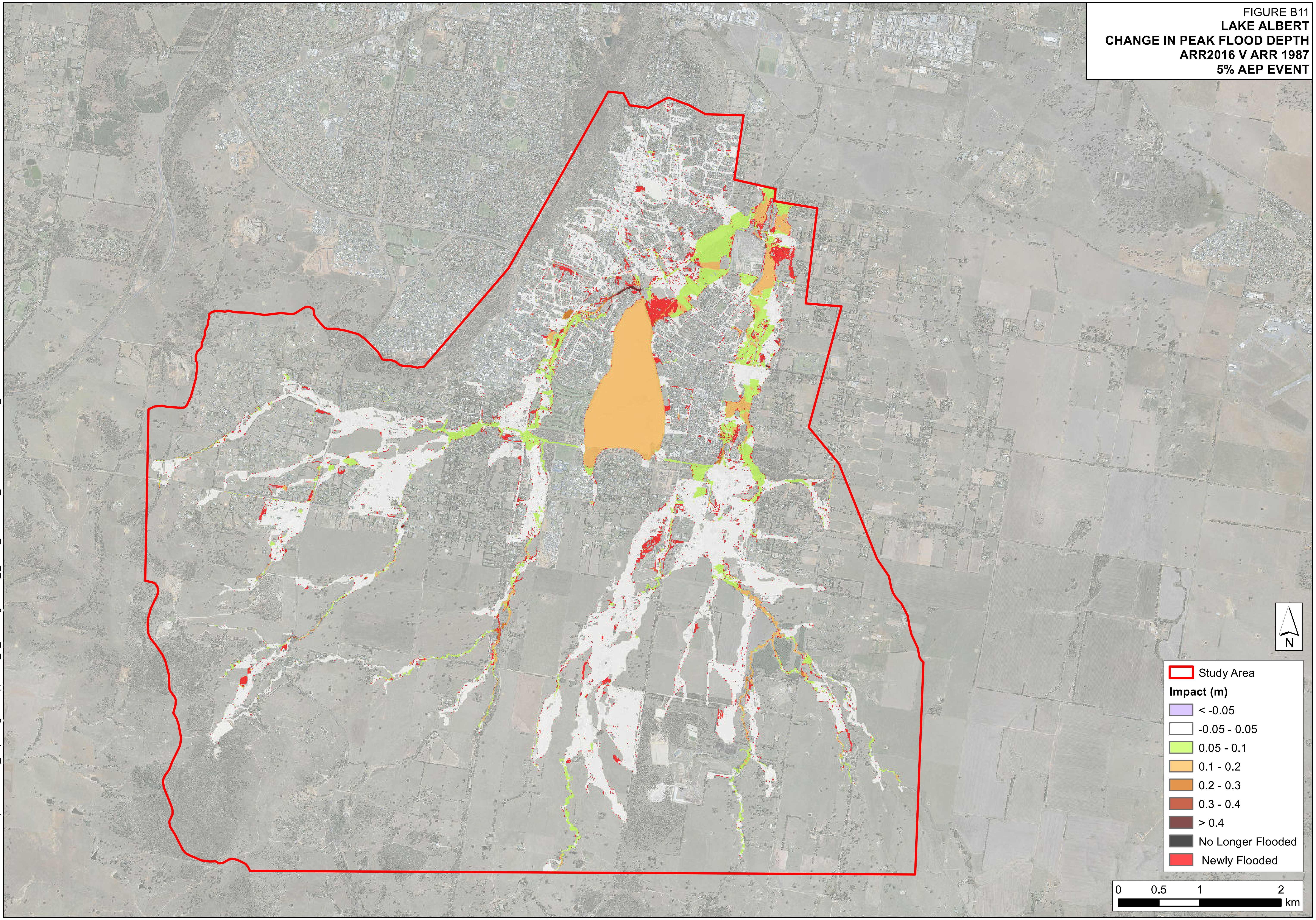


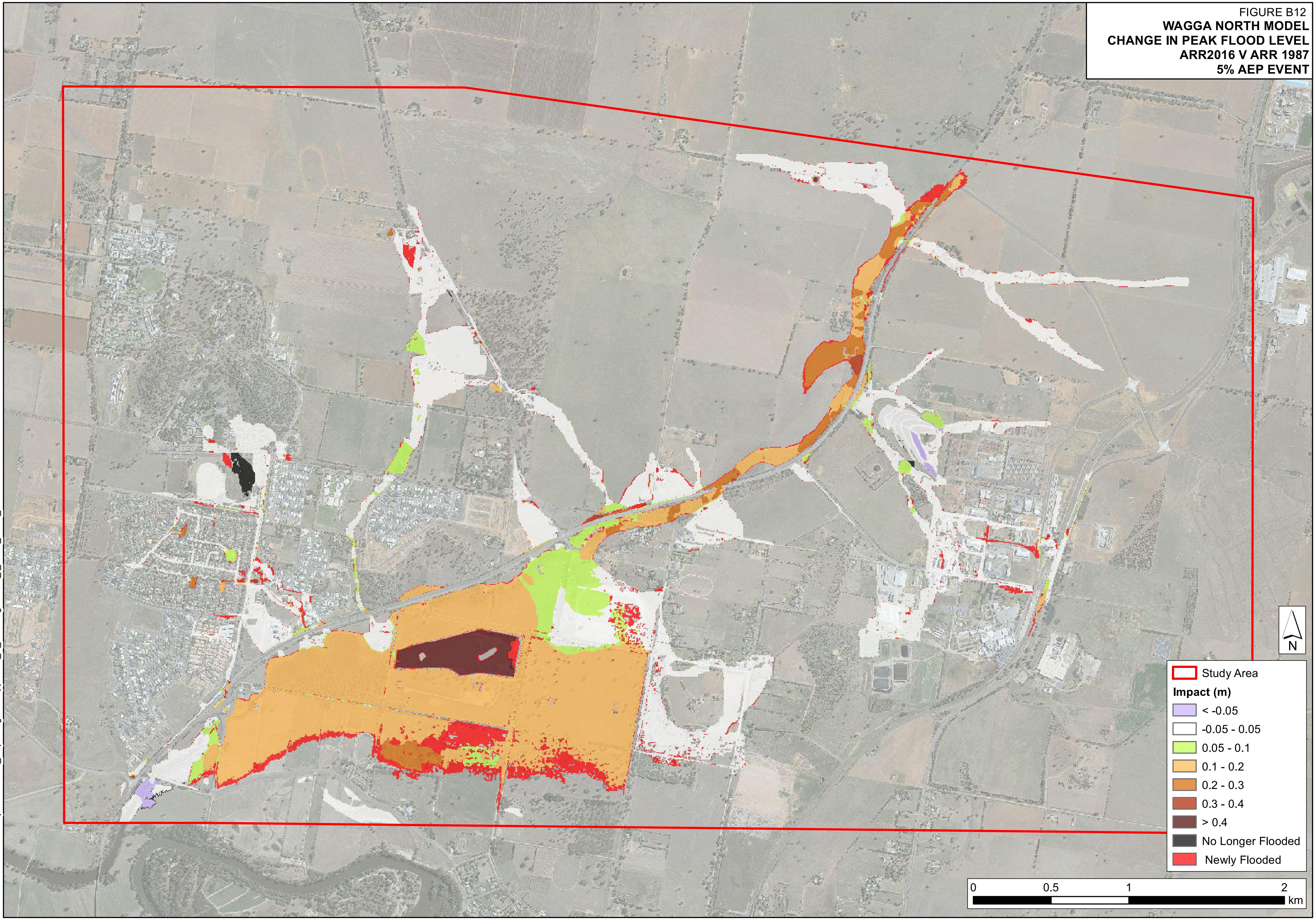
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB10_I_020Y_East_ARR2016VARR1987.mxd

