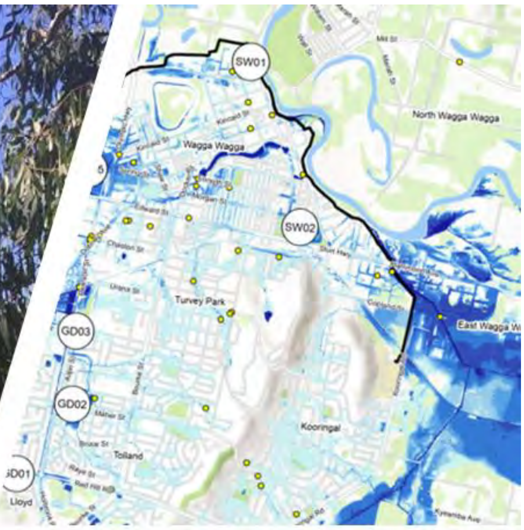
WAGGA WAGGA CITY COUNCIL

WAGGA WAGGA MAJOR OVERLAND FLOW FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL



MAY 2021

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Project Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan	**Project Number** **117047**
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Revision/Report	Description	Distribution	Date
Final	Final	WWCC, DPIE	May 2021
PE	Draft for Public Exhibition	WWCC, DPIE	Feb 2021
05	Lake Albert Enhanced Flow and Flood Modification Options	WWCC, DPIE	Mar 2020
04	Flood Emergency Response	WWCC, DPIE	Dec 2019
03	Planning Policy Review	WWCC, DPIE	Sep 2019
02	Flood Damages Assessment	WWCC, DPIE	Apr 2019
01	Draft Report (Revised ARR 2019 Guidance)	WWCC, DPIE	Apr 2019
A	Draft Report	WWCC, DPIE	Jan 2019

EXECUTIVE SUMMARY

The Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan (FRMS&P), which follows on from the Wagga Wagga Major Overland Flow Model Update Report (Reference 6), has been undertaken in accordance with the NSW Government's Flood Prone Land Policy. This study provides recommendations for reducing flood risk due to overland flooding in Wagga Wagga. This was first identified in 2011 through the Wagga Wagga Major Overland Flow Flood Study (Reference 4) which developed a model that has been thoroughly reviewed and revised in accordance with best practice in the interim.

In this study, a full assessment of the existing flood risk in the catchment has been carried out, including flood hazard across the study area, over floor flooding of residential, commercial, and industrial properties, identification of known flooding issues and hotspots, and emergency response during a flood event. Various measures aimed at managing this flood risk were assessed for their efficacy across a range of criteria. The options were rated according to a detailed matrix of possible impacts. Those rated highest have been recommended in the Floodplain Risk Management Plan, and prioritised based upon how readily the management measures can be implemented, their capital cost, what constraints exist and how effective the measures are. Measures with little cost that can readily be implemented, and which are effective in reducing damage or personal danger would have high priority.

Flood Prone Land Policy Framework

The NSW Government Flood Prone Land Policy supported by the Floodplain Development Manual provides a framework for the assessment and management of flood risk across the state. Specifically, the Floodplain Development Manual guides Councils in the development and implementation of detailed local floodplain risk management plans in order to plan for and manage flood risk. The Floodplain Development Manual outlines the process and the roles and responsibilities of the various stakeholders involved in the process.

Council (both elected members and Council staff) are primarily responsible for managing flood prone land through the implementation of floodplain risk management strategies. The Floodplain Risk Management Advisory Committee assists Council in the development and implementation of these strategies by providing a forum for discussion of the differing viewpoints within the study area, identifying management options and considering and making recommendations to Council on appropriate measures and controls with the primary objective of achieving a beneficial but equitable result for the study area. The committee is the driving force behind the study and may be required to vote to determine the majority opinion if consensus cannot be reached.

State Government agencies provide funding and technical support to assist Council and the committee in developing a robust Floodplain Risk Management Plan. In most cases a specialist consultant is engaged by Council to undertake the required technical investigations and assessment. The committee directs the consultant through this investigation and receives this information from the consultants to assist with their deliberations.

WMAwater has undertaken the investigation and assessment for this Wagga Wagga Major Overland Flow FRMS under the guidance and direction of the Floodplain Risk Management Advisory Committee and developed the Wagga Wagga Major Overland Flow FRMP.

Background

The area considered in the Wagga Wagga Major Overland Flow Floodplain Risk Management Study incorporates catchments with an area of 233 km² and a hydraulic modelling extent of 167 km² both south and north of the Murrumbidgee River as shown in Figure 1.1 and Figure 1.2. The City of Wagga Wagga is the largest inland city in NSW and is the regional centre of the Riverina district. The City is the regional focus for major commercial, retail and business centre activities, with many secondary and service industries supporting primary industry.

Land Use Types in the study area vary considerably with East Wagga largely characterised by General and Light Industrial with areas of Large Lot Residential or Primary Production. The City domain is largely General Residential, and Commercial Core/Business Development. The Lake Albert domain is similar, with large areas of Large Lot Residential with general residential and industrial areas typically fund in the Wagga North domain.

Existing Flood Environment

Overland flow flood behaviour typically occurs as when the capacity, of the local drainage and the smaller creek systems flowing into the Murrumbidgee, is exceeded. The system has an estimated capacity of less than a 5 year ARI (0.2EY). The system and the capacity of the overland flow routes has been tested with recent rainfall events such as 2010, this was a particularly challenging event as it coincided with a riverine flood event hindering drainage of these local systems.

The updated hydraulic models were run for the 0.2 EY, 10%, 2%, 1% and 0.5% and 0.2% AEP events as well as the PMF using the ARR 2019 methodologies.

Economic Impact of Flooding

A flood damages assessment was carried out for the inundation of residential and commercial properties in the study area. The internal damages assessment was based on surveyed and estimated floor levels. The assessment identified 1962 properties impacted by flooding over floor and 12,934 properties impacted externally across the Study Area. The annual average damages for residential and commercial/industrial properties was found to be $16.09M. This represents the average cost of flooding each year.

Flood Risk Management Options

This Floodplain Risk Management Study process under the direction of the Floodplain Risk Management Advisory Committee has identified and assessed a range of risk management measures that would help mitigate flooding to reduce existing and future flood damages. The options were assessed using a multicriteria analysis, which considered not only flood impacts, but also construction feasibility, economic merits and the alleviation or exacerbation of property damages, risk to life and pressure on the SES.

These measures have been grouped into the following general categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity) by undertaking structural works in particular areas of the floodplain. Among the flood modification options considered are upgrades to the stormwaters lines, and retarding or detention basins.

Property modification measures modify the existing land use or buildings as well as development controls for future development. These measures primarily involve updating policies and regulations which relate to development on the floodplain. Property modification measures including Voluntary Purchase and Voluntary House Raising were assessed, as well as a broad range of planning measures that aim to reduce flood risk to life, to proposed development and to the wider floodplain.

Response modification measures are aimed at changing and enhancing the community's response to the potential hazards of flooding. This is achieved by educating the property owners and the wider community about flooding, its behaviour and potential damages, so that they can make better informed decisions. The response modification measures considered in this FRMS are generally to 'continue and improve' Wagga Wagga's current flood emergency management systems and practices including improvements to driver safety.

Recommended Options

The outcomes of the analysis undertaken in this Floodplain Risk Management Study are presented in this report and from that information the Floodplain Risk Management Advisory Committee has made recommendations which include property modification (for example, planning controls), flood modification (for example, drainage improvements) and response modification (for example, community education, flood emergency management planning), and are detailed in Table 1 overleaf. The Final Draft Floodplain Risk Management Study and Plan was placed on public exhibition to allow the broader community and stakeholders to provide feedback on the recommendations. The Floodplain Risk Management Advisory Committee considered the submissions received, and made any appropriate changes before finalisation and adoption of the Floodplain Risk Management Plan by Council.

Table 1: Wagga Wagga Major Overland Flow Floodplain Risk Management Plan

HIGH PRIORITY										
Option ID	**Type**	**Option**	**Description**	**Benefits**	**Concerns**	**Responsibility**	**Funding**	**Cost**	**B/C Ratio**	**Priority**
RM01	Response Measure	Amend Flood Plans to include Overland Flow Flood Information	Amend local flood plans and operational plans to include information on flood risk due to overland flow, drawing on modelling and information provided in this FRMS&P	Detailed information will allow for better management of overland flow flood risk and will increase understanding of the different levels and types of risk present in Wagga Wagga.	Modelled results should be used as a guide only, as real flood behaviour may vary from modelled design results.	SES	SES	In house	N/A	High
RM04	Response Measure	Community Flood Awareness	Establish and implement ongoing and collaborative education to improve flood awareness.	Flood awareness significantly improves preparedness for and recovery from flood events, building a more flood resilient community.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	Council in collaboration with other response agencies and community organisations.	Council	Annual Budget to be determined and allocated.	N/A	High
RM05	Response Measure	Improvements to Driver Safety	Undertake an investigation using the outputs from the FRMS&P to identify locations for the installation of road flood signage.	The installation of appropriate road signage pointing to routes likely to be cut and alternate routes, reduces the risk to drivers during floods, reducing the number of incidences of motorists driving through floodwater. Could potentially reduce demand on SES with a reduced number of incidents.	Community attitudes, awareness of, and behaviour during overland flood events will need to be considered. Signage needs to be as automated as possible to reduce additional demand on Council resources.	Council	Council/ TfNSW	In house	N/A	High
P01	Property	Adoption of Overland Flow Flood Planning Area	Adopt the Overland Flow Flood Planning Area developed in the FRMS&P.	FPLs are effective tools to limit property damage to new development and redevelopment. FPLs may pertain to minimum floor levels or flood proofing levels depending on the type of development.	A planning proposal is required to amend the LEP and implement the new FPL. May be considered more onerous for developers.	Council	Council	In house	N/A	High
P02	Property	Adoption of Overland Flow Flood Planning Level	Adopt the Overland Flow (Residential) Flood Planning Level developed in the FRMS&P defined as the 1% AEP level plus 0.3 m freeboard. Modify the Wagga Wagga LEP to contain the definition consistent with Reference 7.	The FPA will provide clear guidance on the properties subject to flood related development controls.	A planning proposal is required to amend the LEP and implement the new FPA definition. Consultation would be required.	Council	Council	In house	N/A	High
P05	Property	Appropriate Land Use Zoning in Future Development Areas	For areas not covered by existing flood mapping, undertake a flood investigation to develop flood mapping and allow for an appropriate assessment of flood risk. Ensure Planning Proposals for the rezoning of future growth areas are undertaken with due consideration of flood risk using information available to Council through its various Floodplain Risk Management Studies and Plans. If no flood information is available, consideration should be given to undertaking further analysis prior to determining land use zoning for future development areas. Ensure Development Planning Controls are implemented to manage development in areas of new growth in relation to flooding. This may include, for example, guidelines relating to the permissible proportion of impervious surfaces in areas of new development.	Considering flood risk in future development areas will allow early decisions to be made to reduce flood risk and minimise the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous or likely to reduce the development yield.	Council	Council	In house	N/A	High
P07	Property	Appropriate Management of areas subject to both riverine and overland flow flood risk.	Proposed development is to be assessed (and designed) with due consideration of the full range of flood risk present at the site, i.e., riverine, overland flow, or both mechanisms. For residential development both Riverine and Overland Flow FPAs are to be considered, while critical utilities or vulnerable facilities may warrant consideration of the PMF for either or both flood mechanisms, particularly when considering Flood Planning Levels, evacuation constraints and other methods to manage the full range of flood risk.	Considering flood risk from all mechanisms will ensure development is appropriate given the prevailing risk, minimising flood risk and the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous.	Council	Council	In house	N/A	High
P08	Property	Confirm suitability of riverine flood related development controls within the overland flow PMF extent.	Controls to reduce riverine flood risk (e.g. by filling above a particular level) may inadvertently exacerbate the flood risk due to overland flow. It is recommended that Council's flood related development controls are assessed for their suitability in relation to overland flow flood information provided in this Study.	Considering flood risk from all mechanisms will ensure development is appropriate given the prevailing risk, and ensuring impacts are not worsened by controls to protect against one mechanism.	Individual consideration may be required.	Council	Council	In house	N/A	High

HIGH PRIORITY										
Option ID	**Type**	**Option**	**Description**	**Benefits**	**Concerns**	**Responsibility**	**Funding**	**Cost**	**B/C Ratio**	**Priority**
P09	Property	Inclusion of Overland Flow flood information on Section 10.7 Planning Certificates	In Section 10.7 Planning Certificates, notations regarding flooding should provide information on all mechanisms of flood risk at the site, including riverine, overland flow, or if appropriate, both. A greater level of detail can be provided via Section 10.7(5) certificates using high-resolution outputs from this Study and Council's other Floodplain Risk Management Studies.	The more informed a home owner is, the greater the understanding of their flood risk. During a flood event this information can help prepare residents to evacuate and reduces the number of residents that elect to take shelter in high hazard areas.	Limited - s10.7(2) certificates already contain basic information, Council to provide further detail from current FRMS&P results. May increase demand on Council staff, however GIS systems can be established to provide this information efficiently.	Council	Council	In house	N/A	High
GD01 (Glenfield Drain)	Flood	Red Hill Road and Glenfield Road Basin (further investigation)	Aim: To reduce peak flows entering Glenfield Drain by temporarily storing runoff and releasing it at a lower flow rate; • Involves augmentation of the existing retarding basin south of Red Hill Road by excavating approximately 5,000 m^3, and building up the existing Red Hill Road/ Glenfield Road intersection to raise the basin embankment, resulting in a total capacity of approximately 5.1 ML; Low spots in the existing embankment north east of the roundabout were filled	Reduced flood levels on and adjacent to Glenfield Road up to the railway in the 1% AEP event, including properties no longer flooded on the eastern side of Glenfield Road.	Increased flood depths upstream of the embankments, both in the designated basin southwest of the intersection, as well as the downstream parts of Jubilee Park. Public safety considerations due to prolonged ponding in roadside basin.	Council	May be eligible for NSW Government funding	$1,000,000	<0.5	High
GD02 (Glenfield Drain)	Flood	Adjin Street & Maher Street Intersection Civil Works (further investigation)	Suite of civil works intended to reduce inundation of properties and roads between Maher Street and Glenfield Road.	Removes external flood affectation for 47 properties and over-floor flooding for 4 dwellings in the 1% AEP event. Significant reductions in flood levels east of Glenfield Road.	Minor increase in flood levels in the industrial properties and vacant land upstream of the railway.	Council	May be eligible for NSW Government funding	$800,000	>1.5	High
GD03 (Glenfield Drain)	Flood	Anderson Oval Basin and Swale Augmentation (further investigation)	Aim: Increase flood storage capacity at Anderson Oval to reduce flooding on Finch Place and to reduce (and delay) peak inflows from entering Glenfield Drain; • Increase existing embankment height around Anderson Oval from 1 m to 2.25 m; • A spillway is provided in the north western section of the basin, set 0.25 m lower than the remainder of the embankment; A swale was excavated to allow runoff from Finch Place to flow towards Fernleigh Road rather than back up behind the basin embankment.	The extent of reductions in flood levels is significant and can be observed up to the northern extent of the City model. Effective in reducing peak flood levels across a range of events.	Public safety concerns as a significant depth (> 1 m) would be ponded within the playing field in a 5% AEP event. Reduction in amenity and usability of the oval following rain events.	Council	May be eligible for NSW Government funding	$510,000	>1.4	High
GD05 (Glenfield Drain)	Flood	Flowerdale Lagoon Drainage Improvements	Aim: Improve drainage of the Flowerdale Storage Area by installing an additional major levee pipe between Floodgates 01 and 02 (Flowerdale Lagoon and Wiradjuri Reserve); The installation of three 1.8 m diameter levee pipes has been tested near the Wiradjuri Walking Track, between Flood Gates 1 and 2.	Significant flood level reductions along Spring Street and the Olympic Highway up to Evans Street and Shaw Street (up to 0.42 m). Similar reductions can be seen along Pearson Street (up to 0.38 m). Major flood level reductions observed on the vacant land between the lagoon and the Olympic Highway (up to 0.66 m); Minimal works required.	Construction at this location would interfere with the Main City Levee Spillway. Potential for constraints relating to cultural and heritage values of Flowerdale Lagoon.	Council	May be eligible for NSW Government funding	Variable	Likely >1	High
SW01	Flood	Incarnie Crescent Stormwater Line	Aim: Reduce flood levels along Incarnie Crescent; Connect existing drainage line along Incarnie Crescent via a new 525 mm pipe to the trunk drainage line east towards the river.	Peak flood level reductions can be observed from Incarnie Cres all the way west to the Wiradjuri Walking Track. No increases in flood level can be seen. Scope of work is not extensive.	Incarnie Crescent will require closure while works are underway.	Council	Council	$500,000	>1.5	High
LA01 (Lake Albert)	Flood	Raising Lake Albert Road	Raise Lake Albert Road at the north east corner of Lake Albert by approximately 1 m-1.5 m over a length of 450 m, and Lakeside Drive by approximately 1 m for 200 m from its intersection with Lake Albert Road. Increase airspace in Lake Albert to provide storage capacity during flood events; Involves reducing the Lake Albert outlet capacity by approximately 50% to limit peak outflows. To be undertaken in conjunction with LA02 and LA03	Reduces peak flood levels downstream of Lake Albert in the 1% AEP by up to 0.47 m immediately downstream of the road, and to a lesser degree across the East Wagga commercial area. Minor increase in surface area of Lake Albert due to relatively gently sloping banks;	Increases flood levels by up to 0.45 m in the 1% AEP event in Lake Albert. Potential adverse impacts to properties at southern end of the Lake. Lake Albert Road will require closure while works are underway.	Council	May be eligible for NSW Government funding	$1,900,000	0.23 (Combined 0.9)	High

LA02 (Lake Albert)	Flood	Augmentation of Crooked Creek Diversion into Lake Albert	Increase capacity of the existing Crooked Creek diversion south of Craft Street, to reduce flood risk further north by diverting flows into Lake Albert; Construct a 1 m high diversion embankment along Craft Street to assist in function of the Crooked Creek diversion channel and provide protection to residences north of Craft Street. To be undertaken in conjunction with LA01 and LA03	The extent of reductions in flood levels is significant and can be observed from Craft Street through to East Wagga along the Crooked Creek system.	Environmental factors including retention of 'low flow' through the original creek channel. Erosion, scouring and sedimentation concerns will need to be considered in the design of widened channels. Potential loss of habitat. Acquisition of privately owned land adjacent to the creek may be necessary depending on preferred channel width.	Council	May be eligible for NSW Government funding	$500,000	0.9 (Combined 0.9)	High
LA03 (Lake Albert)	Flood	Augmentation of Stringybark Creek Diversion into Lake Albert	Increase capacity of the Stringybark Creek diversion south of Nelson Drive and reduce flood risk along Plumpton Road and further downstream by diverting flows into Lake Albert; Construct a diversion embankment 1 m high, parallel to Nelson Drive;	Reductions in peak flood levels observed from Nelson Drive through to East Wagga. Reductions in over-road inundation, particularly Plumpton Road;	Environmental factors including retention of 'low flow' through the original creek channel. Erosion, scouring and sedimentation concerns will need to be considered in design of widened channels. Acquisition of privately owned land adjacent to the creek may be necessary depending on preferred channel width.	Council	May be eligible for NSW Government funding	$1,300,000	0.46 (Combined 0.9)	High

MEDIUM PRIORITY

Option ID	Type	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Priority
RM02	Response Measure	Flood Emergency Response Coordination	The ongoing improvement of the coordination within and between the response agencies to ensure: • Roles and responsibilities are well defined and understood by each agency (and the broader community); • Hazards can be responded to quickly, efficiently and safely; and Calls from the public can be directed to the appropriate agency and responded to effectively.	Ongoing improvements to the coordination between and within emergency service agencies. Improvements to volunteer coordination. Identify vulnerable occupants.	Challenges include change of personnel, difficulty in organising meetings and exercises between flood events.	All response agencies, including but not limited to the SES, Council, RFS, Fire and Rescue, and community organisations.	Council	In house	N/A	Medium
RM03	Response Measure	Flood Warning System	Utilise Severe Weather Warnings from the BOM to prepare for potential flash flooding events, couple with community awareness campaigns and utilise information from the FRMS&P to understand the consequences of the warning.	Improve current system using outputs from the FRMS&P. Potentially increase warning time available to the community.	May not be possible to increase warning time in overland catchments due to short catchment response time. Communication needs to be at the correct level to avoid false alarms and complacency.	Council, SES	SES and Council	In house	N/A	Medium
P03	Property	Adoption of Flood Related Development Controls for development within the Overland Flow FPA	Incorporation of flood related development controls in the Wagga Wagga DCP to manage development in areas of Wagga Wagga prone to flood risk from overland flow. The intent and objectives of the development controls is to be consistent with those applied to the riverine FPA, however adjustment of the phrasing or implementation criteria may be necessary to better suit the context of overland flow flood risk.	Improve clarity of DCP (Flood for the benefit of both developers and Council assessors/approvers. Enable proponents to design, build and manage development using the best available flood information.	There may be resistance from developers who consider new controls to be onerous.	Council	Council	In house	N/A	Medium
P04	Property	Development Controls on Low Flood Risk Areas	Modify the Wagga Wagga LEP to enable Council to apply flood related development controls to critical facilities and vulnerable land uses between the FPA and PMF extent, as defined in this study and the Revised Murrumbidgee River at Wagga Wagga FRMS&P for overland flow and riverine flood risk, respectively.	Ensure critical utilities and vulnerable facilities are designed, constructed and managed in such a way as to minimise flood risk to the structure and (if relevant) its occupants.	This amendment to the LEP would require Council to submit a planning proposal, which could be lodged in conjunction with Option PM01.	Council	Council	In house	N/A	Medium
SW02	Flood	Bolton Park Drainage Gate Automation	Aim: To allow control of the outlet flow from the existing Bolton Park storage to alleviate pressure on the downstream system and reduce flooding in Morgan and Berry Streets; Install automated penstock operation	Minor flood reductions along Morgan Street and Berry Street for frequent events, potential reduction in duration of inundation.	Ineffective in rarer events. Public safety risks, and changes to amenity and usability of the field during and following storm events.	Council	May be eligible for NSW Government funding	$50,000 - $100,000	>1.0	Medium
FM01	Flood	Willans Hill Overland Flow Options Assessment	Aim: To ultimately develop mitigation strategies for properties impacted by rainfall runoff in the Willans Hill area. Establish an appropriate tool that can identify issues and assess mitigation options for the runoff and overland flow impacting the Willans Hill area. The assessment should also consider the impacts of development. Undertake a drainage investigation study of the area.	A more appropriate scaled hydraulic model will allow strategies to be developed that can minimize the impacts of runoff and overland flow in this area.	Very targeted area, there may be other areas which require a similar assessment. Suggested works will likely need to be funded by private landowners or in some cases Council (unlikely to be funded by the State).	Council	May be eligible for NSW Government funding	$50,000 (study only)	>1.0	Medium

FM02	Flood	McNickle and Roach Road Intersection	Aim: To improve flood immunity at the Roach and McNickle Road intersection to improve access for residents in Riverview Drive. Install culvert with conveyance area of 5m^2 and reinstate channel downstream of intersection.	Relatively minor upgrades to the culvert at the intersection and reinstatement of a channel downstream can significantly improve the flood immunity of the intersection. Overall a general reduction of flood levels in the area.	Very targeted area, there may be other areas which require a similar assessment. Intersection will require closure while works are undertaken and alternative access will be required. Suggested works would not be eligible for State funding.	Council	Council	$300,000	<1.0	Medium
LOW PRIORITY										
Option ID	**Type**	**Option**	**Description**	**Benefits**	**Concerns**	**Responsibility**	**Funding**	**Cost**	**B/C Ratio**	**Priority**
GD04 (Glenfield Drain)	Flood	Rabaul Place Trunk Drainage Line (further investigation)	Aim: Reduce inflows into Glenfield Drain to reduce demand on the existing open channel, by diverting flows to Ashmont Drain; Significant trunk drain installation, involving 3 x 1.8m diameter pipes from immediately downstream of the western railway culvert near Rabaul Place to the channel north of Ashmont Avenue.	Significant reductions in peak flood levels along Pearson Street and Dobney Avenue with some areas showing a 0.2 m reduction in flood level for the 1% AEP event. Effective in reducing peak flood levels in frequent events.	Increases peak flood levels at and around the northern end of the channel near the Sturt Highway. Staged construction would be required to allow affected roads to remain trafficable.	Council	May be eligible for NSW Government funding	$2,900,000	<0.5	Low

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Note: Figure Sheets

A – City
B – Lake Albert
C – Wagga East
D – Wagga North

LIST OF ACRONYMS

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

ADOPTED TERMINOLOGY

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

ARR 2019 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

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

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

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

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

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

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

FOREWORD

The NSW State Government's Flood Prone Land Policy provides a framework to ensure the sustainable use of floodplain environments. The primary objective of the NSW Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. At the same time, the policy recognises the benefits flowing from the use, occupation and development of flood prone land (Reference 3).

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through five sequential stages:

1. ***Data Collection***
   - Compilation of existing data and collection of additional data.
2. ***Flood Study***
   - Determine the nature and extent of the flood problem.
3. ***Floodplain Risk Management***
   - Determines options in consideration of social, ecological and economic factors relating to flood risk.
4. ***Floodplain Risk Management Plan***
   - Preferred options are publicly exhibited and subject to revision in light of responses. Formally approved by Council after public exhibition and any necessary revisions due to public comments.
5. ***Implementation of the Plan***
   - Implementation of flood, response and property modification measures (including mitigation works, planning controls and flood warnings for example) by Council.

Wagga Wagga City Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Department of Planning, Industry and Environment.

1. INTRODUCTION

This Study has been prepared by WMAwater on behalf of Wagga Wagga City Council (Council). The Study builds on flood modelling initially developed in the Wagga Wagga Major Overland Flow Flood Study (MOFFS) (August 2011, Reference 4), which has been as part of this study based on recommendations of the Wagga Wagga Major Overland Flow Floodplain Risk Management Study - Scoping Study (Reference 5) and outcomes of the Major Overland Flow Model Update (Reference 6). Work undertaken in these studies has been expanded upon in this Major Overland Flow Floodplain Risk Management Study and Plan (MOFFRMS&P) to further understand and determine the nature and extent of the overland flow flood risk at Wagga Wagga.

The Study is comprised of two phases:

1. The Wagga Wagga Major Overland Flow Floodplain Risk Management Study; and
2. The Wagga Wagga Major Overland Flow Floodplain Risk Management Draft Plan.

1.1. Study Objectives

The main objective of this MOFFRMS&P is to develop flood risk mitigation strategies that address existing, future and continuing flood problems due to local catchment (not riverine) flooding in Wagga Wagga. The study is undertaken in accordance with the NSW Government's Flood Policy, as detailed in the “Floodplain Development Manual: the management of flood liable land”, New South Wales Government, April 2005 (Reference 3).

Note that riverine flooding from the Murrumbidgee River is not assessed in this Study. For information on riverine flooding and mitigation measures please refer to the Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan, (Reference 7), adopted by Council in March 2018. The Objectives of this study are more specifically described in Section 1.1.1 and 1.1.2 below.

1.1.1. Floodplain Risk Management Study Objectives

The objective of the Floodplain Risk Management Study is to investigate a range of flood mitigation works and measures to address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Policy. This includes the following tasks:

- Update topography and the built environment to reflect current conditions;
- Assess the sensitivity of the existing flood model to Australian Rainfall and Runoff 2019 methodologies and update the flood model accordingly;
- Review Council’s existing environmental planning policies and instruments including Council’s long-term planning strategies for the study area;
- Identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events and taking into account the potential impacts of climate change;

- To assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future;
- To consider whether the proposed works and measures might produce adverse effects (environmental, social, economic, or flooding) in the floodplain and whether they can be minimised;
- In terms of the Department of Planning Circular PS 07-003 and "Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual, determine if and where exceptional circumstances are appropriate for flood related development controls on residential development on land above the residential flood planning area;
- Review the local flood plan, identify deficiencies in information and address the issues identified in the DECCW Guideline "SES Requirements from the FRM Process.";
- Examination of the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's development and disaster planning requirements;
- Investigate options for Lake Albert;
- Identification of modifications required to current policies in the light of investigations.

1.1.2. Floodplain Risk Management Draft Plan Objectives

The Floodplain Risk Management Draft Plan makes a range of recommendations relating to flood mitigation works and measures that address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Prone Land Policy. The recommended works and measures presented in the Plan aim to:

- Reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk (taking into account the potential impacts of climate change).
- Reduce private and public losses due to flooding.
- Protect and where possible enhance the creek and floodplain environment.
- Be consistent with the objectives of relevant State policies, in particular, the Government's Flood Prone Land and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act, 1979.
- Ensure that the draft floodplain risk management plan is fully integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council's obligations under the Local Government Act, 1993 and has the support of the local community.
- Ensure actions arising out of the draft plan are sustainable in social, environmental, ecological and economic terms.
- Ensure that the draft floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans.
- Establish a program for implementation and suggest a mechanism for the funding of the plan and include priorities, staging, funding, responsibilities, constraints, and monitoring.

2. BACKGROUND

2.1. Study Area

The area considered in the Wagga Wagga Major Overland Flow Floodplain Risk Management Study incorporates catchments with an area of 233 km^2 and a hydraulic modelling extent of 167 km^2 both south and north of the Murrumbidgee River as shown in Figure 1.1 and Figure 1.2. Within the overall extent are distinct areas with localised and independent flooding issues, and for this reason (and to manage model run times) the Study Area has been broken up into four domains indicated on Figure 1.2 and summarised in Table: 2.

Table: 2 Study Areas

Domain	Area (km^2)	Key Features
City	42	• Glenfield Drain, Wagga Wagga CBD and outer areas lying on the southern Murrumbidgee River floodplain.
Lake Albert	69	• Includes the upstream catchment of Lake Albert as well as the inflows to and outflows from Lake Albert; • Flow from Stringybark Creek (running from the south to the west of the lake) is directed into Lake Albert for all events less than approximately the 10% AEP event; and • Crooked Creek runs from the south and to the east of Lake Albert, and is also diverted into Lake Albert in frequent events.
East	26	• Marshall's Creek and Gregadoo Creek • Eastern Industrial area
Wagga North	35	• Duke's Creek from its headwaters to its confluence with the Murrumbidgee River (Gobbagombalin Lagoon). • Includes inflows from Estella, Boorooma, and vacant land south of the Olympic Highway; • Note the suburb of North Wagga is located to the east of the Dukes Creek floodplain and is therefore not included in this modelling.

2.2. Land Use

The City of Wagga Wagga is the largest inland city in NSW and is the regional centre of the Riverina district. The City is the regional focus for major commercial, retail and business centre activities, health care facilities, and many secondary and service industries supporting primary industry. Figure 1.3 presents the 2010 Wagga Wagga Local Environmental Plan (2010 LEP) land use mapping. The existing land use can influence and guide the types of measures that are recommend to manage flood risk in the study area.

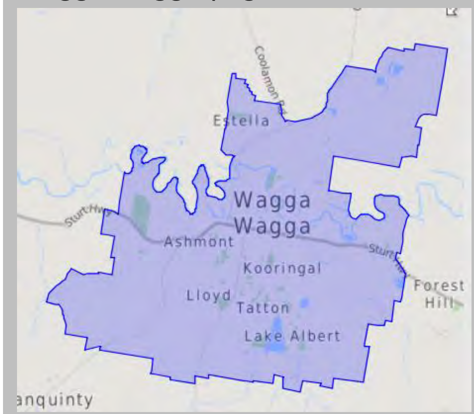
The land use types vary considerably between the four model domains. East Wagga is characterised by IN1 and IN2 (General and Light Industrial) along Hammond Avenue and Copland Street, with areas of R5 Large Lot Residential towards the south and east of the model extent, and the remainder predominantly vacant land zoned as RU1 Primary Production. The City domain is largely R1 General Residential, with pockets of RE1 Public Recreation, SP2 Infrastructure and B3/B5 Commercial Core/ Business Development.

The Lake Albert domain is similar, with large areas of R5 Large Lot Residential south of Lake Albert (which itself is zoned as W2 Recreational Waterways), and the golf course zoned as RE2 Private Recreation. The Wagga North domain contains R1 General Residential in the Estella Area, IN1 General Industrial in the Bomen Area. The remainder of the domain is generally RU1 Primary Production or SP2 Infrastructure. Flood risk mitigation options investigated later in this study will consider the appropriateness of these zonings in relation to the flood risk.

2.3. Demographic Overview

Understanding the social characteristics of the Study Area can help in ensuring that the right risk management practices are adopted, and shape the methods used for community engagement. Census data regarding house tenure and age distribution can also provide an indication of the community's lived experience with recent flood events, and hence an indication of their flood awareness. The following information has been extracted from the 2016 Census for the city of Wagga Wagga and is considered relevant. Table 3 shows some of the characteristics of the Wagga Wagga Significant Urban Area (SUA) compared to the NSW average. Note that the Wagga Wagga LGA has a total population of 62,400, and includes a number of villages including Uranquinty, Forest Hill, Ladysmith, Oura, Tarcutta, and Galore.

Wagga Wagga (Significant Urban Area) Demographic Overview



Population: 54,411
No. of Private Dwellings: 23,004
No. of lone person households: 5,397
Property Tenure:

- 64.2% owned (either outright or with a mortgage)
- 34.8% rented

Language

- 87.5% of people speak only English at home

No. persons over the age of 75: 4,026
Note: Elderly people are often more frail and unable to respond as quickly to flood emergencies without some assistance

No. single parent families: 2,508
Note: Single parent families can mean a low adult-to-child ratio within the household and therefore can make evacuation more difficult.

Statistics from:
http://www.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/1034?opendocument

Table 3: Characteristics of the Wagga Wagga Significant Urban Area (SUA) (Australian Bureau of Statistics, 2016)

	Wagga Wagga SUA	NSW
Population Age:		
0 – 14 years	20.2%	18.5%
15 - 64 years	64.2%	65.1%
> 65 years	15.6%	16.2%
Average people per dwelling	2.5	2.6
Own/mortgage property	64.2%	64.5%
Rent property	34.8%	31.8%
No cars at dwelling	6.4%	9.2%
Speak only English at home	87.5%	68.5%

The above statistics can help inform appropriate community engagement and flood -related communication strategies. For example, with a high proportion of the population speaking English at home, communication materials in English are considered appropriate for use in this study (see Section 5). The high proportion of children (20.2% compared to 18.5% in NSW), and large number of single parent households (~2,500) should also be considered as the low adult-to-child ratio can make evacuation more difficult or time consuming.

2.4. Local Environment

The environment surrounding Wagga Wagga is highly modified from its original state. Early settlement of the area saw extensive clearing of native vegetation for farming and grazing and, eventually, development of the urban infrastructure. A site visit was undertaken by WMAwater staff on the 17th April 2018 to inspect the Study Area, specifically the flooding hotspots identified by Council and to gather information on hydraulic structures such as bridges and culverts. Figure 1.4 shows photos at key sites and provides an indication of the vegetation conditions throughout the catchments.

Urban Salinity is recognised as one of Wagga Wagga's most significant land degradation concerns. Annually Wagga Wagga City Council works with the community to adopt management practices to reduce salinity in the urban environment. Council has a network of piezometers used to continually monitor groundwater levels, and water quality testing is carried out regularly to monitor salinity levels. Some strategies to manage urban salinity currently implemented by Council include revegetation works, land use planning controls to limit excessive infiltration, and community awareness initiatives to encourage residents to make ‘waterwise’ choices when choosing vegetation for their gardens – i.e. planting native vegetation that lowers the water table, rather than introduced species or having large areas of lawn that have shallower root systems and elevate the water table.

Another environmental concern in Wagga Wagga pertains to the popular recreational facility, Lake Albert, which caters for boating, fishing, swimming and other aquatic activities and is surrounded by a 5.5 km walking track. Lake Albert's water level is reliant on stormwater from the catchment area, and as such, receives a high dose of nutrients from inflows that pick up fertilisers and animal manure when it rains. The nutrient rich conditions when coupled with warm temperatures provide an ideal environment for algal blooms, especially blue-green algae. The water quality of Lake Albert is therefore regularly monitored to ensure it is safe for the public to swim in. Council publicises the sample results on their website, and classifies the lake's status according to the Blue Green Algae and Bacterial Content measured. The water quality is classified as Green Level (surveillance mode), Amber Level (alert mode) or Red Level (action mode).

3. PREVIOUS STUDIES

3.1. Wagga Wagga Major Overland Flow Flood Study (Reference 4)

The Wagga Wagga Major Overland Flow Flood Study, completed for Council in 2011 by WMAwater, provided detailed local (not Riverine) design flooding information for an area of ~ 167 km^2 on a 5 m grid resolution. The study area is presented in Figure 1.2.

Due to the large size of the study area it is divided into four model domains (locations presented in Figure 1.2) as per the following:

- East Wagga– Marshalls and Crooked Creeks;
- Wagga North – Duke's Creek;
- City – Glenfield Drain, Silvalite Reserve, various CBD bound flow paths; and
- Lake Albert – Stringybark Creek, Crooked Creek.

The study utilised a hydrologic/hydraulic (WBNM/TUFLOW) modelling system, calibrated and validated to historic events, to define design flood behaviour for the 3 hour duration event. No critical duration assessment was undertaken as part of the Wagga Wagga Major Overland Flow Flood Study (Reference 4).

3.2. Wagga Wagga Major Overland Flow Floodplain Risk Management Scoping Study (Reference 5)

The Wagga Wagga MOFFS Scoping Study (Reference 5) was carried out to contextualise findings from the Wagga Wagga Major Overland Flow Flood Study (Reference 4) prior to a Floodplain Risk Management Study being commenced. The Scoping Study made recommendations that led to the Wagga Wagga MOFFS Model Update Report in 2012 (see below). The recommendations included:

1. Model revision to include detailed structure survey (bridges, culverts etc) previously not included;
2. Tailwater sensitivity assessment was required to be examined for the City model domain. the Wagga Wagga Major Overland Flow Flood Study (Reference 4) used a 2Y ARI river level and did sensitivity testing with the 5Y ARI event. Subsequent assessment found sensitivity around a river level of 10% AEP, particularly in the area of the Flowerdale Storage Area (FSA). Further, the December 2010 event demonstrated flood liability for simultaneous Riverine and Major Overland Flow (MOF) flooding. The Wagga Wagga MOFFS Scoping Study (Reference 5) recommended that the impacts of elevated tailwater levels on peak flood levels should be investigated.
3. the Wagga Wagga Major Overland Flow Flood Study (Reference 4) modelling used the three hour duration only. As such a critical duration assessment is required to be undertaken as part of the MOFFRMS&P.

3.3. Wagga Wagga Major Overland Flow Model Update Report (Reference 6)

In response to the recommendations made in The Wagga Wagga MOFFS Scoping Study (Reference 5), the Major Overland Flow flood models originally established in the Wagga Wagga Major Overland Flow Flood Study (Reference 4) were updated in 2015. Key updates included the following:

- New survey was carried out and updated structure details fed into the model;
- Initial water levels for various storages (Lake Albert, Wollundry Lagoon, Flowerdale Storage Area etc.) were revised;
- Revised Areal Reduction Factors (ARFs) were applied from the 2013 ARR Revision;
- A more recent version of TUFLOW was applied (2012 versus 2009 previously used);
- 1% AEP local rainfall runs were combined with a 2Y ARI River level; and
- A variety of durations have been assessed via hydrologic and hydraulic modelling to produce a suite of design results based on a peak envelope approach.

The resulting flood models are used in the current MOFFRMS investigation.

3.4. Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan (Reference 7)

The Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan was adopted by Council in May 2018. This study and plan assessed, and ultimately recommended, a broad range of mitigation options to manage flood risk in Wagga Wagga due to Murrumbidgee River flooding. While the current MOFFRMS&P project focuses on overland flow, this report is referred to in regards to tailwater conditions, as the Murrumbidgee River forms the downstream model boundary for the City and East Wagga model domains. The levels occurring in the Murrumbidgee River in various events are defined by the modelling produced in the Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan (Reference 7). The application of tailwater conditions is described in Section 6.4.

4. AVAILABLE DATA

4.1. Topographic Data

Light Detection and Ranging (LiDAR) survey of the Study Area and its immediate surroundings was provided for the study by Fugro Spatial Systems Pty Ltd. LiDAR is aerial survey data that provides a detailed topographic representation of the ground with a survey mark approximately every square metre. The data for the Wagga Wagga area was collected in 2008, and was used for the 2011 MOFFS (Reference 4) as well as the recently completed Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan (Reference 6). The accuracy of the ground information obtained from LiDAR survey can be adversely affected by the nature and density of vegetation, the presence of steeply varying terrain, the vicinity of buildings and/or the presence of water. The vertical accuracy is typically ± 0.15 m for clear terrain. The LiDAR was used with some local refinements to ensure small creeks and gullies were represented. These refinements are described further in Section 6.2.1.

Two basins were constructed upstream of Jubilee Park on Bourkelands Drive (estimated to have been completed around 2010), and as such were not captured in the LiDAR (from 2008). To ensure that the basins are represented appropriately in the DEM, 5 m x 5 m resolution photogrammetry was obtained from Geoscience Australia - Elevation Information System (ELVIS) produced in 2014.

4.2. Hydraulic Structures

Details of key hydraulic structures within the Study Area, including culverts and bridges, were obtained from previous reports (References 3-6) and supplemented where needed with information gathered through a series of site visits. WMAwater inspected and measured approximately 100 hydraulic structures across the Study Area, with the majority in the City and Lake Albert domains. This data was used to supplement surveyed details obtained by Hinchcliffe T J & Associates Pty Ltd in Reference 6.

4.3. Pit and Pipe Network

A significant amount of additional stormwater pit and pipe data was provided by Council for this study that had not previously been available. Where needed, additional details were gathered via visual inspection or assumed based on location, surrounding pipes, available LiDAR data and reasonable pipe cover depths. Pit inverts were assumed to be 1-1.5 m below the ground level (from LiDAR), and were manually adjusted where needed to ensure no negative grades were assigned to pipes.

4.4. Levee Pipe Details and Closure Procedure

In addition to the pit and pipe data, further detail on the pipes through the levee were provided by Council. The data set contained 34 pipes through the CBD levee, as well as details on pipe invert levels, diameters, gate/valve structures, and the gauge height at which they are to be closed (to prevent water from the Murrumbidgee River backwatering through the pipes and flooding areas behind the levee). The dataset also contained levee pipe details for the North Wagga levee, however being outside the MOFFRMS&P study area these details were not utilised.

4.5. Design Rainfall

Design rainfall information for use with ARR 1987 methodologies was adopted directly from Reference 6. New Intensity Frequency Duration (IFD) for the Study Area was obtained from the Bureau of Meteorology (BoM) website for the purpose of the ARR 2019 Sensitivity Assessment. Table B1 to Table B2 (see Appendix B) contain the ARR 2019 IFD data for the centroid of the four catchments. Graph B1 to Graph B4 (see Appendix B) have also been included to indicate the change in depth between the ARR 1987 and ARR 2019 IFD data sets for the four catchments.

4.6. Floor Level Database

A key outcome of the current study is a flood damages assessment. To complete this aspect of the study, floor level estimates are required to undertake a broad assessment of flood affectation. While the assessment uses floor level data for individual properties, the results are not an indicator of individual flood risk exposure but part of a regional assessment of flood risk exposure. For each property, the floor level estimation captured the following descriptors:

- Ground Level (in mAHD);
- Indication of house size (number of storeys);
- Location of the front entrance to the property; and
- Local Environmental Plans (LEP) land use (residential, commercial, industrial, primary production, or public recreation and infrastructure).

Typically a floor level data base would include all properties within the PMF extent. In the Wagga Wagga overland catchments however, this would amount to over 20,000 properties, many of which would be subject to only very shallow flooding. To manage the time and cost associated with developing the data base, floor levels were estimated for all properties within the 1% AEP extent, which was trimmed to exclude flood depths of less than 150 mm. It was found that the average floor height of dwellings in this extent was 0.26 m, so the assumption that properties affected by depths less than 150 mm would not be flooded over-floor was deemed appropriate. In addition, the Building Code of Australia stipulates that slab-on-ground constructions must be a minimum of 150 mm above ground. This further supports the exclusion of properties affected by less than 150 mm from the internal flood damages assessment. While this may exclude some low-set commercial premises (i.e. warehouses), the approach is considered to provide a reasonable level of detail in light of the overall study objectives for this Floodplain Risk Management Study.

The external flood damages (that is, damage to garages, carports etc), were assessed across the entire PMF extent for each model domain, using the building footprint layer developed as per Section 6.2.5. The building footprint was buffered (expanded) by 5 m, and the peak flood depth occurring within this polygon (in each design event) was taken as the representative depth. For the estimation of external damages, the peak flood depth within 5 m of the building footprint was taken as the representative flood depth. This was done to ensure that flood depths were not overestimated in large lots where there may be a gully or watercourse through the cadastral lot that is well away from garages, carports or possessions in the backyard. This methodology and assessment results are described in detail in Section 10.

Where available, floor level data was taken from the database established in the Riverine FRMS (Reference 7). Due to the large number of properties that require floor level estimates within the City domain, the Riverine FRMS used a sample population to determine the average floor level height above ground for properties within the levee. This information was then combined with LiDAR data to estimate floor levels for all properties. The resulting floor levels were reviewed to confirm suitability for use in the current study. In addition to this, WMAwater used LiDAR data and visual inspection to estimate floor levels for all properties within the PMF extent. A summary of the total floor level estimates is provided in Table 4 below.

Table 4: Floor Level Database

	Internal Damages Assessment			External
Property Type	Residential	Non-Residential	Total (Internal)	No. Properties included
City	2217	511	2728	13181
Lake Albert	1045	25	1070	6226
Wagga North	43	12	55	1001
East Wagga	38	252	290	893
Total	**3343**	**800**	**4143**	**21301**

5. COMMUNITY CONSULTATION

5.1. Purpose of Consultation

One of the central objectives of the FRMS process is to actively liaise with the community throughout the process, keep them informed about the current study, identify community concerns and gather information from the community on potential management options for the floodplain. “Community” refers to all spheres of local government, business, industry and the general public. Consultation with the community is an important element of the Floodplain Risk Management process facilitating community engagement, building confidence in flood modelling tools, and leading to acceptance and ownership of the overall project and its outcomes.

5.2. Consultation Approach

A newsletter and questionnaire were distributed to residents within the 1% AEP flood extent (excluding depths less than 150 mm). A press release was published in the Daily Advertiser on the 23rd June 2018. Initial submissions received tended to focus on nuisance stormwater drainage issues, rather than major flooding. To ensure residents understood the scope of the project, a second press release was issued on the 11th of July 2018 to ensure the focus of responses was on more significant flooding issues within the local catchments. A copy of the materials is provided in Appendix D. The outcomes are described below.

5.3. Outcomes

93 responses were received from the community via online and hardcopy questionnaires. Most consultations were submitted via hardcopy or with an accompanying letter. Chart 1 shows the distribution of response methods by the community.

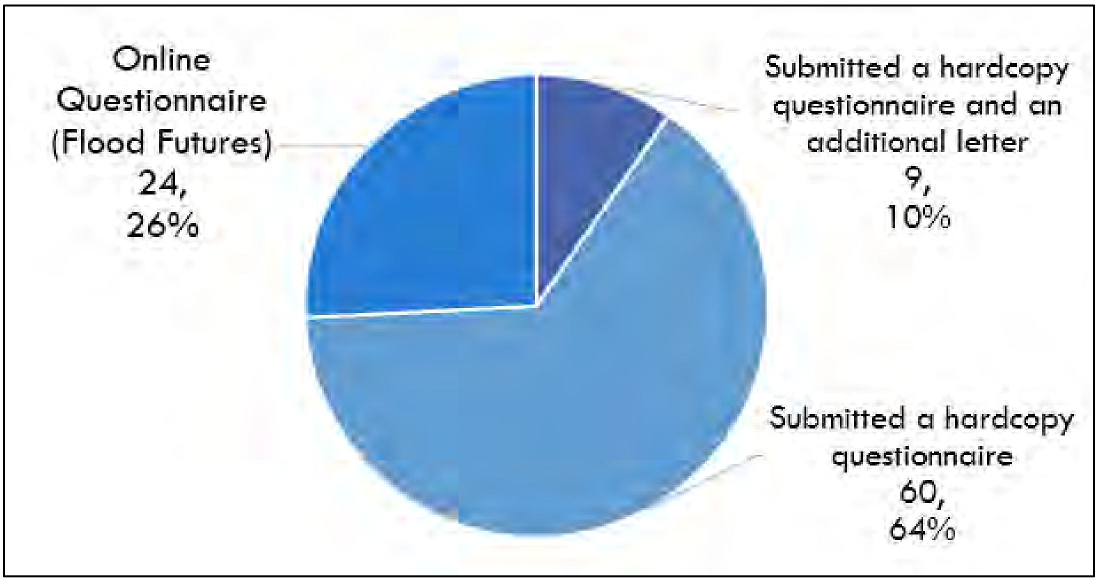


Chart 1 Distribution of community repsponses.

From the responses, 93% of residents that responded agreed that flood mitigation is needed in Wagga Wagga (Chart 2).

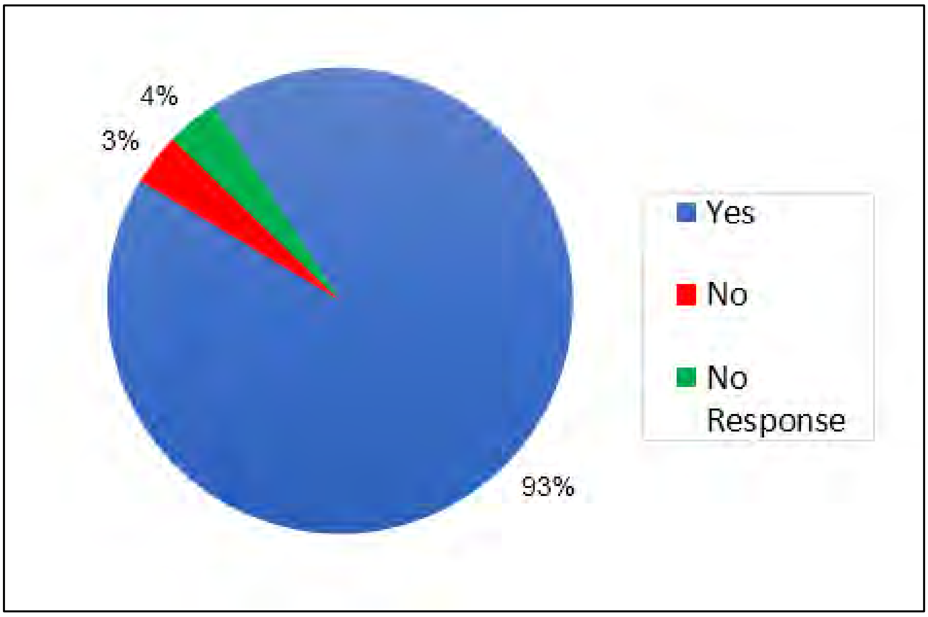


Chart 2 "Do you think something should be done to reduce flood risk in Wagga due to local catchment rainfall?"

The survey asked for preferences for various mitigation options. The respondents ranked the options in four categories: not at all suitable, somewhat unsuitable, somewhat suitable, and very suitable. The responses were compiled to show the total positive and negative response for each mitigation option, shown in Chart 3. The mitigation options with the most positive responses include flood warning systems, drain and channel upgrades, and flood intelligence systems.

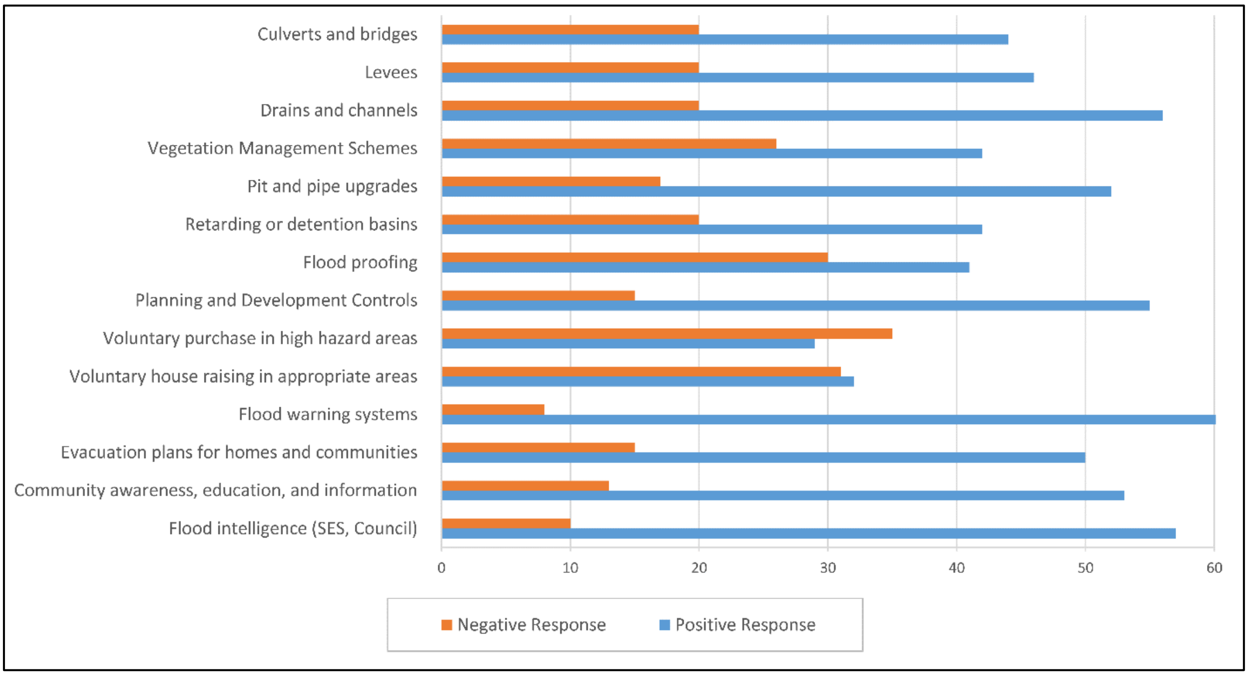


Chart 3 Preferences for Mitigation Options

The survey results were analysed to find flooding hotspots in the Study Area. The severity of reported flooding was documented and comments were categorised into internal property flooding, external property flooding, insufficient drain capacity, or road inundation. The hotspots identified from reported flooding experiences are shown in Figure 1.20, along with the following Council-identified hotspots:

- Flowerdale Storage Area
- Chaston St
- Hakea Pl
- Stringybark Creek Diversion Structure
- Crooked Creek Diversion
- Jones St
- Brunskill Rd
- Sycamore Rd
- Copeland St
- Glenfield Basins
- South Wollundry Lagoon
- Bolton Park
- Plumpton Rd
- McNickle Rd Drain
- Ashmont Reserve (note – outside Study Area)

Being the most populous area, the City domain had the most responses and reports of flooding hotspots. Key locations commonly mentioned include the area around Flowerdale Lagoon, Wollundry Lagoon, Glenfield Drain (especially near the Bunnings), Huthwaite Street Reserve, Willans Hill and Marshalls Creek. In the Wagga North model domain, respondents were mainly concerned about extra runoff being caused by new development and associated paving (roads, driveways etc.), and that runoff from the newly established industrial area would pollute agricultural land downstream. Concerns in the East Wagga domain mainly focused on the impacts that new developments would have on overland flow, and maintenance of Marshalls Creek. Within the Lake Albert domain, community responses called for better maintenance of Crooked Creek around Gregadoo Road, increased drainage capacity along (and beneath) Plumpton Road, and identified frequent flood issues at Brunskill and Sycamore Roads and the Rawlings Park area. These hotspots will be reviewed in detail when considering opportunities for flood risk mitigation in the later stages of this Study.

5.4. Public Exhibition

The Draft Floodplain Risk Management Study and Plan was placed on a period of public exhibition from the 26th of March 2021 to the 5th of May 2021. This period allowed the community and other stakeholders to provide feedback on the report and its outcomes.

Digital copies of the report were made available on the Council website. Two drop-in sessions were held on Tuesday, 20th April 2021 from 3:00 pm – 6:00 pm and on Wednesday, 21st April 2021 from 10:30 am – 2:00 pm. The drop-in session provided an opportunity for residents and stakeholders to discuss the study and outcomes with Council and WMAwater staff in an informal setting. Additionally, residents could make submissions either by writing a letter or email directly to Council, or by submitting an online form via the Council website. A total of eight submissions were made, all of which were read and logged by Council and WMAwater. The outcomes of the feedback received during the public exhibition period have been summarised in Table 5.

