YASS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

VOLUME 1 – REPORT

JULY 2021

The flood that occurred in July 1900 (refer top photo) is believed to be the flood of record at Yass, while the flood that occurred in October 1959 which peaked 0.3 metres lower (refer bottom photo) was equivalent to about a 1 in 100 year event.

Job No: ES447 File: YFRMS_V1_Report_[Rev 1.7].doc	Date: July 2021 Rev No: 1.7	Principals: SAB Authors: TDR/SAB

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FOREWORD

NSW Government's Flood Policy

The NSW Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that 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 subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities. The Policy provides for technical and financial support by the State through the following four sequential stages:

1.	Data Collection and Flood Study	Collects flood related data and undertakes an investigation to determine the nature and extent of flooding.
2.	Floodplain Risk Management Study	Evaluates management measures 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. Improvements to flood emergency management procedures.

Presentation of Study Results

The results of the *Updated Flood Study* investigation commissioned by Yass Valley Council are presented in **Appendix C** of this report. Both the *Updated Flood Study* and the *Floodplain Risk Management Study* have been prepared under the guidance of the Floodplain Risk Management Committee comprising representatives from Yass Valley Council, the NSW Department of Planning, Industry and Environment, the NSW State Emergency Service and community representatives.

ACKNOWLEDGEMENT

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

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ABBREVIATIONS

AEP	Annual Exceedance Probability (%)
AHD	Australian Height Datum
ARI	Average Recurrence Interval (years)
ARR 1987	Australian Rainfall and Runoff (1987 Edition)
ARR 2019	Australian Rainfall and Runoff (2019 Edition)
BoM	Bureau of Meteorology
Council	Yass Valley Council
DECC	Department of Environment and Climate Change
DPIE	Department of Planning, Industry and Environment
FDM	Floodplain Development Manual, 2005
FRMC	Floodplain Risk Management Committee
FPL	Flood Planning Level
FPA	Flood Planning Area
FRMS	Floodplain Risk Management Study
FRMP	Floodplain Risk Management Plan
FRMS&P	Floodplain Risk Management Study and Plan
LEP	Local Environmental Plan
LiDAR	Light Detection and Ranging (survey)
MHFL	Minimum Habitable Floor Level
NSWG	New South Wales Government
NSW SES	New South Wales State Emergency Service
PMF	Probable Maximum Flood

SUMMARY

S1 Study Objectives

Yass Valley Council (**Council**) commissioned the preparation of a Floodplain Risk Management Study and Plan for the township of Yass. The overall objectives of the *Yass Floodplain Risk Management Study* (***Yass FRMS***) were to assess the impacts of flooding, review existing Council policies as they relate to development of land in flood liable areas, consider measures for the management of flood affected land and to develop the *Yass Floodplain Risk Management Plan* (***Yass FRMP***) which:

i) Proposes modifications to existing Council policies to ensure that the development of flood affected land is undertaken so as to be compatible with the flood hazard and risk.

ii) Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding.

iii) Provides a program for implementation of the proposed works and measures.

The study area for the *Yass FRMP* applies to areas that are affected by the following two types of flooding at Yass:

- **Main Stream Flooding**, which occurs when floodwater surcharges the inbank area of the existing river and creek systems. Main Stream Flooding is typically characterised by relatively deep and fast flowing floodwater, but may be shallower and slower moving in flood fringe areas.
- **Major Overland Flow** which occurs during storms which result in the surcharge of the existing piped drainage system. It is also present in the upper reaches of the study catchments.

Figure 1.1 (2 sheets) is a location and catchment plan, while **Figure 2.1** (4 sheets) shows the key features of the existing stormwater drainage system at Yass.

S2 Study Activities

The activities undertaken in this FRMS included:

1. Undertaking a consultation program over the course of the study to ensure that the Yass community was informed of the objectives, progress and outcomes over the course of the study (**Chapter 1** and **Appendix A**).
2. Review and updating of flooding patterns in Yass for flood events up to the Probable Maximum Flood (**PMF**). (**Chapter 2**, as well as **Appendices B** and **C**).
3. Assessment of the economic impacts of flooding, including the numbers of affected properties and estimation of flood damages (**Chapter 2** and **Appendix D**).
4. Review of current flood related planning controls for Yass and their compatibility with flooding conditions (**Chapter 2**).
5. Strategic review of potential floodplain risk management works and measures aimed at reducing flood damages, including an economic assessment of the most promising measures (**Chapter 3** and **Appendix E**).
6. Ranking of works and measures using a multi-objective scoring system which took into account economic, financial, environmental and planning considerations (**Chapter 4**).
7. Preparation of the *Yass FRMP* (**Chapter 5**).

S3 Summary of Flood Impacts

Figures 2.2 and **2.3** show the indicative extent and depths of inundation of both the 1% Annual Exceedance Probability (**AEP**) and PMF events, respectively, while **Figure 2.4** shows design water surface profiles along the Yass River, Chinamans Creek and Bango Creek. **Figure 2.5** shows the time of rise of floodwaters, while **Figure 2.6** shows the indicate extent of flooding at Yass for flood of between 20% and 0.2% AEP events, as well as the PMF event.

At the 1% AEP level of flooding, 23 dwellings and 34 commercial/industrial buildings are subjected to above-floor inundation, noting that no public buildings are above-floor inundated during a flood of this magnitude. The total flood damages in Yass amounts to $6.59 Million in the event of a 1% AEP flood, increasing to about $154 Million in a PMF event. **Figures 2.2** and **2.3** show the location and indicative depth of above-floor inundation in properties that are affected by the 1% AEP and PMF events, respectively.

The "*Present Worth Value*" of damages resulting from all floods up to the magnitude of the 1% AEP at a seven per cent discount rate and a 50 year economic life is about $3.5 Million. This amount represents the amount of capital spending which would be justified if a particular flood mitigation measure prevented flooding for all properties up to the 1% AEP event.

While the flood range in areas subject to Major Overland Flow is relatively small, it is relatively large in areas subject to Main Stream Flooding, especially in those areas that are subject to flooding from the Yass River. For example, the peak 1% AEP flood level on the Yass River at Yass is over 5 m higher than the corresponding peak 20% AEP flood level, while the peak PMF level is about 15 m higher than the corresponding peak 1% AEP flood level.

This large flood range in combination with the relatively rapid response time of the catchment to flood producing rain and the absence of an effective flood warning system for Yass poses a significant risk to life for occupiers of those areas that are subject to Main Stream Flooding. It also poses problems for agencies such as NSW State Emergency Services (**NSW SES**) given the relatively short period of time that is available to evacuate people from areas that could, depending on the intensity of the storm event, be subject to hazardous and life threatening flooding conditions.

S4 Flood Risk and Development Controls

An approach which uses the concepts of *flood hazard* and *hydraulic categorisation,* and is aimed at imposing a graded set of controls over development according to the flood risk has been recommended for incorporation in a new valley-wide Development Control Plan which Council is currently in the process of preparing. The delineation of flood planning constraint categories is based on the proximity to flow paths, depths and velocities of flow, the rate of rise of floodwaters and ease of evacuation from the floodplain in the event of a flood emergency.

Figure E1.1 in **Appendix E** is an extract from the *Flood Planning Map* relating to Yass. The extent of the Flood Planning Area (**FPA**) (the area subject to flood related development controls) has been defined as follows:

- In areas subject to Main Stream Flooding, the FPA is based on the traditional definition of the area inundated by the 1% AEP plus freeboard (where a freeboard of 1.2 m was adopted for defining the extent of the FPA along the Yass River, while a freeboard of 0.5 m was adopted for defining the extent of the FPA along its major tributaries).

- In areas subject to Major Overland Flow, the FPA is defined as the extent of areas which act as a floodway, as well as areas where depths of inundation exceed 0.1 m in a 1% AEP event.

Minimum habitable floor level requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on the *Flood Planning Map*. The minimum habitable floor levels for all land use types with the exception of "critical uses and facilities" is the level of the 1% AEP flood event plus 0.5 m freeboard in the case of areas affected by Main Stream Flooding and plus 0.3 m freeboard in areas affected by Major Overland Flow.

S5 Yass Floodplain Risk Management Plan

The *Yass FRMP* showing recommended flood management measures for the study area is presented in **Chapter 5**, with the recommended works and measures summarised in **Table S1** at the end of this Summary. The recommended works and measures have been given a provisional priority ranking, confirmed by the Floodplain Risk Management Committee, according to a range of criteria, details of which are set out in **Section 4** of the report.

The *Yass FRMP* comprises four "non-structural" management measures which could be implemented by Council with the assistance of NSW SES using existing data and without requiring Government funding. The measures are as follows:

- **Measure 1** – Inclusion of a new special flood considerations clause in the *Yass Local Environmental Plan 2013 (**Yass LEP 2013**)* which would apply to land which lies between the FPA and the extent of the PMF, noting that the wording in clause 6.2 titled *Flood planning* will be automatically updated by the NSW Government on 14 July 2021. The changes to *Yass LEP 2013* will provide flexibility in defining the Flood Planning Level (**FPL**) in areas subject to different types of flooding across the whole of the Local Government Area and also for ease of implementing **Measure 2**.
- **Measure 2** - The application of a graded set of planning controls for future development that recognise the location of the development within the floodplain; to be applied through a new valley-wide Development Control Plan. Suggested wording for inclusion in the new Development Control Plan is set out in **Appendix E**.
- **Measures 3** - Improvements in the NSW SES's emergency planning, including use of the flood related information contained in this study to update the *Yass Valley Local Flood Plan*. Information in this present report which would be of assistance to NSW SES includes data on the nature and extent of flooding at Yass, times of rise of floodwaters, duration and depths of inundation at major road crossings for a range of flood events and properties affected by flooding.
- **Measure 4** - Council should take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplain of the flood risk. This could be achieved through the preparation of a *Flood Information Brochure* which could be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with rate notices.

In addition to the above measures, the *Yass FRMP* includes the following two additional "non-structural" type measures which would require Government Funding:

- **Measure 5**, which involves the investigation and design of an integrated flood warning system for the Yass Valley which would include the installation of a network of pluviographic rain gauges, along with a series of telemetered stream gauges. An automated alarm and public announcement system should be linked to the telemetered stream gauges warning residents and business owners that a key trigger level(s) has been reached and to monitor and take action where required. Other improvements include the installation of manual read water level gauges at Sutton, Gundaroo and Yass, as well as the installation of warning signs and self-deploying boom gates on river and creek crossings.
- **Measure 6**, which involves the implementation of the abovementioned integrated flood warning system for the Yass Valley.

While several potential flood modification works in the form of upgrades to the existing stormwater drainage system and the construction of a detention basin in publically owned land were assessed as part of the *Yass FRMS*, none were considered to provide sufficient benefit in terms of a reduction in flood affectation and hazard in existing development to justify their inclusion in the *Yass FRMP*. However, the *Yass FRMS* did conclude that there is merit in developing and implementing a *Vegetation Management Plan* for Chinamans Creek where it runs through the urbanised parts of Yass, noting that while the removal of dense vegetation from inbank areas would not have a significant impact on peak 1% AEP flood levels, it would reduce the frequency of nuisance flooding and the risk of blockage of hydraulic structures (**Measure 7**).

S6 Timing and Funding of FRMP Measures

The total estimated cost to implement the *Yass FRMP* is **$0.82 Million**, exclusive of Council, NSW SES and Bureau of Meteorology staff costs. The timing of the measures will depend on Council's overall budgetary commitments and the availability of both Local and State Government funds.

Assistance for funding qualifying projects included in the *Yass FRMP* may be available upon application under the Commonwealth and State funded floodplain management programs, currently administered by NSW Department of Planning, Industry and Environment.

S7 Council Action Plan

1. Council to update *Yass LEP 2013* and prepare a new valley-wide Development Control Plan incorporating the suggested form of wording set out in **Appendix E** of this report (**Measures 1** and **2** of the *Yass FRMP*).
2. NSW SES to update the *Yass Valley Local Flood Plan* using information on flooding patterns, peak flood levels, times of rise of floodwaters and flood prone areas identified in this report (**Measure 3** of the *Yass FRMP*).
3. Council to inform residents of the flood risk, based on the information presented in the *Yass FRMS*. (e.g. displays of flood mapping at Council offices, preparation of *Flood Information Brochure* for distribution with rate notices, etc) (**Measure 4** of the *Yass FRMP*).
4. Council to commission the investigation, design and implementation of an integrated flood warning system for the Yass Valley (**Measure 5** and **6** of the *Yass FRMP*).
5. Council to develop and implement a *Vegetation Management Plan* for Chinamans Creek (**Measure 7** of the *Yass FRMP*).

TABLE S1
RECOMMENDED MEASURES FOR INCLUSION IN YASS FLOODPLAIN RISK MANAGEMENT PLAN

Measure	Required Funding	Features of the Measure	Priority
1. Update of *Yass LEP 2013*	Council's staff costs	➢ A new *special flood considerations* clause should be incorporated in *Yass LEP 2013* which applies to land that lies between the FPA and the PMF. The new clause relates to development with particular evacuation or emergency response issues (e.g. group homes, residential aged care facilities, etc). It is also aimed at protecting the operational capacity of emergency response facilities and critical infrastructure during extreme flood events. ➢ It is noted that the wording in clause 6.2 of *Yass LEP 2013* titled *Flood planning* will be automatically updated by the NSW Government on 14 July 2021 as part its recent reform of the *NSW Flood Prone Land Package*.	**High Priority**: this measure is designed to mitigate the flood risk to future development and has a high priority for inclusion in the *Yass FRMP*. It does not require Government funding.
2. Incorporate recommended approach to managing future development on flood prone land in new valley-wide Development Control Plan.	(Council's staff costs)	▪ Graded set of flood controls based on the type of development and their location within the floodplain, defined as land inundated by the PMF. ▪ Floodplain divided into five zones based on the assessed flood hazard and hydraulic categorisation. ▪ The minimum floor levels for all land use types is the level of the 1% AEP flood event plus 0.5 m freeboard in the case of areas affected by Main Stream Flooding and plus 0.3 m freeboard in areas affected by Major Overland Flow. ▪ Additional controls applied to development that is located on land which lies above the Flood Planning Level where the large flood range is considered to pose a significant risk to life.	**High Priority**: this measure is designed to mitigate the flood risk to future development and has a high priority for inclusion in the *Yass FRMP*. It does not require Government funding.
3. Ensure flood data in the *Yass FRMS* are available to the NSW SES for improvement of flood emergency planning.	NSW SES costs	➢ NSW SES should update the *Yass Valley Local Flood Plan* using information on flooding patterns, times of rise of floodwaters and flood prone areas identified in this report.	**High Priority**: this measure would improve emergency response procedures and has a high priority. It does not require Government funding.
4. Implement flood awareness and education program	Council staff costs	➢ Council to inform residents of the flood risk, based on the information presented in the *Yass FRMS*. (e.g. displays of flood mapping at Council offices, preparation of *Flood Information Brochure* for distribution with rate notices, etc).	**High Priority**: this measure would improve the flood awareness of the community and has a high priority. It does not require Government funding.
5. Investigate and design an integrated flood warning system for the Yass Valley	$0.07 Million	➢ The installation of a network of telemetered pluviographic rain gauges in combination with a series of telemetered stream gauges would assist BoM and NSW SES in providing more accurate and timely flood warnings for urbanised areas in the Yass Valley. ➢ The linking of an alarm and public announcement system to the telemetered stream gauges (where applicable) would warn residents and business owners that a key trigger level(s) has been reached and to monitor and take action where required. ➢ The installation of manually read water level gauges at key locations would allow NSW SES to monitor river and creek levels during a flood event. ➢ The installation of warning signs and self-deploying boom gates at river and creek crossings would prevent motorists from accessing inundated roads.	**High Priority**: this measure would reduce flood damages by providing advance warning of potential flooding.
6. Implement integrated flood warning system for the Yass Valley	$0.5 Million		
7. Develop and implement *Vegetation Management Plan* for Chinamans Creek	$0.25 Million	➢ The *Vegetation Management Plan* will identify the reaches of Chinamans Creek which require regular maintenance. It will also describe the scope of any rehabilitation works which would be required following the completion of any inbank works. ➢ The required funding would permit the development of the *Vegetation Management Plan*, the removal of dense vegetation from the inbank area of the watercourse and the implementation of a regular maintenance program over a five year period.	**Low Priority**: this measure would reduce the risk of a blockage being experienced at the various road crossings, as well as reduce the frequency of nuisance flooding.
Total Estimated Cost	**$0.82 Million**		

1 INTRODUCTION

1.1 Study Background

Yass Valley Council (**Council**) commissioned the preparation of the *Yass Floodplain Risk Management Study and Plan* (***Yass FRMS&P***) in accordance with the New South Wales Government's *Flood Prone Land* policy. **Figure 1.1** (2 sheets) shows the location of Yass, as well as the extent of the catchment contributing to flow in the Yass River at the town. It also shows the extent of the catchments which contribute to the two major creek systems which are located in the study area.