FIGURE B11
LAKE ALBERT
CHANGE IN PEAK FLOOD DEPTH
ARR2016 V ARR 1987
5% AEP EVENT

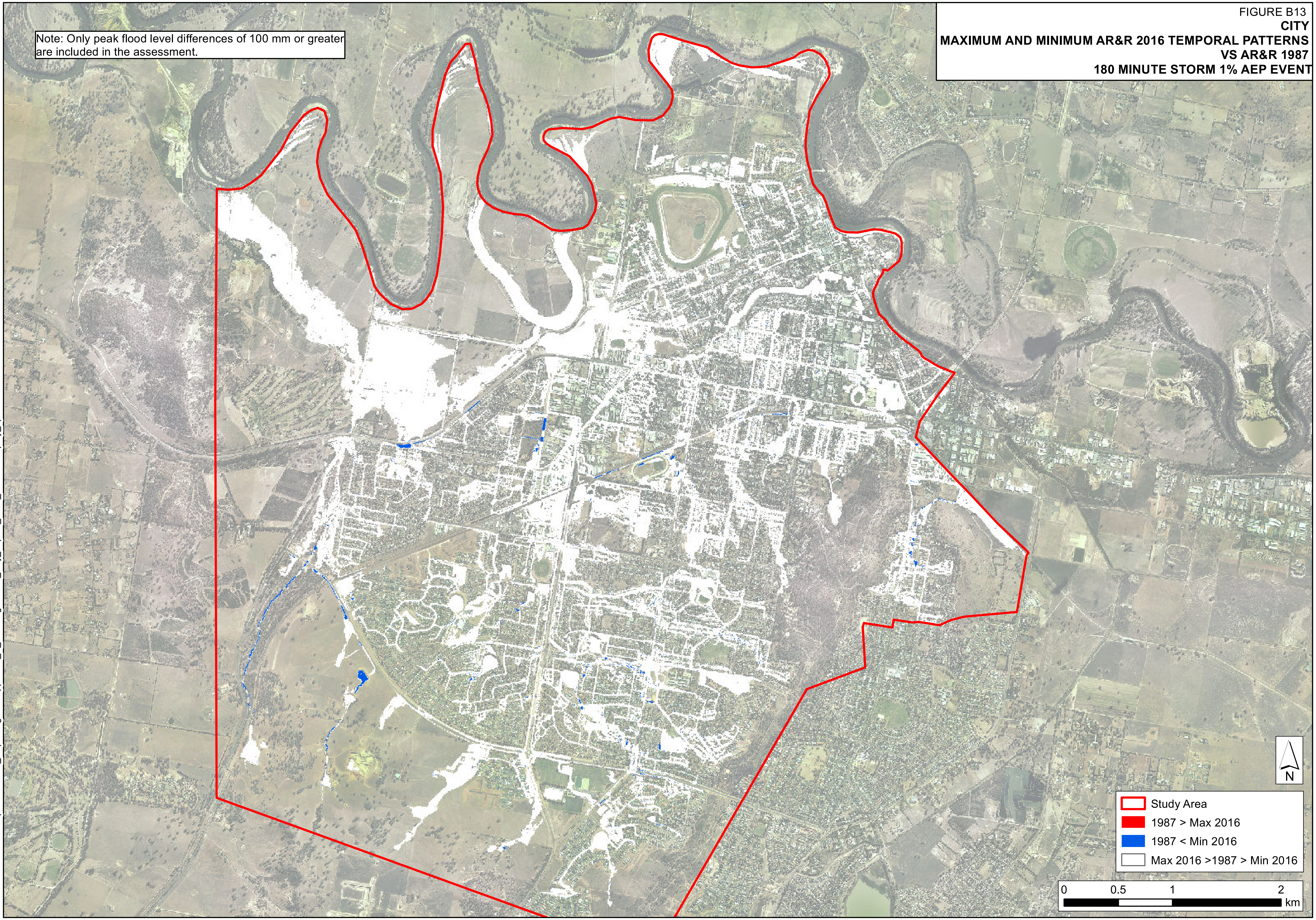


J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB11_I_020Y_LakeAlbert_ARR2016VARR1987_final.mxd

FIGURE B12
WAGGA NORTH MODEL
CHANGE IN PEAK FLOOD LEVEL
ARR2016 V ARR 1987
5% AEP EVENT



J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB12_I_020Y_North_ARR2016VARR1987.mxd



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Appendix C

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	147.344
Latitude	-35.126
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show

Data

River Region

Division	Murray-Darling Basin
River Number	12
River Name	Murrumbidgee River

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10} Duration\right) Duration^{-d} + e\, Area^{f} Duration^{g}\left(0.3 + \log_{10} AEP\right) + h\, 10^{i\frac{Area\, Duration}{1440}}\left(0.3 + \log_{10} AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \times 10^{-3} \times Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \times Area^{0.213} \times 10^{-0.021\frac{(Duration - 180)^{2}}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	30818.0
Storm Initial Losses (mm)	26.0
Storm Continuing Losses (mm/h)	4.7

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2016_v1

Temporal Patterns | Download (.zip) (http://arr-data-dev.wmawater.com.au/static/temporal_patterns/TP/MB.zip)

code	MB
Label	Murray Basin

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (http://arr-data-dev.wmawater.com.au/./static/temporal_patterns/Areal/Areal_MB.zip)