Table 5: Public Exhibition Outcomes

Type	Item	Summary	Response
Flooding Concerns	FC1	Concern regarding the frequent flooding experienced at the McNickle Road and Roach Road intersection.	Following Public Exhibition further investigation has been undertaken in this area. A number of options have been considered to improve the flood risk at this intersection. The outcomes are documented in Section 11.6.13.
	FC2	Concern regarding the regular flooding at the bottom of Hardy Avenue and the corner of Cullen Road.	The current study is aimed at the estimation of overland flow flood behaviour resulting from creeks and remnant drainage lines; and developing strategies to mitigate the impacts of this flood mechanism. Small scale property inundation (often including footpaths, driveways etc) can also result from concentration of rainfall runoff before it enters the systems described above. A review of inundation reports from Council's database identified a number of drainage issue reports in locations not identified as part of the broader study. Investigation of these locations identified that the drainage issues may be a result of the smaller scale runoff process. Strategies to mitigate this type of runoff affectation are typically at a much smaller scale to that being assessed as part of this study and may include small drainage upgrades, regrading gutters and driveways or foot paths, for example. These strategies would be investigated in a localised investigation rather than a catchment wide investigation such as this study.
	FC3	Concern regarding the exclusion of the San Isidore area, surrounding villages in the LGA and new development areas, such as Gobbagombalin and Boorooma from the investigation.	The current Floodplain Risk Management Study and Plan has been undertaken in accordance with the NSW Government Floodplain Risk Management Process, which generally includes a Flood Study, to define flood behaviour and then a Floodplain Risk Management Study and Plan, to development strategies to manage flood risk. The Flood Study for the current study area was completed in 2015 and subsequently followed by this Floodplain Risk Management Study and Plan investigation. The Flood Study for other areas of the LGA including other villages and development areas has not yet been undertaken. Noting that a Floodplain Risk Management Study and Plan for the villages of Tarcutta, Ladysmith and Uranquinty has also recently been completed. Council actively seeks funding to assist in the development of flood investigations for other areas of the LGA and will continue to extend the available flood information through the NSW Government process.
Maintenance	MA1	Concern regarding the blockage and regular maintenance of the stormwater network on Urana Street. It is suggested that preventative action is taken to remove debris particularly when a rain event is forecast.	As noted in the submission, Council has actively worked in this area and is aware of the ongoing concerns. A range of possible drainage improvement strategies are being considered in the area, outside of this Floodplain Risk Management Study and Plan. Potential strategies to avoid the build up of debris are also being considered.
	MA2	Suggestion that bark mulch not be used on Council property in overland flow areas, as this can add to blockage of pit inlet structures.	This is a good suggestion and has been taken under consideration.

Type	Item	Summary	Response
	MA3	The importance of maintenance (rubbish and fallen timber removal) along the entire Crooked Creek corridor. Submission suggests that due to other man made works (diversion into Lake Albert and Sycamore and Grevillea Drains) the section of Crooked Creek downstream of the diversion should be reclassified as a drain and appropriately maintained.	Currently, the Crooked Creek diversion is designed to operate effectively only in frequent events and does not serve the purpose of completely removing the northern flowpath downstream of Craft Street. The intent of the option is to modify the existing diversion to improve its efficiency and reduce some of the downstream flood risk and property impacts. An option which diverts the entire catchment into Lake Albert would have significant consequences on the lake as well as the important drainage corridor of Crooked Creek downstream of the diversion and is unlikely to be viable. Additionally, options which consider conversion of this natural creek system into a drain would need to consider visual and community amenity, environmental and habitat impacts, land acquisition and changes to flood risk (as in some cases non natural channels require widening to maintain bank stability) and are unlikely to be viable.
	MA4	Responsibility of the Sycamore Drain easement being too burdensome on residents.	Maintenance in this area is currently the responsibility of land owners and Council is restricted from undertaking works. The submission references a request for Council to take ownership of the land, this proposal is currently under consideration.
Development	D1	Concern that the increased flooding on Davison Street may be due to increased development to the north of Dukes Creek. Concern regarding future development in the Crooked Creek catchment.	The Floodplain Risk Management Study and Plan provides information on flooding constraints that allows a strong framework to be set within Council's policies to ensure that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas. The Floodplain Risk Management Study and Plan has assessed and recommended measures to offset or mitigate the changes in flood behaviour as a result of future development within the catchment. In addition, Council's existing controls require that any proposed development demonstrates its impacts on flood behaviour and that appropriate mitigation strategies are implemented. It is noted that flood behaviour at this location is also influenced by the interaction with the Murrumbidgee River floodplain, typified by broad inundation.
	D2	Concern regarding the proposal of the new museum on the Willians Hill site impacting downstream flood behaviour.	Please refer to response for D1. Impacts of developments in the surrounding area has been added as a consideration in FM01.
	D3	Concern that development has not included onsite detention and that the impacts of increased runoff have not been considered.	Please refer to response for D1.

Type	Item	Summary	Response
	D4	Concern regarding the benefits of decommissioned local dams on flood behaviour and impacts of local works in the creek on flood behaviour.	The Floodplain Risk Management Study and Plan is a catchment wide study providing a broad representation of the flood risk. Local scale features such as minor channel works and small dams may change the local flood behaviour particularly in frequent events. The Floodplain Risk Management Study and Plan considers the impacts of flooding across a range of flood event sizes including the 1% AEP which is the event selected for planning purposes as in a 70 year period, you have a better than even chance of experiencing a flood of this size, this is considered a reasonable level of risk to mitigate against. The volume of the 1% AEP event in this portion of the catchment is approximately 895,000m^3. In comparison, the largest dam within the Crooked Creek catchment near Power Road has an approximate potential storage volume of 17,000m^3, representing 2% of the total 1% AEP volume and is unlikely to significantly impact an event of this size. This section of creek is currently owned and maintained by landholders and Council can not undertake works in this area.
Modelling	MO1	Concern regarding the use of 5 – 7 year old LiDAR and that the study did not update the information in relation to the previous studies done.	The modelling has been undertaken in accordance with industry best practice including utilising the most recently available data (including LiDAR). In addition, additional significant developments undertaken since the acquisition of the LiDAR have been included within the model, noting that the model aims to provide a catchment wide representation of flood behaviour. Refer to Section 6 for details of updates to the model. In addition, the previous assessments have been undertaken utilising the methodologies described in Australian Rainfall and Runoff 1987, the current investigation has been undertaken utilising the methodologies described in Australian Rainfall and Runoff 2019, this process is described in Section 7. For practical reasons, the model represents the catchment at a point in time and typically development following that point are managed via an assessment of the developments' impact on flood behaviour.
	MO2	Request for the WMAwater flood model to be public available.	This request has been taken on board and will inform decisions on a Council Policy position for access to flood models and data.

<table>
<tr><th>Type</th><th>Item</th><th>Summary</th><th>Response</th></tr>
<tr><td></td><td>MO3</td><td>Section 11.6.11.4 refers to a works length of 580m on the Crooked Creek diversion, the submission seeks clarification on where this is measured from.</td><td>


The extent of the proposed works spans 580 m in length from Main Street to the east (parallel to Craft Street).</td></tr>
<tr><td>Recommended Options</td><td>RO1</td><td>Submission supportive of FM01 encouraging Council to move forward ASAP.</td><td>Noted. The submission also provided useful information regarding flood behaviour that can assist in the proposed detailed study.</td></tr>
<tr><td></td><td>RO2</td><td>Request for local residents to be notified when FM01 is undertaken.</td><td>A key component of the investigation will be understanding the localised nature of flood behaviour in this area and it is recommended that site visits and community engagement is undertaken.</td></tr>
<tr><td></td><td>RO3</td><td>Submission supportive of recommendations in Section 11.3.3.2 (Provision of Flood Information on Council Website) and Section 11.1.1.2 (Amend Flood Plans to Include Overland Flow Flood Information) as these recommendations will increase awareness of impacted locations to drive Council maintenance programs.</td><td>The Floodplain Risk Management Study and Plan provides information on flooding constraints that allows a strong framework to be set within Council's policies to ensure the impacts of local overland flow are considered. The comments around agency awareness have also been added to the recommendation.</td></tr>
<tr><td></td><td>RO4</td><td>Submission supportive of LA01, LA02 and LA03.</td><td>Noted</td></tr>
</table>

Type	Item	Summary	Response
	RO5	Improving driver awareness due to flooding at the Urana Street roundabout and other flood impacted locations. In addition, the submission suggests that driver education should extend to understanding the consequences of driving though floodwater on surrounding areas (such as water diversion) and not just regarding driver safety.	A key recommendation of the study is for Council to consider road signage at key flooding locations in addition to complementary education programs which can included these aspects. Please refer to Section 11.4.
	RO6	Feedback received during the drop in session raised concerns regarding LA01, LA02 and LA03 and the impacts of raised water levels and duration of raised water levels in Lake Albert on the existing boating facilities.	The next stage for recommendations LA01, LA02 and LA03 is for a further detailed assessment and design to be developed. As part of this assessment the associated impacts on existing infrastructure will be reviewed and potential strategies to offset these impacts will be identified. This stage will included consultation with the existing lake users to understand the impacts of increased lake levels on the operation of the existing facilities.

6. FLOOD MODEL REVISIONS AND UPDATES

The Wagga Wagga Major Overland Flow Flood Study (Reference 4) completed in August 2011 was completed by WMAwater for Wagga Wagga City Council (Council) in accordance with the NSW Government's Flood Prone Land Policy. The Flood Study aimed to determine design flood behaviour in the area and used a WBNM hydrologic model and a 1D/2D TUFLOW hydraulic model. The models were subsequently updated in 2015 in the Wagga Wagga Major Overland Flow – Model Update Report (Reference 6). The updated models have been reviewed to determine the suitability for use in the Floodplain Risk Management Study. The following sections describe revisions and updates to the existing models.

6.1. Hydrologic Model Revisions/Updates

The WBNM models developed in (Reference 4) and updated in (Reference 6) were reviewed and deemed representative of current conditions, and suitable for use moving forward with the MOFFRMS&P, with one amendment. External inflows into the City WBNM model at the domain are derived from runoff generated upstream of the model boundary, that is, within the Lake Albert model domain. Previously, this was managed by running the Lake Albert hydrologic model first, then manually extracting the appropriate flows to apply as inflows in the City Domain. In order to improve efficiency, the City hydrologic model boundary has been extended towards the south (to overlap with the Lake Albert hydrologic model), allowing the necessary sub-catchments to be included in the City model. Flows modelled in the Lake Albert model are no longer transferred into the City model. This allows the Lake Albert and City models to be run simultaneously, as the City WBNM hydrologic model can now function independent of the Lake Albert model.

It is noted that care must be taken to ensure that the overlapping model domains areas are not 'double counted'. For clarity, all flood metrics (depth, hazard, hydraulic categories) are mapped separately for each model domain. The flood damages assessment uses distinct floor level datasets for each domain. In the overlapping areas, the model domain producing the higher flood levels is used preferentially to ensure that damages are not underestimated.

While there has been significant development in Wagga Wagga in recent years, the proportion of impervious surfaces (i.e. roads, buildings, driveways) is minor compared to each subcatchment area, and the overall catchment area. The estimation of 'percentage impervious area' in the current WBNM model is considered appropriate for continued use in the FRMS, as the overall proportion has not been changed materially. It should be noted however that future updates to the WBNM model should review this assessment, especially in areas of growth in Wagga Wagga in which a greater proportion of impervious areas may occur in the future.

6.2. Hydraulic Model Revisions/Updates

Since the Wagga Wagga Major Overland Flow - Model Update Report (Reference 6), a number of revisions have been made to the TUFLOW hydraulic model. The majority of changes aimed to update the models to reflect current conditions, including new development, more recent topographic data, improvements to the pit and pipe network and levee pipe systems.

6.2.1. Refinement of Topographic Data

The 2D model terrain is derived from 1 m resolution LiDAR gathered in 2008, sampled to produce a 5 m x 5 m grid. A review of the topography found that some features of the terrain, such as small channels and gullies, may not be appropriately represented by this resolution. The locations of such sub-grid features were identified using the original 1 m LiDAR and aerial imagery, and breaklines were digitised in the model to ensure they were represented appropriately. This has had the effect of reducing the occurrence of shallow sheet flow across open areas, with more flow being contained within the small gullies and flowpaths. This refinement was carried out across each model domain, with the most noticeable differences found in undeveloped parts of the Wagga North and Lake Albert model domains.

As described in Section 4.1, two basins were constructed upstream of Jubilee Park on Bourkelands Drive (estimated to have been completed around 2010), and as such were not captured in the LiDAR (from 2008). To ensure that the basins are represented appropriately in the DEM, 5 m x 5 m resolution photogrammetry was obtained from Geoscience Australia - Elevation Information System (ELVIS) produced in 2014. The DEM was processed manually to ensure any vegetation was removed from the grid and that ground level was appropriately represented. The outlet structures were inspected and measured by WMAwater staff during a site visit.

6.2.2. Hydraulic Structures

A number of significant hydraulic structures such as bridges and culverts are situated in the Study Area. In previous studies, survey details provided by Council accounted only for a small proportion of the structures, and the absence of complete data led to the dimensions and locations of many structures being assumed or omitted. With new pit and pipe data made available (see 6.2.3), significant effort was made to improve the representation of hydraulic structures. A series of field trips were undertaken to inspect and measure approximately 100 hydraulic structures across the Study Area, and subsequently incorporate these into the TUFLOW model as 1D elements.

6.2.3. Pit and Pipe Network

Pit and pipe networks play an important role in managing runoff in frequent events, and are essential to the estimation of overland flow as a flood mechanism in Wagga Wagga. A significant amount of additional stormwater pit and pipe data was provided by Council for this study. Where needed, additional details were gathered via visual inspection or assumed based on location, surrounding pipes, available LiDAR data and reasonable pipe cover depths. Pit inverts were assumed to be 1-1.5 m below the ground level (from LiDAR), and were manually adjusted where needed to ensure no negative grades were assigned to pipes. This approach is considered to provide a reasonable level of detail and modelling accuracy in light of the overall study objectives. However, it is noted that there may be localised inaccuracies that should be taken into account when considering detailed flood behaviour on an individual property scale. Details for around 5000 additional pit and pipe elements were provided for the City domain, 1900 in the Lake Albert, and around 500 in each the East Wagga and Wagga North domains, greatly improving the estimation of overland flow behaviour across the Study Area, especially in frequent events.

6.2.4. Levee Pipes

In addition to the pit and pipe data, further detail on the pipes through the levee were provided. The Wagga Wagga CBD is protected from Murrumbidgee River flooding by a levee constructed of compacted earth embankment and steel sheet piling where there are space constraints. The levee upgrade was functionally completed in June 2020 and provides a 1% AEP level of protection. There is a system of pipes through the levee bank to allow local runoff (from local rain events) to drain through the levee to the Murrumbidgee River. In times when the river level is elevated, the levee pipes are closed (via flap or gate valves) to prevent water from the river backwatering through the pipes and flooding the city areas. Flooding behind the levee is greatly affected by the status of each pipe, so it is necessary to ensure these are included appropriately in the flood model.

Levee pipe locations, invert levels and diameters were updated to reflect the data recently provided by Council for this study. These pipes play a significant role in the drainage of the lower lying areas of the City domain behind the levee bank, as well as the interaction between the City and East Wagga Domains at Marshalls Creek. This interaction is described further in Section 6.3.2. In addition, the levee pipe closure procedure has been provided and will be reviewed in detail to identify any issues or opportunities for revision.

6.2.5. Buildings

The representation of buildings within the study area is based on the same approach used in the previous studies, and is typical of overland flood estimation. In this method, buildings are ‘nulled out’, or removed from the computational grid to effectively exclude any flow from entering buildings. While this is not necessarily realistic (as flow can enter buildings), it is an appropriate method that simulates the obstruction that buildings can impose on floodwaters. The existing building footprints has been reviewed and the schematisation has been amended in some areas to ensure that flow paths between buildings are appropriately represented, and that buildings less than 5 m apart (the model grid cell resolution) do not act to artificially obstruct flows.

Since the most recent study (2015), there has been significant growth and development in Wagga Wagga as a result of land releases and rezoning. Major growth areas have included the Springvale and Tatton Areas (in the Lake Albert domain), East Wagga, Glenfield Park and Lloyd (City domain) and Boorooma (Wagga North domain). Some 7,000 additional buildings have been digitised across the entire Study Area for incorporation into the hydraulic model, and subsequently, the flood damages assessment.

6.3. Interaction between Model Domains

The total hydraulic model area is approximately 167 km^2. Given that a 5 m grid was used, to maintain reasonable model run times (and to make the runs possible given limitations in computer memory) it was necessary to split the study area into four separate model domains (Wagga North, City, East Wagga and Lake Albert). Being north of the Murrumbidgee River, the overland flow behaviour in Wagga North is independent of the other three domains. However, there is a degree of interaction between the City, East Wagga and Lake Albert Domains. This is because the model domain boundaries are not aligned with actual catchment boundaries. For example, much of East Wagga's catchment lies within the Lake Albert model domain. For this reason, flows coming out of the Lake Albert Area need to be inserted into the upstream (southern) end of the East Wagga to ensure that the appropriate amount of flow coming from outside the model boundary is accounted for. The interactions are described in more detail below. The Figures 1.2 A-C show the area of each model interacting with each other as a red dashed polygon.

6.3.1. Lake Albert and East Wagga Domains

Within the East Wagga Model, upstream Marshalls Creek inflows are extracted from the Lake Albert (LA) model. The extraction occurs at the Vincent Road bridge. This allows all upstream flows from LA to be modelled and attenuated by the lake in a single model along with diversion works on Crooked Creek and Stringybark Creek. In large events not all the flow of Crooked Creek systemconverges with Marshall Creek before Vincent Road and instead overtops Laurel Rd. For large events then, flow from Laurel Road is recorded from the LA model and additionally transferred to the East model as an upstream inflow along with Vincent Road flows. The interaction between LA and the East model was reviewed and adjusted to ensure the flows exiting the LA model was consistent with those entering the East model.

6.3.2. City and East Wagga Domains

With the recent availability of pit and pipe network information, and levee pipe data, this Study has identified interaction between the City and East Wagga domains that had not previously been accounted for. The model domains have been extended (to now overlap one another), such that the below interactions could be appropriately modelled:

6.3.2.1. Flow from the City domain to the East Wagga domain:

Runoff generated upstream (south) of the railway embankment, e.g. the hill west of the Wagga Wagga Monumental Cemetery, was previously impounded on the southern side of the railway embankment as details of culverts were not available. The addition of culverts to the model (4 x 1.4 m diameter pipes, 3 x 0.6 m diameter pipes and 4 x 1.4 x 1.4 m box culverts) now allows the model to simulate flow being conveyed through the railway embankment towards Marshalls Creek. In addition to this overland flow, runoff generated in the commercial areas north of the railway between Copland Street and Hammond Avenue had been previously retained behind the levee bank. Following the provision of details from Council, three levee pipes (Gates 22, 24, 25) were incorporated into the model, allowing flows to be conveyed into Marshalls Creek, if the water levels in Marshalls Creek are sufficiently low.

6.3.2.2. Flow from the East Wagga domain to the City Domain

The addition of levee pipes however has also demonstrated that flow can back up from Marshalls Creek, through the levee and into the commercial areas behind the levee. Whilst Gate 22 has a flap valve that prevents backflow, Gates 24 and 25 have gate valves whose closure is based on levels in the Murrumbidgee River (rather than Marshalls Creek). In events where the Murrumbidgee levels are lower than the trigger level, but levels in Marshalls Creek are above the pipe inverts, flow can back up through the open levee pipes and increase flood levels within the City Domain. The installation of one-way valves at Gates 24 and 25 or revision of the gate closure procedure would greatly reduce the incidence of backwatering at this location. This will be considered in the flood risk mitigation options assessment at a later stage in this Study.

6.4. Tailwater Conditions

Tailwater refers to the level of downstream (receiving) waters, and in the context of the current study refers to Murrumbidgee River levels. The Murrumbidgee River forms the downstream boundary of the City and East domains, and as such, the flood behaviour in these domains, particularly close to the levee, is sensitive to river levels and subsequently, whether the levee gates are open or closed.

The December 2nd 2010 event established that elevated River levels can coincide with significant rainfall and that when this occurs significant flooding can occur. As such it is reasonable for Council to consider utilising elevated River levels in setting design flood levels for MOF catchments. However, Council does not wish to overly restrict development by imposing higher design standards than considered standard practice. That is, Council wishes to achieve design flood levels that are consistent with the 1% AEP event, as per the NSW Floodplain Development Manual requirements (Reference 3).

The previous study (Reference 6) undertook a sensitivity assessment to determine the effect of different tailwater levels on the flood behaviour. It found that within the City domain, there was sensitivity in the lower areas. The area most affected was the Flowerdale Storage Area (FSA), where levels for the 5Y ARI River versus the 2Y ARI River (both combined with the 1% AEP local rainfall event) were 1 m higher in some locations. Following the assessment, it was recommended that the 2Y ARI tailwater level was applied in conjunction with the 1% AEP local event rainfall.

With the recent availability of detailed levee pipe data and operational details as part of the Wagga Wagga Levee, Levee Owner's Manual (October 2020 Reference 26), the suitability of this recommendation has been reassessed. The Levee Owner's Manual Appendix B lists the sequence of the levee pipe closure, outlining the river levels at which pipes are to be shut off. This sequence has been applied as part of this sensitivity modelling. The 1% AEP local event rainfall was modelled in conjunction with three different river levels: a "normal" low river level (1.95 m at the gauge), 2Y ARI (6.96 m at the Hampden Bridge gauge), and the 5Y ARI (9.81 m at the gauge). It is noted that the 5Y ARI river level would cause ALL levee pipes to be closed, which is not considered appropriate, however has been included to test the sensitivity of flood levels inside the levee to this scenario.

As expected, the 5Y ARI river level condition, with all levee pipes closed as per the operational procedure, greatly increases peak flood levels across the city, with the most significant increases in flood levels occurring at Flowerdale Lagoon (up to 1 m higher) and throughout East Wagga (up to 0.5 m higher) compared to the 2Y ARI river level scenario. This confirmed the expectation that the 5Y ARI would be overly conservative, and therefore not appropriate for use as part of this Study. Refer to Figure 4.6.

The sensitivity assessment then compared the “low river” level to the 2Y ARI, in which 8 gates (out of a total 34) would be closed. It was found that generally, peak flood levels across the city were unchanged between the two cases, indicating that much of the model domain is insensitive to the selection of either the 2Y ARI or “low river” tailwater conditions. However, there are noticeable differences in Wollundry Lagoon, due to the closure of Gate 13 triggered at a level of 4.8 m at the gauge, causing peak flood levels within the lagoon to increase in the order of 100 mm. These impacts are contained to the lagoon itself. The Flowerdale Storage Area is also affected by the selection of tailwater condition, as in the 2Y ARI river level scenario Gate 1 is required to be closed when the river reaches a gauge level of 4.8 m, preventing the free drainage of this area into Flowerdale Lagoon. It has been noted that the invert on the “river side” (i.e. the Flowerdale Lagoon end) of the gate is at 175.005 mAHD (from the Levee Pipe Database), and that the level in the Murrumbidgee River (and possibly Flowerdale Lagoon itself) is significantly lower than this when it is ordered to be closed. As part of the subsequent flood mitigation option investigation, the sensitivity of this gate to alternative closure levels will be assessed. It is noted though that the scheduling of gate closures can also be based on availability of resources, for example closing some gates earlier than needed to free up resources when the river level is higher and other actions are required. This will also be considered as part of the future investigation.

Following the sensitivity analysis undertaken as part of this Study, and given the previous work and historic events that demonstrated the concurrence of high river levels during local rain events, it is recommended the 2Y ARI river level continue to be applied as the tailwater condition across the suite of design events.

7. ARR 2019 SENSITIVITY ASSESSMENT

7.1. Overview

The Australian Rainfall and Runoff (ARR) guidelines were updated in 2016 due to the availability of numerous technological developments, a significantly larger dataset since the previous edition (in 1987) and development of updated methodologies. A key input to the process is information derived from rainfall gauges, and the dataset now includes a larger number of rainfall gauges which continuously recorded rainfall (pluviometers) and a longer record of storms, including additional rainfall data recorded between 1985 and 2012.

As part of the current Wagga Wagga Major Overland Flow Flood Risk Management Study and Plan (MOFFRMS&P), sensitivity of the design event modelling to the use of the ARR 2019 methodologies has been undertaken and a comparison made to the results produced using the updated models (as described in Section 4) with the ARR 1987 process.

7.2. ARR 2019 – Design Rainfall Update

Three major changes have been made to the approach adopted in ARR 1987 (Reference 1) for ARR 2019 (Reference 2):

1. The recommended Intensity, Frequency and Duration (IFD) rainfall data, preburst, and initial and continuing loss values across Australia have been updated based on analysis of available records;
2. ARR 2019 recommends an ensemble assessment of 10 temporal patterns for each storm duration in order to determine the median catchment response for each design event. In this case, the temporal pattern that produces flood levels closest to and above the mean level within each duration was selected to be representative of the median catchment response. The *critical duration* is the duration for which the selected temporal pattern produces the maximum flood level; and
3. The inclusion of Areal Reduction Factors (ARFs) based on Australian data for short (12 hours and less) and long durations (larger than 12 hours). ARFs are an estimate of how design rainfall intensity varies over a catchment, based on the assumption that large catchments will not have a uniform depth of rainfall across their entire area.

7.3. IFD Data

Revised IFD curves are available on the Bureau of Meteorology (BoM) website. Table B1 to Table B2 (see Appendix B) indicate the ARR 2019 IFD data for the centroid of the four catchments. Graph B1 to Graph B4 (see Appendix B) have also been included to indicate the change in depth between the ARR 1987 and ARR 2019 IFD data sets for the four catchments. The following are noted:

- There is an overall increase in design intensities for all four catchments;
- Increases in design intensities are much higher (increases greater than 10%) for shorter durations than for longer durations (increases less than 5%, with a decrease in intensities for durations above 120 minutes);

- Increases in design intensities for the 5% AEP event are higher than increases for the 1% AEP event for shorter durations, whilst the increase is smaller for the 5% AEP than the 1% AEP for durations above 120 minutes; and
- Very long duration (above 1 Day) intensities for the 5% AEP event generally decrease compared to ARR 1987.

7.3.1. Rainfall Losses

Rainfall losses are generally categorised as initial and continuing. The initial loss represents the wetting of the catchment prior to runoff starting to occur and the filling of localised depressions, and the continuing loss represents the ongoing infiltration of water into the saturated soils while rainfall continues. Methods for modelling the proportion of rainfall that is “lost” to infiltration are outlined in ARR 1987 (Reference 1) and ARR 2019 (Reference 2). The guidelines both describe a method that applies an initial loss (in millimetres) and continuing loss (in millimetres per hour) to the design rainfall.

7.3.1.1. ARR 1987 Losses

The previous study used loss values derived from a combination of ARR 1987 recommendations and previous studies.

Table 6: ARR 1987 Model Loss Values

	ARR 1987
Initial Loss (mm)	15
Continuing Loss (mm/hr)	2.5

7.3.1.2. ARR 2019 Losses

In January 2019 the NSW Department of Planning Industry and Environment released new guidance regarding the implementation of ARR2019 methodologies in NSW specifically: *“Incorporating 2016 Australian Rainfall and Runoff in Studies Section 3.7.1 Initial and continuing losses, pre-burst and burst losses in NSW”.* The new guidance was developed in response to a study that indicated that there is significant bias in the standard ARR 2019 design event method with default ARR 2019 losses and pre-burst, available from the ARR 2019 Data Hub (refer to Appendix C). It identified that default continuing losses ARR 2019 over-estimated losses and therefore were not fit for purpose and should only be used where better information was not available. If default continuing losses from the ARR datahub are to be used these should only be used with a multiplier of 0.4 applied.

In the absence of the availability of calibrated losses (i.e. calibrated flow to a stream gauge) in or around the Wagga Wagga Major Overland Flow catchments, the factored ARR 2019 Data Hub continuing loss rate has been applied for this study, in conjunction with Probability Neutral Burst Losses (available through the ARR 2019 Data Hub and recommended in DPIE guidance) in place of calculated pre-burst and initial loss inputs. The probability-neutral burst losses vary with each design event and duration, and are shown in Table: 8 below.

Table 7: ARR 2019 Model Loss Values

	ARR 2019
Initial Loss (mm)	See Table: 8
Continuing Loss (mm/hr)	0.4 x 4.7 = 1.88

Table: 8 Probability- Neutral Burst Initial Losses (mm)

Duration (minutes)	Duration (hours)	AEP(%)					
		50	20	10	5	2	1
60	1	18	11.1	11	11.6	11	9.1
90	1.5	17.5	11.6	11.4	12.3	11.8	9.3
120	2	16.4	11.1	10.6	11.4	11.1	9.6
180	3	17.7	12.5	11.1	11.4	9.7	7.3
270*	4.5	17.95	13.1	12.25	12.75	10.9	7.45
360	6	18.2	13.7	13.4	14.1	12.1	7.6
540*	9	19.85	14.8	14.15	14.45	12.3	8.5
720	12	21.5	15.9	14.9	14.8	12.5	9.4
1080	18	22.2	17.4	16.6	17.1	14.6	9.6
1440	24	24.1	19.1	18.4	18.4	16.7	11.5
2160	36	25.7	21.1	20.6	21.1	19.2	15.8
2880	48	26	21.5	21.3	22.1	20.5	15.6
4320	72	26.6	22.4	23	23.5	21.5	15.2

*denotes interpolated values

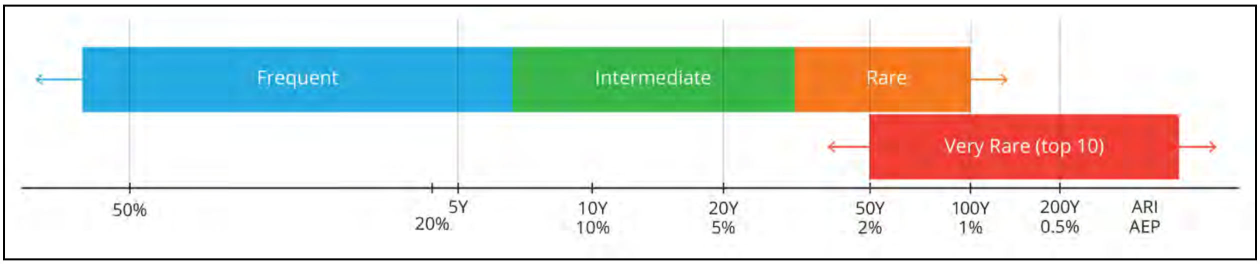
7.3.2. Storm Temporal Patterns

ARR 1987 provided a single temporal pattern for each storm duration for:

- Events less than a 30 year ARI; and
- Events greater than a 30 year ARI.

ARR 2019 provides several patterns for each duration now divided into 4 AEP bins. The temporal patterns were extracted from the storms occurring across Australia and are different for each region. The data hub provides a table with all the temporal patterns that could be used at a given location using coordinates. (The temporal patterns are grouped in bins based on the intensity of the recorded storms. A brief explanation of the bins is shown in Diagram 1.

Diagram 1: Temporal Pattern Bins



ARR 2019 recommends the use of 10 temporal patterns for design storm analysis. The 10 patterns have the same total rainfall depth, but there are differences in rainfall distribution across the storm duration: some patterns may represent storms with intense bursts at the start, middle or end of the storm duration, some may represent storms with multiple bursts, and some may represent storms with constant rainfall. Different patterns can produce different peak flood levels for the same catchment depending on catchment topography and response.

The representative temporal pattern (used as part of the critical duration analysis) is the pattern which produces peak flood levels just greater than the average of the 10 temporal patterns (not the temporal pattern which produces the largest peak level) for each storm duration. This can be calculated by running each of the 10 temporal patterns through the hydrologic and hydraulic models and determining the average flood level produced. The critical storm duration is the duration whose representative temporal pattern produces the maximum flow or level.

7.4. ARR 2019 Model Results

The hydrologic model adopted in the Wagga Wagga MOFFS (WBNM) was revised to incorporate the three changes in design methodology described above. The following process was used for determining the ARR 2019 5% and 1% AEP design flood results for each catchment:

- All 10 temporal patterns were input into the hydrologic model for the 30 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 9 hours, 12 and 24 hour durations to derive the associated flow;
- The resulting flows were then input into the TUFLOW hydraulic model and the model re-run for all 10 temporal patterns for the above durations;
- Peak flood levels were extracted for all 10 temporal patterns for the eight durations;
- The temporal pattern giving the peak flood level greater than the average of the 10 patterns across each catchment was selected for each duration; and
- The critical duration for each catchment was determined by comparing the peak flood levels produced by the selected temporal patterns for the durations. The critical duration was selected for each of the three temporal pattern bins indicated in Diagram 1.

No single temporal pattern produced results just above the average of the 10 patterns across the entirety of a catchment. The temporal pattern producing the flood level just above the average across most of the catchment (within 0.1m) was selected. Figure B1 to Figure B4 show the critical duration analysis outlined above for the four catchments for the 1% AEP event only, however the process was also undertaken for the 5% AEP and 20% AEP events, as representative events for each temporal pattern bin shown in Diagram 1. The critical duration variability across the catchment is highlighted on each figure. A description of the 1% AEP critical duration assessment for each catchment is included in Table 9.

Table 9: Critical Duration Assessment 1% AEP event

Catchment	Critical Duration	Notes
City	2 to 12 hour	Critical durations highly variable across the City Domain. In particular, the 3 hour storm is generally critical for the urban area, while the 9 hour storm critical in storage areas (e.g. Flowerdale Storage Area, Wollundry Lagoon).
East Wagga	6 to 12 hour	12 hour storm critical through much of the developed areas, 9 hour storm critical west of Marshalls Creek and the 6 hour storm critical further east in the upstream areas of Marshalls and Gregadoo Creeks.
Lake Albert	1 to 12 hour	1 hour and 3 hour storms critical in urban areas with the 12 hour storm critical in storage areas. The 4.5 hour storm is critical along major flow paths, particularly Crooked Creek and Stringybark Creek.
Wagga North	2 to 12 hour	4.5 hour storm critical along much of the main Dukes Creek channel and flow paths through Booroma, while the 6hr, 9 hour and 12 hour storm produces highest peak flood levels in the open areas south of the Olympic Highway.

The MOFFS model update report (Reference 6) identified the 1, 3, 12 and 24 hour durations as critical for all four catchments using ARR 1987. Thus for comparison purposes, all critical durations have been enveloped for both ARR 1987 and ARR 2019.

7.5. Comparison of Critical Duration Results

The peak flood levels produced using ARR 2019 were compared to those produced using ARR 1987 – both using the updated model as described in Section 4. Figure B5 to Figure B8 show a comparison of peak 1% AEP flood levels produced using ARR 2019 and ARR 1987 methodologies for the four catchments. Figure B9 to Figure B12 show the same comparison for the 5% AEP event.

In all four catchments, ARR 2019 peak flood level results are equivalent to or higher than results produced using ARR 1987. These differences are outlined in detail for the 1% AEP event in Table 10 below, with the 5% AEP event results following similar trends, as can be seen on Figure B9 to Figure B12. In addition to these peak flood level differences, it is noted that the flood extents remain largely unchanged between the ARR 1987 and ARR 2019 results.

Table 10: ARR 2019 Sensitivity (1% AEP Peak Flood Levels)

Catchment	Variations in 1% AEP Event
City	Flood levels largely consistent between ARR methodologies (within +/- 50 mm). ARR 2019 results are generally 0.05 – 0.3 m higher in areas of flood storage, including Wollundry Lagoon and Flowerdale Storage Area.
East Wagga	ARR 2019 results generally 0.05 to 0.4 m higher than ARR 1987 results, particularly in open areas along Marshalls Creek and Gregadoo Creeks. ARR 2019 levels are over 0.4 m higher in the developed areas closer to the Murrumbidgee River.
Lake Albert	Results are generally equivalent (+/- 50 mm) on the flood fringes and areas of shallow affectation, with levels up to 0.1m higher in Lake Albert using ARR 2019. The greatest differences are immediately downstream of Lake Albert where ARR 2019 produces peak flood levels over 0.4 m higher than ARR 1987 levels.
Wagga North	ARR 2019 peak flood levels are up to 0.3 m higher in Duke's Creek and the vacant land south of the Olympic Highway. Peak flood levels produced by ARR 2019 and ARR 1987 are generally consistent through urbanised parts of Boorooma, Estella and Bomen.

7.6. Conclusion

The 2019 revision of Australian Rainfall and Runoff includes a range of up to date methodologies and data for the determination of design flood levels. An assessment has been undertaken to determine the sensitivity of the flood behaviour to the change in methodologies. The recently updated flood models were run using both the ARR 1987 and ARR 2019 methodologies to compare the results using a consistent basis.

The assessment has determined that in general, peak overland flood levels in Wagga Wagga produced using ARR 2019 are 0.05-0.4 m higher than those produced using ARR 1987. It is therefore recommended to utilise ARR 2019 for the Wagga Wagga MOFFRMS&P, as ARR 1987 methodologies are likely to underestimate the flood risk throughout overland catchment areas. The design flood behaviour described in Section 8 has been produced using ARR 2019 methodologies. These design results will form the basis of assessment for floodplain risk mitigation options to be undertaken later in this study.

8. DESIGN FLOOD BEHAVIOUR

8.1. Peak Flood Depths and Levels

The updated hydraulic models were run for the 0.2 EY, 10%, 2%, 1% and 0.5% and 0.2% AEP events as well as the PMF using the ARR 2019 methodologies. Key inputs from the ARR 2019 Data Hub are provided in Appendix C. The peak flood depth results for each event, in each model domain, on Figure 1.5 to Figure 1.12 Sheets A-D.

8.2. Hydraulic Categorisation

Hydraulic categorisation of the floodplain is used in the FRMS&P process as a tool to assist in the assessment of the suitability of future types of land use and development, and the formulation of floodplain risk management plans. The Floodplain Development Manual (Reference 3) defines land inundated in a particular event as falling into one of the three hydraulic categories listed in Table 11.

Table 11: Hydraulic Categorisation Definitions (*Floodplain Development Manual* (Reference 3))

Category	Definition
Floodway	• Those areas where a significant volume of water flows during floods; • Often aligned with obvious natural channels; • Areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which may adversely affect other areas; and • Often, but not necessarily, areas with deeper flow or areas where higher velocities occur.
Flood Storage	• Parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood; • If the capacity of a flood storage area is substantially reduced, for example by the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased; and • Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.
Flood Fringe	• Remaining area of land affected by flooding after floodway and flood storage areas have been defined; • Development in flood fringe areas would not be likely to have any significant effect on the pattern of flood flows and/or flood levels.

To define the floodway, the Howells et al. (Reference 9) methodology has been applied. This method differentiates the floodway from other hydraulic categories by selecting a velocity-depth product criteria that exceeds a specific threshold.

The parameters used to define the floodway, flood storage and flood fringe were consisted across the four model domains. The resulting parameters are provided in Table 12, where V = Velocity (m/s) and D= Depth (m).

Table 12: Floodway Definition Parameters

Waterway	Floodway Definition Parameters
Floodway	a) VD > 0.25 m^2/s AND V > 0.25 m/s; b) or V > 1.0 m/s AND D > 0.01 m
Flood Storage	a) D > 0.2 m
Flood Fringe	Remaining areas not defined by floodway or flood fringe.

In areas subject to mainstream flooding, these parameters would normally be confirmed iteratively through encroachment analysis, in which all areas not defined as 'floodway' would be totally excluded from the modelling domain, and the subsequent impact on flood levels examined. If the reduction in conveyance area resulted in an increase in greater than 0.1 m to existing flood levels, the floodway area was increased. This approach is informed by Section L4 of the Floodplain Development Manual (Reference 3), which defines Flood Storage areas as *"those areas outside floodways which, if completely filled with solid material, would cause peak flood levels to increase anywhere by more than 0.1 m and/or would cause the peak discharge anywhere downstream to increase by more than 10%."*

This approach was not deemed appropriate for the overland catchments in Wagga Wagga as the floodways are typically much more confined, and a much greater proportion of the floodplain is classified as flood fringe due to the presence of shallow overland flow. As such, the impact of blocking out *all* areas of flood fringe and storage using the above method would significantly (and unrealistically) overestimate the peak flood levels within the floodways. The below method of parameter verification was therefore applied as an alternative.

The 2012 paper by Thomas et al. (Reference 10) presented an investigation which observed that "the 'corridor' required to convey approximately 80% of the peak 1% AEP flow correlated well with most of the other parameters that are relied upon to estimate the floodway extent" (e.g. the 0.1 m afflux approach described above). The selected parameters (shown in Table 12) were verified by investigating the percentage of flow (in a particular cross section perpendicular to the direction of flow) conveyed within the floodways in Dukes Creek in the Wagga North domain, Marshalls Creek in the East Wagga domain, and Crooked Creek in the Lake Albert domain. The verification assessment confirmed floodways in these domains met the ~80% total flow criteria described in Reference 10. When applied in the City domain, it was found that floodways (such as through Glenfield Drain) accounted for ~90% of the flow, as the floodways typically occurred in formalised drainage lines through highly developed urban areas, and tended not to be surrounded by areas of flood storage or flood fringe due to their proximity to buildings or other infrastructure (levees, roads etc).

Hydraulic categories for the 0.2% AEP, 1% AEP and 5% AEP events are shown on Figure 1.13A-D to Figure 1.15A-D respectively. The following comments are made about each domain:

City: Floodways in the City domain are typically much narrower than the other catchments, as they occur in formalised drainage lines and are constrained by various buildings or roads. The main floodway is the Glenfield Drain, though a number of its tributaries are also classified as floodway due to the high flow velocities and depths. During larger events (1% AEP) additional floodways are generate along the eastern edge of Glenfield Road, downstream of Ramez Park through to Jack Avenue, along Brookong Ave and Dobney Ave in addition to some of the area within Anderson Oval. A number of flood storage areas occur on sports fields and parks and at the downstream areas around Flowerdale Lagoon, however much of the floodplain is classified as flood fringe as it is relatively slow, shallow flow typical of overland flow behaviour.

Lake Albert: A number of tributaries to Crooked Creek and Stringybark Creek are classified as floodways in the southern half of the Lake Albert model domain. Lake Albert itself is predominantly a flood storage area, with a floodway marked along the eastern side generated from the south eastern corner where Crooked Creek joins the lake. In the northern section of the domain, the overland flow generally spreads out between properties and is predominantly classified as flood fringe, while a well defined drainage line (that eventually joins Marshalls Creek) becomes one of the only floodways moving north. During larger events floodways are more broad along both Stringbark and Crooked Creeks in addition to the areas downstream of Lake Albert Road. Secondary floodways are generated adjacent to Crooked and Stringybark Creeks upstream of Gregadoo Road, upstream and downstream of Holbrook Road on Stringybark Creek and upstream of Brunskill Road, through the football fields.

East Wagga: Marshalls Creek and Gregadoo Creeks form the floodway in the East Wagga domain, surrounded by broad areas of flood storage extending across the relatively flat terrain. During larger events additional floodways form more broadly around Bakers Lane, in addition to the areas downstream of Lake Albert Road. To the north additional floodways are generated along Stuart Road, Kooringal Road and the Highway.

Wagga North: The floodway is generally confined to the Dukes Creek channel and an unnamed creek line running from north to south through Boorooma for both the 1% AEP and 5% AEP events. Additional floodways are generated in larger events in the area to the west of the harness racing facility, through the existing lake area and along Boorooma Street. Majority of the floodplain outside of the channels is classified as flood storage, with broad areas of flood fringe at the upstream ends of the two main flow paths.

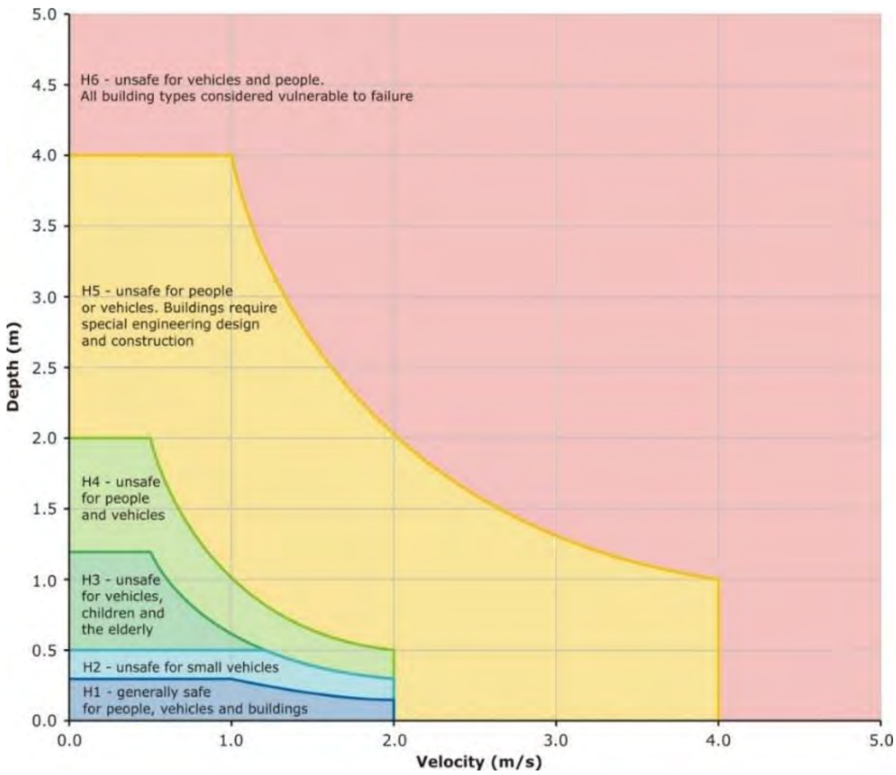
8.3. Hydraulic Hazard Classification

Hazard classification plays an important role in informing floodplain risk management in an area. In the Floodplain Development Manual (Reference 3) hazard classifications are essentially binary – either Low or High Hazard as described in Figure L2 of that document. However, in recent years there has been a number of developments in the classification of hazard especially in *Managing the floodplain: a guide to best practice in flood risk management in Australia* (Reference 8).

For this study Flood Hazard Categorisation mapping has been provided utilising techniques from Reference 8. This approach provides revised hazard classifications which add clarity to the hazard categories and what they mean in practice. The classification is divided into 6 categories which indicate the restrictions on people, buildings and vehicles:

- H1 - No constraints;
- 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; and
- H6 – Unsafe for people or vehicles. All buildings types considered vulnerable to failure.

Diagram 2: Hazard Classifications



Hazard Classifications for the 0.2% AEP, 1% AEP and 5% AEP events are shown on Figure 1.16A-D to Figure 1.18A-D respectively. The following comments are made about each domain:

City: Majority of the City domain floodplain is classified as H1-H2, consistent with the shallow flooding and large areas of flood fringe discussed previously. The Glenfield Drain is amongst the most hazardous parts of the City domain, classified as H5. Consideration should be given to public safety if options to enlarge or modify the Glenfield Drain are investigated later in the MOFFRMS&P.

Lake Albert: Similar to the City domain, majority of the Lake Albert domain is low hazard (H1-2), with Lake Albert itself classified as H5 due to depths that occur within it (consistent with its classification as Flood Storage). The 5% AEP and 1% AEP classifications are generally consistent, with the key flowpaths (towards Marshalls Creek from Lake Albert and Crooked Creek) becoming more hazardous in the rarer event, however much of the remainder of the floodplain remaining unchanged between the two events.

East Wagga: The most hazardous part of the East Wagga domain is Marshalls Creek, classified as H5 from the inflow point from the Lake Albert model, to H6 at its downstream end. The rest of the floodplain is between H1-H3, again consistent with the flood storage/fringe hydraulic categorisation discussed earlier. Areas of H5 occur in the larger events (1% AEP), north of the Sturt Highway, adjacent to Gillard Road and the existing turf farm.

Wagga North: Dukes Creek is classified as H5-H6 in the reaches where it is constrained and channelised (downstream of Boorooma Street, and upstream of Coolamon Road). Between these points the flow spreads out across open land and the hazard classification reduces to H1-H3. Much of the remainder of the floodplain is also in the low hazard constraint range (H1-H3). Areas of H5 occur in the larger events (1% AEP), north of the Olympic Highway, through the Creek reserve in Boorooma.

8.4. Outputs to Assist Emergency Flood Response Planning

8.4.1. Flood Emergency Response Classification

Flooding can result in the isolation of the landscape and the subsequent obstruction of evacuation routes and access to medical/emergency facilities. The Flood Emergency Response classification (FERC) provides a basis for understanding the varying nature, seriousness and scale of these issues, particularly isolation, across the floodplain, and is described in Reference 8.

An earlier version of these classifications, known as Emergency Response Planning (ERP) classifications (Reference 17), was developed by the NSW SES in conjunction with DPIE, and used to classify the riverine floodplain (Reference 4). The Murrumbidgee River floodplain was divided into categories which consider flood affected communities as those in which the normal functioning of services is altered, either directly or indirectly, because a flood causes disruption which results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue.

Key outcomes from the riverine classification included areas such as North Wagga, Gumly Gumly and East Wagga being classified as 'Low Flood Islands', and higher ground along the edges of the floodplain classified either as 'Area with Overland Escape Route' or 'Rising Road Access', indicating that egress (either vehicular or on foot) would be available on the flood fringes.

Following discussions with Council and SES staff involved in this Study, it was decided that there would be limited value in delineating the urban, overland flow areas of Wagga Wagga using the same classifications. The key reasons for this were:

- Relatively short duration of overland flow events limits the potential for isolation;
- Flashy nature of flooding means that safe evacuation is not likely to be feasible; and
- The scale of potential isolation and consequences of flood risk in overland areas is significantly different to that associated with riverine flooding, and it may be misleading to label parts of the overland floodplain with the same classifications, particularly if classifications are used by SES staff or volunteers unfamiliar with the region (particularly during coincident flood events).

Therefore, rather than producing Emergency Response Planning (ERP) classifications or Flood Emergency Response Classifications (FERC), a range of other materials have been produced using results from this Study to assist in the preparation of Emergency Response Plans for overland flow events in Wagga Wagga. These are described below, and feed directly into recommendations in Section 11.1.

8.4.2. Relationship between Rainfall Depth and Duration and Design Flood Behaviour

Design flood behaviour produced in this Study (MOFFRMS&P) is based on rainfall data provided by Australian Rainfall and Runoff 2019 (Reference 2). For each AEP design event, the prescribed rainfall depths are provided for a range of storm durations, from short storms lasting 15 minutes, to sustained rainfall lasting up to 7 days. Earlier sections provides a detailed technical explanation of this aspect of modelling, but broadly, the duration that produces the highest peak flow, or in this case, peak flood levels, is considered the 'critical duration', and is selected for the purposes of design flood modelling. Depending on the catchment characteristics, topography and surface types, different storm durations may be responsible for the highest peak flood levels that occur. In the Wagga Wagga local catchments, three different storm durations contribute to the design flood behaviour (across the full suite of design events): the 2 hour, 6 hour, and 12 hour storms. Figure 4.1 and Figure 4.2(A-D) have been prepared to indicate the depth and duration of rainfall that was used to determine the 10% AEP and 1% AEP design flood behaviour in each of the four model domains developed for MOFFRMS&P.

This information can give insight into the relationship between rainfall and flooding for use internally within emergency response agencies. However, it is important to remember that every flood is different, and a range of factors including antecedent rainfall, spatial distribution and temporal distribution (variation in rainfall depth across the duration of the storm) can affect how rainfall translates into flood behaviour. It is recommended therefore that this information is used only to develop an estimate of the order of magnitude of event that might occur given forecast and observed rainfall, and are not relied upon to predict or respond to flash flooding in the Wagga Wagga region.

8.4.3. Classification of Communities

While the FERC approach is not preferred in overland areas for the reasons described in Section 8.4.1, it is still important and useful to identify parts of the floodplain community subject to the greatest flood risk, so that emergency response resources (including both Council and SES) can be allocated appropriately and so that community education programs can be targeted to the areas at greatest risk.

Eight (8) key areas prone to overland flow flood risk have been identified using the following:

- Peak flood depth and hazard mapping in a range of design event frequencies;
- "First Event Flooded" data from the Flood Damages Assessment;
- Topographic information (LiDAR) to identify trapped low points and depressions;
- Submissions received from affected residents via Community Consultation activities; and
- Information from Council staff.

The key areas at risk during overland events are described in Table 13 below, and are shown on Figure 4.3 along with the 1% AEP flood extent with low tailwater assumption, and the areas newly flooded in a 1% AEP event if the river were at a level of 9.7 m at the Hampden Bridge gauge (10% AEP) shown in red.

Table 13: Overland Flow Flood Risk Areas

Model Domain	Name	Affected Area	Source of Flood Risk	Description of Flood Behaviour and Affectation	Is flood risk exacerbated by elevated river levels?
Lake Albert	Crooked Creek (Upstream of Craft Street)	Properties upstream (south) of Craft Street and southeast of Lake Albert, including areas around Bell Gum Place, Poplar Road, and Gregadoo Road between Olearia Place and Redbank Road	Crooked Creek, and downstream reaches of Boiling Down Creek	Out of bank flow occurs in events greater than and including the 20% AEP event. Properties on the eastern side of Bell Gum Place flooded above floor in 20% AEP and 10% AEP events. Access may be restricted across Craft Street, Gregadoo Road and further south where Crooked Creek crosses Boiling Down Road.	No
	Crooked Creek (Downstream of Brunskill Road)	Residences north of Brunskill Road (downstream of Rawlings Park), including Sycamore Road, Vincent Road and adjoining streets.	Crooked Creek (Sycamore Drain)	In the 10% AEP event and greater, Sycamore Drain overtops Brunskill Road, restricting access. Properties along Sycamore Road are inundated above floor in the 10% AEP event. In the 5% AEP event, Sycamore Road is overtopped.	No
	Stringybark Creek Area	Residences along Stringybark Creek from Springvale Road to Lake Albert Road/Kooringal Road.	Stringybark Creek and overland flow along Plumpton Road	Over-floor inundation occurs at properties on Hakea Place adjacent to the Lake Albert diversion channel in events as frequent as the 20% AEP event. Springvale Drive is also overtopped in this event between Mallee Road and Featherwood Road.	No
City	Wollundry Lagoon Drainage Area	Parts of the CBD that drain to Wollundry Lagoon, including Berry Street between Morgan Street and Tompson Street, O'Reilly Street, Forsyth Street west of Thorne Street, and Morundah Street and Murray Street.	Accumulation of local runoff in trapped low points, delayed drainage to Wollundry Lagoon/ Tony Ireland Park during periods of heavy rain.	A limited number of low-set properties flooded above floor in the 20% AEP event. Road access restricted due to runoff ponding in sag points, however velocity is low in trapped low points compared to the flow paths further south, around Lake Albert.	Yes- when Flood Gate 15A is closed, pumping is required to transfer water from Tony Ireland Park into the river, which can take time, causing flow to back-up over roadways, particularly in O'Reilly Street, increasing flood levels by up to 0.25 m in a 1% AEP event.
	Flowerdale Lagoon Area	Parts of the CBD that are adjacent to the Flowerdale Lagoon area, including Spring Street, Vestey Street, Kincaid Street and surrounds	Accumulation of local runoff in trapped low points, delayed drainage to the Flowerdale Lagoon Pumping area.	Above-floor inundation occurs in a range of events including and more frequent than the 1% AEP. Note that design overland flow results are based on the assumption that Flood Gate No. 1 would be closed, and Flood Gate No. 2 open (in accordance with the operation procedure).	Flood Gate No. 2 (Flowerdale Lagoon at Kincaid Street) is closed when the river reaches 8.5 m at the Hampden Bridge Gauge (lower than a 20% AEP event (9.1 m)). Pumping is needed to drain this area, however while this occurs local rainfall and runoff accumulates and ponds across a greater area.
	Turvey Park Overland Flow Path	Parts of Turvey Park between Urana Street and the railway line (mainly residential)	Local runoff from Willans Hill and south	Low set properties along the flow path between Urana Street and the railway line are flooded in the 20% AEP event. Short duration ponding occurs at sag points, including the intersection of Urana Street and Macleay Street, and Trevor Street and Wooden Street.	No – runoff along this flow path is not sensitive to whether the levee gates are open or closed.
	Glenfield Road Industrial Areas	Commercial and industrial properties along Glenfield Road, upstream and downstream of the railway embankment, particularly at the Dobney Avenue Roundabout where Glenfield Drain makes a 90-degree turn to the west.	When the capacity of Glenfield Drain is exceeded flow can break out and inundate surrounding streets and properties.	Relatively few properties are flooded above floor in events more frequent than a 5% AEP, however Glenfield Road is overtopped (near the Dobney Avenue roundabout) in a 20% AEP event.	No – runoff along this flow path is not sensitive to whether the levee gates are open or closed.
East Wagga	East Wagga Industrial Area	Commercial and Industrial properties along both sides of Hammond Avenue between Marshalls Creek and Blaxland Road (approx.)	Marshalls Creek, Gregadoo Creek, Murrumbidgee River	Generally, properties have been constructed 0.5 m above the 5% AEP riverine peak flood level, however are likely to be flooded above floor in a 2% AEP overland flow event.	Yes – even in a 20% AEP riverine event (9.1 m at the Hampden Bridge Gauge), out of bank flow from the Murrumbidgee River affects parts of East Wagga (particularly north of Hammond Avenue).