The *Yass FRMS&P* focuses on the following two types of flooding which are present in different parts of the study area:

- **Main Stream Flooding**, which occurs when floodwater surcharges the inbank area of the existing river and creek systems. Main Stream Flooding is typically characterised by relatively deep and fast flowing floodwater, but may be shallower and slower moving in flood fringe areas.
- **Major Overland Flow** which occurs during storms which result in the surcharge of the existing piped drainage system in Yass. It is also present in the upper reaches of the study catchments.

The *Yass Floodplain Risk Management Study (**Yass FRMS**)* reviewed baseline flooding conditions, including an assessment of economic impacts and the feasibility of potential measures which are aimed at reducing the impact of flooding on both existing and future development. The review was based on flood behaviour which was defined using updated versions of the flood models that were originally developed as part of the *Yass Flood Study* (WMAWater, 2016a) (herein referred to as the ***Updated Flood Study***). This process allowed the formulation of the *Yass Floodplain Risk Management Plan* (***Yass FRMP***) for the study area.

1.2 Background Information

The following documents were used in the preparation of this report.

- *Floodplain Development Manual* (New South Wales Government (NSWG), 2005)
- *Yass Local Environmental Plan, 2013* (*Yass LEP 2010*)
- *Yass Shire Council – Multi-unit Residential Development* (*Yass DCP 2003*)
- *Yass Dam 3.0 m Raising Concept Design Report* (NSW Department of Commerce (**DoC**), 2010)
- *Yass Valley Local Flood Plan* (NSW State Emergency Service (**NSW SES**), 2013) (***Yass Valley Local Flood Plan**)*
- *Extreme Flood Discharge Estimate for Yass Dam* (WRM Water + Environment, 2015)
- *Yass Flood Study* (WMAWater, 2016a)
- *Gundaroo Floodplain Risk Management Study and Plan* (WMAwater, 2016b)
- *Sutton Floodplain Risk Management Study and Plan* (WMAwater, 2016c)
- *Dam Safety Emergency Plan for Yass Dam* (NSW Public Works, 2016)
- *Hydraulic Assessment at Location of Proposed Causeway Crossing of Yass River* (Lyall & Associates, 2019)

1.3 Overview of Yass FRMS Report

The results of the *Yass FRMS* and the *Yass FRMP* are set out in this report. Contents of each Chapter of the report are briefly outlined below:

- **Chapter 2**, **Baseline Flooding Conditions**. This Chapter includes a description of the existing drainage system at Yass, as well as the nature of flood behaviour in the study area based on the findings of the *Updated Flood Study*. The Chapter also summarises the economic impacts of flooding on existing urban development, reviews Council's flood planning controls and management measures and NSW SESs flood emergency planning.
- **Chapter 3**, **Potential Floodplain Management Measures**. This Chapter reviews the feasibility of floodplain management measures for their possible inclusion in the *Yass FRMP*. The list of measures considered is based on input from the Community Consultation process, which sought the views of residents and business owners in the study area in regard to potential flood management measures which could be included in the *Yass FRMP*. The measures are investigated at the strategic level of detail, including indicative cost estimates of the most promising measures and benefit/cost analysis.
- **Chapter 4**, **Selection of Floodplain Management Measures**. This Chapter assesses the feasibility of potential floodplain management strategies using a multi-objective scoring procedure which was developed in consultation with the Floodplain Risk Management Committee (**FRMC**) and outlines the preferred strategy.
- **Chapter 5, Yass Floodplain Risk Management Plan** presents the *Yass FRMP* which comprises a number of structural and non-structural measures which are aimed at increasing the flood awareness of the community and ensuring that future development is undertaken in accordance with the local flood risk.
- **Chapter 6** contains a glossary of terms used in the study.
- **Chapter 7** contains a list of References.

Five technical appendices provide further information on the study results:

Appendix A – Community Consultation and Historic Flooding summarises residents' and business owners' views on potential flood management measures which could be incorporated in the *Yass FRMP*.

Appendix B - Photos Showing Historic Flooding at Yass contains a series of plates which show the nature of Main Stream Flooding which was experienced in parts of Yass during the major floods that occurred in 1900, 1925 and 1959. Also included are a number of photos showing the flooding that was experienced on the Yass River at Yass during the recent flood that occurred in August 2020.

Appendix C – Hydrologic and Hydraulic Modelling Update deals with the update of the hydrologic and hydraulic models that were developed as part of WMAwater, 2016a based on the procedures set out in the 2019 edition of Australian Rainfall and Runoff (Geoscience Australia, 2019) (**ARR 2019**).

Appendix D – **Flood Damages** is an assessment of the economic impacts of flooding to existing residential, commercial and industrial development, as well as public buildings at Yass. The damages have been re-assessed using the results of the updated flood modelling, as well as surveyed and estimated floor levels, the latter which were derived from a combination of a "drive-by" property survey, as well as data from LiDAR survey.

Appendix E – **Suggested Wording for Inclusion in Yass Valley Development Control Plan** presents guidelines for the control of future urban development in flood prone areas in the Yass Local Government Area (**LGA**). The guidelines cater for both Main Stream Flooding of the river and creek systems, as well as Major Overland Flow resulting from surcharging of the stormwater drainage systems in the overland flow paths draining the urbanised parts of the LGA.

1.4 Community Consultation

Following the Inception Meeting of the Floodplain Risk Management Committee (**FRMC**), a *Community Newsletter* was prepared by the Consultants and distributed to residents and business owners by Council. A *Community Questionnaire* was also distributed by Council seeking details from residents and business owners regarding their attitudes toward potential floodplain management measures. Community responses are summarised in **Chapter 3** of this report, with supporting information in **Appendix A**. The views of the community on potential flood management measures to be considered in the study were also taken into account in the assessment presented in **Chapter 3** of this report.

The FRMC reviewed the potential flood management measures developed in **Chapter 3** and assessed the measures using the proposed scoring system of **Chapter 4**. The *Yass FRMS* and accompanying *Yass FRMP* were also reviewed by the FRMC and amended prior to the preparation of the public exhibition report.

The draft *Yass FRMS&P* report was placed on public exhibition over the period 23 May 2021 to 25 June 2021, while a "drop-in" session was held between 6-8 pm on 16 June 2021. Two pop-up displays that provided a visual representation of the large flood range at Yass were also set up, one near the carpark on Riverbank Park (adjacent to Cobblestone Cottage) and the other on the corner of Comur Street and Rossi Street outside the Yass Court House.

A total of five (5) written submissions were received from the public during the exhibition period, three of which were supportive of the findings and recommendations set out in the document, while another requested that location specific peak flood and ground level data be provided prior to the "drop-in" session.[1] The remaining submission related to the frequent inundation that is currently being experienced in private property that is located on the northern (downstream) side of Browne Street as a result of flow which surcharges an adjacent transverse drainage structure.

While the present study found that the aforementioned transverse drainage structure is surcharged during storms that are more frequent than 20% AEP (the most frequent storm event assessed as part of the present study) and that flooding in the downstream property is exacerbated by the fact that the low point in the road is not centred on the downstream reach of channel, it was concluded that due to the relatively shallow nature of the flow and the limited flood damages that would be experienced in private property during storm events which surcharge the existing transverse drainage structure, any upgrade works would not be eligible for funding under the NSW Government's floodplain management program. While its ineligibility for State Government funding has resulted in it not being incorporated in the *Yass FRMP*, it is recommended that Council further investigate the capacity of the existing transverse drainage structure as based on the findings of the present study its hydrologic standard appears to be too low and therefore there would be merit in its future upgrade by Council.[2]

[1] It is noted that the requested data were provided to the respondent prior to the drop-in session.

[2] It is noted that Council has previously considered a report on this matter.

During presentations that were given by the Consultant to both the FRMC and Councillors on the findings and recommendations set out in the draft *Yass FRMS&P* report, concerns were raised in relation to the controls that would be imposed on "Sensitive Uses and Facilities", namely for this type of development to be located off the floodplain. These controls were considered to have an unacceptable impact on the ability for people housed in this type of development to easily access essential community services in Yass. In the knowledge that the *Yass FRMP* includes the requirement to develop and implement an integrated flood warning system for the Yass Valley, Council requested that the controls for Main Stream Flooding be amended to more closely reflect those for residential type development, noting that it would still be a requirement for an Applicant to demonstrate that users could be evacuated from the proposed development to flood free land in a safe and orderly manner.

Following a review of the draft *Yass FRMS&P* report, the Department of Planning, Industry and Environment (**DPIE**) recommended that the wording be updated to reflect the State Government's new *NSW Flood Prone Land Package* and how its introduction will affect future flood and floodplain risk management planning at Yass.

1.5 Flood Frequency and Terminology

In this report, the frequency of floods is referred to in terms of their Annual Exceedance Probability (**AEP**). The frequency of floods may also be referred to in terms of their Average Recurrence Interval (**ARI**). The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) – %	Average Recurrence Interval (ARI) – years
0.2	500
0.5	200
1	100
2	50
5	20
10	10
20	5

The AEP of a flood represents the percentage chance of its being equalled or exceeded in any one year. Thus a 1% AEP flood, which is equivalent to a 100 year ARI, has a 1% chance of being equalled or exceeded in any one year and would be experienced, on the average, once in 100 years; similarly, a 20 year ARI flood has a 5% chance of exceedance, and so on.

The 1% AEP flood (plus freeboard) is usually used to define the Flood Planning Level (**FPL**) and Flood Planning Area (**FPA**) for the application of flood related controls over residential and commercial/industrial development. While a 1% AEP flood is a major flood event, it does not define the upper limit of possible flooding. Over the course of a human lifetime of, say 70 years, there is a 50 per cent chance that a flood at least as big as a 1% AEP event will be experienced. Accordingly, a knowledge of flooding patterns in the event of larger flood events up to the Probable Maximum Flood (**PMF**), the largest flood that could reasonably be expected to occur, is required for land use and emergency management planning purposes. In the *Updated Flood Study*, flooding patterns in the study area have been assessed for design floods ranging between 20% AEP event and the PMF.

2 BASELINE FLOODING CONDITIONS

2.1 Physical Setting

The township of Yass has a population of about 6,400 and lies on the Yass River approximately 50 km north of Canberra in the Murrumbidgee River basin. **Figure 1.1**, sheet 1 shows that the headwaters of the Yass River are located about 80 km to the south-east of Yass in the vicinity of the village of Sutton. The Yass River flows in a westerly direction through Yass where it discharges to Burrinjuck Dam which is located about 25 km to the west of the township. The Yass River catchment is characterised by hilly pastoral land and has an area of about 1,230 km^2 at the town.

The developed parts of Yass are drained primarily by Chinamans Creek and Bango Creek (refer **Figure 1.1**, sheet 2). While the majority of development at Yass is situated on high ground, as will be explained later in this chapter, a large number of properties are subject to hazardous flooding conditions during very rare and extreme flood events due to the large flood range in the Yass River.

2.2 Drainage System

Figure 2.1 (4 sheets) shows the existing stormwater drainage system at Yass. The majority of the urbanised part of Yass that is located to the south of the Yass River is drained by a series of roadside gutters and stormwater pipes that discharge to Chinamans Creek. Chinamans Creek has a catchment area of about 3.7 km^2 at the point at which it discharges to the Yass River. **Figure 2.1**, sheet 2 shows that Chinamans Creek has been enclosed where it flows beneath existing roads and development. Two on-site stormwater detention basins have recently been constructed in the headwaters of the catchment as part of residential subdivisions that are located in the vicinity of Colls Close and Nicholson Drive.

Figure 2.1, sheet 4 shows the extent of a 1.5 km^2 catchment that may have originally drained to Chinamans Creek, but has been diverted to the Yass River via a single 1200 mm diameter pipe that runs in a northerly direction along Dutton Street.

Figure 2.1, sheet 3 shows that the urbanised part of the town that is located on the northern side of the Yass River is drained by piped drainage systems that discharge to the river at the southern ends of O'Brien Street and Hume Street, or via piped culverts that are located beneath the disused railway line at the western ends of Grapian Street, Mount Street and Orion Street. Existing development that is located north of Orion Street drains to Bango Creek via a piped drainage system that is located along Yass Valley Way.

Figure 2.1, sheets 3 and 4 show that Bango Creek drains the largely undeveloped rural land that is located to the north of the town and has a catchment area of about 67 km^2 at its point of discharge to the Yass River. The Hume Highway and the Main Southern Railway runs in an east-west direction through the Bango Creek catchment.

2.3 Flood History

2.3.1 Gauge History

The *Yass River at Yass* stream gauge (GS 410026) (**Yass stream gauge**) was first established in August 1915 when daily gauge heights were manually-read until it was decommissioned in 1956 and replaced by another manually-read gauge that was located approximately 3.5 km downstream at the Railway Weir (refer **Figure 2.1**, sheet 3 for location).

In 1961 the aforementioned stream gauge was decommissioned and a new telemetered stream gauge installed on the right bank of the Yass River about 100 m downstream of Flat Rock Crossing.

2.3.2 Historic Flood at Yass

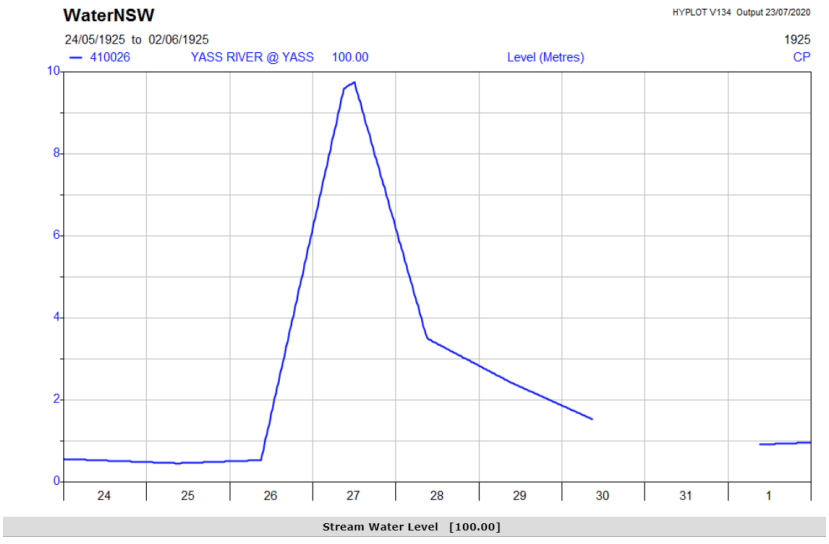
Yass has experienced several large floods that have inundated the floodplain and isolated parts of the town since settlement occurred in the 1830s. While stream gauge records only extend back to 1915, archival information contained in WMAwater, 2016a indicates that major flood events occurred in July 1852, July 1864, April 1870, June 1891 and July 1900.