code	MB
arealabel	Murray Basin

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-35.126&longitude=147.344&sdmin=true&sdhr=true& to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	08 February 2019 02:46PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.7 (0.081)	1.5 (0.051)	1.4 (0.039)	1.2 (0.031)	0.8 (0.017)	0.5 (0.010)
90 (1.5)	2.5 (0.107)	1.7 (0.052)	1.1 (0.030)	0.6 (0.014)	0.6 (0.011)	0.6 (0.009)
120 (2.0)	4.3 (0.171)	3.2 (0.092)	2.5 (0.061)	1.8 (0.038)	0.8 (0.015)	0.1 (0.001)
180 (3.0)	3.1 (0.111)	3.1 (0.081)	3.1 (0.068)	3.1 (0.059)	1.8 (0.028)	0.8 (0.011)
360 (6.0)	2.0 (0.059)	1.1 (0.025)	0.6 (0.011)	0.1 (0.001)	1.3 (0.017)	2.2 (0.027)
720 (12.0)	0.0 (0.001)	0.8 (0.015)	1.4 (0.021)	1.9 (0.025)	2.8 (0.031)	3.4 (0.035)
1080 (18.0)	0.0 (0.000)	0.4 (0.006)	0.6 (0.009)	0.9 (0.011)	2.0 (0.021)	2.9 (0.027)
1440 (24.0)	0.0 (0.000)	0.1 (0.001)	0.1 (0.002)	0.2 (0.002)	0.5 (0.005)	0.8 (0.007)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.1 (0.004)	0.0 (0.001)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.1 (0.003)	0.0 (0.001)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	13.1 (0.644)	12.5 (0.438)	12.1 (0.353)	11.8 (0.294)	11.9 (0.249)	12.0 (0.222)
90 (1.5)	14.5 (0.630)	12.4 (0.385)	11.0 (0.285)	9.6 (0.215)	10.3 (0.194)	10.9 (0.181)
120 (2.0)	15.9 (0.637)	15.8 (0.456)	15.8 (0.381)	15.8 (0.327)	12.0 (0.210)	9.3 (0.144)
180 (3.0)	12.1 (0.436)	15.8 (0.410)	18.2 (0.396)	20.5 (0.385)	20.1 (0.318)	19.8 (0.278)
360 (6.0)	13.1 (0.389)	12.1 (0.263)	11.4 (0.210)	10.8 (0.171)	17.5 (0.234)	22.5 (0.269)
720 (12.0)	4.8 (0.120)	8.3 (0.152)	10.7 (0.165)	12.9 (0.172)	16.7 (0.189)	19.6 (0.198)
1080 (18.0)	2.4 (0.053)	5.7 (0.094)	7.9 (0.110)	10.0 (0.121)	11.9 (0.122)	13.3 (0.122)
1440 (24.0)	0.3 (0.007)	3.6 (0.055)	5.7 (0.074)	7.7 (0.088)	9.0 (0.086)	9.9 (0.085)
2160 (36.0)	0.0 (0.000)	0.8 (0.011)	1.3 (0.015)	1.8 (0.018)	3.2 (0.028)	4.2 (0.033)
2880 (48.0)	0.0 (0.000)	0.4 (0.005)	0.7 (0.007)	0.9 (0.009)	1.1 (0.009)	1.2 (0.009)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	33.2 (1.625)	28.1 (0.982)	24.8 (0.721)	21.6 (0.538)	29.2 (0.610)	34.9 (0.646)
90 (1.5)	33.2 (1.441)	30.8 (0.959)	29.3 (0.761)	27.8 (0.620)	29.9 (0.560)	31.5 (0.524)
120 (2.0)	37.5 (1.501)	35.3 (1.017)	33.9 (0.816)	32.5 (0.673)	32.1 (0.560)	31.9 (0.494)
180 (3.0)	24.3 (0.873)	29.3 (0.762)	32.7 (0.711)	35.9 (0.673)	40.1 (0.633)	43.2 (0.608)
360 (6.0)	25.5 (0.761)	27.1 (0.589)	28.1 (0.515)	29.0 (0.461)	43.3 (0.580)	54.0 (0.645)
720 (12.0)	15.1 (0.373)	23.9 (0.436)	29.7 (0.459)	35.3 (0.473)	36.5 (0.414)	37.4 (0.378)
1080 (18.0)	15.4 (0.341)	18.8 (0.310)	21.1 (0.294)	23.2 (0.281)	27.7 (0.285)	31.1 (0.285)
1440 (24.0)	7.5 (0.155)	14.4 (0.221)	19.0 (0.247)	23.3 (0.264)	23.7 (0.227)	24.0 (0.206)
2160 (36.0)	0.9 (0.018)	8.4 (0.117)	13.3 (0.158)	18.1 (0.186)	16.4 (0.143)	15.1 (0.118)
2880 (48.0)	0.7 (0.013)	7.0 (0.091)	11.1 (0.123)	15.1 (0.146)	17.6 (0.144)	19.5 (0.143)
4320 (72.0)	0.0 (0.000)	2.5 (0.030)	4.2 (0.043)	5.8 (0.051)	14.0 (0.106)	20.2 (0.137)

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.816 (4.1%)**	0.726 (3.6%)	**0.934 (4.7%)**
2040	**1.046 (5.2%)**	1.015 (5.1%)	**1.305 (6.6%)**
2050	**1.260 (6.3%)**	1.277 (6.4%)	**1.737 (8.8%)**
2060	**1.450 (7.3%)**	1.520 (7.7%)	**2.214 (11.4%)**
2070	**1.609 (8.2%)**	1.753 (8.9%)	**2.722 (14.2%)**
2080	**1.728 (8.8%)**	1.985 (10.2%)	**3.246 (17.2%)**
2090	**1.798 (9.2%)**	2.226 (11.5%)	**3.772 (20.2%)**

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	18.0	11.1	11.0	11.6	11.0	9.1
90 (1.5)	17.5	11.6	11.4	12.3	11.8	9.3
120 (2.0)	16.4	11.1	10.6	11.4	11.1	9.6
180 (3.0)	17.7	12.5	11.1	11.4	9.7	7.3
360 (6.0)	18.2	13.7	13.4	14.1	12.1	7.6
720 (12.0)	21.5	15.9	14.9	14.8	12.5	9.4
1080 (18.0)	22.2	17.4	16.6	17.1	14.6	9.6
1440 (24.0)	24.1	19.1	18.4	18.4	16.7	11.5
2160 (36.0)	25.7	21.1	20.6	21.1	19.2	15.8
2880 (48.0)	26.0	21.5	21.3	22.1	20.5	15.6
4320 (72.0)	26.6	22.4	23.0	23.5	21.5	15.2

Layer Info

Time Accessed	08 February 2019 02:46PM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Download TXT (downloads/5a913645-2e58-41f1-b895-fdc76320e8dc.txt)

Download JSON (downloads/033c8686-71a8-427c-9e2a-f67a6ff29b55.json)

Download PDF ()

Appendix D

Wagga Wagga Major Overland Flow Floodplain Risk Management Study & Plan

Once complete, the Wagga Wagga Major Overland Flow Floodplain Risk Management Study & Plan will contain flood mitigation options for overland flooding in Wagga Wagga. Council will seek to implement the recommendations in the study and plan by applying for funding through the NSW Government's Flood Risk Management Program.

What is overland flow flooding?

