CULCAIRN FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

GREATER HUME SHIRE COUNCIL
FINAL REPORT

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Level 2, 160 Clarence Street
Sydney, NSW, 2000

Tel: 02 9299 2855
Fax: 02 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

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Client Greater Hume Shire Council	**Client's Representative** Michael Oliver
Authors Zac Richards Beth Marson Stephen Yeo Neil Kennan	**Prepared by**  Zac Richards
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ACRONYMS

AAD	Annual Average Damages
ABCB	Australian Building Codes Board
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ALS	Airborne Laser Survey (also see LiDAR)
ARI	Average Recurrence Interval
ARTC	Australian Rail Track Corporation
AWE	Average Weekly Earnings
B/C	Benefit Cost Ratio
BCA	Building Codes Australia
BoM	Bureau of Meteorology
CFERP	Community Flood Emergency Response Plan
CMA	Catchment Management Authority
DA	Development Application
DCP	Development Control Plan
DEM	Digital Elevation Model (A grid of terrain elevations usually obtained from ALS)
DRM	Direct Rainfall Method
EP&A Act	Environmental Planning and Assessment Act
EPA	Environmental Protection Authority
ERP	Emergency Response Planning
FPA	Flood Planning Area
FPL	Flood Planning Level
FRMC	Flood Risk Management Committee
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
IPCC	Intergovernmental Panel for Climate Change
LEP	Local Environment Plan
LFP	Local Flood Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging (also see ALS)
mAHD	Meters above Australian High Datum
MHL	Manly Hydraulics Laboratory
NCC	National Construction Code
OEH	Office of Environment and Heritage
OSD	On Site Detention

PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PWD	Public Works Department
RMS	Roads and Maritime Services (formerly RTA)
SEPP	State Environmental Planning Policy
SES	State Emergency Services
TUFLOW	A one-dimensional (1D) and two-dimensional (2D) hydraulic computer model
WBNM	Watershed Bounded Network Model (hydrologic computer model)
WSUD	Water Sensitive Urban Design

In addition to the above listed Acronyms, a Glossary of terms is presented in Appendix A.

FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

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 Federal Government may also provide subsidies in some circumstances.

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

1. ***Flood Study***
   - Determine the nature and extent of the flood problem.
2. ***Floodplain Risk Management***
   - Evaluates management options for the floodplain in respect of both existing and proposed development.
3. ***Floodplain Risk Management Plan***
   - Involves formal adoption by Council of a plan of management for the floodplain.
4. ***Implementation of the Plan***
   - Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

This report relates to the Floodplain Risk Management Study and Floodplain Risk Management Plan phases of the process.

The Culcairn Floodplain Risk Management Study & Plan (FRMS&P) presented herein constitutes the second and third stages in the NSW Floodplain Risk Management Program for the township of Culcairn and follows on from the Flood Study prepared in September 2013. WMAwater have been engaged by Greater Hume Shire Council to prepare this FRMS&P under the guidance of Council's Floodplain Risk Management Committee (FRMC).

This report has been prepared 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 Office of Environment and Heritage.

1. INTRODUCTION AND BACKGROUND

This Study has been prepared by WMAwater on behalf of Greater Hume Shire Council (Council). The Study is composed of two phases:

1. The Culcairn Floodplain Risk Management Study; and
2. The Culcairn Floodplain Risk Management Plan.

This document details; The Culcairn Floodplain Risk Management Study; and The Culcairn Floodplain Risk Management Plan (abbreviated to FRMS&P). This FRMS&P follows on from the Flood Study which defined the design flood behaviour in the township of Culcairn under existing conditions to determine the nature and extent of the existing flood problem.

1.1. Objectives

The main objective of this FRMS&P is to identify floodplain risk, test amelioration strategies for the management of risk and to put forward priorities and approximately costed recommendations in regards to flood risk mitigation at Culcairn.

Council requires consideration of a range of management options to effectively manage existing, future and continuing flood risks at Culcairn. The outcomes from the Floodplain Risk Management Study and Floodplain Risk Management Plan will also assist the SES in preparing a Local Flood Plan for Culcairn.

The Objectives 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:

- Review of Council's existing environmental planning policies and instruments including Council's long term planning strategies for the Study Area;
- Obtain damage estimates under the range of design floods mention under existing conditions;
- Identification of works, measures and restrictions aimed to reduce 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;
- To assess the effectiveness of the works and measures for reducing the effect 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;
- Examination of the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's developments and disaster planning requirements.

- Examine ways in which the river and floodplain environment may be enhanced by preparing a strategy for vegetation planning that will create a valuable corridor of vegetation without having a detrimental effect on flooding; and
- Identification of modifications required to current policies in the light of investigations.

1.1.2. Floodplain Risk Management Plan Objectives

The Floodplain Risk Management 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 Policy. The recommended works and measures presented in the Plan are aimed to:

- Reduce the flood hazard and risk to people and property in the community and to ensure future development is controlled in a manner consistent with the flood hazard and risk;
- Reduce private and public losses due to flooding;
- Protect and, where possible, enhance watercourses/creeks and floodplain environment;
- Be consistent with the objectives of relevant State policies, in particular, the Government's Flood Prone Lands and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act, 1979;
- Ensure that the 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 management plan are sustainable in social, environmental, ecological and economic terms;
- Ensure that the 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 a mechanism for the funding of the plan and should include priorities, staging, funding, responsibilities, constraints, and monitoring; and the
- Preparation of concept design for recommended works with sufficient detail to enable Council to apply for funding and progress to the investigation and design stage.

1.2. The Study Area

The township of Culcairn is located in the Greater Hume Shire Local Government Area (GHSC) situated in the Riverina region of southern New South Wales (NSW). GHSC is surrounded by the LGA's of Wagga Wagga, Urana, Tumut, Corowa, Tumbarumba, Albury and Indigo.

Culcairn is the second largest town in the GHSC with a population of 1,423 (2011 census). It is located on the Olympic Highway between Albury and Wagga Wagga and as such is an important supply centre for nearby towns and villages (see Figure 1 for Study Area layout).

The town lays predominately on the northern side of Billabong Creek which at Culcairn has a catchment area of 1,800 km² (see Figure 1 for study area). Flooding in the region is caused by local overland flow, Billabong Creek flooding and flooding in an old anabranch that exits Billabong Creek on the northern side of town approximately 2 km upstream of the Olympic Highway at Culcairn. The anabranch sinuously runs parallel to Billabong Creek where it finally enters the town passing under Balfour Street near the corner of Federal Street. From here it continues to wind in a north-westerly direction through the town before crossing the Olympic Highway north of Hopetoun Street. This flow path is only activated above a certain threshold and as such only occurs during larger flood events such as the October 2010 and June 1931 floods (Reference 2).

1.3. Flood History of Culcairn

In Culcairn floods have been recorded for over 120 years and are known to have occurred in July 1995, August 1983, October 1975, October 1974, September 1970, October 1960, July 1956, Jul 1939, August 1934, October 1917, July 1900, and July 1891. More recently events have also occurred in March 2010, December 2010 and January and February 2011 (Reference 2).

It is likely that the largest flood event to be recorded at Culcairn occurred in June 1931 and was measured to be 42'9" at the Culcairn railway bridge. Unfortunately exact comparisons to more recent events are not possible as heights are now measured on a new gauge for which no correlation to the old gauge exists. However, based on newspaper articles from the time, flood depths in Balfour Street are likely to have been 100 – 300 mm deeper in 1931 than what were observed in the second largest flood during October 2010 (Reference 2). It is of interest that the flooding mechanism was notably similar between these two events with floodwater entering the eastern end of Balfour Street from the anabranch mentioned in Section 1.2.

Flood behaviour at Culcairn during the October 2010 event was complex, involving overland flow inundation from local rainfall on Friday 15th October and flooding from Billabong Creek which peaked at 10.2 m on the Billabong Creek gauge on the afternoon of Saturday 16th October. It is reported that an effect of the Billabong Creek flood was causing water to flood back up the Gordon Street stormwater system to inundate areas not directly adjacent to the creek. Numerous homes were inundated by both overland flow and creek flooding although creek flooding dominates flood liability in Culcairn (see Section 4.5) (Reference 2).

The March 2012 event (9.65 m on the Culcairn gauge), which is likely the third largest event to have occurred at Culcairn, was recorded as 0.55 m lower than the October 2010 event. As was reported for the October 2010 flood, water from the Creek came up through the town drainage system causing some ponding near the corner of Gordon Street and Henty Street East, as well as in Blair Street. Drainage work carried out at the Federal Street stormwater pipe reportedly prevented water coming up that pipe[1]. The anabranch flow path down Balfour Street from the east that was observed in both the June 1931 and October 2010 floods was not activated in the March 2012 flood (although the placement of a bund at the breakout location may also have limited the anabranch ability to run). This suggests that there is a distinct threshold (between 9.65 m and 10.2 m on the Culcairn gauge) above which floodwater leaves Billabong Creek upstream of the town and rises at the corner of Balfour and Federal Streets (there is some thought that this runner is triggered when the base of the railway bridge structure is reached at 10.0 m on the Culcairn gauge) (Reference 4).

1.4. Previous Reports

Previous reports have been reviewed and summarised in the Flood Study (Reference 2) including:

- Flood Intelligence Collection and Review for Towns and Villages in the Murray and Murrumbidgee Regions following the October 2010 Flood (Reference 3);
- Flood Intelligence Collection and Review for Towns and Villages in the Murray and Murrumbidgee Regions following the March 2012 Flood (Reference 4);
- Billabong Creek Floodplain Management Plan - Phase A – Data Review and Flood Behaviour (Reference 5)

1.5. Available Data for FRMS&P

1.5.1. Floor Level Survey

Floor level survey was performed by Hydrographic & Cadastral Survey Pty. Ltd. for properties which were determined to experience 1% AEP peak flood level depths equal to or exceeding 300 mm adjacent to the building footprint. In total 120 properties (95 residential and 25 non-residential) were surveyed in Culcairn with the location of these properties displayed in Appendix B, Figure B1.

The floor levels of the remaining properties within the 1% AEP extent were estimated by use of ALS data in combination with visual inspection of properties floor level heights from ground by WMAwater engineers. For all other properties in the Study Area up to the PMF extent, floor levels were estimated using ALS data and the average floor height from ground of the surveyed and estimated floor levels.

[1]Sandbags were used to seal the pit.

1.6. Overview of Existing Catchment

1.6.1. Land Use and Demographic Overview

Understanding the social characteristics of the area can help in ensuring that the right risk management practices are adopted. The Census data can provide useful information on categories including dwelling and tenure type, languages spoken, age of population and movement of people into and from the area. Information has been extracted for the 2011 Census. The urban centre of the suburb of Culcairn has a population of 1,423 living in 616 private dwellings.

Of interest is the data on population movement in recent years. Generally residents who have lived in an area for a longer time will have a better understanding of flooding issues in their area than those who have recently moved to the area. Within the last five years prior to the 2011 census 30% of the population has moved to the Culcairn area and in the year prior to the 2011 census 13% of the population moved into the area. This means that the majority of the current population would have experienced one or both of the recent flood events and therefore likely have good awareness of flood risk in the region.

It is useful to consider the tenure of housing. Those living in properties which they own are more likely to be aware of the flood risks and have measures in place to reduce them (where possible). Rental properties are likely to have a higher turnover of people living in them compared to privately owned properties and therefore those people in rental properties may be less aware of the flood risk. In Culcairn 19% of houses are rented.

The languages spoken by the population are also useful to consider as this can have implications in regard to the provision of flood information to the public. In Culcairn less than 8% of the population speak a language other than English at home.

Land use from the LEP 2011 is shown in Figure 2. The majority of Culcairn is comprised of lots zoned RU5 Rural Village areas. The RU5 classification not only allows for residential properties, but also commercial/industrial of which there are approximately 70 in Culcairn. Land use outside of the township of Culcairn in the Billabong Creek catchment is generally zoned RU1 Primary Production with usage primarily devoted to grazing and cropping endeavours. Special Purpose zones (displayed as ‘special’ in Figure 2) are distributed throughout the town and allow for infrastructure uses, schools, churches and other community facilities.

The Billabong Creek channel is designated as W1 Natural Waterway which has limitations on permitted uses. Zone W1 predominantly aims to allow for boating uses, flood mitigation works, jetties, kiosks, recreation areas and facilities, roads and emergency services facilities. Commercial, industrial and residential land uses are prohibited (LEP 2011). Accordingly, the W1 Natural Waterway zoning is suitable for implementation with the floodway classification (see Section 4.3).

Outside the town boundaries, the only structures on the floodplain are roads and rail, individual farmhouses and other farm related infrastructure. Most roads are unsealed and creek and stream crossings are generally formed by low level causeways.

1.6.2. Key Infrastructure on the Floodplain

Key infrastructure in the floodplain are those that impact on flood levels, for example upstream backwatering (and retention of floodwater) and lower levels in the downstream (relative to the case if the major structure was not there). Some of these may be deliberate flood management measures to control flooding. Culcairn's key infrastructure is summarised in the Flood Study (Reference 2) including location map and photographs. Table 1 below summarises each feature with the locations displayed on Figure 3.

Table 1: Key Infrastructure on the Floodplain

ID	Structure	Comment
1	Railway Bridge over Billabong Creek	The railway bridge over Billabong Creek is situated to the south of the Culcairn township. This structure was surveyed as a part of the Flood Study (Reference 2). This bridge is approximately 80 m in length with five spans. The bridge deck is 1.1 m thick which an average height of 4 m. This structure has a smaller cross sectional area than Structure #2, making it the control for the region.
2	Olympic Highway Bridge over Billabong Creek	The Olympic Highway Bridge over Billabong Creek is approximately 45 m downstream of Structure #1 and was also surveyed during the Flood Study. Similar to Structure #1, this bridge is approximately 85 m long with five spans and a deck thickness of 1.1 m. The bridge is on average 6 m high.
3	Culvert crossing the Railway near Victoria Street	A culvert, approximately 300 m north of Balfour Street, carries overland flow beneath the railway near Victoria Street to the western side of Culcairn. This culvert is approximately 58 m in length with a diameter of 0.6 m.
4	Culvert crossing Railway north of Hopetoun Street	Four 1.8 m x 1.2 m box culverts transfer flow from the Billabong Creek anabranch and overland flow across the railway to the western side of Culcairn. These culverts are approximately 200 m north of Hopetoun Street.
5	Gordon Street outlet to Billabong Creek	The Gordon Street culvert has been acknowledged as a key infrastructure for Culcairn. In the 2010 and 2012 flood events, this pipe contributed to the flooding in Culcairn from the backwatering of flow from Billabong Creek. The Gordon Street pipe has an approximate length of 630 m and diameter of 0.9 m.
6	Gamble Street drain outlet to Billabong Creek	Similar to Structure #5, the Gamble Street drain is likely to have a reverse flow effect when Billabong Creek is in flood, causing a flood problem for Culcairn. Hence the culvert crossing Gamble Street is a key infrastructure, with an approximate length of 20 m and diameter of 0.6 m.
7	Balfour Street Culvert connecting Billabong Creek anabranch	The Balfour Street culvert connects the Billabong Creek anabranch at this location. Once the capacity of this culvert is reached, floodwaters are likely to flow across Federal Street and cause flooding in town. This culvert is approximately 30 m in length with a diameter of 0.4 m.

2. COMMUNITY CONSULTATION

Community consultation is an important element of the floodplain risk management process ultimately facilitating community engagement and acceptance of the overall project. During the Flood Study (Reference 2), community consultation was undertaken to assess the flood experience of the community and gather additional data. Further community consultation has also been undertaken as part of the FRMS&P. To date this has included a questionnaire, a community open day and a number of FMC meetings. Goals of ongoing community consultation are to keep residents informed of progress and in the later stages gain their feedback on potential mitigation and management measures proposed. Final community consultation proposed is in the form of public exhibition of the Floodplain Risk Management Study and Floodplain Risk Management Plan.

It should also be noted that as part of the SES Data Collection Studies (Reference 3 and 4) following the 2010 and 2012 events, considerable consultation was performed including questionnaire distribution and interviews.

2.1. Questionnaire Distribution

A community newsletter and questionnaire (presented in Appendix C) was distributed to residents in Culcairn during September 2014. The newsletter aimed to inform the community of the Culcairn FRMS&P and the survey provided the community with an opportunity to highlight their flood affectation and to provide input into the current study. In particular, the questionnaire was intended to obtain ideas for mitigation works or management plans to reduce flood risk and to determine if the community is interested in Voluntary Purchase (VP) or Voluntary House Raising (VHR) schemes (see Sections 5.4.1 and 5.4.2).

A total of 14 replies (out of 738 distributed) resulted in a return rate of 2% which is low for this kind of study. It is normal that responses predominately come from residents that have been affected by flooding, however 14 is significantly less than the number of residents impacted by the recent events. The reduced return rate may have been due to the questionnaire being focused on obtaining flood risk solutions that many people are possibly not well placed to provide.

A summary of the questionnaire results is presented in Figure 4 with the questionnaire returnee locations displayed in Figure 5. All questionnaire respondents except one mentioned that they thought flood risk at Culcairn should be ameliorated, particularly for flood risk due to Billabong Creek (9 responses) and surcharging stormwater pipes (7 responses). Approximately five respondents thought that flooding at a frequency of less than 100 years is acceptable which is generally in line with the aims of the current study. However, two respondents mentioned that they thought any degree of flooding is never acceptable which would require the engineering of mitigation structures to the PMF. It was also found that the majority of people were interested in VP (6 respondents interested) scheme however not interested in the VHR (2 respondents interested) scheme.

Respondents provided a range of flood mitigation ideas to reduce flood risk in Culcairn. Many of these suggestions have been modelled and their viability has been assessed in Section 5. The Community Consultation responses included the following potential flood mitigation measures:

- Inserting a non-return valve to the Gordon Street culvert (see Section 5.3.5.1);
- Closing the Billabong Creek Anabranch (see Section 5.3.3.3);
- Clearing Billabong Creek (see Section 5.3.3.4);
- Levee banks to redirect flow away from Culcairn township (see Section 5.3.1);
- Increasing drainage capacity at Melrose Street (see Section 5.3.2); and
- Creating a depression along the Stock Route near the intersection with Balfour Street to prevent water building up (see Section 5.3.4.3).

2.2. Community Consultation Open Day

A WMAwater engineer attended the township of Culcairn on the 14th of October 2014 with the purpose of interviewing residents to gain potential flood mitigation ideas to reduce flood affectation in Culcairn.

The meeting was attended by approximately 9 people with many of these people also returning the questionnaire. Consequently, many of the concerns raised by the returned questionnaires were also discussed at the open day. A list of these topics is presented in Section 2.1. Another topic of concern for residents was the local drainage issues in Culcairn particularly at Gordon Street, Henty Street, Munro Street and Elizabeth Street.

Three attendees expressed concerns about raising the level of Walbundrie Road and the potential flood impacts on their properties. Whilst this location is outside the Culcairn study area, council was contacted and advised of these concerns and the negative impact on flood behaviour for these residents (see Appendix D).

2.3. Flood Risk Management Committee

The Culcairn Floodplain Risk Management Committee (FRMC) comprises a number of representatives from the local community, including residents, members of Council, the SES and OEH.

Regular meetings have been held (6 in total) in order to inform the FRMC of the study progress regarding data collection and community consultation as well as the modelling of flood mitigation measures. Following review and edits, the draft report requires recommendation to Council for endorsement in order to progress. At this stage exhibition of the draft document would be the normal course of action.

2.4. Public Exhibition of the Draft Final Culcairn FRMS&P

Public exhibition of the Draft Final Culcairn FRMS&P was undertaken to ensure community support of these documents. The Report was available to the public for scrutiny, for the period of one month. Digital copies of the reports were available on the Council website and a hard copy of the report was available at Council Offices and the local library. No submissions were received in relation to the Culcairn FRMS&P.

3. FLOOD STUDY SUMMARY AND FLOOD BEHAVIOUR

3.1. Aims and Objectives of the Flood Study

The information and results obtained from the Flood Study (Reference 2) defined existing flood behaviour and provide a firm basis for the development of the FRMS&P. Primarily, the study was developed in order to meet the objective of defining the flood behaviour for the 5-year ARI, 10%, 2%, 1%, 0.5% AEP events and the PMF in Culcairn and to:

- Define flood behaviour in terms of flood levels, depths, velocities, flows and flood extents within the study area;
- Prepare flood extent mapping (for all design events modelled); and to
- Create a modelling system that might be used in the subsequent FRMS&P to test whatever flood mitigation works might be proposed by either the community, OEH, Council or the consultant.

In order to define flood behaviour, the Flood Study developed a hydrological model, WBNM, in conjunction with a 1D/2D hydraulic model, TUFLOW. This methodology is presented in the Flood Study (Reference 2).

3.2. Flood Mechanisms

Culcairn is affected by two primary sources of flooding. These are:

- Local overland flow flooding; and
- Billabong Creek flooding. This incorporates the;
    - Billabong Creek anabranch breakout; and
    - Surcharging Gordon and Gamble Street drains.

The greatest degree of flood liability is due to Billabong Creek and the associated anabranch breakout, however surcharging of the Gordon and Gamble Street drains due to elevated creek levels does also cause flooding of properties (see Section 4.5).

Local overland flow is also a source of significant flood affectation in Culcairn, mainly affecting the central and northern areas. Three primary flow paths exist, namely the:

- Northern Flow Path (situated north of Hopetoun Street);
- Central Flow Path (situated north of Prince Street); and
- Southern Flow Path (flowing west along Balfour Street).

All three flow paths have their headwaters to the east of town. It is important to note that the Southern Flow Path upstream of town is formed from local catchment rainfall entering the Billabong Creek anabranch which routes water into town via the same mechanism as Creek breakouts and predominately affects Hotspot #1 (see Section 3.6.1). The local upstream catchment area of this flow path is 80 ha and produces a flow of 5 m³/s which is substantial in terms of flood liability due to local flows.

Flood affectation from these flow paths is exacerbated by water ponding on the upstream side of raised roads such as Munro Street and the Olympic Highway.

Local overland flow and Creek flooding can occur independently or concurrently. However for most events overland flow flooding will occur prior to Billabong Creek flooding as occurred for both the 2010 and 2012 events.

It is important to recognise that different types of flooding will need different management measures. Mitigation works for both Creek and local flow flooding scenarios have been derived and assessed independently. Furthermore, different flooding mechanisms will require a different emergency response.

3.3. Design Events

The hydraulic model was run for the 5-year ARI, 10%, 2%, 1% and 0.5% AEP events as well as the PMF, for which a number of maps have been produced displaying the flood affected regions (see mapping included in the Flood Study – Reference 2). Please note that these maps have not been reproduced in the current study to account for minor changes to the model, as the impact on peak flood levels and extents are relatively insignificant. However, all modelling undertaken as part of the current study (mitigation runs, FPA and hydraulic categorisation) has been performed with the updated hydraulic model.

3.3.1. Critical Durations

For design flood events, the Billabong Creek critical duration at Culcairn is 24 hours. Local flows generated from the local catchment model were determined to have critical durations of 1 and 6 hours (spatially variable).

The critical duration of the PMF at Culcairn, was found to be 24 hours for Billabong Creek and 3 hours overland flows.

3.3.2. Peak Flows

The peak flows for Billabong Creek at the railway bridge, upstream of the Olympic Highway for the calibration/validation and design flood events are presented in Table 2.

Table 2: Billabong Creek, near Olympic Highway - WBNM Model Peak Flows (m³/s)

	5Y	10%	5%	*2012 Event*	2%	*2010 Event*	1%	0.5%	PMF
Culcairn	247	314	424	469	552	613	686	812	7306

The 1% AEP event has a flow of 686 m³/s which is slightly more than the 2010 event which is estimated to have an ARI of approximately 70 years. The 2012 event ARI is estimated to be approximately 30 years.

3.3.3. Flood Depths and Levels

Mapping of peak flood depths and levels is included in the Flood Study (Reference 2) the map set includes the following;

- Peak flood depths and levels for the design flood events (PMF, 5-year ARI, 10%, 5%, 2%, 1% and 0.5% AEP) (all depths < 100 mm clipped, see paragraph below);
- Flood profiles along Billabong Creek for each design flood event;
- Provisional Hazard and Hydraulic Category maps; and
- A summary of the performance of key hydraulic structures.

When establishing inundation patterns and/or peak flood levels, these are based on best available estimates of flood behaviour within the catchment. Inundation from creek and particularly local overland flow may vary depending on the actual rainfall event and local influences, for example; change in topography, blocked structures, road works etc. For the design events depths less than 100 mm have been considered 'drainage' rather than 'flooding' and accordingly, the design results figures only display flood depths in excess of 100 mm.

3.3.4. Flood Travel Time

Pluviographs and hydrographs for the October 2010 and March 2012 events are plotted in Chart 1 and Chart 2 respectively. The lag time – the time between the decisive rainfall burst and the flood peak at Culcairn – is about 24 hours for both events.

Flood travel times between the NSW Office of Water gauge located at Billabong Creek downstream of the junction of Ten Mile and Mountain Creeks (No. 410186) and the manual gauge at the Culcairn railway bridge are extracted for recent historical events from the flood intelligence reports (References 3 and 4) and are presented in Table 3. Travel times between the two gauges have varied between less than 7 hours and more than 13 hours, though this obscures the fact that sometimes the Culcairn flood hydrographs are relatively flat-topped and so the stated flood peak travel time is sensitive to the frequency and precision of measurements at the manual Culcairn gauge. Faster flood travel times in February 2011 could reflect the limited flood storage areas available towards the end of the wet 2010/11 summer (recalling there was also a flood in December 2010). The faster travel time on 4-5 March 2012 makes sense because it was the third flood in quick succession.

Table 3: Flood Peak Travel Times – Billabong Creek

Event	410186 peak (m)	410186 peak (date/time)	Culcairn peak (m)	Culcairn peak (date/time)	Travel time (hh:mm)
2010 Mar 8-9	7.31	8/3/2010 - 15:00	6.5	9/3/2010 - ~04:30	~13:30
2010 Oct 15-16	10.40	16/10/2010 - 03:00	10.2	16/10/2010 - ~13:10	~10:10
2011 Feb 6	8.52	6/2/2011 - 08:18	8.15	6/2/2011 - 15:00	6:40
2011 Feb 12-13	7.60	12/2/2011 - 08:41	7.1	12/2/2011 - 17:00	8:20
2011 Feb 18-19	7.68	18/2/2011 - 07:11	7.1	18/2/2011 - 16:00	8:50
2012 Mar 2	4.50	2/3/2012 - 03:30	3.6	2/3/2012 - 12:39	9:10
2012 Mar 4-5	9.95	4/3/2012 - 17:00	9.65	5/3/2012 - 00:05	7:05

Note: Data is adjusted to Eastern Daylight savings Time

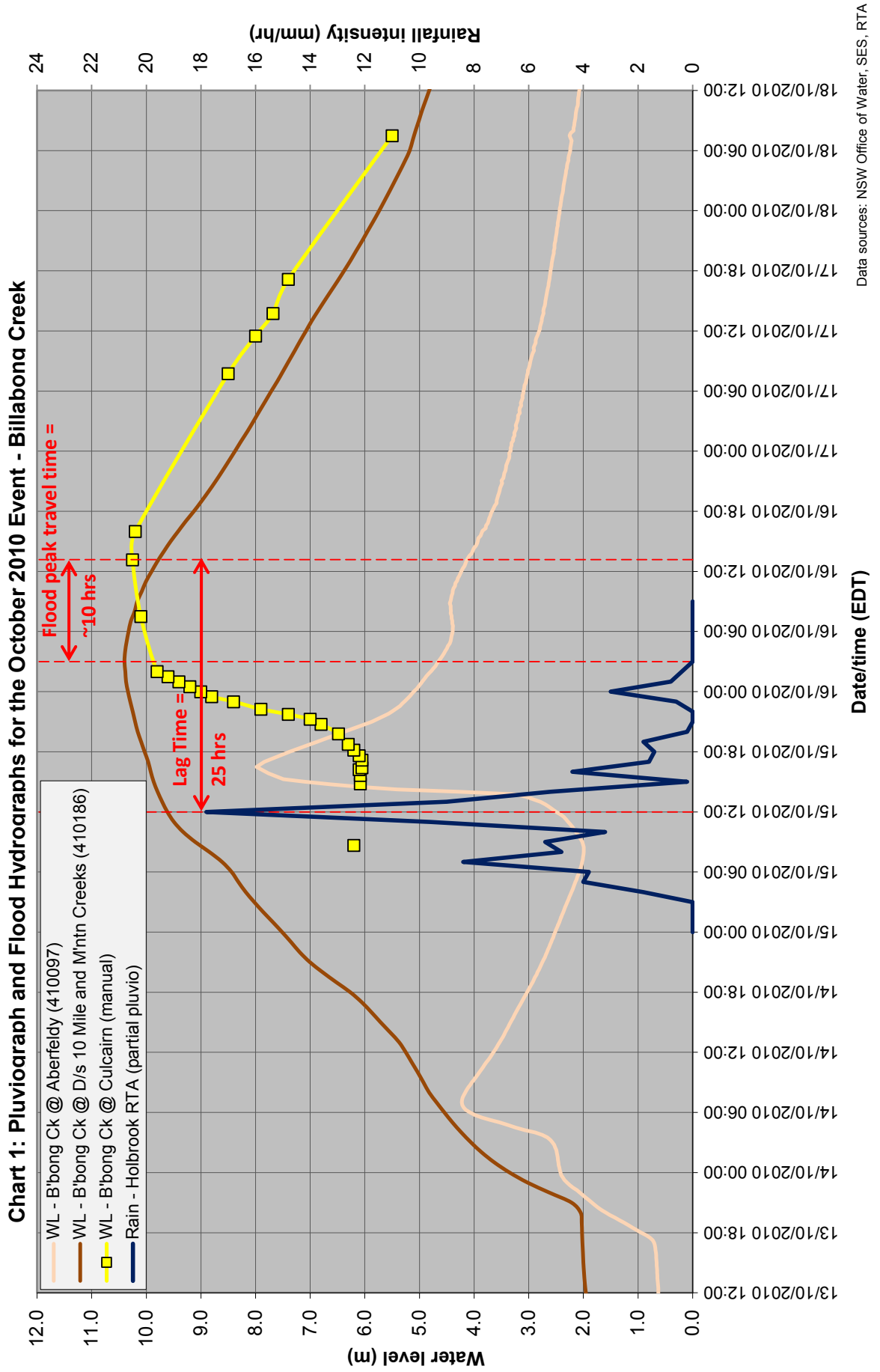


Chart 1: Pluviograph and Flood Hydrographs for the October 2010 Event - Billabong Creek
Rainfall intensity (mm/hr)
Water level (m)
Date/time (EDT)
Data sources: NSW Office of Water, SES, RTA
WL - B'bong Ck @ Aberfeldy (410097)
WL - B'bong Ck @ D/s 10 Mile and M'ntn Creeks (410186)
WL - B'bong Ck @ Culcairn (manual)
Rain - Holbrook RTA (partial pluvio)
Flood peak travel time =
~10 hrs
Lag Time =
25 hrs

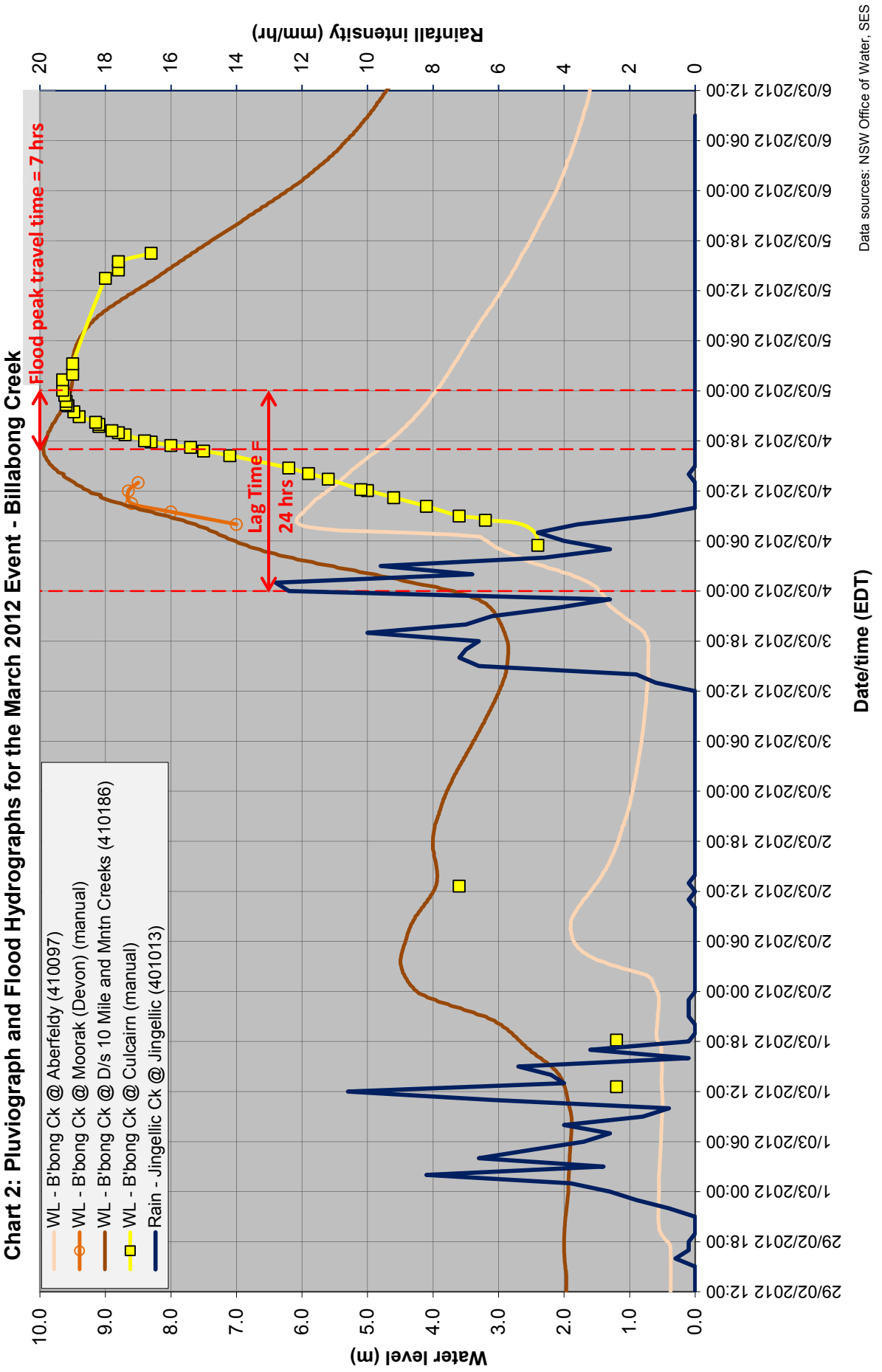


Chart 2: Pluviograph and Flood Hydrographs for the March 2012 Event - Billabong Creek
Flood peak travel time = 7 hrs
Lag Time = 24 hrs
WL - B'bong Ck @ Aberfeldy (410097)
WL - B'bong Ck @ Moorak (Devon) (manual)
WL - B'bong Ck @ D/s 10 Mile and Mntn Creeks (410186)
WL - B'bong Ck @ Culcairn (manual)
Rain - Jingellic Ck @ Jingellic (401013)
Water level (m)
Rainfall intensity (mm/hr)
Date/time (EDT)
Data sources: NSW Office of Water, SES

3.4. Provisional Hydraulic Categories

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The *Floodplain Development Manual* (Reference 1) defines flood prone land to fall into one of the following three hydraulic categories (refer definition in Appendix A);

- Floodway;
- Flood Storage; and
- Flood Fringe.

Floodways are areas of the floodplain where a significant discharge of water occurs during floods and by definition if blocked would have a significant effect on flood flows, velocities or depths. Flood storage are areas of importance for the temporary storage of floodwaters and if filled would significantly increase flood levels due to the loss of flood attenuation. The remainder of the floodplain is defined as flood fringe. There is no technical definition of hydraulic categorisation and different approaches are used by different consultants and authorities.

Based on exploratory work carried out at Henty and reported upon in Appendix I of the Flood Study (Reference 2), provisional floodways were defined on the following basis:

*Floodway = Velocity * Depth > 0.25m^2/s AND Velocity > 0.25m/s OR Velocity > 1m/s*

The remainder of the floodplain outside the Floodway becomes either Flood Storage or Flood Fringe. In the Reference 2 study Flood Storage was defined as the land outside the Floodway if the depth is greater than 0.5 m and Flood Fringe if the depth is less than 0.5 m.

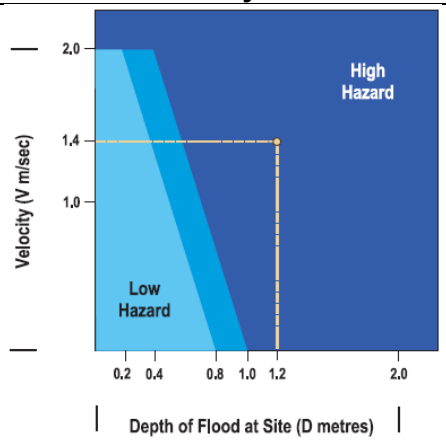
Using this classification system, limited extents in Culcairn are defined as floodway which seems appropriate given the distributed nature of flows in the overbank areas, away from defined watercourses. Nevertheless, there were some residential areas interacting with defined floodways, for example on Henty and Victoria Streets.

A more detailed look at the floodway definition for Culcairn has been undertaken as part of the current study. The investigation takes into account Velocity x Depth criteria, encroachment analysis and percentage flow distribution. The true hydraulic categorisation is presented in Section 4.3.

3.5. Provisional Hydraulic Hazard Classification

The Flood Study (Reference 2) defined provisional flood hazard categories in accordance with the Floodplain Development Manual (Reference 1). Provisional hazards only take account of the hydraulic aspects of flood hazard; depth and velocity (Diagram 1), while true hazard (see Section 4.4) takes into account additional factors such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows.

Diagram 1: Provisional Hydraulic Hazard Categories



Notes

The degree of hazard may be either -

- reduced by establishment of an effective flood evacuation procedure.
- increased if evacuation difficulties exist.

In the transition zone highlight by the median colour, the degree of hazard is dependant on site conditions and the nature of the proposed development.

Example:

If the depth of flood water is **1.2 m**
and the velocity of floodwater is **1.4 m/sec**
then the provisional hazard is **high**

FIGURE L2 - Provisional Hydraulic Hazard Categories

Extracted from The Floodplain Development Manual (Reference 1)

The Flood Study (Reference 2) established high and low provisional hazard areas for the 5% AEP and 1% AEP events and the PMF. 1% AEP event high hazard areas tend to be limited to the Billabong Creek and anabranch breakout channels (see Section 3.2).

3.6. Flood Liable Areas and Infrastructure

The October 2010 flood event provides an indication of flood liability and affected infrastructure as it approximates a 70 year ARI flood event.

Results of the Flood Study (Reference 2) indicate that numerous properties will suffer some degree of inundation during the 1% AEP event. Properties in the centre of Culcairn, particularly along Henty Street become inundated by events as small as the 5% AEP event. For the 1% AEP flood as many as 33 homes and 11 commercial lots are likely to become inundated above floor and many more will experience significant flooding of property lots (not necessarily over floor level inundation).

In terms of flood affectation, Henty and Victoria Streets are particularly notable. Flood depths and duration are the highest in the study area which when combined with the number of properties that are affected impacts significantly on flood damages.

The following roads are also cut during the 1% AEP event by Billabong Creek and overland flows:

- Olympic Highway (both to the north and south of town);
- Culcairn - Holbrook Road (to the east)
- Walbundrie Road (to the west);
- Balfour Street; and
- Melrose Street.

During such an event access to the township of Culcairn will be restricted by flooding in all directions. The PMF is found to inundate much of the town and in many locations will be 1.5 - 2 m higher than the 1% AEP event. This is indicative of a high risk flood situation.

3.6.1. Hotspots

The Flood Study identified a number of flooding "Hotspots" which are specific areas of interest from a flooding perspective. These include; locations where many residences are liable to flooding, where key drainage assets are not meeting design standards or where key infrastructure, such as major roads, are flood affected. The hotspots, typically SES locations of interest, were identified and discussed in the Flood Study with respect to the behaviour of flooding at each location. The identified hotspots are summarised in Table 4 and displayed in Figure 3. For further information on the hotspots see the Culcairn, Henty and Holbrook Flood Studies (Reference 2).

Table 4: Hotspots

Hot Spot	Name	Comment
1	**Federal Street**	The residential area between Federal, King, Munro and Balfour Streets can be flooded from the Billabong Creek anabranch (see Section 3.2) from both local and Creek flows (see Section 3.2). Balfour Street acts as an obstruction to flows in the anabranch which causes overtopping of Federal Street and flows entering from the area from the east.
2	**Henty Street**	Henty Street and its surrounds experience peak flood depths predicted to exceed 0.5 m for the 1% AEP event. Flooding in the region can be due to local overland flow, anabranch flows and/or surcharging of the Gordon Street pipe.
3	**Melrose Street**	Flood water carried into the northeast of Culcairn by the anabranch has caused issues with flooding along Melrose Street. Most of the properties around Melrose Street are located in a small dip, exacerbating the flood problem and resulting in flood depths exceeding 0.5 m for the 1 % AEP. Melrose Street itself is subject to depths of more than 0.6 m cutting off the major evacuation route. The area around Melrose Street drains north via Hopetoun Street heading to the box culverts at the railway.
4	**Olympic Highway**	This hotspot falls into one of the rezoning areas. As the highway is significantly flooded both from the northern and the southern side, the lack of an evacuation and escape route becomes an issue. The flooding problem at this hotspot can be caused by anabranch and local flow flooding however Olympic Highway flooding is greatest due to overland flows ponding along the railway.

3.7. Future Development and Flooding

A current planning proposal seeks to amend the LEP 2012 land zoning at Culcairn with three areas proposed for rezoning in the study area (locations presented in Figure 1). These proposed rezoning regions have varying degrees of flood liability and an investigation into the suitability of these areas for rezoning has been undertaken in Section 4.2.

Future development within the FPA is not permitted with the NSW Environment Planning Assessment Act 1979 (EP&A Act) stating in Clause (5) of Direction 4.3:

> *(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.*

Further details pertaining to Planning to the planning aspects of this study are presented in Sections 4.8 and 5.6.

4. FLOODPLAIN RISK MANAGEMENT STUDY

4.1. Objectives of the Floodplain Risk Management Study

The primary 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, as detailed in the Floodplain Development Manual (Reference 1). Other objectives include:

- 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;
- 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) on the floodplain and whether they can be minimised;
- Examination of the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's developments and disaster planning requirements.
- Examine ways in which the river and floodplain environment may be enhanced by preparing a strategy for vegetation planning that will create a valuable corridor of vegetation without having a detrimental effect on flooding;
- Identification of modifications required to current policies in the light of investigations; and
- Undertake effective community consultation and participation throughout the Study.

Further to this, this section considers the true hydraulic categorisation, true flood hazard classification, impacts of flooding to properties in Culcairn and key access issues. It also considers existing floodplain management at Culcairn in terms of both policy and planning as well as flood response. Structural flood management features are also considered. Potential options to reduce flood risks are discussed in Section 5.