Table 2.1 over provides a comparison of the maximum water levels that have been reached in the Yass River at the location of the various stream gauges with peak design floods levels derived as part of the present study at the location of the current telemetered stream gauge for a range of design flood events. The gauge heights corresponding with Minor, Moderate and Major Floods as advised by NSW SES are also shown.

The July 1900 flood event is estimated to be the flood of record at Yass. While details of the extent of flooding during this event are limited, archival newspaper articles indicate that significant damage occurred at Yass and at least fifteen residential properties were inundated.

The October 1959 flood event is the largest to occur since official records began in 1915. Archival news footage from 1959 indicates that a dozen residential premises were evacuated during the event and three service stations, as were "several" shops in Comur Street. The floodwaters reached the steps of the Yass Court House in Rossi Street. The October 1959 flood event reached RL 5.9 m on the Railway Weir stream gauge which is equivalent to about 10.0 m on the Yass stream gauge.[3] **Table 2.1** shows that the October 1959 flood event was equivalent to a design flood event with an AEP of 1 per cent. It is noted that time-based water level data at the Yass stream gauge are not available for the October 1959 flood event.

The third largest flood event on record at Yass occurred in May 1925. Archival newspaper articles indicate that the flood occurred after almost nine inches of rain were recorded over the preceding days. As shown on the adjacent stage hydrograph, water levels in the river commenced to rise around mid-day on 26 May 1925, continuing into the night. Reports state that by sunrise the Yass River was approximately a quarter of a mile (about 400 m) wide at the location of the Hume Bridge, with the floodwater said to have begun receding at about 14:00 hours on the 27 May. There are no records of the number of properties that were impacted by the May 1925 flood event.



Appendix B contains a series of photos that show the flooding that was experienced in Yass during the 1900, 1925 and 1959 floods. Also included are a number of photos showing the flooding that was experienced at Yass during the recent flood that occurred in August 2020 which is estimated to have had an AEP slightly larger than 10 per cent.

[3] Source: WMAwater, 2016

TABLE 2.1
FLOOD HISTORY AND DESIGN FLOOD LEVELS[1,2]
YASS RIVER STREAM GAUGE (GS 410026)

Flood Event	Height on Yass Stream Gauge (m)[3]
PMF Event without Dam Failure[4]	25.5
0.2% AEP	13.1
0.5% AEP	11.3
July 1900[5]	10.3
1% AEP	10.1
October 1959[5]	10.0
May 1925[5]	9.75
June 1891[5]	>8.8
June 1952[5]	8.8
April 1870[5]	8.8
2% AEP	8.8
Major Flood[6]	8.0
August 1974[5]	7.6
5% AEP	7.2
July 1922[5]	7.0
October 1934[5]	7.0
April 1950[5]	7.0
Moderate Flood[6]	6.0
10% AEP	5.9
20% AEP	4.7
Minor Flood[6]	4.6

1. Peak historic flood levels which pre-date the installation of the current telemetered stream gauge are either estimates or relate to the earlier manually-read stream gauges that were not necessarily located at the same location along the river.
2. Design peak flood levels relate to the findings of the *Updated Flood Study*.
3. Gauge zero on Yass gauge = 475.52 m AHD.
4. While failure of the Yass Dam was assessed as part of NSW Public Work, 2016, the approximate gauge height reached during the assessed dam break scenarios was not reported.
5. Source: WMAwater, 2016a
6. NSW SES provided written advice on the Major/Moderate/Minor classifications for Yass as they are not defined in the *Yass Valley Local Flood Plan*.

2.4 Design Flood Behaviour

2.4.1 Background to Previous Studies

WMAwater, 2016a defined the nature of flooding in the study area for design storms ranging between 20% and 0.5% AEP, as well as the PMF event. Flood behaviour was defined using a three-staged approach to design flood estimation at Yass:

1. A flood frequency analysis which was undertaken for the Yass stream gauge using the TUFLOW Flike software.
2. The development and running of a hydrologic model of the local catchments in and around Yass which was based on the DRAINS rainfall-runoff software.
3. The development and running of a hydraulic model of the Yass River, Chinamans Creek and Bango Creek, as well as their minor tributaries which was based on the TUFLOW software.

The flood frequency analysis was used to derive design peak flow estimates at the Yass stream gauge. The ordinates of the discharge hydrograph that was recorded at the stream gauge during a flood event that occurred on March 1989 were factored to match the flood frequency derived design peak flow estimates. These hydrographs were then applied to the upstream boundary of the TUFLOW hydraulic model.

The DRAINS model was used to generate design discharge hydrographs which were also applied to the TUFLOW hydraulic model. The design discharge hydrographs were based on design storms that were derived based on procedures set out in the 1987 edition of *Australian Rainfall and Runoff* (Institute of Engineers, Australia (**IEAust**), 1987) (**ARR 1987**).

The TUFLOW model used a two-dimensional (in plan), grid-based representation of the natural surface based on LiDAR survey data, as well as piped drainage data that were provided by Council. Field survey was also used to capture details of the existing stormwater drainage system.

It was not possible to calibrate the DRAINS model as there are no stream gauges in the Chinamans Creek or Bango Creek catchments. Rather it was necessary to adopt an iterative approach whereby the hydrologic and hydraulic models were run in series, with changes made to model parameters until a reasonable match was achieved between modelled and observed flood behaviour for a storm event that occurred in December 2010. The TUFLOW model was also calibrated to observed peak flood levels from the March 1989 flood event.

An “envelope” approach was adopted for defining design water surface elevations and flow patterns throughout the study area. The procedure involved running the model for the 60 minute storm duration which was found to be critical for maximising peak flood levels along Chinamans Creek and Bango Creek and the factored March 1989 discharge hydrographs on the Yass River to define the upper limit (i.e. the envelope) of expected flooding for each design flood frequency.

Lyall & Associates recently undertook a flooding investigation for a planned privately owned bridge crossing of the Yass River upstream of Yass (Lyall & Associates, 2019). The DRAINS software was used to develop a RAFTS based hydrologic model of the Yass River catchment upstream of the Yass stream gauge. The hydrologic model was tuned to the flood frequency relationship presented in WMAwater, 2016a for the Yass stream gauge, with design storm losses based on the median pre-burst depths which were sourced from the *ARR Data Hub*. The hydrologic model was used to derive peak flows and design discharge hydrographs at the proposed bridge site.

2.4.2 Background to Development of Updated Flood Models

The hydrologic and hydraulic models that were developed as part of WMAwater, 2016a were updated as part of the present study using the procedures set out in ARR 2019. The structure of the models was also updated to improve the definition of flood behaviour in several areas.

The hydrologic model that was developed as part of Lyall & Associates, 2019 was also updated to incorporate the probability-neutral burst initial loss values which have recently been released for use in NSW.

The updated flood models were used to define the nature of flooding in Yass for design storms of between 20% and 0.2% AEP, as well as the PMF event. **Appendix C** of this report sets out the details of the hydrologic and hydraulic modelling that was undertaken as part of the present study.

2.4.3 Design Flooding Patterns

Figures 2.2 and **2.3** show the nature of flooding at Yass for the 1% AEP and PMF events, respectively, while **Figures C4.1** to **C4.6** in **Appendix C** of this report show similar information for the 20%, 10%, 5%, 2%, 0.5% and 0.2% AEP flood events. These figures show the indicative extent and depth of inundation along the Yass River, Chinamans Creek and Bango Creek, as well as along the Major Overland Flow paths for the assessed design flood events. Also shown on these figures are Peak Flow Locations (**PFLs**) which are referred to in the following discussion. Peak flows for the assessed design flood events at each PFL are tabulated in **Table C1** in **Attachment C3** of **Appendix C**.

Figure 2.4 shows water surface profiles along the Yass River, Chinamans Creek and Bango Creek for the assessed design flood events, while **Table 2.1** sets out the design peak flood levels at the Yass stream gauge. **Figure 2.5** shows the time of rise of floodwater at key locations throughout the study area, including at several major road crossings.

The key features of flooding on the Yass River at Yass are as follows:

- Floodwater is contained within the river banks in a 20% AEP flood event.
- Floodwater commences to surcharge the southern bank of the river at its confluence with Chinamans Creek in a 10% AEP design flood event.
- Access between the northern and southern sides of Yass is cut in a 5% AEP flood event as floodwater commences to surcharge Comur Street at the low point that is located about 80 m to the north of its intersection with Rossi Street. Floodwater backs up Chinamans Creek and inundates Rossi Street to a depth of about 0.5 m.
- Rossi Street is inundated to a depth of about 3.5 m in a 1% AEP flood event. .
- Floodwater commences to surcharge the right bank of the Yass River in the vicinity of its confluence with Bango Creek where it would inundate Yass Valley Way to a depth of about 0.9 m in a 1% AEP event.
- Peak 0.5% and 0.2% AEP flood levels in the Yass River are respectively 1.2 m and 3.0 m higher than corresponding peak 1% AEP flood levels.
- Peak PMF flood levels on the Yass River are about 15 m higher than corresponding peak 1% AEP flood levels.

The key features of flooding along Chinamans Creek are as follows:

- Floodwater is generally contained within the banks of the creek in a 20% AEP event with the exception of the following locations:
    - in the vicinity of Perry Street where floodwater surcharges onto the road and flows in an easterly direction before turning and flowing in a northerly direction along Brennan Street; and
    - in Cobham Street, where floodwater inundates an existing commercial building that is located on the northern side of the road (refer PFL Q08 on sheet 2 of series).
- Floodwater commences to surcharges onto Green Street in a 10% AEP event (refer PFL Q07 on sheet 2).
- Floodwater commences to surcharge MacDonald Street in a 5% AEP event (refer PFL Q10 on sheet 2). Floodwater that surcharges the creek at this location flows in a northerly direction through existing commercial development before discharging back to the creek on the northern side of Petit Street.
- Floodwater also commences to surcharge the creek at a location about 100 m to the south of Meehan Street (refer PFL Q13 on sheet 2) in a 5% AEP event where it will flow in a northerly direction across the Yass Soldiers Club carpark.
- The 420 m long piped reach of Chinamans Creek immediately downstream of Browne Street (refer PFL Q11 on sheet 2) commences to surcharge in a 1% AEP event. Floodwater that surcharges the creek at this location flows in a northerly direction along Comur Street where it discharges to the Yass River in the vicinity of the Hume Bridge.
- The peak flow in the Chinamans Creek for the PMF is about 10 times that of the 1% AEP flood event.

The key features of flooding in the Bango Creek are as follows:

- Floodwater is generally contained within the creek banks in a 20% AEP flood event with the exception of the following locations:
    - in the vicinity of the upstream extent of the model (refer PFL Q34 on sheet 4) where the floodplain is about 150 m wide; and
    - at a location about 350 m north of Yass Valley Way where floodwater that surcharges the western bank of the creek inundates Wargeila Road to a depth of about 0.4 m.
- Fairy Hole Road is inundated in the vicinity of Fairy Hole Creek (refer PFL Q42 on sheet 4) and one its tributaries that is located about 200 m to the south (refer PFL Q45 on sheet 4) in a 20% AEP event, resulting in the isolation of the dwellings that are located in the headwaters of the Bango Creek catchment.
- The Hume Highway generally remains flood free in a 0.2% AEP event except at a location about 230 m west of the Fairy Hole Road crossing where shallow overland flow surcharges onto the road and flows in a westerly direction before discharging to Fairy Hole Creek.
- Shallow overland flow surcharges onto the Main Southern Railway in the vicinity of its junction with the Disused Railway Line in a 5% AEP event. Floodwater also surcharges the Main Southern Railway at a location about 800 m further to the north in a 2% AEP event.
- The peak flow in Bango Creek for the PMF is about 12 times that of the 1% AEP flood event.

The key features of Major Overland Flow in Yass are as follows:

- The existing stormwater drainage system generally has a 20% AEP capacity with the exception of the following locations:
    - the low point in Browne Street in the vicinity of its intersection with Demestre Street (refer PFL Q16 on sheet 2);
    - in the vicinity of the intersection of Polding Street and Pritchard Street where floodwater surcharges the piped drainage system and flows through existing residential development;
    - on the northern side of Lead Street where overland flow overtops the northern kerb and flows through existing residential development between Pritchard Street and Chinamans Creek;
    - in the vicinity of the Lead Street crossing of Chinamans Creek where overland flow surcharges the right bank of the concrete lined channel in the vicinity of the TAFE and flows in a northerly direction through existing development;
    - at the eastern end of the Disused Railway (refer PFL Q23 on sheet 2) where flow that surcharges the piped drainage system discharges in a northerly direction along Dutton Street before flowing through existing commercial development toward Comur Street;
    - through existing residential development that is bounded by Rossi Street to the north, Pritchard Street to the east, Meehan Street to the south and Church Street to the west; and
    - in the vicinity of the intersection of Reddall Street and Yass Valley Way where flow that surcharges the existing piped drainage system flows in a northerly direction along Yass Valley Way towards Bango Creek.
- Overland flow commences to surcharge the existing piped drainage system at the intersection of Grand Junction Road and Cobham Street (refer PFL Q15 on sheet 2) in a 10% AEP event where it flows in a north-westerly direction through existing commercial development.
- Overland flow commences to surcharge the existing piped drainage system in the intersection of Green Street and Nicholls Drive in a 10% AEP event where it flows in a westerly direction through existing commercial development
- Overland flow commences to surcharges the existing piped drainage system in the vicinity of the intersection of Links Road and Cliff Street in a 5% AEP event where it flows in an easterly direction through existing residential development.
- Depths of overland flow along the abovementioned flow paths are generally less than 0.5 m in a 1% AEP event, except in locations where floodwater ponds on the upstream side of road crossings and buildings where greater depths of inundation are experienced.

2.5 Existing Flood Mitigation Measures

Apart from two stormwater detention basins that have recently been constructed in the upper reaches of the Chinamans Creek catchment as part of two new residential subdivisions, there are no other formal flood mitigation measures in Yass.

2.6 Economic Impacts of Flooding

The economic consequences of floods are discussed in **Appendix D** of this report, which assesses flood damages to residential, commercial and industrial property, as well as public buildings in areas affected by both Main Stream Flooding and Major Overland Flow. There were only limited data provided by respondents to the *Community Questionnaire* on historic flood damages to the urban sectors in the study area. Accordingly, it was necessary to use data on damages experienced as a result of historic flooding in other urban centres. The residential flood damages were based on the publication *Floodplain Risk Management Guideline No. 4, 2007* (**Guideline No. 4**) published by the Department of Environment and Climate Change (**DECCW**) (now DPIE). Damages to industrial and commercial development, as well as public buildings were evaluated using data from previous floodplain risk management investigations in NSW.

It is to be noted that the principal objectives of the damages assessment were to gauge the severity of urban flooding likely to be experienced at Yass and also to provide data to allow the comparative economic benefits of various flood modification measures to be evaluated in **Chapter 3** of the report. As explained in **Appendix D**, it is not the intention to determine the depths of inundation or the damages accruing to *individual properties*, but rather to obtain a reasonable estimate of damages experienced over the extent of the urban area in the town for the various design flood events. The estimation of damages using *Guideline No. 4* (in lieu of site specific data determined by a loss adjustor) also allows a uniform approach to be adopted by Government when assessing the relative merits of measures competing for financial assistance in flood prone centres in NSW.