The susceptibility of these areas to flood risk may change over time as structural flood modification measures are installed, and will warrant reassessment in the future. In particular, modifications to Lake Albert and the diversions from Crooked Creek and Stringybark Creek will have major benefits for properties along both creeks, and downstream within the East Wagga area, and significantly reduce the flood risk to which these areas are subject.

It is noted also that no 'at-risk areas' have been identified within the Wagga North area (Dukes Creek catchment), as a result of the Dukes Creek floodplain being largely constrained to the south of the Olympic Highway, and residential properties located away from flowpaths draining towards the creek. Localised shallow runoff does affect some streets in the Estella and Boorooma regions, but not to the degree that causes over-floor property inundation or prolonged periods of flooded roads that pose flood risk to motorists.

8.4.4. Locations of Community Assets

The NSW Emergency Management Plan, EMPLAN, contains a register of community assets, including vulnerable facilities such as pre-schools, primary schools, high schools, aged care facilities and hospitals (including contact details and the number of enrolments/beds) and utilities such as telecommunication exchanges and gas stations. For ease of use, the community assets listed in the register have been mapped as part of this Study (MOFFRMS&P) and are provided as Figure 4.4. Additional assets were identified via the Wagga Wagga Community Directory (https://www.mycommunitydirectory.com.au/ New_South_Wales/Wagga_Wagga), including childcare centres and aged care services.

Figure 4.4 shows the location of assets in relation to the overland flow PMF extent, and the riverine PMF extent, defined in Reference 7. Knowing the locations of community assets is essential to understanding the facilities that may be at risk, and also identifying facilities that could potentially serve as evacuation centres (if flood-free access is available).

It is noted also that as many community facilities are commercial services or premises, regular updates are required to ensure the asset register remains current.

8.4.5. Changes in Flood Behaviour During "Dual Threat" Events

A "Dual Threat" event refers to an event where local rainfall coincides with elevated water levels in the Murrumbidgee River, to the point where levee gates are closed and internal drainage is restricted. Although rare, elevated river levels can coincide with substantial local rainfall and when this happens, significant flooding can occur. On the 2nd of December 2010, approximately 65 mm of rain fell over a period of two to three hours in the afternoon. At the time the river level was approximately 7 m (and as such between a 2Y and 5Y ARI level). Due to a river flood level prediction of 9.7 m (at the Hampden Bridge Gauge) all operable gates had been manually shut (this excludes the flap gated culverts at the Flowerdale Storage Area (FSA)). Significant flooding occurred across Wagga Wagga, including (but not limited to) the CBD, Turvey Park, Lake Albert, Springvale and East Wagga Areas.

As noted in Reference 6, no high resolution rainfall data was available for the event, however given the recorded depth and the two to three hour duration, the AEP of the 2010 event was estimated as being between 10% and 5%. Council staff indicated that the flooding was similar to the 1% AEP (overland flow) design flood information previously provided, although this used a 2Y ARI tailwater level in the river).

Following the analysis provided in the model update and design flood modelling, it was deemed appropriate to apply a 2Y ARI tailwater level (6.96 m at the Hampden Bridge Gauge) when defining design flood behaviour in the local catchment, and for use in development planning. However, given the potential consequences of a coincident flood event, it is considered reasonable for emergency response agencies (and the community) to understand the differing risks that may occur in overland flow areas when levee gates are closed, and to develop plans for both ‘high river’ (i.e. when levee gates are closed) and ‘low river’ (levee gates open) scenarios.

Impact mapping has been provided to show how design flood behaviour in the Study Area is affected by elevated tailwater levels in the Murrumbidgee River. The figures compare the “base case” 1% AEP overland flow flood depths (with a 2 year ARI tailwater level (8 out of 32 gates closed)), with the depths that would occur if the same event coincided with a 10% AEP tailwater level (9.7 m at the Gauge, all 32 gates closed).

As shown in the figures and as described in Table 13, the area’s most sensitive to elevated river levels are those directly connected to the key pumping areas, including the Flowerdale Lagoon area, where 1% AEP levels are increased by approximately 0.8 m when levee gates are closed, and the Berry Street flowpath towards Tony Ireland Park, where levels would be elevated by 0.2 m. It is noted that the 10% AEP tailwater scenario assumes that pumps would not be operational, in order to give a picture of the ‘worst case’ internal flooding that might occur.

The northern most parts of the East Wagga model domain are highly sensitive to elevated river levels, both due to out-of-bank flow from the Murrumbidgee River inundating low lying parts of East Wagga, and due to flows backing up in Marshalls Creek. Peak flood levels in the 1% AEP overland flow event are likely to be up to 0.6 m higher on the western side of Marshalls Creek, while flood levels on the eastern side of the creek are less sensitive, increasing by less than 0.1 m. Looking further south however, it is evident that the influence of the tailwater levels does not extend south of the railway line, indicating that elevated levels in Marshalls Creek are unlikely to impact on flood behaviour further upstream (in the Lake Albert model domain). Even in an 0.5% AEP riverine event (11.8 m at the gauge), flow moving northwards from Crooked Creek and Stringybark Creek is not impacted by the downstream tailwater conditions. This is due to a significant drop in elevation in the topography north of Laurel Road, where ground levels in the East Wagga domain are approximately 12 m lower than ground levels at the northern end of the Lake Albert model domain.

9. EXISTING FLOODPLAIN RISK MANAGEMENT

Overland flow has been an ongoing issue in Wagga Wagga for many years, and Council has implemented several strategies to manage the flood risk associated with overland flow. Some examples of this include formalising drainage lines such as the Glenfield Drain and Ashmont Drain, and using playing fields as detention basins, including Bolton Park and parts of Jubilee Park, for example. In addition to these, discussions with Council and the Floodplain Risk Management Advisory Committee over the past studies have raised suggestions of a range of mitigation options for investigation. These include the sustainable removal of debris and vegetation in Flowerdale Lagoon, diversion of Glenfield Drain (from upstream of the railway line via supplementary pipe/drain to Ashmont Drain) and installation of a pipeline from upstream of the Sturt Highway on Glenfield Drain to downstream of Flowerdale Lagoon levee. There has been much discussion around utilising Wollundry Lagoon and Lake Albert for flood mitigation purposes whilst meeting operational and aesthetic/recreational objectives, which will be reviewed in detail in the subsequent stages of this study. In addition, suggestions received from the community (described in Section 5) have been included in the options assessment.

It is noted that in urbanised areas, it is often difficult to find space to construct a new flood risk mitigation infrastructure (such as levees or basins), and underground piping options for example can be extremely costly and disruptive to existing buildings and residents. In many cases, planning controls are a more feasible method of reducing the long term flood risk in urban areas. In addition to considering the flood modification options described above, this study reviews existing flood planning documents and makes recommendations that allow for appropriate development in Wagga Wagga whilst ensuring all development is compatible with the flood risk in which it is located. An overview of the existing policy context is provided in the following sections. Later sections contain recommendations in relation to planning policy.

Flood risk management also encompasses the ways in which the community prepares for, responds to and recovers from flooding. This study will assess a range of response modification measure, including review of current flood warning procedures, community awareness and education needs, Council and SES action plans, and evacuation routes/centres, aiming to identify opportunities for improvement applicable in Wagga Wagga.

9.1. Current Planning Context

Wagga Wagga City Council (Council) is responsible for local planning and land management in the Wagga Wagga LGA, including the management of the floodplain and drainage systems. The planning policies held and used by Council in their management of the floodplain are underpinned and bound by National and State Planning Legislation. It is important to understand the National and State context prior to making recommendations for Council to amend its own local planning policies to ensure that any changes are consistent with the requirements of state and national legislation. An overview of the national and state planning instruments is provided below to provide this background. It is noted also that NSW State Planning Legislation and local Council policies and plans apply consistently to the Wagga Wagga MOFFRMS&P Study Area, which falls entirely within the Wagga Wagga Local Government Area.

9.2. National Planning Provisions

9.2.1. 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. Section 3.1.2.3 refers specifically to drainage of surface water and finished slab heights, and contains the requirements shown overleaf:

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.

Building Code of Australia (Reference 1)

3.1.2.3 Surface water drainage

Surface water must be diverted away from Class 1 buildings as follows:

(a) Slab-on-ground — finished ground level adjacent to buildings:
the external finished surface surrounding the slab must be drained to move surface water away from the building and graded to give a slope of not less than (see Figure 3.1.2.2):
- (i) 25 mm over the first 1 m from the building in low rainfall intensity areas for surfaces that are reasonably impermeable (such as concrete or clay paving); or
- (ii) 50 mm over the first 1 m from the building in any other case.

(b) Slab-on-ground — finished slab heights:
the height of the slab-on-ground above external finished surfaces must be not less than (see Figure 3.1.2.2):
- (i) 100 mm above the finished ground level in low rainfall intensity areas or sandy, well-drained areas; or
- (ii) 50 mm above impermeable (paved or concreted areas) that slope away from the building in accordance with (a); or
- (iii) 150 mm in any other case.

9.3. State Planning Provisions

9.3.1. 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 overleaf:

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.

9.3.2. 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, Industry and Environment 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.

9.3.3. 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 with 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.

9.3.4. 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 (as referred to in Ministerial Direction 4.3, Clause 4, presented in Section 9.3.2).

The changes follow community concern over notations about low flooding risk being included on Section 10.7 Planning Certificates *[formerly known as Section 149 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".*

9.3.5. 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, or *"advice on other such relevant matters affecting the land of which it may be aware" (EP&A Act, 10.7 (5)).*

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

The aims of State Environmental Planning Policy (Exempt and Complying Development) (SEPP) 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.

Part 3 of the SEPP contains standards relating to development in flood control lots. This is described below.

9.3.7. 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****.*

9.3.8. 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 9.3.7, 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)*

9.4. Local Planning Provisions

9.4.1. Local Environmental Plan

Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages and risk to life.

Environmental Planning Instruments (EPIs) such as Local Environmental Plans (LEP) guide land use and development by zoning all land and identifying appropriate land uses allowed in each zone. LEPs are used as tools to guide new development away from high flood risk locations and ensure that new development does not adversely affect flood behaviour. LEPs can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

LEPs are made under the EP&A Act. In 2006, the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to. Wagga Wagga LEP 2010 was prepared under the Standard Instrument LEP program. Clause 7.2 of Wagga Wagga LEP 2010 relates to flood planning and states:

Wagga Wagga LEP 2010: Clause 7.2 Flood Planning

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to:

(a) land that is shown as "Flood planning area" on the Flood Planning Map, and

(b) other land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the NSW Government's Floodplain Development Manual published in 2005, unless it is otherwise defined in this clause.

(5) In this clause:

flood planning level *means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.*

flood planning map *means the Wagga Wagga Local Environmental Plan 2010 Flood Planning Map*

Editorial note. When this Plan was made there was no Flood Planning Map.

9.4.2. Wagga Wagga Development Control Plan 2010

Section 4.2 of Wagga Wagga Development Control Plan (DCP) 2010 is titled "Flooding" and applies to land that is identified as flood prone. The DCP notes that the section *"is based on the terminology and recommendations of the Wagga Wagga Floodplain Risk Management Study 2009".* The DCP is based around the flood risk precincts, identified in the FRMS, reproduced below overleaf:

Flood risk precinct	Levee	Flood risk
Central Wagga	Protected by levee	Low
Central Wagga	Not protected by levee	High
North Wagga	Protected by levee	High
Gumly/Oura/Collingullie	N/A	High
Rural floodplain	N/A	Low
Rural floodplain	N/A	High
Eastern Industrial	N/A	Medium

The stated objectives of the flood related development controls are:

O1 Minimise the public and private costs of flood damage.
O2 Minimise the risk of life during floods by encouraging construction and development that is "flood proofed" and compatible with the flood risk of the area.
O3 Ensure that development and construction are compatible with the flood hazard.
O4 Require compatibility with the Floodplain Development Manual 2005 as relevant.

The DCP then stipulates objectives, controls or conditions for each precinct, tailored to development use and specified flood risk (low, medium or high). Controls may relate to floor levels, structural soundness, management and design, flood affectation, and evacuation.

The above listed precincts do not include areas subject only to overland flow flood risk (ie southern parts of the City, areas around Lake Albert, or within the Dukes Creek catchment on the northern side of the Murrumbidgee River.

At the time of writing, Wagga Wagga City Council was undertaking a review of the Development Control Plan – Section 4.2, in order to incorporate recommendations from the recently completed Riverine FRMS (Reference 7) and make general improvements in regards to the clarity and defensibility of the controls included therein.

9.5. Existing Emergency Response Plans

Table 14 provides an overview of the emergency response plans and policies that apply to different types of flooding within the Wagga Wagga LGA. These are described in more detail in the subsequent sections.

Table 14: Flood related emergency response plans for Wagga Wagga

Report Section	Title	Applies to:	Flood Mechanism
9.5.1	Wagga Wagga Local Flood Plan	NSW SES	Riverine
9.5.2	Wagga Wagga Local Emergency Management Plan	All relevant emergency response agencies (including NSW SES, Wagga Wagga City Council)	Riverine Flash Flooding Storms
9.5.3	Draft Wollundry Lagoon Operational Regime	Wagga Wagga City Council	Overland Flow
9.5.4	Draft Flood Emergency Operational Response Plan	Wagga Wagga City Council	Riverine

9.5.1. Wagga Wagga Local Flood Plan, NSW SES, 2006 (Reference 14)

The Wagga Wagga Local Flood Plan *"covers preparedness measures, the conduct of response operations, and the coordination of immediate recovery measures from flooding within the Wagga Wagga City Council area. It covers operations for all levels of flooding within the council area."* (Reference 14).

The plan specifically relates to mainstream flood risk from the Murrumbidgee River, and acknowledges the risk of overland flow affectation in the Central Wagga Wagga area (i.e. inside the main city levee) when the river is elevated:

"Storm water runoff within Central Wagga Wagga cannot drain during floods due to the obstruction of the levee, hence resulting in ponding inside the levee. To manage this problem the Wagga Wagga City Council maintains and operates various pumping stations around Central Wagga Wagga." (Reference 14).

No further details are provided regarding overland flow affectation in Wagga Wagga, nor discussion of overland flow flood risk when the river level is low enough to allow free drainage of leveed areas.

Section 11.1.1 provides recommendations for the inclusion of information about overland flow flood risk, based on the modelling and analysis undertaken in this Study (MOFFRMS&P).

9.5.2. Wagga Wagga Local Emergency Management Plan, June 2015 (Reference 14)

The Wagga Wagga Local Emergency Management Plan (EMPLAN) has been prepared by the Wagga Wagga Local Emergency Management Committee in compliance with the State Emergency & Rescue Management Act 1989. The EMPLAN details arrangements for prevention of, preparation for, response to and recovery from emergencies within the Wagga Wagga Local Government Area.

The EMPLAN provides an introduction to the Wagga Wagga region, its topography, climate, land use, population data, major transport routes and an overview of the economy and industry. A Local Emergency Risk Management (ERM) Study, undertaken by the Wagga Wagga Local Emergency Management Committee (LEMC), (date not provided) identified the hazards that "*have risk of causing loss of life, property, utilities, services and/or the community's ability to function within its normal capacity.*"

Amongst a range of hazards, the ERM identified riverine and flash flooding as hazards in Wagga Wagga, with the risk characteristics identified in Table 15.

Table 15: Wagga Wagga Hazards and Risks Summary (Reproduced from Reference 14)

Hazard	Risk Description	Likelihood Rating	Consequence Rating	Risk Priority	Combat /Responsible Agency
Flood (Flash)	Heavy Rainfall causes excessive localised flooding with minimal warning time	Unlikely	Major	High	NSW SES
Flood (Riverine)	River flows exceed the capacity of normal river systems resulting in flood waters escaping and inundating river plains	Almost Certain	Catastrophic	Extreme	NSW SES
Storm	Severe storm with accompanying lightning, hail, wind, and/or rain that causes severe damage and/or localised flooding. (Includes tornado)	Almost Certain	Major	Extreme	NSW SES

The EMPLAN does not contain specific instructions, actions or guidance for "what to do in the event of a flood", but rather summarises all hazards that may apply to Wagga Wagga, and points to the relevant sub-plan or policies that supplement the EMPLAN itself. In regards to flooding, the EMPLAN lists the 'Wagga Wagga Flood Plan' as the supporting plan. This is assumed to be the Wagga Wagga Local Flood Plan (Reference 14) described in Section 9.5.1.

The EMPLAN contains a register of community assets, including vulnerable facilities such as pre-schools, primary schools, high schools, aged care facilities and hospitals (including contact details and the number of enrolments/beds) and utilities such as telecommunication exchanges and gas stations. Community assets listed in the register (and additional assets listed in an online community directory) have been mapped as part of this Study (MOFFRMS&P) and are provided as Figure 4.4, and are discussed further in Section 8.4.4 of this report.

The EMPLAN is required to be reviewed by the Wagga Wagga Local Emergency Management Committee (LEMC) every three years, or following any:

- Activation of the Plan in response to an emergency;
- Legislative changes affecting the Plan; and
- Exercises conducted to test all or part of the Plan.

9.5.3. Draft Wollundry Lagoon Operational Regime, Wagga Wagga City Council (no date) (Reference 15)

Wollundry Lagoon has a catchment of 3.57 km^2 (Reference 15) and plays a major role in the retention of stormwater from the Turvey Park and Central Wagga Wagga drainage systems. The lagoon has been highly modified from its natural state, with the installation of bridges, stormwater infrastructure and the removal of remnant vegetation from its banks. It currently provides a number of beneficial functions to the community, including:

- focal point for an extensive recreational reserve stretching through the centre of the township;
- habitat for fauna;
- water storage for park irrigation;
- the operation of the heat exchange coils for the Civic Centre air conditioning system;
- major detention pond for the city's stormwater drainage system; and
- a pollution trap for the urban stormwater catchment it serves, protecting the receiving waters of the Murrumbidgee River.

The lagoon discharges to the Murrumbidgee River via a number of mechanisms and has the following outlet arrangements:

- Eastern weir with top level of 177.1 mAHD;
- Outlet structure contains a 1200 mm pipe that conveys flow to the lagoon Tony Ireland Park (Cnr Tompson Street and Tarcutta Street);
- Outlet structure with three penstocks that can be lowered to achieve an invert level of 176.5 mAHD (to be confirmed by WWCC);
- Pump installed at the eastern end that can pump water directly up Cross Street and into the Murrumbidgee River;
- Temporary Weir located beneath Ivan Jack Drive bridge.

In the event of a high river and impending rainfall, the volume of water in the lagoon is reduced to increase the storage capacity. This is completed by either lowering the penstocks, pumping the water along Cross Street (and out to the river), or a combination of both. The level in Tony Ireland Lagoon can be lowered using the pump at Levee Gate 15A. The Wollundry Lagoon Operation Regime notes the importance of monitoring the level in Tony Ireland Lagoon to ensure water does not overflow back into Wollundry Lagoon.

9.5.4. Draft Flood Emergency Operational Response Plan, Wagga Wagga City Council, Revised March 2017, (Reference 16)

The NSW SES is the legislated Combat Agency for floods and is responsible for the control of flood operations. This includes the coordination of other agencies and organisations for flood management tasks. The SES Local Controller is responsible for dealing with floods as detailed in the State Flood Plan. In addition to the role of the NSW SES, Wagga Wagga City Council plays a significant role in ensuring the safety of its community in times of emergency. This involves the preparedness of the organisation in the lead up to an event such as a flood, its response, integration with other emergency services and recovery from the event.

The Draft Flood Emergency Operational Response Plan details the assistance provided to the community through the engineering capabilities of the Council, primarily in times of flood. Council's Delivery and Operational Plans specify that Council is required to:

- Collaborate with local emergency organisations to ensure effective emergency and disaster plans are in place;
- Lead and support the Local Emergency Management Committee; and
- Partner with State Government to manage the Wagga Wagga district floodplain;

The Flood Emergency Operational Response Plan relates specifically to riverine flooding in the Murrumbidgee River, and details the necessary actions and required resources depending on the predicted peak flood level (in metres at the Hampden Bridge Gauge).

A key role of Wagga Wagga City Council is to allocate pairs of staff to undertake continuous levee inspections of the Main City Levee and North Wagga Levee (ceasing when the river reaches a gauge height of 9.0 m), as well as daily inspections of the Gumly Gumly and Uranquinty levees.

It is noted that if a 'moderate flood' is forecast, i.e. predicted gauge height of 9.0 m – 9.6 m "Commercial Operations shall operate a 24 hours duty roster with operators, plant and trucks being available at short notice. Rain and internal runoff shall require additional Operations staff to man pumps and adjust flood gates. The Operations Section shall arrange the mobilisation of the necessary workforce. Usually a crew of 5-6, plus an engineer operates at North Wagga Wagga on 2 x 12 hour shifts, with the remainder of the Outdoor staff on a similar roster working out of the Fernleigh Road Depot."

In a major flood (over 9.6 m at the gauge), the intensity of levee inspections increases as the risk of levee failure increases. Ten pairs of levee inspectors are required to operate in approximately 500-600 m lengths, checking both the levee condition and any flood gates within their section continuously.

The field response by operational staff in the event of an emergency includes staffing, plant and equipment to undertake the response as required by the relevant combat agencies. This will be considered based on the capability of the plant available and the skills and training of the Council staff. The Plan notes that usage of PPE and fatigue management of the work crews is paramount in ensuring the safety of staff and the public.

Table 16: WWCC Operational Response (Reproduced from Table 5.1, Reference 16)

Situation	Response	Comment
Major Accident causing Traffic Disruption	Traffic control assistance Clean up of debris Repair of damaged roads/assets	Council may be required to assist the Police or RMS subject to the extent of the accident
Flood Event	Provision of staffing, plant and equipment to implement this Plan including assisting the SES, Police and the Community. Clearing of blocked drains Provision of sand bagging materials Clean up of public areas, roads and bridges Assessing damage to assets Inspection and maintenance of the levee Maintain the control and operation of floodgates Provide traffic control services at road closures Maintain road closures across LGA Install, maintain and control SW pumps as necessary across the city and LGA	Liaise with SES Controller
Storms	Provision of staffing, plant and equipment to implement this Plan including assisting the SES, Police and the Community Clean up of public areas Assessing damage to assets	Liaise with SES Controller
Fire	Provision of staffing, plant and equipment to implement this Plan including assisting the RFS, Police and the Community.	Liaise with RFS

The Flood Emergency Operational Response Plan highlights the demands on Council's resources during a mainstream event. Section 8.4 and 11.1 of this report provide information and recommendations that aim to assist in Council's management of overland flow flood risk without significantly increasing the burden on Council staff. This is particularly important during a mainstream event, as highlighted by the response requirements in a riverine event outlined above.

10. ECONOMIC IMPACTS OF FLOODING

10.1. Overview

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. This report describes the factors that contribute to flood damages, and the methodology used to undertake the damages assessment for the Wagga Wagga Major Overland Flow Floodplain Risk Management Study & Plan (MOFFRMS&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.

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.

10.2. Flood Damage Categories

The Floodplain Development Manual (Reference 3) 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:

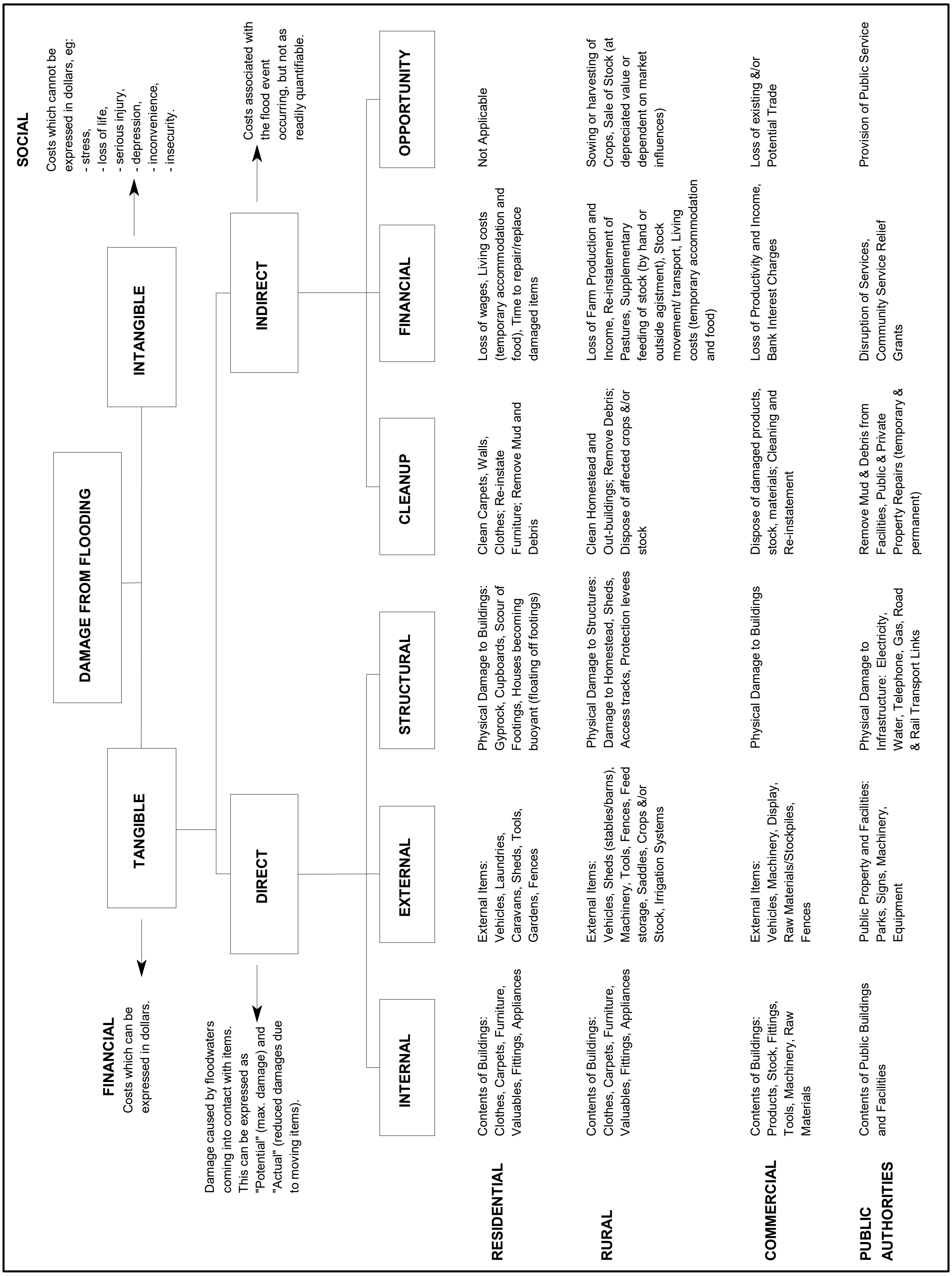
- Intangible damages are difficult, if not impossible to quantify in financial terms, and may include:
    - o increased levels of emotional stress and mental and physical illness caused by the flood episode;
    - o Sense of loss and despondency caused by the destruction of memorabilia (family photographs and documents) or loss of pets;
    - o Stress caused by additional (and at times quite large) financial outlays to replace flood damaged possessions; and
    - o 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 3. 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:

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

There are a range of other direct, tangible damages that are not included in the assessment as there is insufficient data, or no clear assessment methodology currently available. 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 3: Flood Damage Categories



10.3. Floor Level Data

A key outcome of the current study is a flood damages assessment. To complete this aspect of the study, floor level estimates are required to undertake a broad assessment of flood affectation. While the assessment uses floor level data for individual properties, the results are not an indicator of individual flood risk exposure but part of a regional assessment of flood risk exposure. For each property, the floor level estimation captured the following descriptors:

- Ground Level (in mAHD);
- Indication of house size (number of storeys);
- Location of the front entrance to the property; and
- Local Environmental Plans (LEP) land use (residential, commercial, industrial, primary production, or public recreation and infrastructure).

Typically a floor level database would include all properties within the PMF extent. In the Wagga Wagga overland catchments however, this would amount to over 20,000 properties, many of which would be subject to only very shallow flooding. To manage the time and cost associated with developing the data base, floor levels were estimated for all properties within the 1% AEP extent, which was trimmed to exclude flood depths of less than 150 mm. It was found that the average floor height of dwellings in this extent was 0.26 m, so the assumption that properties affected by depths less than 150 mm would not be flooded over-floor was deemed appropriate. In addition, the Building Code of Australia stipulates that slab-on-ground constructions must be a minimum of 150 mm above ground. This further supports the exclusion of properties affected by less than 150 mm from the internal flood damages assessment. While this may exclude some low-set commercial premises (i.e. warehouses), the approach is considered to provide a reasonable level of detail in light of the overall study objectives for this Floodplain Risk Management Study.

The external flood damages (that is, damage to garages, carports etc), were assessed across the entire PMF extent for each model domain, using the building footprint layer developed as per Section 6.2.5. The building footprint was buffered (expanded) by 5 m, and the peak flood depth occurring within this polygon (in each design event) was taken as the representative depth. This methodology and assessment results are described in detail in this report.

Where available, floor level data was taken from the database established in the riverine FRMS (Reference 7). Due to the large number of properties that require floor level estimates within the City domain, the Riverine FRMS used a sample population to determine the average floor level height above ground for properties within the levee. This information was then combined with LiDAR data to estimate floor levels for all properties. The resulting floor levels were reviewed to confirm suitability for use in the current study. In addition to this, WMAwater used LiDAR data and visual inspection to estimate floor levels for all properties within the PMF extent. A summary of the total floor level estimates is provided in Table 4.

Table 17: Floor Level Database

	Internal Damages Assessment			External
Property Type Model Domain	Residential	Non-Residential	Total (Internal)	No. Properties included
City	2,217	511	2,728	13,181
Lake Albert	1045	25	1070	6,226
Wagga North	43	12	55	1,001
East Wagga	38	252	290	893
Total	**3343**	**800**	**4143**	**21,301**

10.4. 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 10.6 describes the process of determining financial losses.

Available floor levels, ground levels and peak flood levels were analysed to identify a representative flood depth for each property in each design event. Floor levels were adopted from the estimation techniques described in Section 10.3. The ground level was extracted from the digital elevation model 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. For the estimation of external damages, the peak flood depth within 5 m of the building footprint was taken as the representative flood depth. This was done to ensure that flood depths were not overestimated in large lots where there may be a gully or watercourse through the cadastral lot that is well away from garages, carports or possessions in the backyard.

It is noted the approach is somewhat limited in that it does not necessarily account for variations in water level across a property due to undulating ground levels, or factors that local raise flood levels such as wave action, wind setup or local surge. 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.

10.5. Tangible 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 Department of Planning Industry and Environment (DPIE) has carried out research and prepared a methodology (Reference 11) 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.

10.5.1. Residential Damages

As described in Reference 11, several 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 they have contributed to the development of the DPIE residential flood damage curve, which has been applied in this damage assessment. Diagram 4 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 Diagram 5. 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 Diagram 5, 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.

Diagram 4: Residential Damage Curve (House on a Slab)

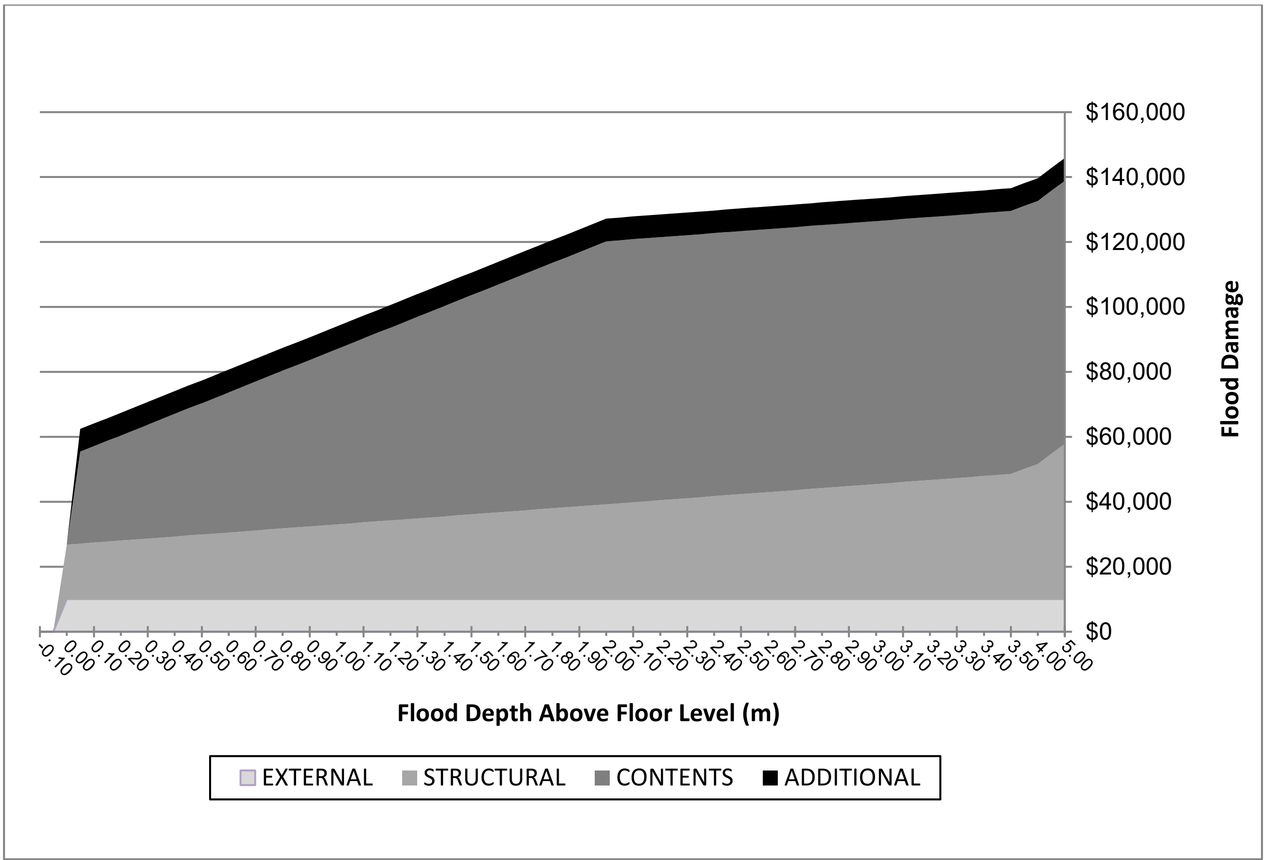
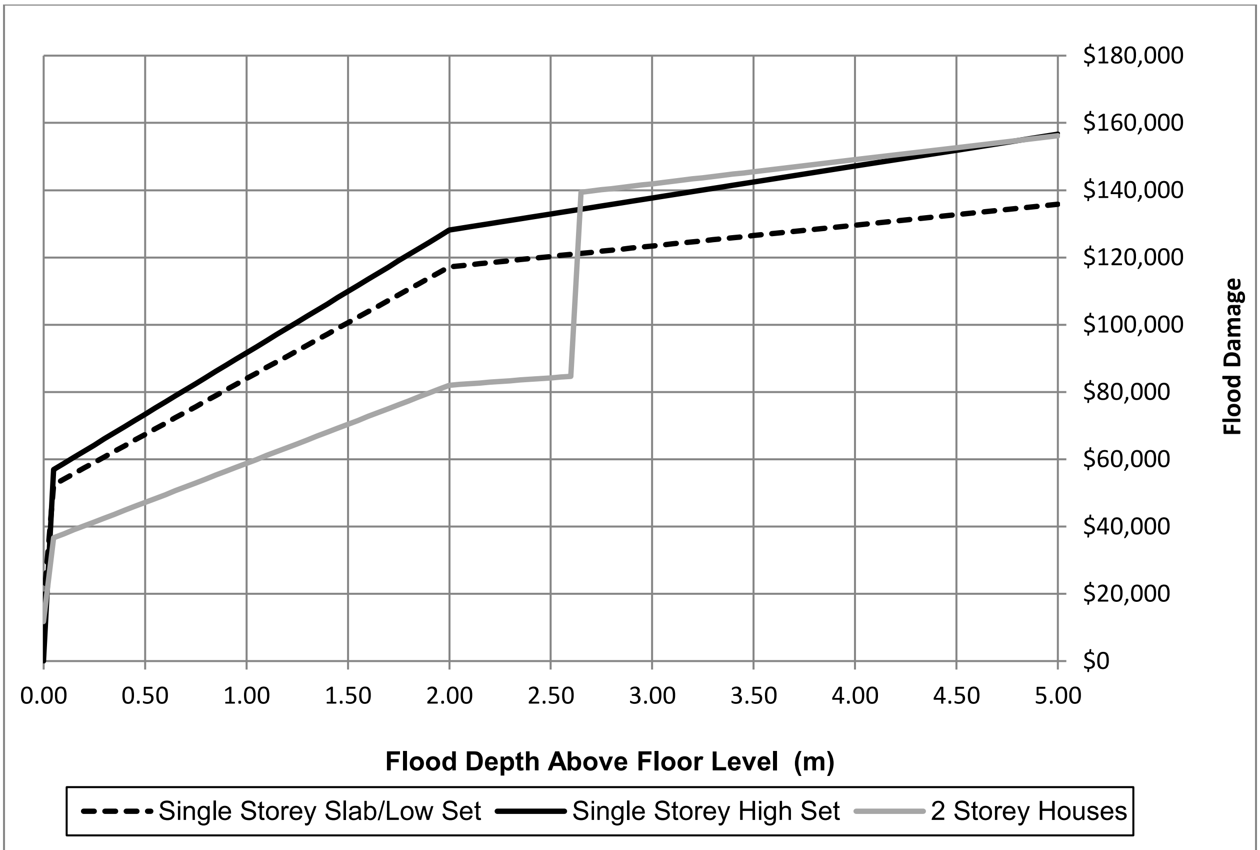


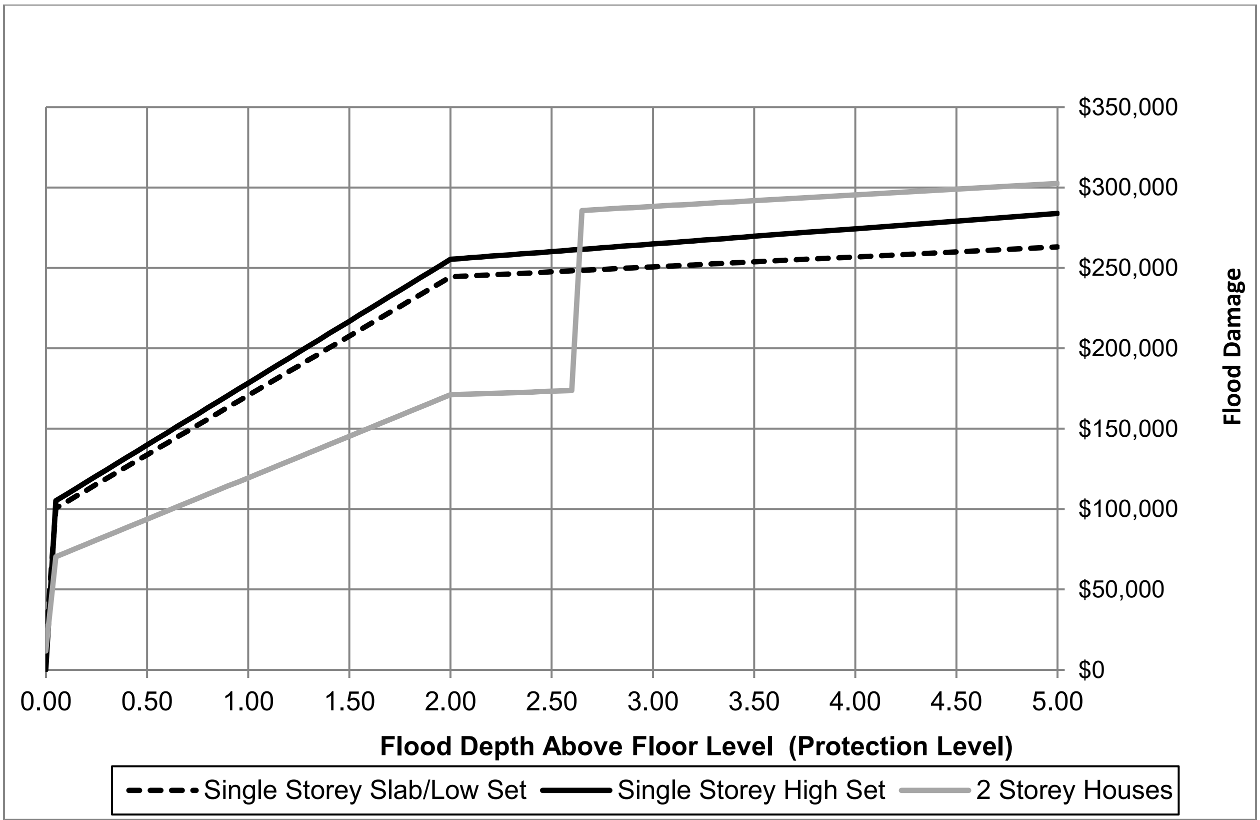
Diagram 5: Residential Damage Curves



10.5.2. 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 6: Flood Damages Curves – Commercial Property



10.6. Expressing Flood Damages

10.6.1. Annual Average 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 considering 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 Wagga Wagga, the 0.2 EY event was the smallest (most frequent) flood event modelled.

10.6.2. 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 2.1A-D show the frequency of over floor flood affectation due to overland flooding in each model domain. The coloured dots on each property indicate the event in which properties are first affected over floor, thereby giving an indication of frequently affected properties.

10.7. Results

10.7.1. Overall

A summary of the residential, non-residential and combined flood damage assessment for Wagga Wagga (across all four overland model domains) is shown in Table 18 to Table 20 below.

Table 18: Residential Flood Damages for Wagga Wagga

Event	No. Properties Affected [(1)]	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	5292	112	$ 29,502,000	31	$ 5,600
10% AEP	5949	173	$ 35,849,000	23	$ 6,000
5% AEP	6514	233	$ 42,232,000	14	$ 6,500
2% AEP	6991	383	$ 53,574,000	11	$ 7,700
1% AEP	7492	515	$ 64,390,000	6	$ 8,600
0.5% AEP	7945	637	$ 75,512,000	5	$ 9,500
0.2% AEP	8363	746	$ 87,197,000	5	$ 10,400
PMF	11310	1420	$ 176,311,000	5	$ 15,600
Average Annual Damages (AAD)			**$ 12,528,000**		**$ 1,100**

NOTE (1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

Table 19: Non-Residential Flood Damages for Wagga Wagga

Event	No. Properties Affected[(1)]	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	656	23	$ 5,477,000	23	$ 8,300
10% AEP	776	52	$ 8,919,000	21	$ 11,500
5% AEP	886	84	$ 12,634,000	16	$ 14,300
2% AEP	1040	218	$ 30,477,000	18	$ 29,300
1% AEP	1135	261	$ 37,682,000	9	$ 33,200
0.5% AEP	1185	296	$ 43,660,000	5	$ 36,800
0.2% AEP	1255	333	$ 50,109,000	4	$ 39,900
PMF	1624	542	$ 96,860,000	4	$ 59,600
Average Annual Damages (AAD)			**$ 3,557,000**		**$ 2,200**

NOTE (1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

Table 20: Combined Flood Damages for Wagga Wagga

Event	No. Properties Affected[1]	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	5948	135	$ 34,979,000	33	$ 5,900
10% AEP	6725	225	$ 44,768,000	25	$ 6,700
5% AEP	7400	317	$ 54,866,000	15	$ 7,400
2% AEP	8031	601	$ 84,051,000	13	$ 10,500
1% AEP	8627	776	$ 102,072,000	6	$ 11,800
0.5% AEP	9130	933	$ 119,172,000	3	$ 13,100
0.2% AEP	9618	1079	$ 137,306,000	2	$ 14,300
PMF	12934	1962	$ 273,171,000	3	$ 21,100
Average Annual Damages (AAD)			**$ 16,085,000**		**$ 1,200**

NOTE (1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

10.7.2. City Damages

The flood damages assessment results for the City are provided in Table 21 to Table 22 below. The results indicate that relatively frequent flood events, especially the 10% AEP and 0.2 EY events, constitute over 50% of the residential and non-residential annual average damages (AAD). It is also notable that many more properties are subject to external inundation (e.g. in 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 21: Residential Flood Damages (City)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	3571	71	$ 19,853,000	36	$ 5,600
10% AEP	4010	105	$ 24,074,000	26	$ 6,000
5% AEP	4399	141	$ 28,110,000	16	$ 6,400
2% AEP	4705	226	$ 35,080,000	11	$ 7,500
1% AEP	5061	315	$ 42,106,000	5	$ 8,300
0.5% AEP	5334	396	$ 49,667,000	3	$ 9,300
0.2% AEP	5604	465	$ 57,853,000	2	$ 10,300
PMF	7554	913	$ 118,438,000	2	$ 15,700
Average Annual Damages (AAD)			**$ 8,379,000**		**$ 1,100**

NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

Table 22: Non-Residential Flood Damages (City)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	565	16	$ 4,560,000	29	$ 8,100
10% AEP	646	38	$ 7,064,000	25	$ 10,900
5% AEP	691	59	$ 9,205,000	17	$ 13,300
2% AEP	706	89	$ 12,922,000	14	$ 18,300
1% AEP	757	102	$ 15,383,000	6	$ 20,300
0.5% AEP	779	128	$ 18,419,000	4	$ 23,600
0.2% AEP	824	151	$ 22,214,000	3	$ 27,000
PMF	1073	279	$ 48,732,000	3	$ 45,400
Average Annual Damages (AAD)			**$ 2,361,000**		**$ 2,200**

NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

Table 23: Combined Residential and Non-Residential Flood Damages (City)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	4136	87	$ 24,413,000	34	$ 5,900
10% AEP	4656	143	$ 31,138,000	26	$ 6,700
5% AEP	5090	200	$ 37,315,000	16	$ 7,300
2% AEP	5411	315	$ 48,002,000	12	$ 8,900
1% AEP	5818	417	$ 57,489,000	5	$ 9,900
0.5% AEP	6113	524	$ 68,086,000	3	$ 11,100
0.2% AEP	6428	616	$ 80,067,000	2	$ 12,500
PMF	8627	1192	$ 167,170,000	2	$ 19,400
Average Annual Damages (AAD)			**$ 10,740,000**		**$ 1,200**

NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

10.7.3. Lake Albert Damages

The flood damages assessment results for the Lake Albert domain are provided in Table 24 to Table 26 below. The results indicate that relatively frequent flood events, especially the 0.2 EY event, constitutes 39% of the residential average annual damages (AAD), and 36% of the non-residential AAD. It is also notable that many more properties are subject to external inundation (e.g. in rear or front yards) than over floor inundation, indicating that flood depths are relatively shallow compared to the height of floor levels.

Table 24: Residential Damages (Lake Albert)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	1613	39	$ 9,113,000	35	$ 5,600
10% AEP	1813	64	$ 11,156,000	26	$ 6,200
5% AEP	1963	88	$ 13,348,000	16	$ 6,800
2% AEP	2119	149	$ 17,391,000	12	$ 8,200
1% AEP	2226	180	$ 20,353,000	5	$ 9,100
0.5% AEP	2308	205	$ 22,689,000	3	$ 9,800
0.2% AEP	2385	237	$ 25,058,000	2	$ 10,500
PMF	3279	454	$ 51,308,000	2	$ 15,600
Average Annual Damages (AAD)			**$ 3,898,000**		**$ 1,200**

NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

Table 25: Non- Residential Flood Damages (Lake Albert)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	21	4	$ 234,000	19	$ 11,100
10% AEP	23	7	$ 666,000	24	$ 28,900
5% AEP	26	7	$ 879,000	21	$ 33,800
2% AEP	29	11	$ 1,296,000	18	$ 44,700
1% AEP	29	13	$ 1,719,000	8	$ 59,300
0.5% AEP	31	13	$ 1,775,000	5	$ 57,200
0.2% AEP	32	13	$ 1,839,000	3	$ 57,500
PMF	34	15	$ 2,736,000	2	$ 80,500
Average Annual Damages (AAD)			**$ 185,000**		**$ 5,400**

NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

Table 26: Combined Residential and Non-Residential Flood Damages (Lake Albert)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	1634	43	$ 9,347,000	34	$ 5,700
10% AEP	1836	71	$ 11,822,000	26	$ 6,400
5% AEP	1989	95	$ 14,227,000	16	$ 7,200
2% AEP	2148	160	$ 18,687,000	12	$ 8,700
1% AEP	2255	193	$ 22,072,000	5	$ 9,800
0.5% AEP	2339	218	$ 24,464,000	3	$ 10,500
0.2% AEP	2417	250	$ 26,897,000	2	$ 11,100
PMF	3313	469	$ 54,044,000	2	$ 16,300
Average Annual Damages (AAD)			**$ 4,083,000**		**$ 1,200**

NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

10.7.4. East Wagga Damages

The flood damages assessment results for the East Wagga domain are provided in Table 27 to Table 29 below. The results indicate that flood events from the 0.2 EY event to the 2% AEP event cause limited over-floor inundation in this domain. This is likely to be a result of the requirement for commercial premises to have their minimum floor levels 0.5 m higher than the 5% AEP Murrumbidgee River (riverine) flood level (as defined in Reference 7), which in some parts of the domain has the effect of protecting the building from overland flow also.

Table 27: Residential Damages (East)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	20	0	$ 60,000	17	$ 3,000
10% AEP	30	0	$ 90,000	14	$ 3,000
5% AEP	32	0	$ 123,000	10	$ 3,800
2% AEP	39	0	$ 248,000	10	$ 6,400
1% AEP	60	12	$ 962,000	11	$ 16,000
0.5% AEP	80	25	$ 1,923,000	13	$ 24,000
0.2% AEP	98	32	$ 2,619,000	13	$ 26,700
PMF	148	35	$ 3,973,000	12	$ 26,800
Average Annual Damages (AAD)			**$ 54,000**		**$ 400**

NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

Table 28: Non- Residential Flood Damages (East)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	53	2	$ 494,000	8	$ 9,300
10% AEP	90	5	$ 961,000	8	$ 10,700
5% AEP	150	16	$ 2,309,000	9	$ 15,400
2% AEP	283	115	$ 15,989,000	29	$ 56,500
1% AEP	325	143	$ 20,287,000	19	$ 62,400
0.5% AEP	349	152	$ 23,154,000	12	$ 66,300
0.2% AEP	372	166	$ 25,643,000	8	$ 68,900
PMF	483	240	$ 44,769,000	7	$ 92,700
Average Annual Damages (AAD)			**$ 936,000**		**$ 1,900**

NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

Table 29: Combined Residential and Non-Residential Flood Damages (East)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	73	2	$ 554,000	8	$ 7,600
10% AEP	120	5	$ 1,051,000	8	$ 8,800
5% AEP	182	16	$ 2,432,000	9	$ 13,400
2% AEP	322	115	$ 16,237,000	28	$ 50,400
1% AEP	385	155	$ 21,249,000	19	$ 55,200
0.5% AEP	429	177	$ 25,077,000	12	$ 58,500
0.2% AEP	470	198	$ 28,262,000	8	$ 60,100
PMF	631	275	$ 48,742,000	8	$ 77,200
Average Annual Damages (AAD)			**$ 990,000**		**$ 1,600**

NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

10.7.5. Wagga North Damages

The flood damages assessment results for the Wagga North are provided in Table 30 to Table 32 below. Compared to the City and Lake Albert domains, there are far fewer residential properties affected by external and over-floor inundation, reflected in the significantly lower AAD. Furthermore, the number of properties affected over-floor does not increase dramatically between the 0.2 EY and the PMF event, consistent with the design flood results that show a fairly consistent flood extent across all the design events, and that majority of the properties are away from the main Dukes Creek flow path.

Table 30: Residential Damages (Wagga North)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	88	2	$ 476,000	36	$ 5,400
10% AEP	96	4	$ 529,000	26	$ 5,500
5% AEP	120	4	$ 651,000	15	$ 5,400
2% AEP	128	8	$ 855,000	11	$ 6,700
1% AEP	145	8	$ 969,000	5	$ 6,700
0.5% AEP	223	11	$ 1,233,000	3	$ 5,500
0.2% AEP	276	12	$ 1,667,000	2	$ 6,000
PMF	329	18	$ 2,592,000	2	$ 7,900
Average Annual Damages (AAD)			**$ 197,000**		**$ 600**

NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

Table 31: Non- Residential Flood Damages (Wagga North)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	17	1	$ 189,000	38	$ 11,100
10% AEP	17	2	$ 228,000	28	$ 13,400
5% AEP	19	2	$ 241,000	16	$ 12,700
2% AEP	22	3	$ 270,000	10	$ 12,300
1% AEP	24	3	$ 293,000	4	$ 12,200
0.5% AEP	26	3	$ 312,000	2	$ 12,000
0.2% AEP	27	3	$ 413,000	1	$ 15,300
PMF	34	8	$ 623,000	1	$ 18,300
Average Annual Damages (AAD)			**$ 75,000**		**$ 2,200**

NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

Table 32: Combined Residential and Non-Residential Flood Damages (Wagga North)

Event	No. Properties Affected(1)	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	105	3	$ 665,000	37	$ 6,300
10% AEP	113	6	$ 757,000	26	$ 6,700
5% AEP	139	6	$ 892,000	15	$ 6,400
2% AEP	150	11	$ 1,125,000	11	$ 7,500
1% AEP	169	11	$ 1,262,000	4	$ 7,500
0.5% AEP	249	14	$ 1,545,000	3	$ 6,200
0.2% AEP	303	15	$ 2,080,000	2	$ 6,900
PMF	363	26	$ 3,215,000	2	$ 8,900
Average Annual Damages (AAD)			**$ 272,000**		**$ 700**

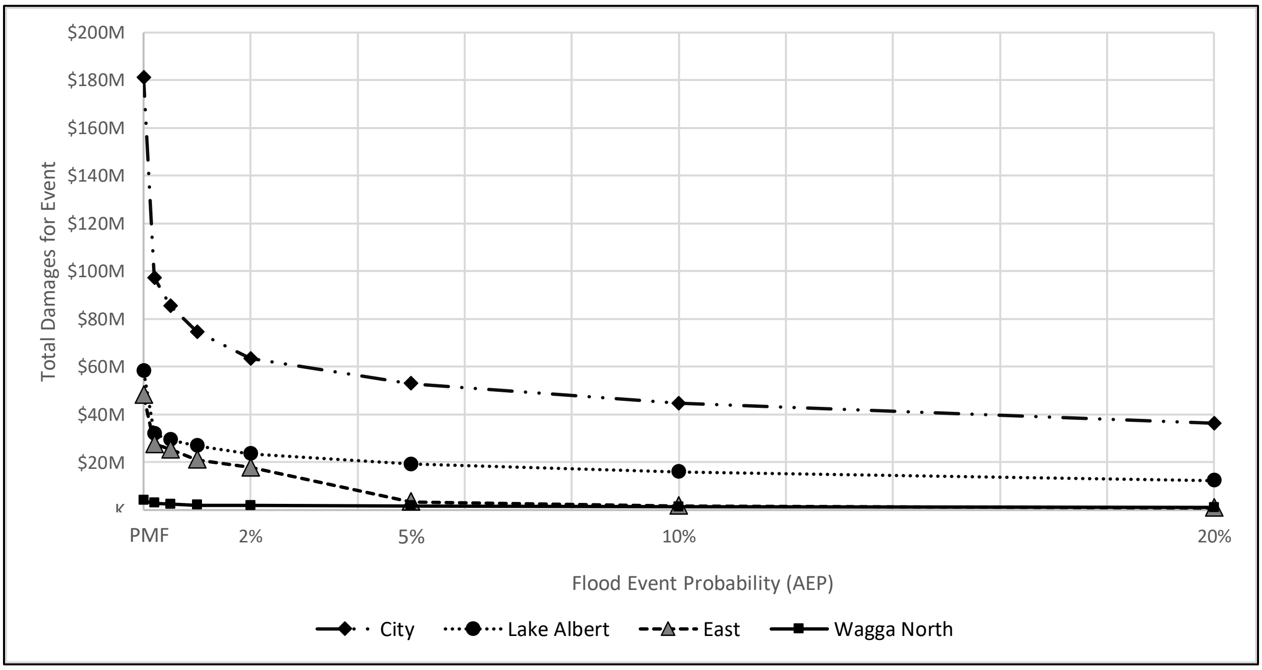
NOTE(1): Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded.