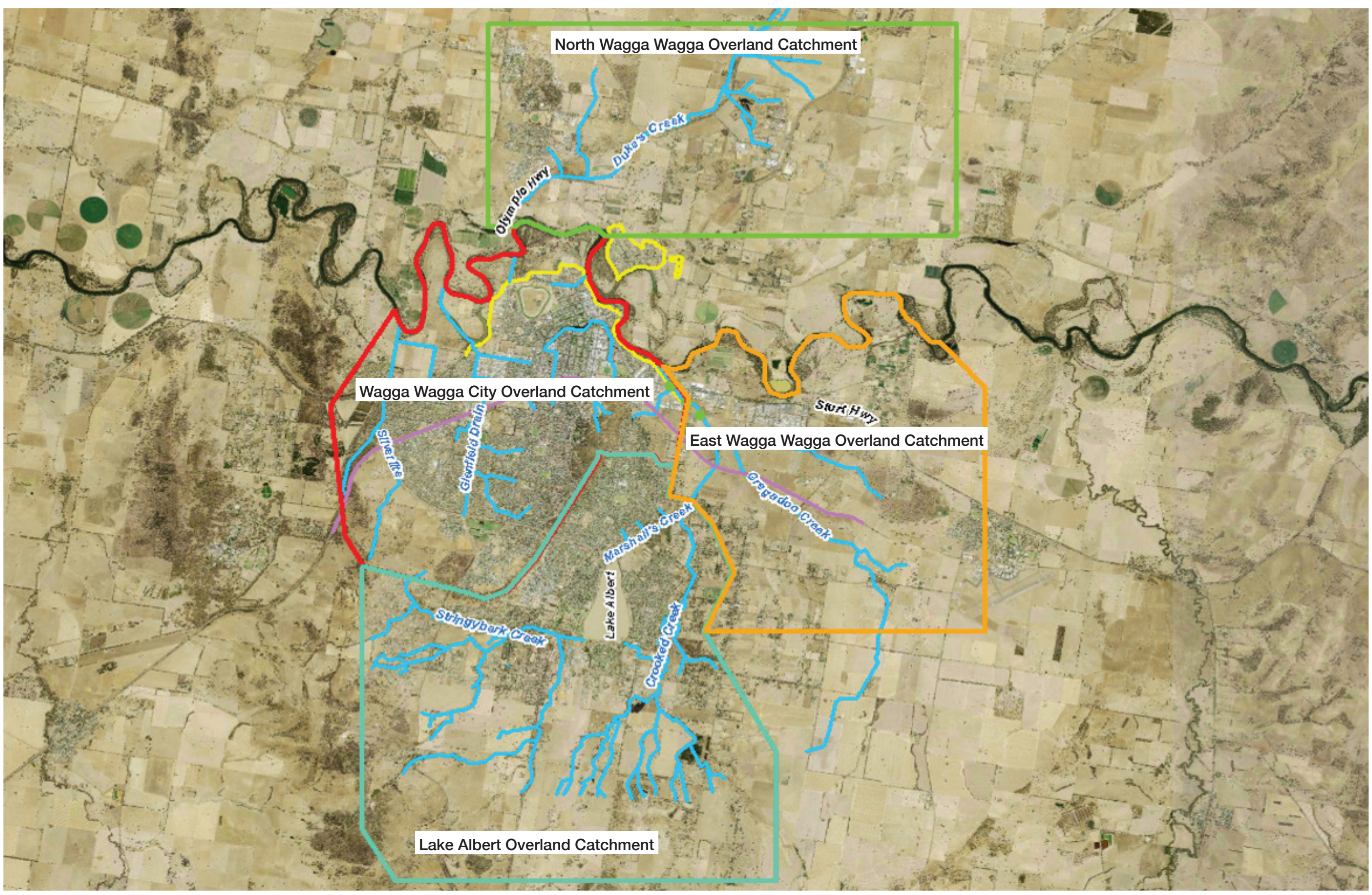
Overland flow flooding is caused by excess rainfall that leads to local runoff. It is different to riverine flooding, such as that from the Murrumbidgee River. However, elevated levels in the Murrumbidgee River can exacerbate overland flooding if the flood gates are shut at the same time as a significant localised rainfall event. This scenario occurred in December 2010 when water levels raised dramatically in the CBD after the flood gates were shut.

Where does overland flooding occur in Wagga Wagga?

Overland flooding due to local rainfall runoff occurs in several locations throughout the Wagga Wagga Local Government Area. The Wagga Wagga Major Overland Flow Floodplain Risk Management Study & Plan looks at overland catchments in East Wagga, North Wagga, Wagga Wagga City and Lake Albert (see map below). Overland flooding in villages will be subject to a separate study and plan.

The Wagga Wagga Major Overland Flood Flow Study identified hotspots at the following locations:

- Flowerdale Storage Area
- Chaston Street
- Hakea Place
- Crooked Creek
- Jones Street
- Brunskill Road
- Glenfield Basins
- South Wollundry Lagoon
- Bolton Park
- Plumpton Road
- Ashmont Reserve



City of Wagga Wagga

Flood Futures

What is Council doing about overland flooding?

AUGUST 2011

Wagga Wagga Major Overland Flow Flood Study received by Wagga Wagga City Council.