Further to this, three rezoning regions are proposed throughout the study area. These proposed rezoning regions have varying degrees of flood liability and further details are presented in the Flood Study (Reference 2). Further comment/investigation has also been in Section 4.2.

4.2. Proposed Rezoning Regions Planning Measures

Culcairn is currently experiencing increased growth due to its proximity to the regional centres of Wagga Wagga and Albury. Council is responding to this by considering rezoning a number of areas within the township. Predominantly rural land (RU1) is being reviewed and assessed to identify areas that can support future residential development.

Council is currently considering the rezoning of three sites as presented in Table 5 with the locations displayed in Figure 1 and Figure 2.

Table 5: Proposed Rezoning Areas

Zone Id	Current Zoning	Proposed Zoning	Area (ha)	Proposed Rezoning Suitability
1	RU1 Primary Production	RU4 Rural Small Holdings	61.7	Yes*
2	RU1 Primary Production	RU5 Village	14.6	Yes*
3	RU1 Primary Production	RU5 Village	22.3	Yes*

* Not all areas of the proposed rezoning region are suitable for rezoning. Regions within the Culcairn FPA cannot be rezoned to a zone type that can lead to increased development (see Section 3.7, Clause (5) of Direction 4.3 of the EP&A act).

Each site has been analysed for its suitability for rezoning with details presented below. As part of this analysis, Figure 6 illustrates the rezoning areas currently under consideration with the Culcairn FPA (see Section 5.6.3) overlaid and Figure 7 presents the hydraulic hazard (see Section 4.4) with the rezoning regions.

It is important to note that not all areas that are suitable for rezoning are flood free and accordingly it is recommended that the following is addressed before future development is undertaken:

- Consider ease/need for egress in relation to larger/rarer floods;
- Consider and apply appropriate flood proofing controls to industrial development within the FPA and more specifically the floodway; and
- Set minimum floor heights for dwellings in the Flood Planning Area (FPA).

Rezoning Area #1

Rezoning Area #1 is situated north of Baird Street and to the east of the Olympic Highway. The proposed Rezoning Area has an area of 66.7 ha. Examination of the Culcairn FPA indicates that the majority of the proposed rezoning area is outside of the FPA extent (see Figure 6), with the exception of two areas bordering the Olympic Highway. Therefore rezoning of this area is not in disagreement with Clause (5) of Direction 4.3 of the EP&A Act (see Section 3.7), and from a flooding perspective this land is suitable for rezoning to RU4 Rural Small Holdings.

Rezoning Area #2

Rezoning Area #2 is situated on the south-west corner of Baird Street and the Olympic Highway and has an area of 16.8 ha. Examination of the Culcairn FPA indicates that the majority of the proposed rezoning area is outside of the FPA extent (see Figure 6), with minor pockets of FPA situated on the rezoning area extent. Therefore rezoning of this area is not in disagreement with Clause (5) of Direction 4.3 of the EP&A Act (see Section 3.7), and from a flooding perspective this land is suitable for rezoning to RU5 Village.

Rezoning Area #3

Rezoning Area #3 is situated on the north-east corner of Balfour and Federal Streets. The site has an area of 23.4 ha. Examination of the Culcairn FPA indicates that the majority of the proposed rezoning area is outside of the FPA extent (see Figure 6), however the Billabong Creek anabranch (see Section 3.2) flows through the site and is classed as a high hazard flow area (see Figure 7) and as a floodway (see Figure 8) in the 1% AEP event. Areas situated outside of the Culcairn FPA and the Billabong Creek anabranch are suitable for rezoning as they are not in disagreement with Clause (5) of Direction 4.3 of the EP&A Act (see Section 3.7). From a flooding perspective Rezoning Area #3 is suitable for rezoning to RU5 Village.

4.3. True Hydraulic Categorisation

The Flood Study (Reference 2) defined the provisional hydraulic categorisation while the FRMS&P revised this to identify the true hydraulic categorisation.

Appendix E details the methods used to determine the floodway at Culcairn. Once the floodway was defined the remainder of the floodplain outside the floodway becomes either flood storage or flood fringe. In this study Flood Storage was defined as the land outside the Floodway if the depth is greater than 0.5 m and Flood Fringe if the depth is less than 0.5 m.

Hydraulic categorisation for the 1% and 0.5% AEP events and the PMF are presented in Figure 8 to Figure 10. The investigation into appropriate criteria for defining the Culcairn floodway is provided in Appendix E.

Using the methodology presented in Appendix E, the floodway is mainly contained to the Billabong Creek in-bank areas with the exception of the Billabong Creek anabranch through the Culcairn township. However, no residential properties are defined within the anabranch floodway with all properties situated in the flood fringe. Culcairn overland flows were determined to not produce a significant floodway due to the relatively slow velocities and shallow depths in the region.

4.4. True Flood Hazard Classification

The Flood Study (Reference 2) defined the provisional hydraulic hazard while the FRMS&P is required to consider the true flood hazard. The Flood Study (Reference 2) found that high provisional hydraulic hazard tends to be limited to defined flow paths including the anabranch and also those areas where water depths accumulate, including areas where flows are trapped behind the railway embankment. However, few provisional high hazard areas are in populated areas of Culcairn for the 1% AEP event.

To assess the true flood hazard all adverse effects of flooding have to be considered. As well as considering the provisional (hydraulic) hazard it also incorporates other criteria such as threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production and those detailed in Table 6.

Table 6: Hazard Classification

Criteria	Weight [1]	Comment
Size of the flood	Medium	The size or magnitude of the flood can affect depths and velocities. Relatively low flood hazard is associated with more frequent minor floods while less frequent major floods are more likely to present a high hazard situation.
Depth and velocity of floodwaters	High	The provisional hazard is the product of depths and velocity of flood waters. These are influenced by the magnitude of the flood. By and large at Culcairn, high velocities and depths during the 1% AEP event are confined to the creek channel, to well-defined anabranches both north and south of the creek and to some locations immediately east of the railway where deep flows can accumulate. In the PMF, the entire town would be inundated by high hazard conditions (as defined by Figure L2 of the Floodplain Development Manual) and the depths and velocities in some areas – especially upstream of the railway – could pose a risk to the structural stability of buildings (after Reference 7).
Rate of rise of floodwaters	Medium	Rate of rise of floodwaters is relative to catchment size, soil type, slope and land use cover. It is also influenced by the spatial and temporal pattern of rainfall during events. Relative to Henty and Holbrook, the rate of rise for Billabong Creek floods at Culcairn is relatively long (~18 hours for the October 2010 and March 2012 floods) due to the large catchment area.
Duration of flooding	Low	The greater the duration of flooding the more disruption to the community and potential flood damages. A short period of inundation may allow some materials to dry and recover whereas a long duration may increase damages to roads or cause damages beyond repair. The October 2010 flood exceeded 9 m at the Culcairn gauge (at about which height flooding of streets commences) for about 27 hours and the March 2012 flood for about 18 hours (see Chart 1 and Chart 2). The modelled 1% AEP flood exceeds this height for about 27.5 hours.
Effective warning and evacuation time	High	This is dependent on the rate at which waters rise, an effective flood warning system and the awareness and readiness of the community to act. No Bureau of Meteorology flood warnings are issued for the streams and creeks in the Greater Hume LGA. Nevertheless, flood travel times allow potential for significant improvement to flood warning systems.
Flood awareness and readiness of the community	Medium	The community of Culcairn has a degree of flood awareness but it is likely to be limited to those people who experienced recent events. Community consultation undertaken as part of the current flood risk management process (of which this report forms part) has raised awareness of the flood problem. The awareness of the community has a medium weight in considering flood hazard as a more aware community may be able to better prepare and therefore potentially evacuate before hazards become high. General community awareness tends to reduce as the time between flood events lengthens and people become less prepared for the next flood event. Even a flood-aware community is unlikely to be wise to the impacts of a larger, less frequent event.
Effective flood access	High	Access is affected by the depths and velocities of flood waters, the distance to higher ground, the number of people using and the capacity of evacuation routes and good communication. A number of roads in Culcairn could become impassable in extreme floods.
Evacuation problems	High	Evacuation problems could also be exacerbated by the time of day during which flooding occurs. A flood at night would be more difficult to detect and flooded roads would be more difficult to navigate. The number of people to be evacuated can make evacuation difficult. Mobility of people, such as the elderly, children or disabled, who are less likely to be able to move through floodwaters is also challenging.
Type of development	Low	The type of flood prone development will influence the ease of evacuation. Longer term home owners would likely have a better understanding of flood risk than a guest at a hotel while residents from a residential care home are likely to be less mobile than average.

[1] Relative weighting in assessing the hazard for Culcairn determined by interrogation of Reference 2 results

The flood hazard for the study area varies by location based on the relative depths, velocities and effective flood access. Flood hazard will vary depending on the magnitude of the event, and therefore its AEP.

Only minor amendments (increased hazard classification of low hazard areas totally surrounded by high hazard areas) to the provisional flood hazard have been made with the true flood hazard for the 1% AEP event displayed in Figure 11.

There may be some localised areas subject to higher hazard where flood velocities are high, such as near obstructions to flow or culverts and drains that would not be identified at the current scale of the result mapping.

4.5. Impacts of Flooding

4.5.1. Residential Properties

Residential properties suffer damages from flooding in a number of ways. Direct damages include loss of property contents and/or damage to the structure of the property. Indirect damage costs can be incurred when property occupiers live elsewhere while repairs are being made. A flood damages assessment was undertaken for 525 residential properties. Surveyed floor level data was not available for all properties. Therefore in some cases floor level estimates were made by site visit and ALS data (see Section 1.5.1). A summary of the flood damages assessment is provided in the following sections with full details included in Appendix F.

This flood damages assessment accounted for three possible flooding scenarios in Culcairn; flooding from Billabong Creek; flooding from overland flow and a combination of the creek and overland flow flooding. These scenarios were investigated separately for the purpose determining the viability of potential flood mitigation measures, which would only alleviate a specific type of flooding in Culcairn.

4.5.1.1. Number of Inundated Residential Properties

The floor level survey and design results (Reference 2) were used to identify over floor flood affectation for residential properties and to determine what AEP is responsible for over floor flooding in the first instance. Figure 13 presents the design event during which residential properties are first inundated above floor level while Table 7 below details the total number of properties flooded in each design event when Culcairn is flooded from Billabong Creek and overland flow.

Table 7: Number of Flood Prone Residential Properties

Event	No. Properties Affected	No. Flooded Above Floor Level
5-year ARI	10	1
10% AEP	15	1
5% AEP	21	4
2% AEP	32	6
1% AEP	98	33
0.5% AEP	189	103
PMF	524	524

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

Although the majority of residential floor levels are not inundated until the PMF event, a substantial number are inundated above floor in smaller events. One residence along Munro Street is identified as being flooded above floor level in the 5 year ARI. The majority of flood affectation in Culcairn for the 1% AEP flood is to properties situated along Henty Street with 11 (of 33) residential properties flooded over floor during this event being situated in this region (see Figure 13).

4.5.1.2. Residential Flood Damages Assessment

In assessing various mitigation measures it is important to compare them using a suitable metric. By applying a monetary value to property damages and then comparing damage estimates for the existing situation with assumed mitigation work (approximately costed) a benefit/cost (B/C) ratio can be calculated which is readily comparable. A flood damages assessment was undertaken for 525 residential properties likely to be affected in the PMF event in order to identify potential flood damages for a range of design events. A summary of the assessment is provided in the following sections with full details included in Appendix F.

Table 8 shows the potential damages for a range of design events and the Annual Average Damage (AAD) when Culcairn is affected by flooding from both Billabong Creek and local overland Flow.

Table 8: Total Potential Residential Damages for Culcairn

Event	No. Flooded Above Floor Level	Total Damages for Event	Event Contribution to AAD (%)
5-year ARI	1	$ 105,000	7
10% AEP	1	$ 138,000	5
5% AEP	4	$ 241,000	4
2% AEP	6	$ 342,000	4
1% AEP	33	$ 2,145,000	5
0.5% AEP	103	$ 6,943,000	10
PMF	524	$ 52,005,000	64
Average Annual Damages (AAD)		**$ 228,000**	

Table 9 and Table 10 provide the individual potential flood damages for Billabong Creek (including the anabranch breakout and Gordon Street pipe surcharging) and local overland flows respectively. These form the base cases against which damages from implemented mitigation measures can be assessed. It should be noted that as Creek and overland flow flooding are not dependent (see Section 3.2), damages have been assessed depending on the responsible flood mechanism. Investigation into variation of damage values and B/C ratios for various flood mitigation management options are presented in Section 5.3 for preferred management options.

Table 9: Potential Residential Damages for Culcairn - Billabong Creek Flooding

Event	No. Flooded Above Floor Level	Total Damages for Event	Event Contribution to AAD (%)
5-year ARI	0	$ -	0
10% AEP	0	$ -	0
5% AEP	0	$ -	0
2% AEP	2	$ 63,000	1
1% AEP	30	$ 1,953,000	6
0.5% AEP	102	$ 6,877,000	12
PMF	524	$ 52,005,000	82
Average Annual Damages (AAD)		**$ 180,000**	

Table 10: Potential Residential Damages for Culcairn – Overland Flow Flooding

Event	No. Flooded Above Floor Level	Total Damages for Event	Event Contribution to AAD (%)
5-year ARI	1	$ 105,000	17
10% AEP	1	$ 138,000	13
5% AEP	4	$ 241,000	10
2% AEP	6	$ 342,000	10
1% AEP	8	$ 590,000	5
0.5% AEP	11	$ 774,000	4
PMF	194	$ 13,958,000	40
Average Annual Damages (AAD)		**$ 91,000**	

4.5.2. Non-Residential - Commercial, Industrial and Agricultural Activities

There is no specifically zoned commercial land in Culcairn (Figure 2), rather the main developed area is zoned RU5 Rural Village. This allows for a range of land uses, services and facilities that are associated with a rural village and includes some small commercial properties. The majority of non-residential properties are situated on Balfour Street, which is also where the most non-residential lot flood affectation occurs. Commercial damages would also be sustained in agricultural areas zoned as RU1 Primary Production. These areas are predominantly used for grazing and cropping.

Non-residential properties are affected either directly by flood damage or indirectly by loss of business due to restricted customer and/or employee access. Costs vary significantly dependent on the type of activity;

- Type of business – stock based or not, costs of damages to goods;
- Duration of flooding – affects how long a business may be closed for, not just whether the business itself if closed, but when access to it is restored;
- Ability to move stock or assets before onset of flooding - some large machinery will not be able to be moved and in other instances there may be no sufficient warning time to move stock to dry locations; and
- Ability to transfer business to a temporary location.

The magnitude of flood damages to agricultural activities can be largely dependent on the depth and duration of flooding. Longer duration flooding can damage crops and ground leading to loss of harvest or suitable grazing lands. Although grazing animals such as sheep and cattle may be able to be moved this would often be to less suitable grazing land.

An explanation of the methods used to assess commercial damages is provided in Appendix F.

4.5.2.1. Number of Inundated Non-Residential Properties

The floor level survey and design results (Reference 2) were used to identify over floor flood liability and first event to cause the same for non-residential properties in Culcairn. Figure 13 shows the design event during which non-residential properties are first inundated above floor level while Table 11 below details the total number of non-residential properties flooded in each design event for flooding from Billabong Creek and local overland flow.

Table 11: Number of Flood Prone Non-Residential Properties

Event	No. Properties Affected	No. Flooded Above Floor Level
5-year ARI	3	1
10% AEP	2	1
5% AEP	3	1
2% AEP	11	5
1% AEP	17	11
0.5% AEP	30	24
PMF	67	67

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

Approximately one third of non-residential properties in Culcairn (approximately 67 in total) are flooded over floor in the 0.5% AEP flood and 11 are flooded over floor in the 1% AEP event. The majority of these properties are situated on Balfour Street.

4.5.2.2. Non-Residential Flood Damages Assessment

A flood damages assessment was undertaken for 67 PMF flood liable non-residential properties to calculate flood damages for a range of design events. A summary of the assessment is provided in the following sections with full details included in Appendix F.

Table 12 shows the potential damages for a range of design events and the Annual Average Damage (AAD) when Culcairn is affected by flooding from both Billabong Creek and local overland flow.

Table 12: Total Potential Non-Residential Damages for Culcairn

Event	No. Flooded Above Floor Level	Total Damages for Event	Event Contribution to AAD (%)
5-year ARI	1	$ 124,000	18
10% AEP	1	$ 121,000	12
5% AEP	1	$ 135,000	6
2% AEP	5	$ 542,000	10
1% AEP	11	$ 992,000	7
0.5% AEP	24	$ 2,757,000	9
PMF	67	$ 13,538,000	39
Average Annual Damages (AAD)		**$ 105,000**	

Table 13 and Table 14 provide the individual potential flood damages for Billabong Creek and local overland flows respectively. These form the base cases against which damages from a number of mitigation measures can be assessed. Investigation into variation of damage values and B/C ratios for various flood mitigation management options are presented in Section 5.3 for preferred management options.

Table 13: Potential Non-Residential Damages for Culcairn - Billabong Creek Flooding

Event	No. Flooded Above Floor Level	Total Damages for Event	Event Contribution to AAD (%)
5-year ARI	1	$ 114,000	18
10% AEP	1	$ 114,000	12
5% AEP	1	$ 122,000	6
2% AEP	1	$ 122,000	4
1% AEP	9	$ 937,000	6
0.5% AEP	23	$ 2,730,000	10
PMF	67	$ 13,538,000	44
Average Annual Damages (AAD)		**$ 93,000**	

Table 14: Potential Non-Residential Damages for Culcairn – Overland Flow Flooding

Event	No. Flooded Above Floor Level	Total Damages for Event	Event Contribution to AAD (%)
5-year ARI	0	$ 9,000	5
10% AEP	0	$ 7,000	3
5% AEP	0	$ 14,000	2
2% AEP	4	$ 420,000	21
1% AEP	7	$ 489,000	15
0.5% AEP	7	$ 682,000	10
PMF	40	$ 4,913,000	46
Average Annual Damages (AAD)		**$ 31,000**	

4.5.3. Public Infrastructure and Other Land Uses

Public sector (non-building) damages include; recreational/tourist facilities; water and sewerage supply; gas supply; telephone supply; electricity supply including transmission poles/lines, sub-stations and underground cables; rail; roads and bridges including traffic lights/signs; and costs to employ emergency services and assist in cleaning up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

Costs to Councils from flooding typically comprise;

- Clean-up costs;
- Erosion and siltation;
- Drain cleanout and maintenance;
- Removing fallen trees;
- Inundation of Council buildings;
- Direct damage to roads, bridges and culverts;

- Removing vehicles washed away;
- Assistance to ratepayers;
- Increases in insurance premiums;
- Closures of streets;
- Loss of working life of road pavements; and
- Operational costs in the lead up to and during flood events.

4.5.3.1. Electricity

An Essential Energy substation is located at the corner of Melville Street (Olympic Highway) and Baird Street. Liaison with Essential Energy revealed that it was not affected in the October 2010 event, which is in agreement with the Reference 2 modelling as it is not inundated in design events up to and including the 1% AEP event. However, the substation would be inundated by about 0.25 m in the 0.5% AEP event, and by about 1.4 m in the PMF. In these larger events, flows pond behind the railway to inundate the site where the substation is located.

4.5.3.2. Culcairn High Pressure Gas Pumping Station

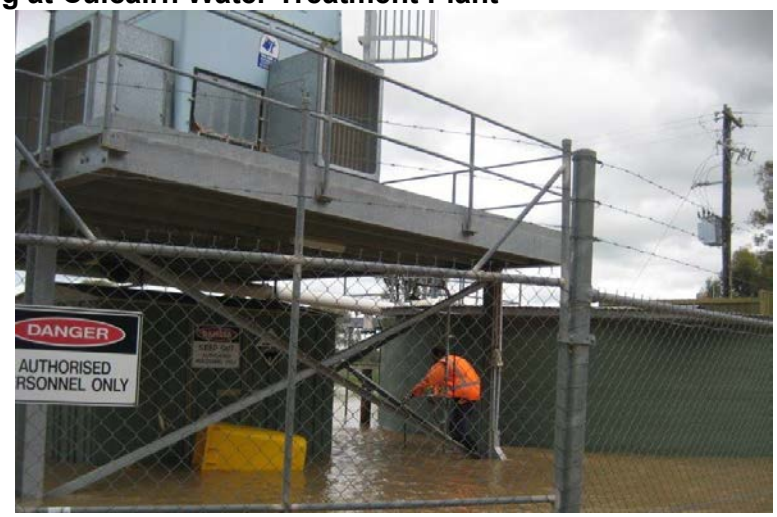
Culcairn High Pressure Gas Pumping Station operated by APA Group is located at 202 Walbundrie Road. Photography indicates that the site was inundated in the October 2010 event (Reference 3) but well below a level that would affect the operation of the station (APA Group, pers. comm.). Design flood modelling indicates the site is not expected to be flooded in events up to and including the 2% AEP flood, but would be flooded to a depth of about 0.4m in the 1% AEP event, by about 0.5 m in the 0.5% AEP, and by about 1.4 m in the PMF.

4.5.3.3. Water

Culcairn is serviced by borewater, with a borehead located about 280 metres north of the intersection of Waterworks Road and Taylors Road, south of Billabong Creek. The water treatment plant is located along Waterworks Road about 410 metres north of that location. In the October 2010 flood, the borewater was contaminated when floodwater entered the borehead. The water treatment plant was also flooded (Image 1), to a depth of about 0.4 m in the 'dosing' pump room and 0.1 m in the electrical switchboard room. An alternative water source was provided by Riverina Water, which has a pipe through Culcairn, until normal borewater service was restored after about a week. In the March 2012 flood, the 'dosing' pump room was again flooded but the electrical switchboard room was not, and the borehead was not reached. In response to the flooding, the borehead was raised about 1.2 m above the ground and sealed. Temporary flood protection devices such as flood gates could be used to prevent inundation of the electrical switchboard room in future floods.

Design flood modelling indicates that the treatment plant could be flooded even in the 5 year ARI event. Like the electricity substation, the site is located immediately upstream of the railway embankment where floodwater could accumulate to damaging depths (1.7 m in the PMF).

Image 1: Flooding at Culcairn Water Treatment Plant



Source: Council

4.5.3.4. Sewerage

Culcairn's sewage treatment plant is located on the north-eastern side of the town next to the cemetery. It was not directly affected in the October 2010 overland flow event and is modelled as directly affected only in events rarer than the 0.5 % AEP flood.

During the October 2010 flood, the sewerage system was overwhelmed when stormwater entered the system, with the result that people were unable to flush toilets and some houses were affected by sewage backflow.

4.5.3.5. Schools

Culcairn has three schools, namely:

- Culcairn Public School - 43 Balfour Street;
- St Josephs Primary School - 8 Blair Street; and
- Billabong High School - 36 Gordon Street.

There is also an Early Childhood Centre at 1 Federal Street. The degree of flood affectation for each school is summarised in Table 15. This shows that even up to the 0.5% AEP event, the schools are only marginally flooded above floor if at all. But in the October 2010 event, access to the schools was compromised by flooding of Balfour, Gordon and Federal Streets.

Table 15: School Flood Affectation

Event	Early Childhood Centre	Culcairn Public School	St Josephs Primary School	Billabong High School
5y ARI	Below floor	Below floor	Below floor	Below floor
10% AEP	Below floor	Below floor	Below floor	Below floor
5% AEP	Below floor	Below floor	Below floor	Below floor
2% AEP	Below floor	Below floor	Below floor	0.0 m over floor
1% AEP	Below floor	Below floor	Below floor	0.0 m over floor
0.5% AEP	0.1 m over floor	0.1 m over floor	Below floor	0.1 m over floor
PMF	1.6 m over floor	1.6 m over floor	0.9 m over floor	1.6 m over floor

Inundation at the schools would have different impacts depending on the time of day. The most serious scenario is probably if a heavy local storm occurs as the school day is ending, and parents and children should be educated about the danger of entering floodwaters. It is important that the schools have effective emergency plans that consider flooding.

4.5.3.6. Medical Services

Culcairn Multi-Purpose Health Service is located at 57 Balfour Street with a 27 bed hospital providing emergency, aged and community nursing services. It was not flooded over floor in October 2010 but did come within about 0.15 m height of entering the main entrance, and was also under the Community Health building towards the back of the site. Design modelling indicates it is not expected to be flooded above floor in events up to and including the 0.5% AEP event but would be flooded to a depth of about 1.3 m in the PMF.

A doctor's surgery at 81 Balfour Street was flooded over floor in the October 2010 event and is modelled to be flooded over floor in events rarer than the 2% AEP flood.

4.5.3.7. Operations Centre

Culcairn SES Local Headquarters is based in Gamble Street. There was some floodwater in the yard in the October 2010 event. Design modelling indicates it is not expected to be flooded above floor in events up to and including the 2% AEP event but would be flooded to a depth of less than 0.1 m in the 1% AEP event, to about 0.15 m in the 0.5% AEP event and to 1.6 m in the PMF.

A secondary Emergency Operations Centre is located at the Council Chambers at 40 Balfour Street. Located west of the railway, it enjoys a lower flood affectation. Of the modelled design events, it would only be flooded over floor (to a depth of 1.6m) in the PMF.

4.5.3.8. Evacuation Centre

Culcairn Recreation Ground in Federal Street was used as an evacuation centre in the October 2010 event and although not flooded over floor was found to be unsuitable because the access was constrained by flooded roads.

The Greater Hume Local Flood Plan (Volume 1, Section 3.18.42) lists the Culcairn Memorial Hall in Balfour Street as a suitable evacuation centre. This is also located west of the railway and so enjoys a lower flood affectation. Of the modelled design events, it is only expected to be flooded above floor (to a depth of about 0.5 m) in the PMF. The floor level is about 0.7 m higher than the 0.5% AEP flood peak, suggesting it is a suitable centre for almost all floods.

4.5.3.9. Railway

The Main Southern Railway between Sydney and Melbourne passes through Culcairn. Of the design events, it is modelled to be overtopped only in the PMF. However, in the October 2010 flood (approximate 70 year ARI event), services were disrupted by inundation of the railway north of Culcairn and by loss of ballast.

4.6. Road Inundation and Access

Understanding flood access issues is critical to effective evacuation and flood response planning.

During the October 2010 flood, Culcairn was cut off from the north and south by flooding of the Olympic Highway, from the east by flooding of Culcairn-Holbrook Road and from the west by flooding of Walbundrie Road. Olympic Highway was also flooded within the town (Reference 3).

The Flood Study (Reference 2) modelled peak flows, flood levels and velocities within the Culcairn area. A selection of flood depths at road low-points is presented in Table 16.

The Olympic Highway within the town would be cut in the 1% AEP event. (It might be cut further north in more frequent events). It appears to be trafficable within the modelled area south of the town for all design events except the PMF. (But it might be cut further south, as in October 2010). Walbundrie Road is cut within the modelled area in the 1% AEP event. Balfour Street just east of Melville Street is seriously affected in the 2% AEP event, when the anabranch taking flow from Billabong Creek near 'Round Hill' through the golf course is active. Railway Parade is affected by flows coming through a railway culvert, isolating about 12 houses to the north of the low-point from the 1% AEP event. Henty Street East, Federal Street and Blair Street are affected by overland flows ponding even in frequent events, especially the latter.

Table 16: Flood Depths at Road Low-Points

Location	Easting	Northing	5y ARI	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
Cnr Melville St/ Victoria St	503538	6053143	n/a	n/a	n/a	n/a	0.20	0.48	1.85
Walbundrie Rd	501559	6052539	n/a	n/a	n/a	n/a	0.42	0.56	1.48
Balfour St westbound	503536	6052928	0.09	0.10	0.15	0.41	0.54	0.70	2.08
Railway Pde	503547	6053851	n/a	n/a	0.00	0.04	0.14	0.33	1.35
Henty St East	503689	6053103	0.08	0.09	0.11	0.11	0.50	0.81	2.27
Federal St	504157	6052953	0.06	0.06	0.07	0.14	0.31	0.52	2.06
Blair St	503187	6052681	0.47	0.48	0.50	0.52	0.53	0.54	1.88

Note: These depths in metres are derived by subtracting the 1m DEM grid from the flood height surface grids.

Research undertaken for the revision of *Australian Rainfall and Runoff* shows that vehicles can become unstable in shallow depths (~0.1 m) where velocities approach 3 m/s. Small cars can float in still water depths of only 0.3 m (Reference 9).

Information about the depths and velocities of road inundation and likely timing of road closures can aid flood response planning, and ensure that evacuation occurs in a timely fashion before conditions deteriorate and hinder the evacuation process, requiring rescue boats and helicopters.

Council manages all roads within the Shire other than the Hume Highway and Olympic Way, which are managed by RMS. Both Council and the RMS have primary responsibility for closing and reopening flooded roads, though the NSW Police Force also has this authority. NSW SES may assist these organisations where resources allow.

4.7. Evacuation Constraints

In order to assist in the planning and implementation of response strategies, the NSW SES in conjunction with OEH has developed guidelines to classify communities according to the ease of evacuation (Reference 14). These flood Emergency Response Planning (ERP) classifications are mapped for various design floods by considering the inundation of land, roads and overland evacuation routes. Based on the guidelines, communities are classified as either: Flood Islands; Rising Road Access; Overland Escape Route; Trapped Perimeter or Indirectly Affected areas. The classification relates directly to the operational questions of evacuation, rescue and resupply (Table 17).

Table 17: Emergency Response Planning Classification of Communities

	EMERGENCY RESPONSE		
Classification	**Resupply**	**Rescue/Medivac**	**Evacuation**
High flood island	Yes	Possibly	Possibly
Low flood island	No	Yes	Yes
Area with rising road access	No	Possibly	Yes
Area with overland escape routes	No	Possibly	Yes
Low trapped perimeter	No	Yes	Yes
High trapped perimeter	Yes	Possibly	Possibly
Indirectly affected areas	Possibly	Possibly	Possibly

Provisional ERP classification was undertaken for the 5% AEP, 1% AEP and PMF events with the classified regions presented in the Flood Study (Reference 2). These are reconsidered here. In the 5% AEP flood, north of Billabong Creek there is generally Rising Road Access to land that is not flooded. South of Billabong Creek, a few properties are isolated as High Flood Islands in this event when Waterworks Road is flooded.

In the 2% AEP flood, activation of the northern anabranch which spills into Balfour Street creates a High Flood Island south of Balfour Street, east of Melville Street, west of Federal Street. The anabranch would also isolate several homesteads located east of Culcairn as High Flood Islands. Overland flows could cut the Olympic Highway north of the town, but the Olympic Highway southbound is not modelled to be cut.

In the 1% AEP flood, several properties north of the creek and south of Balfour Street are inundated (especially around Fahey Crescent), and, having first lost their access by flooding of Balfour Street, are therefore categorised as Low Flood Islands. (Relatively few of these houses would be flooded over floor, so if floor levels are taken into consideration, most houses effectively become High Flood Islands surrounded by water). In the 1% AEP event, the north-eastern part of town is either High or Low Flood Island. North of the creek but west of the railway, the flooding is reduced by the railway, and the Olympic Highway southbound is not modelled to be cut, which suggests that there may be Rising Road Access to the south, depending on local creek flooding en route to Albury. However, flooding of Railway Parade isolates about 12 houses to the north. Some properties south of the creek and east of the railway would be flooded, having previously lost their access (i.e. Low Flood Island).

In the 0.5% AEP event, much of the area north of Billabong Creek and east of the railway would be flooded (Low Flood Island), with some patches of High Flood Island especially between Wattle and King Streets. The area north of the creek but west of the railway is still only modestly affected but modelling shows that the Olympic Highway southbound might just be inundated.

In the PMF, the entire town would be flooded (Low Flood Island). There is high land along Culcairn-Holbrook Road about 2.5km ENE of the railway station, with several homesteads, which could possibly provide shelter above such an extreme, rare flood.

4.8. Legislative and Planning Management

4.8.1. State Legislative and Planning Context

It is important to understand the state legislation that overarches all local legislation to enable appropriate floodplain risk management measures to be proposed that are in keeping with both state and local statutory requirements. This section discusses the state legislation that influences planning in relation to flood risk at the local government level.

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling 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. Specifically, Direction 4.3 states:

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.

4.8.1.1. NSW Flood Prone Land Policy

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

- to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and
- 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.

The Manual outlines a merits approach based on floodplain management. 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.

The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both, it recognises that a different emphasis is required to address issues particular to a rural floodplain. These issues include:

- The large area of land under investigation;
- The complexity of flood behaviour;
- The impacts of protection works for valuable crops on flood behaviour;
- The period of inundation;
- The uncertainties associated with flood related data, and
- The environmental values associated with flood dependent ecosystems on a rural floodplain.

4.8.1.2. Section 149 Planning Certificates

Section 149 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.

The Environmental Planning and Assessment Regulation 2000 prescribes the matters which must be included in a s.149 Planning Certificate, including whether a parcel of land is subject to controls relating to flooding.

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

The aims of State Environmental Planning Policy (Exempt and Complying Development) 2008 are:

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.

4.8.1.4. General Housing Code

Part 3 of the SEPP relates to the *"General Housing Code"*.

Division 1 of Part 3 of the SEPP, which comprises clauses 3.1-3.6 of the SEPP, relates to:

Development that is complying development under this code

Clause 3.1 states:

3.1 Land to which code applies

This code applies to development that is specified in clauses 3.2-3.5 on any lot in Zone R1, R2, R3, R4 or RU5 that:

(a) has an area of at least 200 m^2, and

(b) has a width, measured at the building line fronting a primary road, of at least 6m.

Clause 3.2 of the SEPP states:

3.2 New single storey and two storey dwelling houses

The erection of a new single storey or two storey dwelling house is development specified for this code.

Clauses 3.3-3.5 generally relate to single and two storey dwelling houses and ancillary development.

Division 2 of Part 3 of the SEPP contains:

> ***Development standards for this code***

Subdivision 9 contains:

> ***Development standards for particular land***

Subdivision 9 contains Clause 3.36C of the SEPP which relates to development standards for the General Housing Code on *"flood control lots"*. A *"flood control lot"* is defined in the SEPP as:

> ***flood control lot*** *means a lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing).*
>
> ***Note.*** *This information is a prescribed matter for the purpose of a certificate under section 149 (2) of the Act.*

As such, a *"flood control lot"* is a lot where the Council has provided for flood related development controls, which are all lots with notation on a s.149 Planning Certificate that flood related development controls apply. This is generally land which falls within the *"Flood Planning Area"*.

Clause 3.36C states:

> ***3.36C Development standards for flood control lots***
>
> *(1) This clause applies:*
>
> *(a) to all development specified for this code that is to be carried out on a flood control lot, and*
>
> *(b) in addition to all other development standards specified for this code.*
>
> *(2) The development must not be on any part of a flood control lot unless that part of the lot has been certified, for the purposes of the issue of the relevant complying development certificate, by the council or a professional engineer who specialises in hydraulic engineering 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.

(3) The development must, to the extent it is within a flood planning area:

(a) have all habitable rooms no lower than the floor levels set by the council for that lot, and

(b) have the part of the development at or below the flood planning level constructed of flood compatible material, and

(c) be able to withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), and

(d) not increase flood affectation elsewhere in the floodplain, and

(e) have reliable access for pedestrians and vehicles from the development, at a minimum level equal to the lowest habitable floor level of the development, to a safe refuge, and

(f) have open car parking spaces or carports that are no lower than the 20-year flood level, and

(g) have driveways between car parking spaces and the connecting public roadway that will not be inundated by a depth of water greater than 0.3m during a 1:100 ARI (average recurrent interval) flood event.

(4) A standard specified in subclause (3) (c) or (d) is satisfied if a joint report by a professional engineer who specialises in hydraulic engineering and a professional engineer who specialises in civil engineering confirms that the development:

(a) can withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), or

(b) will not increase flood affectation elsewhere in the floodplain.

(5) If a word or expression used in this clause is defined in the Floodplain Development Manual, the word or expression has the same meaning as it has in that Manual unless it is otherwise defined in this clause.

(6) In this clause:

***flood compatible material** means building materials and surface finishes capable of withstanding prolonged immersion in water.*

***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.*

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

4.8.1.5. Rural Housing Code

Part 3A of the SEPP contains the *"Rural Housing Code"*.

Division 1 of Part 3A of the SEPP defines:

Development that is complying development under this code

Clauses 3A.1 and 3A.2 state:

3A.1 Land to which code applies

This code applies to development that is specified in clauses 3A.2-3A.5 on lots in Zones RU1, RU2, RU3, RU4, RU6 and R5.

3A.2 New single storey and two storey dwelling houses

(1) The erection of a new single storey or two storey dwelling house is development specified for this code if the development is erected on a lot:

(a) in Zone RU1, RU2, RU4 or RU6 that has an area of at least 4,000m^2, or

(b) in Zone R5.

(2) This clause does not apply if the size of the lot is less than the minimum lot size for the erection of a dwelling house under the environmental planning instrument applying to the lot.

Clause 3A.38 contains:

Development standards for flood control lots

The development standards contained in clause 3A.38 are the same as those contained in clause 3.36 as detailed above.

4.8.1.6. Summary of State Legislative and Planning Polices

From the above discussion of both the General Housing Code and the Rural Housing Code, it is clear that, unless a lot affected by flooding is included as a *"flood control lot"*, a s.149 notification is not required and, as a result, planning controls relating to flooding do not apply and a Complying Certificate can be granted without having regard to any Council flood controls. This scenario has considerable implications with regard to Council deciding whether a lot which is flood affected is included in the Floor Planning Area.

4.8.2. Local Council Policy

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding. Plans and Polices have been discussed below and have been reviewed in regards to flood risk management to identify where improvements might be made (see Section 0).

A LEP guides land use and development by zoning all land, identifying appropriate land uses that are allowed in each zone, and controlling development through other planning standards and Development Planning Controls (DCPs). LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to. Greater Hume Shire Council's LEP was adopted in 2012 and was prepared under the Standard Instrument LEP program.

4.8.2.1. Greater Hume Local Environment Plan 2012 (LEP 2012)

Clause 6.1A of LEP 2012 relates to flood planning and states:

> ***6.1A 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 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) will not 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 Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 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.

4.8.2.2. Greater Hume Development Control Plan 2013

Chapter 8 of the Greater Hume DCP 2013 deals with flood liable land.

Chapter 8 contains a number of objectives for development, some of which relate to outdated definitions or documents which has been repealed, for example, objective (l) is:

(l) deal consistently with applications for development on flood affected land, generally in accordance with the Floodplain Management Manual: The Management of Flood Liable Land issued by the New South Wales Government 2005;

A number of recommended amendments to Chapter 8 of the DCP, including use of the 1% AEP design flood level plus freeboard are given in Section 5.6 and a draft policy is presented in Appendix G.

5. FLOODPLAIN RISK MANAGEMENT MEASURES

5.1. Identifying Floodplain Risk Management Measures

This FRMS aims to identify and assess risk management measures which could be put in place to mitigate flooding risk and reduce flood damages. This section sets out a number of measures which could be of benefit to Culcairn. As well as the hydraulic impacts, flood risk management measures are assessed against the legal, structural, environmental, social and economic conditions or constraints of the local area. In the following sections a range of management options have been considered to effectively manage existing and future flood risks at Culcairn.

5.2. Risk Management Measures Categories

The 2005 NSW Government's Floodplain Development Manual (Reference 1) separates risk management measures into three broad categories.

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 also be considered where practical.

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

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.

Table 18 provides a summary of typical floodplain risk management measures that have been assessed for the current study. It should be noted that many of these management measures are not appropriate for Culcairn and have not been recommended.

Table 18: Flood Risk Management Measures

Flood Modification	Property Modification	Response Modification
Levees and embankments (Lv)	Land zoning	Community awareness
Temporary defences (TD)	Voluntary purchase	Flood warning
Channel Construction (CC)	Building & development controls	Evacuation planning
Channel Modification (CM)	Flood proofing	Evacuation access
Major Structure Modification (MSM)	House raising	Flood plan / recovery plan
Drainage Network Modification (DNM)	Flood access	
Drainage Maintenance (DM)		
Retarding Basins (RB)		

5.3. Flood Modification Measures

The purpose of flood modification measures is to modify the behaviour of the flood itself by reducing flood levels or velocities by excluding water from areas under threat. These measures usually involve structural works, most often permanent but temporary structures can be deployed where sufficient flood warning is available. This section considers management measures which modify flood behaviour on a wider scale. Flood modification measures at the individual property scale are discussed in Section 5.4.4.

It is important to note that many of the mitigation options that have been tested are composed of different flood modification measure types (see Table 18). An attempt has been made to describe each mitigation option in their relevant section (i.e. embankments in the embankment section, drainage in the drainage section etc.) and then where a number of combined mitigation types are used the combined Options are presented in Section 5.3.8.

Table 19 lists the trialled modification options and Figure H 1 (Appendix H) displays spatial locations of the trialled options.

Table 19: Flood Modification Measures Tested

Option	Description	Type*	Report Section
L1	An embankment that is incorporated with the Option A1 (see Section 5.3.4.1) drainage channel to redirect floodwaters away from Billabong High School	(Lv)	5.3.1.1
L2	Dual embankments used in an attempt to stop flood water from the Northern Flow Path (see Section 3.2) travelling south towards Hopetoun Street.	(Lv)	5.3.1.2
L3	Embankment at the corner of Balfour and Federal Streets to stop Southern Flow Path (see Section 3.2) flows travelling east along Balfour Street.	(Lv)	5.3.1.3
S1	Increased channel conveyance on the channel north of Hopetoun Street on the Northern Flow Path (see Section 3.2).	(CM)	5.3.3.2
S2	Blockage of the Billabong Creek anabranch in two locations to stop Creek breakouts and flow through town.	(CM)	5.3.3.3
S3	Clearing of the Billabong Creek channel by modelling decreased roughness.	(CM)	5.3.3.4

Option	Description	Type*	Report Section
S4	Connecting the anabranch near the corner of the Olympic Highway and Melrose Street.	(CM)	5.3.2
S5	Routing flow from the lowered Munro Street Option to a downstream retarding basin on the Central Flow Path (see Section 3.2).	(CM)	5.3.3.6
A1	Lowering Munro Street near Billabong High School to reduce upstream backwatering due to Central Flow Path flows (see Section 3.2).	(MSM)	5.3.4
A2	Lowering Munro Street south of Baird Street to reduce upstream backwatering due to Central Flow Path flows (see Section 3.2).	(MSM)	5.3.4.2
A3	Lowering the Stock Route near the Balfour Street intersection to reduce upstream backwatering.	(MSM)	5.3.4.3
A4	Lowering the Olympic Highway near Prince Street to reduce upstream backwatering due to Central Flow Path flows (see Section 3.2).	(MSM)	5.3.4.4
A5	Lowering the Olympic Highway at Henty Street to reduce upstream backwatering due to Southern Flow Path flows (see Section 3.2).	(MSM)	5.3.4.5
A6	Removing the historic railway on the Billabong Creek southern floodplain.	(MSM)	5.3.4.6
A7	Construction of a non-return valve on the Gordon Street drain.	(DNM)	5.3.5.1
A8	Construction of a non-return valve on the Gamble Street drain.	(DNM)	5.3.5.2
A9	Increasing existing culvert capacity at Hopetoun Street.	(DNM)	5.3.5.3
A10	Increasing existing culvert capacity at Melrose Street.	(DNM)	5.3.5.4
B1	Construction of a retarding basin on the Central Flow Path (see Section 3.2) Upstream of Federal Street.	(RB)	5.3.7.1
B2	Construction of a retarding basin on the Northern Flow Path (see Section 3.2) Upstream of Federal Street.	(RB)	5.3.7.2
B3	Construction of a retarding basin on the Central Flow Path (see Section 3.2) Upstream of Gordon Street.	(RB)	5.3.7.3
B4	Construction of a retarding basin on the corner of Federal and King Streets.	(RB)	5.3.7.4
Combined S2 / A7 / A8	Combined Option to remove Billabong Creek flood affectation within Culcairn for events up to and including the 1% AEP flood.	(CM) (DNM)	5.3.3.3 5.3.5.1 5.3.5.2
Combined L3 / A5 / B4	Combined Option to reduce flood affectation associated with the Southern Flow Path (Section 3.2).	(Lv) (DNM) (RB)	5.3.1.3 5.3.4.5 5.3.7.4
Combined L1 / S5 / A1 / B1 / B3	Combined Option to reduce flood affectation associated with the Central Flow Path (Section 3.2).	(Lv) (CM) (DNM) (RB)	5.3.1.1 5.3.3.6 5.3.4 5.3.7.1 5.3.7.3

* See Table 18 for Type classification description

Flood impact maps have been produced to display the effect that the various mitigation structures have on flood behaviour. These maps display the difference in peak flood level between the 1% AEP design event and the same event with the mitigation structure implemented. Impact maps have only been presented where significant impacts have been produced.