10.8. Discussion

10.8.1. Total Flood Damages

The total damages in each event caused by overland flow in each model domain are shown in Diagram 7 below. The chart displays how the scale of flood damages changes with event frequency. The Wagga North damages do not scale significantly between events, owing to the relatively consistent flood extents and low number of properties located within this extent. The City domain however shows that considerably higher damages occur in rarer events. This domain shows the greatest variation in damages across the suite of design flood events included in the assessment.

Diagram 7: Total Flood Damages (Combined Residential and Non-Residential)



10.8.2. Annual Average Damages

The Annual Average Damages (AAD) for flooding are identified in the previous results tables and summarised in Table 33 below.

Table 33: Average Annual Damages in Wagga Wagga

	City	Lake Albert	East	Wagga North	Total
Residential	$8,379,000	$3,898,000	$54,000	$197,000	$12,528,000
Non-Residential	$2,361,000	$185,000	$936,000	$75,000	$3,557,000
Combined	**$10,740,000**	**$4,083,000**	**$990,000**	**$272,000**	**$16,085,000**

As indicated in Table 33 residential damages due to overland flooding in the City catchment contribute the highest proportion to the Average Annual Damages, as it contains the greatest number of properties affected by both external and over-floor flooding.

10.8.3. Comparison to Riverine Flood Damages

A flood damages assessment was undertaken in the Wagga Wagga Revised Murrumbidgee River FRMS&P (Reference 7), which determined the flood damages in Wagga Wagga due to riverine flooding. The overall AAD calculated for Murrumbidgee River flooding was $5.6M, which is significantly lower than the overall AAD due to overland flow ($16.1M), determined in this report. The following factors contribute to the substantial difference in AAD between the two flood mechanisms:

- In the most frequent design event (0.2EY), the Murrumbidgee River is generally contained within its banks and for the most part does not cause out of bank flooding. The 0.2 EY event was therefore not included in the riverine flood damages assessment. In contrast, the 0.2 EY overland flow event causes widespread shallow flooding across the four model domains, particularly the City and Lake Albert domains, and the high number of properties externally affected contributes significantly to the AAD. It is important to remember that frequent flood events are weighted more heavily than rare floods when calculating the AAD as the damages from these events occur more often and add up to form a significant proportion of the overall flood damages.
- The extent of the floodplain is considerably greater for overland catchments than for riverine flooding. The Murrumbidgee River floodplain is constrained by the Wagga Wagga CBD Levee for events up to and including the 1% AEP event, meaning that some ~4000 properties are protected from over-floor and external flood damages for these events more frequent events. However, majority of the city behind the levee is affected to some degree by overland flow in events as frequent as the 0.2 EY.
- In events greater than the 1% AEP, the extent of riverine flooding is controlled by the steeply rising hills in the south of Wagga Wagga, preventing inundation occurring south of the Sturt Highway (approximately). In contrast, the Lake Albert and City model domains show overland flooding occurring across this area, meaning that a far greater number of properties is affected by this type of flooding.

10.9. 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 that may occur from floods in Wagga Wagga are discussed below.

10.9.1. 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 short warning time available in Wagga Wagga may mean there is not enough time for residents to safely prepare and evacuate before becoming stranded. It is acknowledged that not all residents will receive 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.

10.9.2. Population Demographics

Analysis of the 2016 Census data indicates that there are some features of the population demographics of the community in Wagga Wagga that may contribute to additional intangible damages, particularly community resilience. For example, the proportion of residents aged over 65 years is 15.6% (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 Wagga Wagga 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 lower than the NSW average. For example, the median weekly income for households in Wagga Wagga is $1,334 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.

10.9.3. 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, and the importance of support during these times should not be underestimated.

10.9.4. 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.

10.10. Estimating the Scale of Intangible Damages

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 report. Analysis of intangible damages will instead be captured via a multi-criteria matrix assessment for each flood risk mitigation option investigated in this Study.

10.11. 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 Wagga Wagga 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 drains;
- damage to public amenities such as toilets, parks and gardens, footpaths and cycleways; and
- costs of emergency management operations, such as rescue (particularly to vehicles caught in flash flooding), emergency management coordination, and evacuation centres.

As described earlier, 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.

11. FLOODPLAIN RISK MANGEMENT MEASURES

The 2005 NSW Government's Floodplain Development Manual (Reference 3) separates risk management measures into three broad categories.

Response modification measures modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

Property modification measures modify existing properties, and land use and development controls for future new development or redevelopment. This is generally accomplished through such means as flood proofing, or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or purchase/voluntary house raising.

Flood modification measures modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvements, levees or defined floodways. Pit and pipe improvement and even pumps may be considered where practical.

This study assesses options from each category.

The Wagga Wagga Major Overland Flow Floodplain Risk Management Study assessed a range of potential options for the management of flooding. The assessment process started with identifying options that may be effective in mitigating flood risk. Suggestions for options were gathered from the community via the initial consultation period (see Section 5), as well as discussions with Council, Emergency Services and the examination of available flood modelling and identified hotspots (Reference 4). Options were then shortlisted for hydraulic assessment, and if effective, proceeded to detailed assessment and multicriteria analysis. Options that are scored positively in the multicriteria analysis are typically included in the Floodplain Risk Management Plan for implementation.

The assessment of flood modification options aimed to improve floodplain risk management in Wagga Wagga and to enhance utilisation of Lake Albert for flood mitigation purposes. This report does not consider flood modification options relating to riverine flood risk from the Murrumbidgee River; these have been assessed in detail in the Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan (WMAwater, 2018, Reference 7). Rather, this report focuses on options that reduce flood risk due to overland flow, which in this case, generally involves local runoff draining through various parts of city *towards* the Murrumbidgee River.

Note: Due to the limited property damages observed in the "Wagga North" model domain, no structural mitigation options have been assessed at this time. Note: The "Wagga North" area refers to Estella, Boorooma and other parts of the Dukes Creek catchment, rather than the North Wagga village. Figure 1.2 contains mapping indicating the extents of the model domains. Flood risk mitigation options relating to the North Wagga village, and broader northern Murrumbidgee floodplain, are assessed in the Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan (Reference 7).

An overview of the assessed flood modification options is provided in Figure 5.1.

Included in this report is discussion and determination of the overland flow Flood Planning Area and Flood Planning Level(s), and assessment of future development areas in relation to flood risk. Additionally, recommendations for flood related development controls are made for application in areas subject to overland flow, as well as provision of information to residents via Section 10.7 Planning Certificates. In general, recommendations made in this report are intended to achieve objectives consistent with those made in the Wagga Wagga Revised Murrumbidgee River FRMS&P (Reference 7), however are adjusted as needed to suit to the context of overland flow flood risk.

11.1. Response Modification Measures

11.1.1. RM01: Amend Flood Plans to include Overland Flow Flood Information

Recommendation RM01: Amend Flood Plans to include Overland Flow Flood Information

☑ Applies to: Wagga Wagga Local Flood Plan (NSW SES)
Wagga Wagga Draft Flood Emergency Operational Response Plan (WWCC)

Description: Amend local flood plans and operational plans to include information on flood risk due to overland flow, drawing on modelling and information provided in this FRMS&P

Considerations:

- Significant risk to life exists during flash flood events, particularly where there is flow across roads;
- Resources are likely to be limited if an overland flow event coincides with a riverine flood event, so the consideration of efficient ways to manage overland flow flood risk without increasing the burden on the combat agencies is critical;
- Allow for periodic review of plans: every 3-5 years, or following an event or exercise in which the plan(s) are implemented.
- Ties in with Recommendation RE2 – Flood Emergency Management Planning (Reference 7).

11.1.1.1. Description

As described in Section 9.5, the current Council and SES Flood Plans pertaining to Wagga Wagga focus on the actions required to safely respond to flood risk from the Murrumbidgee River. For the SES, these actions typically focus on evacuations, particularly from the North Wagga area and other floodplain areas, and for Council, on the continuous inspection of condition of levees, levee gate operations, and road closures.

It is recommended that flood information regarding overland flow risk is incorporated into these documents, for two main reasons:

- To allow SES and Council to better prepare for and respond to overland flow flood risk when the river level is low (i.e. flood gates are open);
- To have an understanding of the areas and roads at risk when a local overland flow event coincides with a riverine flood event (i.e. flood gates are closed).

11.1.1.2. Recommendation

Following completion of this study, Council and the SES will be provided with a range of outputs that can be used to develop plans relating to overland flow flood risk. Such outputs include:

- High resolution GIS results including peak flood depths and levels, hazard and hydraulic categories (Section 8);
- Information pack with GIS layers that can be used to relate rainfall intensities and durations, and tailwater levels in the river, to design flood events (Section 8.4.2);
- Identification of parts of the Study Area at greatest risk (Section 8.4.3);
- Locations of Community Assets (Section 8.4.4);
- Identification of roads that are prone to flooding (Section 11.4.2); and
- Identification of areas most sensitive to changes in river levels during an overland flow event (Section 8.4.5).

Importantly, the recommendations made in the subsequent sections of this report should also be considered when updating the various Flood Plans that apply in Wagga Wagga. The subsequent recommendations endeavour to reduce flood risk to the community without increasing the burden on SES and Council staff, as it is understood that both SES and Council resources will necessarily be diverted to the management of riverine flood risk or other storm-related responses if needed. The recommendation to incorporate overland flow flood risk information into local flood planning documents ties into Recommendation RE2: “Flood Emergency Management Planning” from the Riverine FRMS&P (Reference 7).

11.1.2. RM02: Coordination of Emergency Services and Response Agencies

Recommendation RM02: Flood Emergency Response Coordination	
☑	Ongoing facilitation of improved coordination between and within emergency service agencies is recommended to be continued, for example via the following: • Regular meetings of all responders and 'peace time exercises' between flood events; • Build relationships between Council, SES and other agencies and/or community groups; • Improvement of volunteer coordination for more effective utilisation during clean-up and recovery.

11.1.2.1. Description

During an overland flow event in Wagga Wagga, the two main response agencies are the SES and Wagga Wagga City Council. Each have defined roles and responsibilities, and come together quarterly via Local Emergency Management Committee (LEMC) meetings, which are also attended by representatives of other response and support agencies. This recommendation relates to the ongoing improvement of the coordination within and between the response agencies to ensure:

- Roles and responsibilities are well defined and understood by each agency (and the broader community, as described in Section 11.3);
- Hazards can be responded to quickly, efficiently and safely; and
- Calls from the public can be directed to the appropriate agency and responded to effectively.

Wagga Wagga City Council also plays a significant role in ensuring the safety of its community in times of emergency, including preparedness of the organisation in the lead up to an event such as a flood, its response, integration with other emergency services and recovery from the event. During a local storm or flash flood event, Council is responsible for responding to issues relating to public areas and infrastructure, for example, road closures, cleaning out drains, operation of levee gates and pumps, and debris removal within road reserves or riparian corridors.

The SES on the other hand is the legislated Combat Agency for floods and is responsible for the control of flood operations, including the coordination of evacuation and welfare of affected communities. The SES is able to respond to calls regarding private property, including storm damage, evacuations (if appropriate) and rescues (e.g. motorists or pedestrians who have entered floodwaters). Section 11.3 highlights the importance of sharing information about the typical roles of each agency with community members, to allow them to contact the appropriate agency in the event of a flood related emergency, to ensure their call is responded to without unnecessary delay, and not place additional burden on agencies that cannot assist directly.

11.1.3. Opportunities and Constraints

The LEMC meets quarterly to strategically plan for a range of emergencies, including bushfires, floods, urban fire, and major transportation incident. Throughout the year, exercises are held to practice each agency's response and coordination. Discussions with SES and Council staff have highlighted that in addition to hosting meetings and exercises to improve plans at the strategic level, there would be significant benefit in including a broader range of representatives from each agency in these meetings. In particular, the inclusion of Council engineering and outdoor staff, and SES volunteers and volunteer coordinators, would ensure that the individuals who are most likely to be active during the event would benefit from the training exercises, and could add input from their own experience. Not only will this help more responders prepare for flood events, but increase familiarity between representatives of each agency.

Difficulties in achieving the above objectives stem from the logistics of gathering the relevant parties at a mutually convenient time, staff changeover within agencies, and location and availability of out-of-area volunteers. It may be more feasible to have regular, smaller meetings, where representatives from each agency can attend and report back to their teams, and perhaps aim to hold a larger-scale gathering and training day once or twice a year to ensure individuals can plan their attendance well in advance.

11.1.4. Recommendation

The below items are recommended to improve coordination between and within emergency service agencies:

- Continuation of regular Meetings of the Local Emergency Management Committee (Council), ensuring the inclusion and involvement of responders 'on the ground,' e.g. volunteers and Council outdoor staff, particularly for the benefit of new staff and volunteers;
- Incorporate training specifically relating to overland flow/flash flooding events within Wagga Wagga;
- Hold 'peace time exercises' between flood events (or other threats) to maintain relationships and familiarity with roles and responsibilities;
- Develop plans for the effective coordination of out-of-area volunteers who may travel to Wagga Wagga to assist during the recovery period immediately following a flood (particularly riverine or 'dual threat' events); and
- Undertake exercises relating to "dual threat" flood events, i.e. when local rain and riverine flooding is occurring concurrently.

11.2. RM03: Flood Warning System

Recommendation RM03: Flood Warning Systems

☑ Use Severe Weather Warnings from the Bureau of Meteorology to prepare for potential flash flooding events. Community awareness campaigns may assist residents in interpreting warnings from the BOM, and to prepare accordingly.

☑ Information from this FRMS&P can be used internally by Council and the SES to relate forecast or recorded rainfall data to potential flood scenarios.

☒ The development of a flash flood warning system is not recommended for local catchment flooding in Wagga Wagga, due to the lack of time available to effectively interpret rainfall data, and then prepare and disseminate a flood warning message to the community. The need to install additional rain gauges in the local catchment would also significantly increase the initial and ongoing cost of any flood warning system, without materially increasing the length of warning time available.

11.2.1. Background

The purpose of a flood warning is to provide advice on impending flooding so people can take action to minimise its negative impacts. Where effective flood warnings are provided, risk to life and property can be significantly reduced. Studies have shown that flood warning systems generally have high B/C ratios if sufficient warning time is provided and if the population at risk is aware of the threat and prepared to respond appropriately. Investigation into a flood warning system for Wagga Wagga to prepare for riverine flood events was recommended in the Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan (Reference 7) (Reference RE1).

Flooding along the Murrumbidgee River typically occurs with days' warning, and there is a far-reaching network of upstream gauges monitoring flow travelling down the river that can be used to predict flooding in Wagga Wagga. However, flooding in Wagga Wagga due to local rain can occur very quickly after the rain falls (within hours), making the development of a flood warning system for the local catchment a very complex task.

Flash floods are floods of a short duration and a relatively high flow that occur within six hours of rain falling (Bureau of Meteorology, BOM). While the BOM does not provide warnings for flash flood catchments (such as Crooked Creek, Stringybark Creek and Marshalls Creek), it does provide forecasts and warnings for severe weather conditions and potential heavy rainfall that can cause flash flooding. Flash flood warnings themselves are provided by state and local government where gauges and warning systems are available.

11.2.2. Description

Flood warnings are effective if they enable people to take action to lessen the negative impacts of a flood and help agencies to carry out their essential tasks during flood events (Australian Institute for Disaster Resilience, 2009). A total flood warning system includes a number of components that must be integrated for the system to operate effectively (Diagram 8) including:

- monitoring of rainfall and river flows that may lead to flooding;
- prediction of flood severity and the time of onset of particular levels of flooding;
- interpretation of the prediction to determine the likely flood impacts on the community;
- construction of warning messages describing what is happening and will happen, the expected impact and what actions should be taken;
- dissemination of warning messages;
- response to the warnings by the agencies involved and community members; and
- review of the warning system after flood events.

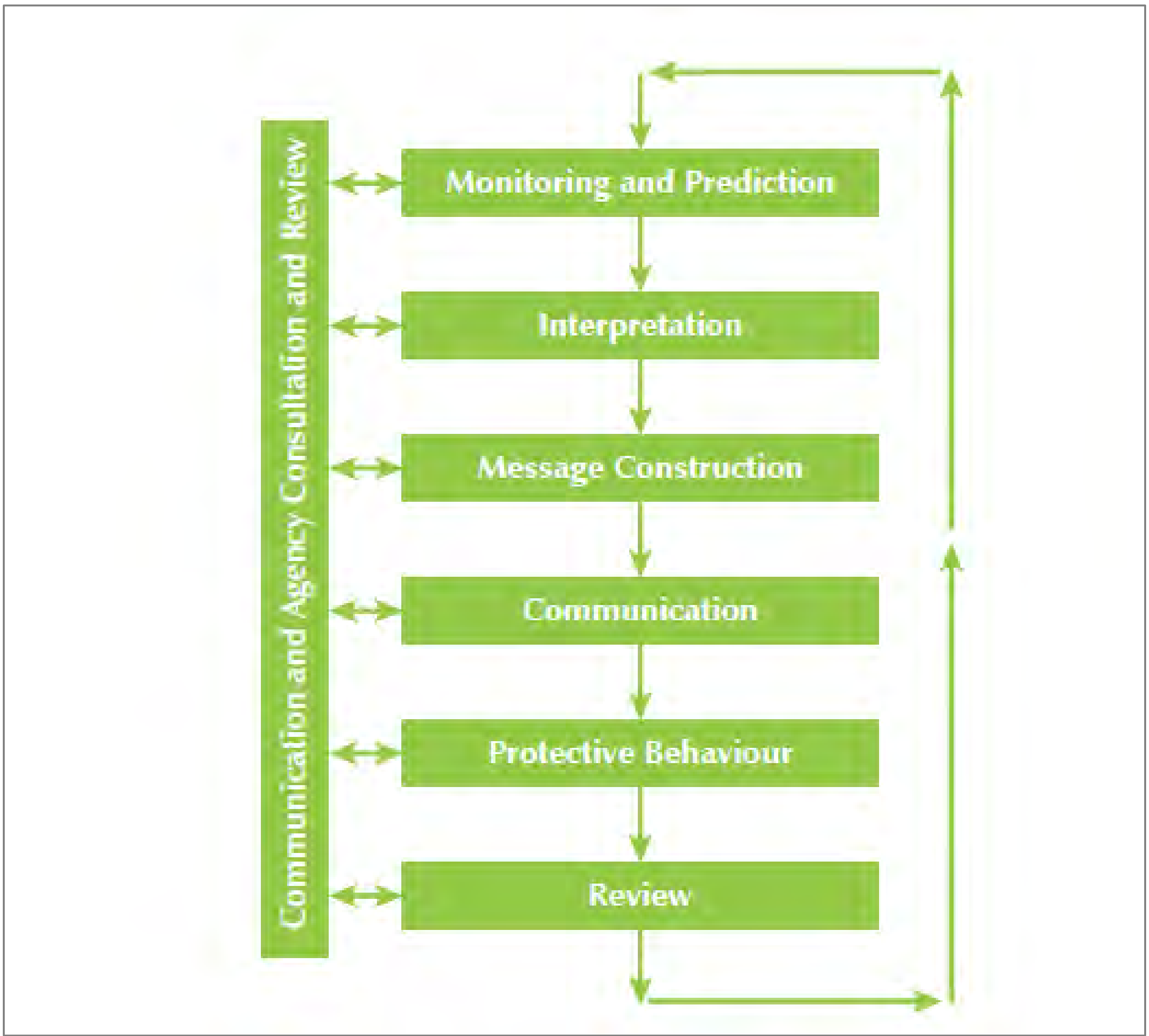


Diagram 8: Components of the total flood warning system - from (Australian Institute for Disaster Resilience, 2009).

A wide range of prediction tools are available, from basic flash flood information systems that use real-time rainfall triggers, to complex flash flood warning systems that run real-time hydrodynamic models informed by radar rainfall estimates. Systems such as these have high computational requirements to continuously run detailed models, high initial and ongoing costs, and are generally unable to be run in-house within Council and so are typically outsourced to specialist consultancies. Hydrodynamic models are often not suitable for flash flood forecasting applications due to the time they take to run and the complex computing environment required. When determining a suitable warning system, there is therefore a need to find an appropriate balance between model complexity (and cost), length of warning time, and accuracy of prediction.

11.2.3. Suitability in Wagga Wagga (Local Catchment Flooding)

Due to the nature of overland flow in the MOFFRMS&P Study Area, flood warnings are difficult to prepare and disseminate. The quick catchment response time does not allow time to interpret recorded rainfall data, construct and disseminate a flash flood warning, with enough time for the community to be able to take meaningful action to prepare. In addition, there are currently no rain gauges in the upper reaches (southern parts) of the local catchment, and the installation and operation of additional gauges would involve significant upfront and ongoing costs.

Decisions made on the basis of rainfall observations carry a significant degree of uncertainty. Forecast rainfall has an even greater degree of uncertainty associated with estimating flood affectation. Evacuations or other response actions based on uncertain triggers may be theoretically defensible in a purely risk-avoidance context but are likely to be viewed as socially and economically unsustainable (Reference 19). There is also the issue that frequent ‘false alarms’ could lead to a situation where warnings are ignored by most of the community.

Investment in flood warning systems in flash flood environments may be warranted where significant flood risk (to life and/or property) exists, where actions must be taken in order to limit damage or risk to personal safety. In Wagga Wagga’s local catchment however, alternative actions can be taken to reduce flood risk, including structural options, improvement of community flood awareness and education, and the below suggestions.

11.2.4. Alternatives

11.2.4.1. Severe Weather Warnings

As an alternative to a flash flood warning system in Wagga Wagga, severe weather warnings issued by the Bureau of Meteorology (BOM) can be used as a caution to the potential onset of flooding in Wagga Wagga's overland flow areas coupled with education and awareness. Severe weather warnings are issued when severe weather or thunderstorms are expected – these are the types of storms that can cause flash flooding in Wagga Wagga. The warning may also note the hazards associated with the storm including damaging wind gusts, large hail and flash flooding. These alerts can also be made available on Council's website and sent directly to residents through SMS alerts. A flood awareness campaign can assist in providing guidance to residents on how to interpret BOM weather warnings and how to manage flooding (see Section 11.3).

11.2.4.2. Use of Modelled Data

Upon completion of the MOFFRMS&P, Council and the SES will be provided with high resolution GIS layers of design flood behaviour, including extents, depths and hazards. Design flood behaviour is estimated based on a specific duration and intensity of rainfall (known as the "critical duration"). Council and SES will be able to use information from the MOFFRMS&P to relate forecast rainfalls and river levels to potential flood scenarios, and prepare accordingly. Example figures have been prepared to indicate the critical duration across different parts of the Study Area for both the 1% AEP and 10% AEP event. These are provided in Figure 4.1 and Figure 4.2, and described further in Section 8.4.2.

11.3. RM04: Community Flood Awareness

Recommendation RM04: Community Flood Education and Awareness	
☑	It is recommended that Council establishes and implements an ongoing and collaborative education program to improve flood awareness, particularly in areas prone to overland flow flood risk. Key messages to be communicated to the residents include: • General information about overland flow in Wagga Wagga, and how it differs from local stormwater drainage issues and riverine flooding; • Specific information about key flow paths and associated flood behaviour (for key areas at risk); • How to interpret and prepare when a 'severe weather warning' is issued by the BOM; • How to interpret flood depth indicators and understand the risk it represents; • How to interpret flood hazard (e.g. slow moving water can be hazardous if deep, and shallow flow can be hazardous if it is fast flowing); • Guidance on the roles and responsibilities of the SES and Council, and contact details of each agency; • General information regarding personal safety during a flash flood event, particularly, how to interpret a roadside depth indicator, and appreciate the risks of driving across flooded roads, even if flow is shallow

11.3.1. Description

A key step towards modifying the community's response to a flood event is to ensure that the community is fully aware that floods are likely to interfere with normal activities in the floodplain (Reference 3). Flood awareness is a vital component of flood risk management for people residing and working in the floodplain, as well as for those reliant on services operated from within flood prone areas. Flood awareness can be developed through a range of strategies with varying levels of community participation. Strong flood awareness can significantly improve the way a community prepares for, and recovers from flooding.

Recommendations regarding community education about overland flow complements Recommendation RE3 ("Community Flood Education) from the Wagga Wagga Revised Murrumbidgee River FRMS&P (Reference 7). Where appropriate, there may be efficiencies in undertaking flood education activities for both mechanisms together, though the different degrees of flood risk, areas affected, and actions required by residents, may mean this is not appropriate in some areas.

11.3.2. Key Messages

Overland flow flood risk is distinct from riverine flood risk in Wagga Wagga, and different messaging is needed to ensure that the community understands, and can respond to their risk appropriately. Discussions with Council and the SES have identified a number of key messages that would be beneficial to share with the community, particularly for residents near major overland flowpaths within the Wagga Wagga Overland Flow Study Area (identified in Table 13).

Key messages to be communicated to the community include:

- General information about how overland flow in Wagga Wagga is generated, where it is conveyed and typical durations of inundation;
- Specific information about flow paths and associated flood behaviour (for key areas at risk, identified in Figure 4.3);
- Guidance on the roles and responsibilities of the SES and Council, and contact details of each agency;
- What to do when BOM issues a severe weather warning for the Wagga Wagga area;
- General information regarding personal safety during a flash flood event, particularly, the risks of driving across flooded roads, even if flow is shallow;
- How elevated river levels affect overland flow behaviour – i.e. depths may be greater in particular areas, and take longer to drain as water needs to be pumped out (either at Flowerdale Lagoon and/or Tarcutta Street opposite Tompson Street).

11.3.3. Engagement Methods

Ongoing flood awareness campaigns can be costly and can become ineffective over time with residents becoming bored or dismissive of messaging, particularly in periods of little rainfall. With Wagga Wagga's identity closely tied to the Murrumbidgee River (and associated riverine flood risk), overland flow flood risk may be perceived as less important or hazardous in comparison. However, as seen in 2010 and 2012, overland flow events do occur, and bring with them their own risks, particularly relating to flash flooding of roads, and driver safety. It is key to keep overland flow flood awareness current, as flash floods can occur frequently and quickly, without days (or weeks) warning time, as might be available in the lead up to a riverine flood event. Three engagement methods are recommended for the dissemination of overland flow flood information to the Wagga Wagga community.

11.3.3.1. Wagga Wagga Flood Information Leaflet

A leaflet containing specific information about flood behaviour, and what to do in the event of a flash flood is an effective way of providing information to the Wagga Wagga community, without necessarily requiring active participation from residents. A leaflet/pamphlet from Council may be sent (annually or biannually) with the rate notice (or separately). A Council database of flood liable properties/addresses (i.e. properties within specific at-risk areas, or within the Flood Planning Area), makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of on-going implementation of Floodplain Risk Management Plans, changes to flood levels, climate change or any other relevant information. It can also be used to clarify the difference between riverine and overland flow flood risk (as distinct from stormwater drainage issues) in Wagga Wagga, and to provide information on the actions Council is taking to reduce the flood risk in their area. A set of leaflets could be developed, each addressing the flood risk in specific parts of Wagga Wagga, as listed in Table 13 and shown in Figure 4.3.

An example leaflet has been prepared to demonstrate the type of information that could be provided. Development of the full set of leaflets would need to be undertaken outside of the MOFFRMS&P project, as a collaborative exercise between Council and the SES, ensuring use of appropriate branding and approvals and licencing obtained where necessary. Due consideration of the sensitivity of the information is also needed, as the use of specific street names when describing affected areas may be off-putting to residents who may perceive property values are negatively affected.

11.3.3.2. Provide Flood Information on Council Website

Council already provides a substantial amount of flood information on their website, including previous studies and key figures from those studies (e.g. the 1% AEP flood depth maps). It is recommended that upon completion of this study, that Council update the website to provide up to date overland flow flood information.

In addition, it is recommended that information about what to do in the event of a flood (either riverine or overland) and how to stay safe, is also provided. This could include, for example, links to SES Floodsafe Materials and campaigns such as “15 to Float”, “If it’s flooded forget it” and “Turn Around Don’t Drown”, which aim to improve driver safety during flood events.

As described in Section 11.2.4.1, the Council website and social media accounts could also be used to share Severe Weather Warnings issued by the BOM, and adding comments (where appropriate) about the areas likely to be affected by heavy rainfall and potential flash flooding.

11.3.3.3. Provide Information to Residents via Section 10.7(2) and (5) Planning Certificates

Planning Certificates are described in detail (Section 9.3.5, and Section 11.5.14.1) and are issued by Council in accordance with the Environmental Planning & Assessment Act 1979. A person may request a Section 10.7 Planning Certificate at any time to obtain information about his or her own property, but generally the certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the Conveyancing Act 1919 requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale.

Provision of flood information to residents via Section 10.7(2) and (5) Planning Certificates can be an effective method of providing site-specific flood information to residents. Sophisticated data and mapping produced in this study will assist in the dissemination of accurate and site-specific information to the community.

A GIS based map can provide useful information to a property owner and simplify the identification of issues by a Council staff member. Section 17.2 and 17.3 of Appendix I to the FDM (Reference 3) detail typical examples of information for inclusion in Section 10.7 (2) and (5) Planning Certificates, and include the following:

- Whether the land is within the FPA (overland, riverine, or both) and if flood related development controls apply, (10.7(2));
- Design flood levels/depths specific to the property for the 1% AEP, 5% AEP and PMF events, (10.7(5));
- Percentages of lots affected by the FPA(s) if not 100%, (10.7(5));
- Likelihood of flooding and mechanism (riverine/ overland flow/ both) (10.7(5));
- Flood hazard (10.7(5));
- Hydraulic categorisation (e.g. floodway) (10.7(5));
- Evacuation routes/ constraints (10.7(5)); and
- Associated Mapping for the above items (10.7(5)).

The more informed a home owner is, the greater the understanding of their flood risk. During a flood event, having this understanding may help prepare residents for evacuation and reduce the number of residents that elect to shelter in place in high hazard areas, which can increase pressure on the SES if they are isolated or their homes inundated.

Recommendation P09 relates specifically to the provision of flood information to residents via Section 10.7 Planning Certificates, and has been reproduced below:

“Recommendation PO9: In Section 10.7 Planning Certificates, notations regarding flooding should provide information on all mechanisms of flood risk at the site, including riverine, overland flow, or if appropriate, both. A greater level of detail can be provided via Section 10.7(5) certificates using high-resolution outputs from this Study and Council’s other Floodplain Risk Management Studies.”

11.4. RM05: Improvements to Driver Safety

Recommendation RM05: Improvements to Driver Safety	
☑	It is recommended that, using the information available in this report, an investigation is undertaken regarding road flood signage in Wagga Wagga, with a view to proceed to installation in accordance with the outcomes of that investigation. The investigation should consider: • Compliance with Australian Standards; • Community Awareness and Attitudes; • Demand on Council Staff; • Most appropriate type and location of each flood sign/ depth marker. A complementary education program also presents an opportunity to educate drivers, not only about the risks to their own safety but of the consequences of driving through floodwaters on surrounding areas (such as wave action and flow diversion).

11.4.1. Description

One of the key hazards associated with local overland flow in Wagga Wagga is flash flooding across roads. The below section contains discussion of the practical considerations that are involved when installing new flood signage on roads within the local overland catchments, in addition to suggested locations. It is recommended that an investigation be undertaken by Council to confirm the most appropriate locations for and types of flood signage, and complementary education programs to most effectively reduce flood risk to motorists and consequences to flood behaviour in surrounding areas (such as wave action and flow diversion).

11.4.2. Recommended Locations for Road Flood Signage

One of the main hazards that occurs during local rain events is flash flooding across roads. With the quick catchment response to local rainfall in Wagga Wagga, water can rise to dangerous depths and velocities before a formal road closure can be implemented, and traffic rerouted safely. In the past, this has resulted in local residents directing traffic, or drivers entering floodwaters and becoming stuck or swept away. Flooding in Wagga Wagga can cause a number of roadways to become overtopped, depending on the location and intensity of rainfall. In most cases, alternative safe routes can be taken, however, unless residents are aware of them, some may attempt to cross through flood waters, putting themselves and others at risk. This is particularly likely if visibility is poor during heavy rain, as water over the road is either not noticed, or the risk of driving through it is not appreciated.

A recent campaign by the Victorian Sate Government (15tofloat.com.au) highlighted that "it only takes 15 cm to float" – i.e. for water flowing with a velocity of 3.6 km/h (1 m/s), a depth of 15 cm is enough for a small car (1.05 tonnes) to become buoyant, causing the driver to lose control. Therefore, driving through even shallow floodwater can put the driver at risk, and also increase the demand on SES resources (and risk to their lives) if rescue is required.

It is noted that deeper water at lower velocities is also hazardous to vehicles, as identified in Reference 8, which has been used to categorise the design flood behaviour in Wagga Wagga into 6 hazard categories, from H1 to H6. As shown in Table 33 below, areas classified as H2 or higher are considered dangerous for vehicles.

In order to communicate potential flood risk to drivers, it is recommended that appropriate signage is installed at key locations. Such signage might include depth indicators, warning signs, hinged flood signs, or signs fitted with flashing lights. Potential locations for flood signage have been shortlisted below and are shown on Figure 4.5, based on modelled flood information across a range of design events, discussions with Council, and feedback from the community consultation.

Table 34: Potential Locations for Flood Warning Signage and/or Depth Markers (Refer to Figure 4.5)

ID	Location	Nearest Landmark	Hazard Classification in 1% AEP event (see note below)
1	Ivan Jack Drive	Wollundry Lagoon	**H3**
2	Forsyth Street	Kmart Wagga Wagga	**H3**
3	Dobney Avenue	Dobney Avenue & Pearson Street roundabouts	**H3**
4	Kooringal Road	Marshalls Creek	**H5**
5	Copland Street	Marshalls Creek	**H4**
6	Bakers Lane	Dandaloo Road intersection	**H5**
7	Lake Albert Road	Lake Albert, Lakeside Drive intersection	**H5**
8	Brunskill Road	Sycamore Road intersection	**H4**
9	Plumpton Road	Stringybark Creek	**H4**
10	Springvale Drive	Between Mallee Road and Featherwood Road	**H5**
11	Lloyd Road	Plane Tree Drive intersection	**H4**
12	Boiling Down Road	Crooked Creek	**H5**
13	Mitchell Road/Gregadoo E Road	Ashford Road intersection	**H5**

Note: H3 – Unsafe for vehicles, children and the elderly
H4 – Unsafe for people and vehicles
H5 – Unsafe for people or vehicles. Buildings require special engineering design and construction (Reference 8)

11.4.3. Considerations for Further Investigations

11.4.3.1. Compliance with Australian Standards

Flood signs must be installed in accordance with AS1742.2-2009 *Manual of Uniform Traffic Control Devices Part 2: Traffic Control Devices for General Use*, which stipulates that *"The 'ROAD SUBJECT TO FLOODING, INDICATORS SHOW DEPTH' sign shall be erected on the left side of the road on which Depth Indicators are used, to advise drivers that the road ahead may be covered by floodwaters…the NEXT x km sign may be used in conjunction with this sign when there are two or more floodways ahead, not more than 2km apart." (Clause 4.10.6.9)*

It also specifies that a G9-22-1 depth indicator sign *"…shall be used at all fords, floodways and low level bridges. It shall be displayed so as to be clearly visible to drivers before reaching the flooded part of the road. Where necessary, separate indicators should be provided on each approach. The zero mark shall be set at the lowest pavement level on the section of road liable to flooding." (Clause 4.10.6.10)*

Where flood depths are in excess of 1.5 m, the G9-22-2 depth indicator sign is to be used. Furthermore, the G9-22-1 indicator is to be used when flood depths are expected to exceed 3.5m (refer to Diagram 9).

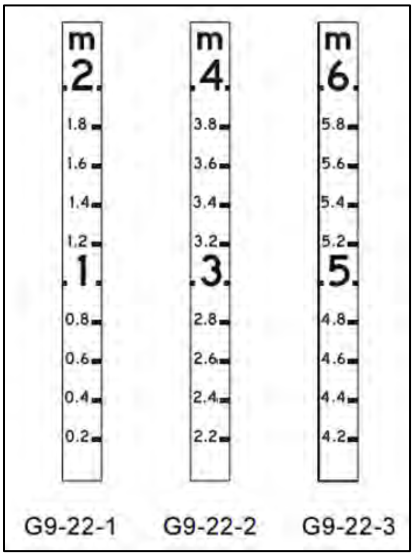


Diagram 9: G9-22 Flood Depth Indicators (Reference 20)

Where special attention is required due to the "extreme severity of the hazard to which they refer, or lack of adequate sight distance to the hazard, or a combination of the two" (Appendix E), flashing lights can be set up alongside the warning signs. The flashing lights must comply with the requirements of AS2144 and consist of 200 mm diameter traffic signal lanterns flashing at a rate of 40 to 60 flashes per minute with the light on for 40 to 60% of the time (Reference 20). Examples are provided below.

Diagram 10: Examples of Warnings Signs with Flashing Lights (Reference 20)

11.4.3.2. Community Awareness and Attitudes

Placement of depth markers in an overland flow area requires careful consideration. If depth markers are placed where flooding is short-lived or shallow, they may be dismissed, which may lead to drivers ignoring depth markers at roads overtopped by fast flowing water. In addition, residents may be concerned that installation of depth markers or other flood warning signs may detract from the amenity of their area, and or perceived to affect property values.

Conversely, if road closure signs are left out for hours or days after water has drained away, drivers are likely to ignore the signs and drive through. This may lead to future complacency or dismissiveness when the road is actually flooded.

Installation of depth markers or other flood signs should be undertaken in conjunction with extensive community education, for two key reasons:

- to ensure drivers understand what the depth marker shows (i.e. depth of water over road);
- to educate the community about the potential flood risk associated with water at that depth, and the danger of driving through even shallow water, as velocity can be hard to judge, and
- to educate the community regarding the potential consequences to flood behaviour such as wave generation, flow diversion and impacts on property.

Recommendations relating to community flood education and awareness are provided in Section 11.3.

11.4.3.3. Demand on Council Staff

With the potential for Council resources to be focused on storm-related responses (e.g. debris removal from roads), or diverted to riverine flood risk management operations, it is recommended that where possible, flood signs that require manual activation are not installed. Instead, warning signs and/or depth indicators (with or without automated flashing lights), that can give information to or warn drivers, without increasing the burden on Council's staff are likely to be preferable. Depending on the location and size of the event, installation of depth indicators or warning signs will not replace the need for Council to formally close roads, though they may assist in dissuading drivers to enter flood waters before the road is officially closed.

It is noted also that during local overland events, regional roads within the LGA outside of the study area may also be affected and require closure. To ensure that Council can respond to these as efficiently as possible, it is recommended that the locations of existing and new flood signs, and roads where official closure is commonplace in local rain events, are captured in GIS format, along with available information regarding the flow path or specific actions required.

11.4.4. Recommendation

While this report has shortlisted potential locations for driver safety flood signage, further consideration of the above factors is needed to identify the most appropriate type of sign, specific placements, and accompanying community education needed to most effectively convey flood risk to motorists. It is recommended that, using the information available in this report, a detailed study is undertaken to confirm the preferred locations and residual flood risk (i.e. need for road closure), then proceed to installation in accordance with the outcomes of that study.

11.5. Property Modification Measures

11.5.1. Future Property Development Measures

11.5.2. P01: Flood Planning Area

The Flood Planning Area (FPA) is an area to which flood related planning controls are applied, and is a required outcome of the FRMS&P. Typically, and as per the Manual (Reference 3), the FPA will be based on the flood extent formed by the Flood Planning Level (FPL) (i.e. typically the 1% AEP mainstream flooding event plus 0.5 m freeboard), and therefore, extend further than the extent of the 1% AEP event. This definition has been applied in Wagga Wagga for areas affected by mainstream flooding from the Murrumbidgee River, and an accompanying Flood Planning Area map was produced in the respective Floodplain Risk Management Study and Plan (Reference 7).

However, application of the '1% AEP + 0.5 m' definition is not necessarily appropriate for the determination of an overland flow FPA. Overland flow is typically much shallower, often characterised by sheet flow. In addition, variations in flood behaviour between different AEP events occurs within a much smaller range (compared to say, riverine flooding). The extent of the 1% AEP overland flood event plus 0.5 m would include a significant area, including areas outside of the PMF extent, and therefore, land *not* subject to any flood risk.
The application of flood related development controls in such areas is not justified, and would lead to overly onerous requirements of developers and Council planning staff alike. It may also have a negative outcome in regard to street activation, accessibility and aesthetics if overly high floor level controls are applied where the flood risk does not warrant it.

Conversely, the FPA should not exclude properties that are subject to flood risk, as this may result in development in areas that puts occupants and/or buildings at risk, leading to flood damages that could have been prevented or reduced via flood related development controls.

11.5.2.1. Determination of Overland Flood Planning Area

With the above factors in mind, a workshop was held with Council planning and engineering staff on the 7th May 2019 to discuss various approaches to defining the FPA in areas of Wagga Wagga affected by overland flow. The following criteria has been applied to determine the FPA in overland flow affected areas:

a) The extent of 1% AEP result grid was 'trimmed' to exclude areas affected by depths of less than 150 mm. The following considerations were taken into account in reaching this decision:
    - The Building Code of Australia requires dwellings to be constructed with a minimum slab thickness of 150 mm;
    - 'Waffle Pod Construction', commonly used in dwelling construction, generally results in a finished floor level at least 300 mm above ground level;
    - It is therefore reasonable to assume that where flooding is less than 150 mm deep, houses would not be flooded above floor level.
    - It is therefore considered reasonable to not apply flood related development controls to properties that are subject to flood depths of less than 150 mm;
    - However, it is noted that shallow flooding that is fast flowing should still be considered as it is a source of flood risk. Therefore, Steps 2 and 3 (below) were followed.

b) Areas defined as 'floodway' in the 1% AEP event (refer to Hydraulic Categorisation), were included in the FPA (including areas where the peak flood depth was less than 150 mm); and
c) Areas defined as H5 and H6 in the 1% AEP hazard classification were included in the FPA (including areas where the peak flood depth was less than 150 mm).

The resulting FPA in overland areas is effectively the extent covered by the envelope of the following:
1. 1% AEP flood extent excluding areas with depths of less than 150 mm;
2. 1% AEP Floodway (including areas with depths less than 150 mm); and
3. 1% AEP H5 and H6 Hazard Classification (including areas with depths less than 150 mm).

The Overland Flow FPA is presented on Figure 3.1 Sheets A-D.

11.5.2.2. Recommendation

Recommendation P01: Adoption of Overland Flow Flood Planning Area	
☑	Adopt the Overland Flow Flood Planning Area developed in this Study (Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan).

It is noted that the Overland Flow Flood Planning Area overlaps with the Riverine Flood Planning Area in several locations. These locations, and management of development within them, is discussed in detail in Section 11.5.13.

11.5.3. P02: Flood Planning Level

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (the Manual, Reference 3) provides a comprehensive guide to the purpose and determination of FPLs. The FPL is derived from a combination of a flood event and a freeboard and provides a development control measure for managing future flood risk, reducing damage, and setting minimum levels for floodplain mitigation works.

The FPL for planning purposes is generally the height at which new (or redeveloped) residential building floor levels should be built to minimise frequency of inundation and associated damage. It may also refer to the height to which flood proofing should be applied to reduce damages to commercial properties. Other FPLs may be applied to other land use categories, and these are described further in Section 11.5.3.2.

A variety of factors need to be considered when calculating the FPL for an area. A key consideration is the flood behaviour and resultant risk to life and property. The Floodplain Development Manual identifies the following issues to be considered:

- Risk to life;
- Long term strategic plan for land use near and on the floodplain;
- Existing and potential land use;
- Current flood level used for planning purposes;
- Land availability and its needs;
- FPL for flood modification measures (levee banks etc.);
- Changes in potential flood damages caused by selecting a particular flood planning level;
- Consequences of floods larger than that selected for the FPL;
- Environmental issues along the flood corridor;
- Flood warning, emergency response and evacuation issues;
- Flood readiness of the community (both present and future);
- Possibility of creating a false sense of security within the community;
- Land values and social equity;
- Potential impact of future development on flooding; and
- Duty of care.

As detailed in Section 1.1.2 of the Manual (Reference 3), the NSW Flood Prone Land Policy provides for a merit based approach to selection of appropriate flood planning levels (FPLs). This recognises the need to consider the full range of flood sizes, up to and including the PMF and the corresponding risks associated with each flood, whilst noting that with few exceptions, it is neither feasible nor socially or economically justifiable to adopt the PMF as the basis for FPLs [for residential purposes]. FPLs for typical residential development would generally be based on the 1% AEP event plus an appropriate freeboard. Justification for the use of the 1% AEP event is provided below, and discussion on the determination of appropriate freeboard is provided in Section 11.5.3.1.

As a guide, Table 35 has been reproduced from the NSW Floodplain Development Manual (Reference 4) to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life, or during the design life of a structure. The data indicates that there is a 50% chance of a 100 year Annual Recurrence Interval (ARI) (1% AEP) event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1% AEP flood event as the basis for the residential FPL. Given the social issues associated with a flood event, and the non-tangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 200 Year ARI (0.5% AEP) magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of more vulnerable development.

Table 35: Likelihood of given design events occurring in a period of 70 years

Size of Flood (Chance of occurrence in any year) ARI (AEP)	Probability of Experiencing the Given Flood in a Period of 70 years	
	At least once (%)	At least twice (%)
1 in 10 (10%)	99.9	99.3
1 in 20 (5%)	97.0	86.4
1 in 50 (2%)	75.3	40.8
1 in 100 (1%)	50.3	15.6
1 in 200 (0.5%)	29.5	4.9

11.5.3.1. Freeboard Selection

As noted above, the Flood Planning Level is typically derived from a design flood event (usually the 1% AEP) plus a freeboard allowance. The freeboard can be considered as a compulsory 'safety factor' used to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of an FPL, is actually provided given the following factors:

- Uncertainty in estimating flood levels;
- Differences in water level because of local factors;
- Increases due to wave action, and
- The cumulative effect of subsequent infill development.

This section discusses freeboard for development planning purposes only, however it should be noted that a greater freeboard is usually appropriate for mitigation works such as levees to account for structural factors such as settlement or defects that may occur over time.

The Manual states that, in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard which is typically 0.5 m. This Floodplain Risk Management Study offers an opportunity to undertake a freeboard assessment to determine the suitability of this freeboard allowance as it applies to areas subject to overland flow in Wagga Wagga.

The freeboard assessment is presented in Appendix E. The assessment concluded that a freeboard of 0.3 m for residential Flood Planning Levels is appropriate in areas affected by overland flow.

11.5.3.2. Other Considerations

Depending on the nature of the development and the level of flood risk, individual FPLs can be varied based on either the design flood event selected or the choice of freeboard. Selecting the appropriate FPL involves trading off the social and economic benefits of a reduction in the frequency, inconvenience, damage and risk to life caused by flooding against the social, economic and environmental costs of restricting land use in flood prone areas and of implementing management measures. Section K4.4.1 of the Manual (Reference 3) states the following:

> Considering a reduction in the FPL for new residential development below this level is not a simple balance between different levels of flood damage and development costs. It has significant social equity implications as damages will be borne by future residents whilst any cost savings related to lower fill levels are made by developers of the land.
>
> The greater flexibility of business in managing risk and recovering financially from flooding, means that FPLs for industrial and commercial development may be based upon a more frequent flood event. An acceptable level of risk may become a business decision for the owner or occupier. This allows for trade-offs between council's responsibility to present and future owners and occupiers and the latter's natural preference to accept the risk and potential damages as a business cost to lower initial set up costs.

The FPL can also be varied depending on the vulnerability of the building/development to flooding. For example, residential development could be considered more vulnerable due to people being present (and potentially asleep), whilst commercial development could be considered less vulnerable, or it could be accepted that other policies and controls are more effectively applied at commercial properties. For developments where the consequences of flooding are significantly more severe, for example hospitals, schools, electricity sub-stations, seniors housing and the like, the FPL can be varied based on the selection of the design flood event. Ideally, consideration should be given to events rarer than the 1% AEP when determining their FPL and either consider the PMF or situating those developments outside the floodplain where possible. In situations where this may be inconsistent with other strategies, other controls can be used to support flood risk minimisation. Further discussion regarding this approach is provided in Section 11.5.5.

11.5.3.3. Comparison to Current Policy

The Wagga Wagga DCP 2010 (Section 4.2) currently requires all development types in the 'Wagga Central Business Area (Protected by levee)' to have their minimum floor height at least 225 mm above ground level within the building footprint.

Applying a freeboard of 300 mm above the 1% AEP, whilst being higher than the current requirement, is not considered to be materially more onerous for the following reasons:

- The FPL requirements will be applied only to development that is located within the FPA, significantly reducing the number of properties to which minimum floor level controls are applied;
- Contemporary construction techniques, such as waffle pod concrete slabs, are generally deeper than standard slabs, often resulting in finished floor levels at least 300 mm above ground levels;

- Shallow flood depths occurring in overland flow affected areas mean that the FPL is not likely to be significantly more than 300 mm above ground in most locations.

11.5.3.4. Recommendation

Recommendation P02: Adoption of Overland Flow Flood Planning Level	
☑	Adopt the Overland Flow (Residential) Flood Planning Level developed in this Study (Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan) defined as the 1% AEP level plus 0.3 m freeboard.
☑	Modify the Wagga Wagga LEP to contain the following definition (consistent with Reference 7): ***flood planning level*** *means the level of a 1% AEP (annual exceedance probability) flood event plus 0.5 metre freeboard, or other level as determined by any floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual.*

11.5.4. P03 – P04: Other Planning Controls

Appropriate planning controls which ensure that development is compatible with flood risk can significantly reduce flood damages. Planning instruments can be used as tools to:

- Reduce risk to life;
- Reduce damage to the proposed development itself; and
- Reduce damage to the broader floodplain and existing development.

In this section, ‘development’ is as defined in the Environmental Planning Assessment Act 1979, and includes buildings of all types, infrastructure, levees, roads, etc. The Floodplain Development Manual (Reference 3) describes the following types of development:

- **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.
- **New development:** refers to development of a completely different nature to that associated with the former land use. E.g. the urban subdivision of an area previously used for rural purposes. New developments typically require extensions of existing urban services such as roads, water supply, sewerage and electricity.
- **Redevelopment:** refers to rebuilding in an area. E.g. as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require major extensions to urban services.

The Wagga Wagga LEP 2010 applies to the entire Wagga Wagga LGA, however Wagga Wagga DCP 2010 has a focus on areas subject to riverine flood risk (from the Murrumbidgee River), and areas of the Central Business Area (as it is called in the DCP) behind the levee. It does not contain provisions for development in other areas of Wagga Wagga subject to overland flow flood risk, for example in the Lake Albert area or Turvey Park in the city’s south.

The Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan (Reference 7) made a number of recommendations for flood related development controls suitable for application in Wagga Wagga. Following adoption of the Murrumbidgee River FRMS&P, Council commenced a review of its DCP to incorporate the recommendations contained within the Plan. At the time of writing, work on this review was on hold in anticipation of similar recommendations made in this study for areas subject to overland flow flood risk, such that these could be incorporated at the same time.

It is noted that ultimately, the phrasing of flood related development controls, and decisions regarding criteria for their implementation, rests with Council. However, the subsequent section describes *types* of controls that are considered appropriate to apply in areas subject to overland flow flood risk to achieve the objectives outlined above; that is, to limit or reduce flood risk(and resulting damage) to life, to proposed development and to the broader floodplain.

11.5.5. Controls to Reduce Risk to Life

The following types of controls are available to Council to implement to limit or actively reduce the risk to life due to exposure to flood risk. Further detail on the below are provided in Section 9.7.3 of Reference 7.

- Requirement for development consent for critical and vulnerable land uses between the FPA and PMF (see below);
- Requirement for Site Specific Emergency Management Plans (generally more suited to commercial premises rather than residential dwellings);
- Provision of flood information to residents and business owners via Section 10.7 (2) and (5) Planning Certificates;
- Controls to manage carparking arrangements, specifically prevention of (or protection against) ingress of water into basement carparks.

11.5.5.1. Development Controls on Low Flood Risk Areas

Clause 7.2 of the Wagga Wagga LEP enables Councils to apply development controls to land within the Flood Planning Area. However, as described in Section 9.3.4, Planning Circular PS 07 - 003 notes 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 Wagga Wagga, this is particularly important for the development of critical infrastructure inside the Main City Levee, which, though protected from riverine flooding in floods up to the 1% AEP event, would be exposed to flood risk in events that overtop or breach the levee. As a result, Reference 7 recommended that the Wagga Wagga LEP be revised to allow Council to apply flood related development controls between the riverine FPA and PMF extent (Recommendation PL3).

This Study echoes Recommendation PL3 (Reference 7) in the context of Major Overland Flow flood risk in Wagga Wagga. As shown on Figure 3.3, there exists a significant area, particularly south of the Central Business Area, Gumly Gumly and Estella, where land within the floodplain (i.e. PMF extent), is not included within the Overland Flow FPA.

Therefore, to complement Clause 7.2 of Wagga Wagga LEP 2010, and as per Recommendation PL3 in the Revised Murrumbidgee River at Wagga Wagga FRMS&P (Reference 7), it is recommended that the below clause is included in the LEP, to enable Council to apply development controls to areas between the FPA and PMF (both in terms of riverine and overland flow flooding), when considering development applications pertaining to critical utilities and vulnerable facilities.

7.2A Floodplain risk management

(1) The objectives of this clause are as follows—

- *(a) in relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding in events exceeding the flood planning level,*
- *(b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.*

(2) This clause applies to land between the flood planning level and the level of a probable maximum flood, but does not apply to land at or below the flood planning level.

(3) Development consent must not be granted to development for any of the following purposes on land to which this clause applies unless the consent authority is satisfied that the development is consistent with any relevant floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual, and will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land—

- *a) caravan parks,*
- *b) centre-based child care facilities,*
- *c) correctional centres,*
- *d) emergency services facilities,*
- *e) group homes,*
- *f) hospitals,*
- *g) residential care facilities,*
- *h) respite day care centres,*
- *i) tourist and visitor accommodation.*

(4) In this clause— probable maximum flood has the same meaning as it has in the Floodplain Development Manual.

Note. The probable maximum flood is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation.

11.5.6. Controls to Reduce Risk to Proposed Development

The below controls relate directly to the building being developed (rather than its occupants or neighbours), and are intended to limit or reduce the potential flood damage that occurs to the building and its contents. Described in detail in Section 9.7.4 of Reference 7, such controls might include:

- Controls to Set Minimum Floor Levels and/or Flood Proofing Levels (refer to Section 11.5.3); and
- Controls to ensure appropriate building siting, design and materials, for example requirement for flood compatible building materials and structural certification.

11.5.7. Controls to Reduce Risk to the Wider Floodplain

A key objective of the Wagga Wagga Local Environmental Plan 2010 is 'to avoid significant adverse impacts on flood behaviour and the environment' (1c). Section 9.7.5 of Reference 7 provides detailed discussion on a number of ways in which Council can use the DCP to achieve these objectives. The approaches outlined in Reference 7 are summarised below:

- Requirement for flood impact assessments to demonstrate that the proposed development would not cause adverse changes to flood behaviour;
- Where suitable, requirement for development design considerations may assist in the reduction of adverse flood impacts. These may include requirement for the proposed building to be sited on a different part of the lot (away from flooded areas), or be of suspended construction to allow the free flow of floodwater beneath the property, (noting the risks involved if this approach is taken, including potential isolation of residents, or periods of increased dampness beneath the dwelling that may need pumping or ventilation).

11.5.8. Recommendation

Recommendation P03: Adoption of Flood Related Development Controls for development within the Overland Flow FPA

☑ Incorporation of flood related development controls in the Wagga Wagga DCP to manage development in areas of Wagga Wagga prone to flood risk from overland flow. The intent and objectives of the development controls is to be consistent with those applied to the riverine FPA, however adjustment of the phrasing or implementation criteria may be necessary to better suit the context of overland flow flood risk.