2013/14

Pump 15A on Tarcutta Street upgraded to increase the amount of water that can be pumped from the Wollundry Lagoon to the Murrumbidgee River in the event that the flood gates are shut.

NOVEMBER 2015

Modelling updates completed following the inclusion of additional surveyed hydraulic structures. This resulted in revised flows and levels for design events including the 1 in 100 Annual Exceedance Probability (AEP) event.

NOW

Wagga Wagga Major Overland Flow Floodplain Risk Management Study & Plan is currently being developed.

NEXT

Once the study and plan is adopted Council will seek to implement the recommendations by applying for funding from the NSW Government's Flood Risk Management Program.

Have your say

Help Council identify problem areas and solutions by completing the online questionnaire at wagga.nsw.gov.au/floodfutures before Friday 29 June 2018.

Alternatively you can pick up a hard copy at the Civic Centre Customer Service desk or request one by calling 1300 292 442.

Examples of flood mitigation options

The following options options may be considered in the study:

1. FLOOD MODIFICATION

Modify the physical behaviour of a flood itself.

- Culverts and bridges: allow water to flow under roads, train tracks or similar obstructions.
- Levees: used to exclude flood water from flood prone areas. Levees are often constructed from earth embankments, concrete walls or sheet piles.
- Drains and channels: increase the rate at which water is removed from a flood affected area.
- Vegetation Management Schemes: aims to ensure that flood behaviour is not worsened over time by increased riparian roughness due to increased vegetation density.
- Pit and pipe upgrades: assessing the existing capacity of the stormwater infrastructure (stormwater pits and pipes) and investigate upgrades where necessary.
- Retarding or detention 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.

2. PROPERTY MODIFICATION

Modify existing properties (for example house raising or flood proofing) and/or applying flood related development controls on property and infrastructure development.

- Flood proofing: often divided into two categories; wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damages and/or reduce recovery times by choice of materials which are resistant to flood waters and facilitates drainage and ventilation after flooding. Dry proofing aims to totally exclude flood waters from entering a building and is best incorporated into a structure at the construction phase.
- Planning and Development Controls: can include improvements to the Local Environment Plan and Development Control Plan and can help reduce risk to residents, existing and new developments across the wider floodplain.
- Voluntary purchase and voluntary house raising in appropriate areas

3. RESPONSE MODIFICATION

Modify the response of the population at risk to better cope with a flood event.

- Flood warning system: aims to provide advice on impending flooding so people can take action to minimise its negative impacts.
- Evacuation plans for homes and communities, can include improving evacuation routes
- Improved information, awareness and education of the community
- Flood intelligence (SES, Council)

City of Wagga Wagga

Flood Futures

QUESTIONNAIRE

Wagga Wagga Major Overland Flow Floodplain Risk Management Study & Plan

Once complete the Wagga Wagga Major Overland Flow Floodplain Risk Management Study & Plan will contain flood mitigation options for overland flooding in Wagga Wagga. Council will seek to implement the recommendations in the study and plan by applying for funding through the NSW Government's Flood Risk Management Program. Please note flooding from the Murrumbidgee River is subject to a separate Study & Plan, this document will address local catchment flooding caused by excess rainfall that leads to local runoff.

You can help Council identify problem areas and solutions by reading through the attached fact sheet and returning this completed questionnaire before Friday 29 June 2018.

You can also complete this questionnaire online at wagga.nsw.gov.au/floodfutures

For more information please call 1300 292 442 or email floodfutures@wagga.nsw.gov.au

Your details

All personal details will be held confidential. Please note your email and telephone details are optional and will only be used to contact you, with your permission, for more information regarding this study.

Name:

Address/Suburb:

Email:

Phone:

How long have you lived in this area (years + months)?

Can we contact you for more information? ☐ Yes ☐ No

If yes, please indicate preferred contact method: ☐ Phone ☐ Email

Reducing flood risk

Do you think something should be done to reduce flood risk in Wagga Wagga due to local catchment rainfall?

☐ Yes ☐ No

If yes, please describe the location/s where you think flood risk should be considered. Please name the nearest street and cross street and other useful information to identify the location of flood risk, and type of problem that occurs.

Flood Futures

As a local resident who may have witnessed flooding, you may have your own ideas about how to reduce overland flow flood risks. Please assess each potential option below and rate its suitability for Wagga Wagga's overland flood flow catchment. See more information on each option in the attached fact sheet.

Please tick (✓) your rating for each option

FLOOD MODIFICATION: **Modify the physical behaviour of a flood itself**	Not at all suitable	Somewhat unsuitable	Somewhat suitable	Very suitable
Culverts and bridges				
Levees				
Drains and channels				
Vegetation Management Schemes				
Pit and pipe upgrades				
Retarding or detention basins				

Thinking about the above options you consider suitable, where do you think they would work best?

PROPERTY MODIFICATION: **Modify existing properties and/or applying flood related development controls on property and infrastructure development.**	Not at all suitable	Somewhat unsuitable	Somewhat suitable	Very suitable
Flood proofing				
Planning and Development Controls				
Voluntary purchase in high hazard areas				
Voluntary house raising in appropriate areas				

Thinking about the above options you consider suitable, where do you think they would work best?