Damages were estimated for the design flood levels determined from the hydraulic modelling undertaken as part of the present study. The elevations of 2,068 building floors levels were based on information contained in the property database that was developed as part of WMAwater, 2016a, with adjustments made where necessary by adding the height of floor above a representative natural surface within the allotment (as estimated by visual inspection) to the natural surface elevation determined from LiDAR survey. The number of properties predicted to experience “above-floor” inundation in Yass, together with estimated flood damages is listed in **Table 2.2** over.

At the 1% AEP level of flooding, 23 dwellings and 34 commercial/industrial buildings are subjected to above-floor inundation, noting that no public buildings are above-floor inundated during a flood of this magnitude (refer **Figure 2.2** for the location of affected properties). During a PMF event, 276 dwellings, 152 commercial buildings and 32 public buildings would experience above-floor inundation (refer **Figure 2.3** for the location of affected properties).

The maximum depth of above-floor inundation in the worst affected residential and commercial properties increases from about 4 m for a 1% AEP flood event to about 17 m for the PMF.

The total flood damages in Yass amounts to $6.59 Million in the event of a 1% AEP flood, increasing to about $154 Million in a PMF event. For a discount rate of 7% pa and an economic life of 50 years, the *Present Worth Value* of damages for all flood events up to the 1% AEP flood is about $3.5 Million. Therefore one or more schemes costing up to this amount could be economically justified if they eliminated damages in Yass for all flood events up to this level. While schemes costing more than this value would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility. Flood management measures are considered on a multi-objective basis in **Chapter 4**.

TABLE 2.2
FLOOD DAMAGES

Design Flood Event (% AEP)	Residential			Commercial			Public			Total Damage ($ Million)
	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	Number of Properties		Damage ($Million)	
	Flood Affected	Flooded Above Floor Level		Flood Affected	Flooded Above Floor Level		Flood Affected	Flooded Above Floor Level		
20%	8	0	0.13	3	1	0.06	1	0	0.02	0.21
10%	18	1	0.31	9	3	0.23	1	0	0.02	0.56
5%	29	3	0.64	23	14	0.70	1	0	0.02	1.36
2%	48	12	1.76	42	18	2.04	1	0	0.02	3.82
1%	63	23	3.14	56	34	3.39	4	0	0.06	6.59
0.5%	84	32	4.62	80	60	5.67	8	3	0.21	10.50
0.2%	103	44	6.40	103	80	10.50	13	7	1.27	18.17
PMF	442	276	35.22	160	152	91.99	32	32	26.67	153.88

2.7 Impact of Flooding on Vulnerable Development and Critical Infrastructure

Figure 2.6 (4 sheets) shows the location of vulnerable development and critical infrastructure relative to the extent of inundation resulting from the assessed flood events, while **Table 2.3** over the page sets out the frequency of floods which would impact this type of development/infrastructure in Yass.[4]

Community Assets

The sewage pump station SS2 that is located on the western side of Laidlaw Street opposite the extension of Grampian Street would be impacted by Major Overland Flow during storms as frequent as 20% AEP. Sewage pump stations SS4 and SS6 would be impacted by 1% AEP and 2% AEP floods, respectively, while the remainder would be impacted by less frequent flood events. Several road crossings are also inundated by floodwater during floods that are more frequent than 1% AEP, further details of which are set out in **Section 2.8** below.

Emergency Services

The NSW Police, Fire & Rescue NSW and Ambulance stations are located on land which is impacted by a 0.2% AEP flood event on the Yass River, as is the Yass Soldiers Club which is identified as an evacuation centre in the *Yass Valley Local Flood Plan*. The NSW SES Local Unit headquarters is impacted by riverine type flooding during a PMF event, as is a portion of the Yass High School which is also nominated in the *Yass Valley Local Flood Plan* as an evacuation centre.

Vulnerable Development

The Yass Early Childhood Centre (CC3) which has been built over an enclosed section of Chinamans Creek north of Meehan Street is impacted by riverine type flooding during a 1% AEP flood event, while the TAFE NSW campus (EF5) on Church Street is impacted by Major Overland Flow during a 0.2% AEP storm event. The Yass Little Learners (CC2) and Goodstart Early Learning Yass (CC4) child care centres are impacted by the PMF event, as is the Yass Public, Yass High, Berinba Public and Mt. Carmel schools.

All of the existing aged care facilities in Yass (AC1, AC2 and AC3) are located off the floodplain, with the exception of Apex Homes (AC4) which is impacted by a 2% AEP flood. While the majority of the Yass District Hospital (MC1) is located off the floodplain, the Atherfield Medical Centre (MC3) on the northern side of Lead Street is impacted by Major Overland Flow in a 0.5% AEP storm event, while the Old Linton (MC2) and Yass (MC4) medical centres are impacted by riverine type flooding during a PMF event.

2.8 Hydrologic Standard of Existing Road Network

Both major and minor roads in the study area are vulnerable to inundation during flood events as frequent as 20% AEP. Identification of such roads is important to providing knowledge to NSW SES, identifying hazardous areas during floods, and evacuation planning.

[4] Critical infrastructure has been split into two categories; community assets and emergency services.

TABLE 2.3
IMPACT OF FLOODING ON VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE LOCATED IN THE STUDY AREA[(1)]

Type	Development/Structure	Location Identifier[)]	Design Flood Event							
			20% AEP	10% AEP	5%AEP	2% AEP	1% AEP	0.5%	0.2%	PMF
Community Assets	Telephone Exchange	-	O	O	O	O	O	O	O	X
	Sewerage System (Yass Sewage Treatment Plant)	SS1	O	O	O	O	O	O	O	X
	Sewerage System (Pump Station)	SS2	X	X	X	X	X	X	X	X
	Sewerage System (Pump Station)	SS3	O	O	O	O	O	O	X	X
	Sewerage System (Pump Station)	SS4	O	O	O	O	X	X	X	X
	Sewerage System (Pump Station)	SS5	O	O	O	O	O	O	O	X
	Sewerage System (Pump Station)	SS6	O	O	O	X	X	X	X	X
	Sewerage System (Pump Station)	SS7	O	O	O	O	O	X	X	X
	Water Supply (Pump Station)	-	O	O	O	O	O	O	X	X
	Major Road Crossing (Warrambalulah Road (Flat Rock Crossing))	RC1	X	X	X	X	X	X	X	X
	Major Road Crossing (Comur Street)	RC2	O	O	X	X	X	X	X	X
	Major Road Crossing (Yass Valley Way)	RC3	O	O	O	O	X	X	X	X
	Major Road Crossing (Hume Highway)	RC4	O	O	O	O	O	O	O	X
Emergency Services	RFS Brigade	-	O	O	O	O	O	O	O	X
	Police Station	-	O	O	O	O	O	O	X	X
	Fire & Rescue NSW Station	-	O	O	O	O	O	O	X	X
	Ambulance Station	-	O	O	O	O	O	O	X	X
	NSW SES Facility	-	O	O	O	O	O	O	O	X
	Evacuation Centre (Yass Soldiers Club)	EC1	O	O	O	O	O	O	X	X
	Evacuation Centre (Yass High School)	EC2	O	O	O	O	O	O	O	X
Vulnerable Development	Educational Facility (Yass Public School)	EF1	O	O	O	O	O	O	O	X
	Educational Facility (Yass High School)	EF2	O	O	O	O	O	O	O	X
	Educational Facility (Berinba Public School)	EF3	O	O	O	O	O	O	O	X
	Educational Facility (Mt. Carmel Sschool)	EF4	O	O	O	O	O	O	O	X

Refer over for footnotes to table

TABLE 2.3 (Cont'd)
IMPACT OF FLOODING ON VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE LOCATED IN THE STUDY AREA[(1)]

Type	Development/Structure	Location Identifier[)]	Design Flood Event							
			20% AEP	10% AEP	5%AEP	2% AEP	1% AEP	0.5%	0.2%	PMF
Vulnerable Development	Educational Facility (TAFE NSW - Yass)	EF5	O	O	O	O	O	O	X	X
	Child Care Facility (Yass Pre-Kindergarten)	CC1	O	O	O	O	O	O	O	O
	Child Care Facility (Yass Little Leaners)	CC2	O	O	O	O	O	O	O	X
	Child Care Facility (Yass Early Childhood Centre)	CC3	O	O	O	O	X	X	X	X
	Child Care Facility (Goodstart Early Learning Yass)	CC4	O	O	O	O	O	O	O	X
	Child Care Facility (Yass Montessori Preschool)	CC5	O	O	O	O	O	O	O	O
	Tourist Park (Yass Caravan Park)	-	O	O	O	O	O	O	O	O
	Aged Care Facility (Horton House and Warmington Lodge)	AC1	O	O	O	O	O	O	O	O
	Aged Care Facility (Thomas Eccles Garden)	AC2	O	O	O	O	O	O	O	O
	Aged Care Facility (Linton Village Yass)	AC3	O	O	O	O	O	O	O	O
	Aged Care Facility (Apex Homes)	AC4	O	O	O	X	X	X	X	X
	Medical Centre (Yass District Hospital)	MC1	O	O	O	O	O	O	O	O
	Medical Centre (Old Linton Medical Centre)	MC2	O	O	O	O	O	O	O	X
	Medical Centre (Atherfield Medical Centre)	MC3	O	O	O	O	O	X	X	X
	Medical Centre (Yass Medical Centre)	MC4	O	O	O	O	O	O	O	X

1. Refer **Figure 2.6** (4 sheets) for location of vulnerable development and critical infrastructure.

"O" = Infrastructure not impacted by flooding.
"X" = Infrastructure impacted by flooding.

While the Warrambalulah Road crossing (Flat Rock Crossing) (RC1) is inundated during freshes in the Yass River, the results of the hydraulic modelling show that a section of Comur Street immediately south of the Hume Bridge (RC2) would be inundated during a 5% AEP flood on the Yass River, with the town cut in two for a period of over half a day in the case of a 1% AEP flood event. Yass Valley Road at its crossing of Bango Creek (RC3) is inundated by backwater flooding from the Yass River during a 1% AEP flood event, which would prevent vehicle movements into and out of Yass from the north for a period of several hours.

2.9 Potential Impacts of a Change in Hydraulic Roughness

An analysis was undertaken to assess the sensitivity of flood behaviour to potential changes in hydraulic roughness. **Figure 2.7** (4 sheets) shows the impact that a 20% increase in the "best estimate" hydraulic roughness values would have on flood behaviour for a 1% AEP flood event.

The analysis showed that peak 1% AEP flood levels along the Yass River and Bango Creek would typically be increased in the range 0.5 to 0.7 m and 0.2 to 0.4 m, respectively. Increases in the depth of Major Overland Flow would generally be in the range 10 to 50 mm, with increases in the range 50 to 100 mm present in a number of isolated locations

While the above finding would indicate that the adoption of a 0.5 m freeboard for setting minimum floor levels in future development would generally cater for any potential increases in peak 1% AEP flood levels associated with changes in hydraulic roughness, further consideration of the freeboard requirements for future development which takes these potential impacts into account is presented in **Section 3.5.1.2** of this report.

2.10 Potential Impacts of a Partial Blockage of Hydraulic Structures

The mechanism and geometrical characteristics of blockages in hydraulic structures and piped drainage systems are difficult to quantify due to a lack of recorded data and would no doubt be different for each system and also vary with flood events. Realistic scenarios would be limited to waterway openings becoming partially blocked during a flood event (no quantitative data are available on instances of blockage of the drainage systems which may have occurred during historic flood events).

A blockage assessment was undertaken based on the procedures set out in ARR 2019. A blockage factor of 50% was found to be applicable for the minor piped drainage lines within the urbanised parts of Yass, while blockage factors of 10% to 50% were found to be applicable for the culvert / bridge crossings of the major watercourses. Based on this finding, a constant blockage factor of 50% was applied to all hydraulic structures in the study area for the purpose of the sensitivity analysis.[5]

Figure 2.8 (4 sheets) shows the afflux for a 1% AEP storm resulting from a partial blockage of hydraulic structures at Yass. While increases in peak 1% AEP flood levels of greater than 0.5 m occur upstream of several hydraulic structures that are located to the north of the Yass River, the impacts are confined to *Primary Production* (RU1), *Large Lot Residential* (R5) and *Infrastructure* (SP2) land that is presently undeveloped. In all other areas the increase in peak 1% AEP flood

[5] Based on the procedures set out in ARR 2019, a non-floating blockage factor of 25% was found to be applicable at the Hume Bridge crossing of the Yass River as the "Site Based Debris Potential" is classified as "High". It is considered unrealistic that the Hume Bridge would be subject to 25% blockage due to non-floating debris considering the high flow velocities (greater than 3 m/s) in the river at this location. As such, the assessed blockage factor at the Hume Bridge of 10% is based on the floating debris potential only.

levels is generally less than 0.1 m, with the exception of along the enclosed reach of Chinamans Creek upstream of Lead Street where increases of up to 0.3 m could occur at specific locations.

While the above finding would indicate that the adoption of a 0.5 m freeboard for setting minimum floor levels in future development would generally cater for any potential increases in peak 1% AEP flood levels associated with a partial blockage of hydraulic structures, further consideration of the freeboard requirements for future development which is subject to flooding from the Yass River is presented in **Section 3.5.1.2** of this report.

2.11 Potential Impacts of Future Urbanisation

Future urbanisation has the potential to increase the rate and volume of runoff conveyed by the various watercourses, as well as increase the frequency of surcharge of the local stormwater drainage system. It is also likely to result in changes to the existing drainage system. For example, while existing minor watercourses are likely to be retained and formalised in drainage reserves, piped drainage systems associated with urban subdivisions will result in significant amendments to existing overland flow paths leading to the watercourses.

While there is evidence that Council is requiring developers to incorporate flow control measures such as detention basins in residential subdivisions, infill development at an individual allotment scale has the potential to increase flow in the receiving drainage lines. As there is presently no Development Control Plan or policy in place for Yass which sets out the maximum permissible hard stand area within an individual allotment (refer **Section 2.15** of this report for further details), it has been assumed that a value of 70% would apply for the purpose of assessing the impact that future infill development could have on flood behaviour. While **Figure 2.9** shows that an increase in hard stand area to a maximum of 70% in individual allotments would not have a significant impact on peak 1% AEP flood levels in the urbanised parts of Yass, it can be expected that infill type development would have a greater impact on flooding resulting from more frequent storm events given the disproportionate increase in rainfall excess.

2.12 Potential Impacts of Future Climate Change

DPIE recommends that its guideline *Practical Consideration of Climate Change, 2007* be used as the basis for examining climate change in projects undertaken under the State Floodplain Management program and the *FDM, 2005*. The guideline recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent.

On current projections the increase in rainfalls within the service life of developments or flood management measures is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit which may apply near the end of the century. Under present day climatic conditions, increasing the 1% AEP design rainfall intensities by 10 per cent would produce about a 0.5% AEP flood; and increasing those rainfalls by 30 per cent would produce about a 0.2% AEP event.

For the purpose of the present study, the impact 10% and 30% increases in design 1% AEP rainfall intensities would have on flooding behaviour was assessed by comparing the peak flood levels which were derived from the flood modelling for design events with AEP's of 1, 0.5 and 0.2 per cent.

Figures 2.10 and **2.11** (4 sheets each) show the increase in peak 1% AEP flood levels that would occur if rainfall intensities were to increase by 10% and 30% as a result of future climate change, respectively, while **Figure 2.12** (4 sheets) shows the impact these potential changes would have on the extent of a 1% AEP flood event.