Recommendation P04: Development Controls on Low Flood Risk Areas

☑ Modify the Wagga Wagga LEP to enable Council to apply flood related development controls to critical facilities and vulnerable land uses between the FPA and PMF extent, as defined in this study and the Revised Murrumbidgee River at Wagga Wagga FRMS&P for overland flow and riverine flood risk respectively.

11.5.9. P05: Future Development Areas

11.5.9.1. Potential Areas for Growth

Future Development in Wagga Wagga is guided by the Wagga Wagga Spatial Plan 2013-2043. The Wagga Wagga Spatial Plan (Spatial Plan) provides clear strategic indicators for the development of Wagga Wagga over the next 30 years and beyond. It is the key strategic planning document for directing and managing urban growth and change. The Spatial Plan explores the issues that currently face the Wagga Wagga Local Government Area and recommends a planning approach to address these issues. The plan will provide the framework to guide planning and land use outcomes for the Local Government Area to 2043.

Areas for future growth have been identified in the Spatial Plan, and are classified in the following categories:

- Potential Western Growth (west of the City model domain);
- Potential Employment Areas (near East Wagga);
- Potential Intensification (e.g south of Lake Albert and east of Crooked Creek); and
- Potential Urban Areas.

11.5.9.2. Available Flood Information

To assist Council in the management of flood risk in these areas, the proposed areas for future growth have been mapped on Figure 3.2 with the overland flow and riverine (Reference 7) flood planning areas shown.

Figure 3.2 indicates that the areas in Pomingalarna and San Isidore to the west of the CBD, Kapooka to the southwest of the CBD, and Hillgrove to the north of the Charles Sturt University campus, are outside of the riverine flood planning area. Figure 3.3 indicates that these zones are also outside of the riverine PMF extent (defined in Reference 7) and are therefore not subject to flood risk from the Murrumbidgee River.

However, these particular areas are outside of the MOFFRMS&P Study Area, and as such, Council does not currently have flood information relating to overland flow in these areas.

Within the MOFFRMS&P Study Area, Council has identified Potential Intensification Areas and Potential Urban Areas to the south of Lake Albert, within the Stringybark Creek and Crooked Creek catchments, and Potential Employment Areas in the Gregadoo Creek catchment. Development in these areas will need to be managed to ensure that the existing flowpaths are not obstructed, and that the new development is sited and constructed in such a way that is compatible with its flood risk.

With the completion of the Wagga Wagga Revised Murrumbidgee River FRMS&P, Major Overland Flow FRMS&P and Villages Overland Flow FRMS&P, Council has high resolution flood information across large areas of the LGA, however a number of areas identified in the Spatial Plan sit beyond the currently available flood mapping. A key consideration for these new development areas will be the development of flood mapping and an assessment of the existing flood risk to support appropriate decisions regarding land use and drainage corridors to be made.

11.5.9.3. Land Use Planning in Future Development Areas

Land use planning limits and controls are an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed appropriately (Reference 3). To enable new development in the areas identified in the Spatial Plan, it is likely that rezoning will be required to support new or intensified development. At present, many of the proposed potential growth areas are located within areas zoned as Large Lot Residential, Primary Production, or similar (based on Wagga Wagga LEP 2010), where residential or commercial development potential is limited. 'Zoning' is included as a type of Property Modification Measure as defined in the Manual (Reference 3).

With the recently completed Wagga Wagga Revised Murrumbidgee River FRMS&P, and the hydraulic assessments underpinning the MOFFRMS&P, Council is able to take advantage of the high resolution flood information available when considering changes to land use zoning in these future growth areas. As per the Manual (Reference 3), a key consideration in new development cases is the ability of people to financially recover from severe flood events. Direction No. 15 – Flood Prone Land (Section 117 Ministerial Directions, Revised direction no. 15, 31 January 2007 (Planning Circular PS 07-003)) applies when a council prepares a draft LEP that creates, removes or alters a zone or provision that affects flood prone land. However consideration should be given to the existence of floodways, flood storage and high hazard areas and the restriction of development through these areas to avoid impacts on the development as well as impacts on others as a result of the development.

Well informed decisions at the planning proposal stage regarding land use zoning will yield a range of benefits well into the future in Wagga Wagga, including but not limited to:

- Limit risk to life by prohibiting development (both residential and commercial) in known floodways, and therefore limiting the number of occupants in hazardous areas that may be subject to flash flooding;
- Limit risk to proposed development by only making land that is either flood free or subject to low flood hazard available for development and thereby reducing the potential financial burden following severe floods for future residents;
- Ensure flood risk to the broader floodplain is not exacerbated (e.g. by prohibiting development in locations that would obstruct flowpaths and redistribute flows);

Following on from the above, sensible decisions at the land-use planning stage will assist Council (and developers) in the long term. By limiting development to areas of low (or no) flood risk, there will be a reduced need for reliance on development controls to manage flood risk to new development.
This will make lodgement and assessment of Development Applications less onerous on both developers and Council's planning staff, and likely result in improved aesthetic and/or street activation outcomes (for example, suitability of lower floor levels). However, the Manual also states that the NSW Government's Flood Prone Land Policy does not support the use of zoning to unjustifiably restrict development simply because land is flood prone. Zoning of flood prone land should be based on an objective assessment of land suitability and capability, flood risk, environmental and other factors (Reference 3).

Planning proposals are assessed and approved/rejected at a state level via the NSW Department of Planning, Industry and Environment (DPIE). Part of the approvals process involves the consideration of flood risk in relation to the proposed rezoning. By considering flood risk in the early stages of putting together the Planning Proposal, Council may avoid having their proposal rejected and needing to submit an amended version. Given the Planning Proposal approval process is typically 12-18 months, it would be in Council's interests to avoid unnecessarily delaying the process where possible.

11.5.9.4. Recommendation

It is recommended that changes to land use zoning in areas of potential growth are drafted and objectively assessed with due consideration to the flood risk (including hydraulic categorisation and hydraulic hazard), in addition to other factors (e.g. environmental). For areas not covered by the existing flood risk information, flood mapping should be developed, and an assessment of the flood risk undertaken to support further determination of appropriate land use zonings. Possible considerations also include retention of riparian corridors and buffer zones around known flow paths (floodways) (and any other appropriate areas not represented in the broadscale assessments such as this Study). These buffer zones could be zoned with a classification that does not support development (such as an environmental recreational classification). Precluding development in such areas would greatly reduce the effort needed to manage future development in these areas in relation to flood risk, and limit the exposure of new development to known areas of flood risk or impacts that may occur as a result of development. If no information is available, it is recommended that Council consider undertaking further hydrologic/hydraulic analysis prior to lodging rezoning planning proposals.

It is also recommended that development in areas of new growth is guided by appropriate flood related development controls. In particular, converting large areas of land from unpaved to paved surfaces can have significant implications for overland flow behaviour, as less rain can infiltrate into the ground, and runoff can flow along smooth, impervious surfaces (i.e. roads and driveways) at a faster rate. A high-level assessment has shown that in the proposed areas south of Crooked Creek (within the MOFFRMS&P model extent), increasing the proportion of impervious surfaces from 0% (i.e. undeveloped, vegetation) to 55%, yields a 5-10% increase in peak flows at a subcatchment level in a 1% AEP event. The cumulative effect of this increase in runoff, and the effect it may have on the timing of peak flows at points of concentration, indicates that it is fitting to consider development controls that manage the total area and siting of newly paved surfaces when designing new urban areas.

It is noted that guidelines relating to proportion of impervious surfaces (or ‘hardstand’) allowable are already in use by Wagga Wagga City Council to manage urban salinity within the Lloyd Urban Release area.

Recommendation P05: Appropriate Land Use Zoning in Future Development Areas

☑ For areas not covered by existing flood mapping, undertake a flood investigation to develop flood mapping and allow for an appropriate assessment of flood risk.

☑ Ensure Planning Proposals for the rezoning of future growth areas are undertaken with due consideration of flood risk using information available to Council through its various Floodplain Risk Management Studies and Plans. If no flood information is available, consideration should be given to undertaking further analysis prior to determining land use zoning for future development areas.

☑ Ensure Development Planning Controls are implemented to manage development in areas of new growth in relation to flooding. This may include, for example, guidelines relating to the permissible proportion of impervious surfaces in areas of new development or for development to be excluded from floodway, flood storage and high hazard areas.

11.5.10. Existing Property Measures

In addition to flood modification options, the NSW State Government has two schemes available to reduce flood risk to existing development in flood prone communities: Voluntary House Raising (VHR) and Voluntary Purchase (VP). This section describes the two schemes, and assesses their viability in overland flow affected areas of Wagga Wagga.

11.5.11. P06: Voluntary House Raising

11.5.11.1. Description

Voluntary house raising (VHR) seeks to reduce the frequency of exposure to flood damage of the house and its contents by raising the house above the Flood Planning Level (FPL). This results in a reduction in the frequency of household disruption and associated trauma and anxiety, however other external flood risks remain, such as the need to evacuate prior to properties being isolated by floodwaters. VHR schemes are eligible for state government funding based on criteria set out in the *Guidelines for Voluntary House Raising Schemes* (Reference 12). According to these guidelines, VHR is generally excluded in floodways, is limited to low hazard areas, and applies only to houses constructed before 1986. House raising is most suitable for non-brick single storey buildings on piers, and is typically not feasible for slab-on-ground constructions. However, advancements in construction techniques and other alternatives may make house raising a viable option for slab-on-ground constructions, or alternatively, repurposing the ground floor for non-habitable use and constructing a second story (above the FPL) for habitable use.

11.5.11.2. Suitability in Overland Flow affected areas of Wagga Wagga

Outputs from the MOFFRMS&P flood damages assessment and classification of the floodplain into hydraulic categories and hazard classifications have been used to identify residential properties that are a) located outside of the floodway (as defined in Section 8.2) are inundated over floor in events up to and including the 1% AEP event.

In general, overland flow is shallow even in the 1% AEP event, and typically constrained to roadways. As a result, over floor inundation is relatively limited and occurs sporadically across the floodplain where dwellings have been built with lower floor levels or are located in sag points. There are however some localised areas with clusters of properties flooded above floor in events including and more frequent than the 1% AEP event. In the City Domain, such areas include Vestey Street, Spring Street/Campbell Place, and east of Wollundry Lagoon around Forsyth Street, Morundah Street and Wynyard Court. In the Lake Albert Study Area, there are similar clusters of residential properties around Brunskill Road and Sycamore Road near Sycamore Drain, Vincent Road, and upstream of Crooked Creek (e.g. around Bell Gum Place), and west of Lake Albert around Lansdowne Avenue, Coventry Place, and Springvale Drive. It is noted that these locations correspond with areas from which multiple submissions were received during the community consultation period, and are known flooding hotspots where a range flood modification measures have also been investigated. These clusters indicate that there could be a small number of dwellings that may benefit from participation in a VHR Scheme.

However, the VHR Guideline (Reference 12) states that *"VHR can be an effective strategy for existing properties in low flood hazard areas where mitigation works to reduce flood risk to properties are impractical or uneconomic."*

As part of this study, a range of flood modification options have been assessed for their efficacy in reducing flood risk across the study area, with a focus on structural works that reduce peak flood levels and/or the duration of inundation in these particular hotspots. Section 11.6 detail the options assessed and identifies a number of options that are effective and practical. The economic assessment is continuing, however initial indications suggest many of the recommended options involve limited capital works, and hence are expected to be economically viable for Council to implement as the opportunity arises.

It is also noted that in areas where over-floor flooding occurs, the nearby roads and open areas are also inundated. While structural mitigation options have the capacity to reduce the flood risk more broadly (i.e. to motorists and pedestrians) in addition to properties, a VHR scheme would *only* reduce flood risk to properties – that is, flooding around the dwellings would remain. It is therefore considered more appropriate to invest in structural mitigation works (such as culvert upgrades, or diversion drains), that reduce the broader flood risk rather than in a scheme that only provides benefits to residential dwellings.

11.5.11.3. Summary

Voluntary House Raising is not considered the preferred approach to reducing property damages for dwellings in areas of Wagga Wagga affected by overland flow. The key reason for this is that there is a range of practical structural works available that could mitigate flood risk in these areas more effectively. In addition, it is expected that the economic assessment would indicate that Voluntary House Raising is not economically viable, as a large proportion of the properties that could be considered eligible are of brick and slab-on-ground construction. Whilst not technically impossible, it is significantly more costly to raise habitable areas of these dwellings of this type compared to dwellings constructed on piers. Furthermore, the VHR scheme is open only to dwellings constructed after 1986, which may further limit the number of potential participants for the Scheme. In addition, through adoption of an overland Flood Planning Level, over time dwellings will be redeveloped and set at a higher level, gradually reducing the need for and viability of a VHR Scheme.

11.5.12. P06: Voluntary Purchase

11.5.12.1. Description

Voluntary Purchase (VP) Schemes are a long-term option to remove residential properties from areas of high flood hazard. Voluntary purchase (VP) is recognised as an effective floodplain risk management measure for existing properties in areas where:

- There are highly hazardous flood conditions and the principal objective is to remove people living in these properties and reduce the risk to life of residents and potential rescuers;
- A property is located within a floodway and its removal may contribute to a floodway clearance program that aims to reduce significant impacts of flood behaviour elsewhere in the floodplain by improving the conveyance of the floodway; or
- Purchase of a property enables other flood mitigation works to be implemented (e.g. channel improvements or levee construction).

In the NSW Government *Guidelines for Voluntary Purchase Schemes* (Reference 13), eligibility criteria notes that VP will be considered only where no other feasible flood risk management options are available to address the risk to life at the property (5.2), and, that subsidised funding is generally only available for residential properties and not commercial and industrial properties (5.3). Once a dwelling is purchased it would be demolished, and a restriction placed upon the lot to prevent future residential or commercial development.

Reference 13 sets out the way in which a VP scheme should be undertaken and how properties should be valued. Valuations are to assume there are no flood related development constraints applied to the property. The aim of this is to allow those who take up voluntary purchase to be able to buy a similar property in a location not subject to flood risk, acknowledging that flood impacted properties often have lower value.

11.5.12.2. Suitability in Overland Flow affected areas of Wagga Wagga

Voluntary Purchase is not considered an appropriate approach to flood risk management in areas of Wagga Wagga subject to overland flow affectation. The reasons for this assessment are outlined below:

- The floodway is generally constrained to well defined flow paths and drains, with limited residential development occurring within it;
- Compared to the riverine floodway, the overland floodway does not typically correspond to the higher hazard classifications (H5-H6) as it is characterised by considerably shallower flow;
- Therefore, the few dwellings that are within the floodway extent do not have a material risk to life associated with them. A key driver for Voluntary Purchase is that it reduces the risk to lives of residents in high hazard areas.

As stated above, the Guideline (Reference 13) indicates that 'VP will be considered only where no other feasible flood risk management options are available to address the risk to life at the property (5.2).' It is considered that alternative, more suitable flood risk management measures are available, and that Voluntary Purchase is not recommended to be pursued in areas subject to overland flow affectation in Wagga Wagga. Recommendations for more suitable risk management measures may include adoption of planning controls (described in Section 11.5) or implementation of flood modification options. These approaches are recommended to be complemented by flood education and awareness improvements and emergency management measures to improve the community's preparedness for flooding, and resilience in recovery. These types of measures are referred to as 'response modification' measures, and are discussed in detail in 11.1.

11.5.12.3. Recommendation

Recommendation P06: Do not pursue Voluntary Purchase nor Voluntary House Raising Schemes in areas subject only to overland flow flood risk.	
☒	Voluntary Purchase (VP) and Voluntary House Raising (VHR) are not considered the most appropriate nor effective methods to manage flood risk in Wagga Wagga due to overland flow. It is therefore not recommended that these schemes are investigated further in the context of overland flow flood risk.

Note: It is recommended the above conclusion is included in the Wagga Wagga Major Overland Flow Draft Floodplain Risk Management Plan to definitively close out consideration of these Schemes in areas of Wagga Wagga subject ONLY to overland flow affectation (i.e. the Overland Flow FPA).

Clarification: VHR and VP in Riverine Areas

Voluntary House Raising and Voluntary Purchase have been recommended for further investigation as part of the Wagga Wagga Revised Murrumbidgee River FRMS&P (Reference 7) – this investigation is to continue for areas subject to riverine flood risk (including areas subject to *both* riverine and overland flow flood risk), but is not recommended to be pursued in areas subject *only* to overland flow flood risk.

11.5.13. P07 – P08: Properties Impacted by Multiple Flood Mechanisms

Wagga Wagga City Council is responsible for managing development in flood prone areas. Flood risk in Wagga Wagga arises from two sources: mainstream flooding from the Murrumbidgee River, and overland flow flood risk from the local catchments. Riverine flood risk, and the associated Flood Planning Area, are defined in the Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan (Reference 7).

Some parts of Wagga Wagga are subject to flood risk from both mainstream and overland sources. This section describes three such areas, and discusses considerations essential for the appropriate management of flood risk in these areas. The riverine and overland Flood Planning Areas and PMF extents are shown together on Figure 3.3 to indicate areas where Flood Planning Areas and the various floodplains overlap.

11.5.13.1. Wagga Wagga Central Business Area

With the recent upgrade of the Main City Levee to a 1% AEP level of protection, the Wagga Wagga Central Business Area is excluded from the riverine residential Flood Planning Area. However, flood risk still exists in the city in riverine events greater than the 1% AEP. This is described as 'continuing flood risk' in the Manual (Reference 3) and refers to the risk a community is exposed to after floodplain risk management measures have been implemented. In addition, if the levee were to fail, the Central Business Area could also be subject to riverine flooding in events more frequent than the 1% AEP event. For events large enough to activate the two spillways within the Main City Levee significant flowpaths would be generated through the Central Business Area. The inclusion of the clause recommended in Section 11.5.5.1 provides a recommendation pertaining to the application of development controls to critical utilities and vulnerable facilities in this area, and all other land between the FPA and PMF extent where additional controls may be warranted. Area where significant risk exists as a result of both flood mechanisms would fall into this category. The Central Business Area is also subject to flood risk from overland sources, generally approaching the Murrumbidgee River from the higher ground south of the city.

Assessment of development applications for residential development is therefore required to consider flood risk due to overland flow. However, depending on the type of development, it may be necessary to also consider the flood risk due to the Murrumbidgee River. Examples of such development may include critical utilities such as power stations, telecommunications infrastructure, water supply and sewer, or facilities with vulnerable occupants such as hospitals, aged care facilities, child care facilities. Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety, and therefore, warrant being designed with a higher degree of flood risk in mind. Section 9.7.3.1 in Reference 7 contains detailed discussion and recommendation for the addition of a clause in the Wagga Wagga LEP to allow Council to require development consent for critical utilities and vulnerable facilities within the riverine PMF extent.

11.5.13.2. East Wagga

The commercial and industrial area to the east of the Central Business Area is located outside of the Main City Levee, and is subject to flood risk from the Murrumbidgee River in events approximately as frequent as the 0.2 EY (~5 year ARI) event, equivalent to a height of 9.1 m at the Hampden Bridge Gauge. In addition, Gregadoo Creek, Marshalls Creek and overland flow draining to these creeks contributes to the overland flow flood risk in East Wagga.

Controls currently exist to ensure commercial development is compatible with flood risk from the Murrumbidgee River, as defined in Reference 7, however consideration of flood risk due to overland flow is also warranted in much of East Wagga, particularly near Gregadoo and Marshalls Creeks. It is also noted that the controls designed to reduce the riverine flood risk should not exacerbate (or be in conflict with) overland flow flood risk. One example of this is the current requirement for new commercial development to be constructed 0.5 m above the riverine 5% AEP event level. The suitability of filling to this level should be considered in light of newly available overland flow flood information, to ensure that individual developments, and, in the long term, the cumulative impacts of this filling, do not worsen overland flow behaviour elsewhere. A specific recommendation relating to the assessment of riverine development controls in terms of overland flow flood risk is included in Section 11.5.13.7.

11.5.13.3. Cartwrights Hill and Boorooma

Parts of the Murrumbidgee River northern floodplain (i.e. north of North Wagga) intersect with the Dukes Creek floodplain, particularly the largely undeveloped areas of Cartwrights Hill south of the Olympic Highway. Development in this area should be assessed in the context of both riverine and overland flow flood risk.

It is noted that the North Wagga Village is not subject to overland flow flood risk from Dukes Creek.

11.5.13.4. Application of Development Controls in areas subject to Multiple Sources of Flood Risk

For properties located within both the overland flow and riverine PMF extents, consideration of both flood mechanisms is required to ensure the flood risk associated with the property is appropriately captured and designed for. Two key elements of ensuring the proposed development is designed appropriately relate to flood planning levels and flood impact assessments. Information on these is provided below.

11.5.13.5. Flood Planning Levels

Flood Planning Levels for residential development are defined as follows:

- Riverine: 1% AEP + 0.5 m (Reference 7)
- Overland Flow: 1% AEP + 0.3 m (Section 11.5.3)

For properties that lie within both Flood Planning Areas, it will generally be most appropriate to apply the higher of the two Flood Planning levels to capture the full range of flood risk at the site, and ensure the development is constructed so as to reduce damages in the more severe flood risk scenario. However, prior to determining the FPL, both sources of flood risk, the type of development being proposed, and other factors such as accessibility and street activation outcomes is should be considered. It is noted that depending on the type of development (e.g. commercial), it may be more appropriate to impose flood proofing requirements for parts of the development below the FPL, rather than minimum floor level requirements. If the proposed development is a critical utility or vulnerable facility, alternative flood planning levels (e.g. the PMF or other event rarer than the 1% AEP) may be more appropriate. This is discussed in detail in Section 11.5.3.2.

11.5.13.6. Flood Impact Assessments

Flood impact assessments involve modifying the adopted hydraulic model to represent the proposed development, then comparing peak flood level results to the ‘base case’ to determine how the proposed development would change flood behaviour. Typically, a flood impact assessment would look at how the proposed development changes peak flood levels in a 1% AEP event. However, there are examples of Councils in NSW that also require assessments of change in hazard classification, change in peak flood velocity, and/or assessment of the development in a rarer or more frequent flood event.

In areas where both riverine and overland flow flood risk exist, it is necessary to consider the proposed development in terms of its potential impacts on both mainstream and overland flow flood behaviour. Even a relatively minor development, which may not have a material impact on riverine flood behaviour, might significantly obstruct a local overland flow path and cause flood risk to be exacerbated in the surrounding areas.

11.5.13.7. Recommendation

Recommendation P07: Appropriate Management of areas subject to both riverine and overland flow flood risk.	
☑	Proposed development is to be assessed (and designed) with due consideration of the full range of flood risk present at the site, i.e., riverine, overland flow, or both mechanisms. For residential development both Riverine and Overland Flow FPAs are to be considered, while critical utilities or vulnerable facilities may warrant consideration of the PMF for either or both flood mechanisms, particularly when considering Flood Planning Levels, evacuation constraints and other methods to manage the full range of flood risk.
Recommendation P08: Confirm suitability of riverine flood related development controls within the overland flow PMF extent.	
☑	Controls to reduce riverine flood risk (e.g. by filling above a particular level) may inadvertently exacerbate the flood risk due to overland flow. It is recommended that Council's flood related development controls are assessed for their suitability in relation to overland flow flood information provided in this Study.

11.5.14. P09: Provision of Flood Information to Residents

11.5.14.1. Section 10.7 Planning Certificates

Section 10.7 Planning Certificates (formerly S149 Planning Certificates) are issued in accordance with the Environmental Planning & Assessment Act 1979. They contain information on how a property may be used and the restrictions on development that apply. A person may request a Section 10.7 Planning Certificate at any time to obtain information about his or her own property, but generally the certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the Conveyancing Act 1919 requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale.

Schedule 4 of the Environmental Planning and Assessment Regulations 2000 gives requirement for inclusions on Section 10.7 Planning Certificates under Section 10.7(2) of the Act. In particular Schedule 4, Clause 7A refers to flood related development control information and requires that Council include whether or not development on the land or part of the land is subject to flood related development controls.

Currently Council provides information related to flood related development controls on 10.7(2) Planning Certificates for properties within the Riverine FPA as defined in Reference 7. This is based on a FPL of the 1% AEP flood level + 0.5 m freeboard, which excludes the Central Business Area and residences behind the Main City Levee. The Section 10.7 (5) currently does not provide additional details related to flooding. At present, no information regarding overland flow is provided, however completion of the Wagga Wagga MOFFRMS&P (this Study) will provide Council with high resolution flood information, as well as an Overland Flow FPA, which will enable them to pass on such information to residents.

More sophisticated data and mapping produced in this study will assist in the dissemination of accurate and site-specific information to the community. A GIS based map can provide useful information to a property owner and simplify the identification of issues by a Council staff member. Section 17.2 and 17.3 of Appendix I to the FDM (Reference 3) detail typical examples of information for inclusion in Section 10.7 (2) and (5) Planning Certificates, and include the following:

- Whether the land is within the FPA (overland, riverine, or both) and if flood related development controls apply, (10.7(2));
- Design flood levels/depths specific to the property for the 1% AEP, 5% AEP and PMF events, (10.7(5));
- Percentages of lots affected by the FPA(s) if not 100%, (10.7(5));
- Likelihood of flooding and mechanism (riverine/ overland flow/ both) (10.7(5));
- Flood hazard (10.7(5));
- Hydraulic categorisation (e.g. floodway) (10.7(5));
- Evacuation routes/ constraints (10.7(5)); and
- Associated Mapping for the above items (10.7(5)).

The more informed a home owner is, the greater the understanding of their flood risk. During a flood event, having this understanding may help prepare residents for evacuation and reduce the number of residents that elect to shelter in place in high hazard areas, which can increase pressure on the SES if they are isolated or their homes inundated. This can support flood response strategies.

Land owners will be required to be notified of changes to both the 10.7 (2) and 10.7 (5) Planning Certificates. Land owners can be concerned as to how a notification may impact on their property value or insurance, for example. The Insurance Council of Australia provides detailed fact sheets on how flood information is used for insurance pricing. This should be taken into account when developing a consultation strategy for notification of any changes related to s10.7 Planning Certificates.

11.5.14.2. Recommendation

Recommendation P09: Inclusion of Overland Flow flood information on Section 10.7 Planning Certificates

☑ In Section 10.7 Planning Certificates, notations regarding flooding should provide information on all mechanisms of flood risk at the site, including riverine, overland flow, or if appropriate, both. A greater level of detail can be provided via Section 10.7(5) certificates using high-resolution outputs from this Study and Council's other Floodplain Risk Management Studies.

11.6. Flood Modification Measures

11.6.1. Retarding Basins

A retarding basin is a small dam that provides temporary storage for floodwaters (Reference 3). Basins work by capturing floodwaters during a storm event, to be released at a lower flow rate once the peak of the flood has passed. Retarding basins can be an effective means of reducing peak flood levels, however depending on the outlet design and operation, may increase the duration of flooding by prolonging the release of stored floodwaters.

Depending on the scale of construction and desired level of protection, there are a number of challenges and inherent disadvantages associated with retarding basins to be carefully evaluated, including:

- Availability of land and appropriate topography – a significant area is needed to achieve the necessary storage capacity;
- Public safety during and following a flood event need to be considered, particularly for basins of significant area and/or depth, or basins easily accessed by the public who wish to 'sight-see' during a rainfall event;
- Risk of overtopping or failure if the dam is already full when additional rainfall occurs (e.g. long duration floods or multi-burst storms;
- Community perception (and acceptance) of the level of protection for which the basin is designed, and differing attitudes depending on whether residents are located upstream or downstream of the outlet; and
- Ongoing maintenance requirements to ensure structural integrity of the basin wall/embankment, and to prevent outlet pipes and gates from silting up or being damaged.

A series of relatively minor retarding basins have been considered as a means to reduce inflows into Glenfield Drain. These are described in Section 7.

11.6.2. Bypass Floodways

Floodways, also known as swales or channels, are lower overbank areas which can carry significant flow volumes in times of flood and occur naturally on some floodplains. In some instances, on smaller streams, an artificial floodway can be created in an environmentally sensitive manner to achieve a reduction in upstream flood levels. Due to space constraints in the urban parts of the MOFFRMS&P study area, bypass floodways have not been considered feasible, however, on a smaller scale, major channel modification options have been assessed, and are described in Section 11.6.3 below.

11.6.3. Major Channel Modification

Channel modification can include a range of works, from increasing the size, shape, or bank composition of a channel, to altering the natural surrounds or creek shape via dredging, lining (or naturalising lined channels), or other vegetation management practices. Channel modifications can help to reduce peak upstream flood levels by improving conveyance, although such measures may also increase flood levels in adjacent or downstream locations. Changes to velocity are also likely to occur as a result of changing the channel shape or size. In general, for channel modifications to be effective in reducing flood levels, significant excavation is required, which can have a range of environmental impacts. These include the removal of riparian vegetation, and as a result, loss of native habitat and in some cases, bank stability. Consideration must be given to the scale of works, environmental impacts, potential for sediment transfer, and the availability of an appropriate location to deposit excavated material. Channel modification measures have been assessed for both Crooked Creek (Section 11.6.11.4) and Stringybark Creek (Section 11.6.11.5), as well as part of the Glenfield Drain Scheme (Section 11.6.8).

11.6.4. Major Structure Modification

Hydraulic structures, such as bridges or major culverts, can influence flood behaviour by controlling the amount of flow that can be conveyed. Increasing conveyance capacity (i.e. by lengthening bridge spans or increase culvert dimensions) peak flood levels upstream of a structure may be decreased. Conversely, though generally less commonly, structures can be downsized to reduce conveyance and limit downstream peak flood levels. Major structure modifications have been considered in a range of locations in Wagga Wagga, for example modification of Lake Albert Road and the outlet at the northern end of Lake Albert (Section 11.6.11.3).

11.6.5. Levees and Diversion Embankments

Levees are barriers between a watercourse and developed areas that prevent the ingress of floodwater up to a design height (usually a design event plus freeboard). Levees usually take the form of earth embankments but can also be constructed of concrete walls or steel sheet piles where there is limited space or other constraints. Flood gates, flap valves and pumps are often installed through levees to prevent floodwaters backing up through the drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee.

Levees have not been considered for application in Wagga Wagga's overland flow areas, however minor diversion embankments have been assessed in conjunction with a range of options described in Section 11.6.8 and 11.6.11.

11.6.6. Road Raising

Depending on the topography of an area, floods can leave communities isolated by overtopping access routes. Raising roads to provide flood free access to such areas is commonly investigated in the floodplain risk management process, as it can reduce evacuation time and improve accessibility as the flood progresses. Raised roads can also act like levees and increase flood levels unless culverts or overland bridge spans are used appropriately. Particularly in the southern parts of Wagga Wagga, access routes including Lake Albert Road and Brunskill Road can become overtopped and restrict safe passage, if even only for a relatively short duration (than, say, compared to a riverine flood event). Options to raise Lake Albert Road both for the benefit of retaining flood-free access, and to effectively increase available airspace in Lake Albert, is assessed in Section 11.6.11.3.

11.6.7. Local Drainage Upgrade

Local drainage systems typically reach capacity in an event equivalent to a 20% AEP event, and excess runoff flows overland, potentially posing a threat to pedestrians, motorists, and if of sufficient depth, properties. The options assessed in the following section are intended to decrease the flood risk associated with overland flow in Wagga Wagga. It is noted that these options are unlikely to have significant benefits in terms of reducing property damages, however, the reduction in severity or frequency of nuisance inundation, particularly along roads, could be beneficial to the community. It is noted that recommendations arising from this study regarding options of this nature (e.g. Incarnie Crescent, Section 11.6.9) may fall into the purview of Council's stormwater management rather than floodplain risk management, however this Study has provided an opportunity to assess them using the hydraulic modelling available.

11.6.8. GD: Glenfield Drain Scheme

Glenfield Drain runs from Red Hill Road in the City's south, northwards beneath the railway embankment and Sturt Highway, and discharges to the Flowerdale Storage Area. From here water is transferred into Flowerdale Lagoon via levee pipes No. 1 and 2. Each of these gates is closed when the Murrumbidgee River reaches 4.8 m at the Hampden Bridge Gauge to prevent the pipes from backwatering (as the river fills the adjoining Flowerdale Lagoon). A permanent pump is located at Flood Gate 1 (Flowerdale Lagoon), and is augmented with supplementary mobile pipes as needed.

For the most part, the drain exists as an open channel adjacent to Glenfield Road. Forming the major trunk drain in the southwestern part of the city, Glenfield Drain services the suburbs of Lloyd, Bourkelands, Tolland, Glenfield Park, Mt Austin, Ashmont, and parts of Turvey Park. Information from the community, Council, and results from the available flood modelling, suggests Glenfield Drain is undersized in relation to the current contributing urban catchment, potentially as a result of new development since the drain was designed and constructed, as well as capacity reductions caused by erosion and slumping of channel banks.

Locations where the capacity of the drain is exceeded include the Pearson Street/ Dobney Avenue roundabout, in part due to the reduced hydraulic conveyance that occurs at the two 90° bends in the drain at the north-eastern and north-western corners of the Bunnings carpark. This hotspot has been identified as a relatively frequent source of risk to motorists and pedestrians, and is the target of a range of mitigation measures. In addition, elevated water levels in the Flowerdale Storage Area (FSA) can significantly reduce the ability of the stormwater in the residential area immediately east of the FSA to drain effectively. The FSA drains out to Flowerdale Lagoon via existing levee pipes, however if water levels in the Murrumbidgee River are elevated, the water level in Flowerdale Lagoon also rises, and the FSA can only be drained with the use of permanent and portable supplementary pumps.

A suite of options has been assessed herein to reduce overland flow flood risk along the length of the drain (Figure 5.1), in the contributing urban catchment areas, and in the urban area adjacent to the FSA. Due to space constraints caused by existing roads, infrastructure and development, it is not considered feasible to increase the size of the drain itself. Therefore, the suite of options focuses on reducing and delaying peak inflows into the drain, by creating localised areas of flood storage upstream of the Glenfield Drain, and diverting flows away from the drain, by creating new, complementary drainage lines to reduce demand on the Glenfield Drain (e.g. through Ashmont Reserve).

It is noted that at the time of writing, the Glenfield Drain was of generally poor condition, with dangerous levels of erosion and slumping of channel banks and tension cracks in affected culvert structures. While a condition assessment of Glenfield Drain is outside the scope of this study, the options presented herein should be considered in conjunction with any proposed remediation and maintenance works, as well as any future road upgrade or widening works.

11.6.8.1. Option GD01 – Red Hill Road & Glenfield Road Basin

☑	**GD01: Red Hill & Glenfield Road Intersection Civil Works**
Description	• Aim: To reduce peak flows entering Glenfield Drain by temporarily storing runoff and releasing it at a lower flow rate; • Involves augmentation of the existing retarding basin south of Red Hill Road by excavating approximately 5,000 m^3, and building up the existing Red Hill Road/ Glenfield Road intersection to raise the basin embankment, resulting in a total capacity of approximately 5.1 ML; • Low spots in the existing embankment north east of the roundabout were filled.
Benefits	• Reduced flood levels on and adjacent to Glenfield Road up to the railway in the 1% AEP event, including properties no longer flooded on the eastern side of Glenfield Road.
Concerns	• Increased flood depths upstream of the embankments, both in the designated basin southwest of the intersection, as well as the downstream parts of Jubilee Park; • Public safety considerations due to prolonged ponding in roadside basin.
Approximate Cost	$1,000,000 (Appendix F)
BC Ratio	< 0.5
Outcome	Progress to further investigation to be undertaken in conjunction with other works along Glenfield Drain
Priority	High

Option Description

This option involves lowering the bed levels and raising the embankments of the existing basin at Red Hill Road and Glenfield Road intersection a create a total depth of 2.5 m and a capacity of approximately 5.1 ML. The purpose of the basin is to temporarily store runoff entering from the southwest, and reducing the peak inflows entering Glenfield Drain. The existing pipe beneath Red Hill Road was reduced by 50% to allow the basin to function, and to limit the outflow capacity. Low points in the existing embankment north east of the roundabout were filled in to divert overland flow away the properties along Brooks Circuit (inclusive of Davies Place, Melba Place, and Oliver Place). The embankment's original height was retained. Jubilee Park to the east contains an existing detention basin which could be extended as part of these works.

Modelled Impacts

The option was modelled in the 1% AEP and 5% AEP events, with changes in peak flood levels shown on Figure 5.2 and Figure 5.3 respectively. The proposed option improves property affectation along Brooks Circuit and Oliver Place in both events, however there is limited change to over floor level flooding. Decreases in flood levels are observed in Glenfield Drain, downstream of the basin, as far north as the railway. On the other hand, the eastern channel adjacent to Glenfield Road experiences increases in flood levels for the 1% AEP event as a result of the filled-in diversion embankment, in the order of 0.05 m in the 1% AEP event. The resulting changes in external and over-floor property affectation in each event is provided in Table 36.

Table 36: Option GD01 Property Affectation

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (GD01)	Change	Current	Option (GD01)	Change
20% AEP	4136	4135	-1	87	87	0
10% AEP	4656	4655	-1	143	143	0
5% AEP	5090	5076	-14	200	199	-1
2% AEP	5411	5392	-19	315	314	-1
1% AEP	5818	5796	-22	417	417	0
0.5% AEP	6113	6093	-20	524	524	0
0.2% AEP	6428	6405	-23	616	616	0
PMF	8627	8632	5	1192	1191	-1

Other Concerns and Considerations

Other aspects to consider include the following:

- Signage, fencing and other public safety measures associated with temporary storage of overland flow;
- Ongoing maintenance, including periodic de-silting of the basin bed and ensuring backfill around the outlet pipe is intact;
- Tenure of land identified for proposed works;
- Identification of future opportunities to construct this measure in conjunction with other Council objectives (e.g. widening Glenfield Road) to improve economic merits;
- Refinement of design, potentially including additional stormwater inlet pits on the western side of Glenfield Road.

11.6.8.2. Option GD02 – Adjin Street & Maher Street Intersection Civil Works

☑	**GD02: Adjin Street & Maher Street Intersection Civil Works**
Description	• Suite of civil works intended to reduce inundation of properties and roads between Maher Street and Glenfield Road.
Benefits	• Removes external flood affectation for 47 properties and over-floor flooding for 4 dwellings in the 1% AEP event; • Significant reductions in flood levels east of Glenfield Road.
Concerns	• Minor increase in flood levels in the industrial properties and vacant land upstream of the railway.
Approximate Cost	$800,000 (Appendix F)
BC Ratio	> 1.5
Outcome	Progress to further investigation to be undertaken in conjunction with other works along Glenfield Drain
Priority	High

Option Description

An open stormwater channel runs underneath and perpendicular to Adjin Street. Overtopping of the road occurs even for frequent events (10% AEP and rarer) causing flooding of properties surrounding Adjin Street. Additionally, floodwaters exceeding the banks at the western end of the channel causes inundation of properties adjacent to Glenfield Road. South of the channel, a trapped low point on Maher Street restricts overland flow from reaching the channel, restricting access to the road and properties in this location.

To improve drainage of overland flow in this area, a suite of civil works is proposed. In developing this option, many iterations of the below arrangement have been tested using the hydraulic model, and the most effective combination has been presented. The suite of proposed works involved in this option include:

- Regrading Maher Street to relocate the existing low point eastwards to the intersection at Adjin Street, to allow stormwater to be conveyed north along Adjin Street and into the open channel;
- Excavation of the existing open channel immediately upstream and downstream of the Adjin Street causeway to increase conveyance capacity;
- Construction of an impermeable (sheet pile or concrete) wall on the northern bank of the open channel to prevent breakouts into properties east of Glenfield Road; and
- Installation of a new 1.8 m diameter pipe to cross Glenfield Road (i.e. doubling the existing capacity).

Modelled Impacts

The option was modelled in the 1% AEP and 5% AEP events, with changes in peak flood levels shown on Figure 5.4 and Figure 5.5 respectively. The proposed option is effective in preventing floodwaters from overtopping the channel banks and entering the houses along Adjin Street. Four properties are predicted to be free from over floor inundation on Adjin Street for the 1% AEP event with significant reductions in peak flood levels along the east side of Glenfield Road. However, these works culminate in increased peak flood levels downstream (on the western side) of Glenfield Road. While these increases are mainly contained to the open channel, several industrial properties upstream of the railway embankment would be subject to higher flood levels (in the order of 0.05 m in the 1% AEP event).

Table 37: Option GD02 Property Affectation

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (GD02)	Change	Current	Option (GD02)	Change
20% AEP	4136	4112	-24	87	87	0
10% AEP	4656	4617	-39	143	140	-3
5% AEP	5090	5053	-37	200	196	-4
2% AEP	5411	5362	-49	315	312	-3
1% AEP	5818	5771	-47	417	413	-4
0.5% AEP	6113	6070	-43	524	523	-1
0.2% AEP	6428	6381	-47	616	613	-3
PMF	8627	8629	+2	1192	1184	-8

Other Concerns and Considerations

This option contains a range of works, with an estimated total capital cost in the order of $800,000. However, the degree of complexity and design requirements for the flood wall may lead to this figure increasing. With an allowance of $7000 for annual maintenance, this option would have a Cost Benefit Ratio of 1.02 (noting that the benefits are limited to avoiding property damages, and do not include the benefit of reduced inundation over roads).

Other aspects to consider include the following:

- The option is a combination of discrete works which could be implemented in stages as funding allows or in conjunction with other projects;
- The low flow drainage line should be designed as a grass swale to allow for mowing and maintenance;
- Consideration of public safety around the open channel;
- Cost benefit ratio does not consider reduced nuisance flooding, driver safety, or benefits relating to reduced traffic disruption;
- Targeted consultation may be required to ascertain the value of these works to the local residents;
- Environmental considerations regarding erosion and sediment control in the open channel;
- Compensatory works for adversely affected downstream properties.

11.6.8.3. Option GD03 – Anderson Oval Basin and Swale Augmentation

☑	**GD03: Anderson Oval Basin and Swale Augmentation**
Description	• Aim: Increase flood storage capacity at Anderson Oval to reduce flooding on Finch Place and to reduce (and delay) peak inflows from entering Glenfield Drain; • Increase existing embankment height around Anderson Oval from 1 m to 2.25 m; • A spillway is provided in the north western section of the basin, set 0.25 m lower than the remainder of the embankment; • A swale was excavated to allow runoff from Finch Place to flow towards Fernleigh Road rather than back up behind the basin embankment.
Benefits	• The extent of reductions in flood levels is significant and can be observed up to the northern extent of the City model; • Effective in reducing peak flood levels across a range of events.
Concerns	• Public safety concerns as a significant depth (> 1 m) would be ponded within the playing field in a 5% AEP event; • Reduction in amenity and usability of the oval following rain events.
Approximate Cost	$510,000 (Appendix F)
BC Ratio	>1.4
Outcome	Progress to further investigation to be undertaken in conjunction with other works along Glenfield Drain
Priority	High

Option Description

This option involves increasing the existing 1 m-high embankment around Anderson Oval by 1.25 m on the eastern, northern and western sides of the oval to create additional flood storage capacity. A spillway 65 m in length was incorporated to allow controlled overtopping if the basin were to be filled. The weir was set to a height 0.25 m lower than the embankment. Additionally, a swale was incorporated into the design from Finch Place along the outside of the eastern embankment to Fernleigh Road to reduce flood levels in and around Finch Place, as overland flow from this street and surrounding areas would not be able to enter the basin.

Modelled Impacts

The option was modelled in the 1% AEP and 5% AEP events, with changes in peak flood levels shown on Figure 5.6 and Figure 5.7 respectively. The proposed embankment provides an additional storage of approximately 33 ML resulting in flood depths within the oval of > 1 m in a 5% AEP event. The basin has far-reaching benefits, reducing peak flood levels as far north as Flowerdale Storage Area in the 1% AEP event.

While a large portion of the benefits occur on vacant land, Fernleigh Road, Glenfield Road, Urana Street and Pearson Street all experience decreases in flood levels up to 0.08 – 0.1 m across a range of events. The change in property affectation is presented in Table 38.

Table 38: Option GD03 Property Affectation

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (GD03)	Change	Current	Option (GD03)	Change
20% AEP	4136	4135	-1	87	86	-1
10% AEP	4656	4656	0	143	138	-5
5% AEP	5090	5081	-9	200	195	-5
2% AEP	5411	5406	-5	315	307	-8
1% AEP	5818	5812	-6	417	411	-6
0.5% AEP	6113	6109	-4	524	517	-7
0.2% AEP	6428	6427	-1	616	613	-3
PMF	8627	8634	+7	1192	1190	-2

Other Concerns and Considerations

The proposed embankment and swale works are estimated to cost in the order of $510,000, resulting in an estimated cost benefit ratio of 1.44. This ratio underestimates the true economic benefit of this option, as it does not include quantification of benefits relating to reduced over-road flooding and associated reduction in traffic disruptions and cost of damage to the roads themselves.

Other aspects to consider include the following:

- Affected usage of the playing field whilst ponding water or water-logged;
- Long term damage to existing turf if post-storm drainage is not well managed;
- Lack of existing drainage in sports field;
- Potential salinity issues;
- Public safety considerations and dangers of children using the ponded water to play in, could be mitigated by outlet treatment and grade of field.

11.6.8.4. Option GD04 – Rabaul Place Trunk Drainage Line

☑	**GD04: Rabaul Place Trunk Drainage Line**
Description	• Aim: Reduce inflows into Glenfield Drain to reduce demand on the existing open channel, by diverting flows to Ashmont Drain; • Significant trunk drain installation, involving 3 x 1.8m diameter pipes from immediately downstream of the western railway culvert near Rabaul Place to the channel north of Ashmont Avenue.
Benefits	• Significant reductions in peak flood levels along Pearson Street and Dobney Avenue with some areas showing a 0.2 m reduction in flood level for the 1% AEP event; • Effective in reducing peak flood levels in frequent events.
Concerns	• Increases peak flood levels at and around the northern end of the channel near the Sturt Highway; • Staged construction would be required to allow affected roads to remain trafficable.
Approximate Cost	$2,900,000 (Appendix F)
BC Ratio	< 0.5
Outcome	Progress to further investigation to be undertaken in conjunction with other works along Glenfield Drain
Priority	Low

Option Description

This option aims to reduce the inflows into Glenfield Drain downstream of the railway by diverting flows through a new trunk drain on Rabaul Street, with its outlet at Ashmont Reserve. The option involves installation of three 1.8m diameter pipes, 400 m long underneath Rabaul Place from the railway to the channel (near Ashmont Avenue and Urana Street intersection). It assumes the existing railway embankment and culvert are not modified.

Modelled Impacts

The option was modelled in the 1% AEP and 5% AEP events, with changes in peak flood levels shown on Figure 5.8 and Figure 5.9 respectively. The proposed pipeline is effective in reducing flood levels in Glenfield Drain and Glenfield Road and completely removes over-floor flood affectation in the 1% AEP event for 10 buildings. However, with the newly increased inflow into Ashmont Reserve, peak flood levels in the open channel are increased and in industrial buildings just upstream of the Sturt Highway (Edward Street), flood levels increase by up to 0.06 m in the 1% AEP, and to a lesser extent in the 5% AEP event. These impacts would likely need to be offset by other works if this option were to progress. The change in property affectation is shown in Table 39.

Table 39: Option GD04 Property Affectation

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (GD04)	Change	Current	Option (GD04)	Change
20% AEP	4136	4126	-10	87	86	-1
10% AEP	4656	4643	-13	143	142	-1
5% AEP	5090	5084	-6	200	197	-3
2% AEP	5411	5399	-12	315	308	-7
1% AEP	5818	5792	-26	417	407	-10
0.5% AEP	6113	6091	-22	524	512	-12
0.2% AEP	6428	6418	-10	616	597	-19
PMF	8627	8626	-1	1192	1192	0

Other Concerns and Considerations

To be effective, Option GD04 requires a significant capacity, and has been modelled with a three-cell pipeline of 1.8 m diameter, over 400 m. In addition to this, approximately 26,000 m³ of excavation would be necessary to install these pipes. Construction of these works is estimated to cost $2.5M and, relative to its limited reduction in property damages, is not likely to be economically feasible, with an estimated benefit cost ratio of 0.33, noting that the quantified benefits only consider avoided property damages. During the construction period, works would need to be staged to allow the area to remain trafficable and would lead to disruption to the community, though this is considered manageable.

Other aspects to consider include the following:

- Opportunities to modify the railway culvert and improve the efficiency of this (and other) options in collaboration with ARTC;
- Acquisition of drainage easement between the railway and the Rabaul Place cul de sac;
- Existing condition of the Glenfield Drain and associated hydraulic structures in this area; and
- Environmental considerations of increasing flow through Ashmont Reserve regarding potential erosion, scouring and sedimentation.

11.6.8.5. Option GD05 – Flowerdale Lagoon Drainage Improvements

☑	**GD05: Flowerdale Lagoon Drainage Improvements**
Description	• Aim: Improve drainage of the Flowerdale Storage Area by installing an additional major levee pipe between Floodgates 01 and 02 (Flowerdale Lagoon and Wiradjuri Reserve); • The installation of three 1.8 m diameter levee pipes has been tested near the Wiradjuri Walking Track, between Flood Gates 1 and 2; • Investigation of supporting pumps.
Benefits	• Significant flood level reductions along Spring Street and the Olympic Highway up to Evans Street and Shaw Street (up to 0.42 m); • Similar reductions can be seen along Pearson Street (up to 0.38 m); • Major flood level reductions observed on the vacant land between the lagoon and the Olympic Highway (up to 0.66 m); • Minimal works required.
Concerns	• Construction at this location would interfere with the Main City Levee Spillway; • Potential for constraints relating to cultural and heritage values of Flowerdale Lagoon.
Approximate Cost	Variable
BC Ratio	Likely to be at or greater than 1
Outcome	Undertake further investigation and design
Priority	High

Option Description

The Glenfield Drain discharges to an open area immediately adjacent to Flowerdale Lagoon known as the Flowerdale Storage Area (FSA). Under existing conditions, the FSA drains to Flowerdale Lagoon via two levee pipes (Flood Gate No. 1 and No. 2). This option considers an additional set of levee pipes through or near to the newly constructed spillway to provide additional drainage capacity, with a view to reducing property inundation in the residential areas immediately east of the FSA. This option tests the effect of installing three 1.8 m diameter pipes.

A suite of variations on this option have been assessed including optimisation of pipe sizing, number of pipes and location, as well as alternate discharge points for the Glenfield Drain west of the Flowerdale Storage Area (FSA). The option discussed below presented as the most viable.

Modelled Impacts

The option was modelled in the 1% AEP and 5% AEP events, with changes in peak flood levels shown on Figure 5.10 and Figure 5.11 respectively. The impact maps depict major reductions in peak flood level east of the lagoon as well as an improvement in flood extent. Significant improvements can be observed along Spring Street and the Olympic Highway up to Evans Street and Shaw Street. Similar reductions can be observed along Pearson Street as well as on the vacant land directly adjacent to the lagoon.

While flood levels are shown to increase up to 0.16 m in Flowerdale Lagoon for the 1% AEP event, the rise is confined to the extents of the lagoon and does not negatively impact any other areas.

Additionally, this option is effective in improving property affectation, with 50 properties predicted to be no longer flooded above floor in the 1% AEP event. While there are no improvements to over floor affectation in the more frequent events (20% AEP and 10% AEP), there is significant benefit in the rarer events with 79 and 76 properties being flood free over floor for the 0.5% and 0.2% AEP events respectively. Even in the PMF event, 26 properties are alleviated from over flood flooding. However, depending on the levels in the Murrumbidgee River, and by extension, Flowerdale Lagoon, the effectiveness of this option may be compromised.

Table 40: Option GD05 Property Affectation

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (GD05)	Change	Current	Option (GD05)	Change
20% AEP	4136	4114	-22	87	87	0
10% AEP	4656	4663	+7	143	143	0
5% AEP	5090	5072	-18	200	199	-1
2% AEP	5411	5373	-38	315	286	-29
1% AEP	5818	5757	-61	417	367	-50
0.5% AEP	6113	6037	-76	524	445	-79
0.2% AEP	6428	6345	-83	616	540	-76
PMF	8627	8582	-45	1192	1166	-26

Other Concerns and Considerations

Other aspects to consider include the following:

- Prevention of backwatering when levels in the Murrumbidgee River, and by extension, Flowerdale Lagoon are elevated;
- Review existing infrastructure which may include upgrades to existing pumps;
- Aboriginal cultural values of Flowerdale Lagoon, which are significant to Wiradjuri and associated Aboriginal people today. Consultation with relevant stakeholders is paramount for this option to progress;
- Difficulty of retro-fitting new levee pipes through or near to the recently completed Main City Levee spillway, consideration of alternative locations; and
- Effectiveness of this option during elevated tailwater levels.

11.6.8.6. Combined Glenfield Drain Scheme

In order to understand the overall benefits of GD01 – GD05, a scenario was assessed which included all proposed works along Glenfield Drain. The combined scenario was modelled for the 1% AEP and 5% events, with changes in peak flood levels shown on Figure 5.12 and Figure 5.13, respectively.

The impact maps depict very similar changes in flood behaviour as shown for those with the individual works, suggesting that there is no broadscale cumulative improvement or disbenefit in flood behaviour as a result of the combined scheme. Generally, the combined scheme shows some minor improvements to flood behaviour (for both the 5% AEP and 1% AEP) from that with the individual works in place at the following locations:

- Upstream of Maher Street, a further reduction of up to 0.05m,
- Along the western edge of Glenfield Road, the increase in flood level is reduced to up to 0.1m,
- Upstream of the railway, a further reduction of up to 0.05m, and
- An increase that occurred at Edward Street as a result of Option GD04 is offset by improvements resulting from GD05.

Additionally, the combined scenario is as effective in improving property affectation as the individual works, with 46 properties predicted to be no longer flooded above floor in the 1% AEP event. There are improvements to over floor affectation across all events, with significant benefit in the rarer events with 98 and 101 properties being flood free over floor for the 0.5% and 0.2% AEP events, respectively. Even in the PMF event, 36 properties are alleviated from over flood flooding. However, depending on the levels in the Murrumbidgee River, and by extension, Flowerdale Lagoon, the effectiveness of the overall scheme may be reduced.

Table 41: Option GDSCH Property Affectation

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (GD05)	Change	Current	Option (GD05)	Change
20% AEP	4136	4101	-35	87	86	-1
10% AEP	4656	4603	-53	143	135	-8
5% AEP	5090	5001	-89	200	188	-12
2% AEP	5411	5284	-127	315	269	-46
1% AEP	5818	5664	-154	417	351	-66
0.5% AEP	6113	5947	-166	524	426	-98
0.2% AEP	6428	6254	-174	616	515	-101
PMF	8627	8594	-33	1192	1156	-36

11.6.9. Option SW01 – Incarnie Crescent Stormwater Line

☑	**SW01: Incarnie Crescent Stormwater Line Regrading**
Description	• Aim: Reduce flood levels along Incarnie Crescent; • Connect existing drainage line along Incarnie Crescent via a new 525 mm pipe to the trunk drainage line east towards the river.
Benefits	• Peak flood level reductions can be observed from Incarnie Cres all the way west to the Wiradjuri Walking Track; • No increases in flood level can be seen; • Scope of work is not extensive.
Concerns	• Incarnie Crescent will require closure while works are underway.
Approximate Cost	$500,000 (Appendix F)
BC Ratio	>1.5
Outcome	Undertake the works
Priority	High

Option Description

Under current conditions, stormwater in Incarnie Crescent drains to a pit outside the properties at No. 29-31, which drains southwards to Travers Street and east towards the Murrumbidgee River to Flood Gate 8. This drainage line services a broader area of the city to the west and south of Travers Street from Crampton Street, and can become overloaded in relatively frequent storm events.

Council staff have identified an opportunity to improve drainage of Incarnie Crescent and reduce the load on the broader system. The proposed option includes installing a new 525 mm pipe (approx. 150 m in length) beneath Incarnie Street, from the existing pit, to direct runoff to the east and north to Galing Place, where it would join the existing 525 mm pipe, crossing Narung Street and draining to Flood Gate 7. The proposed alignment is shown in Figure 5.14.

Modelled Impacts

The proposed pipe arrangement was modelled in the 1% AEP and 5% AEP events, with the effect on peak flood levels shown on Figure 5.14 and Figure 5.15 respectively. With the improved drainage capacity, peak flood level reductions occur both in Incarnie Crescent itself as well as the broader area including Leena Place and Wiradjuri Crescent. The change in property affectation in each design event is tabulated in Table 42.