RESPONSE MODIFICATION: **Modify the response of the population at risk to better cope with a flood event**	Not at all suitable	Somewhat unsuitable	Somewhat suitable	Very suitable
Flood warning systems				
Evacuation plans for homes and communities				
Improved information, awareness and education of the community				
Flood intelligence (SES, Council)				

Thinking about the above options you consider suitable, where do you think they would work best?

Please return this survey before Friday 29 June 2018.

Scan and email:
floodfutures@wagga.nsw.gov.au

Post:
PO Box 20, Wagga Wagga NSW 2650

Deliver:
Customer Service Desk
Civic Centre,
cnr Morrow Street and Baylis St

Appendix E

APPENDIX E. FREEBOARD ASSESSMENT

PAGE

LIST OF FIGURES

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;
- Wave action;
- 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 areas of Wagga Wagga subject to overland flow. 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.

The assessment found that the minimum appropriate freeboard for flood planning levels for properties affected by overland flow, a freeboard of 0.3 m (above the 1% AEP level) is appropriate.

Table 1 Wagga Wagga Major Overland Flow Freeboard Assessment Results

Component	Allowance (m)	Probability	Final Component (m)
Uncertainties in Estimated Flood Levels	0.15	1	0.15
Local Water Surge	0.10	0.5	0.05
Wave Action	0.02	0.5	0.01
Climate Change	0.10	1	0.1
Total Freeboard Allowance			**0.3**

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 appendix identifies and subsequently quantifies the various components making up freeboard as they apply to flood planning levels.

E.2.1. Uncertainties in Estimated Flood Levels

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.

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 comparison of peak flood level results derived from using ARR 1987 and ARR 2019 methodologies (provided in Report 01, Appendix B), provides insight into the sensitivity of flood level results to model inputs, particularly design rainfall depths and infiltration losses. The resulting average variation in peak flood level is applied as the appropriate freeboard component.

A value of 0.15 m has been assigned to uncertainties in estimated flood levels.

E.2.2. Local Water Surge

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.

Examples of local surge

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 (as a proxy for say, a truck driving through floodwater) were considered as part of the sensitivity analysis undertaken in this freeboard assessment, and this level of sensitivity has been used to derive the freeboard component related to local surge. The sensitivity assessment considered two scenarios: the application of a blockage factor of 50% to all stormwater pipes (Figure E1) and the application of a blockage factor of 50% to all stormwater pit inlets within the Study Area (Figure E2 and Figure E3). The City and Lake Albert model domains were used as representative areas for the assessment.

A comparison of results in the blockage case and the design case indicated that peak overland flow flood levels in Wagga Wagga are most sensitive to blockage at the railway culvert (Glenfield Drain), where flood levels increase locally by over 500 mm (in a 1% AEP event) on the upstream side of the structure on both sides of Glenfield Road. Generally however, along major flow paths across the city, peak flood levels generally increase by up to 0.1 m in the vicinity of partially blocked hydraulic structures.

A freeboard component of 0.1 m is considered appropriate for overland flow affected areas in Wagga Wagga.

E.2.3. Wave Action

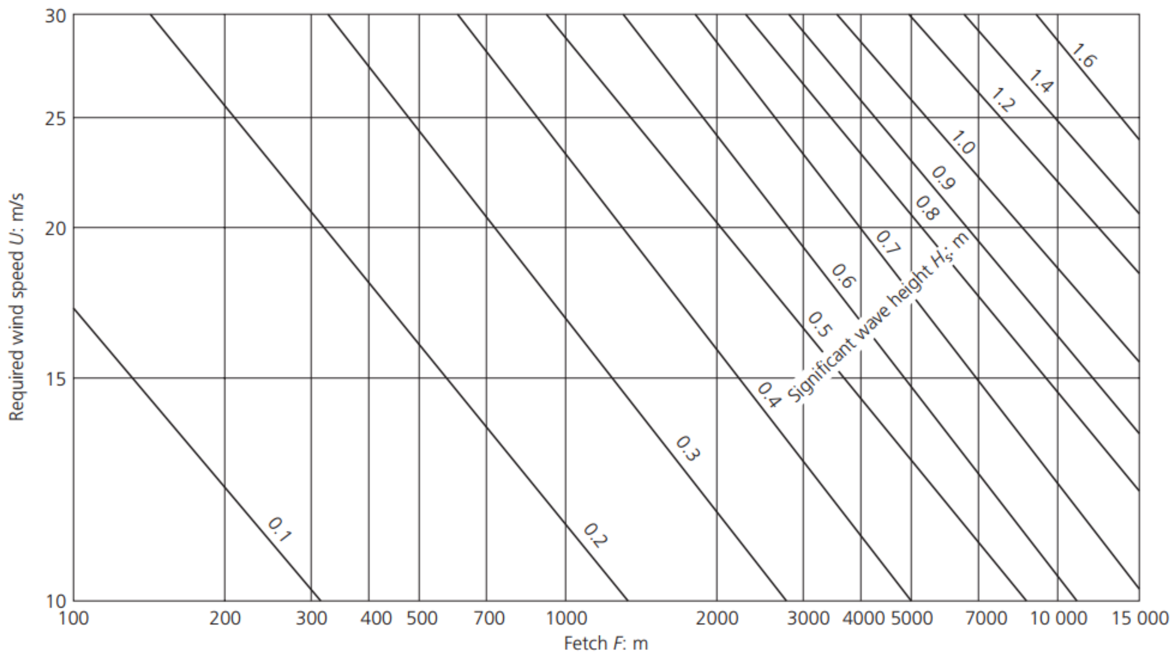
Increases in water level as a result of wave action are not determined in flood modelling. Design wave actions are a product of:

- 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.2.3.1. Component Determination

Wind-induced waves are important to consider where floodplains are expansive, with large stretches of open water (such as the Murrumbidgee River), where high windspeeds can generate significant surface waves. In such floodplains, the freeboard component associated with wave setup can be determined using the relationship between fetch and windspeed. Fetch can be measured from modelled flood behaviour, and directional windspeed can be determined based on data from the Bureau of Meteorology. These elements can be used in conjunction with the chart presented in Diagram 1, taken from Reference 4, to determine the Significant Wave Height, which is applied as the freeboard allowance for Wave Action.

Diagram 1 Simplified relationship between fetch length, wind speed and significant wave height (Reference 4)



While the fetch across Lake Albert could reach up to approximately 1.8 km (measuring north to south), this distance is not considered representative of typical overland flow behaviour in the Wagga Wagga. In addition, the area immediately adjacent to the shores of Lake Albert is not zoned for residential development, and Flood Planning Levels for residential development are unlikely to be applied in this area. More commonly rather, dense urbanisation throughout Wagga Wagga significantly limits the fetches that occurs due to overland flow, often to less than 10 m, and constrained to roadways or open drains. Therefore, it is not considered appropriate to apply the fetch-windspeed relationship shown in Diagram 1 in the overland flow-affected areas of Wagga Wagga. Rather, a nominal freeboard allowance of 0.02 m has been to account for minor variations in estimated flood levels due to wind induced wave actions.

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 and planning controls, 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.

The potential impacts of climate change are approximated by comparing the 0.5% and 0.2% AEP events with the 1% AEP event. These events are commonly used as proxies to assess an increase in rainfall intensity, and the sensitivity of model results to this increase. Within the Study Area, these events correspond to an increase in rainfall intensity of approximately 11% for the 0.5% AEP event and 22% for the 0.2% AEP event, compared to the 1% AEP event. Comparisons of peak flood levels is provided on Figure E4 to Figure E7 and indicates that on average, peak flood levels are approximately 0.05 m higher in the 0.5% AEP (compared to the 1% AEP event), and up to 0.3 m higher in the 0.2% AEP event (compared to the 1% AEP event). An allowance of 0.1 m is therefore considered appropriate for the climate change component of the total freeboard allowance.

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.

Table 2 Joint Probability Factors

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 Picton. 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 3.

Table 3 Wagga Wagga Major Overland Flow Freeboard Assessment Results

Component	Allowance (m)	Probability	Final Component (m)
Uncertainties in Estimated Flood Levels	0.15	1	0.15
Local Water Surge	0.10	0.5	0.05
Wave Action	0.02	0.5	0.01
Climate Change	0.10	1	0.10
Total Freeboard Allowance			**0.3**

Considering the above factors and likelihood of concurrence, a minimum freeboard of 0.3 m is deemed appropriate for Flood Planning Levels in areas of Wagga Wagga subject to mainstream flooding, and 0.3 m for overland flow affected areas.

The appropriate Flood Planning Levels (FPLs) for residential development in Wagga Wagga are therefore:

- Mainstream: 1% AEP level plus 0.5 m freeboard (Reference 3);
- Overland Flow: 1% AEP level plus 0.3 m freeboard.

The adoption of two separate Flood Planning Level freeboard allowances for mainstream and overland flow flood mechanisms, and more specifically, selection of a freeboard of 0.3 m for overland areas, is not without precedent in New South Wales. A number of towns, including for example, Boorowa, Condobolin, Crookwell, Gunning, Collector and Taralga have taken this approach via their respective Floodplain Risk Management Studies (References 6 and 7). This differentiation allows flood related development controls, particularly minimum floor level requirements, to be applied where they are warranted by the type of flood behaviour and degree of flood risk. Flood planning level requirements would be imposed on future development (and re-development) of properties within the Flood Planning Area. The Flood Planning Area and recommendations for flood related development controls are described in Section 3 of Report 03, to which this Appendix is appended.

E.5. REFERENCES

1. NSW Government
Floodplain Development Manual
April 2005

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Floodplain Risk Management Guideline – Residential Flood Damages
NSW State Government, October 2007

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Revised Murrumbidgee River at Wagga Wagga Floodplain Risk Management Study and Plan
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5. NSW Department of Public Works
Wagga Wagga Levee Upgrade – Flood Freeboard
Report No. DC 10096
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6. Lyalls and Associates
Boorowa Floodplain Risk Management Study and Plan
Hilltops Council, March 2018

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The Villages of Crookwell, Gunning, Collector and Taralga Floodplain Risk Management Study and Draft Plan
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