The impact of a potential 10% increase in 1% AEP rainfall intensities on flooding patterns in the study area may be summarised as follows:

- Peak flood levels on the Yass River would be increased by over a 1 m, with the impacts extending south as far as Meehan Street.
- Depths of Major Overland Flow in the Chinamans Creek catchment would generally not be increased by more than 50 mm, although increases in the range 100-200 mm could be expected to occur where the main arm of the creek runs between Petit Street and Polding Street.
- Increases in peak 1% AEP flood levels in the range 50-500 mm would occur along Bango Creek and parts of Fairy Hole Creek.
- There would be a relatively minor increase in the extent of inundation due to the relatively steep sided nature of the floodplain at Yass.

The impact of a potential 30% increase in 1% AEP rainfall intensities on flooding patterns in the study area may be summarised as follows:

- Peak flood levels on the Yass River would generally be increased in the range 2-3 m, with slightly greater increases shown to occur in the vicinity of the Hume Bridge.
- Depths of Major Overland Flow in the Chinamans Creek catchment would generally be increased in the range 100-200 mm, although increases in the range 200-500 mm could be expected to occur where the main arm of the creek runs between Petit Street and Polding Street.
- Increases in peak 1% AEP flood levels in the range 50-500 mm would occur along Bango Creek and parts of Fairy Hole Creek.
- There would be a relatively minor increase in the extent of inundation due to the relatively steep sided nature of the floodplain at Yass.

While the above finding would indicate that the adoption of a 0.5 m freeboard for setting minimum floor levels in future development would not necessarily cater for increases in peak 1% AEP flood levels associated with future climate change, especially in the case of riverine type flooding at Yass, further consideration of the freeboard requirements for future development which takes these potential impacts into account is presented in **Section 3.5.1.2** of this report.

2.13 Flood Hazard Vulnerability and Hydraulic Categorisation of the Floodplain

2.13.1 General

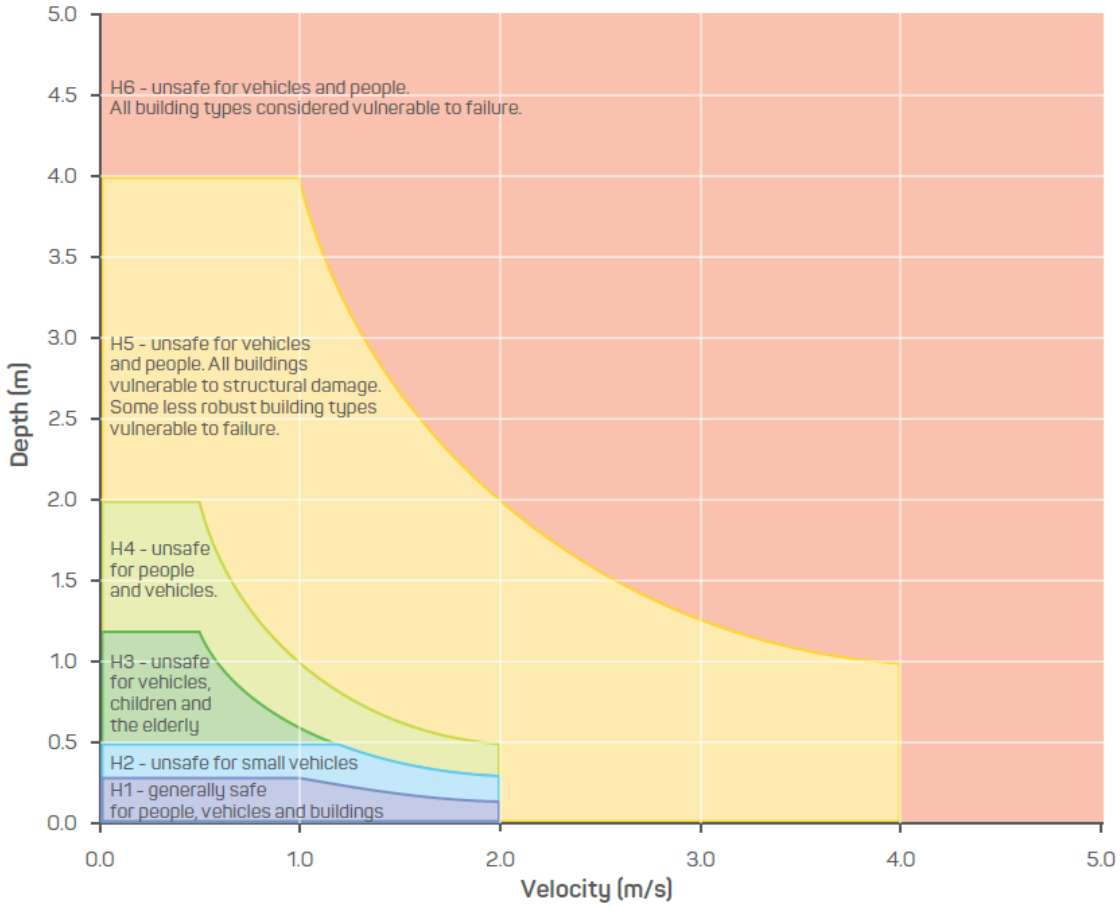
According to Appendix L of *NSWG, 2005*, in order to achieve effective and responsible floodplain risk management, it is necessary to divide the floodplain into areas that reflect:

1. The impact of flooding on existing and future development and people. To examine this impact it is necessary to divide the floodplain into *"flood hazard vulnerability"* categories, which are assessed on the basis of the velocity and depth of flow. This task was undertaken as part of the present study where the floodplain was divided into six flood hazard vulnerability zones. **Section 2.13.2** below provides details of the adopted procedure.

2. The impact of future development activity on flood behaviour. Development in active flow paths (i.e. *"floodways"*) has the potential to adversely re-direct flows towards adjacent properties. Examination of this impact requires the division of flood prone land into various *"hydraulic categories"* to assess those parts which are effective for the conveyance of flow, where development may affect local flooding patterns. While hydraulic categorisation of the floodplain was undertaken as part of WMAwater, 2016a, it was reviewed and updated as part of the present study. **Section 2.13.3** below summarises the adopted procedure.

2.13.2 Flood Hazard Vulnerability Categorisation

Flood hazard categories may be assigned to flood affected areas in accordance with the definitions contained in the publication entitled "*Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia*" (Australian Institute for Disaster Resilience (**AIDR**), 2017). Flood prone areas may be classified into six hazard categories based on the depth of inundation and velocity of flow that relate to the vulnerability of the community when interacting with floodwater, as shown in the illustration over which has been taken from AIDR, 2017:



Figures 2.13 and **2.14** show the *Flood Hazard Vulnerability Classification* based on the procedures set out in AIDR, 2017 for the 1% AEP and PMF events, respectively, while **Figures C4.7** to **C4.8** in **Appendix C** of this report show similar information for the 5% and 0.5% AEP flood events.

While areas classified as H5 and H6 are generally limited to the inbank areas of the major watercourses and incised flow paths in a 1% AEP flood event, they do extend out onto the left bank of the Yass River immediately upstream of the Hume Bridge where a number of residential and commercial allotments are located.

The flooding that is experienced at the road crossings of the major watercourses that are inundated in a 1% AEP event falls within the H1 category with the following exceptions:

- Brennan Street and MacDonald Street crossings of Chinamans Creek where the overtopping flow is categorised as H2;
- Petit Street, Lead Street and Meehan Street crossings of Chinamans Creek where the overtopping flow is categorised as H5;
- Wargeila Road where the overtopping flow is categorised as H5;
- Mont Street crossing of the overland flow path through the Yass Golf Course where the overtopping flow is categorised as H5; and
- Fairy Hole Road crossing of fairy Hole Creek where the overtopping flow is categorised as H6.

The Major Overland Flow paths in the urbanised parts of Yass are generally classified as either H1 or H2 in a 1% AEP event, with the exception of areas where floodwater ponds on the upstream side of roads where it is generally classified as either H3 or H4.

For the PMF event, the width of the H5 and H6 hazard zones increases significantly, mainly along the Yass River and its major tributaries. The hazard category along the majority of the remaining drainage lines increases to between H3 and H5 during a flood of this magnitude.

2.13.3 Hydraulic Categorisation of the Floodplain

According to the *FDM*, the floodplain may be subdivided into the following three hydraulic categories:

- Floodways;
- Flood storage; and
- Flood fringe.

Floodways are those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with obvious naturally defined channels. Floodways are the areas that, even if only partially blocked, would cause a significant re-distribution of flow, or a significant increase in flood level which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.

Flood storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

Floodplain Risk Management Guideline No. 2 Floodway Definition, offers guidance in relation to two alternative procedures for identifying floodways. They are:

- **Approach A**. Using a *qualitative approach* which is based on the judgement of an experienced hydraulic engineer. In assessing whether or not the area under consideration was a floodway, the qualitative approach would need to consider; whether obstruction would divert water to other existing flow paths; or would have a significant impact on upstream flood levels during major flood events; or would adversely re-direct flows towards existing development.
- **Approach B**. Using the hydraulic model, in this case TUFLOW, to define the floodway based on *quantitative experiments* where flows are restricted or the conveyance capacity of the flow path reduced, until there was a significant effect on upstream flood levels and/or a diversion of flows to existing or new flow paths.

One quantitative experimental procedure commonly used is to progressively encroach across either floodplain towards the channel until the designated flood level has increased by a significant amount (for example 0.1 m) above the existing (un-encroached) flood levels. This indicates the limits of the hydraulic floodway since any further encroachment will intrude into that part of the floodplain necessary for the free flow of flood waters – that is, into the floodway.

The *quantitative assessment* associated with **Approach B** is technically difficult to implement. Restricting the flow to achieve the 0.1 m increase in flood levels can result in contradictory results, especially in unsteady flow modelling, with the restriction actually causing reductions in computed levels in some areas due to changes in the distribution of flows along the main drainage line.

Accordingly the *qualitative approach* associated with **Approach A** was adopted, together with consideration of the portion of the floodplain which conveys approximately 80% of the total flow and also the findings of *Howells et al, 2004* who defined the floodway based on velocity of flow and depth. Based on the findings of a trial and error process, the following criteria were adopted for identifying those areas which operate as a "floodway" in a 1% AEP event:

- Velocity x Depth greater than 0.15 m^2/s **and** Velocity greater than 0.25 m/s; or
- Velocity greater than 1 m/s.

Flood storage areas were identified as those areas which do not operate as floodways in a 1% AEP event but where the depth of inundation exceeds 400 mm. The remainder of the flood affected area was classified as flood fringe.

Figures 2.15 and **2.16** show the division of the floodplain into floodway, flood storage and flood fringe areas for the 1% AEP and PMF events, respectively, while **Figures C4.9** to **C4.10** in **Appendix C** of this report show similar information for the 5 and 0.5% AEP flood events.

As the hydraulic capacity of the river and creek channels is not large enough to convey the 1% AEP flow, a significant portion of the total flow is conveyed on the floodplain. As a result, areas which lie on the overbank area also function as a floodway during the 1% AEP flood event. Floodways are also generally present along the Major Overland Flow paths described in **Section 2.4.3**.

Flood storage areas are confined to the major ponding areas which are located on the upstream side of existing road and rail embankments.

2.14 Environmental Considerations

The Yass River, along with the main arms of Bango Creek and Fairy Hole Creek are largely in their natural state where they run through Yass, while Chinamans Creek has been highly modified south of the river.

Rivers of Carbon[6] has set up a project called the *Yass River Linkages* which supports and extends the efforts of the Yass Area Network of Landcare Groups and others to restore and rehabilitate the Yass River and many of its tributaries where they have become degraded as a result of the negative impacts of vegetation loss and flow regulation. The project is in its second phase and is partially funded by the NSW Environmental Trust.

2.15 Council's Existing Planning Instruments and Policies

2.15.1 General

The *Yass Local Environmental Plan, 2013* (***Yass LEP 2013***) is the principal statutory planning document used by Council for controlling development by defining zoning provisions, establishing permissibility of land use and regulating the extent of development in the Yass LGA.

While Council is in the process of preparing a comprehensive Development Control Plan for the LGA, currently there are only two gazetted Development Control Plans for Yass which relate to exempt and complying development and multi-unit residential development, noting that the latter document does not include any flood related development controls. While Council has also adopted a set of policies which relate to development in the LGA, none of these contain any flood related development controls.

Council advised that it has been applying the flood related development controls that are set out in WMAwater, 2016b.

2.15.2 Land Use Zoning – Yass Local Environmental Plan 2013

Figure 2.17 (2 sheets) shows the zonings that are incorporated in *Yass LEP 2013* for the study area. The study area comprises a mixture of *General Residential (R1)* and *Large Lot Residential (R2)* zoned areas, as well as *Local Centre (B2)*, *Business Development (B5)* and *Enterprise Corridor (B6)* zoned areas.

2.15.3 Flood Provisions – Yass LEP 2013

Clause 6.2 of *Yass LEP 2013* entitled "Flood planning" outlines its objectives in regard to development of land that is at or below the FPL. It is similar to the standard Flood Planning Clause used in recently adopted LEPs in other NSW country centres and applies to land at or below the FPL.

[6] *Rivers of Carbon* is the on-ground component of the *Australian River Restoration Centre (ARRC)*, which is a registered charity recognised under the *Australian Charities & Not-for-profits Commission (ACNC)*.

The FPL currently referred to is the 1:100 ARI (or 1% AEP) flood plus an allowance for freeboard of 0.5 m. The area encompassed by the FPL (i.e. the FPA) denotes the area subject to flood related development controls, such as locating development outside high hazard areas and setting minimum floor levels for future residential development. It is currently standard practice for the residential FPL to be based on the 1% AEP flood plus an appropriate freeboard unless exceptional circumstances apply.

It is noted that the NSW Government will be automatically updating the wording in clause 6.2 on 14 July 2021 as part of recent reforms that it has introduced to its *NSW Flood Prone Land Package*. As a result of the update, Council will need to nominate the FPLs that it wishes to use to define the FPA, and make alternative arrangements for making flood planning maps publicly available where previously solely reliant on LEP flood overlay maps.

While clause 6.2 will be automatically updated by the NSW Government on 14 July 2021, it is recommended that the *special flood considerations* clause which forms part of the updated *NSW Flood Prone Land Package* also be incorporated in *Yass LEP 2013*. The objectives of the new clause are as follows:

- in relation to development with particular evacuation or emergency response issues (e.g. schools, group homes, residential care facilities, hospitals, etc.) to enable evacuation of land which lies above the FPL; and
- to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

The new clause would apply to land which lies between the FPL and the level of the PMF. Suggested wording in relation to this new clause is given in **Section 3.5.1.4**.

2.15.4 Flood Related Development Controls

As mentioned, Council does not presently have a Development Control Plan or policy which sets out flood related controls that apply to future development within the LGA. Rather, Council advised that it is currently applying the flood related development controls that are set out in WMAwater, 2016b.

While the flood related development controls set out in WMAwater, 2016b are generally in accordance with contemporary best floodplain risk management practice, they are based on the Flood Risk Precinct type approach rather than the Flood Planning Constraint Category type approach set out in AIDR, 2017. Recommendations relating to the update of the approach set out in WMAwater, 2016b are set out in **Section 3.5.1.4**, while **Appendix E** of this report contains suggested wording for incorporating into the Development Control Plan which is presently being prepared for the Yass Valley.

2.16 Flood Warning and Flood Preparedness

2.16.1 Yass Valley Local Flood Plan

The NSW SES is nominated as the principal combat and response agency for flood emergencies in NSW. NSW SES is responsible for the issuing of relevant warnings (in collaboration with BoM), as well as ensuring that the community is aware of the flood threat and how to mitigate its impact.