Table 42: Option SW01 Change in Property Affectation

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (SW01)	Change	Current	Option (SW01)	Change
20% AEP	4136	4126	-10	87	85	-2
10% AEP	4656	4648	-8	143	142	-1
5% AEP	5090	5087	-3	200	199	-1
2% AEP	5411	5405	-6	315	312	-3
1% AEP	5818	5809	-9	417	415	-2
0.5% AEP	6113	6107	-6	524	522	-2
0.2% AEP	6428	6423	-5	616	613	-3
PMF	8627	8628	+1	1192	1192	0

Other Concerns and Considerations

The works involved in this option are relatively minor and are not expected to have material environmental or social impacts. Access to around 10 dwellings would be temporarily interrupted during construction, which could be scheduled to minimise disruption.

The installation of the new pipe is estimated to cost less than $500,000 and is likely to be able to be undertaken by Council using their own staff and equipment. A high level economic assessment suggests that with the low capital cost, and reduction in property damages, this option would have a cost benefit ratio of over 1.5 indicating it is likely to be economically feasible.

11.6.10. Option SW02 – Bolton Park Drainage Gate Automation

☑	**SW02: Bolton Park Drainage Gate Automation**
Description	• Aim: To allow control of the outlet flow from the existing Bolton Park storage to alleviate pressure on the downstream system and reduce flooding in Morgan and Berry Streets; • Install automated penstock operation
Benefits	• Minor flood reductions along Morgan Street and Berry Street for frequent events, potential reduction in duration of inundation.
Concerns	• Ineffective in rarer events; • Public safety risks, and changes to amenity and usability of the field during and following storm events.
Approximate Cost	$50,000 - $100,000
BC Ratio	>>1
Outcome	Install automated penstock
Priority	Medium

Option Description

Bolton Park is currently designated as a detention basin used to temporarily retain flood waters. To increase the utilisation of this basin, a manually operated penstock exists at the outlet.

The installation of an automation system will allow the penstock to be open and closed remotely depending on the available capacity in the downstream systems, with surcharge spilling into the playing fields. As a result, the flow entering the downstream trunk drainage network is reduced, alleviating pressure on the stormwater system that services Berry Street, Morgan Street and the surrounding commercial precinct, allowing these areas to drain more effectively during rainfall events.

Modelled Impacts

The option was modelled in the 1% AEP and 5% AEP events, with resulting changes in peak flood levels shown on Figure 5.16 and Figure 5.17 respectively. In the 5% AEP event, the closed outlet causes water within the existing trunk drainage network to surcharge onto Bolton Park, increasing peak flood levels by up to 0.25 m. North of Bolton Park peak flood levels are reduced by up to 0.1 m in the 5% AEP event across Berry Street and Morgan Street. Further downstream, the peak inflow into Tony Ireland Park lagoon is reduced, yielding benefits on the upstream Wollundry Lagoon System. However, for the 1% AEP event, the option is ineffective at reducing flood risk, as the capacity of below ground pit and pipe network is already significantly exceeded.

Table 43: Option SW02 Property Affectation

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (LA03)	Change	Current	Option (LA03)	Change
20% AEP	4136	4136	0	87	86	-1
10% AEP	4656	4655	-1	143	140	-3
5% AEP	5090	5058	-32	200	195	-5
2% AEP	5411	5398	-13	315	312	-3
1% AEP	5818	5813	-5	417	416	-1
0.5% AEP	6113	6113	0	524	523	-1
0.2% AEP	6428	6423	-5	616	616	0
PMF	8627	8627	0	1192	1191	-1

Other Concerns and Considerations

This option requires relatively limited capital works. With no roadworks required, it is estimated that this work would cost less than $500,000, and is likely to be able to be carried out by Council using in-house equipment and staff. Additional supporting material will need to be developed around the gate operating procedure and possible installation of downstream monitoring systems. A high-level economic assessment suggests that, with this low capital cost and reduction in property damages (AAD) in the order of $97,000 per year, the option would have a cost benefit ratio much greater than 1. Potential other concerns include:

- Public safety in Bolton Park during storm events;
- Reduced usability or amenity of Bolton Park following flood events.

11.6.11. Lake Albert Enhanced Flow Scheme

Lake Albert ("the Lake") is situated in the southern parts of Wagga Wagga, and is one of the most popular recreational facilities in the city. It caters for boating, fishing, swimming and other aquatic activities, and is encircled by a 5.5 km walking and cycling track, with parks and community facilities along the way. The key features of the Lake are shown in Diagram 11.

Lake Albert is utilised by many parts of the community for many roles, including:

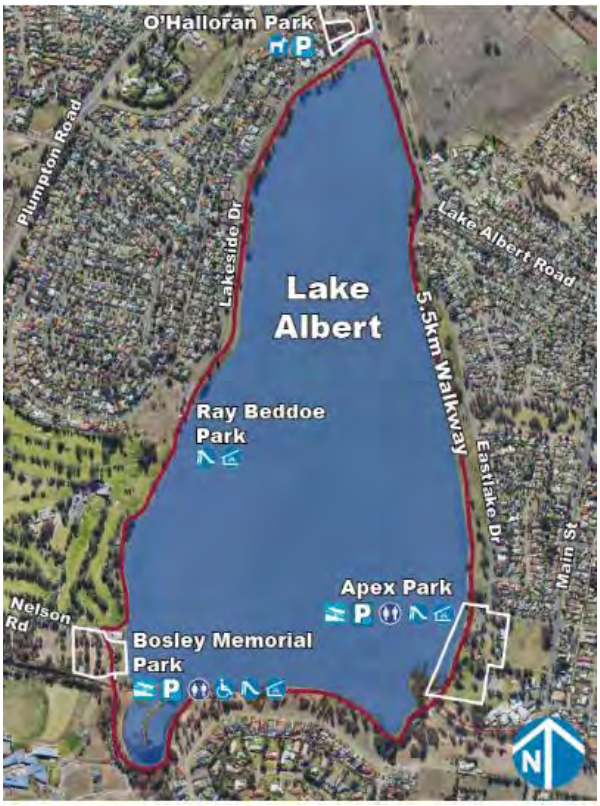
- A body of water, offering a wide range of active and passive recreational opportunities;
- A pollution control pond or sediment trap protecting the Murrumbidgee River from the flow of sediment that has historically flowed from an active erosion catchment;
- A flood mitigation structure, protecting downstream areas of the city (compared to pre-lake conditions);
- A fish breeding ground as the Lake can be a safer habitat for fish than the river systems;
- A potential source of income for the Wagga Wagga community, particularly if it can become a significant tourist attraction;
- A source of water for the Wagga Wagga Country Club and some small parkland irrigation by Council;
- A much sought-after part of Wagga Wagga to live in, with strong environmental and societal benefits (Reference 24).

The Lake however is subject to a range of pressures that reduce its amenity and usability, including low water levels as a result of reduced rainfall during periods of drought, increased sedimentation during periods of filling, water quality concerns (e.g. blue-green algae), and the uncertainty of the future effects of climate change on these factors.

In February 2010, Wagga Wagga City Council produced the Lake Albert Management Plan 2009-2015 (Reference 24), which outlined the decisions that need to be made by Council and the community in relation to the Lake's future, and has a large focus on the variety of methods by which the Lake could be filled (during periods of low rainfall) to retain amenity and water quality. However, Section 6.5 of the Management Plan discusses one use of the Lake that is, in essence, at odds with the rest of its purposes: flood mitigation. The Lake Albert Management Plan recommends that Wagga Wagga City Council develops "localised Flood Management/Mitigation plans around Lake Albert and exercises these with the other relevant NSW agencies." The Wagga Wagga MOFFRMS&P provides an opportunity to assess ways to use Lake Albert to provide flood mitigation to the broader area using the latest available hydraulic modelling based on current catchment conditions and industry guidelines (ARR 2019).

Note: options involving emptying the lake ahead of a rain event were not considered to be feasible (due to the short warning time available) nor palatable to the community and Lake users, who would prefer operational water levels are maintained as much as possible, and so have not been tested as part of this assessment.

Diagram 11: Features of Lake Albert (https://wagga.nsw.gov.au/city-of-wagga-wagga/recreation/lake-albert)

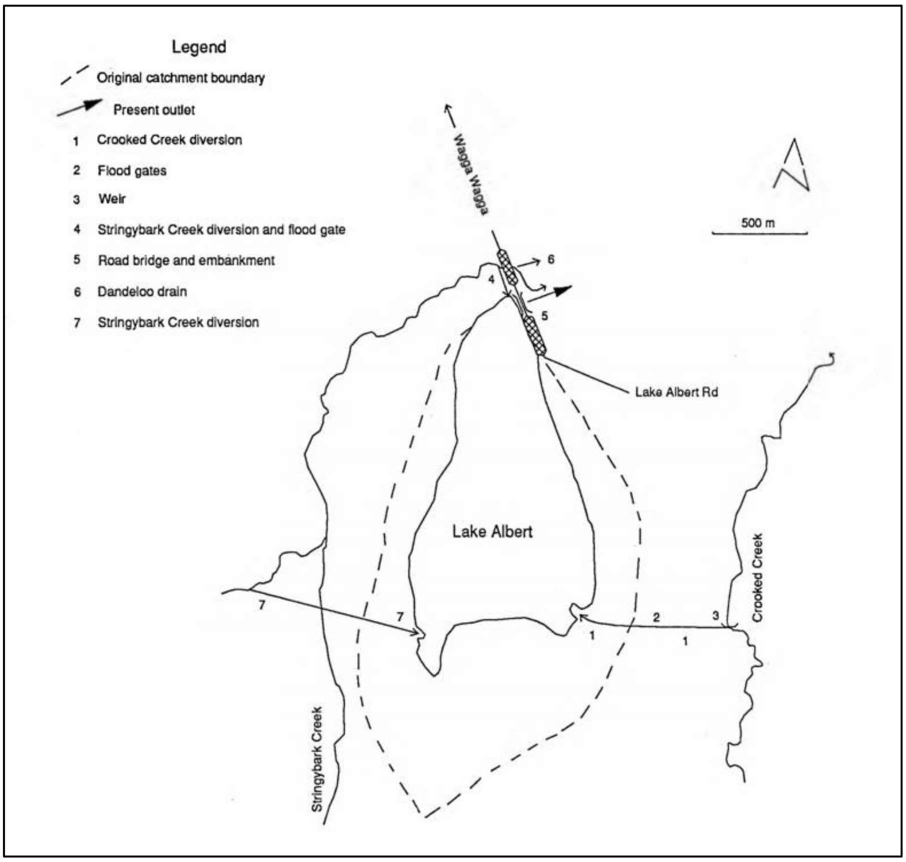


11.6.11.1. Key Events in the History of Lake Albert

To provide further context to the flood mitigation options described in this section, the below timeline has been derived from a range of accounts presented in Reference 24. Numbers in parentheses () refer to items shown on Diagram 12.

Prior to the turn of the century (pre-1898), the natural basin which Lake Albert now occupies was known as Swampy Plain, a reliable source of water for livestock along the travelling stock route, at times supplying water when the Murrumbidgee River was dry. Two stream courses ran close to the western and eastern boundaries of the catchment, namely Stringybark and Crooked Creeks respectively. Between 1898 and 1902, the ground levels around the natural basin were raised to form a lake and a diversion channel was cut from Crooked Creek to the south-eastern corner of the lake. The channel was partially lined with concrete and a wooden flood gate was installed to control water entering the lake. The diversion channel allowed some water to pass over a weir and flow down the natural creek bed while diverting some of the flow into Lake Albert, this partial diversion became a full diversion in the early 1970s. The flood-gates were used to prevent flood flows entering the lake and subsequently overflowing across the Lake Albert Village to Wagga Wagga road [sic] (1), (2) and (3). Later in the early 1930s, Stringybark Creek was diverted into the lake via a cut channel and diversion embankment at the northern end of the lake, south of Lake Albert Road. A flood-gate was also installed to restrict the entry of flood water. This diversion now serves as an alternate lake outlet (4). Later the same decade, a road bridge was constructed across the lake outlet on Lake Albert Road and the road height was raised to the current level (5).

Diagram 12: Lake Albert Schematic (Reference 3)



11.6.11.2. Utilisation of Lake Albert for Flood Mitigation

The Wagga Wagga MOFFRMS&P has provided an opportunity to test a variety of methods to enhance the role that Lake Albert plays in Wagga Wagga's flood mitigation. The flood modification option assessment has culminated in a scheme comprising three key elements.

The "Lake Albert Enhanced Flow Scheme" seeks to reduce flood damages to properties along Crooked Creek, Stringybark Creek, and downstream of Lake Albert Road. The three key elements of the scheme are described below:

- **Stage 1 (LA01):** Raise Lake Albert Road and reduce the capacity of the existing outlet structure beneath Lake Albert Road and Lakeside Drive to:
    a) Increase available airspace in Lake Albert for temporary flood storage capacity above the current water level; and
    b) Reduce the rate at which flow drains out of Lake Albert, thereby reducing peak flood levels downstream.
- **Stage 2 (LA02):** Upgrade the Crooked Creek Diversion Channel to improve conveyance of flow from Crooked Creek into Lake Albert and reduce peak flows in Crooked Creek downstream of Craft Street.
- **Stage 3 (LA03):** Upgrade the Stringybark Creek Diversion Channel to improve conveyance of flow from Stringybark Creek into Lake Albert, thereby reducing peak flows in Stringybark Creek downstream of Nelson Drive.

Details about each individual stage are provided in the subsequent sections of this report.

11.6.11.3. Option LA01 – Raising Lake Albert Road

☑	**LA01: Raising Lake Albert Road**
Description	• Raise Lake Albert Road at the north east corner of Lake Albert by approximately 2 m over a length of 450 m, and Lakeside Drive by approximately 2 m for 200 m from its intersection with Lake Albert Road. • Increase airspace in Lake Albert to provide storage capacity during flood events; • Involves reducing the Lake Albert outlet capacity by approximately 50% to limit peak outflows.
Benefits	• Reduces peak flood levels downstream of Lake Albert in the 1% AEP by up to 0.47 m immediately downstream of the road, and to a lesser degree across the East Wagga commercial area; • Minor increase in surface area of Lake Albert due to relatively gently sloping banks;
Concerns	• Increases flood levels by up to 0.45 m in the 1% AEP event in Lake Albert; • Potential adverse impacts to properties at southern end of the Lake and boating infrastructure surrounding the lake; • Lake Albert Road will require closure while works are underway.
Approximate Cost	$1,900,000 (Appendix F)
BC Ratio	< 1 (0.23)
Outcome	To progress to further investigation in combination with LA02 and LA03
Priority	High

Option Description

Raising Lake Albert Road is the first stage of preparing Lake Albert to be able to store a greater capacity of water during a flood event. The works involved in this stage must be undertaken prior to augmenting the diversions from Crooked Creek (LA02) and Stringybark Creek (LA03), to ensure that the additional inflows into the lake do not simply spill out at the northern end, overtopping the road and exacerbate downstream flooding.

The works involved in this stage include:

- Raising Lake Albert Road by up to 2 m over a length of approximately 450 m at the northern end of Lake Albert;
- Raising Lakeside Drive by up to 2 m at its northern end, and tying into existing levels approximately 200 m southwest of the intersection of Lake Albert Road;
- Modifying the existing outlet structure beneath Lake Albert Road to reduce outflows during a flood event (reducing existing outlet capacity by 50%); and
- Modifying the existing outlet structure beneath Lakeside Drive to reduce outflows during a flood event (reducing existing outlet capacity by 50%).

Modelled Impacts

The option was modelled in the 1% AEP and 5% AEP events, with impacts shown on Figure 5.18 and Figure 5.19 respectively. Under existing conditions, the diversions on Crooked Creek and Stringybark Creek become functional and direct inflows into the Lake. With the raised road, more of this inflow can be stored in Lake Albert, and the modified outflow culvert reduces the rate at which the Lake can drain, lowering peak flows entering Gregadoo and Marshalls Creeks.

As a result, peak flood levels are reduced significantly immediately downstream of Lake Albert Road and more modestly throughout the East Wagga commercial area. The broad reductions in peak flood levels however generally occur in open, undeveloped areas, and as such do not result in a material reduction in property damages.

The option results in a limited increase in water level within the Lake, around 0.13 m in the 5% AEP event, and up to 0.45 m in the 1% AEP event. While the surface area of the Lake is not materially increased, it is noted that the increased flood levels, if not managed appropriately, are likely to impact on dwellings at the south-western end corner of the Lake around Plunkett Drive, as well as the existing Sailing and Boat Club buildings.

The net change in property affectation in the Lake Albert and East Wagga model domains are provided in Table 44 and Table 45 below.

Table 44: Option LA01 Property Affectation for the Lake Albert Region

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (LA01)	Change	Current	Option (LA01)	Change
20% AEP	1634	1633	-1	43	43	0
10% AEP	1836	1835	-1	71	72	+1
5% AEP	1989	1985	-4	95	96	+1
2% AEP	2148	2144	-4	160	160	0
1% AEP	2255	2252	-3	193	194	+1
0.5% AEP	2339	2336	-3	218	219	+1
0.2% AEP	2417	2417	0	250	251	+1
PMF	3313	3311	-2	469	468	-1

Table 45: Option LA01 Property Affectation for the East Wagga Region

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (LA01)	Change	Current	Option (LA01)	Change
20% AEP	73	73	0	2	2	0
10% AEP	120	116	-4	5	4	-1
5% AEP	182	164	-18	16	12	-4
2% AEP	322	318	-4	115	114	-1
1% AEP	385	377	-8	155	149	-6
0.5% AEP	429	421	-8	177	176	-1
0.2% AEP	470	450	-20	198	196	-2
PMF	631	631	0	275	275	0

Table 46: Option LA01 Property Affectation

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (LA01)	Change	Current	Option (LA01)	Change
20% AEP	1707	1706	-1	45	45	0
10% AEP	1956	1951	-5	76	76	0
5% AEP	2171	2149	-22	111	108	-3
2% AEP	2470	2462	-8	275	274	-1
1% AEP	2640	2629	-11	348	343	-5
0.5% AEP	2768	2757	-11	395	395	0
0.2% AEP	2887	2867	-20	448	447	-1
PMF	3944	3942	-2	744	743	-1

Other Concerns and Considerations

The estimated capital cost of raising Lake Albert Road by 2 m is $1.9M, with a benefit cost ratio of 0.23. As a standalone flood mitigation measure, this option would not be recommended. Indeed, similar benefits could likely be achieved by reducing the existing outlet alone and leaving Lake Albert Road as is. However, raising Lake Albert Road is critical for the success of the broader scheme, which is dependent on increased storage capacity within the Lake.

Other items to consider include:

- Major roadworks would require complete closure of Lake Albert Road for the duration of construction – consider availability of alternate routes for local traffic;
- Construction of ramped approaches to the raised portion of the roads may affect visual amenity of local residents;
- Alternative approach may be to install a floodwall (e.g. reinforced concrete or steel sheet pile wall) on the upstream side of Lake Albert Road rather than raising the road itself (though visual impact will need to be considered);
- Consider alternative raising heights;
- Consider impacts on the Lake Club House and associated infrastructure (compensatory measures may be required);
- Optimise the outlet to allow for “back to back” events;
- Consider function of small drainage into the lake;
- Consider impacts on lake and surround road access during times of elevated lake levels;
- A strategy for the management of the airspace would need to be developed to ensure that the competing objectives of lake water levels and flood mitigation can be achieved;
- Consideration of aesthetic values, visual amenity and retention of walking circuit and cycleway around the Lake.

11.6.11.4. Option LA02 – Augmentation of Crooked Creek Diversion into Lake Albert

Note: This option assumes LA01 (Raising Lake Albert Road) is complete.

☑	**LA02: Augmentation of Crooked Creek Diversion into Lake Albert**
Description	• Increase capacity of the existing Crooked Creek diversion south of Craft Street, to reduce flood risk further north by diverting flows into Lake Albert; • Construct a 1 m high diversion embankment along Craft Street to assist in function of the Crooked Creek diversion channel and provide protection to residences north of Craft Street.
Benefits	• The extent of reductions in flood levels is significant and can be observed from Craft Street through to East Wagga along the Crooked Creek watercourse;
Concerns	• Environmental factors including retention of 'low flow' through the original creek channel; • Erosion, scouring and sedimentation concerns will need to be considered in the design of widened channels; • Potential loss of habitat; • Acquisition of privately owned land adjacent to the creek may be necessary depending on preferred channel width.
Approximate Cost	\$500,000 (LA02 works only) (Appendix F)
BC Ratio	0.9 (includes cost of option LA01)
Outcome	To progress to further investigation in combination with LA01 and LA03
Priority	High

Option Description

Under existing conditions, Crooked Creek is partially diverted into Lake Albert, with some flow continuing northwards through a small channel between properties on Bocquet Street and Rowe Street, and a broader flowpath east of Power Street moving through Rawlings Park, across Brunskill Road, then through Sycamore Drain towards Marshalls Creek. Overbank flow from Crooked Creek contributes significantly to over-floor property damages (particularly downstream of Brunskill Road) as well as causing over-road inundation that can temporarily restrict local access and affect the condition of roads themselves.

To reduce the peak flows in the Crooked Creek system downstream (north) of Craft Street, this option proposes to augment the existing diversion, expanding the existing channel by 10 m from upstream of Craft Street to Lake Albert. To ensure the diversion channel functions, and that flow from Crooked Creek does not overtop Craft Street and continue northwards, a 1 m high embankment is proposed between Craft Street and the channel (i.e. along the existing footpath).

Over a length of 580 m, the augmented diversion channel would require the excavation of approximately 6,800 m^3 of earth from the existing creek bank. Depending on the quality of the spoil, some of this cut could be used to construct the new diversion embankment parallel to Craft Street, and otherwise should be deposited outside of the floodplain.

Modelled Impacts

The option was modelled in the 1% AEP and 5% AEP events, with changes in peak flood levels shown on Figure 5.20 and Figure 5.21 respectively. The augmentation of the Crooked Creek diversion channel results in a significant and widespread reduction in peak flood levels north of the works by up to 0.15-0.4 m along Crooked Creek, and by up to 0.18 m further downstream in the East Wagga commercial area in the 1% AEP event. The largest impact occurs directly north of the proposed works and prevents over-floor inundation of 7 properties in a 5% AEP event, and 13 properties in a 1% AEP event. Within Lake Albert, the top water level would be raised by up to 0.72 m in the 1% AEP event, and 0.28 m in the 5% AEP event. The changes to property affectation are tabulated in Table 47 and Table 48.

Note that this option assumes that Option LA01 (Raising Lake Albert Road) has been completed. If LA01 is not implemented, the additional inflow into Lake Albert would pass through the lake (with some attenuation) and ultimately increase the amount of flow exiting the northern end of the Lake, overtopping Lake Albert Road and exacerbating flooding downstream.

Table 47: Option LA02 Property Affectation for the Lake Albert Region

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (LA02)	Change	Current	Option (LA02)	Change
20% AEP	1634	1631	-3	43	43	0
10% AEP	1836	1805	-31	71	66	-5
5% AEP	1989	1954	-35	95	88	-7
2% AEP	2148	2120	-28	160	151	-9
1% AEP	2255	2213	-42	193	180	-13
0.5% AEP	2339	2289	-50	218	208	-10
0.2% AEP	2417	2374	-43	250	241	-9
PMF	3313	3303	-10	469	467	-2

Table 48: Option LA02 Property Affection for the East Wagga Region

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (LA02)	Change	Current	Option (LA02)	Change
20% AEP	73	72	-1	2	2	0
10% AEP	120	115	-5	5	4	-1
5% AEP	182	155	-27	16	11	-5
2% AEP	322	307	-15	115	97	-18
1% AEP	385	360	-25	155	143	-12
0.5% AEP	429	413	-16	177	175	-2
0.2% AEP	470	441	-29	198	194	-4
PMF	631	631	0	275	275	0

Other Concerns and Considerations

Other aspects to consider include the following:

- This option involves extensive excavation, potentially requiring the acquisition of land and removal of trees;
- The potential loss of vegetation could result in adverse environmental impacts for both native habitats as well as bank stability and erosion control;
- Consideration will need to be given to maintaining, as much as possible, the natural amenity of the creek at this location, and involving local residents and users in the process;
- Public safety considerations, including fencing and signage - even when dry, the proposed channel will be a steep, deep excavation;
- The design should consider the ability to capture flow from the eastern portion of the catchment;
- This measure does not reduce flood risk upstream of Craft Street, and the design of the diversion will need to ensure that the works do not exacerbate flooding south of the diversion.

11.6.11.5. Option LA03 – Augmentation of Stringybark Creek Diversion into Lake Albert

Note: This option assumes LA01 (Raising Lake Albert Road) is complete.

☑	**LA03: Augmentation of Stringybark Creek Diversion into Lake Albert**
Description	• Increase capacity of the Stringybark Creek diversion south of Nelson Drive and reduce flood risk along Plumpton Road and further downstream by diverting flows into Lake Albert; • Construct a diversion embankment 1 m high, parallel to Nelson Drive;
Benefits	• Reductions in peak flood levels observed from Nelson Drive through to East Wagga; • Reductions in over-road inundation, particularly Plumpton Road;
Concerns	• Environmental factors including retention of ‘low flow’ through the original creek channel; • Erosion, scouring and sedimentation concerns will need to be considered in design of widened channels; • Acquisition of privately owned land adjacent to the creek may be necessary depending on preferred channel width.
Approximate Cost	$1,300,000 (LA03 works only) (Appendix F)
BC Ratio	0.46 (includes cost of option LA01)
Outcome	To progress to further investigation in combination with LA01 and LA02
Priority	High

Option Description

An unnamed watercourse approaches Plumpton Road from the southwest through Springvale, as a natural watercourse to Springvale Drive, then through an engineered open channel eastwards to Plumpton Road. Under existing conditions, some flow continues eastwards through the existing Stringybark Creek diversion channel where it is joined by flow from Stringybark Creek from the south, into Lake Albert, with the remainder of flow continuing northwards, through the golf course and along Plumpton Road, into another open channel bypassing the northern side of Lake Albert (Dandeloo Drain).

Plumpton Road near Nelson Drive has been identified in the community consultation to be an area that experiences flooding, preventing vehicles from accessing the road. This option proposes raising the road heights on Plumpton Road and Nelson Drive adjacent to the intersection by 1 m to reduce flood risk along Plumpton Road and minimise the overtopping of the road. In addition to this, this option involves widening the Stringybark Creek diversion channel by 10 m from the creek intersection with Plumpton Road to Lake Albert. Over the channel length of 720 m, this option requires the removal of approximately 27,200 m³ of earth from the creek banks and would require transportation offsite to a location outside of the floodplain, or if suitable, could be used in the diversion embankment construction.

Modelled Impacts

The option was modelled in the 1% AEP and 5% AEP events, with the resulting changes in peak flood levels shown on Figure 5.22 and Figure 5.23 respectively. The augmentation of Stringybark Creek reduces peak flood levels north of the works by up to 0.95 m in the 1% AEP event. There is a noticeable decrease in flooded areas with the most prominent being near the Wagga Wagga Country Club. Property affectation is greatly improved for the rarer events mostly along the eastern side of Plumpton Road. Plumpton Road itself experiences significant reductions in peak flood levels, with some portions identified as no longer flooded in a 5% AEP event. Assuming Lake Albert Road is raised (Option LA01), this option would result in 31 properties in the Lake Albert model domain, and a further 7 properties in the East Wagga model domain no longer flooded above floor in a 2% AEP event.

Table 49: Option LA03 Property Affectation for the Lake Albert Region

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (LA03)	Change	Current	Option (LA03)	Change
20% AEP	1634	1633	-1	43	43	0
10% AEP	1836	1829	-7	71	71	0
5% AEP	1989	1942	-49	95	94	-1
2% AEP	2148	2083	-65	160	129	-31
1% AEP	2255	2194	-61	193	162	-31
0.5% AEP	2339	2296	-43	218	182	-36
0.2% AEP	2417	2388	-29	250	224	-26
PMF	3313	3303	-10	469	460	-9

Table 50: Option LA03 Property Affectation for the East Wagga Region

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (LA03)	Change	Current	Option (LA03)	Change
20% AEP	73	73	0	2	2	0
10% AEP	120	116	-4	5	4	-1
5% AEP	182	160	-22	16	12	-4
2% AEP	322	315	-7	115	108	-7
1% AEP	385	361	-24	155	146	-9
0.5% AEP	429	415	-14	177	175	-2
0.2% AEP	470	441	-29	198	196	-2
PMF	631	631	0	275	275	0

Other Concerns and Considerations

Other aspects to consider include the following (most of which are also common to the Crooked Creek Diversion Augmentation Option (LA02)):

- This option involves extensive excavation, potentially requiring the acquisition of land and removal of trees;
- The potential loss of vegetation could result in adverse environmental impacts for both native habitats as well as bank stability and erosion control;
- Consideration will need to be given to maintaining, as much as possible, the natural amenity of the creek at this location, and involving local residents and users in the process;
- Proximity to assets including the Wagga Wagga Sailing and Boat Clubs and public toilets;
- Public safety considerations, including fencing and signage - even when dry, the proposed channel will be a steep, deep excavation;
- Consider sheet piling to assist diversion and groundwater diversion. The area is already subject to significant erosion;
- Need to consider impacts of road overtopping;
- Consider impacts of development to the north of the diversion;
- This measure does not reduce flood risk upstream (west) of Plumpton Road, and the design of the diversion will need to ensure that the works do not exacerbate flooding south of the diversion.

11.6.11.6. Lake Albert Enhanced Flow Scheme - Ultimate Scenario

It is intended, that ultimately, Options LA01, LA02 and LA03 would be completed, to bring about flood mitigation benefits for both the eastern and western sides of Lake Albert, as well as further downstream (to the north) across the East Wagga commercial area.

☑	**Lake Albert Region Ultimate Scenario**
Description	• Aim: Improve flood risk across the broader Lake Albert region and downstream in East Wagga; • Combines all Lake Albert options from LA01 to LA03.
Benefits	• Widespread benefit across the major flooding hotspots within the Lake Albert region;
Concerns	• Total capital costs will be significant (estimated at $3.7 M); • Long-term strategy – this scheme will take time to develop and implement.
Approximate Cost	$3,700,000 (Appendix F)
BC Ratio	0.9 (Combined works)
Outcome	Feasibility Study to further investigate the Lake Albert Flow Enhancement Scheme, with a focus on LA01 and LA02 as primary outcomes and LA03 as a secondary outcome.
Priority	High

Option Description

This option is the amalgamation of all the options in the Lake Albert Region as described in Section 11.6.11.3 to 11.6.11.5. Works involve raising the level of Lake Albert Road and modifying the existing Lake outlet structure (LA01) and, augmenting the existing Crooked Creek and Stringybark Creek diversion channels to increase inflows into Lake Albert (LA02 and LA03 respectively).

Modelled Impacts

The ‘ultimate’ scenario combining options LA01, LA02 and LA03 was modelled in the 1% AEP and 5% AEP events, with changes in peak flood levels shown on Figure 5.24 and Figure 5.25 respectively. The reductions in peak flood levels along each creek are largely consistent with the results of LA02 and LA03 separately (as they each act independently). The benefits of the combined option are most pronounced in East Wagga, where the reductions from both the eastern (Crooked Creek) and western (Stringybark Creek) flow paths occur together. In the 1% AEP event, there are widespread reductions in peak flood levels in the order of 0.2 m across the East Wagga commercial area. The resulting net changes in property affectation (external and over-floor) is shown in Table 51 and Table 52.

Table 51: Ultimate Property Affectation for the Lake Albert Region

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (Ultimate)	Change	Current	Option (Ultimate)	Change
20% AEP	1634	1631	-3	43	44	+1
10% AEP	1836	1799	-37	71	65	-6
5% AEP	1989	1910	-79	95	86	-9
2% AEP	2148	2056	-92	160	118	-42
1% AEP	2255	2154	-101	193	147	-46
0.5% AEP	2339	2252	-87	218	173	-45
0.2% AEP	2417	2344	-73	250	216	-34
PMF	3313	3293	-20	469	459	-10

Table 52: Ultimate Property Affectation for the East Wagga Region

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (Ultimate)	Change	Current	Option (Ultimate)	Change
20% AEP	73	72	-1	2	2	0
10% AEP	120	115	-5	5	3	-2
5% AEP	182	151	-31	16	10	-6
2% AEP	322	294	-28	115	88	-27
1% AEP	385	351	-34	155	140	-15
0.5% AEP	429	410	-19	177	171	-6
0.2% AEP	470	437	-33	198	194	-4
PMF	631	631	0	275	274	-1

Table 53: Ultimate Property Affectation

Event	Properties Affected (externally)			Properties Flooded Over Floor		
	Current	Option (Ultimate)	Change	Current	Option (Ultimate)	Change
20% AEP	1707	1703	-4	45	46	1
10% AEP	1956	1914	-42	76	68	-8
5% AEP	2171	2061	-110	111	96	-15
2% AEP	2470	2350	-120	275	206	-69
1% AEP	2640	2505	-135	348	287	-61
0.5% AEP	2768	2662	-106	395	344	-51
0.2% AEP	2887	2781	-106	448	410	-38
PMF	3944	3924	-20	744	733	-11

Other Concerns and Considerations

See corresponding section for options LA01, LA02 and LA03 for concerns relating to the individual components. The benefit of the Lake Albert Enhanced Flow Scheme is likely to be further increased by:

- Future development south of Lake Albert, wherein increased hardstand (roads, pavements, buildings for example) may result in an increase in the runoff that enters the creek systems;
- Broader benefits to flood levels on roads and bridges downstream. Other stakeholders (such as Transport for NSW) will need to be involved as the design progresses; and
- Elevated water levels in the Murrumbidgee River – particularly relating to the coincident flooding that may be avoided or minimised in the East Wagga areas.

A detailed economic assessment is recommended to be undertaken with these scenarios in mind, to better understand the full range of benefits of this scheme.

The assessment described herein has identified that increasing the storage capacity of Lake Albert and improving diversions from Crooked Creek and Stringybark Creeks would be advantageous from a floodplain risk management perspective. However, a range of other factors require due consideration and investigation in the feasibility study stage of the project. These include, but are not limited to, the following:

Environmental Factors

- Retention of base flows in Stringybark and Crooked Creeks (if any);
- Management of blue-green algae and other water quality issues;
- Protection of native habitat within and in proximity to works zones;
- Designing channel alignments for erosion control;
- Increased inflows to the Lake are likely to lead to increased deposition of sediments unless managed appropriately. Consideration of sediment traps and periodic dredging, particularly at the southern end of the lake, may be required to maintain total storage capacity;
- Groundwater conditions and urban salinity.

Social and Recreational Factors

- Important to maintain the current social and recreational values of the lake and lakeside amenities, not just for local residents but for the broader community;
- Public safety considerations during times of creek flows, elevated lake levels, and restricted usage of the lake during draw-down periods;
- Competing interests from the Lake Albert Sailing Club and other recreational lake users that would prefer higher lake levels year round. A well considered operational manual will be needed to balance the competing objectives of keeping the lake as high as possible whilst maintaining adequate airspace to provide flood mitigation storage capacity; and
- The amenity of the diversion channels, which, in such close proximity to public recreation facilities, may be preferred to be constructed with a ‘natural’ look to the embankments, use of gabion basket retaining walls, rather than concrete lined channels.

11.6.12. Option FM01- Willans Hill Overland Flow Options Assessment

☑	**FM01: Willans Hill Overland Flow Options Assessment**
Description	• Aim: To ultimately develop mitigation strategies for properties impacted by rainfall runoff in the Willans Hill area and to identify other areas where detailed investigations may be required. • Establish an appropriate tool that can identify issues and assess mitigation options for the runoff and overland flow impacting the Willans Hill area. • Undertake a drainage investigation study of the area. • Consider other strategies to minimize inlet pit blockage. • Consider changes to flood behaviour as a result of proposed development in the surrounding area.
Benefits	• A more appropriate scaled hydraulic model will allow strategies to be developed that can minimize the impacts of runoff and overland flow in this area.
Concerns	• Very targeted area, there may be other areas which require a similar assessment; • Suggested works will likely need to be funded by private landowners or in some cases Council (unlikely to be funded by the State).
Approximate Cost	$50,000 (study only)
BC Ratio	>>1
Outcome	Undertake the Willans Hill Drainage Investigation with the aim to develop runoff and overland flow mitigation strategies for the area.
Priority	High

Option Description

The current study is aimed at the estimation of overland flow flood behaviour resulting from creeks and remnant drainage lines; and developing strategies to mitigate the impacts of this flood mechanism. Small scale property inundation (often including footpaths, driveways etc) can also result from concentration of rainfall runoff before it enters the systems described above. A review of inundation reports from Council's database identified a number of drainage issue reports in locations (particularly the Willans Hill area, Hardy Ave and Cullen Road) not identified as part of the broader study. Investigation of these locations identified that the drainage issues may be a result of the smaller scale runoff process.

Strategies to mitigate this type of runoff affectation are typically at a much smaller scale to that being assessed as part of this study and may include small drainage upgrades, regrading gutters and driveways or foot paths, for example. The current hydraulic model does not simulate flow to this level of detail and therefore cannot assess the benefit of works at this scale. The development of a refined and more detailed hydraulic model in these localised areas including Willans Hill will allow for the assessment of this runoff behaviour, identifying the cause and developing a scheme of works to mitigate the impacts. A number of steps will be required, including:

- Refining the hydraulic model topographic representation, this may require additional field survey, site visits and community engagement, ultimately a smaller scale DEM would be produced,

- Refining the existing hydrologic model sub catchments to suit the scale of the flow being assessed,
- Review a range of storm durations,
- Determine localised flow behaviour,
- Review previous reports undertaken in this area,
- Consider changes to flood behaviour and proposed mitigation strategies associated with currently proposed developments in the area,
- Develop strategies to mitigate the impacts of this flow behaviour.

The proposed study should be undertaken in consultation with Council's outdoor staff, with on the ground experience, in addition to Council's Flood and Stormwater teams and residents.

Other Concerns and Considerations
This option requires relatively limited initial expenditure. It is estimated that the investigation could be undertaken for around $50,000. The cost of recommendations out of the study is likely to be variable but some aspects may be the responsibility of landowners or be able to be carried out by Council using in-house equipment and staff. In the context of the economic assessments undertaken in this broader study, on face value, this option is likely to have a low cost benefit ratio and is unlikely to be funded via the NSW Government Floodplain Management Program. With that in mind, the reduced nuisance value and amenity for the community should not be underestimated, particularly given the relatively minor investment that would be required. As part of this investigation Council may also consider strategies to minimise the build up of debris at drainage inlets, including pre-emptive maintenance at known issue locations and avoidance of bark mulch in overland flow areas.

11.6.13. Option FM02 – McNickle and Roach Road Intersection

☑	**FM02: McNickle and Roach Road Intersection**
Description	• Aim: To improve flood immunity at the Roach and McNickle Road intersection to improve access for residents in Riverview Drive. • Install culvert with conveyance area of 5m^2 and reinstate channel downstream of intersection.
Benefits	• Relatively minor upgrades to the culvert at the intersection and reinstatement of a channel downstream can significantly improve the flood immunity of the intersection. • Overall a general reduction of flood levels in the area.
Concerns	• Very targeted area, there may be other areas which require a similar assessment. • Intersection will require closure while works are undertaken and alternative access will be required. • Suggested works would not be eligible for State funding.
Approximate Cost	$300,000
BC Ratio	Less than 1 as there are no property benefits, benefits are related to improved access.
Outcome	Develop a design for an upgrade to the culvert and channel at the McNickle and Roach Road intersection
Priority	Medium

Option Description

Under current conditions, the intersection of Roach and McNickle Roads becomes inundated in frequent events, limiting access to properties in Riverview Drive. An existing channel exists to the west of McNickle Road, with culvert crossings at each road entrance. At Roach Road the channel capacity is reduced to a small dish drain and there is currently no culvert under the intersection.

Council staff have identified an opportunity to improve the flood behaviour at this location. The proposed option includes installing a new culvert with a $5m^2$ flow area beneath the intersection, a slight raising of the intersection and an upgrade to the dish drain downstream. The proposed alignment is shown in Figure 5.26 and Figure 5.27.

Modelled Impacts

The proposed works were modelled in the 1% AEP and 10% AEP events, with the effect on peak flood levels shown on Figure 5.26 and Figure 5.27 respectively. With the improved drainage capacity, peak flood level reductions occur both at the intersection of Roach and McNickle Roads as well as across the broader area. Shallow inundation remains over the road however it it likely that this could be removed via a slight change to the road level. The primary aim of the option is to improve road immunity and therefore there are no property overfloor flooding benefits.

Other Concerns and Considerations

The works involved in this option are relatively minor and are not expected to have material environmental or social impacts. Access to around 25 dwellings would be temporarily interrupted during construction, which could be scheduled to minimise disruption or an alternative temporary route provided.

The road corridor to the north of Roach Road is currently 20m wide and is likely to be able to accommodate a widened channel without the need for property acquisition.

The installation of the culvert and channel is estimated to cost less than $300,000 and is likely to be able to be undertaken by Council using their own staff and equipment. A high level economic assessment suggests that even with the low capital cost, due to no property benefits, this option would have a cost benefit ratio of less than 1.0. This method does not however consider the benefits to access that will be provided.

11.6.14. Other Options Not Considered Further

A range of other options were considered and found to not be viable in reducing flood risk, these locations included:

- An alternative alignment for the Glenfield Drain scheme, the recommended scheme was shown to achieve greater reduction in flood level,
- A detention basin in Ashmont Reserve, at Stirling Boulevard and between Urana and Pearson Streets were found to be ineffective in reducing peak flows,
- An additional swale adjacent to Glenfield Road, near Adjin Street, was found to be ineffective,

- An alternative option in the flowerdale storage area which involved splitting the storage area, was found to be less effective that the recommended scheme,
- Road raising at Brunskill Road and Craft Roads,
- Additional drainage/channel capacity under Gregadoo Road and along Plumpton Road,
- Forsyth Street lowspot, a number of road level adjustment and drainage upgrades were considered to reduce the ponding of floodwaters on Forsyth Street. The topographic constraints and adjacent streetscape do not allow this to be achieved without significant works and subsequent costs.
- Morgan and Berry Street Drainage line, an increased (2x) capacity drainage line was investigated along Morgan and Berry Streets discharging at Tony Ireland Park. Very minor benefits (of up to 0.05m) were shown to occur, limiting the viability of this option when considering the scale of works that would be required.

12. MULTI CRITERIA MATRIX ASSESSMENT

12.1. Introduction

The Floodplain Development Manual (Reference 3) recommends the use of multi-criteria assessment matrices when assessing flood risk mitigation measures. A multi-criteria matrix assessment (MCMA) provides a method by which options can be assessed against a range of criteria, and offers a greater breadth of assessment than is available by considering only the reduction in flood risk or economic damages, for example. Such additional criteria may include social, political and environmental considerations and intangible flood impacts that cannot be quantified or included in a Cost-Benefit Analysis. It should be noted that the assessment of the suitability of floodplain mitigation options is a complex matter, and an MCMA will not give a definitive ‘right’ answer, but will provide a tool to debate the relative merits of each option.

12.2. Scoring System

A scoring system has been devised to allow stakeholders to assess the various options across a consistent basis to allow for direct comparison. The scoring system is divided into four key criteria: Flood Behaviour, Economic, Social and Environmental. Scores for each criterion are to be assigned to each option then summed to determine the overall score. Options with higher scores indicate benefits across a range of criteria and should be prioritised over those with lower positive scores, which may be more neutral or have a combination of pros and cons. Conversely, options with the lowest negative scores indicate the option would cause adverse outcomes in a number of criteria and should not be considered further. The scoring system is provided in Table 54, and the outcomes of the assessment shown in Table 55. Discussion of the results is provided in Section 12.3.

Table 54: Multicriteria Matrix Assessment

	Criteria	Metric	Score -3	-2	-1	0	1	2	3
Economic	Economic Merits	*Comparison of the economic benefits against the capital and ongoing costs*	BC < 0.1	BC: 0.1- 0.5	BC: 0.5-0.9	BC = 1 (Or NA)	BC: 1.0 - 1.4	BC: 1.4 - 1.7	BC >1.7
	Implementation Complexity	*Potential design, implementation and operational challenges and constraints. Risk can increase with implementation timeframe*	Major constraints and uncertainties which may render the option unfeasible	Constraints or uncertainties which may significantly increase costs or timeframes	Constraints or uncertainties which may increase costs or timeframes moderately	NA	Constraints that can be overcome with moderate investment of time and resources	Constraints that can be overcome easily	No constraints or uncertainties
	Staging of Works	*Ability to stage proposed works*			Works cannot be staged	NA	Some minor components of the works may be staged	Some major components of the works may be staged	
Social	Impact on Emergency Services	*Change in demand on emergency services (SES, Police, Ambulance, Fire, RFS etc).*	Major disbenefit	Moderate Disbenefit	Minor Disbenefit	Neutral	Minor Benefit	Moderate Benefit	Major Benefit
	Road Access	*Flood depths and duration changes for key transport routes*	Key access roads become flooded that were previously flood free	Significant increase in main road flooding (depth and/or duration)	Moderate increase in local or main road flooding (depth and/or duration)	No Change	Moderate decrease in local or main road flooding (depth and/or duration)	Significant decrease in main road flooding (depth and/or duration)	Local and main roads previously flooded now flood free
	Impact on critical and/or vulnerable facilities [1]	*Disruption to critical facilities*	Inoperational for several days	Inoperational for one day	Inoperational for several hours	No Change	Period of inoperation reduced by 0-4 hours	Period of inoperation reduced by > 4 hours	Prevents disruption of critical facility altogether
	Impact on Properties	*No. of properties flooded over floor. Across all events*	>5 adversely affected	2-5 adversely affected	<2 adversely affected	None	<5 benefitted	5 to 10 benefitted	>10 benefitted
	Impact on flood hazard	*Change in hazard classification*	Significantly increased in highly populated area (Increasing to H5/H6)	Moderately increased in populated area (Increasing by 2 or more categories)	Slightly increased (Increase by 1 category)	No Change	Slightly reduced (Decrease by 1 category)	Moderately reduced in populated area (Decrease by 2 or more categories)	Significantly reduced in highly populated area (Decrease from H5/H6)
	Community Flood Awareness	*Change in community flood awareness, preparedness and response*	Significantly reduced	Moderately reduced	Slightly reduced	No Change	Slightly improved	Moderately improved	Significantly improved
	Social disruption	*Closure of or restricted access to community facilities (including recreation)*	Normal access significantly reduced or facilities disrupted for > 5 days	Normal access routes moderately reduced or facilities disrupted for 2-4 days	No Change to access but facilities disrupted for up to 12 hours	No Change	Reduces duration of access disruption or facility disruption by up to 12 hours	Reduces duration of access disruption or facility disruption by 2-4 days	Prevents disruption of access or facility altogether
	Community and stakeholder support	*Level of agreement (expressed via formal submissions and informal discussions)*	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	Neutral	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions

	Criteria	Metric	Score -3	-2	-1	0	1	2	3
Environmental	Impacts on Flora & Fauna (inc. street trees)	*Impacts or benefits to flora/fauna*	Likely broad-scale vegetation/habitat impacts	Likely isolated vegetation/habitat impacts	Removal of isolated trees, minor landscaping.	Neutral	Planting of isolated trees, minor landscaping.	Likely isolated vegetation/habitat benefits	Likely broad-scale vegetation/habitat benefits
	Heritage Conservation Areas and Heritage Items	*Impacts to heritage items*	Likely impact on State, National or Aboriginal Heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	No impact	Reduced impact on contributory item within a heritage conservation area	Reduced impact on local heritage item	Reduced impact on State, National or Aboriginal Heritage item
Other Aspects	Financial Feasibility and Funding Availability	*Capital and ongoing costs and funding sources available*	Significant capital and ongoing costs, or no external funding or assistance available	Moderate capital and ongoing costs, no funding available	High capital and ongoing costs, partial funding available	NA	Moderate capital and ongoing costs, partial funding available; or low capital and ongoing costs, no funding available	Low to moderate capital and ongoing costs, partial funding available	Full external funding and management available
	Compatibility with existing Council plans, policies or projects	*Level of compatibility*	Conflicts directly with objectives of several plans, policies or projects	Conflicts with several objectives or direct conflict with one or few objectives	Minor conflicts with some objectives, with scope to overcome conflict	Not relevant	Minor support for one or few objectives	Some support for several objectives, or achieving one objective	Achieving objectives of several plans, policies or projects

[1] Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. These may include fire, ambulance and police stations, hospitals, water and electricity supply, buses/train stations and chemical plants. Vulnerable facilities refer to those properties with vulnerable occupants, such as nursing homes or schools.

12.3. Results

Table 55: Multicriteria Matrix Assessment Results

			Economic			**Social**								**Environmental**		**Other Aspects**		
Category	**ID**	**Option**	Economic Merits	Implementation Complexity	Staging of Works	Impact on Emergency Services	Road Access	Impact on critical and/or vulnerable facilities	Impact on Properties	Impact on flood hazard	Community Flood Awareness	Social disruption	Community and Stakeholder Support	Impacts on Flora & Fauna (inc. street trees)	Heritage Conservation Areas and Heritage Items	Financial Feasibility and Funding Availability	Compatibility with existing Council plans, policies or projects	**Total Score**
Response Modification	RM01	Amend Flood Plans to Include Overland Flow Flood Information	0	1	2	3	0	0	0	0	1	0	1	0	0	1	1	10
	RM02	Coordination of Emergency Services and Response Agencies	0	1	2	2	0	0	0	0	0	0	1	0	0	2	1	9
	RM03	Flood Warning System	0	-1	2	3	0	0	0	0	2	0	0	0	0	1	2	9
	RM04	Community Flood Awareness	0	1	2	2	0	0	0	0	3	0	1	0	0	1	3	13
	RM05	Improvements to Driver Safety	0	2	2	3	0	0	0	0	2	0	1	0	0	1	2	13
Property Modification	P01	Adopt Overland Flow Flood Planning Area	0	1	0	1	0	0	3	0	1	0	0	0	0	1	1	8
	P02	Adopt Overland Flow Flood Planning Level	0	-1	0	1	0	0	3	0	1	0	0	0	0	1	1	6
	P03	Adoption of Flood Related Development Controls for Development within the Overland Flow FPA	0	-1	0	1	0	0	3	0	0	0	1	0	0	1	3	8
	P04	Development Controls on Low Flood Risk Areas	0	1	0	1	0	2	3	0	1	0	0	0	0	1	2	11
	P05	Appropriate Land Use Zoning in Future Development Areas	0	1	0	1	0	2	3	0	0	0	1	0	0	1	3	12
	P07	Appropriate management of areas subject to both Riverine and Overland Flow Flood Risk	0	1	0	1	0	2	3	0	0	0	0	0	0	1	3	11
	P08	Confirm Suitability of riverine flood related development controls within the overland PMF flow extent	0	1	0	1	0	2	0	0	0	0	0	0	0	0	2	6
	P09	Flood Risk Info on s10.7 Planning Certificates	0	1	0	1	0	0	0	0	2	0	1	0	0	1	1	7

			Economic			Social								Environmental		Other Aspects		
Category	ID	Option	Economic Merits	Implementation Complexity	Staging of Works	Impact on Emergency Services	Road Access	Impact on critical and/or vulnerable facilities	Impact on Properties	Impact on flood hazard	Community Flood Awareness	Social disruption	Community and Stakeholder Support	Impacts on Flora & Fauna (inc. street trees)	Heritage Conservation Areas and Heritage Items	Financial Feasibility and Funding Availability	Compatibility with existing Council plans, policies or projects	Total Score
Flood Modification	GD01	Red Hill Road and Glenfield Road Basin	-2	-1	1	1	1	0	1	1	0	1	0	0	0	-1	-1	1
	GD02	Adjin Street and Maher Street Intersection Civil Works	2	-1	2	1	1	0	1	-1	0	1	0	0	0	1	1	8
	GD03	Anderson Oval Basin and Swale Augmentation	2	-1	-1	0	0	0	2	-2	1	-1	0	-1	0	1	1	1
	GD04	Rabaul Place Trunk Drainage Line	-2	-2	1	1	1	0	2	1	0	0	0	0	0	-1	-1	0
	GD05	Flowerdale Lagoon Drainage Improvements	1	-1	-1	1	1	0	3	1	1	1	0	-2	-1	1	1	6
	SW01	Incarnie Crescent Stormwater Line	2	2	-1	1	2	0	1	2	0	1	0	0	0	1	1	12
	SW02	Bolton Park Drainage Gate Automation	1	2	1	1	1	0	1	1	0	-1	0	0	0	2	1	10
	LA01	Raising Lake Albert Road	-2	-1	-1	0	1	0	2	1	0	-1	0	0	0	-1	-1	-3
	LA02	Augmentation of Crooked Creek Diversion into Lake Albert	-1	-1	-1	0	1	0	3	1	0	1	0	0	0	1	1	5
	LA03	Augmentation of Stringybark Creek Diversion into Lake Albert	-2	-1	-1	0	1	0	3	1	0	-1	0	0	0	-1	1	0
	FM01	Willans Hill Overland Flow Options Assessment	-2	1	1	0	1	0	0	1	0	0	1	0	0	1	1	5
	FM02	McNickle and Roach Road Intersection	-2	1	1	1	3	0	0	2	0	1	1	0	0	1	1	10

The results of the multicriteria assessment are provided in Table 55, with each of the assessed management options scored against the range of criteria. It is important to note that the approach undertaken does not provide an absolute “right” answer as to what should be included in the Management Plan but is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis, which stakeholders can then use to make a decision.

For the same reason, the total score given to each option, is only an indicator to be used for general comparison. Options with positive scores indicate that the benefits of the option outweigh negative aspects. These options have been recommended for inclusion in the Floodplain Risk Management Plan (See Section 13).

The highest ranking options are SW01:Incarnie Crescent Stormwater Line, RM04: Community Flood Awareness PM04:Community Flood Awareness and PM05:Improvements to Driver Safety. These option’s high score are a result of relatively low capital cost, compared to other benefits.

Typically, options with negative scores are not recommended for further investigation; in this case LA01:Raising Lake Albert Road plays a key role in the combined scheme for the Lake Albert Enhanced Flow Scheme; and has not been discarded, despite its negative score.

13. DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

The Floodplain Risk Management Plan summarises the recommended measures that have been investigated as part of the Floodplain Risk Management Study. Measures have been assessed for effectiveness against a range of criteria. The assessment criteria included how the option affected property damages, community flood awareness, impact on the SES, and economic merits, and a range of other factors. Recommended options are prioritised based upon how readily the management measures can be implemented, their capital cost, what constraints exist and how effective the measures are. Measures with little cost that can readily be implemented, and which are effective in reducing damage or personal danger would have high priority.

Table 56 lists the mitigation measures that have been recommended by the Floodplain Risk Management Study for implementation and describes the purpose of the measure, as well as its priority, cost, timeframe and the party responsible for its implementation. Detailed description of each recommendation is provided in Section 11 of the Study.

The Floodplain Risk Management Plan has been prepared in accordance with the NSW Floodplain Development Manual.