Mitigation options that were determined to provide significant benefits in terms of reduction in private property inundation have had damages assessments undertaken such that a Cost/Benefit ratio could be determined.

5.3.1. Levees and Embankments

DESCRIPTION

Levees involve the construction of raised embankments between the watercourse and flood affected areas so as to prevent the ingress of floodwater up to a design height. Levees usually take the form of earth embankments but can also be constructed of concrete walls or similar where there is limited space or other constraints. They are more commonly used on large river systems, for example on the Murrumbidgee River at Wagga Wagga or the Murray River at Albury, but can also be found on small creeks in urban areas and in overland flow situations where they usually take the form of smaller embankments. Local overland flows in Culcairn are relatively small and produce shallow flood depths that do not scale significantly (typically the local overland flow PMF levels are 0.3 – 0.5 m higher than the 1% AEP event levels). Accordingly, embankments rather than large levees are more suitable for flood mitigation.

Flood gates, flap valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee.

Localised levees or bunding can be applied around individual properties. Such measures are considered minor property adjustments and are discussed in Section 5.4.4.

DISCUSSION

Once constructed, embankments systems generally have a low maintenance cost although the embankment system needs to be inspected on a regular basis for erosion or failure. Although an embankment can keep out flood waters, flooding can occur within the embankment due to local runoff being unable to drain. In addition, as the embankment causes a displacement of water from one area of the floodplain to another they should be carefully designed using hydraulic modelling techniques so as to ensure the embankment does not increase flood risk to an adjacent area.

The design height of the embankment is the event for which it prevents flooding and usually also includes a freeboard to allow for settlement of the structure overtime or variations in flood levels due to the behaviour of the flood event, wave action from passing vehicles or watercraft and effects of wind.

Various embankment alignments have been considered for Culcairn, generally in conjunction with other mitigation structure types, to mitigate flooding from over land flows. These include:

1. Option L1 – drainage embankment on Munro Street near Billabong High School (see Section 5.3.1.1);
2. Option L2 – dual embankments north of Hopetoun Street (see Section 5.3.1.2); and
3. Option L3 – embankment near the corner of Balfour and Federal Streets (see Section 5.3.1.3).

Further details of these structures are presented in the following sections and their locations displayed in Figure H 1.

5.3.1.1. Option L1 – Munro Street Drainage Embankment

The Option L1 embankment is approximately 100 m long and 0.4 m high (on average, max 0.6 m) and situated on the western side of Munro Street near Billabong High School. The embankment was created to be used in conjunction with the Option S5 (see Section 5.3.3.6) drainage channel to ensure that flood levels do not increase at Billabong High School (see Section 4.5.3.5) with the implementation of the combined Option L1 / S5 / A1 / B1 / B3 (see Section 5.3.8.3).

The Option L1 embankment is not recommended for use in isolation.

5.3.1.2. Option L2 – Dual Embankments North of Hopetoun Street

The Option L2 embankments are situated north of Gordon Street, with a 115 m long and 0.7 m high (on average, max 1.0 m) embankment between the Olympic Highway and Gordon Street and an 85 m long and 0.5 m high (on average, max 0.6 m) embankment across Gordon Street. Both embankments have assumed 0.3 m freeboard (see Appendix I).

The Option L2 embankments were designed to stop flows from the Northern Flow Path (see Section 3.2) entering residential properties to the south. The embankments were designed to be used in conjunction with Option S1 (see Section 5.3.3.2) in the combined Option L2 / S1 (see Section 5.3.8.4).

5.3.1.3. Option L3 – Embankments at the Corner of Balfour and Federal Streets

The Option L3 embankment is the continuation of an existing embankment behind the Culcairn War Memorial Swimming Pool. Preliminary concept design of the embankment indicates that it is required to extend to Balfour Street which will for part of the embankment and then east back towards the anabranch. The embankment is required to be approximately 80 m in length and on average 0.6 m high (from the dry side, including a 0.3 m freeboard).

Option L3 is not recommended for implementation in isolation, however has been further investigated in conjunction with Option B4 (see Section 5.3.7.4) and Option A5 (see Section 5.3.4.5) in the combined Option L3 / A5 / B4 (see Section 5.3.8.2). This combined option is shown to reduce flooding at Hotspot #1 and #3 and is recommended for detailed design.

SUMMARY

Various embankments to restrict local overland flows in Culcairn have been investigated. All of the tested embankment scenarios have been used in conjunction with other mitigation measure types to effectively mitigate the full impact of flooding. All combined mitigation Options are presented in Section 5.3.8.

5.3.2. Temporary Flood Barriers

DESCRIPTION

Temporary flood barriers include demountable defences, wall systems and sandbagging which is deployed before the onset of flooding.

DISCUSSION

Demountable defences can be used to protect large areas and are often used as a means to assist in current mitigation measures rather than as sole protection measures. For example they are best used to fill in gaps in levees or raising them as the risk of levee overtopping develops. The effectiveness of these measures relies on sufficient warning time and the ability of a workforce to install. They are more likely to be used for mainstream fluvial flooding from rivers which have sufficient warning time and are not a suitable technique for overland flooding.

The use of temporary measures in protecting individual properties, such as sandbagging, is discussed in Section 5.4.3.

SUMMARY

In Culcairn, demountable defences are unlikely to be able to be used to reduce flood risk and inundation due to the lack of suitable locations for their placement and insufficient warning time.

5.3.3. Channel Modifications

DESCRIPTION

Channel modification includes a range of measures from increasing the size of a channel, straightening, concrete lining, removal of obstructing structures, dredging and vegetation clearing. In some instances ‘naturalising’ the channel upstream can reduce peak levels downstream by slowing flows and making better use of flood storage. On the other hand, straightening and channelling the flow can improve flooding by removing flood waters from an area more efficiently. However, such measures may also increase flood levels in adjacent or downstream locations.

DISCUSSION

A number of issues relating to existing flow channels have been discussed as part of the community consultation program (see Section 2). Where applicable this has been noted in the following sections. In particular, residents have raised concerns with the amount of debris in Billabong Creek and also the possibility of dredging the Creek (see Section 2). In addition to this, various other channel modifications have been considered for Culcairn to mitigate flooding from over land flows and Billabong Creek. These include:

1. Option S1 – increasing channel conveyance north of Hopetoun Street (see Section 5.3.3.2);
2. Option S2 – blocking the Billabong Creek anabranch (see Section 5.3.3.3);
3. Option S3 – reduction of roughness (vegetation management) in Billabong Creek channel (see Section 5.3.3.4); and
4. Option S4 – connecting the anabranch near the corner of the Olympic Highway and Melrose Street (see Section 5.3.2).

Further details of these Options are presented in the following sections and their locations displayed in Figure H 1.

5.3.3.1. Strategy for Vegetation Planting

The Murray region Local Land Services (LLS) are responsible for Billabong Creek at Culcairn. Council should liaise with LLS to determine to what degree Billabong Creek can be cleared of vegetation, however there is generally no problem with removal of exotic trees and vegetation such as willows. Clearing or dredging on a broad scale would also require approval of various other state government organisations such as Fisheries and Office of Water. The Roads and Maritime Service (RMS) have authority from the Environmental Protection Authority (EPA) to remove debris built up against structures.

Council should request a strategy for vegetation planting of Billabong Creek to examine ways in which the river and floodplain environment may be enhanced to create a valuable corridor of vegetation without having a detrimental effect on flooding. As noted above, clearing of vegetation can be beneficial to reduce flood levels and reduce the risk of blockage of downstream structures. A suitable strategy for vegetation planting would need to balance the need for native vegetation and a thriving riparian corridor whilst managing the build-up of or clearance of vegetation to avoid unwanted effects on flood behaviour.

Management of vegetation can reduce flood levels by increasing the flow area within the channel by reducing potential for obstruction and blockage. Vegetation thinning on a regular basis to prevent build up is recommended with some benefits to such efforts expected as displayed in Section 5.3.3.4.

5.3.3.2. Option S1 – Increased Channel Conveyance North of Hopetoun Street

Option S1 increased the conveyance of the existing drain that flows east to west in the area north of Hopetoun Street with the aim of directing flow from the Northern Flow Path (see Section 3.2) to the culverts under the Olympic Highway. The increased drainage channel was tested in conjunction with the Option L2 embankment (see Section 5.3.1.2) in the combined Option L2 / S1 (see Section 5.3.8.4).

Option S1 doubled the width of the existing drain to 15 m wide and increased the depth of the drain by approximately 0.5 m providing a significant increase in channel conveyance. The channel roughness was assumed to simulate that of well-kept grass.
Option S1 has not been tested in isolation. See Section 5.3.8.4 for the combined Option L2 / S1 results.

5.3.3.3. Option S2 – Blocking Billabong Creek anabranch

Option S2 involves the filling of the anabranch to the top of bank at two locations to stop Billabong Creek breaks outs and flow through the anabranch for events up to and including the 1% AEP event. The locations of these blockages are displayed on the Combined Option S2 / A7 / A8 impact map (Figure H 8) and explained with more detail in Appendix I. The first blockage location is approximately 3.5 km upstream of Culcairn, and is required to be 40 m in length with a maximum height of 1.4 m (average height of 1.0 m). The second location is approximately 1.1 km upstream of Culcairn and has a required length of fill of approximately 400 m and an average height of 0.2 m. This measure protects Culcairn from floodwaters entering the town via the Billabong Creek anabranch and was suggested as a part of the Community Consultation (see Section 2).

It was recognised that Option S2 would only be effective if it was implemented in conjunction with inserting non-return valves onto the Gordon and Gamble Street drains (see Options A7 and A8 in Sections 5.3.5.1 and 5.3.5.2). If only the anabranch is blocked, Culcairn would be flooded by backwater from the Gordon Street and Gamble Street drains. The combined Option S2 / A7 / A8 is examined in Section 5.3.8.1.

5.3.3.4. Option S3 – Clearing of the Billabong Creek Channel (Decrease Roughness)

To simulate vegetation management of the Billabong Creek channel, Option S3 was implemented by reducing channel roughness from a Mannings ‘n’ of 0.09 to 0.07. This change in roughness was aimed to simulate clearing of the channel from its current state to a state potentially achieved by strategies in line with those mentioned in Section 5.3.3.1. Clearing of the Billabong Creek channel was mentioned on numerous occasions as part of the Community Consultation process (see Section 2.1).

The Option S3 impact map for the 1% AEP event is presented in Figure H 2. It was found that a decrease in peak flood level of up to 0.3 m occurs within Billabong Creek in-bank. For populated regions in the township of Culcairn flood levels decreased by up to 0.35 m with some areas no longer affected by flooding. Despite these decreased flood levels, it was found that this measure was not as effective as the combined Option S2 / A7 / A8 (see Section 5.3.3.4). Additionally, creek clearing would need to be maintained year round and would prove to be expensive both financially and environmentally. Accordingly, Option S3 has not been recommended for further investigation with only the general recommendations in Section 5.3.3.1 being recommended in regards to creek clearing.

5.3.3.5. Option S4 - Connecting the Anabranch near the Olympic Highway and Melrose St

Option S4 was implemented by constructing a 1 m deep by 5 m wide channel to connect two portions of the anabranch which have been filled and allow flow to drain in a northerly direction. The Option is situated on the eastern side of the Olympic Highway near the corner of Melrose Street. This measure aimed to reduce flooding at the location described in Hotspot #3 (see Section 3.6.1).

Option S4 was tested for the 1% AEP event and was shown to be ineffective with no significant change in peak flood levels and therefore it would not reduce the flood liability of residential properties.

Due to the lack of significant impacts provided by Option S4, further investigation of this Option is not warranted.

5.3.3.6. Option S5 – Drainage Channel to Divert Flow Away from Billabong High School

Option S5 is a minor drainage channel that routes water from the lowered road at Munro Street (Section 5.3.4) into the Option B3 retarding basin (Section 5.3.7.3). The required channel dimension is 0.5 m deep by 5 m wide and works in conjunction with the Option L1 embankment (Section 5.3.1.1).

SUMMARY

Management of vegetation in Billabong Creek will have some benefits in reducing flood levels and preventing further build-up of debris and siltation of the Creek however should be considered carefully with the implications of environment effects.

Mitigation Options S1 and S2 have been further investigated as combined mitigation options in Sections 5.3.8.4 and 5.3.8.1 respectively.

RECOMMENDATIONS

The following measures are recommended:

► Management of vegetation in Billabong Creek to prevent blockage impacts on flood behaviour.

5.3.4. Major Structure Modification

DESCRIPTION

Hydraulic controls such as raised roads on overland flow paths and bridges or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. By increasing hydraulic conveyance, flood levels upstream of a structure can be decreased. Generally the most effective way of increasing hydraulic conveyance is by increasing a structures cross sectional area (normal to the flow direction). This is often done by lowering a road, lengthening a bridge or raising the deck level.

DISCUSSION

As mentioned in Section 3.2, local flow flooding in Culcairn is exacerbated by raised roads which causes flood waters to pond on their upstream side. All three local overland flow paths mentioned in Section 3.2 cross roads that significantly impact on flood behaviour. Five options that pertain to lowering various roads to reduce local overland flow flood affectation are presented in the following sections. These include:

1. Option A1 – Central Flow Path, Munro Street upgrade near Billabong High School (see Section 5.3.4.1);
2. Option A2 – Northern Flow Path, lowering Munro Street south of Baird Street (see Section 5.3.4.2);
3. Option A3 – Lowering the Stock Route near the Balfour Street Intersection (see Section 5.3.4.3);
4. Option A4 – Central Flow Path, lowering the Olympic Highway near Princes Street (see Section (see Section 5.3.4.4); and
5. Option A5 – Southern Flow Path, lowering the Olympic Highway at Victoria Street (see Section 5.3.4.5).

Additionally, the Community Consultation processes (see Section 2) requested that the impact of removing the historic railway bridge be modelled. This Option was modelled as:

6. Option A6 – Removing the historic railway on southern bank of Billabong Creek (see Section 5.3.4.6).

Further details of these Options are presented in the following sections and their locations displayed in Figure H 1.

5.3.4.1. Option A1 – Central Flow Path, Munro Street upgrade near Billabong High School

Option A1 was aimed to reduce flood affectation in the region upstream of Munro Street opposite Billabong High School. Flooding in this region is due to Central Flow Path (see Section 3.2) flows ponding upstream of Munro Street. Implementation of this Option involved lowering Munro Street over a 70 m stretch of road by approximately 0.4 m to prevent water building up against the road and flooding of upstream properties.

In the 1% AEP event, Option A1 had a considerable impact on peak flood levels upstream of Munro Street with reductions of up to 0.5 m experienced. This lead to one property previously flooding in the 5Y AEI event to be no longer flooding until the 1% AEP event. However, flood levels were significantly increased downstream of Munro Street leading to increased flood affectation and risk at Billabong High School. To counteract increases in flood levels Option A1 has been examined in the combined Option L1 / S5 / A1 / B1 / B3 (see Section 5.3.8.3). The combination of these Options aimed to decrease peak flood levels whilst not adversely affecting properties downstream.

Option A1 is not recommended for use in isolation. See Section 5.3.8.3 for the combined Options L1 / S5 / A1 / B1 / B3 results.

5.3.4.2. Option A2 – Northern Flow Path, Lowering Munro Street South of Baird Street

The northern end of Munro Street, near Baird Street currently acts as an obstruction to flows originating from the Northern Flow Path (see Section 3.2). Implementation of this Option involved lowering Munro Street over a 100 m stretch of road by a maximum of 0.6 m to prevent water building up against the road and flooding of upstream properties.

In the 1% AEP event, Option A2 had a considerable impact on peak flood levels upstream of Munro Street on the Northern Flow Path (see Figure H 3). Three properties are no longer affected by yard flooding in the 1% AEP event with other properties experiencing reduced flood levels by up to 0.4 m. However, there are no properties upstream of Munro Street that are affected by over floor flooding until events greater than the 0.5% AEP which means any reduction in peak flood level provide only minor tangible monetary benefits. In addition to this a number of downstream properties experience increased flood levels increasing flood liability, particularly at Hotspot #2 (see Section 3.6.1).

Due to downstream impacts and the estimated minor financial benefits, Option A2 is not recommended for further consideration.

5.3.4.3. Option A3 – Lowering the Stock Route near the Balfour Street Intersection

Option A3 investigated lowering the stock route near its intersection Balfour Street to allow local flows to pass and alleviate ponding on the upstream (eastern) side. This Option was suggested as part of the Community Consultation process (see Section 2).

Figure H 4 displays the impacts to peak flood levels in the 1% AEP event after the Stock Route was lowered by approximately 0.3 m. It was found that while this scenario does not have a widespread impact in terms of extent for the 1% AEP event, peak flood levels at flood prone properties upstream of Stock Route are reduced by up to 0.3 m and over floor flooding is negated for one property for events from the 5% AEP and larger.

A damages assessment was undertaken to determine the B/C ratio for implementation, see Table 20 and Table 21 below for the residential and non-residential damages.

Table 20: Combined Options A3 – Estimated Residential Damages for Culcairn

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	1	$ 96,000	0
10% AEP	1	$ 129,000	0
5% AEP	3	$ 211,000	1
2% AEP	5	$ 311,000	1
1% AEP	7	$ 563,000	1
0.5% AEP	10	$ 746,000	1
PMF	192	$ 13,906,000	2
Average Annual Damages (AAD)		**$ 86,000**	

Table 21: Combined Options A3 - Estimated Non-Residential Damages for Culcairn

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	0	$ 9,000	0
10% AEP	0	$ 7,000	0
5% AEP	0	$ 14,000	0
2% AEP	4	$ 420,000	0
1% AEP	7	$ 489,000	0
0.5% AEP	7	$ 682,000	0
PMF	40	$ 4,913,000	0
Average Annual Damages (AAD)		**$ 31,000**	

The estimated cost of implementation for the combined Options A3 is estimated to be $58,000. The combined AAD (residential and non-residential) for local overland flow flooding is $117,000 which is a $5,000 reduction in AAD with implementation of the combined Option A3. By estimating the expected damages for the next 50 years assuming implementation of the above mentioned options a B/C ratio of 1.3 has been calculated. It should be noted that the total reduction in AAD is due to reduced flood affectation of residential properties.

Implementation of the proposed mitigation Option A3 provides a B/C ratio greater than one and significantly reduces flood affectation for upstream properties up to the 1% AEP. It is therefore recommended for implementation.

Information on the preliminary costing and design of the combined Options A3 is contained in Appendix I.

5.3.4.4. Option A4 – Central Flow Path, lowering the Olympic Highway near Princes St

Option A4 simulated the lowering of the Olympic Highway near Princes Street to allow local overland flows from the Central Flow Path (see Section 3.2) to pass in the aim of reducing flood levels in the area defined as Hotspot #3 (see Section 3.6.1). The Olympic Highway was lowered by a maximum of 0.4 m over a 250 m stretch of road.

Option A4 was tested for the 1% AEP event and was found to have no impact on peak flood levels. This measure did not improve flood affectation at this location and therefore it is not recommended for further investigation.

5.3.4.5. Option A5 – Southern Flow Path, Lowering the Olympic Highway at Henty St

It was found that the Olympic Highway acts as an obstruction to local overland flows from the Southern Flow Path leading to problem flooding in the area defined at Hotspot #2 (see Section 3.6.1). Some properties in this area experience over floor flooding from this flood mechanism in events as small as the 5% AEP. Option A5 investigated the impact of lowering the Olympic Highway by a maximum of 0.4 m for approximately 120 m at the intersection of the Olympic Highway with Victoria Street.

For the 1% AEP event, Option A5 reduced peak flood levels by up to 0.2 m along Henty Street (see Figure H 5). Peak flood levels are increased downstream, however this does not affect residential properties. Implementation of the Option is therefore recommended.

To increases mitigation potential, Option A5 has been assessed in combination with Options L3 and B4 (see Sections 5.3.1.3 and 5.3.7.4 respectively) in the combined Option L3 / A5 / B4. Further details are provided in Section 5.3.8.2.

5.3.4.6. Option A6 – Removing the historic railway on southern bank of Billabong Creek

Option A6 examined removing the old railway south of Billabong Creek which currently acts as an obstruction to creek breakouts. It was recommended as part of the Community Consultation process (see Section 2) that the removal of this structure be investigated.

This measure was tested for the 1% AEP event and the flood impacts are shown on Figure H 6. Upstream of the railway, peak flood levels were reduced by up to 0.2 m with only minor reductions in Billabong Creek. Downstream of the old railway, flood levels increased by up to 0.25 m. No residential properties were affected by this measure however peak flood levels at Culcairn's bore water supply are increased by up to 0.1 m. This facility was flooded in the 2010 event and hence is already sensitive to flooding.

Option A6 has not been considered for further investigation as it increases peak flood levels on the floodplain and does not benefit any properties in the area.

SUMMARY

Major flow obstructions, such as inadequately designed roads and bridges, restrict flow conveyance capacity and cause increased peak flood levels upstream. It was noted that a number of roads that cross the three local overland flow paths mentioned in Section 3.6.1 obstructed flow and exacerbated flooding. A number of major structure modifications have been suggested, particularly in combination with other mitigation measures (see Section 5.3.8). In isolation, only Option A3 is recommended detailed design.

RECOMMENDATIONS

The following measures are recommended:

► Recommended that detailed costing and design be undertaken for **OPTION A3.**

5.3.5. Drainage Network Modifications

DESCRIPTION

Modification of the existing drainage by installation of larger or more pipes or installation of non-return valves to stop back watering of an existing drainage system can increase system capacity and reduce flood levels. Drainage network modifications can also be used to divert flows from one area to another.

DISCUSSION

Backwatering of the Gordon Street drainage system has been identified as a significant flood mechanism during the October 2010 and March 2012 flood events (Section 3.2) and was recommended for detailed examination as part of the Community Consultation process (see Section 2). Analysis of the flood study (Reference 2) results revealed that the Gamble Street drainage channel also posed similar problems. Construction of Non-return valves for both of these drains has been investigated.

Additionally, the anabranch through town has been filled in numerous locations with culverts in place to assist with flow conveyance. Increased culvert conveyance as a mitigation measures has been investigated to alleviate flow constrictions and reduce flood levels.

The following sections investigate drainage network modifications that aim to reduce flood levels and affectation.

5.3.5.1. Option A7 – Gordon Street Drain Non-Return Valve

Surcharging of the Gordon Street drain has been highlighted as one of the key flood mechanisms at Culcairn (see Section 3.2) and was responsible for over floor property flooding in the October 2010 and March 2012 flood events (References 3 and 4).

Option A7 investigated applying a non-return valve to the Gordon Street drain. This measure protects Culcairn from floodwaters entering the town via surcharging of the drain from elevated Billabong Creek flood levels and was suggested as a part of the Community Consultation (see Section 2).

It was recognised that Option A7 would only be effective if it was implemented in conjunction with inserting a non-return valve onto the Gamble Street drain (see Options A8, Section 5.3.5.2) and blocking the Billabong Creek anabranch (see Option S2, Section 5.3.3.3). The combined Option S2 / A7 / A8 is examined in Section 5.3.8.1 and is recommended for detailed design.

5.3.5.2. Option A8 – Gamble Street Drain Non-Return Valve

Surcharging of the Gamble Street drain has been identified by analysis of the flood study (Reference 2) results as responsible for flooding in Culcairn during the 1% AEP event and larger.

Option A8 investigated applying a non-return valve to the Gamble Street drain. This measure protects Culcairn from floodwaters entering the town via backwatering of the drain from elevated Billabong Creek flood levels.

It was recognised that Option A8 would only be effective if it was implemented in conjunction with inserting a non-return valve onto the Gordon Street drain (see Options A7, Section 5.3.5.1) and blocking the Billabong Creek anabranch (see Option S2, Section 5.3.3.3). The combined Option S2 / A7 / A8 is examined in Section 5.3.8.1 and is recommended for detailed design.

5.3.5.3. Option A9 – Increasing culvert capacity at Hopetoun Street

The conveyance capacity of the culvert beneath Hopetoun Street that connects the Billabong Creek anabranch is exceeded during 1% AEP event. As a result, Option A9 investigated tripling the capacity of this culvert to prevent water flowing over the road and inundating nearby properties in large events.

Option A9 had no significant impact to peak flood levels in the 1% AEP and has not been recommended for further investigation.

5.3.5.4. Option A10 - Increasing culvert capacity at Melrose Street

Similar to Option A9, the conveyance capacity of the culvert beneath Melrose Street that connects the Billabong Creek anabranch is also full in the 1% AEP event. In an attempt to reduce flooding in this area Option A10 investigated tripling the conveyance capacity of the culverts at this location.

Option A10 had no significant impact to peak flood levels in the 1% AEP and has not been recommended for further investigation.

SUMMARY

Construction of non-return valves on the Gordon and Gamble Street drains is recommended for implementation as part of the combined Option S2 / A7 / A8 (see Section 5.3.8.1). Construction of either Option in isolation is not recommended.

Increasing culvert capacity to allow more water to pass through obstructions on the anabranch near Hopetoun and Melrose Streets does not significantly reduce peak flood levels. Accordingly, these options are not recommended for further investigation.

5.3.6. Drainage Maintenance

DESCRIPTION

Maintenance of the drainage network is important to ensure that it is operating with maximum efficiency and to reduce risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network. Vegetation maintenance within the Billabong Creek channel is discussed in Section 5.3.3.4.

DISCUSSION

The Community Consultation process (see Section 2.1) highlighted the community's concerns about Creek and channel maintenance. The introduction of maintenance protocols or policies would ensure that drainage assets are effectively managed and regularly maintained such that they will perform as required particularly on those rare occasions when they are needed.

SUMMARY

Regular maintenance can reduce risk of blockage of structures during flood events and ensure that flood waters are drained efficiently. It would be beneficial for Council to maintain a record of drainage infrastructure within the LGA and of the authority, organisation or body responsible for its maintenance.

RECOMMENDATIONS

The following measures are recommended:

► Identify policies for general maintenance of drains and channels and determination of protocols for ownership maintenance and development / upgrade of infrastructure.

► Develop a database of all drainage infrastructure and its owner and authority, organisation or body responsible for its maintenance.

5.3.7. Retarding Basins

DESCRIPTION

Retarding basins work by storing runoff and releasing it after the event peak. These measures are appropriate for use in controlling flooding by mitigating the effects of increased runoff caused by development and can be either installed as part of a new development to prevent increases in runoff rates, or retrofitted into existing catchment drainage systems to alleviate existing flood problems.

DISCUSSION

These systems are easy to implement when new development is proposed, as Council can place the responsibility on the developer to provide appropriate drainage systems. This is usually implemented through development controls requiring that runoff rates from new developments are not greater than existing rates. Often the 1% AEP event is used as the design event, but flows also need to be restricted back to the pre-development rates for smaller events. Hydraulic structures can be used to restrict the discharge rates from site to a variable rate, dependent on rainfall volumes and the hydraulic head in the retarding basin.

Retarding basins can also have benefits for the community other than flood control. For example, some basins when dry are used as sports fields and recreation grounds, others can be designed to be permanently wet creating scenic wildlife areas. There are also pollution control benefits associated with retention basins allowing the settlement of particulates and sediments.

Large retarding basins can be a safety hazard. Appropriate safety controls such as fencing and signage should be included as part of the overall asset. In NSW, particularly large basins may be prescribed by the Dam Safety Committee (DSC) which means that the DSC will maintain a continuing oversight of their safety. This is applicable to basins identified as a possible threat to communities downstream in case of failure. Like the rest of the drainage system, retarding basins have maintenance requirements. Regular checks and maintenance will be required by Council or agreements put in place with the developer and land holder. This is particularly applicable to basins identified as being a threat to communities downstream in case of failure.

5.3.7.1. Option B1 – Central Flow Path, Upstream Federal Street Basin

Option B1 involved creating a basin on the Central Flow Path (see Section 3.2) in the region upstream of Federal Street to alleviate the flood problem downstream, particularly at Hotspot #3 (see Section 3.6.1). The basin was designed to have an embankment approximately 200 m in length with a maximum height of 1.0 m (average of 0.6 m, including 0.3 m freeboard). A 20 m long spillway constructed at 0.1 m below the 1% AEP level was implemented.

Option B1 was modelled for the 1% AEP event and the impacts of this measure are shown in Figure H 7. The properties between Federal and Munro Streets experience only slight reductions in peak flood levels (less than 0.05 m). Between Munro and Gordon Streets there are areas which are no longer flood affected with reductions of up to 0.2 m. Furthermore, along Melrose Street peak flood levels are reduced by up to 0.1 m.

Option B1 has been considered for further investigation in the combined Option L1 / S5 / A1 / B1 / B3 (see Section 5.3.8.3) but is not recommended for further investigation in isolation.

5.3.7.2. Option B2 - Northern Flow Path, Upstream Federal Street Basin

Option B2 investigated the construction of a basin on the Northern Flow Path (see Section 3.2) upstream of Federal Street to alleviate flooding downstream in the region north of Hopetoun Street. The basin was designed to be 170 m in length with a maximum height of 0.9 m (average of 0.6 m, including 0.3 m freeboard).

Option B2 provided no reduction to peak flood levels downstream of the basin and is therefore not recommended for further investigation.

5.3.7.3. Option B3 - Central Flow Path, Upstream Gordon Street Basin

Option B3 investigated the construction of a basin in the parkland between Gordon and Munro Streets. The basin has a length of 400 m with an average height of 0.6 m (including 0.3 m freeboard).

This basin was designed to be used in conjunction with Option A1 (see Section 5.3.4.1) to mitigate downstream impacts. Accordingly, Option B3 is not recommended for use in isolation but instead has been incorporated into the combined Option L1 / S5 / A1 / B1 / B3 (see Section 5.3.8.3).

5.3.7.4. Option B4 - Basin at the Corner of Federal and King Streets

Option B4 investigated creating a basin in the playing fields near the corner of Federal and King Street. This basin aims to alleviate the flood problem downstream, particularly at Hotspots #1 and #3 (see Section 3.6.1) by capturing flows for a small catchment (11 ha) south of the Southern Flow Path as well as overflow of the Southern Flow Path due to implementation of Option B1 (see Section 5.3.7.1). The basin was designed to have an embankment of approximately 250 m in length with a maximum height of 1.0 m (average of 0.5 m, including 0.3 m freeboard). A 20 m long spillway constructed at 0.1 m below the 1% AEP level was implemented.

Option B4 is not recommended for implementation in isolation, however has been further investigated in conjunction with Option L3 (see Section 5.3.1.3) and Option A5 (see Section 5.3.4.5) in the combined Option L3 / A5 / B4 (see Section 5.3.8.2). This combined option is shown to reduce flooding at Hotspot #1 and #3 and is recommended for detailed design.

SUMMARY

Retarding basins mitigate flow by storing water for a limited period of time. Various retarding basins to minimise local overland flow flooding in Culcairn have been investigated. Options B1, B2 and B4 have been recommended for detailed design in conjunction with other mitigation measure types to effectively mitigate the full impact of flooding. All combined mitigation Options are presented in Section 5.3.8.

5.3.8. Combined Mitigation Options

Numerous combinations of the mitigation Options presented in Sections 5.3.1 to 5.3.7 have been investigated in an attempted to modify flood behaviour and reduce flood affectation. It is important to note that many of the mitigation options that have been tested are composed of different flood modification measure types (see Table 18). For Culcairn, combined Options provide the greatest flood mitigation, with a number of the following combined Options recommended for detailed design.

5.3.8.1. Combined Option S2 / A7 / A8 - Stopping Billabong Creek Flood Affectation

Option S2 / A7 / A8 aimed to prevent Culcairn flooding from Billabong Creek for events up to and including the 1% AEP event. Option S2 / A7 / A8 is a combination of the Options S2, A7 and A8 with details of each Option provided Sections 5.3.3.3, 5.3.5.1 and 5.3.5.2 respectively.

The impacts for Option S2 / A7 / A8 in the 1% AEP event are shown in Figure H 8. Results indicated that the combination of these Options eliminates flood affectation in Culcairn from Billabong Creek flood events (see Section 3.2) up to and including the 1% AEP flood. With implementation of the combined option, only minor (<0.05 m) increases to peak flood levels are experienced in the Billabong Creek channel and no residential properties are adversely affected.

It is important to note that while the risk of flooding from Billabong Creek (see Section 3.2) for the 1% AEP event is eliminated for Culcairn, the potential for flooding from local overland flow in Culcairn has not been mitigated by these measures.

Option S2 / A7 / A8 has undergone a damages assessment to determine the B/C ratio for implementation. The estimated residential and non-residential damages are displayed in Table 22 and Table 23 below.

Table 22: Combined Options S2 / A7 / A8 – Estimated Residential Riverine Flood Damages

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	0	$ -	0
10% AEP	0	$ -	0
5% AEP	0	$ -	0
2% AEP	0	$ -	2
1% AEP	1	$ 69,000	31
0.5% AEP	57	$ 3,866,000	47
PMF	526	$ 52,240,000	0
Average Annual Damages (AAD)		**$ 150,000**	

Table 23: Combined Options S2 / A7 / A8 - Estimated Non-Residential Riverine Flood Damages

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	1	$ 114,000	0
10% AEP	1	$ 114,000	0
5% AEP	1	$ 122,000	0
2% AEP	1	$ 122,000	0
1% AEP	1	$ 122,000	8
0.5% AEP	16	$ 1,624,000	7
PMF	67	$ 13,538,000	0
Average Annual Damages (AAD)		**$ 82,000**	

The estimated cost of implementation for the combined Options S2 / A7 / A8 is estimated to be $470,000. The combined AAD (residential and non-residential) for Billabong Creek riverine flooding is $232,000 which is a $41,000 reduction in AAD with implementation of the combined Option S2 / A7 / A8. By estimating the expected damages for the next 50 years assuming implementation of the above mentioned options a B/C ratio of 1.3 has been calculated. It should be noted that 73% ($30,000) of the reduction in AAD is due to reduced flood affectation of residential properties.

Due to the significant reduction in flood affectation and the high B/C ratio achieved by this Option, further investigation for this Option is recommended.

Information on the preliminary costing and design of the combined Option S2 / A7 / A8 is contained in Appendix I.

RECOMMENDATIONS
The following measure is recommended:

► That detailed costing and design be undertaken for the combined **OPTION S2 / A7 / A8.**

5.3.8.2. Combined Option L3 / A5 / B4 – Southern Flow Path Flood Mitigation

The combined Options L3 / A5 / B4 (see Sections 5.3.1.3, 5.3.7.4 and 5.3.4.5 respectively for further details) has been investigated to mitigate flooding from the Southern Flow Path (see Section 3.2). This combined Options has been shown to minimise flood affectation and property inundation due to local overland flow flood events.

The combined Option L3 / A5 / B4 impact map for the 1% AEP event is presented in Figure H 9. Results indicated that the combination of these Options significantly reduces flood depths, extents and over floor flood liability surrounding Balfour Street and in particular at Hotspots #1 and #3 (see Section 3.6.1). Numerous houses are no longer flood affected in the 1% AEP flood along Federal Street and the northern side of Balfour Street. Decreases in flood depths of up to 0.2 m have been achieved along the particularly flood affected Henty Street (Hotspot #3) and reductions in flood level have been achieved without adversely affecting residential properties in other areas.

A damages assessment was undertaken to determine the B/C ratio for implementation of the combined Option L3 / A5 / B4. The estimated residential and non-residential damages are displayed in Table 24 and Table 25 below.

Table 24: Combined Options L3 / A5 / B4 - Estimated Residential Overland Flow Damages

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	1	$ 104,000	0
10% AEP	1	$ 139,000	0
5% AEP	2	$ 186,000	2
2% AEP	4	$ 266,000	3
1% AEP	5	$ 376,000	4
0.5% AEP	7	$ 439,000	6
PMF	196	$ 14,123,000	0
Average Annual Damages (AAD)		**$ 84,000**	

Table 25: Combined Options L3 / A5 / B4 - Estimated Non-Residential Overland Flow Damages

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	0	$ 9,000	0
10% AEP	0	$ 7,000	0
5% AEP	0	$ 13,000	0
2% AEP	3	$ 273,000	1
1% AEP	4	$ 304,000	3
0.5% AEP	5	$ 334,000	2
PMF	40	$ 4,913,000	0
Average Annual Damages (AAD)		**$ 25,000**	

The estimated cost of implementation for the combined Options L3 / A5 / B4 is estimated to be $255,000. The combined AAD (residential and non-residential) for overland flow flood events is $109,000 which is a $16,000 reduction in AAD with implementation of the combined Option L3 / A5 / B4. By estimating the expected damages for the next 50 years assuming implementation of the above mentioned options a B/C ratio of 0.9 has been calculated.

Information on the preliminary costing and design of the combined Option L3 / A5 / B4 is contained in Appendix I.

SUMMARY

Implementation of the proposed mitigation measure, combined Option L3 / A5 / B4 provides a B/C ratio close to one and significantly reduces flood affectation at Culcairn.

RECOMMENDATIONS

The following measures are recommended:

► Recommended that detailed costing and design be undertaken for the combined **OPTION L3 / A5 / B4.**

5.3.8.3. Combined Option L1 / S5 / A1 / B1 / B3 – Central Flow Path Mitigation

The combined Option L1 / S5 / A1 / B1 / B3 (see Sections 5.3.1.1, 5.3.3.6, 5.3.4, 5.3.7.1 and 5.3.7.3 respectively) has been investigated to mitigate flooding from the Central Flow Path (see Section 3.2), particularly upstream (east) of Munro Street.

Figure H 10 presents the impacts on peak flood levels for this combined option for the 1% AEP event. Properties which have been identified as vulnerable to flooding along Munro Street have reduced peak flood levels by up to 0.2 m. This leads to one residential property that was previously flooded over floor in the 5 year ARI event to be no longer flood affected up to the 1% AEP event. In addition to this a number of properties are no longer flood affected to the north and south of the Central Flow Path at Munro Street. Upstream of the basins flood levels are increased by up to 0.3 m however no residential properties are adversely affected by these measures.

A damages assessment was undertaken to determine the B/C ratio for implementation of the combined Option L1 / S5 / A1 / B1 / B3. The estimated residential and non-residential damages are displayed in Table 26 and Table 27 below.

Table 26: Combined Options L1 / S5 / A1 / B1 / B3 - Residential Overland Flow Damages

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	0	$ 35,000	1
10% AEP	0	$ 64,000	1
5% AEP	3	$ 158,000	1
2% AEP	5	$ 249,000	1
1% AEP	8	$ 492,000	0
0.5% AEP	11	$ 707,000	0
PMF	194	$ 13,958,000	0
Average Annual Damages (AAD)		**$ 65,000**	

Table 27: Combined Options L1 / S5 / A1 / B1 / B3 - Non-Residential Overland Flow Damages

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	0	$ 9,000	0
10% AEP	0	$ 7,000	0
5% AEP	0	$ 14,000	0
2% AEP	4	$ 410,000	0
1% AEP	6	$ 461,000	1
0.5% AEP	6	$ 655,000	1
PMF	40	$ 4,906,000	0
Average Annual Damages (AAD)		**$ 30,000**	

The estimated cost of implementation for the combined Option L1 / S5 / A1 / B1 / B3 is estimated to be $436,000. The combined AAD (residential and non-residential) for overland flow flood events is $95,000 which is a $27,000 reduction in AAD with implementation of the combined Option L1 / S5 / A1 / B1 / B3. By estimating the expected damages for the next 50 years assuming implementation of the above mentioned options a B/C ratio of 0.9 has been calculated. It should be noted that 98% ($26,000) of the reduction in AAD is due to reduced flood affectation of residential properties. While this measure only prevents over floor flooding for one residential property, the AAD is significantly reduced since this property is currently flooded in the 5 year ARI event.

Information on the preliminary costing and design of the combined Options L1 / S5 / A1 / B1 / B3 is contained in Appendix I.

SUMMARY

Implementation of the proposed mitigation measure, combined Option L1 / S5 / A1 / B1 / B3 provides a B/C ratio close to one and significantly reduces flood affectation at Culcairn.

RECOMMENDATIONS

The following measures are recommended:

► Recommended that detailed costing and design be undertaken for the combined **OPTION L1 / S5 / A1 / B1 / B3.**

5.3.8.4. Combined Option L2 / S1 – Re-directing the Northern Flow Path near Baird Street

The combined Option L2 / S1 (see Sections 5.3.1.2 and 5.3.3.2) investigated preventing the Northern Flow Path (Section 3.2) floodwaters from flowing south and flooding residential properties near Baird Street.

The impact of the implementation of Option L2 / S1 for the 1% AEP event has been examined. It was found that this option did very little to relieve flood affectation on the Northern Flow Path (Section 3.2). Peak flood levels near the Option L2 embankments were reduced by less than 0.05 m and up to 0.1 m in some small isolated areas. Option L2 / S1 has not been considered further since it does not have a significant impact on the 1% AEP peak flood levels.

5.4. Property Modification Measures

Property modification measures refer to the modifications to existing development and/or development controls on property and community infrastructure for future development. Flood modification measures which apply at the individual property scale have also been included in this section.

New performance requirements for buildings in flood hazard areas were introduced in the National Construction Code (NCC) in 2013 with The Australian Building Codes Board (ABCB)'s 'Construction of Buildings in Flood Hazard Areas' and the accompanying Handbook (References 16 and 17). This Standard contains requirements to ensure new buildings and structures located in flood hazard areas do not collapse during a flood when subjected to flood actions and includes consideration of appropriate construction, use of appropriate materials, electrical, plumbing and drainage installation as well as setting floor levels. It applies to residential buildings (Classes 1, 2, 3 and 4) and health care buildings (Classes 9a and 9c). The Standard is not intended to override any land use planning controls imposed by Council or the appropriate authority.

5.4.1. House Raising

DESCRIPTION

House raising has been widely used throughout NSW to eliminate or significantly reduce flooding of habitable floors particularly in lower hazard areas of the floodplain, albeit in limited overall numbers. However it has limited application as it is not suitable for all building types being more suitable for non-brick single storey buildings. House raising is unlikely to be approved in high hazard areas.