The *Yass Valley Local Flood Plan* which is published by NSW SES covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures for all levels of flooding within the Yass local government area. *Yass Valley Local Flood Plan* is administered by the Yass Local Commander who controls flood operations within the Yass area. NSW SES maintains a local headquarters in Laidlaw Street near the northern limits of Yass.

Volume 1 of *Yass Valley Local Flood Plan* entitled '*Yass Valley Flood Emergency Sub Plan*' includes sections on flood preparedness, response and recovery. Volume 1 is divided into the following sections:

- ***Introduction****;* this section of the document identifies the responsibilities of the NSW SES Local Controller and NSW SES members and supporting services such as the Police, BoM, Ambulance, Fire Brigades, State Water Corporation, Council, etc. It also identifies the importance for NSW SES and Council to coordinate the development and implementation of a public education program to advise the population of the flood risk.
- ***Preparedness****;* this section of the document deals with activities required to ensure the *Yass Valley Local Flood Plan* functions during the occurrence of the flood emergency. The Plan will devote considerable attention to flood alert and emergency response.
- ***Response***; The NSW SES maintains an operation centre at the Local NSW SES Headquarters in Laidlaw Street. Response operations will commence: on receipt of a BoM Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe Weather Warning for flash flooding; on receipt of a dam failure alert; or when other evidence leads to an expectation of flooding within the council area.
- ***Recovery****,* involving measures to ensure the long term welfare for people who have been evacuated, recovery operations to restore services and clean up and de-briefing of emergency management personnel to review the effectiveness of the *Yass Valley Local Flood Plan.*

Annex A of the *Yass Valley Local Flood Plan* deals with the flood threat at Yass. **Table 2.4** over lists the peak design flood levels that are set out in the document for Yass, noting those derived as part of the present study are also listed for ease of comparison. By inspection, the peak flood levels set out in the *Yass Valley Local Flood Plan* are similar for floods with AEPs of 20% and 1%, but are significantly higher when compared to those derived as part of the present study for floods with AEPs of 10%, 5% and 2%.

Annex B of the *Yass Valley Local Flood Plan* deals with the effects of flooding on the Yass community. The document states that:

a) the majority of Yass is flood free, apart from parts of Riley Terrace and Comur, Church, Rossi and Warrambalulah Streets;

b) there is a small flood prone retirement village known as the Apex Homes, which consists of 20 units that are located adjacent to Chinamans Creek in Rossi Street; and

c) development in close proximity to Banjo Patterson Park on Rossi Street is generally the first to be affected.

Specific areas at risk are shown in Map 3 of the document which has been reproduced at the end of this Chapter.

TABLE 2.4
PEAK FLOOD HEIGHTS FOR YASS STREAM GAUGE(1)
AS SET OUT IN THE YASS VALLEY LOCAL FLOOD PLAN
(m)

Design Peak Flood Level	Yass Valley Local Flood Plan	Present Study
20% AEP	4.60	4.7
10% AEP	6.39	5.9
5% AEP	8.00	7.2
2% AEP	9.39	8.8
1% AEP	10.04	10.1

1. Gauge zero = 475.52 m AHD

Annex B provides the following description as an indication of the way in which flooding develops within Yass township:

- ***0.5 metres:*** *Level of the Flat Rock Crossing between North and South Yass.*
- ***2 metres:*** *An area along Warrambalulah Street upstream of Church Street is flooded.*
- ***4 metres:*** *Flood waters start to break out on the left bank between Church and Dutton Streets. Flooding begins along Chinamans Creek because of backup water from the river.*
- ***6 metres:*** *Some 5 commercial properties and 2 residences in Comur and Rossi streets are in danger of having flood waters exceed the floor levels.*
- ***7 metres:*** *An additional 3 residences (Church, Pritchett and Rossi streets) have water to their doorsteps.*
- ***8 metres:*** *The Apex Homes (retirement village) start to be inundated with water from Chinamans Creek.*

Extreme flooding larger than the 1% AEP flood is said to inundate additional areas of town, including the south western sections of Comur, Dutton and Church Streets; and parts of Meehan and Lead Streets. The document states that an estimated 307 dwellings would be inundated during a PMF. This compares to the 276 dwellings which the present study identified would be above-floor inundated during a PMF event, 201 of which relate to riverine type flooding.

2.16.2 Existing Flood Warning Network

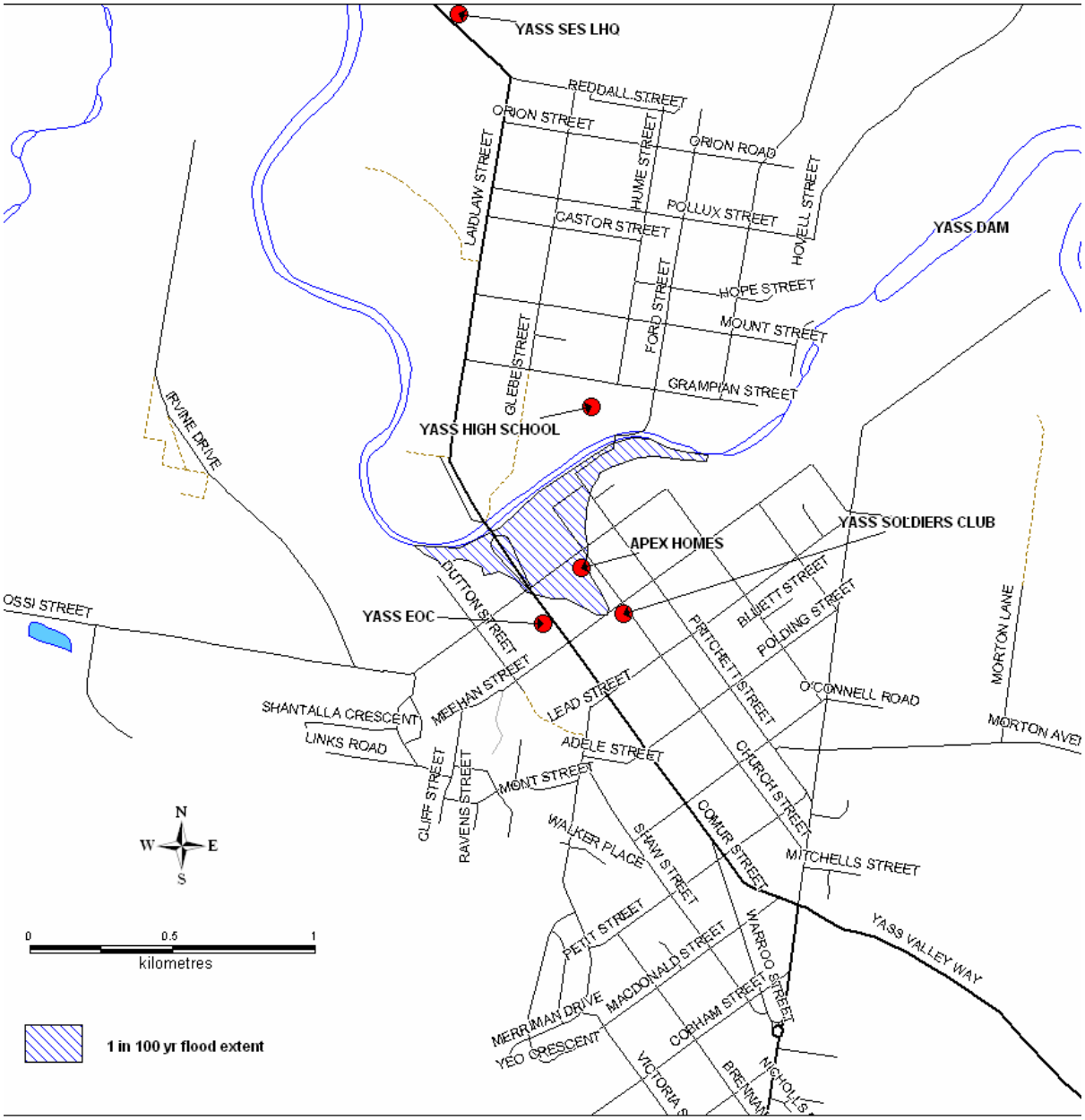
While BoM maintains a flood warning network for the Murrumbidgee Valley which includes the monitoring of a select number of rainfall and stream gauges, as well as the provision of location specific flood warnings and predicted flood level estimates, this service does not extend to the Yass Valley.

There are presently five stream gauges located in the Yass Valley, details of which are set out in **Table 2.5** over and the locations of which are shown on **Figure 1.1**, sheet 1. Of the three stream gauges that are located upstream of Yass, two record water levels in the Yass River, while the third is located on Williams Creek, a minor tributary of the Yass River. It is noted that the closest stream gauge on the Yass River upstream of Yass (i.e. the *Yass River at Gundaroo* stream gauge) controls only about a third of the total catchment at Yass, meaning it may not be a reliable indicator of the magnitude of flood flows that would be experienced at Yass.

Figure 1.1, sheet 1 also shows the location of existing daily read and pluviometric type rain gauges in the vicinity of the Yass Valley. While there are a number of daily read rain gauges located in the Yass Valley, the only pluviographic type rain gauge is located at Yass. There is also an absence of pluviographic type rain gauges to the east and north of the Yass Valley.

TABLE 2.5
DETAILS OF EXISTING STREAM GAUGE NETWORK IN THE YASS VALLEY

Gauge No.	Name	Installation Date	Upstream Catchment Area (km^2)
410851	Yass River at Macks Reef Road	20/02/1976	80
410090	Yass River at Gundaroo	22/09/1937	388
410026	Yass River at Yass	24/08/2015	1230
410176	Yass River U/S Burrinjuck	10/05/1999	1600
410160	Williams Creek at Whitehall	22/06/1988	9



Source: *Yass Valley Local Flood Plan*

3 POTENTIAL FLOODPLAIN MANAGEMENT MEASURES

3.1 Range of Available Measures

A variety of floodplain management measures can be implemented to reduce flood damages. They may be divided into three categories, as follows:

Flood modification measures change the behaviour of floods in regard to discharges and water surface levels to reduce flood risk. This can be done by the construction of levees, detention basins, channel improvements and upgrades of piped drainage systems in urban areas. Such measures are also known as "structural" measures as they involve the construction of engineering works. Vegetation management is also classified as a flood modification measure.

Property modification measures reduce risk to properties through appropriate land use zoning, specifying minimum floor levels for new developments, voluntary purchase of residential property in high hazard and/or floodway areas, or raising existing residences in the less hazardous areas. Such measures are largely planning (i.e. "non-structural") measures, as they are aimed at ensuring that the use of floodplains and the design of buildings are consistent with flood risk. Property modification measures could comprise a mix of structural and non-structural methods of damage minimisation to individual properties.

Response modification measures change the response of flood affected communities to the flood risk by increasing flood awareness, implementation of flood warning and broadcast systems and the development of emergency response plans for property evacuation. These measures are entirely non-structural.

3.2 Community Views

Comments on potential flood management measures were sought from the community by way of the *Community Questionnaire* which was distributed at the commencement of the study. The responses are summarised in **Appendix A** of this report. Question 8 in the *Community Questionnaire* outlined a range of potential flood management measures. The responses are shown on **Table 3.1** over the page together with initial comments on the feasibility of each measure. The measures are discussed in more detail in later sections of this Chapter.

The Community favoured the following measures:

- Management of vegetation along creek corridors.
- Advice of flood affectation via Planning Certificates for properties located in flood liable areas.
- Improved flood warning, evacuation and flood response procedures.
- Improvements in the stormwater system.
- Flood related controls over future development in flood liable areas.
- Community education to promote flood awareness.

TABLE 3.1
COMMUNITY VIEWS ON POTENTIAL FLOOD MANAGEMENT MEASURES

Flood Management Measure		Classification[(1)]	Respondent's Views			Comments
			Yes	No	Don't Know	
a)	Management of vegetation along creek corridors to provide flood mitigation, stability, aesthetic and habitat benefits	FM	68	4	16	While riparian vegetation is presently maintained along the banks of the Yass River where it runs through the town, there is merit in better managing vegetation along Chinamans Creek given the impact that flow which surcharges its inbank area has on existing residential and commercial development. The merits of developing and implementing a Vegetation Management Plan for Chinamans Creek is assessed in **Section 3.4.3**.
b)	Widening of watercourses	FM	25	30	33	While this measure would increase the capacity of Chinamans Creek where it runs through the urbanised parts of Yass, the close proximity of existing development would mean that any widening works would likely require the concrete lining of the watercourse. Due to the impact that the lining of the watercourse would have on existing flora and fauna, its implementation has not been assessed as part of the *Yass FRMS*.
c)	Construct detention basins to temporarily store stormwater runoff and reduce impacts of flooding on existing development	FM	40	16	32	While this option is favoured by the community, it was identified that there is insufficient public land available to construct detention basins in areas which would reduce the impact of flooding on existing development. The one exception is a parcel of land which lies to the south of the Yass Railway Museum in the Chinamans Creek catchment. The benefits that the construction of a detention basin at this one location are assessed in **Section 3.4.2**.
d)	Improve the stormwater system within the town area	FM	57	1	30	While this measure is strongly supported by the community, the assessment of measures aimed at improving the stormwater drainage system at Yass found that they did not provide sufficient benefit in terms of a reduction in flood affectation and hazard in existing development to justify their inclusion in the *Yass FRMP*. Details of the assessment that was undertaken as part of the *Yass FRMS* are set out in **Section 3.4.1**.
e)	Construct permanent levees along the rivers and creeks within the town area	FM	23	36	29	The community is not in favour of this option and there is limited scope to construct a levee that would protect existing development from either Main Stream Flooding or Major Overland Flow. Based on this finding, the construction of flood protection levees at Yass was not considered further.
f)	Voluntary scheme to purchase property in high hazard areas	PM	23	33	32	This option is often adopted to remove residential property in high hazard areas of the floodplain. The results of the present investigation show that there are eleven dwellings that are subject to highly hazardous flooding conditions. While the community is generally not in favour of this option it is reviewed in **Section 3.5.2**.
g)	Provide funding or subsidies to raise houses above major flood level in low hazard areas	PM	18	41	29	The community is generally not in favour of this option. This option would have application for timber framed houses located in low hazard zones on the floodplain and is reviewed in **Section 3.5.3**.
h)	Specify controls on future development in flood-liable areas (eg. Controls on extent of filling, minimum floor levels)	PM	56	9	23	The community strongly supports this option, which is an essential part of the *Yass FRMP*. The issue is covered in **Section 3.5.1**, with the suggested approach for controlling development on flood prone land set out in **Appendix E**.
i)	Improve flood warning and evacuation procedures both before and during a flood.	RM	63	3	22	Deficiencies in the rain and stream gauge network in the Yass Valley which limit the ability of NSW SES and BoM to monitor and issue flood warnings for urban centres that are located in the Yass Valley. The installation of a number of new telemetered rain and stream gauges, along with the implementation of a series of other measures would provide significant improvements to the existing flood warning system for the Yass Valley. This measure is strongly supported by the community and is considered further in **Sections 3.6.1** and **3.6.2**.
j)	Community education, participation and flood awareness programs.	RM	48	10	30	Promotion of awareness of the flood risk is strongly favoured among the community. This option is reviewed in **Section 3.6.3**.
k)	Providing a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected	PM	64	4	20	Provision of information on flood affection of properties is strongly favoured by the community. This may be achieved by notation of flood affectation of allotments on Section S10.7 Planning Certificates. This option is reviewed in **Section 3.5.1**.

FM = Flood Modification Measure

PM = Property Modification Measure

RM = Response Modification Measure

3.3 Outline of Chapter

A range of potential flood management measures were examined at the strategic level of detail and where appropriate, tested for feasibility on a range of assessment criteria in **Chapter 4**. Following consideration of the results by the Floodplain Risk Management Committee, selected measures were included in the *Yass FRMP* in **Chapter 5**.