Table 56: Floodplain Risk Management Plan

Option ID	Type	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Priority
HIGH PRIORITY										
RM01	Response Measure	Amend Flood Plans to include Overland Flow Flood Information	Amend local flood plans and operational plans to include information on flood risk due to overland flow, drawing on modelling and information provided in this FRMS&P	Detailed information will allow for better management of overland flow flood risk and will increase understanding of the different levels and types of risk present in Wagga Wagga.	Modelled results should be used as a guide only, as real flood behaviour may vary from modelled design results.	SES	SES	In house	N/A	High
RM04	Response Measure	Community Flood Awareness	Establish and implement ongoing and collaborative education to improve flood awareness.	Flood awareness significantly improves preparedness for and recovery from flood events, building a more flood resilient community.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	Council in collaboration with other response agencies and community organisations.	Council	Annual Budget to be determined and allocated.	N/A	High
RM05	Response Measure	Improvements to Driver Safety	Undertake an investigation using the outputs from the FRMS&P to identify locations for the installation of road flood signage.	The installation of appropriate road signage pointing to routes likely to be cut and alternate routes, reduces the risk to drivers during floods, reducing the number of incidences of motorists driving through floodwater. Could potentially reduce demand on SES with a reduced number of incidents.	Community attitudes, awareness of, and behaviour during overland flood events will need to be considered. Signage needs to be as automated as possible to reduce additional demand on Council resources.	Council	Council/ TfNSW	In house	N/A	High
P01	Property	Adoption of Overland Flow Flood Planning Area	Adopt the Overland Flow Flood Planning Area developed in the FRMS&P.	FPLs are effective tools to limit property damage to new development and redevelopment. FPLs may pertain to minimum floor levels or flood proofing levels depending on the type of development.	A planning proposal is required to amend the LEP and implement the new FPL. May be considered more onerous for developers.	Council	Council	In house	N/A	High
P02	Property	Adoption of Overland Flow Flood Planning Level	Adopt the Overland Flow (Residential) Flood Planning Level developed in the FRMS&P defined as the 1% AEP level plus 0.3 m freeboard. Modify the Wagga Wagga LEP to contain the definition consistent with Reference 7.	The FPA will provide clear guidance on the properties subject to flood related development controls.	A planning proposal is required to amend the LEP and implement the new FPA definition. Consultation would be required.	Council	Council	In house	N/A	High
P05	Property	Appropriate Land Use Zoning in Future Development Areas	For areas not covered by existing flood mapping, undertake a flood investigation to develop flood mapping and allow for an appropriate assessment of flood risk. Ensure Planning Proposals for the rezoning of future growth areas are undertaken with due consideration of flood risk using information available to Council through its various Floodplain Risk Management Studies and Plans. If no flood information is available, consideration should be given to undertaking further analysis prior to determining land use zoning for future development areas. Ensure Development Planning Controls are implemented to manage development in areas of new growth in relation to flooding. This may include, for example, guidelines relating to the permissible proportion of impervious surfaces in areas of new development.	Considering flood risk in future development areas will allow early decisions to be made to reduce flood risk and minimise the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous or likely to reduce the development yield.	Council	Council	In house	N/A	High
P07	Property	Appropriate Management of areas subject to both riverine and overland flow flood risk.	Proposed development is to be assessed (and designed) with due consideration of the full range of flood risk present at the site, i.e., riverine, overland flow, or both mechanisms. For residential development both Riverine and Overland Flow FPAs are to be considered, while critical utilities or vulnerable facilities may warrant consideration of the PMF for either or both flood mechanisms, particularly when considering Flood Planning Levels, evacuation constraints and other methods to manage the full range of flood risk.	Considering flood risk from all mechanisms will ensure development is appropriate given the prevailing risk, minimising flood risk and the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous.	Council	Council	In house	N/A	High
P08	Property	Confirm suitability of riverine flood related development controls within the overland flow PMF extent.	Controls to reduce riverine flood risk (e.g. by filling above a particular level) may inadvertently exacerbate the flood risk due to overland flow. It is recommended that Council's flood related development controls are assessed for their suitability in relation to overland flow flood information provided in this Study.	Considering flood risk from all mechanisms will ensure development is appropriate given the prevailing risk, and ensuring impacts are not worsened by controls to protect against one mechanism.	Individual consideration may be required.	Council	Council	In house	N/A	High

HIGH PRIORITY										
Option ID	**Type**	**Option**	**Description**	**Benefits**	**Concerns**	**Responsibility**	**Funding**	**Cost**	**B/C Ratio**	**Priority**
P09	Property	Inclusion of Overland Flow flood information on Section 10.7 Planning Certificates	In Section 10.7 Planning Certificates, notations regarding flooding should provide information on all mechanisms of flood risk at the site, including riverine, overland flow, or if appropriate, both. A greater level of detail can be provided via Section 10.7(5) certificates using high-resolution outputs from this Study and Council's other Floodplain Risk Management Studies.	The more informed a home owner is, the greater the understanding of their flood risk. During a flood event this information can help prepare residents to evacuate and reduces the number of residents that elect to take shelter in high hazard areas.	Limited - s10.7(2) certificates already contain basic information, Council to provide further detail from current FRMS&P results. May increase demand on Council staff, however GIS systems can be established to provide this information efficiently.	Council	Council	In house	N/A	High
GD01 (Glenfield Drain)	Flood	Red Hill Road and Glenfield Road Basin (further investigation)	Aim: To reduce peak flows entering Glenfield Drain by temporarily storing runoff and releasing it at a lower flow rate; • Involves augmentation of the existing retarding basin south of Red Hill Road by excavating approximately 5,000 m^3, and building up the existing Red Hill Road/ Glenfield Road intersection to raise the basin embankment, resulting in a total capacity of approximately 5.1 ML; Low spots in the existing embankment north east of the roundabout were filled	Reduced flood levels on and adjacent to Glenfield Road up to the railway in the 1% AEP event, including properties no longer flooded on the eastern side of Glenfield Road.	Increased flood depths upstream of the embankments, both in the designated basin southwest of the intersection, as well as the downstream parts of Jubilee Park. Public safety considerations due to prolonged ponding in roadside basin.	Council	May be eligible for NSW Government funding	$1,000,000	<0.5	High
GD02 (Glenfield Drain)	Flood	Adjin Street & Maher Street Intersection Civil Works (further investigation)	Suite of civil works intended to reduce inundation of properties and roads between Maher Street and Glenfield Road.	Removes external flood affectation for 47 properties and over-floor flooding for 4 dwellings in the 1% AEP event. Significant reductions in flood levels east of Glenfield Road.	Minor increase in flood levels in the industrial properties and vacant land upstream of the railway.	Council	May be eligible for NSW Government funding	$800,000	>1.5	High
GD03 (Glenfield Drain)	Flood	Anderson Oval Basin and Swale Augmentation (further investigation)	Aim: Increase flood storage capacity at Anderson Oval to reduce flooding on Finch Place and to reduce (and delay) peak inflows from entering Glenfield Drain; • Increase existing embankment height around Anderson Oval from 1 m to 2.25 m; • A spillway is provided in the north western section of the basin, set 0.25 m lower than the remainder of the embankment; A swale was excavated to allow runoff from Finch Place to flow towards Fernleigh Road rather than back up behind the basin embankment.	The extent of reductions in flood levels is significant and can be observed up to the northern extent of the City model. Effective in reducing peak flood levels across a range of events.	Public safety concerns as a significant depth (> 1 m) would be ponded within the playing field in a 5% AEP event. Reduction in amenity and usability of the oval following rain events.	Council	May be eligible for NSW Government funding	$510,000	>1.4	High
GD05 (Glenfield Drain)	Flood	Flowerdale Lagoon Drainage Improvements	Aim: Improve drainage of the Flowerdale Storage Area by installing an additional major levee pipe between Floodgates 01 and 02 (Flowerdale Lagoon and Wiradjuri Reserve); The installation of three 1.8 m diameter levee pipes has been tested near the Wiradjuri Walking Track, between Flood Gates 1 and 2.	Significant flood level reductions along Spring Street and the Olympic Highway up to Evans Street and Shaw Street (up to 0.42 m). Similar reductions can be seen along Pearson Street (up to 0.38 m). Major flood level reductions observed on the vacant land between the lagoon and the Olympic Highway (up to 0.66 m); Minimal works required.	Construction at this location would interfere with the Main City Levee Spillway. Potential for constraints relating to cultural and heritage values of Flowerdale Lagoon.	Council	May be eligible for NSW Government funding	Variable	Likely >1	High
SW01	Flood	Incarnie Crescent Stormwater Line	Aim: Reduce flood levels along Incarnie Crescent; Connect existing drainage line along Incarnie Crescent via a new 525 mm pipe to the trunk drainage line east towards the river.	Peak flood level reductions can be observed from Incarnie Cres all the way west to the Wiradjuri Walking Track. No increases in flood level can be seen. Scope of work is not extensive.	Incarnie Crescent will require closure while works are underway.	Council	Council	$500,000	>1.5	High
LA01 (Lake Albert)	Flood	Raising Lake Albert Road	Raise Lake Albert Road at the north east corner of Lake Albert by approximately 1 m-1.5 m over a length of 450 m, and Lakeside Drive by approximately 1 m for 200 m from its intersection with Lake Albert Road. Increase airspace in Lake Albert to provide storage capacity during flood events; Involves reducing the Lake Albert outlet capacity by approximately 50% to limit peak outflows. To be undertaken in conjunction with LA02 and LA03	Reduces peak flood levels downstream of Lake Albert in the 1% AEP by up to 0.47 m immediately downstream of the road, and to a lesser degree across the East Wagga commercial area. Minor increase in surface area of Lake Albert due to relatively gently sloping banks;	Increases flood levels by up to 0.45 m in the 1% AEP event in Lake Albert. Potential adverse impacts to properties at southern end of the Lake. Lake Albert Road will require closure while works are underway.	Council	May be eligible for NSW Government funding	$1,900,000	0.23 (Combined 0.9)	High

LA02 (Lake Albert)	Flood	Augmentation of Crooked Creek Diversion into Lake Albert	Increase capacity of the existing Crooked Creek diversion south of Craft Street, to reduce flood risk further north by diverting flows into Lake Albert; Construct a 1 m high diversion embankment along Craft Street to assist in function of the Crooked Creek diversion channel and provide protection to residences north of Craft Street. To be undertaken in conjunction with LA01 and LA03	The extent of reductions in flood levels is significant and can be observed from Craft Street through to East Wagga along the Crooked Creek system.	Environmental factors including retention of 'low flow' through the original creek channel. Erosion, scouring and sedimentation concerns will need to be considered in the design of widened channels. Potential loss of habitat. Acquisition of privately owned land adjacent to the creek may be necessary depending on preferred channel width.	Council	May be eligible for NSW Government funding	$500,000	0.9 (Combined 0.9)	High
LA03 (Lake Albert)	Flood	Augmentation of Stringybark Creek Diversion into Lake Albert	Increase capacity of the Stringybark Creek diversion south of Nelson Drive and reduce flood risk along Plumpton Road and further downstream by diverting flows into Lake Albert; Construct a diversion embankment 1 m high, parallel to Nelson Drive;	Reductions in peak flood levels observed from Nelson Drive through to East Wagga. Reductions in over-road inundation, particularly Plumpton Road;	Environmental factors including retention of 'low flow' through the original creek channel. Erosion, scouring and sedimentation concerns will need to be considered in design of widened channels. Acquisition of privately owned land adjacent to the creek may be necessary depending on preferred channel width.	Council	May be eligible for NSW Government funding	$1,300,000	0.46 (Combined 0.9)	High
MEDIUM PRIORITY										
Option ID	**Type**	**Option**	**Description**	**Benefits**	**Concerns**	**Responsibility**	**Funding**	**Cost**	**B/C Ratio**	**Priority**
RM02	Response Measure	Flood Emergency Response Coordination	The ongoing improvement of the coordination within and between the response agencies to ensure: • Roles and responsibilities are well defined and understood by each agency (and the broader community); • Hazards can be responded to quickly, efficiently and safely; and Calls from the public can be directed to the appropriate agency and responded to effectively.	Ongoing improvements to the coordination between and within emergency service agencies. Improvements to volunteer coordination. Identify vulnerable occupants.	Challenges include change of personnel, difficulty in organising meetings and exercises between flood events.	All response agencies, including but not limited to the SES, Council, RFS, Fire and Rescue, and community organisations.	Council	In house	N/A	Medium
RM03	Response Measure	Flood Warning System	Utilise Severe Weather Warnings from the BOM to prepare for potential flash flooding events, couple with community awareness campaigns and utilise information from the FRMS&P to understand the consequences of the warning.	Improve current system using outputs from the FRMS&P. Potentially increase warning time available to the community.	May not be possible to increase warning time in overland catchments due to short catchment response time. Communication needs to be at the correct level to avoid false alarms and complacency.	Council, SES	SES and Council	In house	N/A	Medium
P03	Property	Adoption of Flood Related Development Controls for development within the Overland Flow FPA	Incorporation of flood related development controls in the Wagga Wagga DCP to manage development in areas of Wagga Wagga prone to flood risk from overland flow. The intent and objectives of the development controls is to be consistent with those applied to the riverine FPA, however adjustment of the phrasing or implementation criteria may be necessary to better suit the context of overland flow flood risk.	Improve clarity of DCP (Flood for the benefit of both developers and Council assessors/approvers. Enable proponents to design, build and manage development using the best available flood information.	There may be resistance from developers who consider new controls to be onerous.	Council	Council	In house	N/A	Medium
P04	Property	Development Controls on Low Flood Risk Areas	Modify the Wagga Wagga LEP to enable Council to apply flood related development controls to critical facilities and vulnerable land uses between the FPA and PMF extent, as defined in this study and the Revised Murrumbidgee River at Wagga Wagga FRMS&P for overland flow and riverine flood risk, respectively.	Ensure critical utilities and vulnerable facilities are designed, constructed and managed in such a way as to minimise flood risk to the structure and (if relevant) its occupants.	This amendment to the LEP would require Council to submit a planning proposal, which could be lodged in conjunction with Option PM01.	Council	Council	In house	N/A	Medium
SW02	Flood	Bolton Park Drainage Gate Automation	Aim: To allow control of the outlet flow from the existing Bolton Park storage to alleviate pressure on the downstream system and reduce flooding in Morgan and Berry Streets; Install automated penstock operation	Minor flood reductions along Morgan Street and Berry Street for frequent events, potential reduction in duration of inundation.	Ineffective in rarer events. Public safety risks, and changes to amenity and usability of the field during and following storm events.	Council	May be eligible for NSW Government funding	$50,000 - $100,000	>1.0	Medium
FM01	Flood	Willans Hill Overland Flow Options Assessment	Aim: To ultimately develop mitigation strategies for properties impacted by rainfall runoff in the Willans Hill area. Establish an appropriate tool that can identify issues and assess mitigation options for the runoff and overland flow impacting the Willans Hill area. The assessment should also consider the impacts of development. Undertake a drainage investigation study of the area.	A more appropriate scaled hydraulic model will allow strategies to be developed that can minimize the impacts of runoff and overland flow in this area.	Very targeted area, there may be other areas which require a similar assessment. Suggested works will likely need to be funded by private landowners or in some cases Council (unlikely to be funded by the State).	Council	May be eligible for NSW Government funding	$50,000 (study only)	>1.0	Medium

FM02	Flood	McNickle and Roach Road Intersection	Aim: To improve flood immunity at the Roach and McNickle Road intersection to improve access for residents in Riverview Drive. Install culvert with conveyance area of 5m^2 and reinstate channel downstream of intersection.	Relatively minor upgrades to the culvert at the intersection and reinstatement of a channel downstream can significantly improve the flood immunity of the intersection. Overall a general reduction of flood levels in the area.	Very targeted area, there may be other areas which require a similar assessment. Intersection will require closure while works are undertaken and alternative access will be required. Suggested works would not be eligible for State funding.	Council	Council	$300,000	<1.0	Medium
LOW PRIORITY										
Option ID	**Type**	**Option**	**Description**	**Benefits**	**Concerns**	**Responsibility**	**Funding**	**Cost**	**B/C Ratio**	**Priority**
GD04 (Glenfield Drain)	Flood	Rabaul Place Trunk Drainage Line (further investigation)	Aim: Reduce inflows into Glenfield Drain to reduce demand on the existing open channel, by diverting flows to Ashmont Drain; Significant trunk drain installation, involving 3 x 1.8m diameter pipes from immediately downstream of the western railway culvert near Rabaul Place to the channel north of Ashmont Avenue.	Significant reductions in peak flood levels along Pearson Street and Dobney Avenue with some areas showing a 0.2 m reduction in flood level for the 1% AEP event. Effective in reducing peak flood levels in frequent events.	Increases peak flood levels at and around the northern end of the channel near the Sturt Highway. Staged construction would be required to allow affected roads to remain trafficable.	Council	May be eligible for NSW Government funding	$2,900,000	<0.5	Low

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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

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

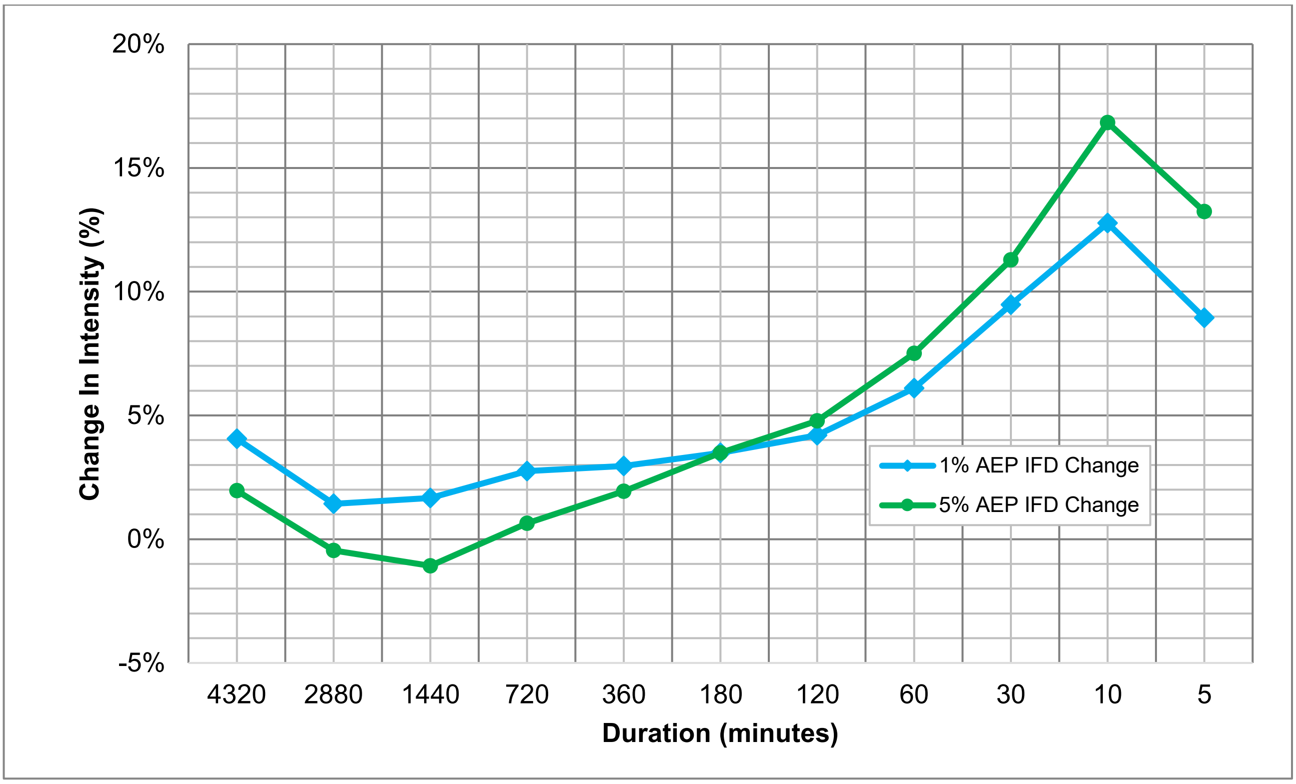
Table B3: BoM 2016 Rainfall Depths – Lake Albert Catchment

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

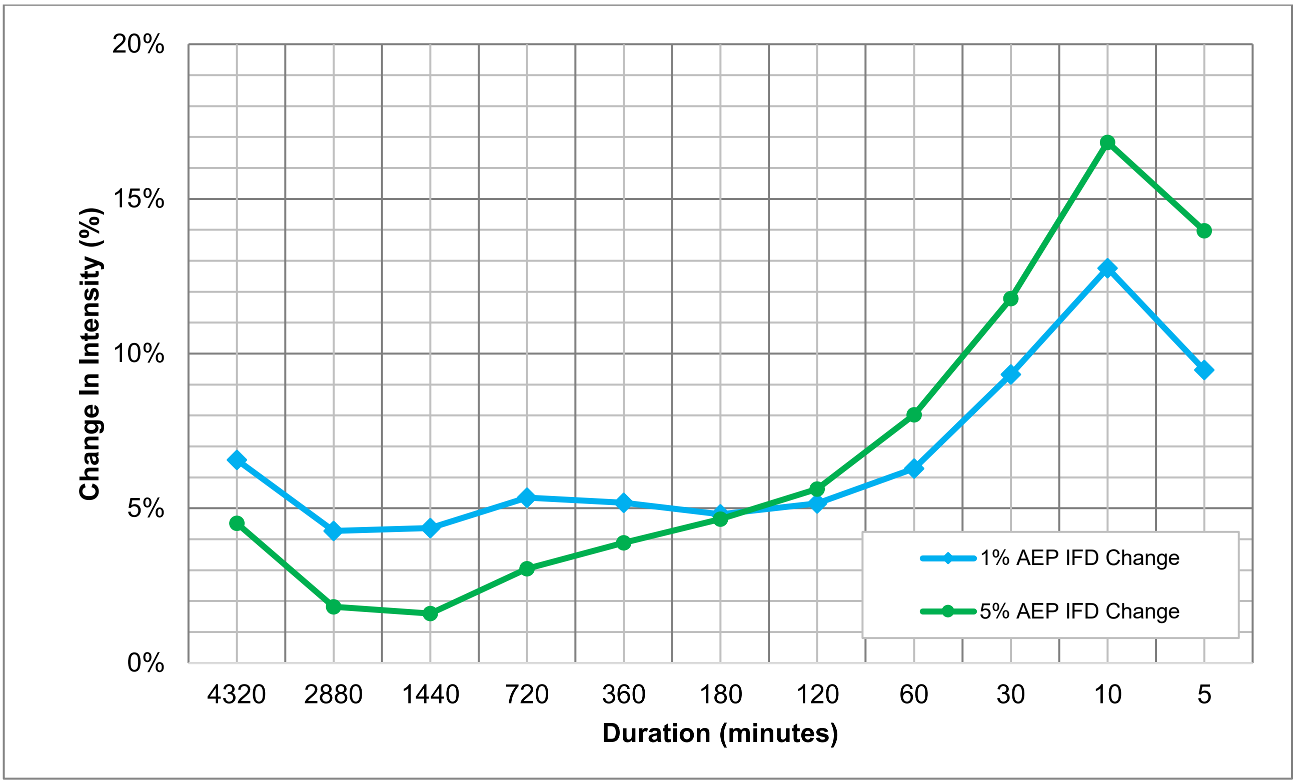
Table B4: BoM 2016 Rainfall Depths – North Catchment

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

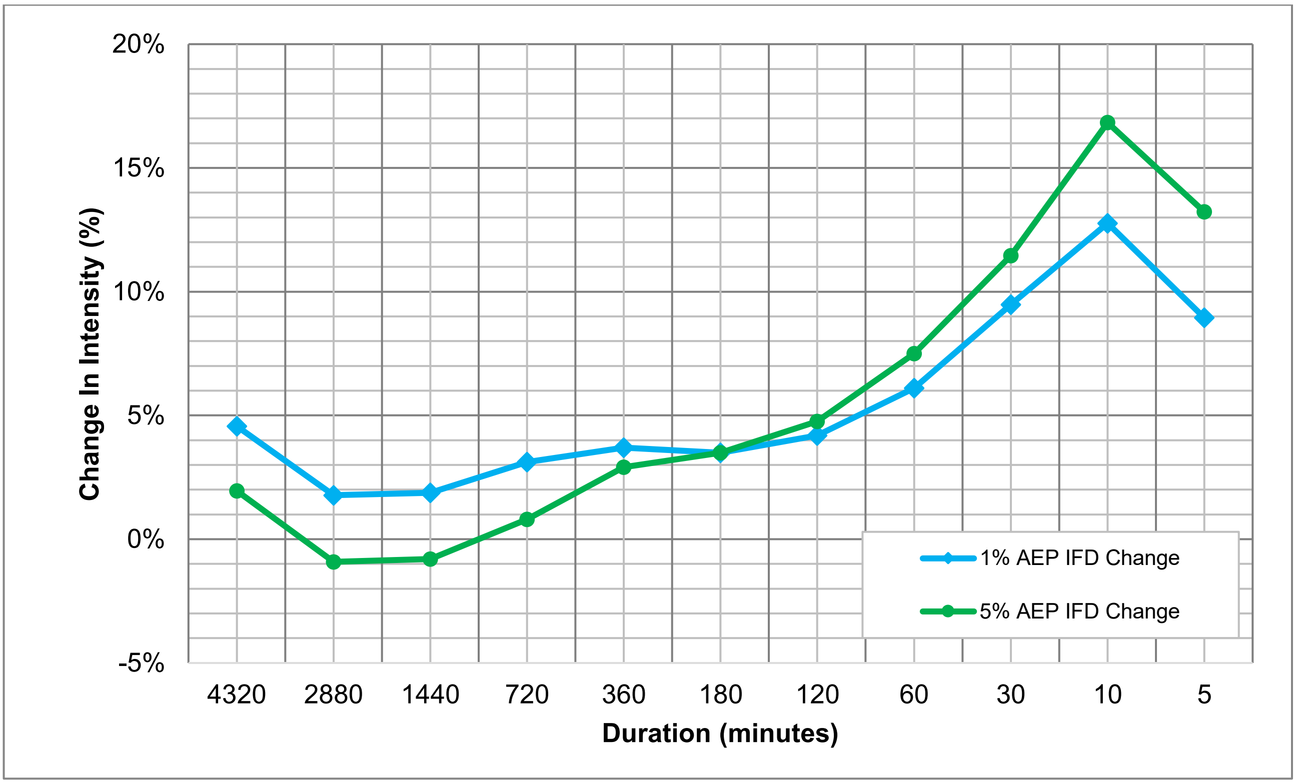
Graph B1: Change in Intensity for 1% AEP and 5 % AEP IFD 2016 v 1987 ARR – City Catchment



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

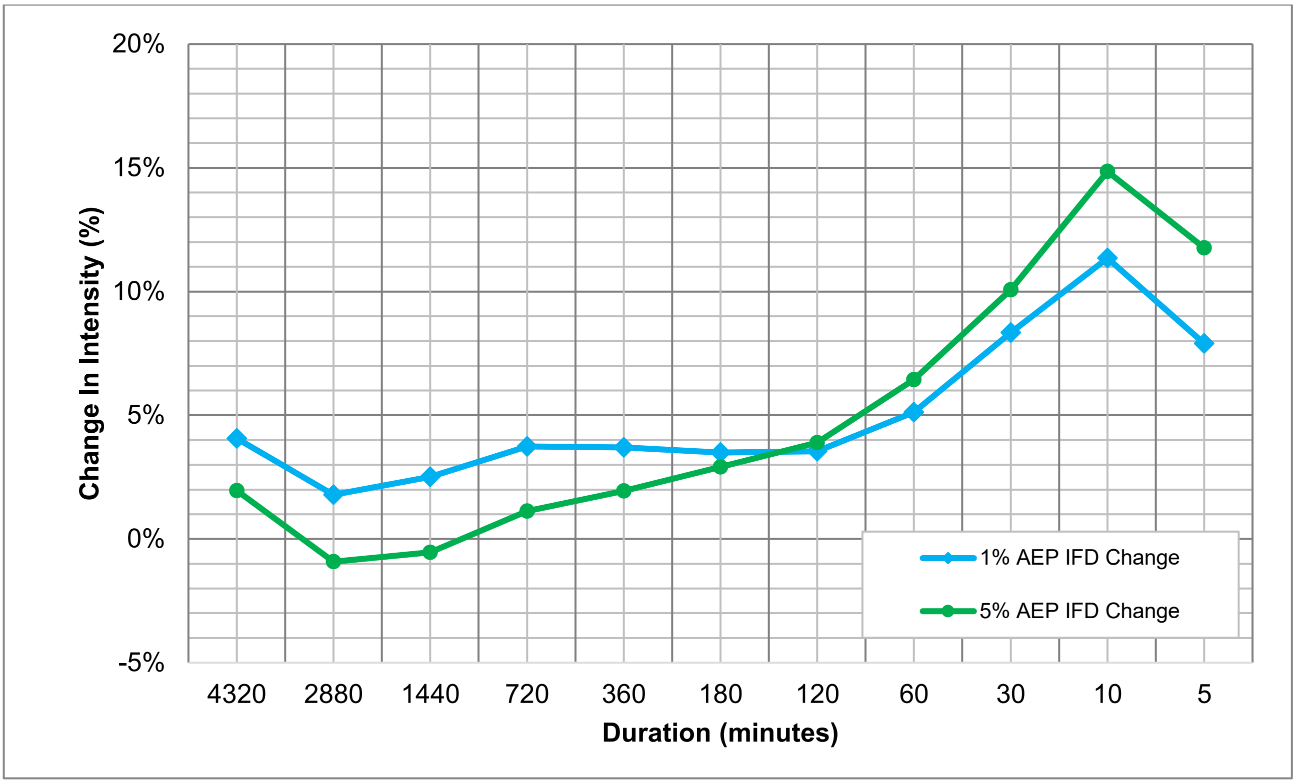


Table B5: Median Pre-Burst Depth Value – City Catchment

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

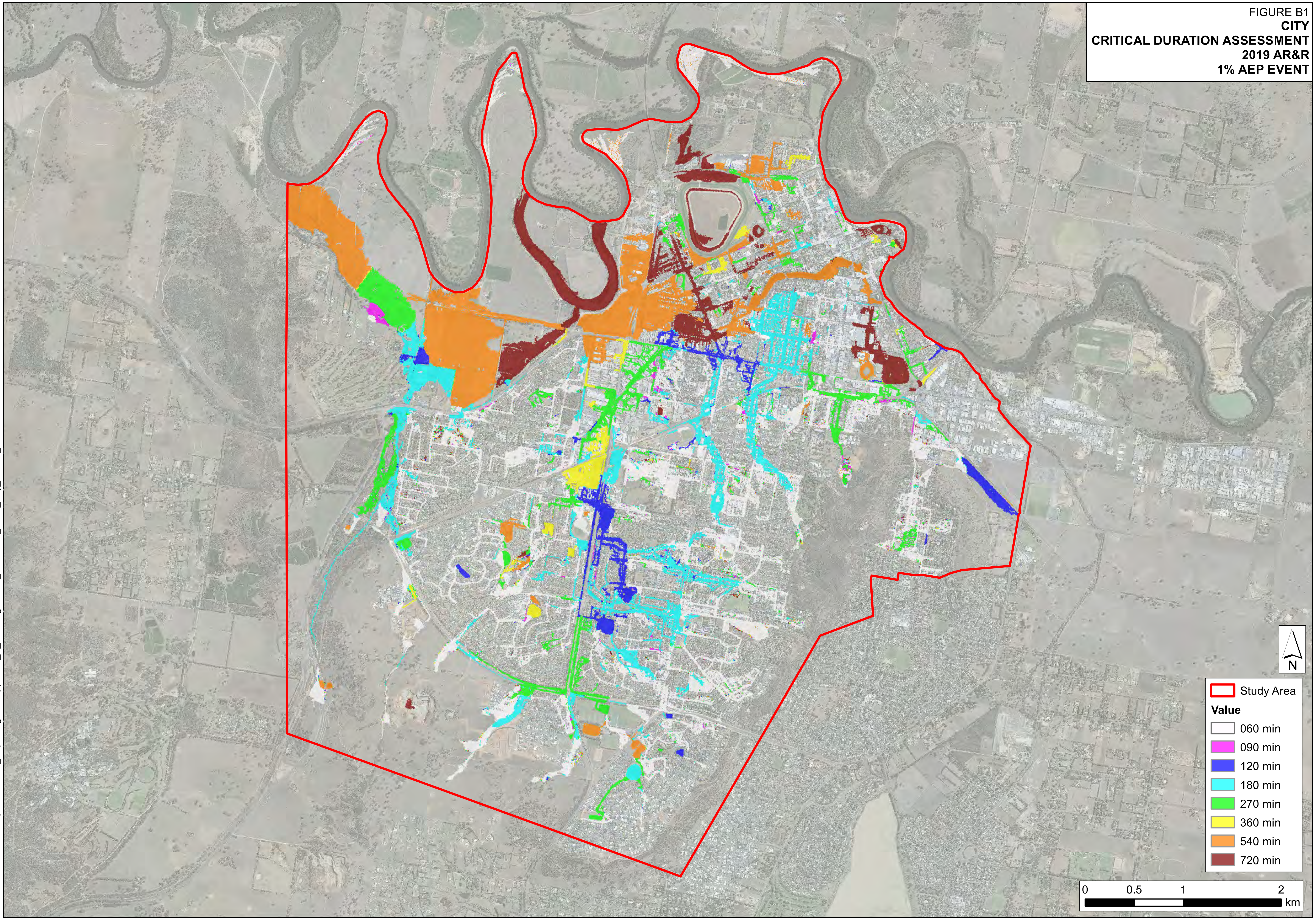
Duration (min)	Annual Exceedance Probability (AEP)					
	50%	20%	10%	5%	2%	1%
60	1.9	1.5	1.3	1.0	0.7	0.5
90	4.5	2.9	1.9	0.9	0.7	0.5
120	4.7	3.0	1.9	0.9	0.4	0.1
180	3.1	2.8	2.6	2.4	1.6	1.0
360	3.0	1.8	0.9	0.2	1.5	2.5
720	0.1	1.0	1.6	2.1	4.7	6.7
1080	0.0	0.3	0.5	0.7	2.8	4.4
1440	0.0	0.2	0.3	0.4	0.7	1.0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



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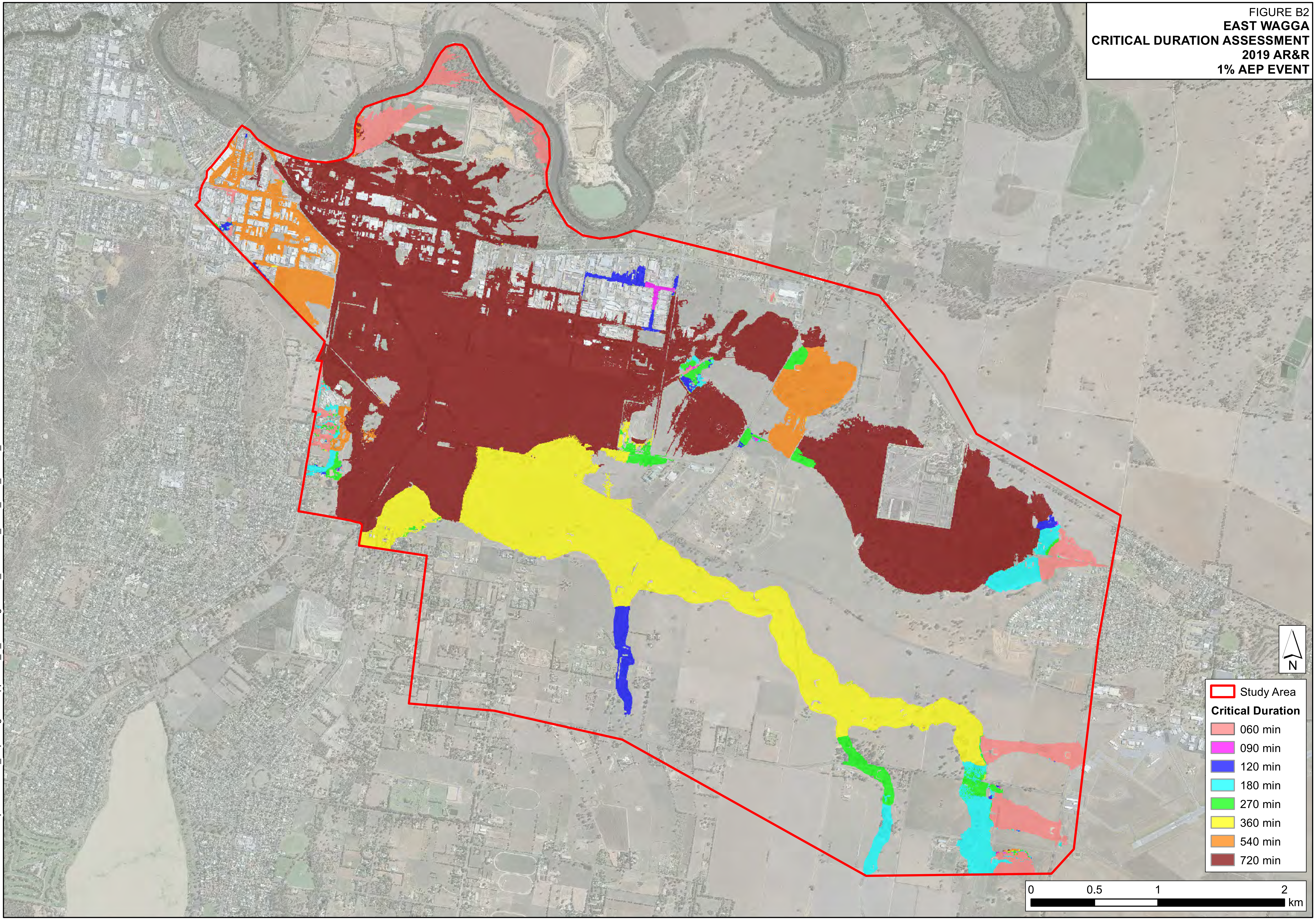
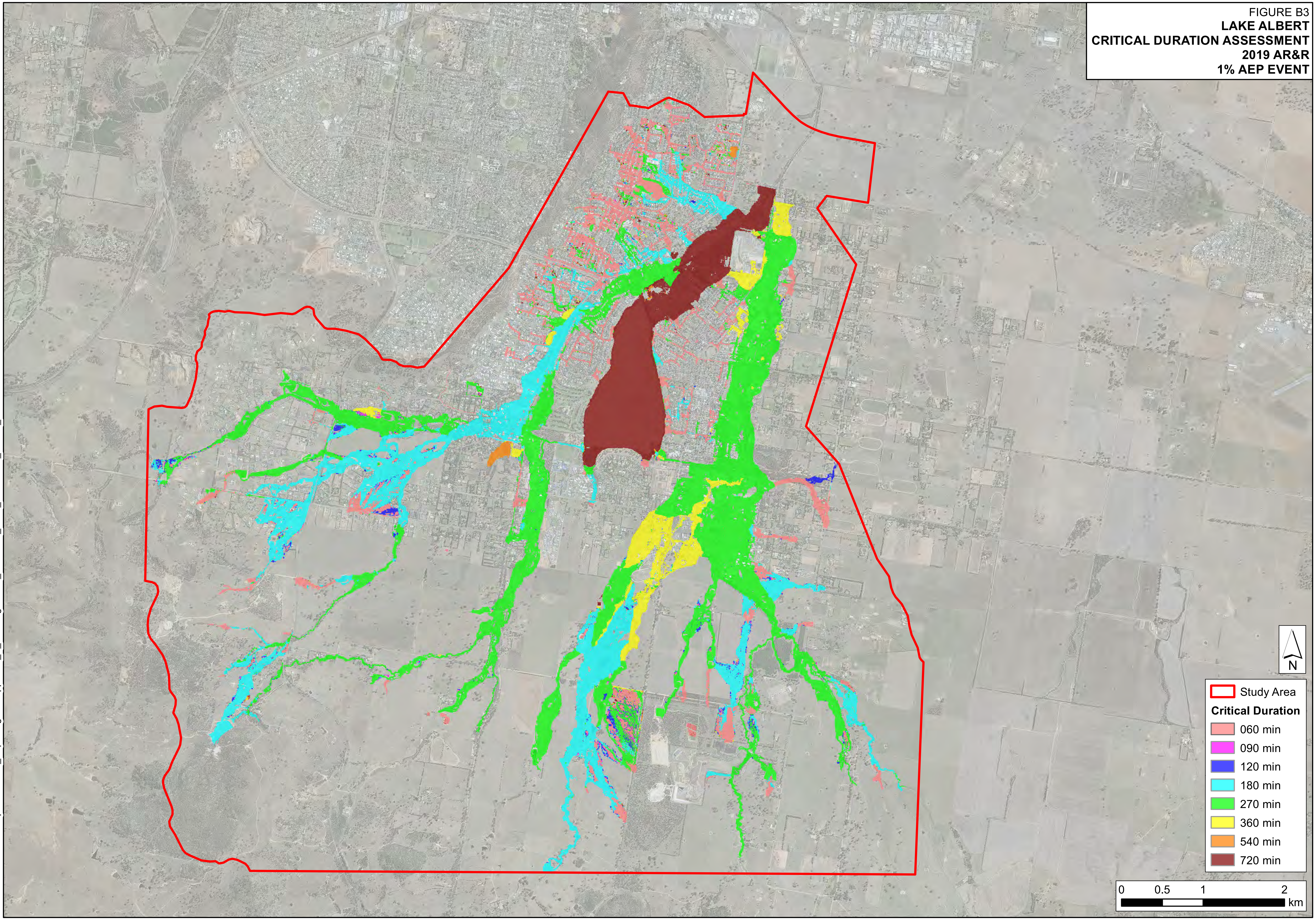


FIGURE B2
EAST WAGGA
CRITICAL DURATION ASSESSMENT
2019 AR&R
1% AEP EVENT
N
Study Area
Critical Duration
060 min
090 min
120 min
180 min
270 min
360 min
540 min
720 min
0
0.5
1
2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB02_ARR2019_100Y_East_Critical_Duration.mxd

FIGURE B3
LAKE ALBERT
CRITICAL DURATION ASSESSMENT
2019 AR&R
1% AEP EVENT



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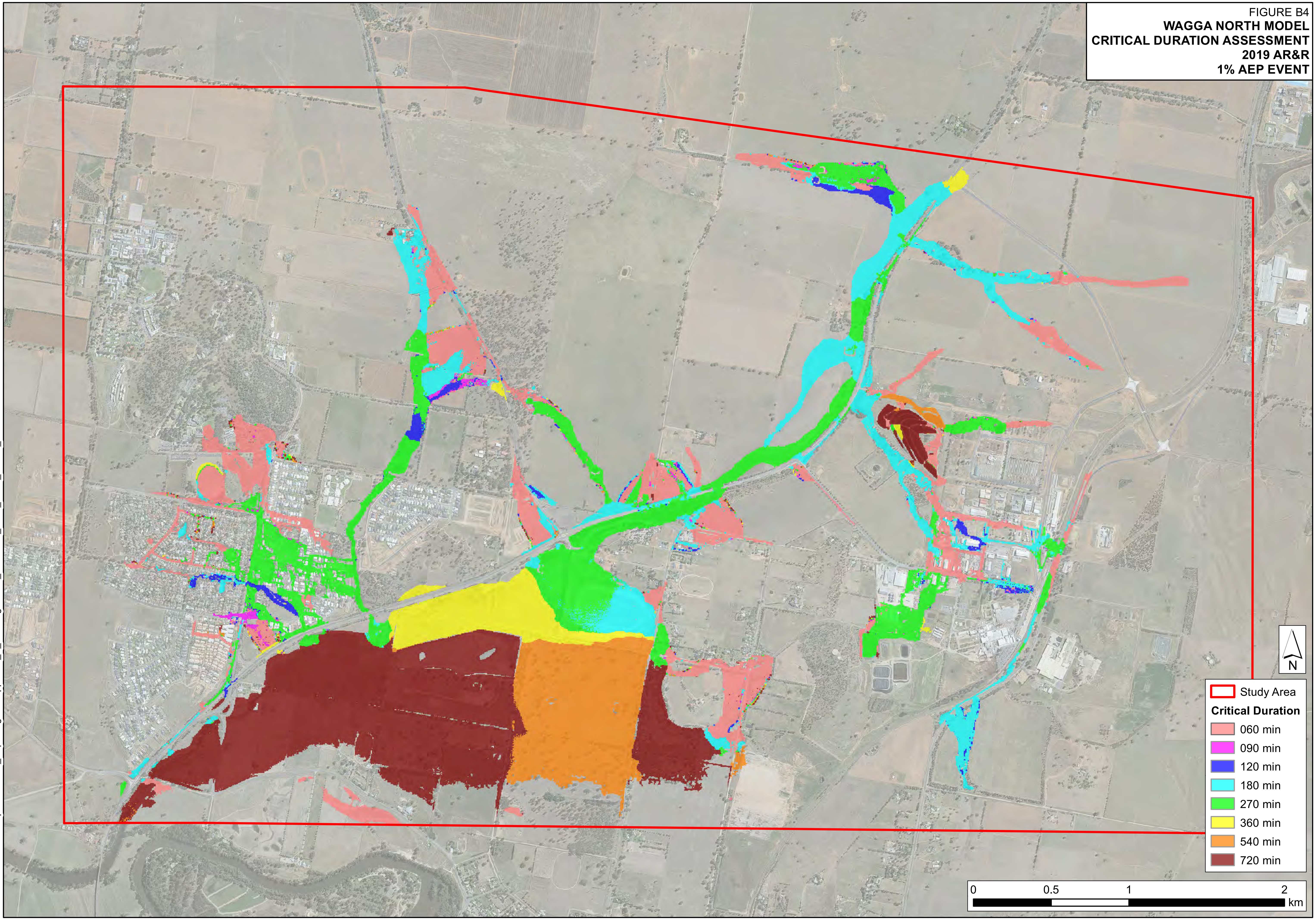
FIGURE B4
WAGGA NORTH MODEL
CRITICAL DURATION ASSESSMENT
2019 AR&R
1% AEP EVENT
N
Study Area
Critical Duration
060 min
090 min
120 min
180 min
270 min
360 min
540 min
720 min
0
0.5
1
2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB04_ARR2019_100Y_North_Critical_Duration.mxd

FIGURE B5
CITY
CHANGE IN PEAK FLOOD LEVEL
ARR2019 V ARR 1987
1% AEP EVENT

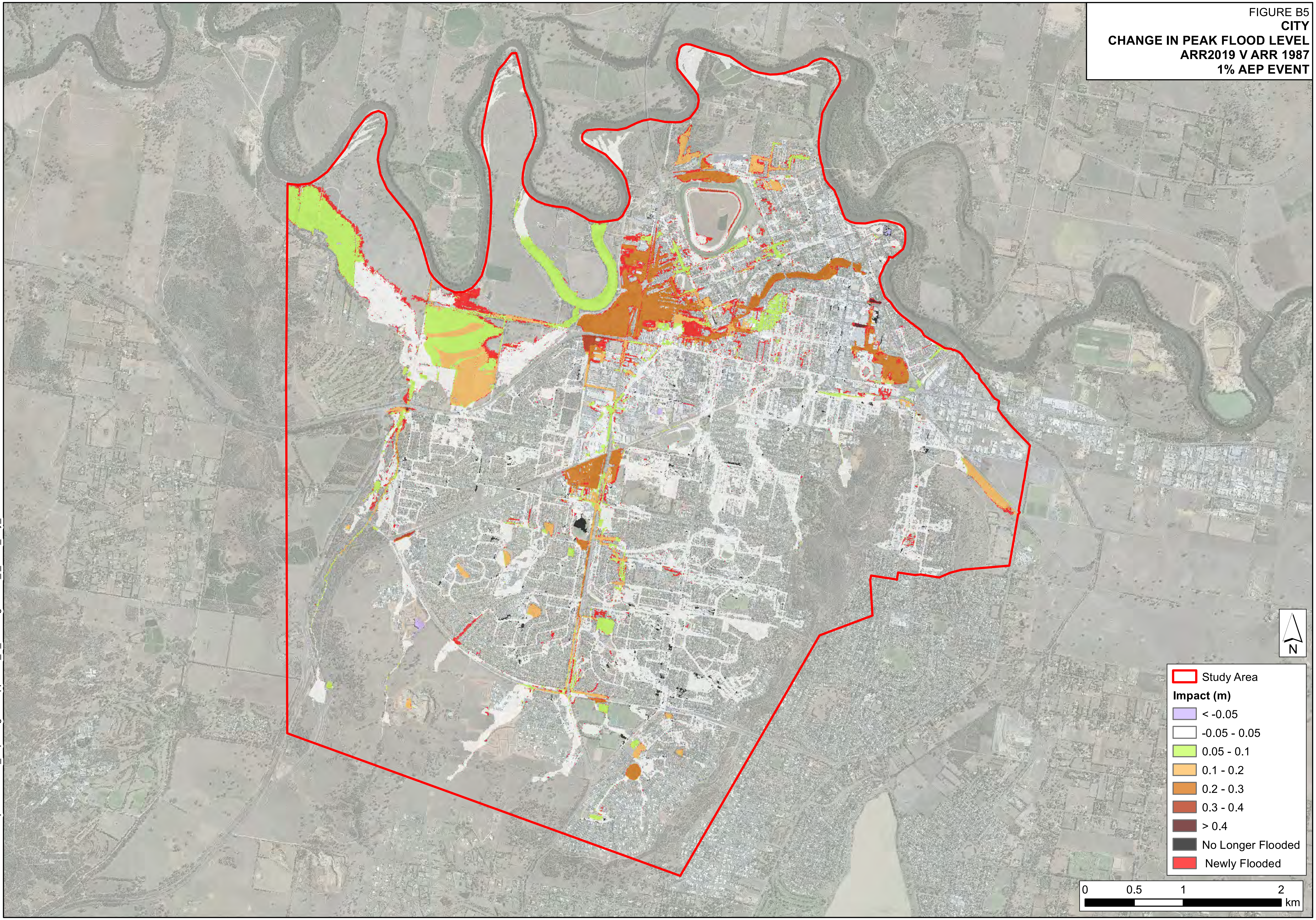

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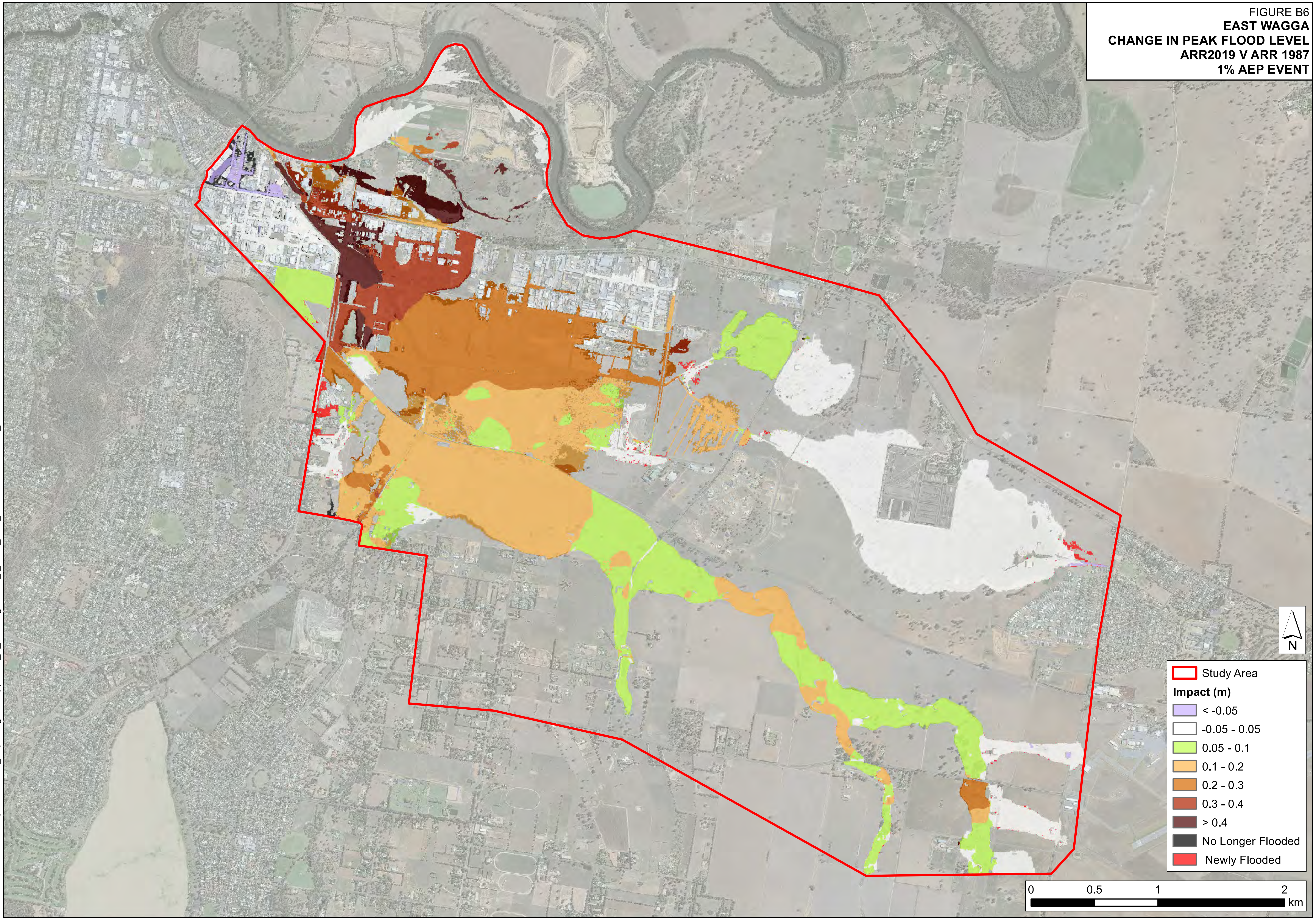
FIGURE B6
EAST WAGGA
CHANGE IN PEAK FLOOD LEVEL
ARR2019 V ARR 1987
1% AEP EVENT



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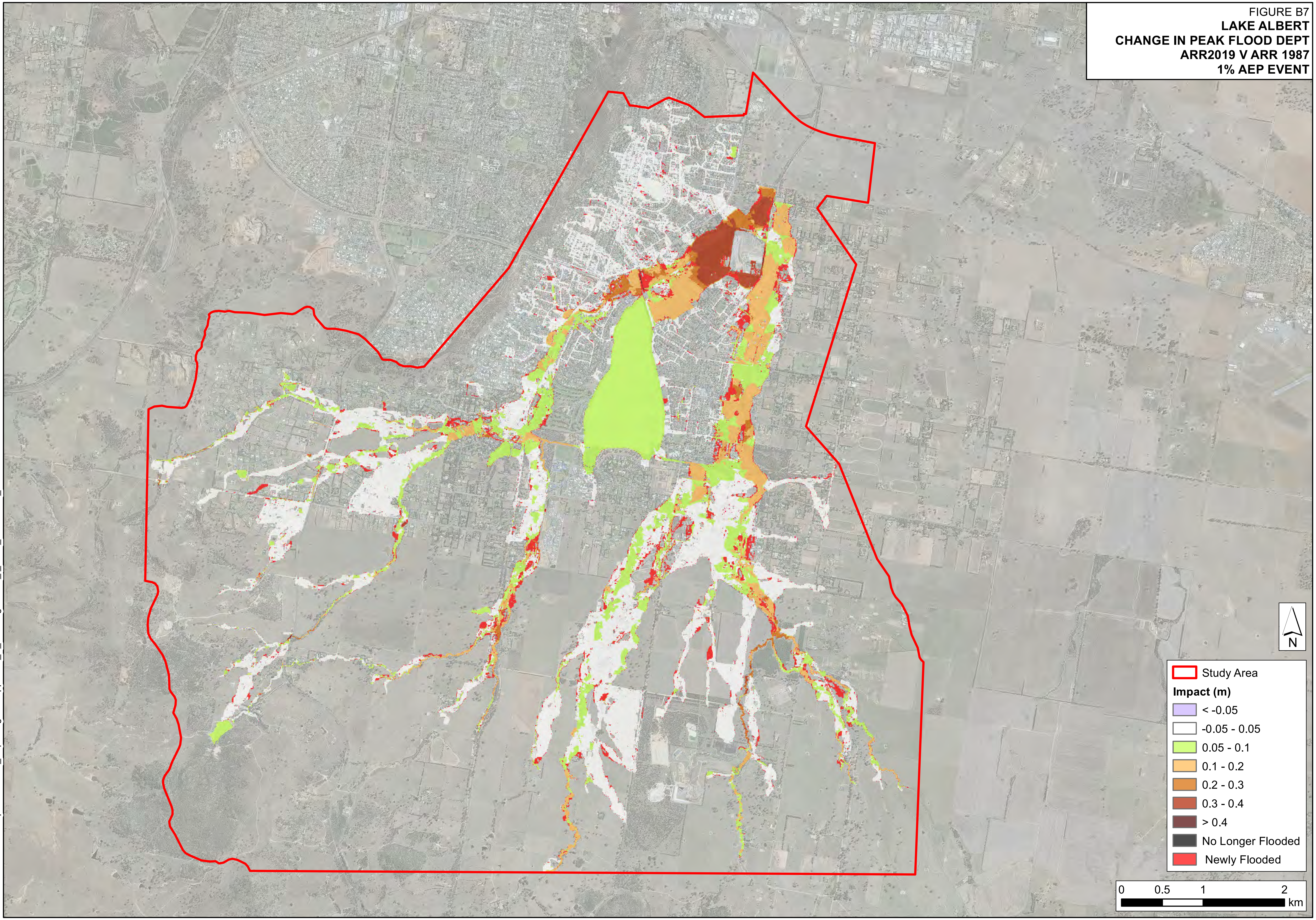