DISCUSSION

The benefit of house raising is that it eliminates above floor flooding and consequently reduces flood damages. House raising also provides a safe refuge during a flood, assuming that the building is suitably designed for the water and debris loading. However the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during a medical emergency or larger floods than the design flood occurs particularly in high hazard areas.

The type of construction of a house can make raising an unfeasible option as raising a brick property can be structurally difficult and also incur significantly higher costs than a timber property. Many of the residences in Culcairn are brick construction or slab and floor and therefore house raising is unlikely.

For new development, floor level requirements will negate the need for future raising of properties.

SUMMARY

A review of at-risk properties in the study area failed to identify any specific houses for house raising. This due to a combination of factors, being:

- Construction material of properties incompatible with house raising;
- Large difference between 1% AEP and PMF design flood levels means that properties raised to above the 1% AEP level will still incur damages in larger floods, thereby reducing the benefits of the option. Raising properties to above the PMF level is not considered practical; and
- Raising properties comes with an associated increased risk with people staying in their houses during a flood event.

House raising is not considered to be a cost effective option for Culcairn and no specific houses have been identified for raising.

5.4.2. Voluntary Purchase

DESCRIPTION

Voluntary Purchase (VP) involves the acquisition of flood affected properties, in particular those frequently inundated in high hazard areas, and demolition of the residence to remove it from the floodplain. Removal of properties can help to restore the natural hydraulic capacity of the floodplain; the storage volume and waterway area. Voluntary purchase is mainly used in more hazardous areas over the long term as a means of removing isolated or remaining buildings to free both residents and potential rescuers from the danger and cost of future floods.

Although measures such as flood proofing or raising could reduce flood damages for properties in high risk areas during smaller events, the high hazard means that conditions are unsafe for people and they would still need to be evacuated before the onset of flooding. Voluntary purchase of the properties would allow the areas to be given over to public open space and would remove the high hazard risk to residents here. Voluntary purchase would be the only way of reducing flood risk and hazard for those residents by encouraging them to move to a less flood hazardous area. The purchased properties should be demolished and the land rezoned as appropriate use such as E2 Environmental Conservation or similar in the LEP so that no development may take place. The land can also be defined as floodway in Council's DCP.

DISCUSSION

Voluntary purchase is an effective strategy where it is impractical or uneconomic to mitigate high flood hazard to an existing property and it is more appropriate to cease occupation to meet the above objectives and is often a measure that is used as part of a wider management strategy than on its own. Government funding for voluntary purchase schemes can be made available through the Floodplain Management Program as long as a number of complying criteria are met. Voluntary purchase areas are not classified under any specific land use in the Standard Instrument LEP. However, Council can consider creating Voluntary Purchase zones through their DCP or requiring that voluntary purchase zones apply to all flood prone areas also identified as being high hazard floodway.

No residences in Culcairn have been identified as being situated in either a floodway or in a high hazard flood area. Accordingly no residences in Culcairn are suitable for VP.

CONCLUSION

VP schemes generally have low B/C ratios and are only likely to obtain funding in high risk flooding situations. Additionally, such schemes often take many years to obtain sufficient funding to purchase all properties eligible for the scheme. Due to a lack of suitable properties a VP scheme is not recommended for Culcairn.

5.4.3. Flood Proofing

DESCRIPTION

Flood proofing is 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.

As an alternative to retrofitting permanent flood proofing measures to existing properties, temporary flood barrier methods can also be achieved by the use of sandbags in conjunction with plastic sheeting or private flood barriers which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding.

DISCUSSION

Retro fitting permanent flood proofing measures can be difficult and permanent flood proofing is best achieved during construction. Temporary flood proofing can be achieved during flooding although relies on someone to put up flood gates or similar and therefore effective flood warning times and the time of flooding can affect their efficiency.

Whilst it is a requirement of the Floodplain Development Manual (Reference 1) that new residential properties have their floor levels above the 1% AEP event plus a freeboard, commercial properties are not subject to such requirements unless stipulated by Councils. New commercial buildings can be required to be flood proofed to the Flood Planning Level (FPL) when constructed which would include consideration of suitable materials, electrical and other services installation and efficient sealing of any possible entrances for water. Council would make these requirements through the DCP and planning controls. It is recommended that planning controls allow some flexibility for either dry or wet flood proofing to be used, and for temporary flood gate options to also be included in building design for low risk non-habitable development.

Temporary flood barrier measures such as sandbagging and flood barriers can be a cheaper option than retrofitting to existing properties and can be useful in areas where there is frequent shallow flooding. Sandbagging, often used in conjunction with plastic sheeting, can provide a solution for dealing with flooding in smaller areas and at individual properties. NSW SES Culcairn Operations Centre maintains a small supply of sandbags and back-up supplies are available through the Murrumbidgee SES Region Headquarters. A motorised sandbag-filling machine is available from Wagga Wagga SES Unit and Murrumbidgee Region Headquarters (Reference 8). Whilst sandbags and plastic sheeting seldom prevent the ingress of floodwaters entirely, they can substantially decrease the depth of over floor flooding and decrease foulness of floodwaters, thus aiding the clean-up process. There is little warning time in Culcairn for flooding associated with overland flows, however Billabong Creek flooding provides some warning time (see Section 5.5.1) to allow for flood preparedness. However, the use of temporary measures should not be relied on as a solution to flood problems at individual properties.

SUMMARY

Flood proofing is a good solution to reducing flood risk to commercial and industrial properties and should be encouraged for all new development of this type, particularly where floor levels may be low. Consideration of appropriate construction materials is still needed for those residential developments where floor levels will be raised above the 1% AEP flood level but structures can still become inundated below the floor level.

Temporary flood proofing techniques may be deployed although lack of warning time may limit their efficiency and they should be considered as a secondary option to more permanent measures being implemented.

RECOMMENDATIONS

The following measures are recommended:

► Include requirements for flood proofing for new development, wet or dry as appropriate, in development controls. In particular this approach should be the minimal requirement for non-habitable buildings such as commercial or industrial developments where floor levels are not always required above the FPL.

5.4.4. Minor Property Adjustments

DESCRIPTION

In overland flow areas minor property adjustments can be used to manage overland flows through private property and minimise impacts on dwellings by helping to divert local overland flows away from dwellings and access points. Such adjustments can include low level bunding (small levees) around individual properties, amendments to fences or construction of fences which act as deflector levees, modifying gardens and ground levels etc. all of which can affect the local continuity of overland flow paths.

DISCUSSION

It is difficult for Council to enforce property adjustments and furthermore the issue can be complicated by requirements of s149 certificates. In addition, adjustments on one property may have knock on effects on adjoining properties, or require modifications on neighbouring properties to be effective. Some residents have commented that they believe small features on neighbourhood properties have increased flooding on their own property. Therefore any works in flood prone areas which could modify the localised flood behaviour should be shown to have no significant impact on adjoining properties and be subject to approval from Council.

SUMMARY

Minor property adjustments can have localised benefits, however they should be assessed for their impact on neighbouring properties. There are no specific recommendations regarding minor property adjustments for Culcairn, however Council may want to consider some controls on this due to impacts on neighbouring properties.

5.5. Response Modification Measures

Response modification measures aim to reduce risks to life and property in the event of flooding through improvements to flood prediction and warning, through improvements to emergency management capabilities and planning, and through better flood-educated communities.

5.5.1. Flood Warning

DESCRIPTION

The purpose of a flood warning is to provide advice on impending flooding so people can take action to minimise its negative impacts. An effective flood warning system requires integration of a number of components (Reference 11):

- 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.

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.

The Bureau of Meteorology does not issue specific flood warnings for Culcairn at the present time. Other Bureau warning products may provide an indication of the flood threat such as Flood Watches and Severe Weather Warnings for torrential rain. The NSW SES might issue Flood Advices or Bulletins based on its own assessment of the threat. If warranted, Evacuation Warnings and Orders may be issued.

The Billabong Creek catchment is large – 1,800 km^2 to Culcairn – which suggests there should be sufficient time to detect and respond to a rising flood. Analysis of the October 2010 (Chart 1) and March 2012 floods (Chart 2) indicates that the lag time – the time between the decisive rainfall and the flood peak at Culcairn – was about 24 hours on both occasions. Thus, with the exception of local overland flooding, the risk of flooding at Culcairn is *not* flash flooding, and from a technical perspective there is considerable scope for improving flood warning services.

DISCUSSION

Consideration has been given to the need and opportunity for providing earlier and more specific warnings for Culcairn.

The need may be assessed by considering the data in Table 28. Up to and including the 5% AEP flood, the impacts are largely associated with overland flow inundation. In the 2% AEP flood, a large number of houses could be isolated when Balfour Street floods, though high clearance vehicles could probably access the area and the period of isolation from central Culcairn would be quite short. In the 1% AEP flood, many households would need to evacuate to other parts of Culcairn prior to flooding, but the large majority of houses would not be flooded. Electricity and water are still anticipated to be operating, but if there is heavy local rain the sewerage system could be overwhelmed. In the PMF, the scale of flooding becomes quite dangerous, with virtually every building in Culcairn flooded over floor, and posing a hazard to the structural integrity of about 21% of houses. This does not necessarily mean that anyone who failed to evacuate Culcairn would drown in a PMF, since there are some buildings in the town with two storeys (e.g. at Billabong High School and at Culcairn Hotel), but essential services would very likely be compromised and flooding could persist for up to two days. The duration of flooding shown in Table 28 relates to the height at the gauge (9 m) at which the lowest roads begin to be inundated – the actual period of isolation would be less than this for most houses.

Table 28: Culcairn Risk Summary

Event	No. houses flooded over floor	No. houses *not* flooded over floor	Max. depth over floor	No. houses > low haz to structure*	Approx. no. houses isolated#	Duration >9m at local gauge
5 year ARI	1	526	0.1m	0	2	n/a
10% AEP	1	526	0.1m	0	2	n/a
5% AEP	4	523	0.2m	0	2	10 hrs
2% AEP	7	520	0.2m	0	112	22 hrs
1% AEP	34	493	0.4m	0	306	27.5 hrs
0.5% AEP	105	422	0.7m	0	306	31 hrs
PMF	526	1	2.2m	111	527	~2 days

* Based on Reference 6, without reference to actual floor heights. # Does not account for flooding outside the study area.

Flood warnings are needed to guide responses. If the magnitude of the rising flood is known with some confidence, the NSW SES and the community could make informed choices about the need to evacuate. Evacuation is not a risk-free choice, particularly for residents of Culcairn Hospital, so knowing whether evacuation is essential would be of great value.

Flood warnings are also needed to provide sufficient time for evacuation. Using the NSW SES Timeline Evacuation Model tool suggests that at least 4.7 hours would be required to fully evacuate Culcairn, including standard allowances for warning acceptance, warning lag and traffic safety factors (see Table 29). This does not include allowances for mobilisation of NSW SES personnel, for the decision to issue an Evacuation Order or for dissemination of the Evacuation Order, which would likely add to the time required.

Table 29: Evacuation Timeline Model Calculation for Culcairn

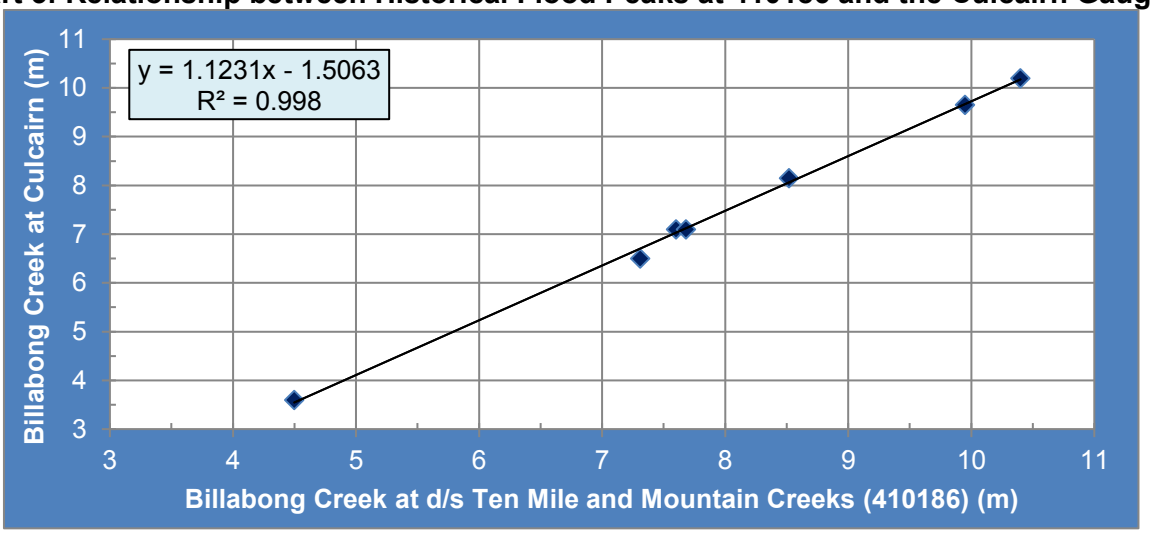
Time required to evacuate		
Number of vehicles		**Data source**
Residential		
Number of dwellings	526	WMAwater
Vehicles per dwelling	1.601	2011 Census
% Census respondents not reporting	4.4%	2011 Census
Residential vehicles	880	Calculated
Commercial		
Number of business premises	67	WMAwater
Vehicles per business	2	Estimate
Commercial vehicles	134	Calculated
Total vehicles (TV)	1014	Calculated
Evacuation route		
Number of lanes	1	Observation
Evacuation route capacity (RC) (veh/hr)	600	SES
Evacuation timing (hrs)		
Warning acceptance factor (WAF)	1	SES
Warning lag factor (WLF)	1	SES
Travel time (TT) =TV/RC	1.7	Calculated
Traffic safety factor (TSF)	1	SES
Total time required to evacuate (TR) = WAF+WLF+TT+TSF	**4.7**	Calculated
Time available to evacuate (hrs)		
BOM forecast time	0	State Flood Plan
Flood travel time	7	Mar 2012 flood
Total time available (TA)	**7**	Calculated
Time deficit or surplus (hrs)		
Time = TA – TR	**+2.3**	Calculated

One option is to apply to the Bureau of Meteorology (BoM) and the NSW Flood Warning Consultative Committee (FWCC) to provide quantitative flood warnings for Culcairn. This could require considerable Council expense to install and maintain sufficient pluviometers to provide adequate coverage of the large catchment to Culcairn. As noted in the Flood Study (Reference 2), the reliability of rainfall triggers can be poor for large catchments unless the gauge network is reasonably extensive. Gauge inbuilt thresholds may also fail to take into account conditions conducive to a flood setup over a long initial period of low intensity or episodic rainfall.

Another option could be to use the established network of water level recorders, but the configuration of sub-catchments means that the best location for a recorder is along Billabong Creek downstream of the junction of Ten Mile and Mountain Creeks, where there is already a NSW Office of Water gauge (No. 410186). This gauge is located about 26 km upstream of the Culcairn gauge (by river chainage), with historical flood peak travel times varying between about 7 and 13 hours (Table 3). Historical flood peak data display a strong correlation between the two gauges (Chart 3), so heights at 410186 have good predictive value for Culcairn. The flood travel times and the good correlation suggest that 410186 could be very useful for predicting flood heights and times at Culcairn downstream. It is possible to pre-configure a water level recorder such that it issues an SMS to the emergency services when a pre-determined threshold is

reached. Potential trigger levels for 410186 are 6.68 m (corresponding to 6.0 m at the Culcairn gauge) and 8.46 m (8.0 m at Culcairn). Having been notified, NSW SES could then remotely monitor water levels at 410186. Ideally, the water levels at this site would also be available for public access on the BoM website (http://www.bom.gov.au/nsw/flood/southwest.shtml). NSW SES should be prepared to use a boat to access the site of 410186 in case of instrument failure. There is also merit in installing an automatic water level recorder at Culcairn to better document flood hydrographs facilitating a better understanding of Culcairn's relationship with the upstream gauge. Also, the manual gauge plates have deteriorated and need replacing and realignment so Culcairn SES is more easily able to read the numbers.

Chart 3: Relationship between Historical Flood Peaks at 410186 and the Culcairn Gauge



Source: Reference 4

Disseminating information to Culcairn's 1,100+ residents, advising them of a rising flood and what they need to do, also requires consideration. The need for very rapid dissemination is not as urgent as for a flash flood situation like Holbrook, but a flood could still rise to damaging heights over the course of a night (as it did in October 2010 – Reference 3). Door-knocking or telephone 'trees' may be too cumbersome for a town with some 500 households. There would be merit in developing and maintaining a system to automatically issue pre-designed SMS or phone calls to registered members of the community when triggers likely to have adverse consequences are exceeded.

SUMMARY

Damaging Billabong Creek floods have been relatively infrequent at Culcairn. Nevertheless, the consequences of rarer floods require some investment in developing a flood warning system, in part to better determine whether and when evacuation is required for particular events. Culcairn is sufficiently far down the catchment that there is opportunity to use information from upstream water level recorders to inform the threat assessment, including the NSW Office of Water (NOW) gauges at Aberfeldy and Holbrook, and gauge No. 410186, which has good predictive value for the Culcairn gauge and historically has provided 7+ hours' warning. There is also a need to consider how to efficiently disseminate flood information and instructions to the community.

RECOMMENDATIONS

The following measures are recommended:

► Open discussions with BoM and the Flood Warning Consultative Committee (FWCC) about providing quantitative flood warnings for Culcairn, using upstream water level recorders (NSW SES Council);

► Alarm No. 410186 to issue SMS to NSW SES personnel when pre-programmed triggers are reached (NOW and NSW SES);

► Show near real-time heights at No. 410186 on Bureau website (NOW and BoM);

► Install automatic water level recorder at Culcairn, as well as new gauge plates at the railway bridge (GHSC);

► Consider constructing and maintaining an SMS/telephone dial-out system for the efficient dissemination of flood information and instructions (NSW SES).

5.5.2. Flood Emergency Management Planning

DESCRIPTION

Effective planning for emergency response is a vital way of reducing risks to life and property, particularly for infrequent floods that are not managed through flood or property modification.

The NSW State Emergency Service (SES) is the legislated combat agency for floods in NSW and is responsible for the control of flood operations. This role is undergirded by detailed flood planning. NSW SES maintains the Greater Hume Local Flood Plan (Reference 8) and flood intelligence cards for key stream gauges.

Residents living in and proprietors working in the floodplain can also prepare individual plans tailored to their situation.

DISCUSSION

The Greater Hume Local Flood Plan (LFP) (Reference 8) is a sub-plan of the Greater Hume Shire Council Local Emergency Management Plan. Volume 1 of the LFP was endorsed in March 2013 and outlines responsibilities and procedures for preparing for, responding to and recovering from floods within the Shire.

Clause 3.5.1 of Volume 1 of the LFP lists the NSW SES Culcairn Operations Centre at Gamble Street, Culcairn. Section 4.5.3.7 outlined the flood risk at this location. It could be flooded over floor to shallow depths in the 1% AEP and 0.5% AEP events but depths might reach 1.6 m in the PMF. This risk should be noted in the LFP.

Clause 3.18.42 of Volume 1 of the LFP lists the Culcairn Memorial Hall, Balfour Street, Culcairn, as suitable for use as a flood evacuation centre. Section 4.5.3.8 outlined the flood risk at this location. The floor level is about 0.7 m higher than the 0.5% AEP flood peak but it would be flooded to a depth of about 0.5 m in the PMF. This risk should be noted in the LFP.

Clause 3.9 of Volume 1 of the LFP deals with the provision of flood information and warnings. If a system similar to that described in Section 5.5.1 is implemented, it is recommended that the LFP be updated to describe this.

Clause 3.17 of Volume 1 of the LFP addresses the management of flood rescue operations, recognising that there may be a residual population which does not evacuate during the early stages of flooding and which subsequently requires rescue. While there are opportunities for improving flood warning systems and levels of community awareness and readiness to promote timely evacuation, the reality is that perhaps a majority of residents may not evacuate in a timely fashion and in an extreme flood could be trapped in houses with water rising. It is recommended that NSW SES give further consideration to developing and maintaining a flood rescue capability for Culcairn.

In some jurisdictions in NSW, particularly for flash flood situations where safe evacuation is difficult to guarantee and where flood durations are typically short, the planning authority requires for new or redeveloped houses in the floodplain that either 1) evacuation to high land can be assured or 2) a structurally sound building contains a PMF refuge so that trapped residents can temporarily evacuate upstairs in a severe flood. This approach is not advisable for Culcairn given longer flood durations and ought to be unnecessary for creek-sourced floods, since there should be sufficient time to evacuate.

However, the most common and reinforcing experience of flooding that residents of Culcairn will have is that floods have little impact on the town and that it is safe to remain in their houses. When this is added to the independent spirit that was evident across communities in south-west NSW during the March 2012 flood operation, it is likely that perhaps a majority of residents might fail to evacuate Culcairn prior to flooding. It is prudent, then, to ensure that there are local evacuation centres above the PMF within each sector that can be isolated. West of the railway, the nominated evacuation centre (Culcairn Memorial Hall) has a floor level assessed as being above most floods, or the second floor of Culcairn Hotel would be entirely above the PMF. North-east of the railway, Billabong High School contains brick, double-storey buildings that could be suitable for emergency shelter. The area located south-east of the railway could be isolated by flooding along Balfour Street and there do not appear to be any suitable buildings that could serve as shelters at the current time. Culcairn Hospital is also located in this sector, and it is recommended that NSW Health consider constructing a building with a level above the PMF to which residents could be evacuated in the event of a severe flood. This might negate the need for evacuation, which is known to be quite risky for patients in residential care. (A mortality rate of 11% has been cited for evacuations of nursing homes). It is understood that the Hospital is slated for a multi-million dollar redevelopment, so it appears to be an opportune time to influence the design so as to provide an area above the PMF (about 1.3 m above current floor level). This should also have an independent power and water supply and effluent-collecting tank.
Other recommended minor amendments to Volume 1 of the LFP are as follows:

- Clause 1.3.3: Billabong Creek is *not* a tributary of the Murrumbidgee River but rather of the Edward River, which subsequently joins the Murray River;
- Clause 3.8.4: NSW Office of Water now makes data available via a free mobile app for iPhone and Android; and
- Attachment 3 needs to show all relevant watercourses (and ideally, water level recorders) in the LGA, including Ten Mile Creek and Mountain Creek.

Volume 2 of the LFP has yet to be finalised and includes Annexes describing the flood threat, effects on the community and response arrangements for each sector such as property protection, evacuation, rescue and resupply. Volume 2 of the post-March 2012 flood intelligence review (Reference 4) included draft updates to Volume 2 of the LFP template to incorporate findings from the flood intelligence review and preliminary results of the Flood Study. As part of this FRMS&P, further amendments to the draft LFP have been made (to the same scope as for Reference 4), drawing on the results of the finalised Flood Study and the assessment of flood problems undertaken as part of this FRMS&P. It is recommended that NSW SES review the proposed changes and complete Volume 2 of the LFP. If any flood mitigation works as implemented as a result of this FRMS&P, the LFP will require additional updates.

Findings of the Flood Study and FRMS&P that need to be incorporated into the LFP include:

- Design flood extents, depths, velocities, hazard and travel times;
- Predicted building inundation in design floods up to PMF;
- Predicted road inundation in design floods up to PMF; and
- Evacuation constraints in design floods up to PMF.

As well as updating the Greater Hume Local Flood Plan, there would be benefit in NSW SES and Council encouraging and helping key floodplain exposures to prepare and update their own flood emergency response plans. Among the higher priorities for flood plans are:

- Culcairn Caravan Park;
- Culcairn Hospital; and
- Culcairn Water Treatment Plant.

Also as part of the post-March 2012 flood intelligence review (Reference 4), the draft flood intelligence card prepared for the Culcairn Railway Bridge manual gauge following the October 2010 flood (Reference 3) was updated. This has again been updated as part of this FRMS&P, with the draft amendments included in Appendix J. It is recommended that NSW SES review the proposed changes.

SUMMARY

Planning for flooding is a vital way of reducing flood risks to life and property. Plans need to be reviewed after flooding and after new information is made available from flood investigations. NSW SES has the lead role in planning for and responding to floods. There is a need to update the Greater Hume Local Flood Plan and relevant flood intelligence cards, but best practice teaches that people will respond more effectively when households and businesses are also engaged in planning to respond to floods.

RECOMMENDATIONS

The following measures are recommended:

► Resource and train Culcairn SES Unit so that it can perform flood rescue function within the town (NSW SES);

► Consider constructing evacuation shelter with floor above PMF in SE Culcairn sector to supplement existing shelters in NE Culcairn (Billabong HS) and W Culcairn (Memorial Hall or Culcairn Hotel) – this shelter could be at the Hospital (Council) ;

► When redevelopment occurs, construct a floor area at Culcairn Hospital above the level of the PMF to lessen need for evacuation of vulnerable patients (NSW Health);

► Review draft updates and complete Greater Hume Local Flood Plan, drawing on flood intelligence from the Flood Study and this FRMS&P (NSW SES);

► Review draft updates to Culcairn flood intelligence card (NSW SES);

► Assist key floodplain exposures (e.g. caravan park, hospital, water supply) to prepare tailored individual flood emergency plans (NSW SES and Council).

5.5.3. Community Flood Education

DESCRIPTION

Actual flood damages can be reduced, and safety increased, where communities are flood-ready:

> *'People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension… Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the combat agency, with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced.'* (Reference 13)

Based on learnings from recent disasters, the focus of community disaster education has now turned from a concentration on raising awareness and preparedness to building community resilience through learning. Simply disseminating information to the community does not necessarily trigger changed attitudes and behaviours. Flood education programs are most effective when they:

- Are participatory i.e. not consisting only of top-down provision of information but where the community has input to the development, implementation and evaluation of education activities;

- Involve a range of learning styles including experiential learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, DVDs, the media), collaborative group learning (e.g. scenario role plays with community groups) and community discourse (e.g. forums, post-event de-briefs);
- Are aligned with structural and other non-structural methods used in floodplain risk management and with emergency management measures such as operations and planning; and
- Are ongoing programs rather than one-off, unintegrated 'campaigns', with activities varied for the learner.

It is difficult to accurately assess the benefits of a community flood education program but the consensus is that the benefits far outweigh the costs. Nevertheless, sponsors must appreciate that ongoing funding is required to sustain gains that have been made.

DISCUSSION

Current levels of flood awareness in Culcairn are relatively high, being within five years of the severe flood of October 2010 when about 21 houses and 6 non-residential buildings were flooded over floor (Reference 3). Lesser floods in 2011 and March 2012 would have taught the community that the October 2010 flood was not a 'one-off'. Nevertheless, Census data indicate that 36% of Culcairn residents lived in a different address 5 years prior to the 2011 Census. Population turnover and the progress of time mean that over time the community's remembrance of the floods of 2010-12 will gradually decline and their readiness to respond appropriately to future flood emergencies will wane. This means that there is a need to build flood readiness for people unfamiliar with flooding and to maintain flood readiness through ongoing flood education. If a flood warning system is developed for Culcairn (Section 5.5.1), it will be vital that the community understands how it operates and how they need to respond.

Table 30 provides a list of methods to build and sustain flood readiness, which may be developed and supported by NSW SES and Council. These include methods both to inform and to prepare the community, with the objective of building resilience.

Table 30: Methods to Increase Flood Awareness and Preparedness

Method	Comment
S149 certificate notifications	Section 149 planning certificates should record whether the land is subject to any planning and development controls due to its flood affectation. Council also has opportunity to provide more detailed information about the land's flood affectation under S149(5) of the EP&A Act 1979. This information may be particularly valued by prospective purchasers but has a limited reach and is typically issued only upon request and payment of a fee.

Method	Comment
Letter/certificate/ pamphlet from Council	These may be sent annually with a rates notice or separately. A Council database of flood liable properties makes this a relatively inexpensive and effective measure. The intention of flood certificates is to inform individual property owners of the flood situation (flood levels, ground levels) at their particular property. It is the site-specific nature of this advice that offers a chance of overcoming the scepticism typical of a community that has not experienced serious flooding for some years. Only after floodplain occupants accept that they could have a problem are they ready to take on board ideas about addressing that problem. A pamphlet can inform residents of the on-going implementation of the Floodplain Risk Management Plan and provide tips to respond appropriately to flooding (e.g. evacuate early; never drive, ride or walk through floodwater). Proactive and regular issuance is desirable.
Council website	Council already provides an 'emergency information' portal on its website. An additional flood management portal would be of value to describe the floodplain management process and include Flood Studies and Floodplain Risk Management Studies, a history of flooding in Greater Hume LGA, procedures for how to obtain flood information, answers to frequently asked questions (FAQs), and advice on becoming flood prepared. The portal could also provide links to Bureau of Meteorology warnings and NSW Office of Water gauge heights.
Community Working Group	Council could initiate a Community Working Group framework to provide a valuable two way conduit between the local residents and Council.
School project	School students can learn about historical floods by interviewing older residents and documenting what happened. A project could also involve talks from various authorities (e.g. NSW SES) and can be combined with topics relating to water quality, drainage management, etc.
Articles in local newspapers	Ongoing articles in the newspapers will ensure that the flood issues are not forgotten. Historical features and remembrance of past events are interesting for local residents and can provoke preparedness for future events.
Library display	The library could collect historical flood photos and stories to prepare a display, which could be accompanied by appropriate flood safety messages. The Greens Gunyah Museum in Lockhart has an impressive collection of historical flood photos.
Mobile display	Such a display as described above could also be used at local festivals and for school visitations, accompanied by NSW SES staff, who should be trained to encourage and equip households to prepare flood emergency plans.
NSW SES FloodSafe Guide	Now that a Flood Study has been prepared, and given the experiences of major floods in the recent past, once the Local Flood Plan is finalised, it would be timely to prepare a FloodSafe guide for Culcairn describing flood behaviours in historical and design floods, describing the local flood warning system (if implemented) and particularly highlighting the priority of early evacuation and the danger of late evacuation. If major flood mitigation works will be implemented following this FRMS&P, it would be advisable to wait until these are done.
NSW SES Business FloodSafe Breakfast	The NSW SES has prepared a FloodSafe Business template, which businesses can use to plan for flooding. A breakfast barbeque could be convened at an appropriate location to promote completion of plans and to provide site-specific flood information.

Method	Comment
'Meet the street' events	'Meet-the-street' events involve NSW SES and Council setting up a stall at an appropriate location at a time that people will be at home. An event would be promoted via personal invitation. The stall could consist of flood maps on boards, NSW SES banners and NSW SES materials to hand out (e.g. Culcairn FloodSafe guide when available). The materials are used to engage with people and make them aware of flood risk, encourage preparedness behaviours (e.g. develop emergency plans) and help them understand what to do during and after a flood. There is also value in encouraging property owners to develop self-help networks and particularly to check on neighbours if a flood is imminent.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or similar to indicate the level reached in historical and design floods. Depth indicators advise of potential hazards, particularly to drivers. These are inexpensive and effective but in some flood communities are not well accepted as it is perceived that they affect property values. A flood marker post could be installed in Jubilee Park (away from private property) to show the height flood waters reached in the 2010 and 2012 events as well as in selected design flood events up to the PMF.

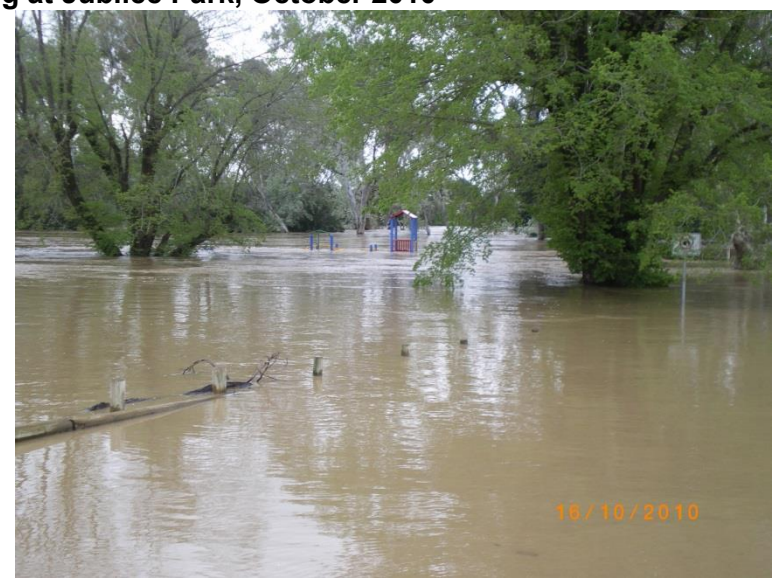
SUMMARY

Although recent flood events and the flood risk management process have raised community flood awareness, this is expected to wane over time. For Culcairn, flooding of a similar magnitude to the October 2010 flood had not occurred since 1931. If there are long periods without damaging flooding, it is difficult to maintain the community's interest and preparedness. Ongoing flood education will be required to build and maintain flood resilience and to prepare the community for larger and faster-rising floods than it has previously experienced. If a flood warning system is developed for Culcairn, education is vital to ensure people understand how they should respond.

Council will need to develop a program from the above measures after taking into account the views of the local community, funding considerations and other education programs within the LGA. However, for the purposes of this FRMS&P, we recommend that the following measures be given a high priority:

- Regular issuance of flood certificates and pamphlets to landowners within the floodplain;
- Preparation of a library flood photo and story display;
- Commemoration of the 10th anniversary of the October 2010 flood;
- Preparation of a Culcairn FloodSafe guide;
- Installation of a flood marker post in Jubilee Park (see Image 2).

Image 2: Flooding at Jubilee Park, October 2010



Source: Les Fraser

RECOMMENDATIONS

The following measures are recommended:

► Engage with community to prepare an ongoing flood education program, with appropriate methods for program evaluation (NSW SES and GHSC);

► Regularly issue flood certificates and pamphlets to landowners within the floodplain (GHSC);

► Prepare a library photo and story display (GHSC and NSW SES);

► Commemorate the 10th anniversary of the 2010 flood (NSW SES and GHSC);

► Prepare a Culcairn FloodSafe guide (NSW SES and GHSC);

► Install a flood marker post in Jubilee Park (GHSC).

5.6. Planning and Future Development Control Measures

5.6.1. Land Use Zoning

DESCRIPTION

Appropriate land use planning can assist in reducing future flood risk and ensure development on flood affected areas is flood compatible. Appropriate land use controls in flood affected areas can prevent inappropriate development from occurring and thus reduce flood risk. Land use zones are generally governed by a Local Environmental Plan (LEP). To make any significant changes to the provisions of a LEP, a planning proposal must be prepared. Residential uses and sensitive land uses such as seniors living facilities, hospitals and child care centres etc. should not be permitted in the floodway or high hazard areas.

Council should consider appropriate controls, including floor levels and/or flood proofing, for commercial and industrial development if permitted on the floodway and ensure that development does not cause flood issues to be offset elsewhere. Ratified flood data and mapping should be utilised to inform the Flood Planning Area and levels set for all residential development on land which is located within the FPA (see Section 5.6.3).

DISCUSSION

The current land use zones for Culcairn are presented in Figure 2. Ratified data and modelling now provide a best estimate of the FPA (see Section 5.6.3).

Flood Hazard categories have been further considered in relation to contextual issues (i.e. high depths and short warning time frames) which can cause potential problems in terms of evacuation.

Figure 80 of the Flood Study, reproduced herein as Figure 12 shows the flood Emergency Response Classifications (ERC) which designate areas for which evacuation may be constrained during a flood event. These "constrained evacuation" areas need careful consideration in terms of existing undeveloped lands and lands subject to planning proposals for rezoning.

Some ways of dealing with "constrained evacuation" areas should include:

1. Rezoning existing undeveloped land to better reflect flood characteristics.
2. Placing a moratorium on any further planning proposals in flood affected areas.
3. Requiring new dwellings to include refuge structures which will be accessible in a PMF event.
4. Include a community refuge as part of any future community building in precincts with "constrained evacuation".

Council should review existing zones against flood information and maps to ensure that current permissible uses are still appropriate or apply flood controls including floor levels or flood proofing where required.

Council should, having regard to Direction 4.3 from the Minister, review any existing planning proposals to account for updated flood planning information and mapping (see Section 4.2).

Flood controls and floor levels should be introduced into the Council's DCP to ensure appropriate management of flood affected land in accordance with existing State policies.

SUMMARY

Appropriate land use planning can assist in reducing future flood risk and ensure development in flooded areas is flood compatible. Residential uses and sensitive land uses such as aged care facilities, hospitals and child care centres etc. should not be permitted in the floodway or high hazard areas. Council should consider appropriate controls including floor levels and or flood proofing for commercial or industrial development if permitted on the flood way and ensure that such development does not cause flood issues to be offset elsewhere. Ratified flood data and mapping should be utilised to inform the FPA and levels set for all residential development on land that exists in the FPA.

Flood data and mapping should be used strategically in the planning process to inform existing zoned areas and proposed rezoning areas in Culcairn.

RECOMMENDATIONS

The following measures are recommended:

►Reconsider existing zones against current flood data and mapping, introduce flood controls or floor levels where appropriate or back zone if land is identified in the flood way.

►Council consider either restricting future development or requiring refuge provision in precincts with known “constrained evacuation” areas.

5.6.2. Flood Planning Levels

DESCRIPTION

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (the Manual) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control measure for managing future flood risk and is derived from a combination of a flood event and a freeboard. Typically, the FPL is used to define the minimum level at which habitable floor levels should be constructed.

The Manual states that, in general, the FPL for standard residential development is the 1% AEP event plus 500 mm freeboard. However, the flood event and selected freeboard used to define the FPL can be varied where it can be clearly demonstrated that there are exceptional circumstances.

According to the Manual, the purpose of the freeboard is 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;
- Changes in rainfall patterns associated with climate change; and
- The cumulative effect of subsequent infill development on existing zoned land.

The Manual notes that selected freeboard may vary for different parts of the floodplain due to spatial variation in the factors influencing freeboard (listed above).

DISCUSSION

Due to the complex flood behaviour described in Section 3.2, three different freeboards have been used in the study area, with the floodplain being divided into the following FPL zones:

- **Zone 1** – situated upstream of the Main Southern Railway Line and north of Balfour Street;
- **Zone 2** – situated upstream of the Main Southern Railway Line and south of Balfour Street;
- **Zone 3** – situated downstream of the Main Southern Railway Line.

These zones, and the applicable FPLs, are presented in Figure 14. Figure 14 should be used to help interpret the following explanation of FPL selection methodology.

The selected methodology has been implemented on the basis that each of the Zones have their own unique spatially varying factors which influence freeboard requirements. These factors are summarised below for each of the Zones:

- **Zone 1** – The Main Southern Railway Line acts as a barrier to flow resulting in higher flood levels on the upstream side. This feature leads to significant scaling between events and flood level sensitivity. The difference in peak flood level between the 1% and 0.2% AEP events, upstream of the railway embankment, is typically 0.6 m. This same flood behaviour is exhibited in Zone 2. However, Zones 1 and 2 differ in that Zone 1 contains:
    - A number of properties that were flooded above floor during the recent 2010 and 2012 events;
    - The Billabong Creek anabranch breakout, which causes significant property inundation from events larger than the 2% AEP; and
    - Culverts though the railway embankment to the north of Billabong Creek that are small and prone to blockage.

  Based on the flood behaviour outlined above, the FPL for most areas within Zone 1 is defined by the 1% AEP + 0.3 m freeboard with the exception of areas which are flooded during the 1% AEP event, in which case a freeboard of 0.5 m has been used. The two Zone 1 FPL regions are presented in Figure 14.

- **Zone 2** – exhibits similar flood behaviour as that displayed in Zone 1, without the added complications outlined in the points above. Accordingly, the FPL in all areas within Zone 2 is defined by the 1% AEP + 0.3 m freeboard (see Figure 14).

- **Zone 3** – as discussed, the railway embankment causes lower flood levels downstream for larger events. This coupled with the broad width of the floodplain in Zone 3, leads to negligible flood level sensitivity. The difference in peak flood level between the 1% and 0.2% AEP events in Zone 3 is typically 0.2 – 0.3 m. Additionally, flooding due to the 1% AEP event is minor and 0.2% AEP floodplain flood depths are shallow (typically < 0.15 m).

Based on the flood behaviour outlined above, the FPL for areas within Zone 3 is defined by the 1% AEP + 0.15 m freeboard with the exception of areas which are flooded in the 1% AEP event, in which case a freeboard of 0.3 m has been used. The two Zone 3 FPL regions are presented in Figure 14.

In addition to the above, further complexity is added when defining the Culcairn FPL as the floodplain slopes away from the Billabong Creek channel. In such situations the floodplain is not constrained by higher ground and when the planning flood is raised using a freeboard and extended to meet the non-existent higher ground, the FPL is prone to be overestimated. To ensure that the extent of the FPL is not exaggerated, the FPLs have not been applied to areas outside of the 0.2% AEP event flood extent trimmed to 0.15 m. In effect, the 0.2% AEP flood extent trimmed to 0.15 m has been used to define the maximum FPL extent. The trimmed 0.2% AEP event was selected for this purpose as it is not too dissimilar to the 1% AEP event and is therefore in agreement with the Manual (NSW, 2005) which states that, 'freeboard acts as a factor of safety which should never be relied on to manage risk in events larger than the event used to derive the FPL'.

At Culcairn, all properties tagged as being within the local overland flow FPA are also contained within the mainstream FPA (see Section 5.6.3) as Billabong Creek is the dominant flood mechanism in terms of flood extent. Accordingly, no FPL was set for overland flow flooding.

For industrial and commercial areas, the Council can either set their own floor height or require flood proofing where the FPA applies to industrial or commercial land.

SUMMARY

The FPL should be used to set finished floor level requirements for residential development. Less vulnerable uses such as commercial developments could be subject to lower floor level requirements but it is recommended that they should be subject to flood proofing to the FPL where floor levels are lower. More vulnerable developments and critical infrastructure should be subject to more stringent requirements if possible.

RECOMMENDATIONS

The following measures are recommended:

► The FPL should be set as the 1% AEP event plus a freeboard (as defined above and in Figure 14) for residential areas within Culcairn and subject to the FPA.

► Council can decide on floor level requirements for non-residential developments at their discretion but should take into account proximity to major overland flow routes, flood hazard at the subject site and surrounding area etc.

► For commercial or industrial developments where finished floor levels are not set at the FPL, flood proofing measures will be required to the FPL.

► More vulnerable developments within Culcairn such as hospitals, schools, services including power should have floor levels and access at the FPL or PMF level, whichever is higher.

5.6.3. Flood Planning Area

DESCRIPTION

The Flood Planning Area (FPA) is an area to which flood planning controls are applied. An FPA map is a required outcome of the FRMS&P.

It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. Typically, and as per the Floodplain Development Manual, the FPA is based on the flood extent formed by the 1% AEP mainstream flooding event plus freeboard (typically 500 mm) and, therefore, extended further than the extent of the 1% AEP event. Planning controls may, therefore, be applied to development which is not necessarily within the 1% AEP flood extent but is in the FPA. The purpose of extending the FPA past the 1% AEP flood extent is to allow for any future increases in flood extent due to climate change, as well as an allowance for differences between flood behaviour during events, however, where flooding is from overland flows, this criteria may not be appropriate and an alternative, more appropriate, criteria needs to be defined.