The assessment of potential flood modification measures was limited to the possible upgrade of the existing stormwater drainage system at three locations, a possible stormwater detention basin south of the Yass Railway Museum on landed zoned *RE1 – Public Recreation* and the management of vegetation along the channel reaches of Chinamans Creek.

The property modification measures considered as part of this study include controls over future development, voluntary purchase of residential properties and the raising of dwellings. Response modification measures such as improvements to emergency planning and responses and public awareness programs have also been considered for Yass.

3.4 Flood Modification Measures

3.4.1 Stormwater Drainage Upgrades

General

Stormwater drainage systems are an effective means of preventing frequent flooding of urban areas by local catchment runoff. Stormwater drainage systems are usually designed to convey flows associated with more frequent rainfall events. Flows resulting from rarer events will usually exceed the capacity of the stormwater drainage system and travel along flow paths as local overland flow. While upgrading key elements of a stormwater drainage system may prevent nuisance flooding in low lying properties or inundation of low points in roads due to small storms that occur frequently, it is generally not a cost effective or practical way to mitigate damaging flooding that results from intense, rare storm events.

While a number of buildings would be subject to shallow above-floor inundation during storms which result in the surcharge of the existing stormwater drainage system in Yass, the majority of these are of a commercial/industrial nature. The exception is two dwellings that are located near the intersection of Lead Street and Church Street, and a third which is located on the eastern side of Pritchett Street at its intersection with Polding Street. Council also advised that it has been liaising with a land owner in regards the apparent frequent inundation of two contiguous properties that are located on the northern side of Browne Street approximately midway between its intersection with Pritchett Street and Demestre Street. While the affected properties are zoned *General Residential (R1)*, they are presently being used by the single owner to store building materials. A large metal shed is also located on one of the affected properties.

Residential

In regards the two affected residential properties near the intersection of Lead Street and Church Street, the removal of above-floor flooding would require the installation of a new stormwater drainage system in Lead Street which would extend from its intersection with Pritchett Street to the main arm of Chinamans Creek (denoted herein as the "**Lead Street Stormwater Drainage Upgrade**"). **Figure 3.1** shows the layout of the Lead Street Stormwater Drainage Upgrade which is estimated to cost about $0.8 Million to construct, as well as the impact that it would have on both the extent and depth of inundation for design storms of 20%, 5% and 1% AEP.

While the Lead Street Stormwater Drainage Upgrade would remove above-floor inundation in the two existing dwellings for storms up to 1% AEP in intensity, it could not be justified economically as its benefit cost ratio is only about 0.4. Coupled with the relatively infrequent and low hazard nature of the flooding that is experienced in the two properties, the inclusion of the Lead Street Stormwater Drainage Upgrade in the *Yass FRMP* is not recommended.

In regards the third affected residential property that is located near the intersection of Pritchett Street and Polding Street, there is limited, if any opportunity to upgrade the existing stormwater drainage system given the close proximity of the recently constructed dwelling and adjacent retaining wall to the existing 1050 mm diameter pipe. While increasing the waterway area of the existing pipe might be possible through the adoption of non-standard (and expensive) trenching techniques, it is questionable whether sufficient inlet capacity could be incorporated in the privately owned land to its east to ensure that the upgraded drainage line runs full.

While a low wall and fence has been constructed around the perimeter of the affected property where it borders the existing pipe, it is noted that the flood hazard vulnerability classification of the overland flow in the narrow flow path which is present between it and the opposing retaining wall increases from H2 in a 5% AEP storm event to H5 in a 1% AEP storm event, with H3 conditions present at the rear of the dwelling. It is critical that Council impose controls on future development in the catchment which lies upstream of the affected dwelling to ensure that flooding conditions are not exacerbated in the affected property and if possible contribute to the cost of constructing future detention basins which are aimed at reducing peak flows in the downstream drainage system when compared to present day conditions.

In regards the two contiguous *General Residential (R1)* zoned properties that are located on the northern side of Browne Street, Council commissioned a site specific survey of the existing stormwater drainage system as part of the present study which included details of the four cell 450 mm diameter pipes which cross Browne Street immediately to the south of the eastern-most property, as well as a stormwater channel which runs along its eastern boundary. The extent of the detailed ground survey that was commissioned by Council is shown on **Figure C2.1**, sheet 2 in **Appendix C** of this report.

The detailed flood modelling that was undertaken as part of the present study found that the four cell 450 mm diameter pipes that cross Browne Street would be surcharged during storms as frequent as 20% AEP (the most frequent storm event assessed as part of the present study), with the result that shallow overland flow would inundate a portion of the unsealed internal access track, as well as the area which lies between it and the stormwater channel, noting that the flooding is exacerbated by the fact that the low point in the road is offset from the downstream reach of channel. The modelling found that overland flow discharging through the eastern-most property would generally not exceed 0.15 m during storms up to 1% AEP in intensity.

While the upgrade of the four cell 450 mm diameter pipes crossing Browne Street would reduce the frequency and rate at which overland flow discharges to the two properties, given the relatively shallow nature of the flow and the limited flood damages that would be experienced in the two properties during a storm event which surcharges the existing transverse drainage structure, the upgrade works would not be eligible for funding under the NSW Government's floodplain management program. As a result, they have not been incorporated in the *Yass FRMP*.[7]

[7] Refer **Section 1.4** of this report for further background and discussion on this particular issue.

Commercial/Industrial

In regards the affected commercial/industrial properties, there is limited opportunity to upgrade the existing stormwater drainage system for those that are located along Comur Street between Lead Street and Rossi Street given the distance to the river and the relatively large flow which would need to be conveyed by the upgraded drainage system in order to mitigate the flood related impacts (in the order of $5m^3/s$).

The other commercial/industrial damage centre is located along the main arm of Chinamans Creek where it runs between Cobham Street and Petit Street. While it might be feasible to upgrade the main trunk line where it runs between Cobham Street and Shaw Street, noting that there are three residential properties that are also flood affected in this area, there is limited opportunity to upgrade it where it runs between MacDonald Street and Petit Street due to the presence of several large commercial buildings that have been constructed over it. Given these constraints and the fact that the existing trunk drainage where it runs between MacDonald Street and Petit Street does not surcharge during storms less than 10% AEP in intensity, its upgrade at this location is not recommended.

The upgrade of the section of trunk drainage line which runs between Cobham Street and Shaw Street (denoted herein as the "**Cobham Street to Shaw Street Stormwater Drainage Upgrade**") would require the replacement of the existing 2000 mm wide by 600 mm high box culvert with twin 1500 mm diameter pipes where it runs through one residential property that is located on Cobham Street and a commercial property that is located on Shaw Street, with the two pipes linking with the existing twin 1500 mm diameter pipes which cross Shaw Street. **Figure 3.2** shows the layout of the trunk drainage upgrade, as well as the impact that it would have on both the extent and depth of inundation for design storms of 20%, 5% and 1% AEP.

While the Cobham Street to Shaw Street Stormwater Drainage Upgrade would reduce the frequency and depth of inundation in existing development that is located between Cobham Street and Shaw Street, the improvements would increase peak flows and hence flood levels further downstream, thereby exacerbating flooding conditions in existing development. Based on this finding, the Cobham Street to Shaw Street Stormwater Drainage Upgrade is not recommended for inclusion in the *Yass FRMP*.

3.4.2 Detention Basins

While the construction of detention basins in the upper and middle reaches of the Chinamans Creek catchment would increase the hydrologic standard of the existing stormwater drainage system where it runs through the urbanised parts of Yass and thereby reduce the impact that flooding has on existing development, Council advised that the majority of suitable vacant land is privately owned, with several residential subdivisions proposed at a number of locations.

A review of the available publically owned land identified a location immediately to the south of the Yass Railway Museum, where flow which surcharges the existing stormwater drainage system impacts mainly commercial development that is located along Comur Street between Lead Street and Rossi Street during storms as frequent as 20% AEP. An assessment was undertaken using the hydraulic model that was developed as part of the present study to quantify the flood mitigation benefits which could be achieved by constructing a detention basin at this location. The following two potential detention basin arrangements were assessed:

- **Yass Railway Museum Detention Basin Option 1**, which comprises the construction of a maximum 2 m high earth embankment which would contain flow which discharges through the *RE1 Public Recreation* zoned land. The existing stormwater drainage system would be configured in the vicinity of the basin to manage the rate at which flow discharges from the basin and also to prevent backwater flooding in Cargo Street.
- **Yass Railway Museum Detention Basin Option 2**, which is identical to Option 1, but includes the lowering of natural surface levels within the footprint of the basin in order to increase the volume of temporary flood storage.

Figures 3.3 and **3.4** show the layout of Yass Railway Museum Detention Basin Options 1 and 2, respectively, as well as the impact that their construction would have on the extent and depth of inundation for design storms of 20%, 5% and 1% AEP. The figures also show the location of buildings that would be rendered free of above-floor inundation as a result of the scheme. **Table 3.2** gives the peak inflows and outflows to the detention basin, as well as the maximum depth of ponding upstream of its embankment for design storms of 20%, 5% and 1% AEP.

TABLE 3.2
SUMMARY OF PEAK FLOWS AND PONDING DEPTHS

Design Storm Event (% AEP)	Yass Railway Museum Detention Basin Option 1			Yass Railway Museum Detention Basin Option 2		
	Peak Inflow (m^3/s)	Peak Outflow[(1)] (m^3/s)	Maximum Ponding Depth (m)	Peak Inflow (m^3/s)	Peak Outflow[(1)] (m^3/s)	Maximum Ponding Depth (m)
20	4.25	3.31 [P] 0.0 [S]	2.73	4.23	3.07 [P] 0 [S]	2.49
5	10.17	3.91 [P] 4.67 [S]	3.53	10.18	3.89 [P] 3.04 [S]	3.46
1	15.26	3.97 [P] 9.46 [S]	3.69	15.20	3.96 [P] 9.23 [S]	3.68

1. [P] = piped flow [S] flow over spillway

Due to the constraints imposed on its size, as well as the elevation of its invert level and embankment, it is not possible to provide sufficient storage to prevent the operation of its spillway for all but relatively frequent storm events. As a result, the basin would only have a limited benefit in terms of reducing the impact that flooding has on existing development, especially for the less frequent storm events.

It is estimated that the *Present Worth Value* of damages saved by the basin for all storms up to 1% AEP in intensity would only be about $0.1 Million. By inspection, the cost of constructing the basin would be significantly greater than this value, meaning that it could not be justified on economic grounds. Coupled with the low hazard nature of the flooding that is experienced in mainly commercial development, the inclusion of this measure in the *Yass FRMP* is not recommended

3.4.3 Vegetation Management

Management programs in creeks typically involve maintenance of batters, the removal of sediment, removal of dense vegetation and the clearance of flood debris after significant flow events. Clearance of debris within the stream corridor reduces the potential for future capture by the flow and blockage of culverts.

While there is merit in removing flood debris on the Yass River after significant flow events as this would reduce its blocking effect on future flood flows, the main concern is Chinamans Creek where there is a large number of culvert crossings which could experience a partial blockage if flood debris is allowed to build up on the floodplain.

The overbank area of the Yass River is generally devoid of dense riparian vegetation, with the exception of the reach of river which runs between the Warrambalulah Street and Laidlaw Street crossings. While the northern overbank is densely vegetated in this area, it is relatively steep and therefore conveys only a small portion of the total flow in the river. As a result, the removal of dense vegetation along this reach of the river would not result in a significant reduction in peak flood levels.

The removal of dense vegetation along the inbank area of Chinamans Creek, especially in its lower reaches would reduce its frequency of surcharge. **Figure 3.5** shows that while reducing the Manning's n hydraulic roughness value of the inbank area of Chinamans Creek to a value of 0.05 (presently assessed as being 0.09) would generally reduce both the extent and depth of inundation in a number of properties, it would result in a minor increase in peak flood levels along the main arm of the creek downstream of Brown Street and Lead Street.[8]

While the implementation of a vegetation management strategy would not reduce the flood risk in Yass from a Main Stream Flooding point of view, there is merit in its application to Chinamans Creek given it would reduce the frequency of surcharge of the inbank area of the watercourse and reduce the risk of the existing culvert structures experiencing a partial blockage during a flood event. For this reason it has been included in the *Yass FRMP*.

3.5 Property Modification Measures

3.5.1 Controls over Future Development

3.5.1.1 Current Government Policy

The NSW Government has recently finalised reforms of the *NSW Flood Prone Land Package*. As part of the reform, the wording in the flood planning clause of all NSW Councils will be updated on 14 July 2021. As part of the reform, Council will need to nominate the FPL or levels that it wishes to define the FPA and make alternative arrangements for making flood planning maps publicly available where previously solely reliant on LEP flood overlay maps. The reforms also include an optional clause titled *special flood considerations* which applies to land which lies between the FPA and the extent of the Extreme Flood. The adopted form of wording for the flood planning and special flood considerations clauses, the former which will automatically come in effect on the 14 July 2021 and the latter which is recommended for inclusion in *Yass LEP 2013* is set out in **Section 3.5.1.4** of this report.

3.5.1.2 Considerations for Setting Freeboard Requirements at Yass

Selection of the FPL for an area is an important and fundamental decision as the standard is the reference point for the preparation of floodplain risk management plans. It is based on the adoption of the peak level reached by a particular flood plus an appropriate allowance for freeboard. It involves balancing social, economic and ecological considerations against the consequences of flooding, with a view to minimising the potential for property damage and the

[8] Note that this increase is relative to current conditions when the inbank area of the creek could be considered to be overgrown in nature.

risk to life and limb. If the adopted FPL is too low, new development in areas outside the FPA (particularly where the difference in level is not great) may be inundated relatively frequently and damage to associated public services will be greater. Alternatively, adoption of an excessively high FPL will subject land that is rarely flooded to unwarranted controls.

Councils are responsible for determining the appropriate FPLs within their local government area. *Yass LEP 2013* currently nominates the "*1:100 ARI (average recurrence interval) flood event plus 0.5 metre freeboard*" as the FPL.

Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Design variables that are typically incorporated in the derivation of freeboard typically comprise the following:

- increases in peak flood levels due to wind and wave action;
- increases in peak flood levels due to local water surge;
- uncertainties in the design flood level estimates due to the confidence limits associated with the design peak flow estimate, inaccuracies in the LiDAR survey data and possible variations in key parameters such as hydraulic roughness; and
- increases in peak flood levels due to future climate change.

Table 3.4 provides a summary of a joint probability analysis that was undertaken to assess the freeboard allowance which should be incorporated in the FPL for areas at Yass that are affected by flooding from the Yass River, noting the methodology for deriving the various components of the freeboard allowance is based on the approach set out in NSW Public Works, 2010.

TABLE 3.4
SUMMARY OF FREEBOARD ANALYSIS
AREAS AFFECTED BY YASS RIVER FLOODING

Design Variable [A]	Probability of Occurrence [B]	Maximum Allowance (m) [C]	Joint Probability Allowance (m) [D]
Wave Action (Run-up)	20%(1)	0.30	0.06
Wave Action (Set-up)	50%	0.02	0.01
Local Water Surge	50%	0.00	0.00
Inaccuracies in Peak 1% AEP Flood Level Estimate			
- LiDAR survey data	100%	0.15	0.15
- Peak flow estimate	50%	0.40	0.20
- Hydraulic roughness	25%	0.60	0.15
Future Climate Change	50%	1.20	0.60
TOTAL			**1.17**

1. Based on no wave run-up in the case of vertical buildings and that the majority of the urbanised area of Yass is located in an embayment.