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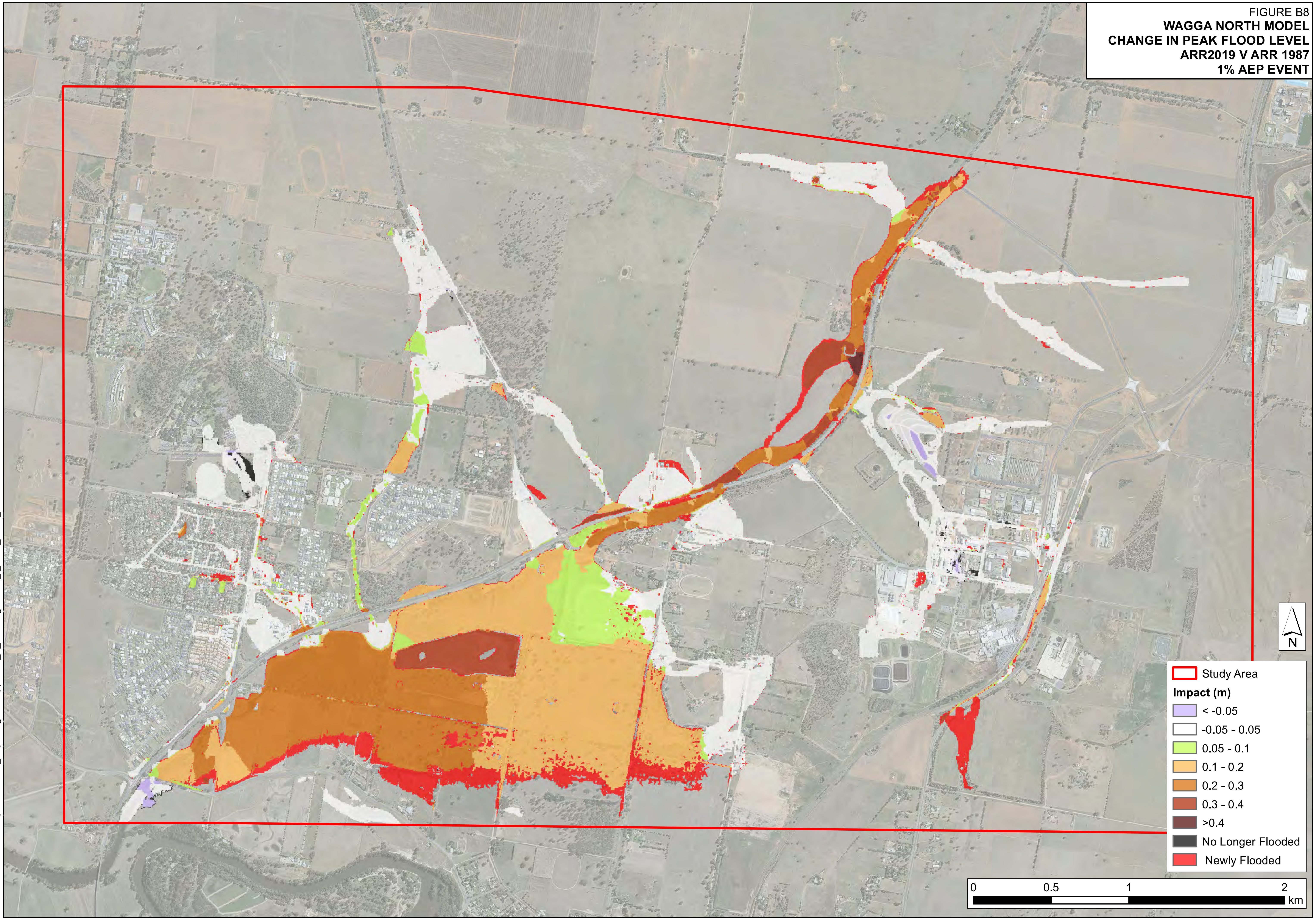
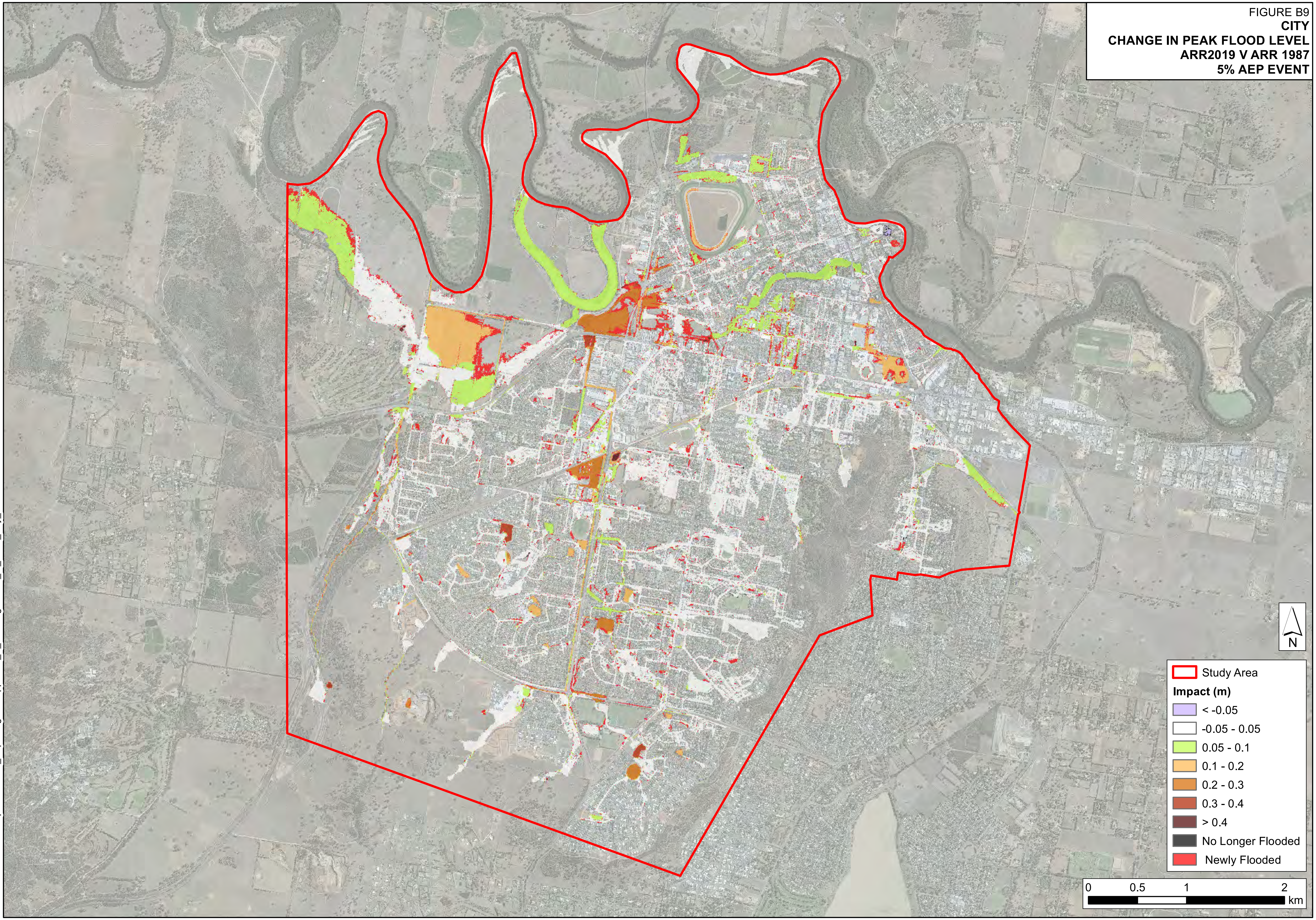


FIGURE B8
WAGGA NORTH MODEL
CHANGE IN PEAK FLOOD LEVEL
ARR2019 V ARR 1987
1% AEP EVENT
N
Study Area
Impact (m)
< -0.05
-0.05 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
>0.4
No Longer Flooded
Newly Flooded
0
0.5
1
2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB08_I_100Y_North_ARR2019VARR1987.mxd

FIGURE B9
CITY
CHANGE IN PEAK FLOOD LEVEL
ARR2019 V ARR 1987
5% AEP EVENT



J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB09_I2_020Y_City_ARR2019VARR1987.mxd

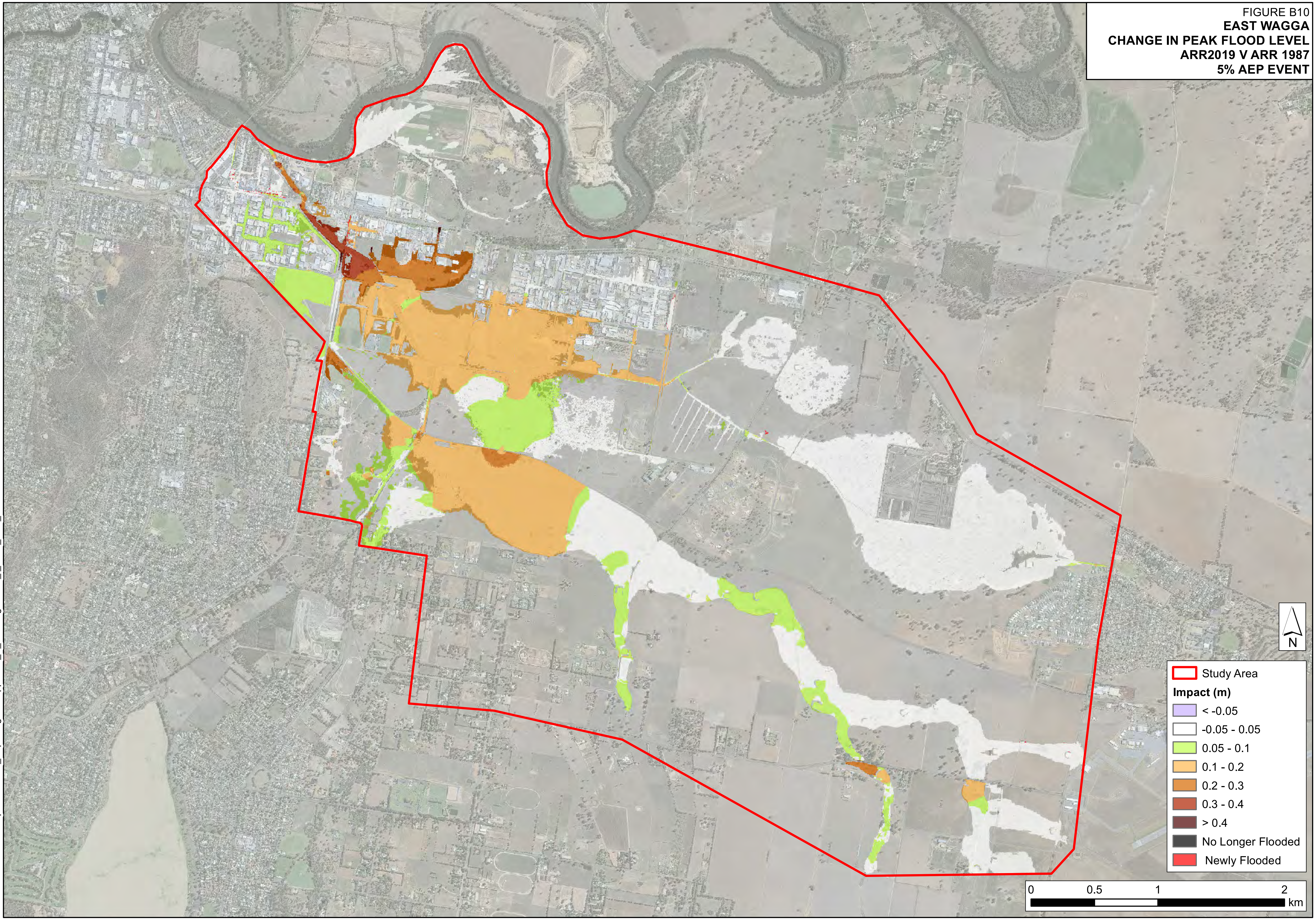
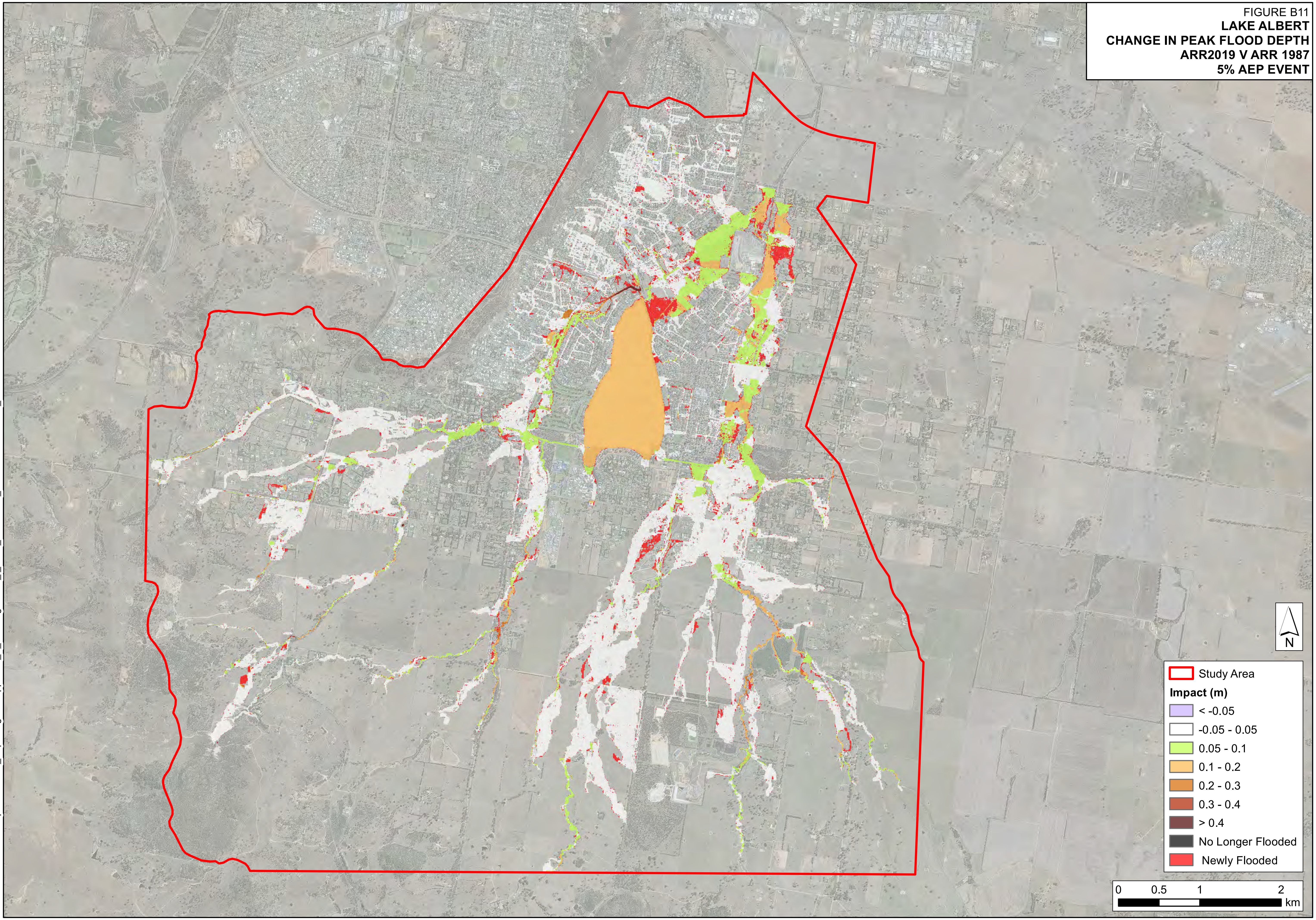


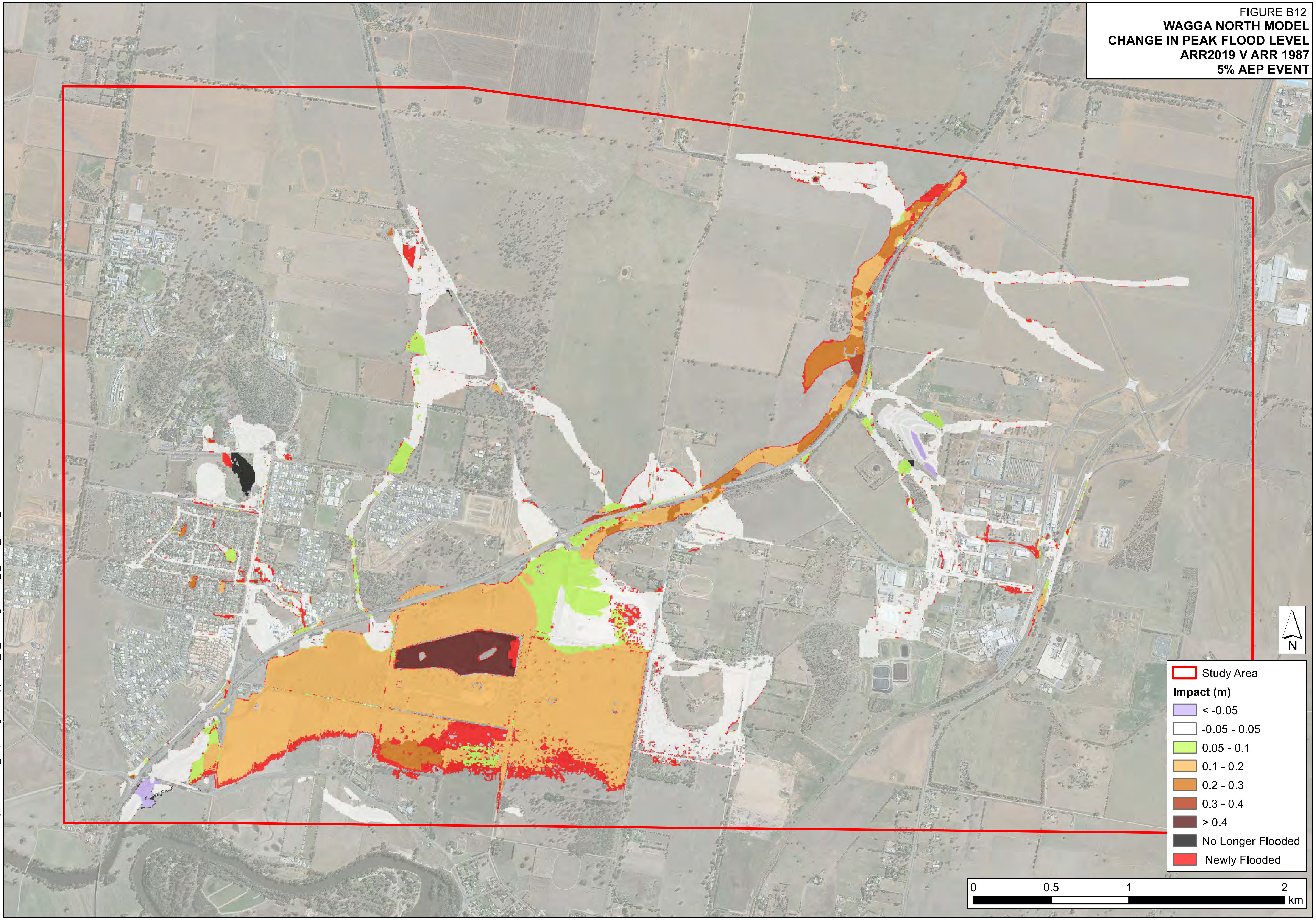
FIGURE B10
EAST WAGGA
CHANGE IN PEAK FLOOD LEVEL
ARR2019 V ARR 1987
5% AEP EVENT
Study Area
Impact (m)
< -0.05
-0.05 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
> 0.4
No Longer Flooded
Newly Flooded
N
0
0.5
1
2
km
J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB10_I_020Y_East_ARR2019VARR1987.mxd

FIGURE B11
LAKE ALBERT
CHANGE IN PEAK FLOOD DEPTH
ARR2019 V ARR 1987
5% AEP EVENT



J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB11_I_020Y_LakeAlbert_ARR2019VARR1987_final.mxd

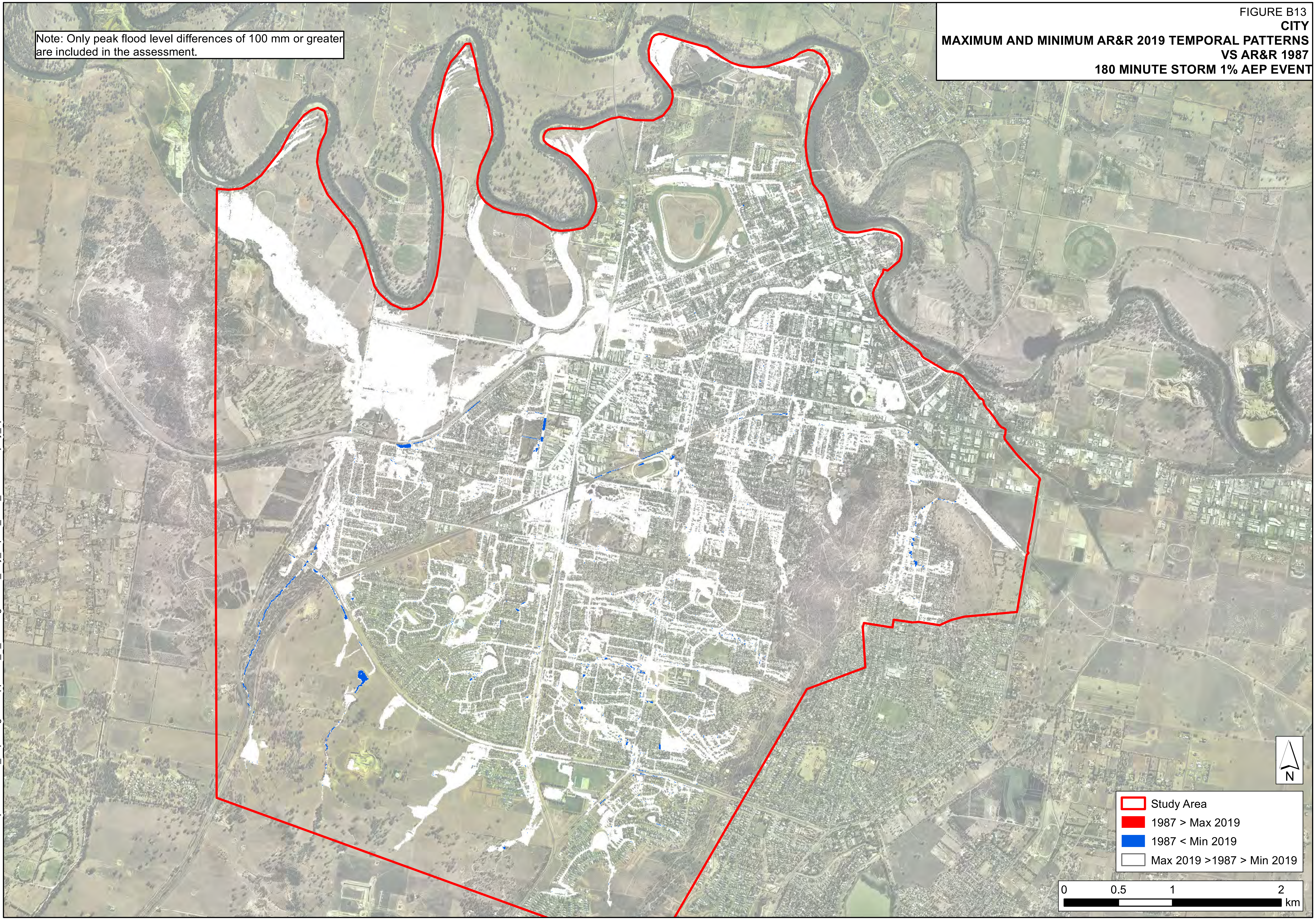
FIGURE B12
WAGGA NORTH MODEL
CHANGE IN PEAK FLOOD LEVEL
ARR2019 V ARR 1987
5% AEP EVENT



J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB12_I_020Y_North_ARR2019VARR1987.mxd

FIGURE B13
CITY
MAXIMUM AND MINIMUM AR&R 2019 TEMPORAL PATTERNS VS AR&R 1987
180 MINUTE STORM 1% AEP EVENT

Note: Only peak flood level differences of 100 mm or greater are included in the assessment.



J:\Jobs\117047\ARC\Maps\ARR2016_ReportFigures\Appendix_B_ARR\FigureB13_City_Impact_ARR_MinMaxDisplay_1pcEvent.mxd

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?

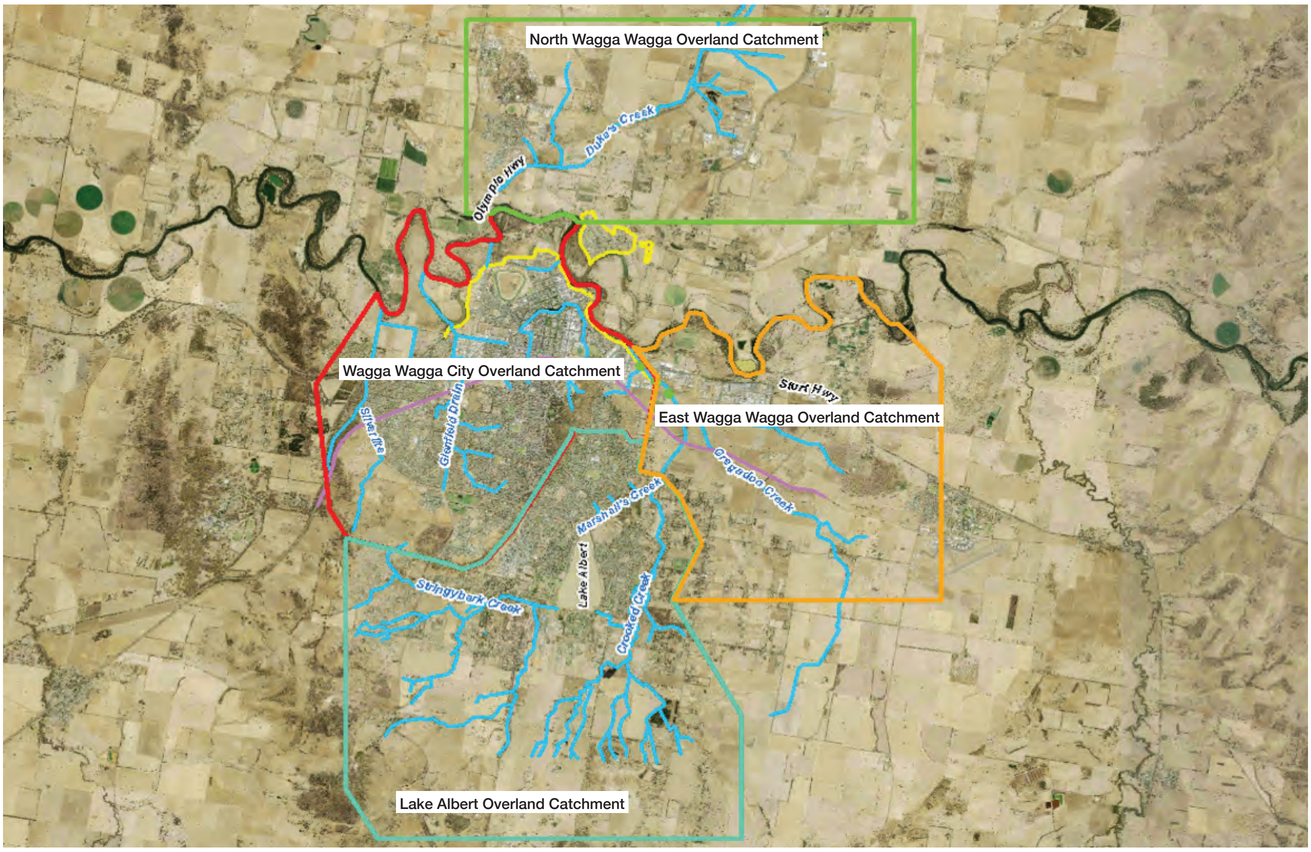
Overland flow flooding is caused by excess rainfall that leads to local runoff. It is different to riverine flooding, such as that from the Murrumbidgee River. However, elevated levels in the Murrumbidgee River can exacerbate overland flooding if the flood gates are shut at the same time as a significant 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.

WAGGA WAGGA City of Wagga Wagga

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

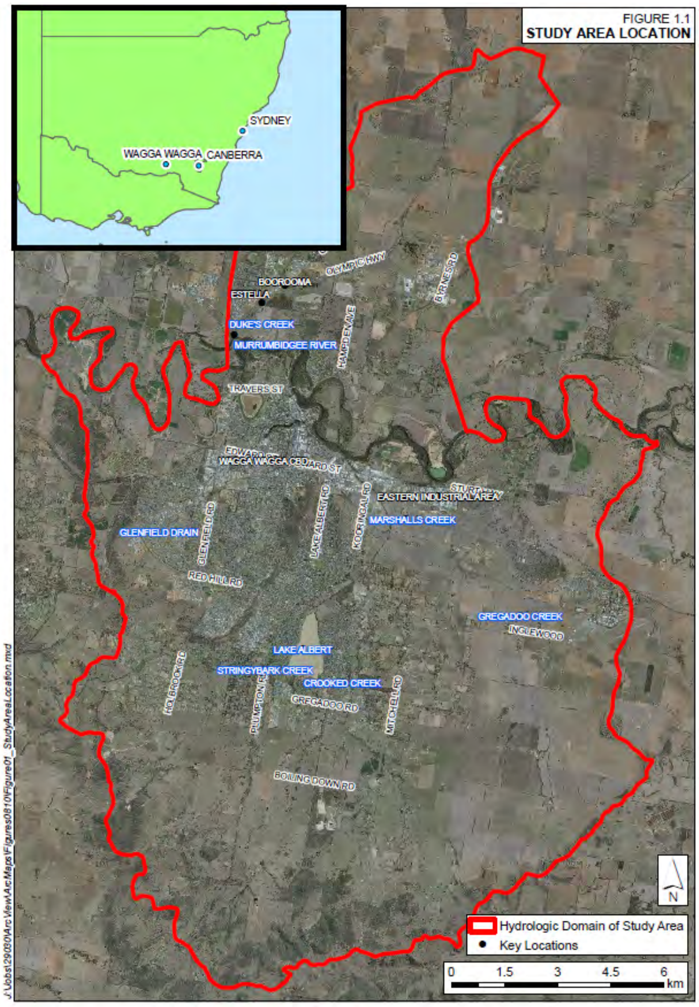
Ph: 1300 292 442 | wagga.nsw.gov.au/floodfutures

City of Wagga Wagga

Major Overland Flow Flooding

Have your say on the Draft Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan (MOFFS)

If you are affected by overland flow flooding in the Wagga Wagga area shown in the coverage map, your feedback is valuable to the consultants who created this draft report, before the report is finalised.



Please take the time to look through the MOFFS - Summary Document (PDF, 506.4 KB) and its recommendations.

More detailed information can be found in the draft report itself, as well as the separate Figures and Attachments documents – all linked on this page.

To discuss the draft report and its recommendations you are invited to book in some time with the consultant to discuss your feedback and ask questions. The days and times for this engagement will be advertised publicly and will be listed here.

READ THE DOCUMENTS | READ THE SUMMARY

SUBMIT YOUR FEEDBACK | BOOK A MEETING

Any questions? Contact us.

For further information about the Draft Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan (MOFFS) that can't be answered via the FAQ's below, please contact Andrew Mason on 02 6926 9130 or mason.andrew@wagga.nsw.gov.au

Draft Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan (MOFFS)

MOFFS - Summary Document | 506.4 KB

DOWNLOAD

These documents are on public exhibition until the 5 May.

DRAFT - 2021 Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan (MOFFS) | 4.2 MB

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DRAFT - 2021 MOFFS - Appendix | 12.3 MB

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DRAFT - 2021 MOFFS - Figures 1-1 - Area of Study Map | 777.6 KB

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DRAFT - 2021 MOFFS - Figures 1-2 to 1-19 | 49.5 MB

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DRAFT - 2021 MOFFS - Figures 2 to 3 | 26.6 MB

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DRAFT - 2021 MOFFS - Figures 4 to 5 | 179.9 MB

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SUBMIT YOUR FEEDBACK

Prefer to have a chat?

Book a one-on-one online session with the experts from WMAwater.

Share your thoughts and get your overland flood-related questions answered.

REGISTER NOW

FAQs

+ What is MOFFS?

Wagga Wagga City Council are primarily responsible for managing flood prone land through the implementation of floodplain risk management strategies. As part of this responsibility, Council has enlisted WMAwater to prepare the Draft **Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan (MOFFS)**.

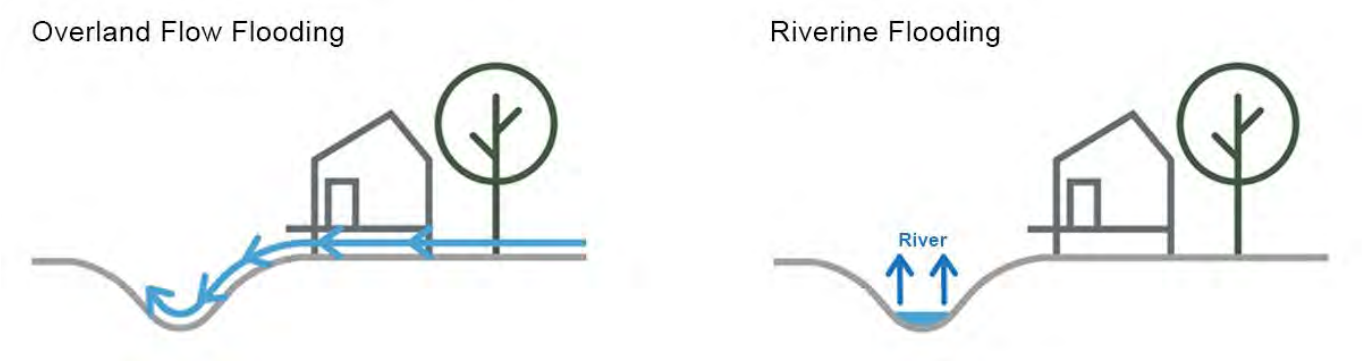
This report outlines the existing and future overland flow flood behaviour in the Wagga Wagga area. It uses the most up to date information and modelling techniques, informed by previous engagement with local residents, to determine overland flow flooding in the catchment.

The study looks at the existing flood environment and the economic impact of flooding and makes recommendations to minimise the future impacts of overland flow flooding in Wagga Wagga's catchment areas.

Note that riverine flooding from the Murrumbidgee River is not assessed in this Study. For information on riverine flooding and mitigation measures please refer to the Riverine Flooding page.

+ What is 'overland flow flooding'?

Overland flow flooding is caused by intense rainfall events, which result in flow paths forming on sloped areas or floodwater pooling in low-lying flatter areas. Water naturally flows to the lowest point, generally ending up in a creek or a drain. Overland flow paths are the routes taken by rainfall runoff and are not always obvious until they flood.



+ What is the Probable Maximum Flood?

The Probable Maximum Flood (PMF) is the largest flood that can occur. It is very rare.

All land inundated under the PMF is considered to be flood prone land.

+ What is the Flood Planning Level?

The Flood Planning Level (FPL) is the height used to set floor levels for houses in flood prone areas. It is defined as the "1% AEP flood level" plus an appropriate freeboard (see explanation of 'freeboard' below). It is used for planning purposes, and land below the FPL is considered to be flood affected and therefore subject to flood related development controls.

The FPL can be calculated as:FPL = 1% AEP flood level + freeboard (typically 0.5m)

+ What is a Freeboard?

A Freeboard is included in the Flood Planning Level as a buffer, to account for factors such as unforeseen blockages, waves from vehicles (such as SES rescue trucks), other localised hydraulic effects and uncertainties in the modelling and determination of flood levels.

Freeboard is typically 0.5m above a flood level, or for some areas of shallow flood depths a reduced freeboard of 0.3m may apply.

+ What is a 1% AEP flood event?

A 1% Annual Exceedance Probability flood event is equivalent to a 1-in-100 year flood, which is a major rain event that occurs on average once every 100 years (i.e. there is a 1% chance of a flood this size or larger occurring at a particular location in any given year). A 2% AEP could occur once every 50 years, a 5% could occur once every 20 years and so on.

+ What area does the study include?

The study area is located completely within the Wagga Wagga Local Government Area.

The area incorporates catchments with an area of 233 km2 and a hydraulic modelling extent of 167 km2 both south and north of the Murrumbidgee River.

A map of the area covered is shown in Figure 1.1.

+ What does this mean for property owners?

For most people, there is nothing to do in response to this flood study as there is no immediate change to the situation. However, property owners who are planning redevelopment of their property may need to take some additional steps as part of the consent process because flood related development controls may apply. This could include the requirement to have the floor levels of new residential development set at or above the Flood Planning Level.

+ My home is on a hill so why am I affected?

If there is significant rain at the top of the hill, the rain will run downhill through low lying gullies, channels and surface depressions. The speed and depth of floodwaters may be less at the top of the catchment than further down the hill, but still be significant enough to pose a risk.

+ What are Councils doing to manage flood risk?

Councils prepare Flood Studies and Plans according to the NSW Government's Floodplain Development Manual (2005) and implement associated recommendations with the financial and technical assistance of the NSW Government through its Flood Prone Land Policy.

This draft document details the recommendations to reduce the effects of overland flow flooding in the Wagga Wagga area.

+ Will this affect property values?

The results from this study will update flood information obtained from previous studies. Almost all properties identified in this study as flood affected have previously been identified as flood affected. Overall, there is a slight reduction in the number of properties identified.

Studies show that an actual flood event, rather than a flood planning notation on a Planning Certificate, is more likely to have an effect on property values.

+ Will this affect my insurance premiums?

Individual insurance companies typically identify Flood Prone Land and assess risk through their own flood studies, analysis and flood mapping exercises, irrespective of whether Council has undertaken a flood study. These calculations are outside Council's control. The information is then used to set policies and premiums.

+ What should I do in the event of a flood?

If it is a life-threatening situation call 000.

In the event of floods, storms or tsunamis, please contact the State Emergency Service (SES) on 132 500 or visit their website at ses.nsw.gov.au.

+ What can I do to prepare in case of a flood?

The State Emergency Service has a useful website providing advice on how to manage flood risk. Visit www.floodsafe.com.au for more information.

+ Where can I get information about flood levels on my property?

To talk with someone at Council about flooding, you can email Council at council@wagga.nsw.gov.au or phone 1300 292 442.

Previous Studies

+ 2011 Wagga Wagga Major Overland Flow Flood Study (MOFFS) - Final Report (August 2011)

Wagga Wagga 2011 MOFFS Final Report 2011 | 1.2 MB

DOWNLOAD

2011 MOFFS Figures 1-3 | 8.9 MB

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2011 MOFFS Figures 4-6 | 2.8 MB

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2011 MOFFS Figures 7-9 | 9.1 MB

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2011 MOFFS Figures 10-11 | 9.6 MB

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2011 MOFFS Figures 12-13 | 9.5 MB

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2011 MOFFS Figures 14a-14b | 6.0 MB

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2011 MOFFS Figures 15-16 | 9.7 MB

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2011 MOFFS Figures 17-18 | 9.5 MB

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2011 MOFFS Figures 19-20 | 9.3 MB

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2011 MOFFS Figures 21-22 | 9.4 MB

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2011 MOFFS Figures 23-24 | 9.1 MB

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2011 MOFFS Figures 25-26 | 9.0 MB

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2011 MOFFS Figures 27-28 | 9.1 MB

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2011 MOFFS Figures 29-30 | 8.9 MB

DOWNLOAD

2011 MOFFS Figures 31-32 | 9.1 MB

DOWNLOAD

2011 MOFFS Figures 33-39 | 1.4 MB

DOWNLOAD

2011 MOFFS Appendix A - Glossary | 73.3 KB

DOWNLOAD

2011 MOFFS Appendix B - 2010 Flood Photos and Miscellaneous Others | 8.2 MB

DOWNLOAD

2011 MOFFS Appendix C - Community Consultation Mail Outs and Correspondence | 5.1 MB

DOWNLOAD

2011 MOFFS Appendix D - December 2010 Validation Work | 270.7 KB

DOWNLOAD

2011 MOFFS Validation Figures for Appendix D - Part 1 | 4.4 MB

DOWNLOAD

Appendix D - Validation Figures (part 2)

2011 MOFFS Appendix E - Response to Public Submissions | 2.1 MB

DOWNLOAD

2011 MOFFS Annex A - Photos Used for Verification | 1.9 MB

DOWNLOAD

2011 MOFFS Annex B - Additional Records of Flooding | 804.0 KB

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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

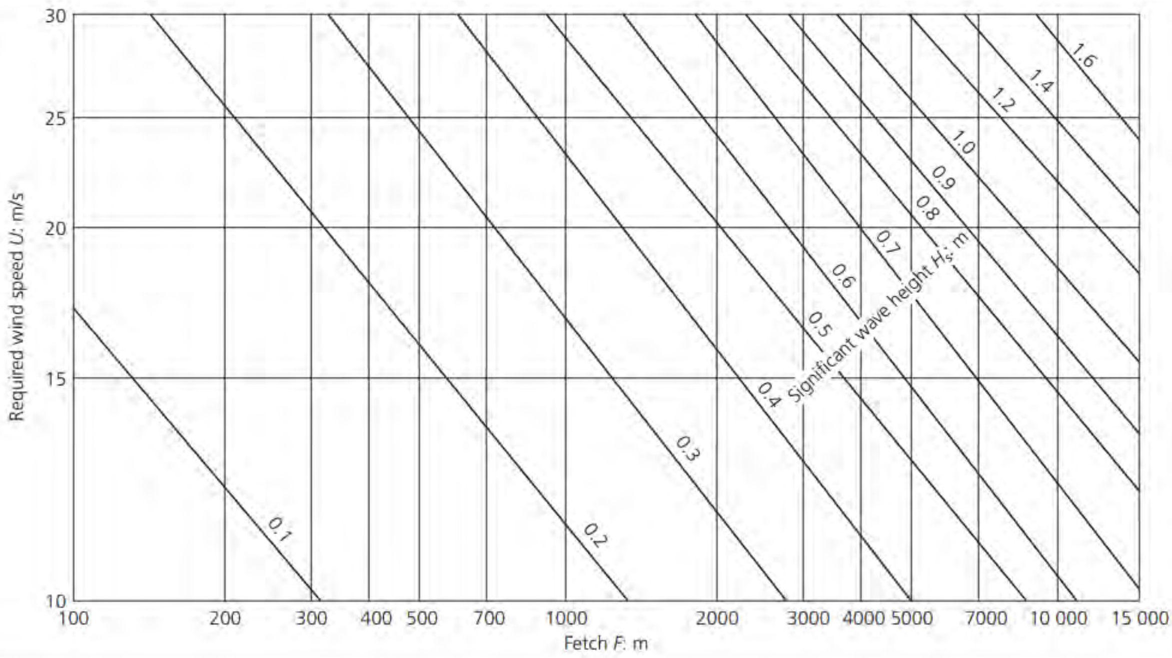
Increases in water level as a result of wave action are not determined in flood modelling. Design wave actions are a product of:

- 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

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

3. WMAwater
Revised Murrumbidgee River at Wagga Wagga Floodplain Risk Management Study and Plan
Wagga Wagga City Council, 2018

4. Institute of Civil Engineers
Floods and Reservoir Safety
1996

5. NSW Department of Public Works
Wagga Wagga Levee Upgrade – Flood Freeboard
Report No. DC 10096
November 2010

6. Lyalls and Associates
Boorowa Floodplain Risk Management Study and Plan
Hilltops Council, March 2018

7. Lyalls and Associates
The Villages of Crookwell, Gunning, Collector and Taralga Floodplain Risk Management Study and Draft Plan
Upper Lachlan Shire Council, June 2017

Appendix F

Option ID: **GD01**

Red Hill Road and Glenfield Road Basin

The cost estimates are intended to be high level estimates only to produce a ball park figure that can be used in the preliminary cost/benefit assessment. It is noted that not all aspects have been considered in these extimates, but that the overall figure is in keeping with similar industry project values when compared on a per metre basis.

	Item	UNIT	QUANTITY	Rate (ex GST)	COST
Design	Feasibility Study, Consultation, Detailed Design	item	1	$ 20,000.00	$ 20,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 105,329.34
Below Ground Detention Basin	Site clearing of rubbish, etc.	Item	1	$ 20,000.00	$ 20,000.00
	Clearing & stripping of topsoil (strip grass to a depth of approximately 100mm)	m2	2,042	$ 0.40	$ 816.80
	Excavation by cut in all classes of material	m3	5,100	$ 5.00	$ 25,500.00
	Place and compact excavated material	m3	5,100	$ 3.00	$ 15,300.00
	Supply and place gabion rock for basin spillway	Item	1	$ 15,000.00	$ 15,000.00
	Disposal of unsuitable materials	m3	5,100	$ 5.00	$ 25,500.00
	Topsoil preparation and seeding	m2	2,042	$ 4.00	$ 8,168.00
	Fuel	l/m3	5,100	$ 0.75	$ 3,825.00
Above Ground Embankment	Site clearing of rubbish, etc.	Item	1	$ 20,000.00	$ 20,000.00
	Clearing & stripping of topsoil (strip grass to a depth of approximately 100mm)	m2	265	$ 0.40	$ 106.01
	Foundation preparation	m2	265	$ 2.00	$ 530.05
	Construction of levee clay core (place and compact)	m3	220	$ 30.00	$ 6,595.99
	Topsoil preparation and seeding	m2	265	$ 4.00	$ 1,060.09
	Fuel	l/m3	220	$ 0.75	$ 164.90
Road/Footpath Raising	Site clearing of rubbish, etc.	Item	1	$ 20,000.00	$ 20,000.00
	Clearing & stripping of topsoil (strip grass to a depth of approximately 100mm)	m2	2,045	$ 0.40	$ 818.00
	Place and compact excavated material	m3	2,045	$ 3.00	$ 6,135.00
	Topsoil preparation and seeding	m2	2,045	$ 4.00	$ 8,180.00
	Fuel	l/m3	2,045	$ 0.75	$ 1,533.75
Pipe & Culvert Upgrade (Including Excavation and Backfill)	Pipe 1350mm Diameter RRJ Class 2 RCPC > 1.5m deep (within road pavement)	m	30	$ 970.00	$ 28,712.00
Road work	Traffic Control	days	5	$ 450.00	$ 2,250.00
	Reinstate Road Surface (inc all subgrade, bitumen, line marking, reflectors etc)	lin.m	615	$ 800.00	$ 492,000.00
Misc	Contingency	**item**	**1**	25%	$ 206,881.23
	Total (ex GST)				$ 1,030,000.00

Option ID: GD02

Adjin Street & Maher Street Intersection Civil Works

The cost estimates are intended to be high level estimates only to produce a ball park figure that can be used in the preliminary cost/benefit assessment. It is noted that not all aspects have been considered in these extimates, but that the overall figure is in keeping with similar industry project

	Item	UNIT	QUANTITY	Rate (ex GST)	COST
Design	Feasibility Study, Consultation, Detailed Design	item	1	$ 150,000.00	$ 150,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 63,188.22
Below Ground Detention Basin	Site clearing of rubbish, etc.	Item	1	$ 20,000.00	$ 20,000.00
	Clearing & stripping of topsoil (strip grass to a depth of approximately 100mm)	m2	1,993	$ 0.40	$ 797.20
	Excavation by cut in all classes of material	m3	598	$ 5.00	$ 2,989.50
	Place and compact excavated material	m3	598	$ 3.00	$ 1,793.70
	Supply and place gabion rock for basin spillway	Item	1	$ 15,000.00	$ 15,000.00
	Disposal of unsuitable materials	m3	598	$ 5.00	$ 2,989.50
	Topsoil preparation and seeding	m2	1,993	$ 4.00	$ 7,972.00
	Fuel	l/m3	598	$ 0.75	$ 448.43
Above Ground Embankment	Site clearing of rubbish, etc.	Item	1	$ 20,000.00	$ 20,000.00
	Clearing & stripping of topsoil (strip grass to a depth of approximately 100mm)	m2	1,538	$ 0.40	$ 615.20
	Foundation preparation	m2	1,538	$ 2.00	$ 3,076.00
	Construction of levee clay core (place and compact)	m3	1,658	$ 30.00	$ 49,728.07
	Topsoil preparation and seeding	m2	1,538	$ 4.00	$ 6,152.01
	Fuel	l/m3	1,658	$ 0.75	$ 1,243.20
Pipe & Culvert Upgrade (Including Excavation and Backfill)	Pipe 1800mm Diameter RRJ Class 2 RCPC > 1.5m deep (within road pavement)	m	53	$ 1,400.00	$ 74,200.00
	Headwall	unit	2	$ 2,000.00	$ 4,000.00
Road work	Traffic Control	days	5	$ 450.00	$ 2,250.00
	Reinstate Road Surface (inc all subgrade, bitumen, line marking, reflectors etc)	lin.m	260	$ 800.00	$ 208,000.00
Misc	Contingency	**item**	**1**	25%	$ 158,610.76
	Total (ex GST)				$ 790,000.00

Option ID: GD03

Anderson Oval Basin and Swale Augmentation

The cost estimates are intended to be high level estimates only to produce a ball park figure that can be used in the preliminary cost/benefit assessment. It is noted that not all aspects have been considered in these extimates, but that the overall figure is in keeping with similar

	Item	UNIT	QUANTITY	Rate (ex GST)	COST
Design	Feasibility Study, Consultation, Detailed Design	item	1	$ 140,000.00	$ 140,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 34,961.50
Above Ground Embankment	Site clearing of rubbish, etc.	Item	1	$ 20,000.00	$ 20,000.00
	Clearing & stripping of topsoil (strip grass to a depth of approximately	m2	4,676	$ 0.40	$ 1,870.37
	Foundation preparation	m2	4,676	$ 2.00	$ 9,351.83
	Construction of levee clay core (place and compact)	m3	4,690	$ 30.00	$ 140,702.63
	Topsoil preparation and seeding	m2	4,676	$ 4.00	$ 18,703.65
	Fuel	l/m3	4,690	$ 0.75	$ 3,517.57
Open Swale Drain	Site clearing of rubbish, etc.	Item	1	$ 20,000.00	$ 20,000.00
	Clearing & stripping of topsoil (strip grass to a depth of approximately	m2	650	$ 0.40	$ 260.00
	Excavation by cut in all classes of material	m3	228	$ 5.00	$ 1,137.50
	Construct 1.2m deep grass lined channel	m	65	$ 65.00	$ 4,225.00
	Disposal of unsuitable materials	m3	228	$ 5.00	$ 1,137.50
	Top soil placement/seeding	m2	650	$ 15.00	$ 9,750.00
	Fuel	l/m3	228	$ 0.75	$ 170.63
Roadwork	Traffic Control	days	5	$ 450.00	$ 2,250.00
Misc	Contingency	**item**	**1**	25%	$ 102,009.54
	Total (ex GST)				$ 510,000.00

Option ID: GD04

Rabaul Place Trunk Drainage Line

The cost estimates are intended to be high level estimates only to produce a ball park figure that can be used in the preliminary cost/benefit assessment. It is noted that not all aspects have been considered in these extimates, but that the overall figure is in keeping with similar

	Item	UNIT	QUANTITY	Rate (ex GST)	COST
Design	Feasibility Study, Consultation, Detailed Design	item	1	$ 150,000.00	$ 150,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 290,377.50
Pipe & Culvert Upgrade (Including Excavation and Backfill)	Pipe 1800mm Diameter RRJ Class 2 RCPC > 1.5m deep (within road pavement)	m	1,200	$ 1,400.00	$ 1,680,000.00
	Junction Pit with Concrete Cover (min internall dimensions = pipe OD + 150mm in length & width)	unit	8	$ 4,200.00	$ 33,600.00
	Headwall	unit	2	$ 2,000.00	$ 4,000.00
Roadwork	Traffic Control	days	5	$ 450.00	$ 2,250.00
	Reinstate Road Surface (inc all subgrade, bitumen, line marking, reflectors etc)	lin.m	270	$ 800.00	$ 216,000.00
Misc	Contingency	**item**	**1**	25%	$ 594,056.88
	Total (ex GST)				$ 2,970,000.00

Option ID: SW01

Incarnie Crescent Stormwater Line

The cost estimates are intended to be high level estimates only to produce a ball park figure that can be used in the preliminary cost/benefit assessment. It is noted that not all aspects have been considered in these extimates, but that the overall figure is in keeping with similar industry project values when compared on a per metre basis.

	Item	UNIT	QUANTITY	Rate (ex GST)	COST
Design	Feasibility Study, Consultation, Detailed Design	item	1	$ 20,000.00	$ 20,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 49,440.00
Pipe & Culvert Upgrade (Including Excavation and Backfill)	Pipe 525mm Diameter RRJ Class 2 RCPC > 1.5m deep (within road pavement)	m	300	$ 375.00	$ 112,500.00
	Junction Pit with Concrete Cover (min internall dimensions = pipe OD + 150mm in length & width)	unit	3	$ 4,200.00	$ 12,600.00
Roadwork	Traffic Control	days	10	$ 450.00	$ 4,500.00
	Reinstate Road Surface (inc all subgrade, bitumen, line marking, reflectors etc)	lin.m	250	$ 800.00	$ 200,000.00
Misc	Contingency	**item**	**1**	25%	$ 99,760.00
	Total (ex GST)				$ 500,000.00

Option ID: **LA01**

Raising Lake Albert Road

The cost estimates are intended to be high level estimates only to produce a ball park figure that can be used in the preliminary cost/benefit assessment. It is noted that not all aspects have been considered in these extimates, but that the overall figure is in keeping with similar industry project values when compared on a per metre basis.

	Item	UNIT	QUANTITY	Rate (ex GST)	COST
Design	Feasibility Study, Consultation, Detailed Design	item	1	$ 250,000	$ 250,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 169,376.16
Above Ground Embankment	Site clearing of rubbish, etc.	Item	1	$ 20,000.00	$ 20,000.00
	Clearing & stripping of topsoil (strip grass to a depth of approximately 100mm)	m2	14,231	$ 0.40	$ 5,692.54
	Foundation preparation	m2	14,231	$ 2.00	$ 28,462.71
	Construction of levee clay core (place and compact)	m3	10,325	$ 30.00	$ 309,750.00
	Topsoil preparation and seeding	m2	14,231	$ 4.00	$ 56,925.41
	Fuel	l/m3	10,325	$ 0.75	$ 7,743.75
Pipe & Culvert Upgrade (Including Excavation and Backfill)	Pipe 1500mm Diameter RRJ Class 2 RCPC > 1.5m deep (within road pavement)	m	30	$ 1,100.00	$ 33,000.00
	Pipe 1800mm Diameter RRJ Class 2 RCPC > 1.5m deep (within road pavement)	m	60	$ 1,400.00	$ 84,000.00
	Headwall	unit	2	$ 2,000.00	$ 4,000.00
Roadwork	Traffic Control	days	40	$ 450.00	$ 18,000.00
	Reinstate Road Surface (inc all subgrade, bitumen, line marking, reflectors etc)	lin.m	702	$ 800.00	$ 561,600.00
Misc	Contingency	**item**	**1**	25%	$ 387,137.64
	Erosion Control, Rip Rap, Gabions Etc	**item**	**14,040**		
	Total (ex GST)				$ 1,940,000

Option ID: LA02

Augmentation of Crooked Creek Diversion into Lake Albert

The cost estimates are intended to be high level estimates only to produce a ball park figure that can be used in the preliminary cost/benefit assessment. It is noted that not all aspects have been considered in these extimates, but that the overall figure is in keeping with similar industry project values when compared on a per metre basis.

	Item	UNIT	QUANTITY	Rate (ex GST)	COST
Design	Feasibility Study, Consultation, Detailed Design	item	1	$ 80,000.00	$ 80,000.00
General	Project Management & General Construction Cost (15% of subtotal)	item	1	15%	$ 40,230.24
Above Ground Embankment	Site clearing of rubbish, etc.	Item	1	$ 20,000.00	$ 20,000.00
	Clearing & stripping of topsoil (strip grass to a depth of approximately 100mm)	m2	2,581	$ 0.40	$ 1,032.24
	Foundation preparation	m2	2,581	$ 2.00	$ 5,161.22
	Construction of levee clay core (place and compact)	m3	1,550	$ 30.00	$ 46,500.00
	Topsoil preparation and seeding	m2	2,581	$ 4.00	$ 10,322.45
	Fuel	l/m3	1,550	$ 0.75	$ 1,162.50
Open Swale Drain	Site clearing of rubbish, etc.	Item	1	$ 20,000.00	$ 20,000.00
	Clearing & stripping of topsoil (strip grass to a depth of approximately 100mm)	m2	5,758	$ 0.40	$ 2,303.20
	Excavation by cut in all classes of material	m3	6,800	$ 5.00	$ 34,000.00
	Disposal of unsuitable materials	m3	6,800	$ 5.00	$ 34,000.00
	Top soil placement/seeding	m2	5,758	$ 15.00	$ 86,370.00
	Fuel	l/m3	6,800	$ 0.75	$ 5,100.00
Roadwork	Traffic Control	days	5	$ 450.00	$ 2,250.00
Misc	Contingency	**item**	**1**	25%	$ 97,107.97
	Total (ex GST)				$ 490,000.00