The NSW Standard Instrument LEP does not include a specific land use zone classification for flood prone land, rather it permits a Flood Planning Area map to be included as a layer imposed across all land use zones.

DISCUSSION

The Floodplain Development Manual (1% AEP + freeboard) method of determining an FPA has been used for areas of mainstream flooding such as those affected by Billabong Creek, using the various freeboards described in Section 5.6.2. These freeboard combinations were determined to be suitable for defining the FPA at Culcairn and have been selected due to the unusual flood characteristic in the study area. Use of the standard 0.5 m freeboard, leads to an exaggeration of the event magnitude that the FPA provides protection for.

To ensure that the extent of the FPA is not exaggerated, the FPA extent was adjusted so that it does not exceed the extent of the 0.2% AEP event flood extent trimmed to 0.15 m.

Definition of a FPA for overland flow at Culcairn was not required as areas affected by local overland flow flooding are contained within the mainstream FPA (see Section 5.6.3), with Billabong Creek flooding being the dominant flood mechanism.

SUMMARY

Defining the FPA is crucial as the FPA is a key concept referred to in the LEP and DCP. The Billabong Creek FPA is defined on the basis of the Floodplain Development Manual using the methodology described in Section 5.6.2.

The Culcairn FPA map is presented in Figure 15.

RECOMMENDATIONS

The following measures are recommended:

► Include the FPA as defined in this study in the DCP (as per Figure 15).

5.6.4. Update Flood Related Planning Policies and Development Controls

DESCRIPTION

Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to:

- Guide new development away from high flood risk locations.
- Ensure that new development does not increase flood risk elsewhere.
- Develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

DISCUSSION

Following a review of the LEP 2012 and Council's current policy regarding flooding the following measures are recommended.

Greater Hume Local Environmental Plan 2012

Council may wish to review land zoning within areas defined as floodway (see Section 4.3) to prevent inappropriate development in these areas.

Flood Policy/DCP

A DCP should be created and it should include the FPA map (5.6.3). In addition to the objectives already stated and considerations included within Chapter 8 of the Greater Hume DCP 2013, it is recommended the Policy should consider:

- Controls on development in flood prone land;
- Controls on development outside the FPA but where development could exacerbate flood risk elsewhere; and
- Controls on drainage easements.

Key considerations for the Flood Policy are listed below. Many of these have been discussed within this report.

For developments with the FPA

- Building floor levels - consideration for different development types;
- Flood Proofing;
- Impact of development on adjacent or surrounding properties; and
- Consideration of hazard at the site and development type.

For all developments within the catchment regardless of flood affectation (could be in a separate OSD or drainage policy)

- Development drainage - limit discharge to that of pre-development site.
- Water quality.
- Responsibility for maintenance and compliance.

Specific text inclusions suggested for a flood management DCP are presented in Appendix G. The DCP should be prepared to be applicable to all flood prone land within the LGA, rather than only specific to Culcairn to provide a consistent approach for development with the LGA. Any recommendations or suggestions in the FRMS&P with regard to planning and policy should be revised and approved by Council planners.

SUMMARY

Up to date planning controls are vital in managing flood risk and Council should update the DCP by introducing a Flood Policy comprising controls on development in flood prone land as well as controls to ensure development, whether or not in flood prone land, will impact on flood behaviour elsewhere. Crucial is inclusion of the FPA in the DCP as a means of determining to which property flood related development controls will apply.

RECOMMENDATIONS

The following measures are recommended:

► Introduce a Flood Policy comprising controls on development in flood prone land, drainage requirements from all new developments (a draft policy is included in Appendix G). Include the FPA in the flooding DCP.

5.6.5. Modification to the S149 Certificates

DESCRIPTION

The Environmental Planning and Assessment Regulation 2000 (the Regulation), at Clause 279 and Schedule 4, prescribes that Councils must provide a disclosure document whereby any interested party can learn the zone and any other planning controls that may apply to a parcel of land.

Schedule 4 of the Regulation prescribes the format of the Planning Certificate. Part 7A of Schedule 4 states:

7A Flood related development controls 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 set out in the Standard Instrument (Local Environmental Plans) Order 2006.

Legal reviews of the effectiveness of s.149 Planning Certificates have suggested it would be appropriate to also provide information as to the scale of the risk (low, moderate or high) and also whether flooding applies generally to the area or more specifically to the land the subject of the certificate.

DISCUSSION

Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on:

- The type of flooding;
- Whether flooding is from major rivers or local overland flooding; and
- The extent of flooding (whether widespread or relatively confined).

It should be noted that the s.149 Planning Certificate only relates to the subject land and not any specific building on the property.

While the legislation currently does not mandate revealing the extent of flood inundation in an s.149(2) Planning Certificate, there is scope within an s.149(5) Planning Certificate for providing this additional type of information.

There can be a general perception from the public that insurance companies, lending authorities or other organisations may disadvantage flood liable properties that have only a very small part of their property inundated by floodwaters. Some Councils have addressed this concern by adding information in s.149(5) Planning Certificates to show the percentage of the property inundated as well as floor levels and other flood related information. In addition, the hazard category could be provided, and also advice regarding climate change increases in flood level.

The compulsory s.149(2) Planning Certificate should include, in terms of flood risk:

- Whether or not the property is in the FPA;
- Any development controls due to the property being within the FPA;
- Responsibility for maintenance and compliance for OSD features; and
- Highlight any drainage easements through the property and controls that apply.

Some Councils include detailed flooding information in s.149(5) Planning Certificates as standard practice. This ensures that residents are made fully aware of flood risks before purchasing a property. However, people who are current property owners often feel that this information devalues their properties and would rather not know. Flood related information in s.149(5) Planning Certificates should include:

- Flood levels / depths over the property;
- Percentage of property which is flood affected;
- The likelihood of flooding;
- Floor levels (from Council's floor level survey if available); and
- Potential flood hazard.

SUMMARY

As Council information for s.149 Planning Certificates and Development Restriction Certificates is obtained mainly from computerised databases and maps, Council should investigate ways to make property-based flooding information more accessible via its web-site.

Data from the hydraulic modelling used in this FRMS&P should be incorporated into Council's s.149 Planning Certificate database. All residents should be advised by personalised mail from Council if their land is affected. Council should determine the appropriate event for advising residents that the same criteria is used as in establishing the FPA.

RECOMMENDATIONS

The following measures are recommended:

► Update and re-issue s149 certificates based on this FRMS. It is encouraged that full details are provided in Part(5) as standard practice when a Part(2) is requested.

► Provide flooding information on Councils website.

6. FLOODPLAIN RISK MANAGEMENT PLAN

This section comprises the Floodplain Management Plan and forms a framework identifying aims, objectives and a guide to the list of strategies by which the plan will be implemented. Any recommendations in terms of policy should be reviewed and approved by Council's planners.

6.1. Aims and Objectives

The primary objective of the Floodplain Management Plan is to recommend a range of property, response and flood modifications that address the existing and future flood problems, in accordance with the Floodplain Development Manual (Reference 1). The recommended works and measures presented in the Plan will:

- 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;
- Reduce private and public losses due to flooding;
- Protect and, where possible, enhance the river and floodplain environment;
- Be consistent with the objectives of relevant State policies, in particular, the Government's Flood Prone Lands and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act, 1979;
- Ensure that the 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 management plan are sustainable in social, environmental, ecological and economic terms;
- Ensure that the floodplain risk management plan is fully integrated with the local emergency management plan (Local Flood Plan) and other relevant catchment management plans; and
- Establish a program for implementation and a mechanism for the funding of the plan and should include priorities, staging, funding, responsibilities, constraints, and monitoring.

6.2. Identification of Actions Suitable For Implementation

The following matrix (Table 31) identifies the practical options which have been identified to the Culcairn Floodplain Risk Management Committee for further approval. Those options or strategies approved by the Committee will be further investigated.

Table 31: Measures Recommended for Implementation – Risk Management Options Matrix

Measure	Description	Priority	Benefits	Concerns	Implementation, Costs and Funding
FLOOD MODIFICATION MEASURES					
Strategy for Billabong Creek vegetation management (Section 5.3.3.1)	Clearing of debris and overgrown vegetation from the Creek.	Medium	Can minimise build-up of debris and hence channel blockage.	Environmental concerns over loss of riparian corridor, habitats and native vegetation.	Council would be responsible for costs and implementation. The Murray LLS would also need involvement. Approval from the relevant government bodies is necessary in some cases and clearance will be limited by legislation.
Option A3 – Lowering of the stock route near Balfour Street intersection (Section 5.3.4.3)	Option A3 investigated lowering the stock route near its intersection with Balfour Street to allow local flows to pass and alleviate ponding on the upstream (eastern) side.	High Consider for detailed design and costing	B/C = 1.3 Peak flood levels at flood prone properties upstream of the Stock Route are reduced by up to 0.3 m and over floor flooding is negated for one property for events from the 5% AEP and larger	None.	Council would be responsible for costs and implementation. Some funding may be available through the Floodplain Risk Management Program.
Drainage maintenance (section 5.3.6)	Council should regularly address drainage maintenance including unblocking and repairing where necessary.	High	Will maintain drainage efficiency in Culcairn and prevent additional flooding caused by blockage of channels or structures.	Structures not under the jurisdiction of Council, including those maintained by RMS and ARTC may not be efficiently maintained.	Council will be responsible for costs and regular maintenance apart from those structures under the jurisdiction of RMS and ARTC.
Drainage Assets Database (Section 5.3.6)	Develop database of all drainage assets and notify body responsible for their maintenance.	Low	Would allow Council to better maintain the drainage in the area and reduce responsibility issues.	Needs to be maintained.	Council would be responsible for costs and implementation of the database as well as RMS and ARTC to establish details of their infrastructure. The Murray LLS would also need involvement.
Combined Option S2 / A7 / A8 – Stopping Billabong Creek Flood Affectation (Section 5.3.8.1)	This combined option is designed to prevent floodwaters from Billabong Creek flooding Culcairn for events up to and including the 1% AEP flood. This is achieved by the following: • Blocking the Billabong Creek anabranch at two key locations; • Applying a non-return valve to the Gordon Street drain; and • Applying a non-return valve to the Gamble Street drain.	High Consider for detailed design and costing	B/C = 1.3 Implementation of the combined Option S2 / A7 / A8 provides a B/C ratio greater than one and effectively removes flood affectation due to Billabong Creek flooding for all properties up to and including the 1% AEP at Culcairn.	None.	Council would be responsible for costs and implementation. Some funding may be available through the Floodplain Risk Management Program.

Measure	Description	Priority	Benefits	Concerns	Implementation, Costs and Funding
Combined Option L3 / A5 / B4 – Southern Flow Path Flood Mitigation (Section 5.3.8.2)	This combined option is designed to minimise flood affectation and property inundation due to local overland flow flood events on the Culcairn Southern Flow Path. This is achieved by the following: • Construction of a basin east of Federal Street; • Placement of an embankment hear Balfour Street; and • Lowering a section of the Olympic Highway.	High Consider for detailed design and costing	B/C = 0.9 Implementation of the combined Option L3 / A5 / B4 provides a B/C ratio close to one and significantly reduces flood depths, extents and over floor flood liability surrounding Balfour Street for events up to and including the 1% AEP event. Numerous houses are no longer flood affected in the 1% AEP flood along Federal Street and the northern side of Balfour Street. Decreases in flood depths of up to 0.2 m are achieved.	None.	Council would be responsible for costs and implementation. Some funding may be available through the Floodplain Risk Management Program.
Combined Option L1 / S5 / A1 / B1 / B3 – Central Flow Path Flood Mitigation (Section 5.3.8.3)	This combined option is designed to minimise flood affectation and property inundation due to local overland flow flood events on the Culcairn Central Flow Path. This is achieved by the following: • The construction of two basins east of Federal Street and Gordon Street; • Lowering of Munro Street; and • Implementation of a drain and diversion embankment.	High Consider for detailed design and costing	B/C = 0.9 Implementation of the combined Option L1 / S5 / A1 / B1 / B3 provides a B/C ratio close to one and significantly reduces flood depths, extents and over floor flood liability for events up to and including the 1% AEP event. Additionally, one residential property that was previously flooded over floor in the 5 year ARI event is no longer flood affected for events up to the 1% AEP with implementation of this option.	None.	Council would be responsible for costs and implementation. Some funding may be available through the Floodplain Risk Management Program.
PROPERTY MODIFICATION MEASURES					
Flood proofing (Section 5.4.3)	Permanent or temporary measures can be used. Possible to retrofit to existing buildings but can be a requirement for new development.	Low	Can reduce damages to properties in flood prone areas.	Can be difficult and costly to retrofit. Temporary measures require time for installation.	Requirements for new development to be flood proofed can be included in the Flood Management DCP.
RESPONSE MODIFICATION MEASURES					
Coordinate with BoM and FWCC to provide quantitative flood warnings for Culcairn using upstream gauges (Section 5.5.1)	Numerous upstream water level recorders could be used to provide warning of an impending flood, including information on travel time and peak level estimates.	Medium	Effective flood warning can significantly reduce risk to life and property. 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.	None.	The NSW SES would be responsible for liaison with BoM and FWCC for implementation of this strategy.

Measure	Description	Priority	Benefits	Concerns	Implementation, Costs and Funding
Alarm existing NOW stream gauge at site 410186 to issue SMS to NSW SES when trigger levels are reached (Section 5.5.1)	The existing NSW Office of Water (NOW) stream gauge (No. 410187), which is located about 26 km upstream of Culcairn could be configured such that an SMS is issued to NSW SES personnel when pre-programmed levels are reached during a rising flood. This would increase flood warning time.	Medium	Automation of stream gauge 410187 would provide additional warning time of an impending flood which would allow additional warning time for evaculation of Culcairn's +1,100 residents. The gauge has historically provided +7 hours' warning time.	None.	Council in conjunction with NOW and NSW SES will be responsible for costs and regular maintenance.
Show real-time gauge heights at site 410186 on BoM website (Section 5.5.1)	Water levels for stream gauge 410186 could be made available on the BoM website for easy public access.	Low	Members of the public that may require access to Billabong Creek during periods of low flow (such as farmers with low level crossings) may benefit from inforamtion relating ot upstream water levels.	None.	The BoM in conjunction with NOW would be responsible for implementation and on-going costs.
Install an automatic water level recorder at Culcairn and replace the Culcairn manual read gauge (Section 5.5.1)	Historical flood peak data display a strong correlation between peak flood heights at Culcairn and at stream gauge 410186. By automating the gauge at Culcairn better documentation of flood hydrographs would facilitate a better understanding of Culcairn's relationship with this upstream gauge. Additionally, this information could also be used to improve warning for Walbundrie situated downstream. The manual read gauge at Culcairn needs to be replaced as the gauge plates have deteriorated and are difficult to read.	Medium	Improved flood warning at Culcairn and further downstream.	None.	Council in conjunction with NOW would responsible for implementation and maintaining the gauge. Estimated cost of installation is $10,000 with the cost of maintenance estimated to be $2,000 per annum.
Implement a SMS/telephone dial-out system for dissemination of flood information (Section 5.5.1)	Disseminating information to Culcairn's +1,100 residents could be achieved by automatically issuing pre-designed SMS or phone calls to registered members of the community when triggers likely to have adverse consequences are exceeded.	Medium	Increased flood warning can significantly reduce risk to life and property.	None.	The NSW SES will be responsible for implementation and maintenance.
Resource Culcairn NSW SES Unit for flood rescue function (Section 5.5.2)	Due to the potential for a large number of residents (+1,100) to become isolated during larger flood events, Culcairn NSW SES Unit should have the capability to undertake flood rescue.	Medium	People at risk during flooding of Culcairn will have assistant during evacuation.	None.	NSW SES are the responsible for implementation and funding.

Measure	Description	Priority	Benefits	Concerns	Implementation, Costs and Funding
Culcairn south-eastern emergency shelter (Section 5.5.2)	Construction of a community building that could function as an emergency evacuation shelter for south-eastern area of Culcairn should be considered. The building must maintain structural integrity in an extreme flood and have reliable access during flood.	Low	Whilst timely evacuation from houses in the south-eastern areas of Culcairn can be achieved it cannot be assumed that all residents will evacuate as some may wait to see the magnitude of a flood, which may lead to it being be too late to evacuate. An emergency shelter in the south-eastern area of Culcairn would provide residents that do not evacuate in time safety during extreme flood events. This is particularly important due to the long flood duration at Culcairn	The shelter would require a day to day use and would likely be quite expensive.	Council would be responsible construction and maintenance costs.
Construct a floor level at Culcairn Hospital above the PMF level (Section 5.5.2)	When redevelopment occurs, construct a floor area at Culcairn Hospital above the level of the PMF to lessen need for evacuation of vulnerable patients	Low	Construction of a floor above the level of the PMF might negate the need for evacuation, which is known to be quite risky for patients in residential care. It is understood that the Hospital is slated for a multi-million dollar redevelopment, so it appears to be an opportune time to influence the design so as to provide an area above the PMF.	Cost of construction may be increased significantly and the logistics of having a multi-story hospital in a confined space must be considered.	Council in conjunction with NSW Health are responsible for implementation and costs.
Review and update the Greater Hume Local Flood Plan and Culcairn Flood Intelligence Card (Section 5.5.2).	Local Flood Plan sets out measures to take before and during flooding. FIC's provide usable flood intelligence that can be used to inform emergency procedure.	High	Provide more information such that informed decision can be made during a flood and allow flood preparedness. Latest information from the Flood Study and the FRMS&P can be included. FICs for Culcairn provide emergency procedure leading to increased efficiency and reduced flood risk.	Need for strong communication with communities of concern.	NSW SES are responsible for maintaining the Local Flood Plan the FICs.
Assist floodplain exposures to develop flood emergency plans (Section 5.5.2)	Key floodplain exposures such as caravan park, hospital, water supply etc. are at risk of flooding due to their locations on the floodplain and should prepare for potential flooding by preparing flood emergency plans.	Medium	Reduce flood risk for vulnerable locations situated in the highest risk areas.	None.	Council and the NSW SES have shared responsibility.

Measure	Description	Priority	Benefits	Concerns	Implementation, Costs and Funding
Undertake a community flood education program (Section 5.5.3).	A community flood education program with the following components should be undertaken: • Engage with the community to prepare an ongoing flood education program. • Regularly issue flood certificates and pamphlets to residents on the floodplain. • Prepare a library photo and story display about the 2010 flood. • Commemorate the 10th anniversary of the 2010 flood. • Prepare a Culcairn FloodSafe guide. • Install historic flood depth marker in Jubilee Park.	On going	Continuing awareness of the community leads to better preparedness and therefore fewer damages during a flood event.	People begin to ignore advice and information if too much is given, particularly if they believe there is little risk of flooding.	Council and NSW SES. Can be variable depending on the methods used. Can be incorporated with other Council information provision to reduce costs.
PLANNING AND FUTURE DEVELOPMENT					
Define a floodway in Council's DCP (Section 4.3 and 5.6.1)	Define a floodway in Council's DCP where no future residential development is permissible. Reconsider existing zones against current flood data and mapping, introduce flood controls or floor levels where appropriate or back zone if land is identified in the flood way.	Medium	Reduced flood risk and development impacts is possible by ensuring that development does not occur in the floodway.	None.	Council are responsible for amending the DCP.
Consider precincts with known 'constrained evacuation' (Section 5.6.1)	Council consider either restricting future development or requiring refuge provision in precincts with known "constrained evacuation" areas	Medium	Reduced risk to life during extreme flood events and reduced requirement on the NSW SES.	None.	Council are responsible for amending the DCP.
Define the Flood Planning Level (Section 5.6.2)	A requirement of the Floodplain Development Manual. Used to set requirements for floor levels and flood proofing in development controls.	High	For residential properties it ensures habitable floor levels are above an appropriate level (typically 1% AEP flood level plus freeboard) and therefore reduced flood damages. For commercial, and other less vulnerable land uses, the FPL can be used to set requirements for minimum floor level or elevation to which flood proofing must be provided.	Can have implications with requirements for maximum building heights and access to buildings for the less able.	Will be implemented through amendments to the DCP through a Flood Policy. Council to make decision on FPL for uses other than residential although recommendations have been given in this report.

Measure	Description	Priority	Benefits	Concerns	Implementation, Costs and Funding
Redefine the Flood Planning Area and incorporate into Council's DCP (Section 5.6.3)	A requirement of the Floodplain Development Manual. The FPA is required to identify all properties to which flood related development controls will apply. More vulnerable developments within Culcairn such as hospitals, schools, services including power should be preferably situated outside the PMF flood extent or at the very least have floor levels and access at the FPL or PMF level, whichever is higher.	High	Provides a clear method of identifying properties subject to flood related development controls.	There is a need to include properties impacted by both mainstream and overland flow. Also good communication with residents about process is key.	The revised FPA map should be included in Councils DCP.
Update and Re-issue S149 certificates (section 5.6.5)	Issued to residents to identify any hazards at their property and development controls that apply.	Medium	Can inform residents of the flood risk at each property and if Part 5 is also included supply additional information such as the type of flooding affecting the property or whether the property is in a high hazard area or floodway. Ensures residents aware of development controls, such as minimum floor levels, at their property. Can also inform residents of drainage easements through properties and their responsibilities.	Part 2 is compulsory. Some residents do not like the additional information provided under Part 5 and believe it can affect insurance premiums and value of land.	To be implemented by Council. Would follow on from adoption of a revised DCP for flooding.
Provide flood information on Council's website (Section 5.6.5)	Provide flood information on Council's website.	Low	Easily accessible information for the community which will typically reduce Council's workload to produce such information on demand.	None.	To be implemented by Council.

7. ACKNOWLEDGEMENTS

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Greater Hume Shire 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 Office of Environment and Heritage.

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Figures

FIGURE 01
CULCAIRN STUDY AREA

ZONE 1
ZONE 2
ZONE 3
Baird Street
Back Henty Road
Hamilton Street
Melville Street
Gordon Street
Munro Street
Hoy Street
Culcairn Cemetery Rd
Elizabeth Street
Queen Street
Victoria Street
Henty Street
Fifield Close
Culcairn Holbrook Road
Balfour Street
Stock Route
Kimdeen Street
McBean Street
Railway Parade
Edward Street
King Street
Wattle Street
Federal Street
Donald Street
Fraser Street
Blair Street
Gamble Street
Walbundrie Road
Billabong Creek
Olympic Highway
Waterworks Road
Taylors Road

N

Land Proposed for Rezoning
Manual Gauge
Study Area
Roads
Creek
Cadastre

0 0.25 0.5 1 1.5 km

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FIGURE 2
CULCAIRN LEP 2012
LAND USE

ZONE 1
ZONE 2
ZONE 3

Back Henty Road
Olympic Highway
Baird Street
Railway Parade
Melville Street
Gordon Street
Hoy Street
Culcairn Cemetery Rd
Hamilton Street
Lions Place
Elizabeth Street
Douglas Street
Melrose Street
Princes Street
Queen Street
Munro Street
Fifield Close
Culcairn Holbrook Road
Victoria Street
Henty Street
Federal Street
Balfour Street
Stock Route
Kirndeen Street
McBean Street
Fahey Crescent
Edward Street
King Street
Wattle Street
Donald Street
Fraser Street
Blair Street
Walbundrie Road
Waterworks Road

N

Study Area
Land Proposed for Rezoning
Roads

LEP Zones

E2
R5
RE2
RU1
RU4
RU5
SP2
Wetlands/Creeks
Special

0 125 250 500 750 1,000
Meters

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FIGURE 3
CULCAIRN
KEY LOCATIONS AND FLOOD HOTSPOTS

Baird Street
Back Henty Road
Melville Street
Railway Parade
Olympic Highway
Hopetoun Street
Hamilton Street
Lions Place
Thomas Place
Elizabeth Street
Douglas Street
McBean Street
Kirndeen Street
Stock Route
Henty Street
Queen Street
Victoria Street
Gordon Street
Munro Street
Hoy Street
Fifield Close
Culcairn Cemetery Rd
Culcairn Holbrook Road
Federal Street
Balfour Street
Edward Street
King Street
Wattle Street
Donald Street
Fraser Street
Blair Street
South Street
Railway Parade
Melville Street
Gordon Street
Sewerage Works Road

4
4
3
3
2
7
1
6
5
2
1

N

Key Hydraulic Structures
Hotspots
Roads
Reporting Area
1% AEP Event Depth (m)
0.1 - 0.5
0.5 - 0.75
0.75 - 1
1 - 2
> 2

0 0.25 0.5 1 1.5 km

NOTE: Displayed inundation patterns and extents pertain to the 1% AEP event and are based on best available estimates of flood behaviour. Acutal inundation patterns may vary slightly during an event. All depths less than 100 mm have been trimmed from this figure.

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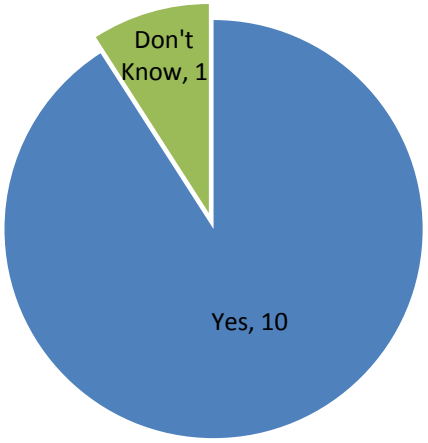
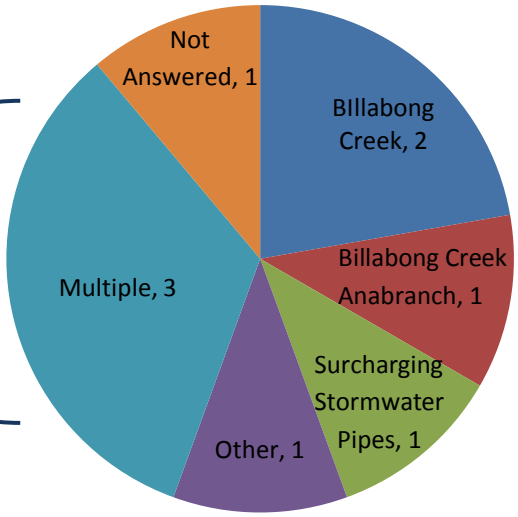
FIGURE 4
COMMUNITY SURVEY RESPONSE SUMMARY
CULCAIRN

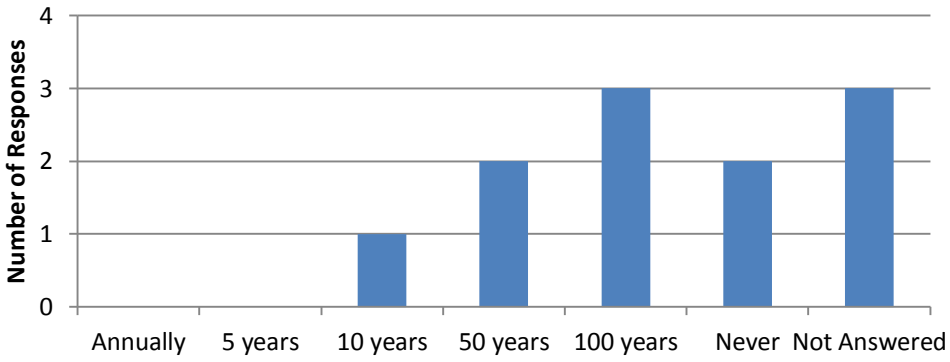
Do you think something should be done to reduce flood risk in Culcairn?



Is the flood risk you are referring to due to: Billabong Creek, Billabong Creek Anabranch or Surcharging Stormwater Pipes



At what frequency would you consider flooding to be "acceptable"?



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

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

FIGURE 05
COMMUNITY CONSULTATION RESPONDENTS
CULCAIRN

Baird Street
Baird Street
Back Henty Road
Melville Street
Gordon Street
Hoy Street
Culcairn Cemetery Rd
Hamilton Street
Melrose Street
Princes Street
Queen Street
Victoria Street
Henty Street
Munro Street
Fifield Close
Culcairn Holbrook Road
Balfour Street
Stock Route
Kirndeen Street
McBean Street
Railway Parade
Federal Street
Edward Street
King Street
Wattle Street
Donald Street
Fraser Street
Blair Street
Gamble Street
Walbundrie Road
Billabong Creek
Olympic Highway
Waterworks Road
Taylors Road

N

Questionnaire Response
Roads
Creek
Cadastre

0 0.25 0.5 1 1.5 km

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FIGURE 6
PROPOSED DEVELOPMENT AREAS
CULCAIRN FLOOD PLANNING AREA

Railway Pde
Olympic Hwy
Baird St
Federal St
Hamilton St
Hopetoun St
Melrose St
Gordon St
Munro St
Douglas St
McBean St
Kimdeen St
Victoria St
Henty St
Balfour St
Culcairn - Holbrook Rd
Culcairn Rd
Fraser St
Wattle St

N

Land Proposed for Rezoning
Culcairn FPA

Meters
0 250 500 1,000 1,500 2,000

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FIGURE 7
PROPOSED DEVELOPMENT AREAS
CULCAIRN 1% AEP HYDRAULIC HAZARD

ZONE 1

ZONE 2

ZONE 3

N

Land Proposed for Rezoning
Reporting Area
True Hydraulic Hazard
Low Hazard
High Hazard

0 0.25 0.5 1 1.5
km

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FIGURE 8
HYDRAULIC CATEGORISATION
1% AEP

Railway Pde
Baird St
Federal St
Hamilton St
Hopetoun St
Melrose St
Melrose St
Gordon St
Munro St
Federal St
Douglas St
Victoria St
Henty St
Balfour St
Culcairn - Holbrook Rd
Kirndeen St
McBean St
Balfour St
Fraser St
Culcairn Rd
Wattle St
Olympic Hwy
Cummings Rd

N

Flood Fringe
Flood Storage
Floodway

0 250 500 1,000 1,500 2,000 m

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FIGURE 9
HYDRAULIC CATEGORISATION
0.5% AEP

Railway Pde
Baird St
Federal St
Hamilton St
Hopetoun St
Melrose St
Melrose St
Gordon St
Munro St
Federal St
Douglas St
Victoria St
Henty St
Balfour St
Culcairn - Holbrook Rd
Kirndeen St
McBean St
Balfour St
Culcairn Rd
Fraser St
Wattle St
Olympic Hwy
Cummings Rd

N

Flood Fringe
Flood Storage
Floodway

0 250 500 1,000 1,500 2,000 m

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FIGURE10
HYDRAULIC CATEGORISATION
PMF

Railway Pde
Baird St
Hamilton St
Hopetoun St
Federal St
Melrose St
Melrose St
Gordon St
Munro St
Federal St
Douglas St
Kirndeen St
McBean St
Victoria St
Henty St
Balfour St
Balfour St
Fraser St
Culcairn Rd
Wattle St
Culcairn - Holbrook Rd
Olympic Hwy
Cummings Rd

N

Flood Fringe
Flood Storage
Floodway

m
0 250 500 1,000 1,500 2,000

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FIGURE 11
TRUE HYDRAULIC HAZARD
CULCAIRN
1% AEP

Back Henty Road
Baird Street
Baird Street
Railway Parade
Melville Street
Gordon Street
Hoy Street
Culcairn Cemetery Rd
Hamilton Street
Melrose Street
Princes Street
Munro Street
Fifield Close
Elizabeth Street
Queen Street
Victoria Street
Henty Street
Henty Street
Federal Street
Federal Street
Balfour Street
Culcairn Holbrook Road
Stock Route
Kimdeen Street
McBean Street
Fahey Crescent
Edward Street
King Street
Wattle Street
Donald Street
Fraser Street
Blair Street
Railway Parade
Melville Street
Walbundrie Road
Olympic Highway
Waterworks Road
Taylors Road

N

Cadastre
Reporting Area
True Hydraulic Hazard
Low Hazard
High Hazard

0 0.25 0.5 1 1.5 km

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FIGURE 12
FLOOD ERP CLASSIFICATIONS
CULCAIRN

ZONE: E
20YR: RISING ROAD ACCESS AREA
100YR: HIGH FLOOD ISLAND
PMP :LOW FLOOD ISLAND

ZONE: A
20YR: NOT FLOOD AFFECTED
100YR: INDIRECTLY AFFECTED
PMP :INDIRECTLY AFFECTED

ZONE: B
20YR: RISING ROAD ACCESS AREA
100YR: HIGH FLOOD ISLAND
PMP :LOW FLOOD ISLAND

ZONE: C
20YR: HIGH FLOOD ISLAND
100YR: LOW FLOOD ISLAND
PMP :LOW FLOOD ISLAND

ZONE: D
20YR: HIGH FLOOD ISLAND
100YR: HIGH FLOOD ISLAND
PMP :LOW FLOOD ISLAND

ZONE: F
20YR: RISING ROAD ACCESS AREA
100YR: HIGH FLOOD ISLAND
PMP :LOW FLOOD ISLAND

ZONE: D
20YR: RISING ROAD ACCESS AREA
100YR: HIGH FLOOD ISLAND
PMP :LOW FLOOD ISLAND

N

ERP ZONE
- A
- B
- C
- D
- E
- F
- 5% Flood Extent
- PMF Flood Extent

1% AEP Flood Depth (m)
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 4.0
- > 4.0

0 0.25 0.5 1 1.5 km

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FIGURE 13
EVENT PROPERTIES FIRST FLOODED ABOVE FLOOR LEVEL

Baird St
Railway Pde
Olympic Hwy
Gordon St
Federal St
Hopetoun St
Hamilton St
Melrose St
Melrose St
Munro St
Federal St
Douglas St
McBean St
Kimdeen St
Victoria St
Henty St
Balfour St
Culcairn - Holbrook
Balfour St
Fraser St
Culcairn Rd
Wattle St

N

Flooding above floor level
- 5yr ARI
- 10% AEP
- 5% AEP
- 2% AEP
- 1% AEP
- 0.5% AEP
- >0.5% AEP

Flooding above floor level
- Residential
- Commercial

0 0.5 1 km

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FIGURE 14
FLOOD PLANNING AREA AND LEVELS METHODOLOGY

Zone 3

- The red area in Zone 3 is defined by the 1% AEP flood extent.
- The yellow area in Zone 3 is the FPA defined as the 1% AEP extent plus 0.3 m freeboard, trimmed such that this FPA extent does not exceed the 0.2% AEP flood extent (trimmed to 0.15 m).

Zone 1

- The blue area in Zone 1 is defined by the 1% AEP flood extent.
- The red area in Zone 1 is the FPA defined as the 1% AEP extent plus 0.3 m freeboard, trimmed such that this FPA extent does not exceed the 0.2% AEP flood extent (trimmed to 0.15 m).

ZONE 1

ZONE 3

ZONE 2

Zone 2

- The red area in Zone 2 is the FPA defined as the 1% AEP extent plus 0.3 m freeboard, trimmed such that this FPA extent does not exceed the 0.2% AEP flood extent (trimmed to 0.15 m).

N

FPA Zones
- Zone 1
- Zone 2
- Zone 3

Proposed FPL
- 1%+0.15m
- 1%+0.3m
- 1%+0.5m

0 0.25 0.5 1 km

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FIGURE 15
FLOOD PLANNING AREA

Back Henty Road
Baird Street
Baird Street
Railway Parade
Melville Street
Gordon Street
Hoy Street
Culcairn Cemetery Rd
Hamilton Street
Melrose Street
Princes Street
Elizabeth Street
Queen Street
Munro Street
Fifield Close
Culcairn Holbrook Road
Victoria Street
Henty Street
Henty Street
Federal Street
Balfour Street
Stock Route
Kirndeen Street
McBean Street
Faney Crescent
Federal Street
Edward Street
Donald Street
Fraser Street
Blair Street
Railway Parade
Melville Street
King Street
Wattle Street
Walbundrie Road
Olympic Highway
Waterworks Road
Taylors Road

N

Cadastre
Reporting Area
Flood Planning Area

0 0.25 0.5 1 1.5
km

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Appendix A

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 flood 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 standard flood event in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or major overland flow paths through developed areas outside of defined drainage reserves; and/or the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding.
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 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

FLOOR LEVEL SURVEY FOR CULCAIRN, HENTY AND HOLBROOK FLOODPLAIN RISK MANAGEMENT STUDIES

1. Background

WMAwater are preparing the Culcairn, Henty and Holbrook Floodplain Risk Management Studies on behalf of Greater Hume Shire Council. Part of this work involves obtaining floor levels of all potential flood liable buildings (habitable and commercial buildings but not sheds or garages) within the study area (attached plans). To undertake the survey WMAwater seeks to appoint a suitably qualified and experienced surveyor to obtain building information for the properties as shown on the attached figures and tables.

You are invited to provide a quotation by **Friday 29th August**, detailing your fixed price proposal and timeframe for completion to undertake the works as described below.

2. Floor Level Survey

Complete the attached example Table 1 for each of the properties/buildings.

The following number of properties will be surveyed:

- Culcairn – 117 buildings
- Henty – 12 buildings
- Holbrook – 108 buildings

In addition to the above listed properties an estimated 10 not yet identified utilities situated within these towns will also require survey. This should be factored into your quote and the locations of these will be provided at a later date. Including these 10 utilities there are total of 247 properties that require survey.

The requested properties with buildings that need to be surveyed are identified on the attached figures and tabulated address lists. These can also be provided in the form of GIS layers (Mapinfo and ArcGIS format) if required. The number of properties does not necessarily indicate the exact number of buildings to be surveyed; this is particularly important for commercial areas. In some instances several properties may span one building or there may be several buildings on each property. Please ensure that where there is more than one building on a property, all commercial, industrial and residential buildings are surveyed (and identified as residential, commercial/industrial or other). Any small sheds or garages do not need to be included. This is not expected to significantly affect the number of properties to be surveyed as the majority of buildings in these towns are stand alone homes.

We have provided the following information to assist you with your quotation:

- Figures showing the properties to be surveyed in each town (this can be provided in GIS format if required - MapInfo or ArcGIS);
- Address lists for each town of the properties that require survey; and
- Example table for format of floor level information.

It is not expected that private property will need to be accessed to complete the proposed works. However please note that the surveyor is to follow all OEH/Council protocols for entering private property and the relevant Occupational Health and Safety requirements for working in traffic. In addition to this, all properties not surveyed will need to detail the reason why survey has not been performed. If a level is taken at a location other than the floor level this must also be noted with details provided.

3. Deliverables

The following deliverables are required for each survey.

- Completed Table 1 in a spreadsheet to include;
    - WMA property ID;
    - Number of buildings on property (small sheds / garages do not need to be included);
    - Property name, number and street address;
    - XY co-ordinate of survey point in MGA56;
    - Indicative ground level of property (taken at the same location as floor level survey mark or as close as possible) in mAHD;
    - Lowest floor level (lowest habitable level if residential) in mAHD;
    - If residential;
        - Habitable floor level;
        - Number of storeys;
        - Comment if habitable uses on ground floor;
        - House size (observational estimate);
        - Floor and Wall construction.
    - If non-residential;
        - Type of use, Commercial, Industrial, Public etc;
        - Name / nature of business or use;
        - Lowest floor level;
        - Approximate floor area;
        - Floor and Wall construction.

For residential blocks where one floor level applied to the block, the number of ground floor properties needs to be noted. Likewise for commercial office blocks, the number of ground floor companies needs to be noted.

4. Projection and Datum

All data is required in the Map Grid of Australia (MGA) Zone 55 projected Cartesian coordinate system, based on the Geocentric Datum of Australia (GDA) 1994 geocentric coordinate system. An easting and northing is required for each survey point. All survey levels will be in metres reduced to Australian Height Datum (m AHD).

5. Tender Requirements

Please provide a fixed price quotation to undertake the above work together with a timetable for completion via email to **richards@wmawater.com.au by Friday 29th August**. Please contact the undersigned if you require any further clarification.

Zac Richards – Project Engineer
WMAwater, Level 2, 160 Clarence Street, SYDNEY, NSW 2000
Telephone: (02) 9299 2855
Email: richards@wmawater.com.au

ATTACHMENTS:

- Figure 1 – Culcairn properties map
- Figure 2 – Henty properties map
- Figure 3 – Holbrook properties map
- Table 1 – Example of data format for completion
- Table 2 – Culcairn properties list
- Table 3 – Henty properties list
- Table 4 – Holbrook properties list

FIGURE 01
CULCAIRN
FLOOR LEVEL SURVEY

Hamilton Street
Lions Place
Thomas Place
Railway Parade
Melville Street
Olympic Highway
Hopetoun Street
Gordon Street
Munro Street
Hoy Street
Melrose Street
Princes Street
Fifield Close
Elizabeth Street
Queen Street
Douglas Street
Douglas Street
Victoria Street
Victoria Street
Black Street
Henty Street
Henty Street
Federal Street
Albert Street
Balfour Street
Balfour St (Service Rd)
Stock Route
Kimdeen Street
McBean Street
Henty Street
Federal Street
Balfour Street
Edward Street
Gordon Street
Gamble Street
Donald Street
Fraser Street
Blair Street
Railway Parade
Munro Street
King Street
King Street
King Street
Wattle Street
Walbundrie Road
South Street
Jubilee Park Road
Waterworks Road

N

Properties
Roads
Cadastre

0 0.25 0.5 1 1.5
km

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FIGURE 02
HENTY
SURVEY PROPERTIES

Angaston Road
Grubben Road
West Showground Road
Henty Pleasant Hills Road
Buckargingah Creek
Olympic Highway
Comer Street
Barisch Avenue
Elm Street
Comer Street
Railway Parade
Fox Street
Graham Street
Keighran Street
Smart Street

N

Properties
Roads
Creek
Cadastre

0 0.05 0.1 0.2 0.3 km

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FIGURE 03
HOLBROOK
SURVEY PROPERTIES

Mountain Creek Road
Culcairn Holbrook Road
Tip Road
Diggers Lane
Millswood Road
Bond Street
Spring Street
Fleet Street
Steel Street
Bath Street
Rankin Street
Ford Street
Racecourse Road
Bruce Street
Morgans Ridge Creek
Raymond Street
Wallace Street
Murdoch Place
Spurr Street
Railway Parade
Webb Street
Stirbeck Street
Croft Street
Welton Street
Frampton Street
Thorpe Street
Swift Street
Peel Street
Vine Street
Ross Street
Young Street
King Street
Wilson Street
Hume Highway
Hume Street
Bowler Street
Halford Drive
Gundagai Street
Hay Street
Young Street
Murray Street
Ten Mile Creek
Nyhan Street
Byng Street
Bardwell Street
Macinnes Street
William Street
Hume Freeway
Malabar Road
Jingellic Road

N

Properties
Roads
Creeks

0 0.25 0.5 1 1.5 2 km

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Table 1 - Format for Provision of Floor Level Data

									RESIDENTIAL BUILDINGS						NON RESIDENTIAL BUILDINGS						
WMA ID	Total number of buildings	Comment	Street Number	Street Name	Sub-Area	Easting	Northing	Indicative Ground Level (m AHD)	Lowest Habitable Floor Level (m AHD)	Number of Storeys	Do people live on the Ground Floor (Y or N)	**House Size** - Small (S), Medium (M), Large (L)	**Floor Construction** Pier (P) or Slab (S) Other - describe	**Wall Construction** Brick stone or rendered (B), Clad (C) , Mixed (M)	Type (commercial = C, industrial = I, public = P)	Name and Nature of Use/Business eg. Bob's Nursery, toilet block	Lowest Floor Level (m AHD)	Approximate Floor Area (m^2)	**Floor Construction** Pier (P) or Slab (S) Other - describe	**Wall Construction** Brick stone or rendered (B), Clad (C) , Mixed (M)	
HOL1	1		31	Smith Street	Holbrook	349719.030	6298859.741	152.53	152.81	1	Y	L	S	B							
HOL2	1		36	Smith Street	Holbrook	349719.030	6298859.741	156.35	154.19	1	Y	L	S	B							
HOL3	2	building 1	38a	Smith Street	Holbrook	349719.030	6298859.741	152.86	153.25	2	Y	L	S	M							
		building 2	38b	Smith Street		349719.030	6298859.741	152.83	153.45	2	Y	L	S	M							
HOL5	2		67	Jones Road	Holbrook	349719.030	6298859.741	152.50							C	BOB'S ELECTRICAL	154.47	225	S	M	second building is shed
HOL6	1		11	Jones Road	Holbrook	349719.030	6298859.741	152.50							C	CENTRAL COAST STAIRS	152.84	1000	S	M	
HOL7	1		15	Jones Road	Holbrook	349719.030	6298859.741	152.08							I	CUSTOM STAINLESS DESIGN	152.30	800	S	B	
HOL8	1		2A	Newcastle Street	Holbrook	349719.030	6298859.741	162.40	162.91	1	Y	L	P	C							
HOL10	1		31	Newcastle Street	Holbrook	349719.030	6298859.741	152.19	152.79	2	Y	S	P	B							
HOL11	1	flats - 5 units on ground floor	1	Bob Street	Holbrook	349719.030	6298859.741	153.26	153.98	56	Y	S	S	C							All units on ground floor have same floor level

Table 2

Culcairn Property Addresses

ID	X	Y	Address	ID	X	Y	Address
CUL1	503992	6052908	16 MUNRO STREET	**CUL73**	503671	6053597	11 MELROSE STREET
CUL2	503888	6052920	VACANT LAND' 22 EDWARD STREET	**CUL74**	503705	6053598	12 MELROSE STREET
CUL3	503655	6053122	24 HENTY STREET	**CUL75**	503768	6053607	14 MELROSE STREET
CUL4	503807	6052940	CULCAIRN HOSPITAL' 53 BALFOUR STREET	**CUL76**	503752	6053645	15 HOPETOUN STREET
CUL5	503997	6052932	18 MUNRO STREET	**CUL77**	503670	6053658	7 HOPETOUN STREET
CUL6	504034	6052925	5 FAHEY CRESCENT	**CUL78**	503610	6053635	1 HOPETOUN STREET
CUL7	504032	6052954	7 FAHEY CRESCENT	**CUL79**	503763	6053735	8 HOPETOUN STREET
CUL8	504145	6053018	81 BALFOUR STREET	**CUL80**	504085	6053466	46 MUNRO STREET
CUL9	504120	6053017	79 BALFOUR STREET	**CUL81**	504141	6053849	84 MUNRO STREET
CUL10	504098	6053014	77 BALFOUR STREET	**CUL82**	504162	6053930	88 MUNRO STREET
CUL11	504137	6052983	17 FEDERAL STREET	**CUL83**	504168	6053950	90 MUNRO STREET
CUL12	504131	6052958	15 FEDERAL STREET	**CUL84**	504170	6053974	90A MUNRO STREET
CUL13	504127	6052935	13 FEDERAL STREET	**CUL85**	504186	6053963	90A MUNRO STREET
CUL14	504119	6052895	9 FEDERAL STREET	**CUL86**	504171	6054016	92 MUNRO STREET
CUL15	504068	6052908	8 FAHEY CRESCENT	**CUL87**	504370	6052288	NILLIMBEK' 165 TAYLORS ROAD
CUL16	504177	6052991	CULCAIRN SWIMMING POOL' FEDERAL STREET	**CUL88**	504398	6052369	NILLIMBEK' 165 TAYLORS ROAD
CUL17	504218	6053183	24 FEDERAL STREET	**CUL89**	504052	6052324	WATTLE STREET
CUL18	504157	6053098	108 BALFOUR STREET	**CUL90**	503662	6052542	1 MELVILLE STREET
CUL19	504034	6053180	30 MUNRO STREET	**CUL91**	503943	6052908	26 EDWARD STREET
CUL20	504147	6053165	19 FEDERAL STREET	**CUL92**	503997	6052965	20 MUNRO STREET
CUL21	503912	6053047	90 BALFOUR STREET	**CUL93**	503525	6052869	6 MELVILLE STREET
CUL22	503869	6053038	86 BALFOUR STREET	**CUL94**	503550	6052897	41 BALFOUR STREET
CUL23	503849	6053035	84 BALFOUR STREET	**CUL95**	503526	6052902	CORNER OF BALFOUR AND MELVILLE STREETS
CUL24	503829	6053035	82 BALFOUR STREET	**CUL96**	503660	6052927	45 BALFOUR STREET
CUL25	503804	6053105	18 GORDON STREET	**CUL97**	503614	6052912	CULCAIRN PUBLIC SCHOOL' BALFOUR STREET
CUL26	503802	6053079	16 GORDON STREET	**CUL100**	503467	6052877	RAILWAY PARADE
CUL27	503836	6053108	29 HENTY STREET	**CUL101**	503280	6052593	CULCAIRN CARAVAN PARK' OLYMPIC HIGHWAY
CUL28	503856	6053112	31 HENTY STREET	**CUL102**	502928	6052585	5 SOUTH STREET
CUL29	503878	6053114	33 HENTY STREET	**CUL103**	503056	6052564	7 SOUTH STREET
CUL30	503897	6053122	35 HENTY STREET	**CUL104**	502417	6052594	WILLESDENE' 101 WALBUNDRIE ROAD
CUL31	503914	6053120	37 HENTY STREET	**CUL105**	502373	6052614	WILLESDENE' 101 WALBUNDRIE ROAD
CUL32	503811	6053151	20 GORDON STREET	**CUL106**	502773	6052349	MALABAR' 2901 OLYMPIC HIGHWAY
CUL33	503835	6053156	20 GORDON STREET	**CUL107**	503108	6052912	18 BALFOUR STREET
CUL34	503831	6053179	20 GORDON STREET	**CUL108**	502919	6052860	2 BALFOUR STREET
CUL35	503860	6053167	38 HENTY STREET EAST	**CUL109**	502949	6052855	8 BALFOUR STREET
CUL36	503631	6052983	66 BALFOUR STREET	**CUL110**	502969	6052909	1 KIRNDEEN STREET
CUL37	503615	6053070	17 HENTY STREET	**CUL111**	503063	6053577	51 MCBEAN STREET
CUL38	503635	6053071	19 HENTY STREET	**CUL112**	503247	6053743	24 HAMILTON STREET
CUL39	503652	6053072	21 HENTY STREET EAST	**CUL113**	503811	6053745	10 HOPETOUN STREET
CUL40	503674	6053077	23 HENTY STREET EAST	**CUL114**	503824	6052575	9 WATTLE STREET
CUL41	503692	6053078	25 HENTY STREET	**CUL115**	503846	6052584	9 WATTLE STREET
CUL42	503738	6053092	23 GORDON STREET	**CUL116**	503881	6052591	11A WATTLE STREET
CUL43	503727	6053061	21 GORDON STREET	**CUL117**	503895	6052594	11A WATTLE STREET
CUL44	503561	6053098	22 MELVILLE STREET	**CUL118**	503925	6052583	13 WATTLE STREET
CUL45	503565	6053123	24 MELVILLE STREET	**CUL119**	503512	6053141	25 MELVILLE STREET
CUL46	503584	6053108	22 MELVILLE STREET				
CUL47	503595	6053112	1 VICTORIA STREET				
CUL48	503592	6053130	1 VICTORIA STREET				
CUL49	503619	6053115	20 HENTY STREET EAST				
CUL50	503635	6053121	22 HENTY STREET				
CUL51	503689	6053128	28 HENTY STREET EAST				
CUL52	503685	6053149	28 HENTY STREET EAST				
CUL53	503672	6053126	26 HENTY STREET EAST				
CUL54	503752	6053208	12 VICTORIA STREET				
CUL55	503701	6053200	8 VICTORIA STREET				
CUL56	503673	6053193	6 VICTORIA STREET				
CUL57	503772	6053218	14 VICTORIA STREET				
CUL58	503574	6053170	26 MELVILLE STREET				
CUL59	503575	6053191	28 MELVILLE STREET				
CUL60	503604	6053265	34 MELVILLE STREET				
CUL61	503631	6053182	2 VICTORIA STREET				
CUL62	503598	6053337	36 MELVILLE STREET				
CUL63	503627	6053375	40 MELVILLE STREET				
CUL64	503635	6053445	2 PRINCES STREET				
CUL65	503595	6053435	44 MELVILLE STREET				
CUL66	503582	6053460	46 MELVILLE STREET				
CUL67	503629	6053524	5 MELROSE STREET				
CUL68	503699	6053529	9 MELROSE STREET				
CUL69	503747	6053537	13 MELROSE STREET				
CUL70	503772	6053551	15 MELROSE STREET				
CUL71	503598	6053564	CULCAIRN MOTOR INN' 2 MELROSE STREET				
CUL72	503591	6053591	CULCAIRN MOTOR INN' 2 MELROSE STREET				

Table 3

Henty Property Addresses

ID	X	Y	Address
HEN1	502338	6070215	'EDEN PARK' 2350 HENTY PLEASANT HILLS ROAD
HEN2	502446	6070178	2363 HENTY PLEASANT HILLS ROAD
HEN3	502647	6070341	'HENTY SHOWGROUND' HENTY PLEASANT HILLS ROAD
HEN4	502341	6070324	2341 HENTY PLEASANT HILLS ROAD
HEN5	502314	6070341	'BUNDERRY' 73 ANGASTON ROAD
HEN6	502527	6070173	2363 HENTY PLEASANT HILLS ROAD
HEN7	503177	6070758	'LOW PLAINS' 5570 OLYMPIC HIGHWAY
HEN8	503199	6070442	5540 OLYMPIC HIGHWAY
HEN9	503205	6070422	5538 OLYMPIC HIGHWAY
HEN10	502730	6069942	ELM STREET
HEN11	503061	6070464	2 ANGASTON ROAD
HEN12	503062	6070532	GRUBBEN ROAD

Table 4

Holbrook Property Addresses

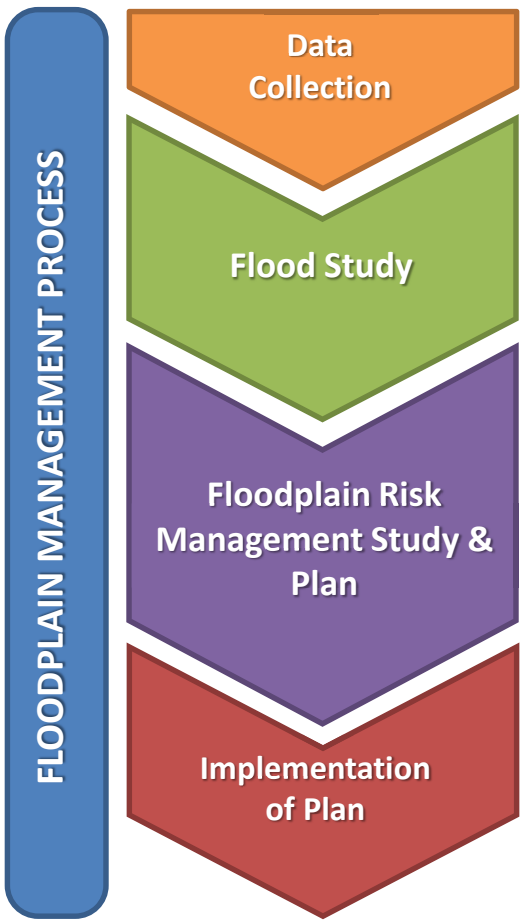
ID	X	Y	Address	ID	X	Y	Address
HOL1	528102	6046836	31 BOWLER STREET	HOL73	528079	6045975	2 BARDWELL STREET
HOL2	528289	6046550	97 ALBURY STREET	HOL74	528102	6045967	2 BARDWELL STREET
HOL3	528286	6046530	89 ALBURY STREET	HOL75	528123	6045974	8 BARDWELL STREET
HOL4	528264	6046479	'HOLBROOK HALL & OLD OFFICES' 40 YOUNG STREET	HOL76	528136	6046019	1 BYNG STREET
HOL5	528344	6046499	78-80 ALBURY STREET	HOL77	528096	6046049	JOLLY SWAGMAN MOTEL' 46 ALBURY STREET
HOL6	528402	6046464	1 SWIFT STREET	HOL78	528121	6046076	JOLLY SWAGMAN MOTEL' 46 ALBURY STREET
HOL7	528602	6046787	53 SWIFT STREET	HOL79	528168	6046080	3 BYNG STREET
HOL8	528594	6046772	51 SWIFT STREET	HOL80	528126	6046151	50 ALBURY STREET
HOL9	528584	6046754	49 SWIFT STREET	HOL81	528109	6046123	48 ALBURY STREET
HOL10	528520	6046400	51 YOUNG STREET	HOL82	528159	6046196	52 ALBURY STREET
HOL11	528496	6046410	49 YOUNG STREET	HOL83	528249	6046210	17 BYNG STREET
HOL12	528477	6046422	47 YOUNG STREET	HOL84	528179	6046237	56 ALBURY STREET
HOL13	528466	6046433	45 YOUNG STREET	HOL85	528182	6046254	60 ALBURY STREET
HOL14	528456	6046445	43 YOUNG STREET	HOL86	528229	6046317	68 ALBURY STREET
HOL15	528475	6046471	10 SWIFT STREET	HOL87	528236	6046336	72 ALBURY STREET
HOL16	528484	6046484	10 SWIFT STREET	HOL88	528252	6046352	76 ALBURY STREET
HOL17	528567	6046485	17 GUNDAGAI STREET	HOL89	528298	6046320	4 HAY STREET
HOL18	528579	6046502	19-21 GUNDAGAI STREET	HOL90	528286	6046331	2 HAY STREET
HOL19	528537	6046572	20 SWIFT STREET	HOL91	527919	6045972	MORRISONS' ALBURY STREET
HOL20	528581	6046559	10 HUME STREET	HOL92	528011	6046071	GLENNDALE PARK MOTEL' 59-65 ALBURY ST
HOL21	528572	6046573	22 SWIFT STREET	HOL93	527938	6046063	2-4 NYHAN STREET
HOL22	528610	6046547	12 HUME STREET	HOL94	527964	6046133	10-12 NYHAN STREET
HOL23	528491	6046504	12 SWIFT STREET	HOL95	527999	6046172	14 NYHAN STREET
HOL24	528650	6046634	11 HUME STREET	HOL96	528036	6046209	10 MURRAY STREET
HOL25	528634	6046633	9 HUME STREET	HOL97	528015	6046220	8 MURRAY STREET
HOL26	528654	6046598	13 HUME STREET	HOL98	527935	6046202	17 NYHAN STREET
HOL27	528635	6046601	11 HUME STREET	HOL99	528369	6045854	31 MCINNES STREET
HOL28	528623	6046613	9 HUME STREET	HOL100	528341	6045943	28 BARDWELL STREET
HOL29	528676	6046773	38 SWIFT STREET	HOL101	528044	6046266	7A MURRAY STREET
HOL30	528731	6046736	65 BOWLER STREET	HOL102	528089	6046238	77 ALBURY STREET
HOL31	528767	6046739	BRIGADOON' 65 BOWLER STREET	HOL103	528107	6046225	77 ALBURY STREET
HOL32	528794	6046730	BOWLER STREET	HOL104	528120	6046241	79 ALBURY STREET
HOL33	528816	6046730	67 BOWLER STREET	HOL105	528130	6046273	HOLBROOK TYRE SERVICE' 81 ALBURY STREET
HOL34	528863	6046750	67A BOWLER STREET	HOL109	528174	6046323	WOOLPACK INN MUSEUM' 83 ALBURY ST
HOL35	527909	6046779	9 PURTELL STREET	HOL111	528317	6046311	6 HAY STREET
HOL36	527745	6046892	1 BOWLER STREET	HOL112	528510	6045862	45 MCINNES STREET
HOL37	527762	6046969	26-28 RAILWAY PARADE				
HOL38	527821	6046907	7-9 BOWLER STREET				
HOL39	528970	6047031	38 PEEL STREET				
HOL40	528987	6047053	40 PEEL STREET				
HOL41	528995	6047072	42 PEEL STREET				
HOL42	529200	6047146	2-8 VINE STREET				
HOL43	529432	6047320	RANKIN STREET				
HOL44	529102	6047110	1 VINE STREET				
HOL45	527594	6047492	PEARDONS MILL' TIP ROAD				
HOL46	527664	6047521	PEARDONS MILL' TIP ROAD				
HOL47	527623	6047529	PEARDONS MILL' TIP ROAD				
HOL48	529896	6044370	WATER PARK' 224 JINGELLIC ROAD				
HOL49	529999	6044248	WATER PARK' 224 JINGELLIC ROAD				
HOL50	528863	6045696	96 JINGELLIC ROAD				
HOL51	528843	6045660	96 JINGELLIC ROAD				
HOL52	528682	6045686	THE OASIS' MCINNES STREET				
HOL53	528695	6045746	THE OASIS' MCINNES STREET				
HOL54	528692	6045730	THE OASIS' MCINNES STREET				
HOL55	528833	6045938	THE OLD PARSONAGE' 78 JINGELLIC ROAD				
HOL56	528508	6045831	45 MCINNES STREET				
HOL57	528486	6045834	43 MCINNES STREET				
HOL58	528469	6045835	41 MCINNES STREET				
HOL59	528451	6045843	39 MCINNES STREET				
HOL60	528428	6045843	37 MCINNES STREET				
HOL61	528404	6045933	32 BARDWELL STREET				
HOL62	528323	6045942	26 BARDWELL STREET				
HOL63	528283	6045944	22 BARDWELL STREET				
HOL64	528262	6045954	18-20 BARDWELL STREET				
HOL65	528267	6046001	21 BARDWELL STREET				
HOL66	528288	6046028	3 NOLAN STREET				
HOL67	528217	6046031	4-6 BYNG STREET				
HOL68	528345	6046268	18 BYNG STREET				
HOL69	528221	6045957	16 BARDWELL STREET				
HOL70	528206	6045963	14 BARDWELL STREET				
HOL71	528183	6045962	10-12 BARDWELL STREET				
HOL72	528152	6045896	11 MCINNES STREET				

Appendix C

Culcairn

Floodplain Risk Management Study & Plan

A Floodplain Risk Management Study and Plan (the Study) is currently being prepared for Culcairn. This is the next phase of the Floodplain Management Process after completion of the Culcairn, Henty and Holbrook Flood Studies (the Flood Study) last year. Greater Hume Shire Council (Council) has appointed WMAwater to undertake this Study.



The Floodplain Management Process

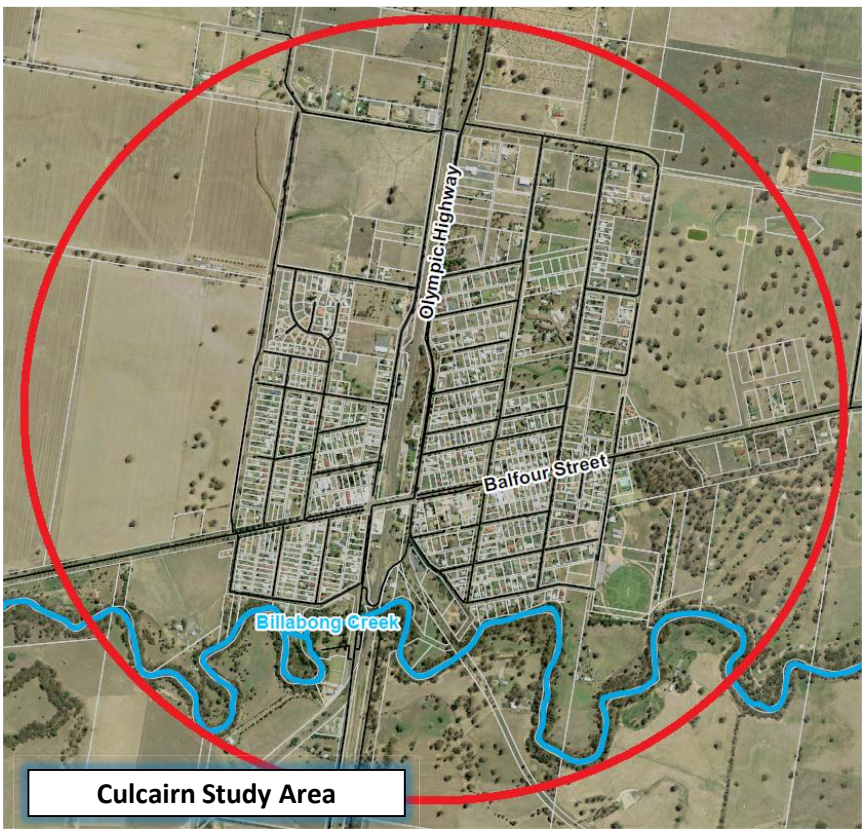
The State Government's Flood Policy aims to reduce the impacts of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding. Under the Policy, local government is responsible for managing flood liable land.

The Policy encourages the development of:

- solutions to existing flood problems in developed areas and
- strategies for ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in existing developed areas.

The State Government's Flood Policy provides for technical and financial support for a number of floodplain management activities. Funding for this study was provided from the State Government's Flood Risk Management Program and Greater Hume Shire Council.

Culcairn Study Area and Flood History



Flood risk at Culcairn is primarily due to Billabong Creek (the Creek) which at Culcairn has a catchment area of 1,800 km². High flood levels in the Creek cause flooding in an anabranch which passes under Balfour Street near Federal Street before flowing in a north-westerly direction through central Culcairn. Elevated Creek levels can also lead to flooding in Gordon, Henty and Blair Streets due to a surcharging stormwater pipe. The anabranch, in combination with the surcharging stormwater pipe and local overland flow flooding, form the dominant mechanisms responsible for over floor flooding in Culcairn.

During October 2010 and again in March 2012 record flooding occurred in Culcairn due to a combination of mechanisms mentioned above. The larger of these two events, the October 2010 flood, inundated approximately 30 homes and businesses over floor level and caused significant damage throughout the town. The Flood Study estimated that this event had an Average Recurrence Interval (ARI) between 50 and 100 years.

Culcairn

Floodplain Risk Management Study & Plan

An important aspect of this Study is devising various flood mitigation options that will reduce flood risk, liability and damage. WMAwater engineers have come up with various mitigation measures, however often flood affected communities also will have various ideas of how flood affectation can be reduced. This is where we need your help. Please complete the attached questionnaire and come to our community workshop day at Culcairn.

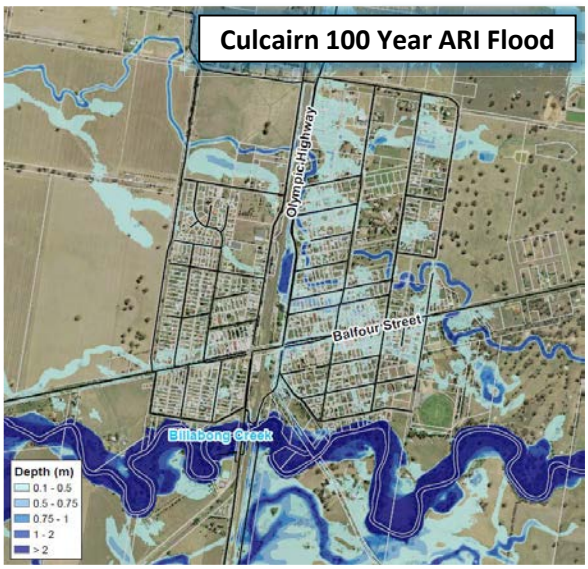
Come along to our Community Workshop

When: **Tuesday 14th October at 2:00 pm to 8:00 pm**

Where: **Culcairn Community Library**
Balfour Street, Culcairn

Flood Mitigation through Computer Modelling

The Flood Study aimed at understanding and determining the nature and extent of flood affectation in Culcairn. As part of this work detailed computer models were established to model flood behaviour in the Study Area. One of the benefits of these models is that various flood mitigation measures can be tested to determine what works will provide the greatest mitigating effect whilst insuring that there are no negative impacts such as increased flood levels in the surrounding areas.



What mitigation works can help reduce flood risks?

Flood Mitigation Works

Various types of flood mitigation works are used to reduce flood affectation. Not all mitigation measures are appropriate for all areas. For example, levees are often used to exclude flood water due to riverine or creek flooding from flood prone areas, however these will often increase flood levels and affectation outside of the levee as well as stopping local runoff from entering the creek, inadvertently causing flooding inside to the levee as well. Accordingly, a detailed investigation of all proposed flood mitigation works must be undertaken using the Flood Study Models.

Levees

Levees are used to exclude flood water from flood prone areas. A well known example of this is at Wagga Wagga where a levee protects the Wagga CBD from Murrumbidgee River flooding. Levees are often constructed of earthen embankments or from reinforced concrete if limited space is available.


Example earth bank levee

Culverts and Bridges

Culverts and bridges allow water to flow under roads, train tracks or similar obstructions. The use of bridges and culverts helps reduce upstream flood levels until the capacity of the structure is exceeded. In some instances it may be beneficial to increase the conveyance capacity of existing culverts to decrease upstream water levels, however the downstream impacts of such works must also be taken into account.

Drains and Channels

Drains and channels assist in the removal of floodwaters by increasing the rate at which flow is dispersed from a flood affected area. These structures are often situated in existing flow paths and are generally either earthen or concrete lined. A good example of a drainage channel in Culcairn is the Billabong Creek anabranch through town. This is a naturally occurring feature which acts as a pseudo drainage channel for local overland flows during smaller rainfall events.

Culcairn

Floodplain Risk Management Study & Plan

In some instances, flood mitigation works such as those mentioned on the previous page may not be suitable for mitigation of flood risk and affectation. In such situations flood risk management measures may be better suited to reduce risk to life and property.

Property Modification Measures

Voluntary Purchase

Voluntary Purchase (VP) involves the acquisition of flood affected properties situated in high hazard areas, and demolition of the residence to remove it from the floodplain. The New South Wales State Government recognises VP as an effective floodplain risk management measure for existing properties in areas where:

- There are highly hazardous flood conditions from riverine or overland flooding 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 the removal of a building may be part of a floodway clearance program that aims to reduce significant impacts on flood behaviour elsewhere in the floodplain by enabling the floodway to more effectively perform its flow conveyance function.
- Purchase of a property enables other flood mitigation works (such as channel improvements or levee construction) to be implemented because the property will impede construction or may be adversely affected by the works with impacts not able to be offset.

High Hazard Flooding

VP is an effective strategy where it is impractical or uneconomic to mitigate high flood hazard to an existing property and it is more appropriate to cease occupation to meet the above objectives. Government funding for VP schemes can be made available through the Floodplain Management Program as long as a number of complying criteria are met.

It is important to note that all properties involved in a VP scheme are valued by Valuer General of NSW and the property is assessed as though it is flood unencumbered. As part of this Study we are interested in determining the level of community interest in such a scheme. The questionnaire attached to this newsletter provides you with an opportunity to tell us if you would be willing to be involved in the VP process. Please note that the VP process is entirely voluntary and anyone involved in the scheme can withdraw at anytime. Also worth noting, where such a scheme is implemented it is done on a priority basis and such schemes can take many years to be carried out in full.

Voluntary House Raising

Voluntary House Raising (VHR) has been widely used throughout NSW to eliminate or significantly reduce flooding of habitable floors particularly in lower hazard flood areas, albeit in limited overall numbers. VHR is recognised as an effective floodplain risk management measure for both riverine and overland flood conditions. It is generally undertaken:

House Raising

- To reduce the frequency of exposure to flood damage of the house and its contents – reducing the frequency of household disruption, associated trauma and anxiety, and clean up after floods may also have social benefits.
- As a compensatory measure where flood mitigation works adversely affect a house which is generally considered part of the mitigation work rather than a separate VHR scheme.

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. It should be part of an overall floodplain risk management strategy for an area rather than a stand-alone option as it does not deal with issues such as risk to life.

More information on the NSW Government's VP and VHR schemes can be obtained from:

http://www.environment.nsw.gov.au/resources/water/coasts/20130055fmpvolpurchase.pdf
http://www.environment.nsw.gov.au/resources/water/coasts/20130056fmpvolraising.pdf

Culcairn

Floodplain Risk Management Study & Plan

Community involvement in the Study is important. The Culcairn Floodplain Management Committee includes members from Council, Office of Environment and Heritage, the State Emergency Services and local residents who will oversee this Study. A questionnaire is included with this newsletter so that your views and ideas can be included in this Study. You are also invited to attend a community workshop where we welcome you to provide input into potential flood management options in more detail as well as to discuss the Study.

How can I have my say?

A questionnaire is enclosed with this newsletter. Please complete this and return to the FREEPOST address in the envelope provided.

Please make sure that all surveys are returned before 24th October 2014 or they may not be counted.

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

The easiest and best way to be heard is to attend the community workshop at Culcairn Library on Tuesday 14th October 2014 between 2 pm and 8 pm.

Feedback from the community will be analysed and considered in this Floodplain Risk Management Study.

The hydraulic models constructed in the Flood Study will be used to assess the impacts of the potential mitigation options raised by the community in more detail and determine if these mitigation ideas are commercially viable. Modelling will also ensure that there are no negative impacts in the surrounding areas. The community workshop will be run in conjunction with this newsletter/questionnaire to provide opportunity for the community to ask questions in an open forum and to assist WMAwater engineers in determining potential mitigation works.

Contacts

If you would like to know more or have any information on flooding which would assist in this Study, please complete the relevant sections on the questionnaire and return using the provided 'postage paid' envelope. Additional information and comment can be attached to the questionnaire when you return it or provided to the contacts below.

Michael Oliver
Manager Infrastructure & Traffic
moliver@greaterhume.nsw.gov.au

Greater Hume Shire Council
40 Balfour Street, Culcairn NSW, 2660

Tel: 02 6029 8588

Zac Richards
Project Engineer
culcairn@wmawater.com.au

WMAwater
Level 2, 160 Clarence Street
Sydney, NSW 2000

Tel: 02 9299 2855

Culcairn

Floodplain Risk Management Study & Plan

Please complete this questionnaire and return to the FREEPOST address in the envelope provided. Please make sure that all surveys are returned before 24th October 2014 or they may not be counted.

1. Your Details

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

Name:

Address:

Telephone:

Email:

2. Can we contact you directly for more information?

☐ Yes ☐ No

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

3. Do you think something should be done to reduce flood risk in Culcairn?

☐ Yes ☐ No ☐ Don't Know

4. Is the flood risk you are referring to due to:

☐ Billabong Creek ☐ The Billabong Creek anabranch ☐ Surcharging Stormwater Pipes ☐ Other

If 'Other', please detail the source of flooding.

5. At what frequency would you consider flooding "acceptable"?

☐ Annually ☐ 5 years ☐ 10 years ☐ 50 years ☐ 100 years ☐ Never

Culcairn

Floodplain Risk Management Study & Plan

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

☐ Yes ☐ No

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

☐ Yes ☐ No

Please note that Questions 6. and 7. are only to obtain an indication of the level of community interest in these schemes. Please feel free to comment on the VP and VHR schemes below.

8. Have you got any ideas to reduce flood risk at Culcairn?

☐ Yes ☐ No

If 'Yes' can you please describe the location of where you think flood risk could be improved (please provide nearest crossroads or known landmarks or alternatively display on the attached map on page 8).

Culcairn

Floodplain Risk Management Study & Plan

Please use this page to describe how flood risk may be reduced?

Please use as many details as possible to describe how flood risk may be reduced. Note that you might find the attached map over page useful to aid in your description.

Culcairn

Floodplain Risk Management Study & Plan

Greater Hume Shire
simply greater

Culcairn 100 year ARI flood depth map – Please indicate how you would reduce flood risk?

Appendix D

General Manager
40 Balfour St
CULCAIRN NSW 2660

Walbundrie_Rd_Submissions.docx

7 November 2014

Dear Michael,

Re: Proposed Walbundrie Road Works and Potential for Flood Impacts

As you know we had our community information session on October 14th. A number of people attended the Culcairn session with many of them raising the specific issue discussed herein. Owing to the fact that road works are imminent (this statement being based on information from attending residents) WMAwater have prioritised the communication of this submission. If WMAwater can provide any further information then please do not hesitate to contact us in this regard.

During the community information sessions three attendees raised the issue of Walbundrie Road works and their potential to impact on flood levels of property lying on the southern side of the road at a location approximately 6 km to the west of Culcairn. Figure 1 over the page notes the location and flood mechanisms that if impacted by the road works are likely to impact flood levels and over floor flood affectation.

Essentially several residences exist in this area and some of these were flooded over floor or came close to being flooded in the events of 2010 and 2012.

Flooding behaviour observed during these events was that flow from Billabong Creek poured over Walbundrie Road to the north. This water then flowed further west prior to running back into the creek ~ 5 km further downstream.

Residents believe that any raising of the road will mean flood levels will be higher by that amount for any event which leads to Billabong Creek water flowing north over the existing road.

It does appear (based on observations by numerous residents and SES personnel) that significant flow moved north over the road in the 2012 event at least. Depths of ~ 0.5 m were noted. As such it is not the case that the potential impacts on flood levels of road raising could be mitigated by implementing culverts. Rather serious consideration should be given to lowering of the road in this area in order to form a causeway and in this way to provide a more effective flow path for flood waters.

WMAwater Pty Ltd (Formerly Webb McKeown and Associates)

ABN 14 600 315 053

DIRECTORS

M K Babister BE(Hons), MEngSc GradDipMgt, FIEAust
R W Dewar BSc(Hons), MEngSc, MAIG, MIEAust
E J Askew BE(Hons), MIEAust
S D Gray BE, MEng

ASSOCIATES

R Hardwick Jones BE(Hons), MEngSc, MIEAust
M E Retallick BE(Hons), BSc, MIEAust

Level 2, 160 Clarence St, SYDNEY NSW 2000
Phone: 02 9299 2855 Fax: 02 9262 6208
Email: enquiry@wmawater.com.au
Website: wmawater.com.au

Please note that given very low gradients in the area downstream of Culcairn any works that seriously impede the downstream flow of floodwaters may lead to exacerbation of flood levels within Culcairn itself.

Given then the potential for impact on flood levels for the local residents and the potential overall negative impact on flood behaviour for Culcairn (more broadly) WMAwater would recommend that any Walbundrie Road works at the very least not increase the road level relative to the current road level.

Yours Sincerely,
WMAwater

Steve Gray
Director

Figure 1: Aerial map of site of interest including flood mechanism

Appendix E

E. Appendix E: Hydraulic Categorisation – Floodway Definition

Introduction

The Culcairn hydraulic categorisation maps for the 5% and 1% AEP events and the PMF are presented in Figure 8 to Figure 10 respectively. The floodway was determined for the 1% AEP events with the same methodology then applied to the 5% AEP and PMF events.

Hydraulic categorisation is the process by which flood behaviour for a given design event is classified into areas of flood storage, flood fringe and floodway. The NSW Floodplain Development Manual 2005 (Reference 1) provides definitions for all three categories, however these are descriptive definitions and aren't suitable for directly calculating/assessing the categories. The definitions as per Reference 1 are provided below for clarity.

> *Floodway*– areas in the floodplain where significant discharge occurs. Often aligned with natural channels. Floodways are areas that even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
>
> *Flood Storage* – those parts of the floodplain important for the temporary storage of floodwaters during a flood. Extent and behaviour of flood storage areas may vary greatly for different events and so a range should be examined.
>
> *Flood Fringe* – remaining areas of land in the floodplain after flood storage and floodway have been defined. (NSW FDM, 2005)

Three further definitions that are suitable for directly calculating/assessing the floodway extent and that are widely used to describe the characteristics of the floodway are described below:

1. The extent which comprises a significant proportion of flow in a flow path (80 to 90% is often used as the portion of flow within the floodway); and
2. The extent which if partially blocked causes impacts in excess of 0.1 m to occur upstream of the partial blockage.
3. The Floodplain Risk Management Guidelines (2007) (Reference 18) advise that the minimum width of a floodway is required to be at least as wide as the main channel as determined from the top of bank.

These three definitions have been used to assist in determining the floodway extent at Culcairn.

Defining the floodway is a critical component of the flood risk management work carried out under the NSW Floodplain risk management program. This relates to the fact that the defined floodway extent will typically not be available for further residential development. As such it is imperative that the floodway definition is appropriate and not conservative.

Approach

Generally speaking there is no definitive method and defining a floodway is often an iterative process. In the context of 2D and 1D/2D models, the output used in the mapping tends to be in

a raster format. A raster presents flood modelling outputs for each grid cell in a gridded format for the given study area. The velocity depth (VD) product for each cell can, and has in previous studies, been used to define the floodway. For example the Howells et al (Howells) method utilises the VD product and the velocity (V) when assessing hydraulic categories.

The Howells method differentiates the floodway from other hydraulic categories by selecting a VD criteria that exceed a specific threshold. Some subjectivity still exists within the methodology and different regions often require different V and VD criteria to produce suitable results. Testing varying V and VD criteria, to some degree, is comparable to a calibration exercise where the VD product to be used as a threshold for defining floodway is modified until such a time as a suitable floodway is obtained.

Given that the VD product can provide a base for defining the floodway extent for raster results, the next issue with floodway definition is defining what the VD product should be "calibrated" to, to achieve a reasonable floodway definition. In other words, what VD product will define a floodway extent which will satisfy the three floodway definitions mentioned above.

Methodology

In the 2012 paper by Thomas et al., the two previously mentioned floodway definitions were investigated and a remarkable correlation was observed between the 80% - 90% flow criteria and a 0.1 m afflux.

The proposed approach builds on the criteria proposed by Howells et al. in their 2004 paper using various VD and V parameters to estimate the floodway and then verifies results using encroachment analysis similar to that found in Thomas et al. (2012).

In the encroachment analysis all areas not defined as floodway via the Howells method have been totally excluded from the modelling domain and the subsequent impact on flood levels is examined. In other words the encroachment run undertaken as a check, conservatively assumes that all areas outside the floodway are blocked and should development occur outside the floodway zone defined herein the impact is likely to be less than 0.1 m

A summary of VD and V values investigated (VDV criteria) is listed below:

a. VD > 0.25 m^2/s and V>0.25 m/s; or V>1.0 m/s;
b. VD > 0.20 m^2/s and V>0.20 m/s; or V>1.0 m/s;
c. VD > 0.15 m^2/s and V>0.15 m/s; or V>1.0 m/s;

In addition to the Howells method, other methods are also utilised to define the Culcairn floodway and further add to the robustness of results. The top of the main channel bank has been adopted as the minimum floodway width, satisfying the guidelines discussed above. Also, the percentage of flow conveyed in the floodway is investigated to see if it fits the 80% - 90% criteria, as previously mentioned.

The remainder of the floodplain outside the defined Floodway becomes either Flood Storage or Flood Fringe.

In the past, the 20Y ARI flood extent has been used to define the 1% AEP floodway. As a

supplementary test, this approach has also been considered in this investigation by comparing the 20Y ARI flood extent (trimmed to remove depths greater than 0.1 m) to the VD and V criteria listed above.

Results

Appendix Figure E 1 displays the afflux associated with the encroachment analysis testing for Culcairn. Regions displayed in red satisfy VDV criteria (b), mentioned previously. This defined floodway was found on encroachment analysis testing to produce an afflux of approximately 0.1 m in the Culcairn township area. In Billabong Creek and the anabranch proximate to Culcairn, VDV criteria (a) was used to produce an afflux of approximately 0.1 m. Using the criteria postulated above, the 2nd floodway definition is satisfied.

In some areas the afflux produced is below 0.1 m. The width of the floodway in these regions could not be decreased without excluding the top of the channel bank and therefore not meeting the guidelines previously outlined. By extending the defined floodway to at least as wide as the main channel (as determined from the top of bank) the 3rd floodway definition is satisfied.

The 20Y ARI flood extent is approximately the same as the floodway defined by the Howells method and accordingly produced a similar afflux. The Howells method extent and the top of bank are more robust than using the 20Y ARI extent and are therefore more appropriate for hydraulic categorisation in Culcairn.

A number of cross sections that measure flow in the model are also displayed in Appendix Figure E 1. For each cross section, the flow distribution (%) both within and outside of the floodway are displayed. It can be seen that the percentage of flow contained within the defined floodway is within 80% – 90% thus satisfying the 1st floodway definition. This adds further robustness to the floodway results.

Conclusions

Defining a floodway is a non-precise process. The goal is to produce floodway extents that match flow behaviour so that the areas which need to be retained for flow are identified whilst other parts of the flood extent can be developed as appropriate. While the allocation of floodway is likely to be a contentious issue that would merit a precise definition, the fact remains that a one size fits all approach still eludes the practitioner. The method presented defines a reasonable floodway extent using VD and V criteria and then confirms the suitability of the defined floodway extent by using afflux testing. The percentage of flow within the floodway was also investigated to see if the 1st floodway definition is satisfied.

The method used in defining the floodway is based on the Howells method but the VD and V thresholds are adjusted according to an encroachment analysis until the 2nd floodway definition is satisfied. When all areas outside the defined floodway are blocked and the resulting afflux is in the region of 0.1 m it can be argued that any development outside this floodway will result in an afflux less than 0.1 m which satisfies our 2nd floodway definition. Additionally, as previously mentioned, the top of bank for the main channel was set as the minimum width of the floodway extent, thus satisfying the 3rd floodway definition.

FIGURE E1
CULCAIRN HYDRAULIC CATEGORISATION INVESTIGATION

Hamilton St
Hopetoun St
Melrose St
Melrose St
Federal St
Douglas St
Kirndeen St
McBean St
Railway Pde
Victoria St
Munro St
Federal St
Henty St
Balfour St
Balfour St
Culcairn - Holbrook Rd
Culcairn Rd
Fraser St
Gordon St
Wattle St
Cummings Rd
Olympic Hwy

0.4 %
2.72 %
95.73 %
0.34 %
0.8 %
90.4 %
0.5 %
8 %
0.3 %

N

Billabong Creek Top of Bank
Flow Distribution Lines
Encroachment Region V*D>0.25

Impact (m)

No longer Flooded
< -0.1
-0.1 - -0.05
-0.05 - -0.01
-0.01 - 0.01
0.01 - 0.05
0.05 - 0.15
0.15 - 0.25
> 0.25
Newly Flooded

0 0.25 0.5 1 1.5 2 km

J:\Jobs\114040\ARC\Arc_Maps\Culcairn\Report_Figures\BodyAppendix_E\FigureE1_HydCat_Investigation_Culcairn.mxd

Appendix F

F. Appendix F: Flood Damages Assessment

F.1. Quantification of Damages

The quantification of flood damages is an important part of the floodplain risk management process. Flood damages can be defined as actual or potential where actual damage refers to the damage incurred during known flood events while potential damage is an estimation of the damage that could occur. Calculating potential flood damages gives a potential value of damage per property per design flood event and an overall average annual damages value which is the average cost to property owners per year owing to flood damages. By quantifying flood damage for a range of design events, appropriate cost effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including;

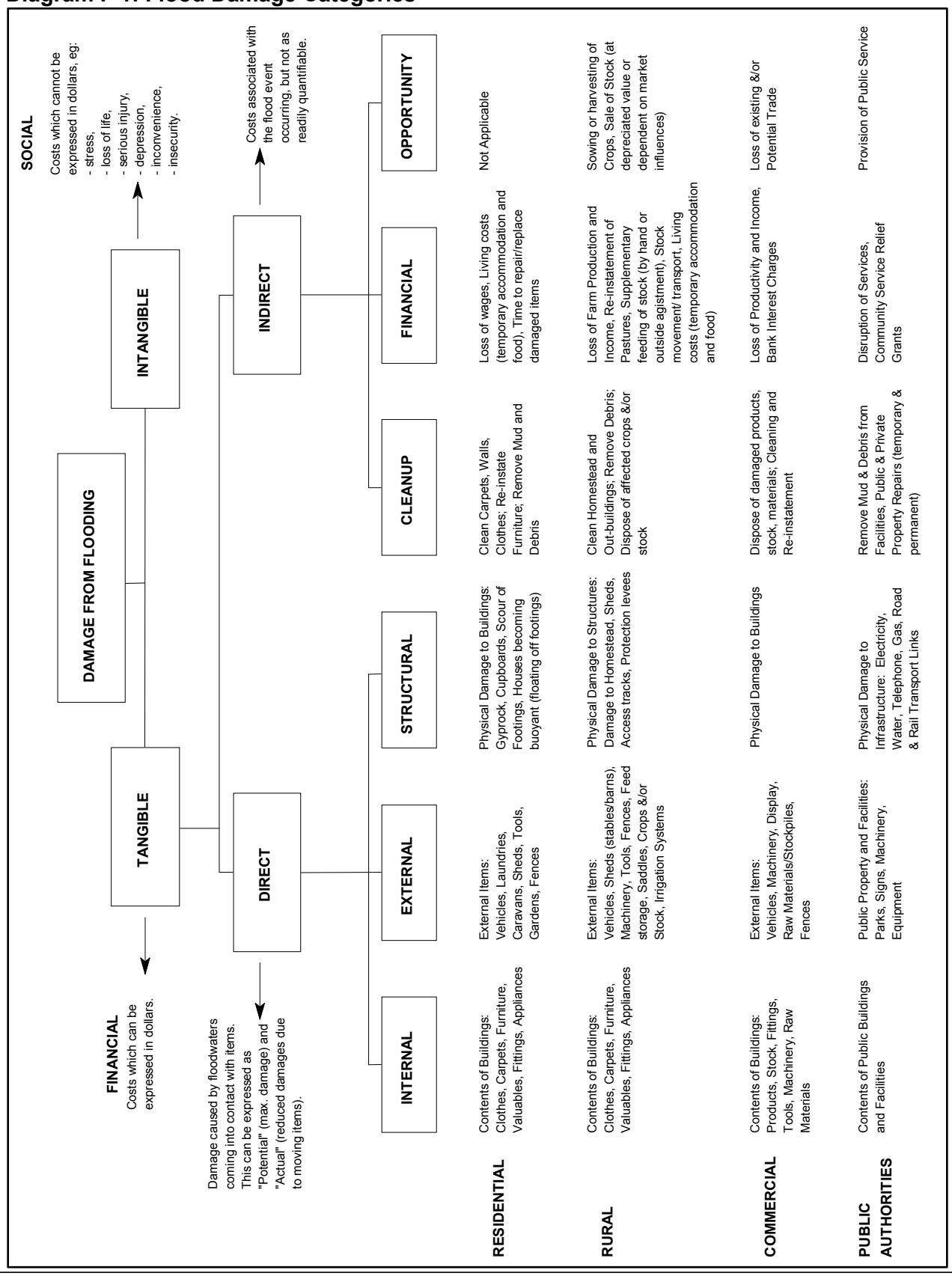
- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding;
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such failure of services (sewerage), flood borne debris; and
- The types of asset and infrastructure affected.

The estimation of flood damages tends to focus on the physical impact of damages on the human environment and can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Types of flood damages are shown on Diagram F 1 over.

To undertake the damages assessment floor level data is required. Floor level survey was performed by Hydrographic & Cadastral Survey Pty. Ltd. for 95 residential properties in Culcairn. The floor levels of the remaining properties were estimated. Further details are presented in Section 1.5.1.

The non-residential damages are more complex than residential damages and have different damages associated with flooding. In Culcairn 25 commercial properties were surveyed Damages for commercial properties have been assessed using separate damage curves to residential damages.

Diagram F 1: Flood Damage Categories



F.2. Identifying Flood Affected Properties

The damages assessment does not only look at potential costs due to flooding but also identifies when properties are likely to become flood affected by either flooding on the property or by over floor flooding. Figure 13 of the main report show in which design event buildings are first flooded above floor level.

Diagram F 2 and Diagram F 3 show the number of flood prone residential properties in Culcairn and the number of residential properties liable to above floor flooding. Diagram F 4 and Diagram F 5 show the number of flood prone non-residential properties in Culcairn and the number of non-residential properties liable to above floor flooding.

Diagram F 2: Number of Flood Prone Residential Properties by Street

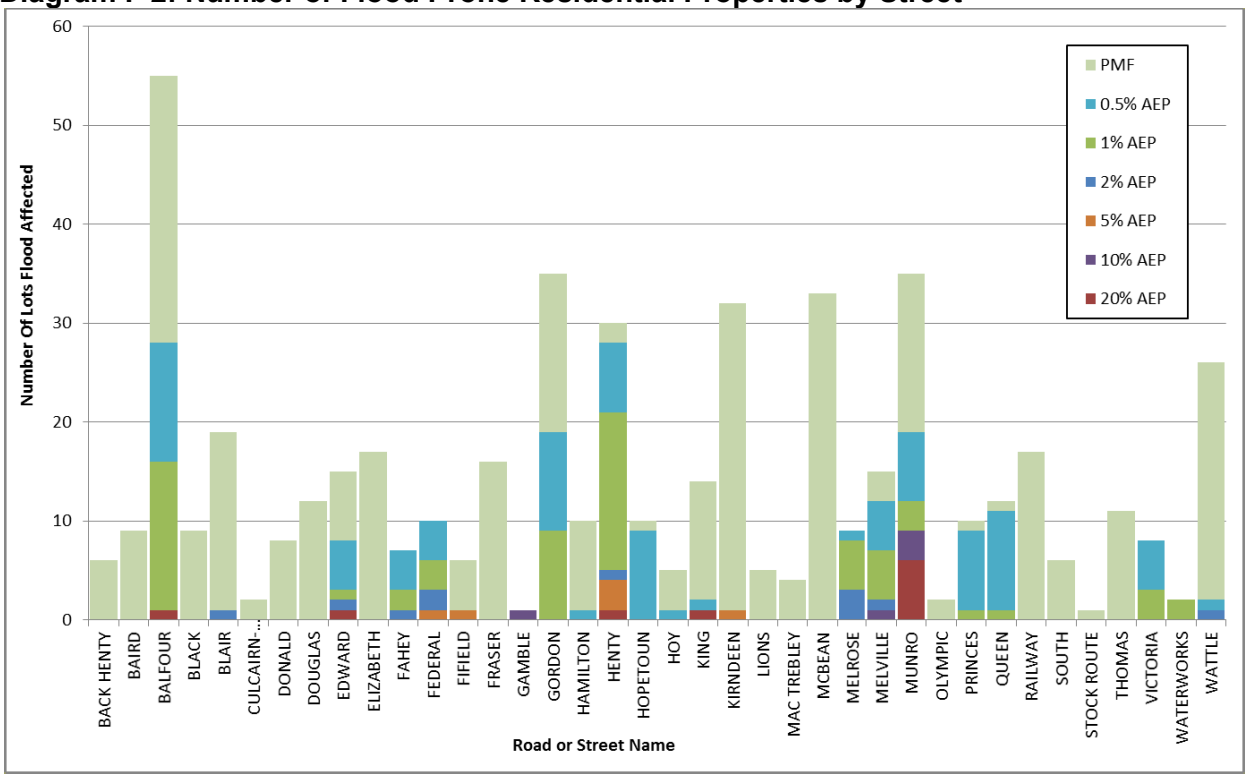


Diagram F 3: Number of Residential Properties Flooded Above Floor Level by Street

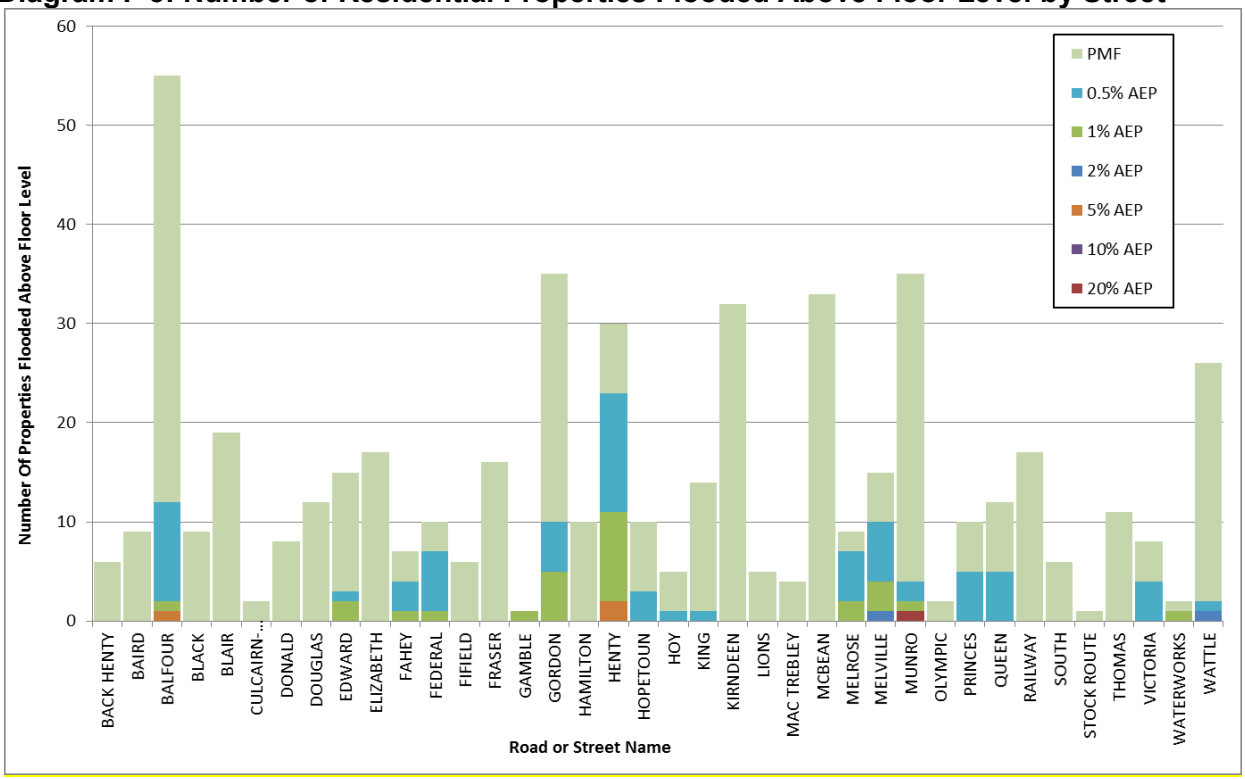


Diagram F 4: Number of Flood Prone Non-Residential Properties by Street

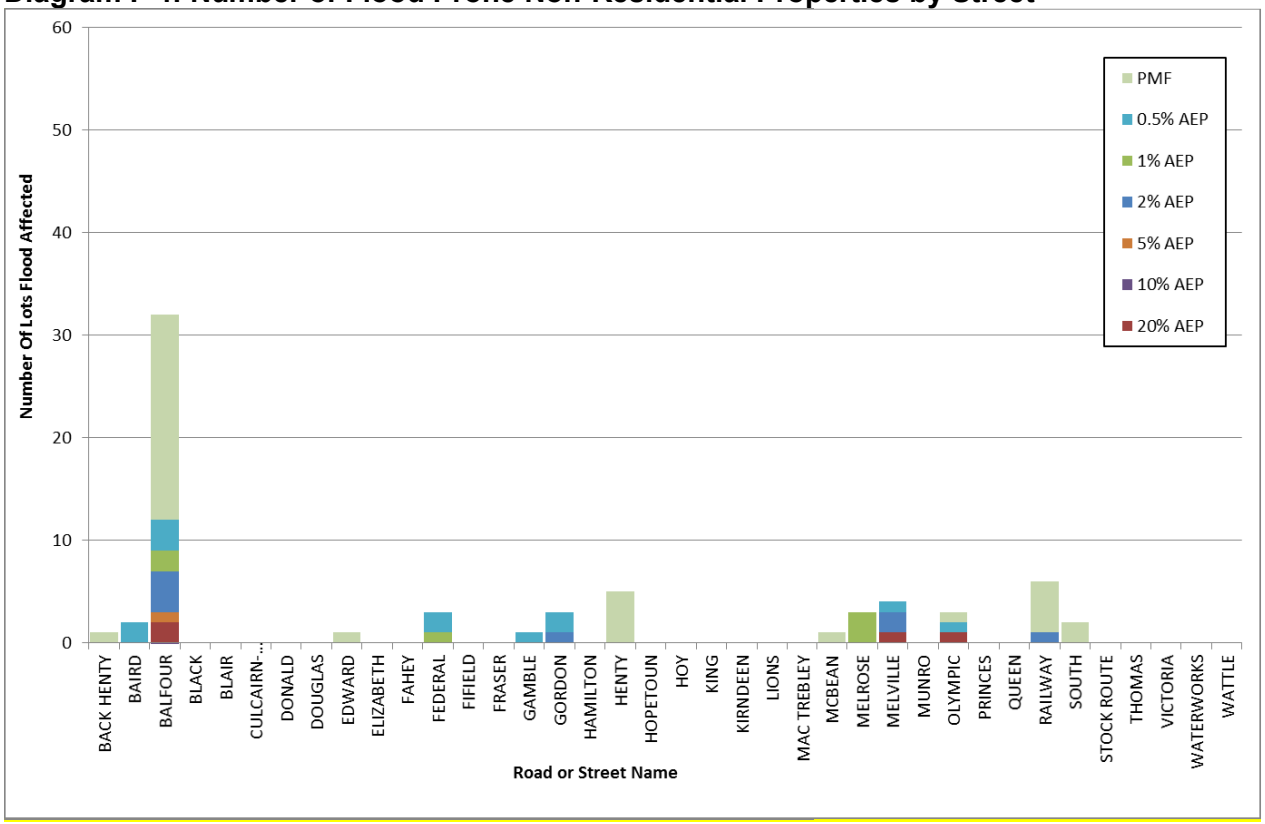
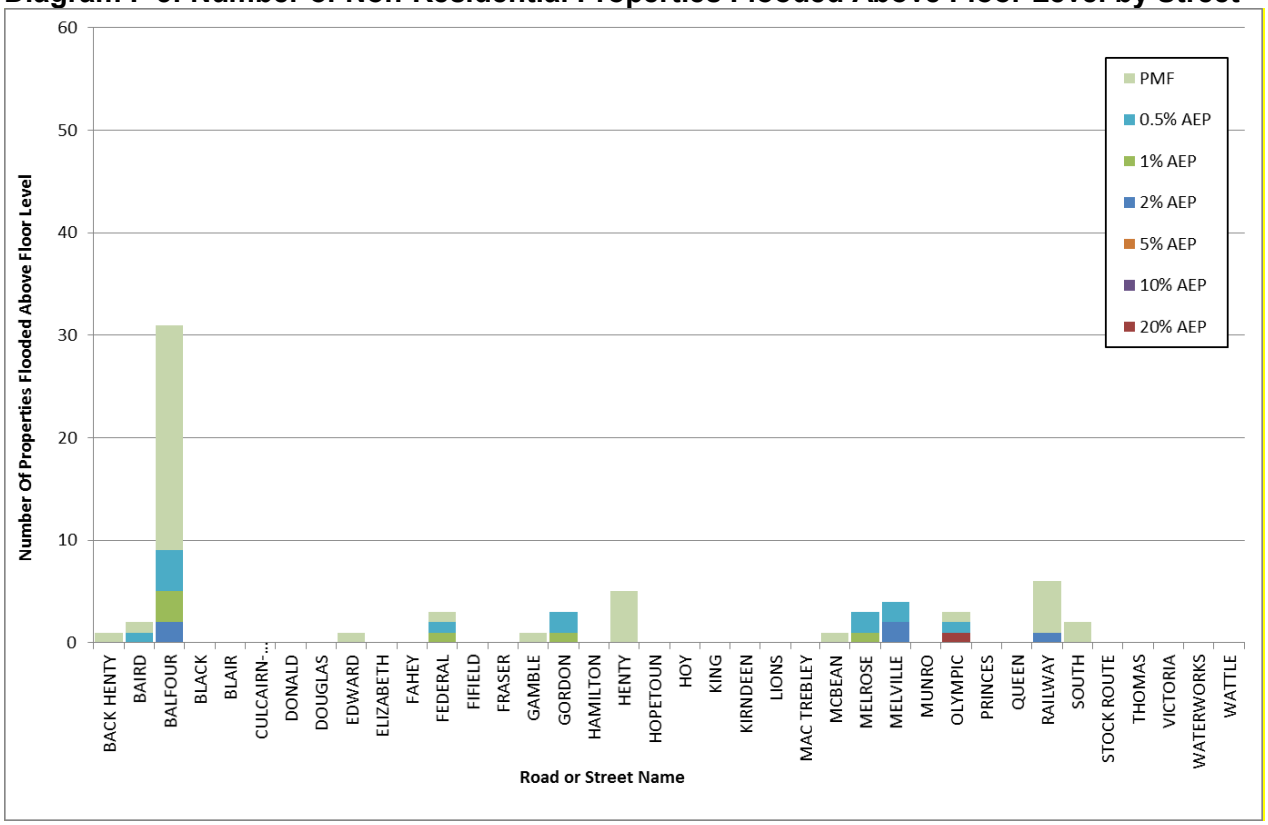


Diagram F 5: Number of Non-Residential Properties Flooded Above Floor Level by Street



F.3. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (Diagram F 1). Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees etc.

Given the variability of flooding and property and content values, the total likely damages figure in any given flood event is useful to get a feel for the magnitude of the flood problem, however it is of little value for absolute economic evaluation. However, considering damages estimates is useful when studying 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.

F.4. Expressing Flood Damages

Average Annual Damages (AAD) is equal to the damage caused by all floods over a period of time divided by the number of years in that period and represents the equivalent average damages that would be experienced by the community on an annual basis. This means that the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods total potential damage refers to the total damage estimated for a given flood event. Average

damage per property is the Total damage estimated for a particular flood event divided by the number of properties flood affected in this event; either by flooding on the yard and/or above floor level of a building.

F.5. Calculating Tangible Flood Damages

The flood damages assessment was undertaken for existing development in accordance with current OEH guidelines (Reference 18) and the Floodplain Development Manual (Reference 1). Potential flood damages were calculated with the use of a height-damage curves which relate the depth of water above the floor with tangible damages. The height-damage curves were established in accordance with OEH guidelines (Reference 18).

For residential damages the values used are based on the recommendations in the guidance with a post late 2001 adjustment factor was applied to increase damage values according to changes in Average Weekly Earnings (AWE) since 2001. Separate curves were established for non-residential damages. The resultant curves are shown in Diagram F 6 and F 7.

Structural damages vary on whether the property is slab/low set or high set. For the purpose of this study, any property with a floor level of 0.5 m or more above ground level was assumed to be high set.

In calculating AAD, it was assumed that there would be no flood damages in events smaller than the 2-year ARI event.

As it is usual that commercial and industrial damages are higher than residential damages a multiplier was applied to the total damage per property for each event by adjusting the typical building size value within the curve development calculations. Other factors including the clean-up costs and external damages were adjusted to reflect the differences between commercial and residential properties.

To adjust the residential damage curve to be applicable to non-residential development, the average contents damages for a business was estimated to be $150,000 and the clean-up cost have been estimated at $4,000. This was done to take account the higher costs that businesses would incur compared to residential dwellings when flooded above floor level. The commercial damages curves were also amended to reduce the bench height based on the assumption that many commercial premises would have stock from floor level. External damage was set at $1,250 as per residential properties.

The parameters mentioned above have been kept consistent with the recently completed Lockhart and The Rock FRMS&P (Reference 19).

Diagram F 6: Flood Damages Curves – Residential Property

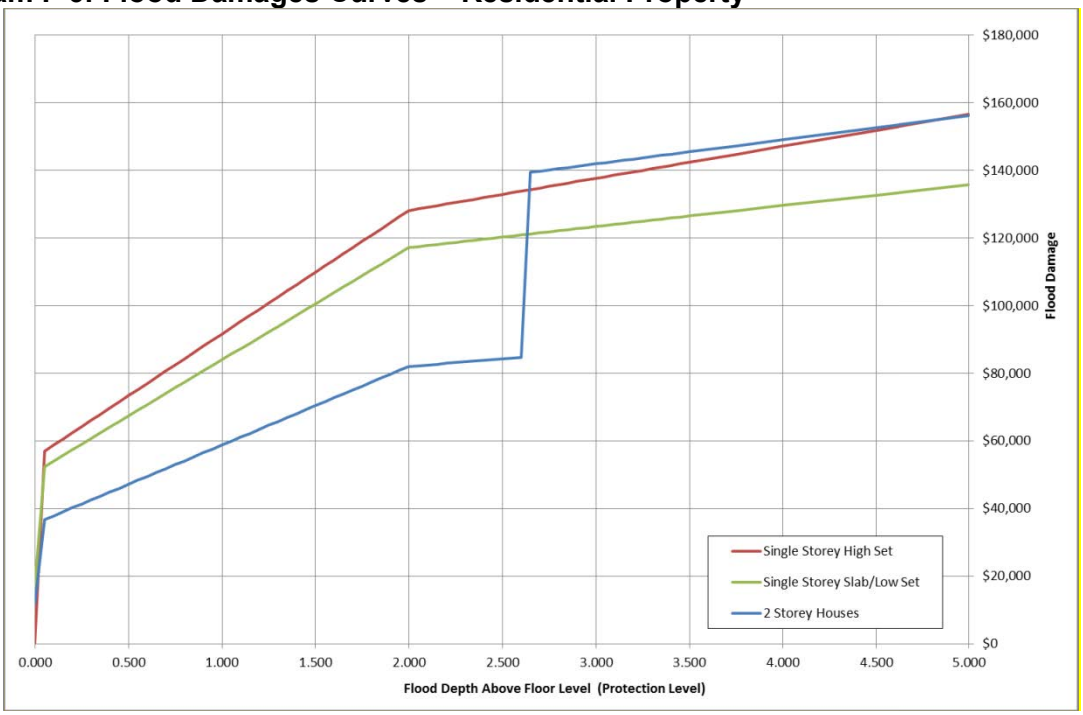
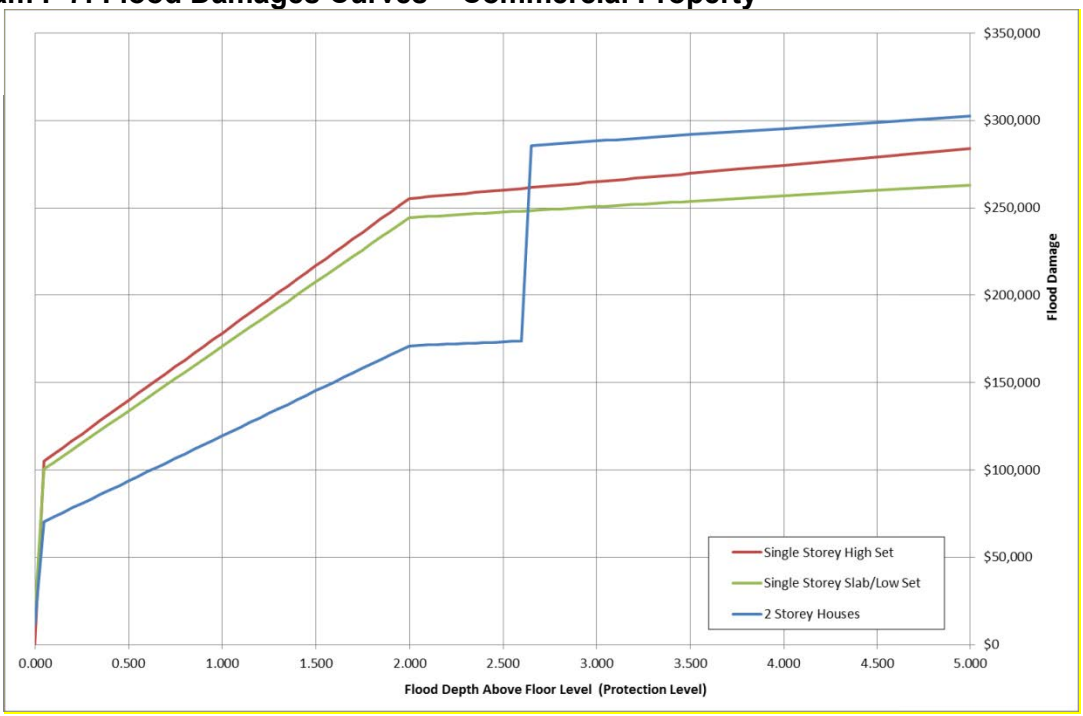


Diagram F 7: Flood Damages Curves – Commercial Property



The OEH guidelines suggest a protection level be applied when calculating damages. This effectively reduces the floor level by the given amount (usually 0.5 m). The level of protection is considered overly conservative and has not been applied in this instance. Applying a level of protection of 0.5 m at Culcairn would increase AAD by 300% and the number of properties flooded above floor level in the 5-year ARI event from 2 to 134. Incorporating this would lead to Council financing flood management measures that provide little benefit.

F.6. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed above, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury, loss of sentimental items etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. However, it is still important that the consideration of intangible damages is included when considering the impacts of flooding on a community.

Post flood damages surveys have linked flooding to stress, ill-health and trauma for the residents. For example the loss of memorabilia, pets, insurance papers and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition flooding may affect personal relationships and lead to stress in domestic and work situations. In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage. The extent of the stress depends on the individual and although the majority of flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

During any flood event there is the potential for injury as well as loss of life due to causes such as drowning, floating debris or illness from polluted water. Generally, the higher the flood velocities and depths the higher the risk. Culcairn study area generally is classified as low hazard within the built up areas. However, there can be local high risk (high hazard) areas where flows may be concentrated around buildings or other structures within low hazard areas.

F.7. Benefit/Cost Analyses for Management Options

To assess the full monetary benefits, including taking into account costs of construction and maintenance, Net Present Value (NPV) calculations were used and the B/C ratio established. The B/C approach is used to quantify the economic worth of each option enabling the ranking against other options. A B/C ratio is the benefits expressed in monetary terms, i.e. the reduction in AAD, compared to the actual likely cost of achieving those benefits, i.e. construction and maintenance costs.

The AAD per annum in today's monetary terms was assumed to apply for each year of the NPV damage calculation and was established for each year based on a discount rate of 7% as per the recommendation in the Residential Flood Damages FRM Guidelines (Reference 18). A construction cost was estimated and, using the NPV of the AAD assuming lifetime of 50-years, the B/C ratio was established for each of the options.

Appendix G

G. Appendix G: Draft Flood Management Development Control Plans & Policy

This draft Flood Management Policy has been prepared based on the findings of the Greater Hume Flood Study and Floodplain Risk Management Study. It is recommended that Council use this draft policy in conjunction with the relevant legislation to produce a DCP that achieve Council's aims.

GREATER HUME LGA
DRAFT DEVELOPMENT CONTROL POLICY
FOR FLOOD PRONE AREAS

Flood Management

A flood is an overflow or accumulation of an expanse of water that submerges land. Floods are a natural and inevitable event that communities must learn to live with while minimising risks to public health and safety, property and infrastructure.

This section recognises that there are some flooding risks that require development controls and guidelines in order to reduce or eliminate their impacts.

Objectives

1. To maintain the existing flood regime and flow conveyance capacity.
2. To enable the safe occupation of, and evacuation from, land to which flood management controls apply.
3. To avoid significant adverse impacts upon flood behaviour.
4. To avoid significant adverse effects on the environment that would cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of the river bank/watercourse.
5. To limit uses to those compatible with flow conveyance function and flood hazard.

Controls

General

1. For proposed development, consideration must be given to such matters as the likely depth and nature of possible floodwaters, flood classification of the area (where applicable) and the risk posed to the development by floodwaters.
2. The applicant must demonstrate:
    i) That the development will not increase the flood hazard or risk to other properties and that details have been provided of the structural adequacy of any buildings works associated with the development with regard to the effects of possible floodwaters;
    ii) That the proposed building materials are suitable;
    iii) That the development is sited in the optimum position to avoid floodwaters and allow evacuation; and
    iv) That all electrical services associated with the development are adequately flood proofed.

3. All applications for development must be accompanied by a survey plan including relevant levels to AHD (Australian Height Datum). Consideration must be given to whether structures or filling are likely to affect flood behaviour and whether consultation with other authorities is necessary.
4. Compliance with flood management controls must be balanced by the need to comply with other controls in this DCP.

Controls for land uses on flood prone land identified on the DCP Flood Map

1. A site emergency response flood plan must be prepared in case of a PMF flood.
2. Adequate flood warning systems, signage and exits must be available to allow safe and orderly evacuation without increased reliance upon the State Emergency Service (SES) or other authorised emergency services personnel.
3. Reliable access for pedestrians or vehicles must be provided from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF

SCHEDULE 1 – Flood compatible materials

Building component	Flood compatible material
Flooring and sub-floor	• Concrete slab on-ground monolith
	• Suspended reinforced concrete slab
Floor covering	• clay tiles
	• concrete, precast or in situ
	• concrete tiles
	• epoxy, formed-in-place
	• mastic flooring, formed-in-place
	• rubber sheets or tiles with chemicals-set-adhesive
	• silicone floors formed-in-place
	• vinyl sheets or tiles with chemical-set adhesive
	• ceramic tiles, fixed with mortar or chemical-set adhesive
	• asphalt tiles, fixed with water resistant adhesive
Wall structure	• solid brickwork, blockwork, reinforced, concrete or mass concrete
Roofing structure (for situations where the relevant flood level is above the ceiling)	• reinforced concrete construction • galvanised metal construction
Doors	• solid panel with water proof adhesives
	• flush door with marine ply filled with closed cell foam
	• painted metal construction
	• aluminium or galvanised steel frame
Wall and ceiling linings	• fibro-cement board
	• brick, face or glazed
	• clay tile glazed in waterproof mortar
	• concrete
	• concrete block
	• steel with waterproof applications

SCHEDUAL 1: FLOOD compatible materials (cont.)

Wall and ceiling linings (cont.)	• stone, natural solid or veneer, waterproof grout
	• glass blocks
	• glass
	• plastic sheeting or wall with waterproof adhesive
Insulation windows	• foam (closed cell types)
	• aluminium frame with stainless steel rollers or similar corrosion and water resistant material
Nails, bolts, hinges and fittings	• brass, nylon or stainless steel
	• removable pin hinges
	• hot dipped galvanised steel wire nails or similar

Electrical and mechanical equipment
For dwellings constructed on land to which this DCP applies, the electrical and mechanical materials, equipment and installation must conform to the following requirements:

Main power supply
Subject to the approval of the relevant authority the incoming main commercial power service equipment, including all metering equipment, must be located above the relevant flood level. Means must be available to easily disconnect the dwelling from the main power supply.

Wiring
All wiring, power outlets, switches, must be to the maximum extent possible, located above the maximum flood level. All electrical wiring installed below this level must be suitable for continuous underwater immersion and must contain no fibrous components. Each leakage circuit-breaker (core balance relays) must be installed. Only submersible type splices must be used below maximum flood level. All conduits located below the relevant designated flood level must be so installed that they will be self-draining if subjected to flooding.

Equipment
All equipment installed below or partially below the relevant flood level must be capable of disconnection by a single plug and socket assembly.

Reconnection
Should any electrical device and/or part of the wiring be flooded it must be thoroughly cleaned or replaced and checked by an approved electrical contractor before reconnection.

Heating and air conditioning systems
Where viable, heating and air conditioning systems should be installed in areas and spaces of the house above maximum flood level. When this is not feasible, every precaution must be taken to minimise the damage caused by submersion according to the following guidelines:

Fuel
Heating systems using gas or oil as fuel must have a manually operated valve located in the fuel supply line to enable fuel cut-off.

Installation
Heating equipment and fuel storage tanks must be mounted on and securely anchored to a foundation pad of sufficient mass to overcome buoyancy and prevent movement that could damage the fuel supply line. All storage tanks must be vented to an elevation of 600 millimetres above the relevant flood level.

Ducting
All ductwork located below the relevant flood level must be provided with openings for drainage and cleaning. Self-draining may be achieved by constructing the ductwork on a suitable grade. Where ductwork must pass through a water-tight wall or floor below the relevant flood level, a closure assemble operated from above relevant flood level must protect the ductwork

Appendix H

FIGURE H1

SUMMARY OF OPTIONS INVESTIGATED

OPTION S1
INCREASED CHANNEL CONVEYANCE
NORTH OF HOPETOUN STREET

OPTION A9
INCREASING CULVERT CAPACITY
AT HOPETOUN STREET

OPTION S4
CONNECTING THE ANABRANCH
NEAR THE OLYMPIC HIGHWAY
AND MELROSE ST

OPTION A4
LOWERING OLYMPIC HIGHWAY AT
MELROSE ST AND
PRINCES ST

OPTION A5
LOWERING OLYMPIC HIGHWAY
AT VICTORIA STREET

OPTION A3
CREATING A DEPRESSION NEAR
BALFOUR ST STOCK ROUTE

OPTIONS S3
VEGETATION MANAGEMENT

OPTION A8
GAMBLE STREET DRAIN
NON-RETURN VALVE

OPTION A7
GORDON STREET DRAIN
NON-RETURN VALVE

OPTION A7
GORDON STREET DRAIN
NON-RETURN VALVE

OPTION S2
BLOCKING BILLABONG CREEK ANABRANCH

OPTION L2
DUAL EMBANKMENTS
NORTH OF HOPETOUN STREET

OPTION A10
INCREASING CULVERT CAPACITY
AT MELROSE STREET

OPTION A1
LOWERING MUNRO ST

OPTION A2
LOWERING MUNRO ST

OPTION S5
TWO DRAINS EITHER SIDE OF MUNRO ST

OPTION L1
MUNRO ST DRAINAGE EMBANKMENT

OPTION B1
BASIN UPSTREAM OF
FEDERAL STREET

OPTION B2
BASIN UPSTREAM OF FEDERAL ST
NEAR BAIRD ST

OPTION B3
BASIN BETWEEN GORDON ST
AND MUNRO ST

OPTION L3
EMBANKMENT AT BALFOUR STREET

OPTION B4
EMBANKMENT AT THE
CORNER OF FEDERAL AND
KING STREET

OPTION A6
REMOVING OLD RAILWAY
SOUTH OF BILLABONG CREEK

Baird Street
Railway Parade
Olympic Highway
Melrose Street
Munro Street
Hoy Street
Lions Place
Thomas Place
Princes Street
Queen Street
Victoria Street
Black Street
Henty Street
Federal Street
Balfour Street
Balfour St (Service Rd)
Kirndeen Street
McBean Street
Stock Route
Walbundrie Road
Donald Street
Fraser Street
Blair Street
Railway Parade
Edward Street
Gordon Street
Munro Street
King Street
Federal Street
Wattle
Gamble Street
Jubilee Park Road
Waterworks Road

N

0 0.25 0.5 1 1.5 2 km

N

Embankment
Basin
Structure Modification
Channel Modification
Drainage Network Modifications
Vegetation Management

0 0.125 0.25 0.5 0.75 1 km

Green: Options recommended for further investigation
Red: Option not advised
Blue: Option recommended for futher investigation
in combination with other Options

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FIGURE H2
FLOOD IMPACT 1% AEP
OPTION S3
CLEARING OF BILLABONG CREEK CHANNEL
VEGETATION MANAGEMENT

Elizabeth Street
Douglas Street
Stock Route
Kirndeen Street
McBean Street
Railway Parade
Henty Street
Queen Street
Gordon Street
Munro Street
Victoria Street
Henty Street
Henty Street
Melville Street
Balfour Street
Balfour St (Service Rd)
Federal Street
Walbundrie Road
Balfour Street
Donald Street
Fraser Street
Blair Street
Railway Parade
Gamble Street
Edward Street
Gordon Street
King Street
Munro Street
Wattle Street
Culcairn
Olympic Highway
Waterworks Road
Taylors Road
Cummings Road

N

Vegetation Management

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500 2,000 m

0 0.5 1 2 3 4 km

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FIGURE H3
FLOOD IMPACT 1% AEP
OPTION A2
NORTHERN FLOW PATH, LOWERING MUNRO STREET

Baird Street
Gordon Street
Munro Street
Hoy Street
B

N

Lowered Munro Street

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 50 100 200 300 400 m

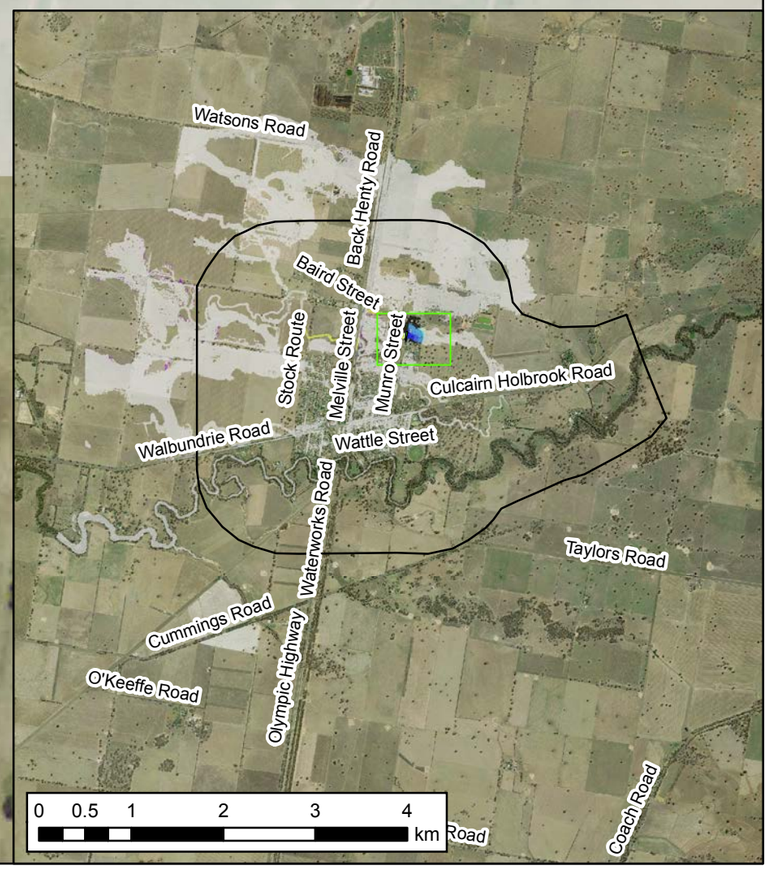

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FIGURE H4

FLOOD IMPACT 1% AEP
OPTION A3
LOWERING THE STOCK ROUTE NEAR THE BALFOUR ST INTERSECTION

Stock Route
Kirndeen Street
McBean Street
Balfour Street
Walbundrie Road
Donald Street
Fraser Street

N

Stock Route Depression

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 25 50 100 150 200 m

0 0.5 1 2 3 4 km

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FIGURE H5

FLOOD IMPACT 1% AEP
OPTION A5
SOUTHERN FLOW PATH, LOWERING OLYMPIC HWY

Hamilton Street
Lions Place
Thomas Place
Melrose Street
Hoy Street
Munro Street
Fifield Close
Gordon Street
Princes Street
Elizabeth Street
Railway Parade
Queen Street
Douglas Street
Douglas Street
McBean Street
Black Street
Victoria Street
Victoria Street
Henty Street
Henty Street
Melville Street
Highway
Balfour Street
Gordon Street
Edward Street

N

Olympic Highway Lowered

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 100 200 400 600 Meters

0 0.5 1 2 3 4 km

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FIGURE H6

FLOOD IMPACT 1% AEP
OPTION A6
REMOVING THE HISTORIC RAILWAY, SOUTH OF CULCAIRN

Elizabeth Street
Douglas Street
Stock Route
Kimdeen Street
McBean Street
Railway Parade
Melville Street
Henty Street
Gordon Street
Munro Street
Fifield Close
Federal Street
Balfour Street
Culcairn Holbrook Road
Fahey Crescent
Edward Street
Federal Street
Walbundrie Road
Donald Street
Fraser Street
Blair Street
Railway Parade
Gamble Street
Melville Street
King Street
Wattle Street
Waterworks Road
Taylors Road
Olympic Highway
Cummings Road

N

Railway Removed

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500 2,000 Meters

0 0.5 1 2 3 4 km

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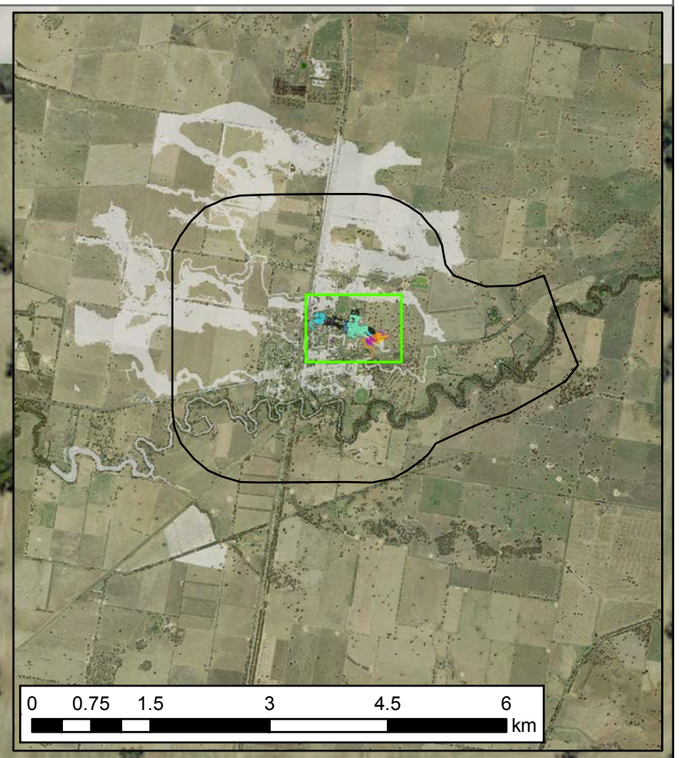
FIGURE H7

FLOOD IMPACT 1% AEP
OPTION B1
CENTRAL FLOWPATH, UPSTREAM FEDERAL STREET BASIN



Railway Parade
Melville Street
Hopetoun Street
Olympic Highway
Melrose Street
Princes Street
Gordon Street
Munro Street
Hoy Street
Fifield Close
Victoria Street
Federal Street
Balfour Street

N

Basin

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 100 200 400 600
Meters

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FIGURE H9

FLOOD IMPACT 1% AEP
COMBINED OPTIONS S2 / A7 / A8
MITIGATING BILLABONG CREEK CHANNEL FLOODING

Hamilton Street
Railway Parade
Melville Street
Gordon Street
Hopetoun Street
Hoy Street
Culcairn Cemetery Rd
Lions Place
Thomas Place
Melrose Street
Munro Street
Fifield Close
Princes Street
Elizabeth Street
Douglas Street
Douglas Street
Queen Street
Culcairn Holbrook Road
Victoria Street
Victoria Street
Henty Street
Henty Street
Balfour Street
Balfour St (Service Rd)
Stock Route
Kimdeen Street
McBean Street
Henty Street
Federal Street
Gordon Street
Edward Street
Walbundrie Road
Balfour Street
Donald Street
Fraser Street
Blair Street
Railway Parade
Gamble Street
King Street
King Street
Wattle Street
D
ympic Highway
orks Road

N

Non-Return Valve
Propoosed Fill

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500 2,000 m

0 0.5 1 2 3 4 km

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FIGURE H9

FLOOD IMPACT 1% AEP
COMBINED OPTIONS L3 / A5 / B4
SOUTHERN FLOW PATH FLOOD MITIGATION

Option L3 Raise Balfour Street
Option L3 Levee
Option L4 Levee
CulcairnA5_region

Change in Flood Level (m)

< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.02
No Impact
0.02 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
> 0.3
No Longer Flooded
Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 125 250 500 750 1,000 Meters

0 0.5 1 2 3 4 km

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FIGURE H10
FLOOD IMPACT 1% AEP
COMBINED OPTIONS L1 / S5 / A1 / B1 / B3
CENTRAL FLOW PATH MITIGATION

B

Railway Parade
Melville Street
Hopetoun Street
Olympic Highway
Melrose Street
Princes Street
Gordon Street
Munro Street
Hoy Street
Fifield Close
Queen Street
Victoria Street
Federal Street
Balfour Street

Baird Street
Back Henty Road
Hamilton Street
Elizabeth Street
Stock Route
Kimdeen Street
McBean Street
Railway Parade
Henty Street
Edward Street
King Street
Culcairn Cemetery Rd

0 0.225 0.45 0.9 1.35 1.8 km

N

- Lowered Munro Street
- Basin
- Embankment
- Drain

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 125 250 500 750 Meters

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Appendix I

I. Appendix I: Mitigation Option Details

This section outlines indicative costs for the investigated Culcairn Options and provides drawings to assist in detail design and investigation works.

These Options include:

- Option A3 – Lowering the Stock Route near the Balfour Street Intersection (see Section 5.3.4.3);
- Combined Option S2 / A7 / A8 - Stopping Billabong Creek Flood Affectation (see Section 5.3.8.1);
- Combined Option L3 / A5 / B4 – Southern Flow Path Flood Mitigation (see Section 5.3.8.2);
- Combined Option L1 / S5 / A1 / B1 / B3 – Central Flow Path Mitigation (see Section 5.3.8.3); and
- Combined Option L2 / S1 – Re-directing the Northern Flow Path near Baird Street (see Section 5.3.8.4).

Note all costs are indicative and are not guaranteed. Cost will vary with contractor prices, market forces and other factors. Detailed design will enable more accurate costs to be prepared.

All of the above listed Options with the exception of Option L2 / S1 are recommended for implementation at Culcairn as they provide significant reductions in flood affectation and risk and have good B/C ratio. Option L2 / S1 is not recommended for implementation at Culcairn.

Freeboard Assumptions

Freeboard is incorporated into the final design height of an embankment (either for a levee or dam wall) and is expressed as the incremental difference in height between the level of the flood the embankment is designed to protect against, and the design crest level of the embankment. Freeboard varies dependant on uncertainties in flood level estimates, wind and wave actions, storm surge, settlement, climate change etc. and therefore requirements can change significantly from embankment to embankment. Applying a standard freeboard allowance for an embankment is considered simplistic, and in many instances, overly conservative (Reference 20).

Typical levee freeboards range from 0.5 m to 1 m in the region. For example the Main City Levee upgrade at Wagga Wagga will use a freeboard of 0.9 m (Reference 20). However, the due to the flat nature of the terrain at Culcairn, and the use of embankments for overland flow flood events only, the expected freeboard will be significantly less than this. A full freeboard assessment is beyond the scope of the current study and will be undertaken as part of the detailed design. An estimated average freeboard allowance of 0.3 m has been assumed for all embankments and dam walls in Culcairn. It should be noted that this freeboard is applied only to overland flow mitigation structures and that scaling (increases in peak flood level) of these types of events is minor and the consequence of failure in terms of risk to life are negligible.

For modelling of design events greater than the design height of an embankment, the freeboard has been incorporated into the modelling with the assumption that the embankment will not fail until it is overtopped.

Option A3

Preliminary concept design information for Option A3 is presented in Figure I 1. This Option involves lowering the stock route by 0.3 m for approximately 20 m length.

Easement Requirements

Nil. All works are undertaken on the road easement.

Third Party Compensation

Nil. No properties affected by increased flood levels.

Option L1 Estimated Costing

A summary of the estimated costings for Option A3 is contained in Table I 1. All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers. It has been assumed that existing culverts will not be replaced, coffer dams and dewatering will not be required and that works will be undertaken during a dry period.

Table I 1: Option A3 – Estimated Costing

Option A3

Road Design

Foundation Preparation	UNIT	QUANTITY	2014 RATE RURAL NSW	COST (with factors)
Road Demolition	m^2	450	20	$ 9,000
Removal of Soil/Road	m^3	90	10	$ 900
compact foundation	m^2	450	3	$ 1,350
Road Resurfacing	m^3	450	55	$24,750
Olympic Hwy Traffic Control				
Traffic Control	weeks	0.5	1,450	$ 725
		Construction Cost		**$ 36,725**

TOTAL PROJECT ESTIMATE	$ 58,200	
TOTAL PROJECT ESTIMATE	$ 58,172	*a+b+c+d+d*
Construction Cost (a)	$ 36,725	
Contingency (b)	$ 7,345	*20% of a*
Design (c)	$ 4,407	*10% of a+b*
Construction Management (d)	$ 5,288	*12% of a+b*
Project Management (e)	$ 4,407	*10% of a+b*

**All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers.*

Combined Options S2 / A7 / A8

Preliminary concept design information for the combined Option S2 / A7 / A8 are presented in Figure I 2. Features of this option include:

- Filling of the east anabranch breakout with approximately 1,700 m³ of earth (max depth 1.4, width of anabranch breakout is 40 m, length of fill is assumed 30 m (see anabranch profile D-E, Figure I 2);
- Filling of the east anabranch breakout with approximately 4,200 m³ of earth (max depth 0.4, width of anabranch breakout is 380 m, length of fill is assumed 30 m (see anabranch profile D-E, Figure I 2);
- No freeboard applied to anabranch fill, instead the anabranch is filled to the surrounding ground level;
- Non-return valve fitted to 0.6 m diameter Gordon Street Drain outlet;
- Non-return valve fitted to 0.6 m diameter Gamble Street Drain culvert under Gamble Street; and
- Design for the 1% AEP flood level.

Freeboard

The anabranch has been filled to the level of the surrounding ground level which is 0.3 m higher than the 1% AEP flood level. Addition of a freeboard above the height of the surrounding ground level is not possible without construction of a levee which would need to be extended to higher ground. This would lead to the levee being several kilometres long and financially unviable.

Easement Requirements

The filling of the anabranch is required on private land and acquisition of easements is necessary. The total area of land that will require acquisition for each works location is presented below:

- East anabranch breakout – 1,200 m²
- West anabranch breakout – 11,400 m²

The area requirement for both easements was determined as the area of fill placement for the anabranch breakouts. The estimated price of land in the region is $15 per/m² (source: realestate.com).

Third Party Compensation

Nil. No properties affected by increased flood levels.

Option S2 / A7 / A8 Estimated Costing

A summary of the estimated costings for the combined Option S2 / A7 / A8 are contained in Table I 2. All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers. It has been assumed that existing culverts will not be replaced, coffer dams and dewatering will not be required and that works will be undertaken during a dry period.

Table I 2: Option S2 / A7 / A8 – Estimated Costing

Combined Option S2 / A7 / A8

Fill Anabranches

Foundation Preparation	UNIT	QUANTITY	2014 RATE RURAL NSW	COST (with factors)
Remove top soil and vegetation	m^3	780	2	$ 1,560
Place Fill	m^2	5,900	13	$ 76,700
Compact Fill	m^3	7800	3	$ 23,400
Finishes				
top soil placement	m^2	7,800	8	$ 62,400
seeding	m^2	7,800	7	$ 54,600

Non return valves

Non return valves				
Cost of non-return valve	per/valve	2	20000	$ 40,000
Attach non-return valve	hours	20	200	$ 4,000

Construction Cost	**$ 262,660**

Option S2 - Easement Costs (f)				
Easement Requirements	m^2	12,600	15	$ 54,000

TOTAL PROJECT ESTIMATE	$ 470,100	
TOTAL PROJECT ESTIMATE	$ 470,053	*a+b+c+d+e+f*
Construction Cost (a)	$ 262,660	
Contingency (b)	$ 52,532	*20% of a*
Design (c)	$ 31,519	*10% of a+b*
Construction Management (d)	$ 37,823	*12% of a+b*
Project Management (e)	$ 31,519	*10% of a+b*

Combined Options L3 / A5 / B4

Preliminary concept design information for the combined Option L3 / A5 / B4 is presented in Figure

I 3. Features of this option include:

Option L3

- Option L3 has an 80 m embankment length;
- Typical Option L3 embankment height of 0.6 m (including 0.3 m freeboard) from dry side;
- Balfour Road incorporated into Option L3 embankment;
- Option L3 embankment top width of 3 m;
- Option L3 embankment slopes at 1:4 ratio for both wet and dry sides;

Option B4

- Option B4 basin has an 250 m dam wall embankment;
- Option B4 basin has an average height of 0.5 m including 0.3 m freeboard;
- Option B1 embankment top width of 3 m;
- Option B1 embankment slopes at 1:4 ratio for both wet and dry sides;

Option A5

- Option A5 lowers the Olympic Highway for approximately 120 m length;
- Option A5 lowers the Olympic Highway by an average of 0.4 m;

Note that all Options have been design for the 1% AEP event.

Freeboard

A freeboard of 0.3 m has been applied to both Options L3 and B4.

Easement Requirements

Nil. All works are proposed for construction on Crown land

Third Party Compensation

Nil. No residential properties are affected by increased flood levels. Increased peak flood levels occur on Crown owned land on the playing fields and around two open walled tin sheds (see Image I 1). Damages associated with filling of the Option B4 basin are negligible.

Image I 1: Tin sheds susceptible to increased peak flood levels on Crown land

Option L3 / A5 / B4 Estimated Costing

A summary of the estimated costings for the combined Option L3 / A5 / B4 are contained in Table

I 3. All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers. It has been assumed that existing culverts will not be replaced, coffer dams and dewatering will not be required and that works will be undertaken during a dry period.

Table I 3: Option L3 / A5 / B4 – Estimated Costing

Combined Option L3 / A5 / B4

Option L3 - Embankment Design and Road Raising

Foundation Preparation	**UNIT**	**QUANTITY**	**2014 RATE RURAL NSW**	**COST (with factors)**
remove top soil and vegetation	m^3	43	5	$ 215
compact foundation	m^2	429	3	$ 1,287
excavate foundation channel (core - assumed 10% of total)	m^3	23	8	$ 184
lime stabilisation (core - assumed 10% of total)	m^3	23	15	$ 345
Embankment Construction				
Material	m^3	228	8	$ 1,824
shaping of batter slopes	m^2	429	2.5	$ 1,073
Compaction	m^2	429	2.5	$ 1,073
Allowance to dispose of unsuitable material (10%)	m^3	23	8	$ 184
Finishes				
top soil placement	m^2	429	8	$ 3,432
seeding	m^2	429	7	$ 3,003
Pavement/Rail Reinstatement				
Road resurfacing	m^2	500	$ 55	$ 27,500
Balfour Street Traffic Control				
Traffic Control	weeks	1	$ 1,450	$ 1,450

Option B4 - Basin Design

Foundation Preparation	**UNIT**	**QUANTITY**	**2014 RATE RURAL NSW**	**COST (with factors)**
remove top soil and vegetation	m^3	203	5	$ 1,015
compact foundation	m^2	2,028	3	$ 6,084
excavate foundation channel (core - assumed 10% of total)	m^3	84	8	$ 672
lime stabilisation (core - assumed 10% of total)	m^3	84	15	$ 1,260
Embankment Construction				

Material	m^3	842	8	$ 6,736
shaping of batter slopes	m^2	2,066	2.5	$ 5,165
Compaction	m^2	2,066	2.5	$ 5,165
Allowance to dispose of unsuitable material (10%)	m^3	48	8	$ 384

Finishes				
top soil placement	m^2	2,066	8	$ 16,528
seeding	m^2	2,066	7	$ 14,462

Option A5 - Road Realignment

Foundation Preparation	**UNIT**	**QUANTITY**	**2014 RATE RURAL NSW**	**COST (with factors)**
Road Demolition	m^2	720	20	$ 14,400
Removal of Soil/Road	m^3	432	10	$ 4,320
compact foundation	m^2	720	3	$ 2,160
Road Resurfacing	m^3	720	55	$ 39,600

Olympic Hwy Traffic Control				
Traffic Control	weeks	1	1,450	$ 1,450

Construction Cost	**$ 160,970**

TOTAL PROJECT ESTIMATE	**$ 255,000**	
TOTAL PROJECT ESTIMATE	$ 254,976	*a+b+c+d+e*
Construction Cost (a)	$ 160,970	
Contingency (b)	$ 32,194	*20% of a*
Design (c)	$ 19,316	*10% of a+b*
Construction Management (d)	$ 23,179	*12% of a+b*
Project Management (e)	$ 19,316	*10% of a+b*

Combined Options L1 / S5 / A1 / B1 / B3

Preliminary concept design information for the combined Option L1 / S5 / A1 / B1 / B3 is presented in Figure I 4. Features of this option include:

Option L1

- Option L1 has an 100 m embankment length;
- Typical Option L1 embankment height of 0.4 m (including 0.3 m freeboard) from dry side;
- Option L1 embankment top width of 3 m;
- Option L1 embankment slopes at 1:4 ratio for both wet and dry sides;

Option S5

- Option S5 drain length of 100 m;
- Option S5 average drain depth of 0.5 m and a width of 5 m (potential channel cross section displayed in Figure I 4);

Option A1

- Option A1 involves lowering a 70 m stretch of Munro Street by approximately 0.4 m;

Option B1

- Option B1 basin has a 200 m dam wall embankment;
- Option B1 basin has an average height of 0.6 m including 0.3 m freeboard;
- Option B1 basin has a 20 m long spillway constructed at 0.1 m below the 1% AEP level;
- Option B1 embankment top width of 3 m;
- Option B1 embankment slopes at 1:4 ratio for both wet and dry sides;

Option B3

- Option B3 basin has a 400 m dam wall embankment;
- Option B3 basin has an average height of 0.6 m including 0.3 m freeboard;
- Option B1 embankment top width of 3 m;
- Option B1 embankment slopes at 1:4 ratio for both wet and dry sides;

Note that all Options have been design for the 1% AEP event.

Freeboard

A freeboard of 0.3 m has been applied to Options L1, B1 and B3.

Easement Requirements

The Option B1 dam embankment is situated on private land and acquisition of an easement is necessary. The total area of land that will require acquisition is estimated to be 1960 m² which was determined by assuming 9.8 m width requirement over the 200 m length of the dam embankment. This allows for the foot print of the embankment plus 1 m from the toe of the embankment on both sides.

The estimated price of land in the region is $15 per/m² (source: realestate.com).

Third Party Compensation

Nil. No residential properties are affected by increased flood levels.

Combined Option L1 / S5 / A1 / B1 / B3 Estimated Costing

A summary of the estimated costings for the combined Option L1 / S5 / A1 / B1 / B3 is contained in Table I 4. All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers. It has been assumed that existing culverts will not be replaced, coffer dams and dewatering will not be required and that works will be undertaken during a dry period.

Table I 4: Option L1 / S5 / A1 / B1 / B3 – Estimated Costing

Combined Options L1 / S5 / A1 / B1 / B3

Options L1 - Embankment Design

Foundation Preparation	**UNIT**	**QUANTITY**	**2014 RATE RURAL NSW**	**COST (with factors)**
remove top soil and vegetation	m^3	62	5	$ 310
compact foundation	m^2	620	3	$ 1,860
excavate foundation channel (core - assumed 10% of total)	m^3	18	8	$ 144
lime stabilisation (core - assumed 10% of total)	m^3	18	15	$ 270
Embankment Construction				
Material	m^3	184	8	$ 1,472
shaping of batter slopes	m^2	620	2.5	$ 1,550
Compaction	m^2	620	2.5	$ 1,550
Allowance to dispose of unsuitable material (10%)	m^3	18	8	$ 144
Finishes				
top soil placement	m^2	630	8	$ 5,040
seeding	m^2	630	7	$ 4,410

Option S5 - Drain Design

Foundation Preparation				
remove top soil and vegetation	m^3	1,500	5	$ 7,500
Excavation (removal of soil)	m^3	600	10	$ 6,000
Channel Shaping	m^2	1,500	4	$ 6,000
Finishes				
top soil placement	m^2	1,500	8	$ 12,000
seeding	m^2	1,500	7	$ 10,500

Option A1 - Road Design

Foundation Preparation	**UNIT**	**QUANTITY**	**2014 RATE RURAL NSW**	**COST (with factors)**
Road Demolition	m^2	800	20	$ 16,000
Removal of Soil/Road	m^3	120	10	$ 1,200
compact foundation	m^2	800	3	$ 2,400
Road Resurfacing	m^3	800	55	$ 44,000

Traffic Control				
Traffic Control	weeks	1	1,450	$ 1,450

Options B1 - Basin Design

Foundation Preparation	**UNIT**	**QUANTITY**	**2014 RATE RURAL NSW**	**COST (with factors)**
remove top soil and vegetation	m^3	156	5	$ 780
compact foundation	m^2	1,560	3	$ 4,680
excavate foundation channel (core - assumed 10% of total)	m^3	65	8	$ 520
lime stabilisation (core - assumed 10% of total)	m^3	65	15	$ 975

Embankment Construction				
Material	m^3	648	8	$ 5,184
shaping of batter slopes	m^2	1,590	2.5	$ 3,975
Compaction	m^2	1,590	2.5	$ 3,975
Allowance to dispose of unsuitable material (10%)	m^3	65	8	$ 520

Finishes				
top soil placement	m^2	1,560	8	$ 12,480
seeding	m^2	1,560	7	$ 10,920

Options B3 - Basin Design

Foundation Preparation	**UNIT**	**QUANTITY**	**2014 RATE RURAL NSW**	**COST (with factors)**
remove top soil and vegetation	m^3	312	5	$ 1,560
compact foundation	m^2	3,120	3	$ 9,360
excavate foundation channel (core - assumed 10% of total)	m^3	130	8	$ 1,040
lime stabilisation (core - assumed 10% of total)	m^3	130	15	$ 1,950

Embankment Construction				
Material	m^3	1,296	8	$ 10,368
shaping of batter slopes	m^2	3,180	2.5	$ 7,950
Compaction	m^2	3,180	2.5	$ 7,950
Allowance to dispose of unsuitable material (10%)	m^3	130	8	$ 1,040

Finishes				
top soil placement	m^2	3,180	8	$ 25,440
seeding	m^2	3,180	7	$ 22,260

Construction Cost	**$**	**256,727**

Option B1 - Easement Costs (f)				
Easement Requirements (dam wall easement 9.8 m x 200 m)	m^2	1,960	15	$ 29,400

TOTAL PROJECT ESTIMATE	**$ 436,100**	
TOTAL PROJECT ESTIMATE	$ 436,055	*a+b+c+d+e+f*
Construction Cost (a)	$ 256,727	
Contingency (b)	$ 51,345	*20% of a*
Design (c)	$ 30,807	*10% of a+b*
Construction Management (d)	$ 36,968	*12% of a+b*
Project Management (e)	$ 30,807	*10% of a+b*

FIGURE I1

FLOOD IMPACT 1% AEP
OPTION A3
LOWERING THE STOCK ROUTE NEAR THE BALFOUR ST INTERSECTION

Stock Route
Kirndeen Street
Balfour Street
Walbundrie Road
Donald Street

N

Stock Route Depression

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

0 12.5 25 50 75 100 m

0 0.5 1 2 3 4 km

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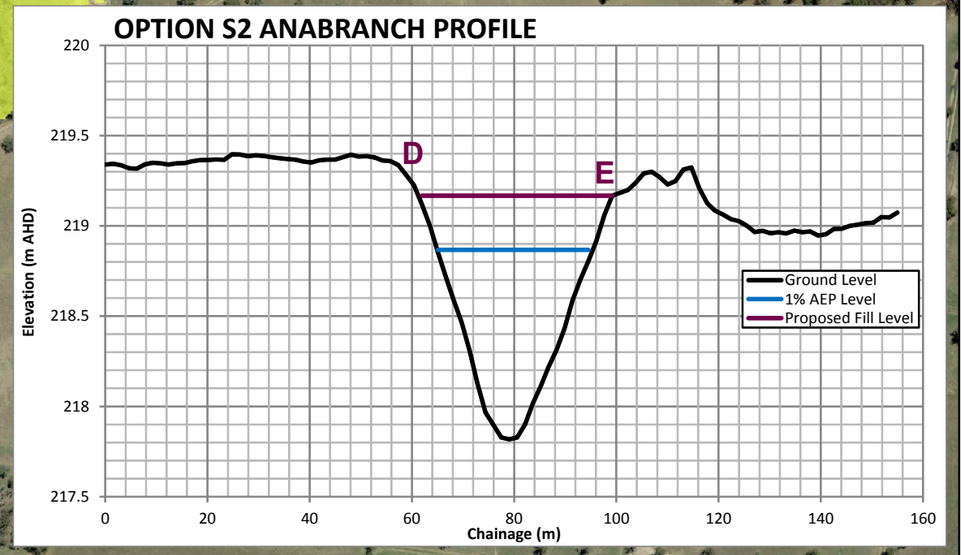
FIGURE I2

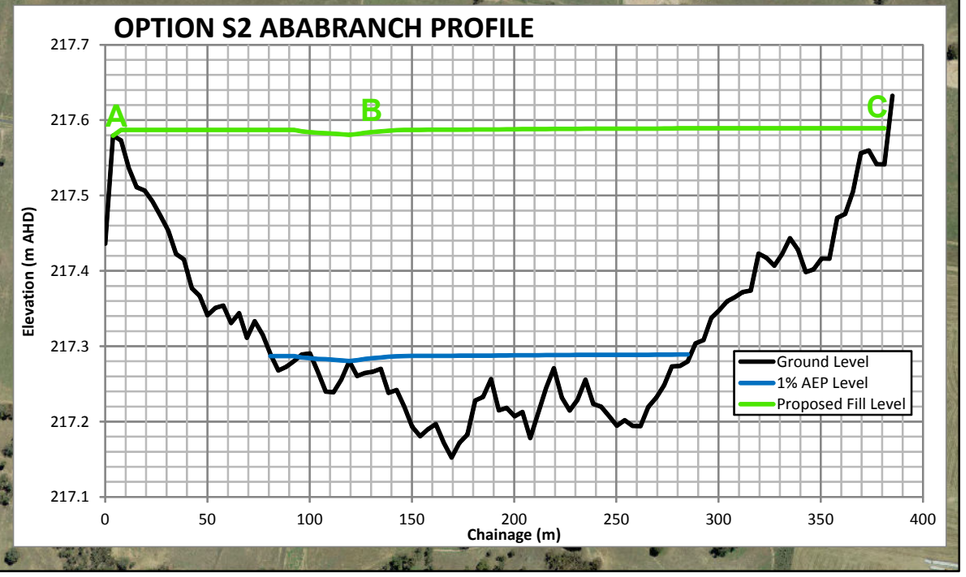
FLOOD IMPACT 1% AEP
COMBINED OPTIONS S2 / A7 / A8
STOPPING BILLABONG CREEK FLOOD AFFECTATION

Melrose Street
Lions Place
Elizabeth Street
Queen Street
Gordon Street
Munro Street
Fifield Close
Culcairn Cemetery Rd
Culcairn Holbrook Road
Kinmade Street
McBean Street
Railway Parade
Melville Street
Victoria Street
Henty Street
Balfour Street
Balfour St (Service Rd)
Edward Street
Federal Street
King Street
Fraser Street
Blair Street
Gamble Street
Wattle Street
South Street
SECTION A
A
B
C
D
E

OPTION S2 ANABRANCH PROFILE



OPTION S2 ABABRANCH PROFILE



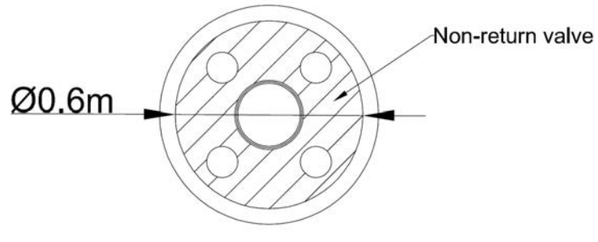
N

Non-Return Valve
Propoosed Fill

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

SECTION A: NON-RETURN VALVE



0 250 500 1,000 1,500 Meters

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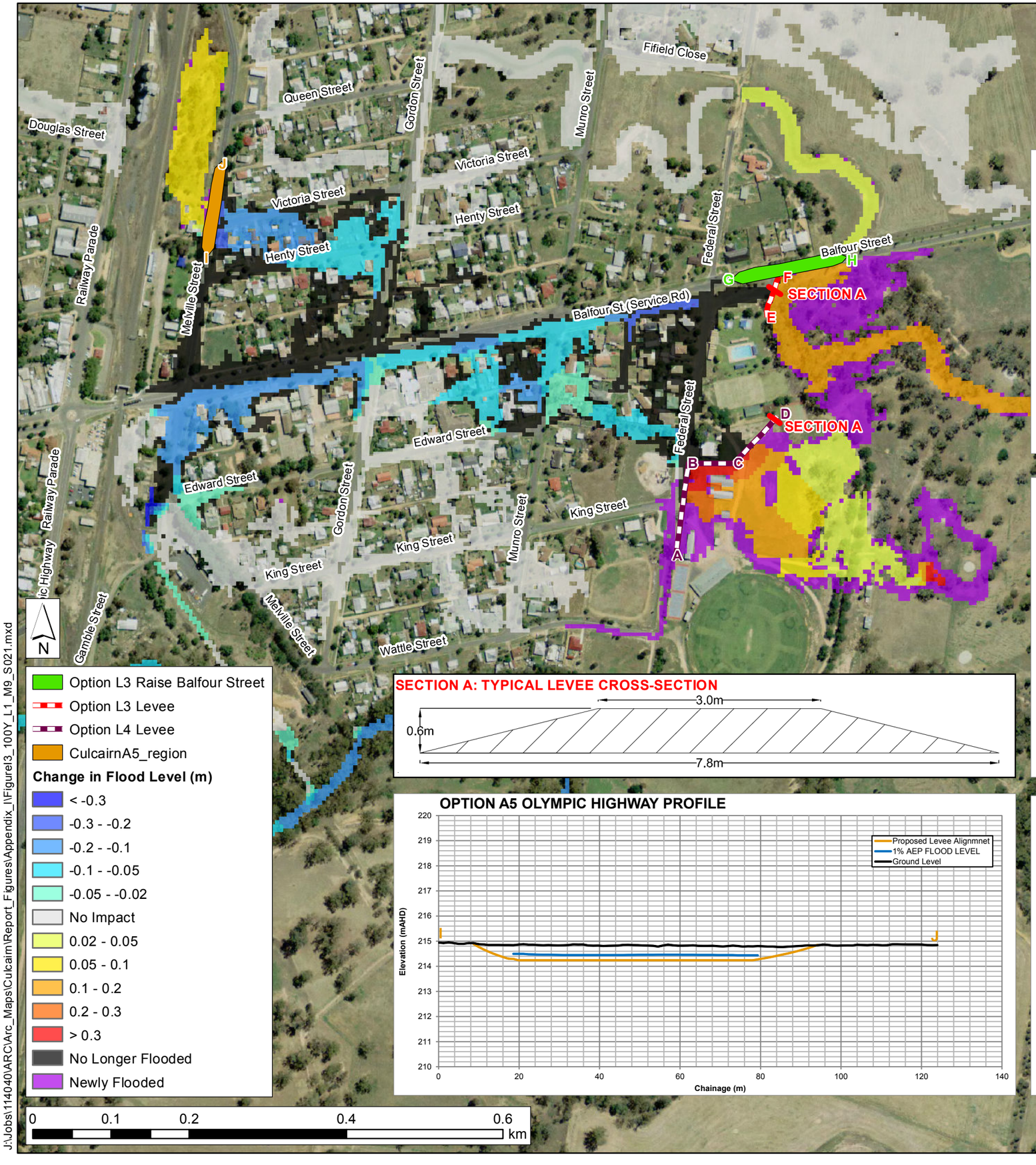
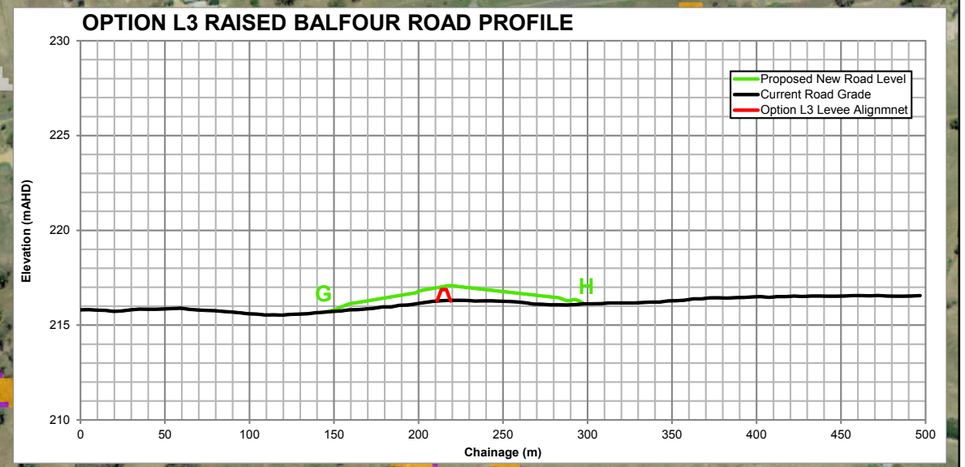
FIGURE I3

FLOOD IMPACT 1% AEP
COMBINED OPTION L3 / A5 / B4
SOUTHERN FLOW PATH FLOOD MITIGATION

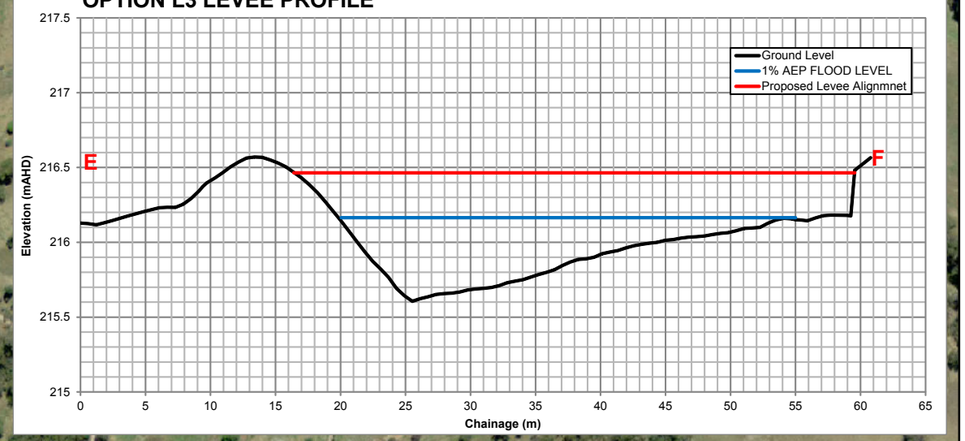


SECTION A: TYPICAL LEVEE CROSS-SECTION

OPTION L3 RAISED BALFOUR ROAD PROFILE



OPTION L3 LEVEE PROFILE



OPTION A5 OLYMPIC HIGHWAY PROFILE

OPTION L4 LEVEE PROFILE

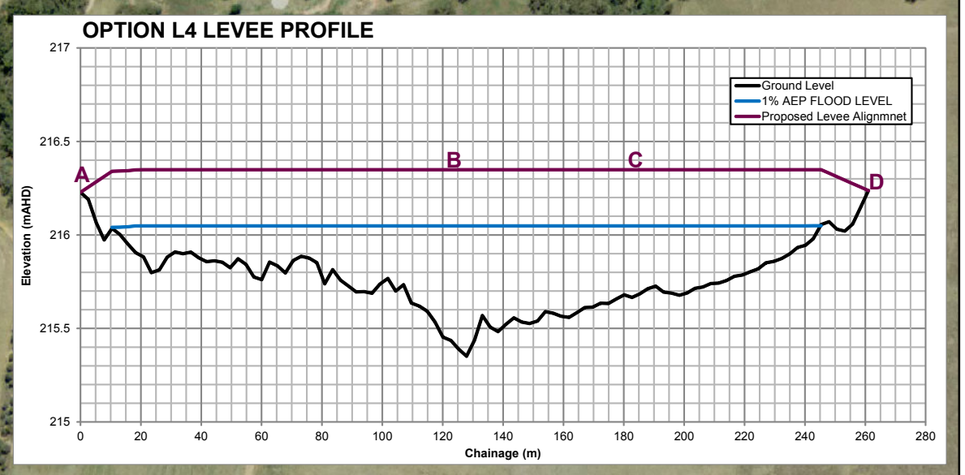


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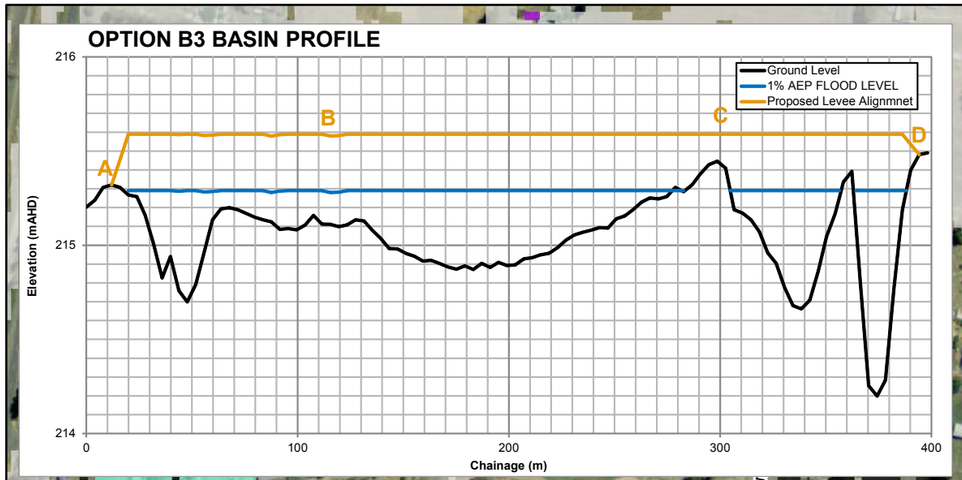
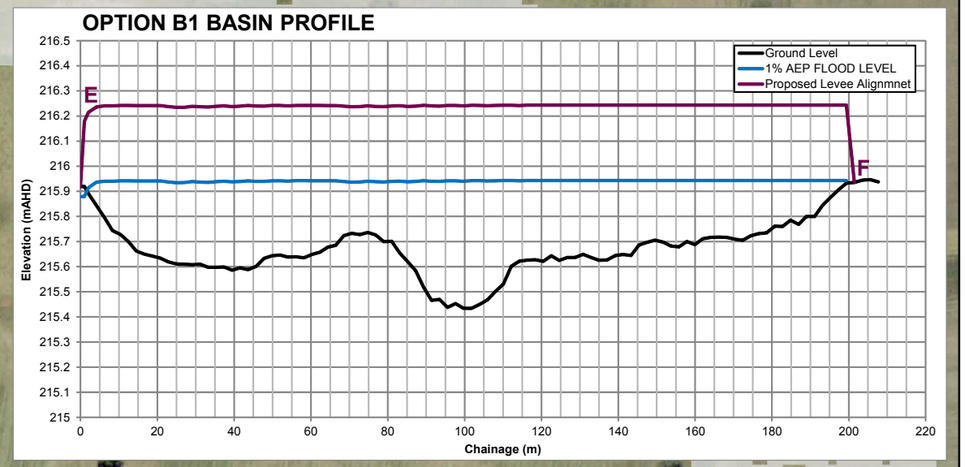
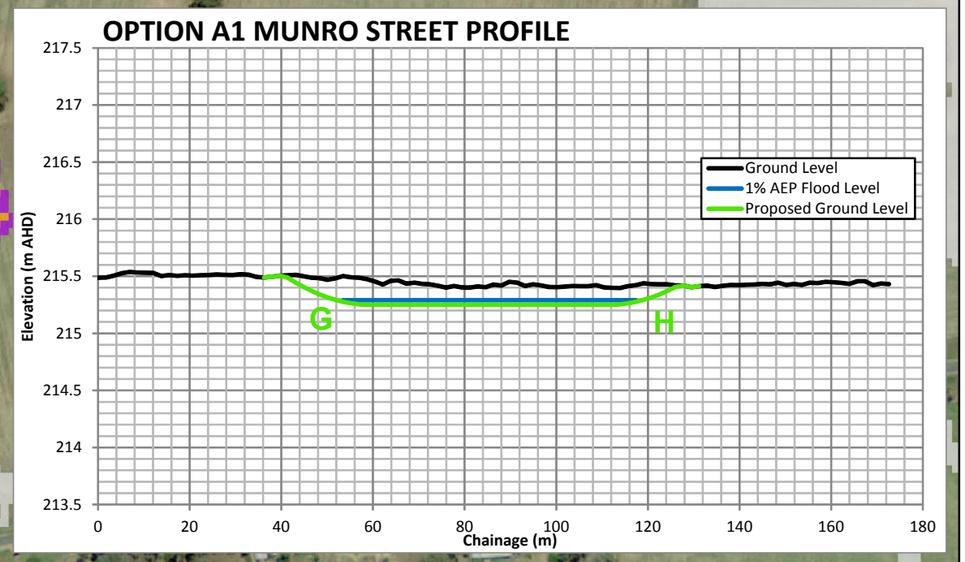
FIGURE I4

FLOOD IMPACT 1% AEP
COMBINED OPTION S2 / A7 / A8
CENTRAL FLOW PATH MITIGATION







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Appendix J

J. Appendix J: SES Flood Intelligence Draft Updates

Flood Intelligence Card

Culcairn Railway Bridge Gauge

Notes:

- design flood levels here are sensitive to blockage (25%) and to the precise location due to large afflux associated with bridge – possibly not the best location for a town gauge
- This will require revision if flood mitigation structures are constructed

Key: to be completed/confirmed (TBC)

CULCAIRN (RAILWAY BRIDGE) GAUGE - STATION NUMBER: TBC
Wednesday, 20 September 2017

Stream:	Billabong Creek			**Gauge Zero**:	204.38
Location:	Downstream side of Railway Bridge in Culcairn			**Datum Type**:	AHD
	Easting: 503356.6	Northing: 6052542.7	- GDA94 (MGA zone 55)	**Owner**:	GHSC
Minor:	**Moderate**:	**Major**: 10.0		**Levee Height**:	N/a
Design Flood Levels: Culcairn, Henty and Holbrook Flood Studies (WMA Water, Sep 2013)					

7

Class	Height (m)	Consequences
	Note:	Culcairn may be affected by overland flows from heavy local rain, typically prior to flooding from Billabong Creek. The consequences of local overland flows may have little bearing to the heights in Billabong Creek.
	Note:	The maximum gauge height is 10.0m. This was exceeded in the October 2010 flood, though there is a good control on the peak height. The record June 1931 flood peak was a little higher in Culcairn and is estimated using a regression with the Walbundrie gauge.
	5.60	8 March 2010. Swimming tower at caravan park under water.
	5.90	8 March 2010. Water starting to cover lower section of caravan park.
	6.10	Likely to cause problems at Walbundrie 14 hours later.
	6.40	9 March 2010. Bottom level of caravan park covered in water. Car park at Jubilee Park beginning to be flooded.
	6.50	9 March 2010: Peak height.
	8.03	5 year ARI design flood level.
	8.10	16 October 2010: Creek backed up stormwater drain to inundate Blair Street.
	8.15	6-7 February 2011: Peak height.

	8.51	10 year ARI design flood level.
	8.80	16 October 2010: Jubilee Park flooded.
	9.10	4 March 2012: Water starting to rise at intersection of Gordon Street and Henty Street East.
	9.15	20 year ARI design flood level.
	9.40	4 March 2012: Water flowing in gutter at intersection of Gordon Street and Henty Street East.
	9.60	4 March 2012: Water from intersection of Gordon Street and Henty Street East creeping west towards Melville Street, above footpath.
	9.65	5 March 2012: Peak height. Anabranch taking flow to eastern end of Balfour Street was not activated (possibly because deliberately blocked at creek offtake). Gordon Street trunk pipe surcharged, causing inundation at intersection of Gordon Street and Henty Street East. No houses or business/public sector buildings inundated above floor. Rear of creek-side Wattle Street properties including some garages likely inundated.
	9.75	50 year ARI design flood level. Creek breaks out into anabranch
	10.0	Base of railway bridge structure. When this level is reached the backing up of floodwater upstream is expected to worsen. This may be the trigger for initiation of flows from the golf course to the corner of Balfour and Federal Streets which then flow westwards down Balfour Street.
	10.13	100 year ARI design flood level. Modelling suggests Olympic Highway to south might not be cut by Billabong Creek flooding (but might well be cut by local flooding), with depths across the road less than 100mm deep for a distance of about 400 metres. Olympic Highway north of corner of Balfour and Melville Streets cut by flooding.
	10.20	16 October 2010: Peak height. Note that the Flood Study model did not replicate this height (peaking about 0.2m lower) but noted that a perfect match could have been achieved by manipulating bridge blockage. Thus the Flood Study estimates this event as 50-100 year ARI. Refer to property register in Bewsher Consulting (2012) report for detailed listing of consequences. Serious flooding in Balfour Street especially near the Federal Street, Munro Street and Melville Street junctions, also Henty Street East and the rear yards of houses on Wattle Street fronting Billabong Creek. 22 houses and 6 business/public sector buildings inundated above floor level (including some from local overland flows, which was about a 50y ARI event). Floodwater almost reached top tier of caravan park. Hospital in Balfour Street almost inundated. All road access to Culcairn cut.
	10.32	200 year ARI design flood level. Much of the area north of Billabong Creek and east of the railway would be flooded (Low Flood Island), with some patches of High Flood Island especially between Wattle and King Streets. The area north of the creek but west of the railway is only modestly affected but modelling shows that the Olympic Highway southbound might just be inundated.
	10.4-10.5	24 June 1931: Estimated peak height. Flood of record. Flow came from Round Hill homestead into Balfour Street from the east, inundating Culcairn public school, the Presbyterian church grounds and business premises and houses. There was between 0.45m and 0.6m water in the street. The south abutment of the railway bridge was washed away. Culcairn isolated by road and rail.
	11.85	PMF design flood level. Inundates entire town. There is high land along Culcairn-Holbrook Road about 2.5km ENE of the railway station, with several homesteads.