The maximum allowance for uncertainties in the peak 1% AEP flood level estimate is comprised of the following:

- inaccuracies in the LiDAR survey data (+0.15 m);
- provision for a 10% increase in the best-estimate peak 1% AEP flow derived by the flood frequency analysis (+0.4 m)[9]
- increase in peak flood levels associated with a possible 20% increase in the best-estimate hydraulic roughness values (+0.6 m).

In regards the potential impacts of future climate change on flood behaviour at Yass, the *ARR Data Hub* gives the following interim climate change factors for Representative Concentration Pathways (**RCPs**) of 4.5 and 8.5 in the years 2050 and 2090:

Year	**RCP 4.5**	**RCP 8.5**
2050	6.3%	11.4%
2090	9.2%	20.2%

It is noted that the design rainfall intensity for the 12 hour 0.5% AEP and 0.2% AEP storm events at Yass is respectively about 15% and 37% higher than the corresponding 1% AEP design rainfall. By comparison with the interim climate change factors, the adoption of the 0.5% AEP would provide a reasonable indicator of the potential for future climate change to impact peak 1% AEP flood levels (+1.2 m).

As mentioned, the Department of Planning Guideline confirmed that unless exceptional circumstances applied, councils should adopt the 1% AEP flood with appropriate freeboard as the FPL for residential development.

While there is a large flood range at Yass, the valley is relatively steep sided with rising ground generally located on either side of the river. As a result, provided future residential and commercial development is set out appropriately and an effective flood warning system is implemented in the Yass Valley, then this should facilitate the safe and orderly evacuation of occupiers of the floodplain in advance of the flood wave.

Having addressed risk-to-life considerations, the other major concern for Yass is the cost that flooding would impose on the community, mainly in regard property related flood damages. In regards Yass River flooding, the adoption of the 1% AEP flood plus a 1.2 m freeboard for setting the FPL[10] means that flood related development controls can be applied to land which could potentially be subject to:

- increased flooding due to future climate change; and
- H5 and H6 type flooding conditions during floods that are slightly larger than the 1% AEP event.

Absent the allowance for the effects of future climate change, it can be seen from the values given in column D of **Table 3.4** that the provision of a 0.5 m freeboard when setting minimum habitable floor levels would account for uncertainties in the peak 1% AEP flood level estimate on the Yass River at Yass. Appreciating that the hydrologic standard of development which is set at this level would reduce over time as a result of future climate change, this would simply impose a

[9] While not included in the joint probability analysis, it should be noted that the 90% confidence limit for the 1% AEP best peak estimate is +1.2 m.

[10] Note that the FPL and hence the FPA simply defines the extent over which flood related development controls apply to future development (i.e. it does not define minimum elevations for future development (e.g. minimum habitable floor levels)).

greater cost on the community in terms of increased flood damages. In order to reduce the costs associated with design flood uncertainty, a control has been imposed on future development that is located on land that is located at or below the FPL which requires the structure to be designed to withstand the forces that would be imposed by floods up to 0.2% AEP in magnitude, noting that the flood modelling indicates that the adoption of a 1.2 m freeboard for setting the FPL as a proxy for the 1% AEP flood plus freeboard would capture land that would be subject to H5 and H6 type flooding during a flood of this magnitude.

While the flood range in the other watercourses which traverse the study area is such that the traditional 0.5 m freeboard is appropriate for setting the FPL, its adoption in areas affected by Major Overland Flow would lead to the FPA extending onto land which would not experience damaging or hazardous flooding during a 1% AEP storm event, even allowing for all the variables which comprise freeboard.

Considerable reduction in the number of properties in Major Overland Flow areas classified as "flood affected" would result by the adoption of a threshold depth of inundation under 1% AEP conditions of 0.1 m as the criterion for defining area which would be subject to the majority of flood related development controls, compared with the traditional approach. Properties with depths of inundation 0.1 m or greater, or in a floodway (i.e. traversed by significant overland flows which may in some cases be less than 0.1 m in depth) would therefore be considered to lie within the FPA. Properties with depths of inundation under 1% AEP conditions of less than 0.1 m would be classified as "Local Drainage" and, as such would be subject to controls such as the Building Code of Australia (**BCA**) requirements, rather than attracting a flood affectation notice. This approach is supported by NSWG, 2005 and would not adversely impact on Council's duty of care in regard to management of flood prone lands. The proposed categorisation of the floodplain, terminology and controls are shown on **Table 3.5**.

TABLE 3.5
PROPOSED CATEGORISATION OF THE FLOODPLAIN

Category (FDM, 2005)	Proposed Terminology used to define inundation in the *FRMS&P* report	Are Development Controls Required?	Is Section S10.7 Notification Warranted?
Main Stream Flooding	"Main Stream Flooding"	Yes	Yes
Local Overland Flooding - Local Drainage - Major Drainage	 "Local Drainage" "Major Overland Flow"	 No (ref. footnote 1). Yes (ref. footnote 2).	 No (ref footnote 1) Yes (ref footnote 3)

1. Inundation in Local Drainage areas is accommodated by the minimum floor level requirement of 0.15 m above finished surface level contained in the BCA and does not warrant a flood affectation notice in S10.7 Planning Certificates.
2. These are the deeper flooded areas with higher flow velocities. Development controls are specified in **Appendix E**.
3. Depth and velocity of inundation in Major Overland Flow areas are sufficient to warrant a flood affectation notice in S10.7 Planning Certificates. Inundation is classified as "flooding".

Figure E1.1 in **Appendix E** is an extract from the *Flood Planning Map* at Yass. The figure includes areas subject to both Main Stream Flooding and Major Overland Flow in the town. The extent of the FPA (the area subject to flood related development controls) is shown in a solid mauve (Main Stream Flooding) and green (Major Overland Flow) colour in **Figure E1.1** and has been defined as follows:

- In areas subject to Main Stream Flooding, the FPA is based on the traditional definition of the area that lies at or below by the 1% AEP plus freeboard (where a freeboard of 1.2 m was adopted for defining the extent of the FPA along the Yass River, while a freeboard of 0.5 m was adopted for defining the extent of the FPA along its major tributaries).
- In areas subject to Major Overland Flow, the FPA is defined as the extent of areas which act as a floodway, as well as areas where depths of inundation exceed 0.1 m in a 1% AEP event.

Also shown in **Figure E1.1** is the extent of the Outer Floodplain, which is the area of land which lies between the extent of the FPA and the PMF.

3.5.1.3 Proposed Planning Controls for Yass

As mentioned, Council does not presently have a Development Control Plan or policy which sets out flood related controls which apply to future development within the LGA. Rather, Council advised that it is currently applying the flood related development controls that are set out in WMAwater, 2016b when assessing applications for new development on the floodplain.

Based on a review of WMAwater, 2016b and in a knowledge of the flood behaviour at Yass, an updated set of planning controls have been recommended for adoption in the Development Control Plan that Council advised is currently being prepared for the Yass Valley (refer **Appendix E** of this report for details).

It is proposed that properties intersected by the extent of the FPA (i.e. the extent of land which lies below the FPL) would be subject to S10.7 flood affectation notification and planning controls graded according to flood hazard and evacuation constraints. NSWG, 2005 suggests wording on S10.7 (2) Planning Certificates along the following lines:

> *"Council considers the land in question to be within the Flood Planning Area and therefore subject to flood related development controls. Information relating to this flood risk may be obtained from Council. Restrictions on development in relation to flooding apply to this land as set out in Council's Development Control Plan which is available for inspection at Council offices or website."*

Annexures 2A and **2B** in **Appendix E** set out the graded set of flood related planning controls which have been developed for areas that are subject to Main Stream Flooding and Major Overland Flow, respectively. **Figure E1.1** in **Appendix E** shows the areas where the graded set of flood related planning controls set out in **Annexures 2A** and **2B** apply.

Minimum habitable floor level (**MHFL**) requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on **Figure E1.1**. The MHFLs for residential land use types is the level of the 1% AEP flood event plus freeboard, whereas for commercial and industrial land use types the MHFL is to be as close to the 1% AEP flood level plus freeboard as practical, but no lower than the 5% AEP flood level plus freeboard. In situations where the MHFL is below the 1% AEP flood level plus freeboard, a mezzanine area equal to 30% of the total habitable floor area is to be provided, the elevation of which is to be set no lower than the 1% AEP flood level plus freeboard.[11]

[11] Freeboard is equal to 0.5 m for development being assessed in areas affected by Main Stream Flooding and 0.3 m for development being assessed in areas affected by Major Overland Flow.

For areas outside the FPA shown on **Figure E1.1**, the MHFL for all land use types is the level of the 1% AEP flood event plus 0.5 m freeboard, with the exception of "critical uses and facilities" which are critical for flood response and recovery where the MHFL is the level of the PMF.

Figure E1.2 in **Appendix E** is an extract of the *Flood Planning Constraint Category Map* for the Yass Valley which shows the subdivision of the floodplain into the following four categories which have been used as the basis for developing the graded set of planning controls:

- **Flood Planning Constraint Category 1 (FPCC 1)**, which comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding.
- **Flood Planning Constraint Category 2 (FPCC 2)**, which comprises areas which lie within the extent of the FPA where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
- **Flood Planning Constraint Category 3 (FPCC 3)**, which comprises areas which lie within the extent of the FPA but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
- **Flood Planning Constraint Category 4 (FPCC 4)**, which comprises the area which lies between the extent of the FPA and the PMF. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to "critical uses and facilities" which are critical for response and recovery.

The derivation of the four FPCCs firstly involved the derivation of a number of sub-regions which were based on the nature of flooding at Yass, the sub-categories of which are set out in **Table 3.6** over. These sub-regions were then combined, with the resulting extents further refined in order to improve the area over which each FPCC applied.

A *Special Flood Consideration Zone* has also been included which relates to areas where the flood risk is considered to be high enough to require additional controls to be applied to future development that is located on land which lies between the Main Stream Flooding FPA and the PMF. The *Special Flood Consideration Zone*, the extent of which is shown on **Figures E1.1** and **E1.2**, has been defined as the extent of land where the flood hazard vulnerability classification for the PMF is H3 or higher, noting that the resulting extent was further refined in order to improve its definition in a number of places. The additional controls in this area relate to the safe and orderly evacuation of people who would be occupying the floodplain at the time of a flood event.

3.5.1.4 Revision of Yass LEP 2013 by Council

Both the *Yass FRMS* and *Yass FRMP* have been developed giving consideration to the following amended form of wording which will automatically come into effect on 14 July 2021:

"6.2 Flood planning

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

TABLE 3.6
KEY ELEMENTS COMPRISING FLOOD PLANNING CONSTRAINT CATEGORIES FOR YASS

Flooding	FPCC	Sub-category	Constraint
Main Stream Flooding	1	a	1% AEP Main Stream Flooding (MSF) Floodway
		b	1% AEP MSF Flood Hazard Vulnerability Classification H6
	2	a	1% AEP MSF Flood Storage
		b	1% AEP MSF Flood Hazard Vulnerability Classification H5
		c	0.2% AEP MSF Flood Hazard Vulnerability Classification H5 and H6 trimmed to the extent of the Main Stream Flooding FPA
		d	1% AEP Flood Emergency Response Classification (Flooded - Isolated - Submerged)
		e	1% AEP Flood Emergency Response Classification (Flooded - Isolated - Elevated)
	3	-	Flood Planning Area
	4	-	Extent of PMF
Major Overland Flow	1	-	1% AEP Floodway AND Flood Hazard Vulnerability Classification H4 - H6
	2	a	1% AEP Floodway AND Flood Hazard Vulnerability Classification H1 - H3
		b	1% AEP Flood Storage Area
		c	0.2% AEP Flood Hazard Vulnerability Classification H5 and H6
		d	1% AEP Flood Emergency Response Classification (Flooded - Isolated - Submerged)
		e	1% AEP Flood Emergency Response Classification (Flooded - Isolated - Elevated)
	3	-	Flood Planning Area
	4	-	Extent of PMF

(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 flood function and behaviour on the land, taking into account projected changes as a result of climate change,

(c) to avoid adverse or cumulative impacts on flood behaviour and the environment,

(d) to enable the safe occupation and efficient evacuation of people in the event of a flood.

(2) Development consent must not be granted to development on land the consent authority considers to be within the flood planning area unless the consent authority is satisfied the development—

(a) is compatible with the flood function and behaviour on the land, and

(b) will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and

(c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and

(d) incorporates appropriate measures to manage risk to life in the event of a flood, and

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

(3) In deciding whether to grant development consent on land to which this clause applies, the consent authority must consider the following matters—

(a) the impact of the development on projected changes to flood behaviour as a result of climate change,

(b) the intended design and scale of buildings resulting from the development,

(c) whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood,

(d) the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding or coastal erosion.

(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.

(5) In this clause—

Considering Flooding in Land Use Planning Guideline means the *Considering Flooding in Land Use Planning Guideline* published on the Department's website on 14 July 2021.

flood planning area has the same meaning as it has in the Floodplain Development Manual.

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

It is also recommended that the optional *special flood considerations* clause be added to *Yass LEP 2013* as follows:

Special flood considerations

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

(a) to enable the safe occupation and evacuation of people subject to flooding,

(b) to ensure development on land is compatible with the land's flood behaviour in the event of a flood,

(c) to avoid adverse or cumulative impacts on flood behaviour,

(d) to protect the operational capacity of emergency response facilities and critical infrastructure during flood events,

(e) to avoid adverse effects of hazardous development on the environment during flood events.

(2) This clause applies to—

(a) for sensitive and hazardous development—land between the flood planning area and the probable maximum flood, and

(b) for development that is not sensitive and hazardous development—land the consent authority considers to be land that, in the event of a flood, may—

(i) cause a particular risk to life, and

(ii) require the evacuation of people or other safety considerations.

(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) will not affect the safe occupation and efficient evacuation of people in the event of a flood, and

(b) incorporates appropriate measures to manage risk to life in the event of a flood, and

(c) will not adversely affect the environment in the event of a flood.

(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.

(5) In this clause—

***Considering Flooding in Land Use Planning Guideline**—see clause 5.21(5).*

***flood planning area**—see clause 5.21(5).*

***Floodplain Development Manual**—see clause 5.21(5).*

***probable maximum flood** has the same meaning as it has in the Floodplain Development Manual.*

***sensitive and hazardous development** means development for the following purposes—*

[list land uses]

Direction— Only the following land uses are permitted to be included in the list—

(a) boarding houses,

(b) caravan parks,

(c) correctional centres,

(d) early education and care facilities,

(e) eco-tourist facilities,

(f) educational establishments,

(g) emergency services facilities,

(h) group homes,

(i) hazardous industries,

(j) hazardous storage establishments,

(k) hospitals,

(l) hostels,

(m) information and education facilities,

(n) respite day care centres,

(o) seniors housing,

(p) sewerage systems,

(q) tourist and visitor accommodation,

(r) water supply systems

The steps involved in Council amending *Yass LEP 2013* following the finalisation and adoption of the *Yass FRMS&P* are:

1. Council Planning Staff consider the conclusions of the *Yass FRMS&P* and suggested amendments to *Yass LEP 2013*.
2. Council resolves to amend *Yass LEP 2013* in accordance with the *Yass FRMS&P*.
3. Council prepares a Planning Proposal in accordance with NSW Planning and Environment Guidelines. Planning Proposal submitted to NSW Planning and Environment in accordance with section 3.33 of the EP&A Act, 1979.
4. Planning Proposal considered by DPIE and determination made in accordance with section 3.34(2) of the EP&A Act, 1979 as follows:
   (a) whether the matter should proceed (with or without variation),
   (b) whether the matter should be resubmitted for any reason (including for further studies or other information, or for the revision of the planning proposal),
   (c) community consultation required before consideration is given to the making of the proposed instrument (the community consultation requirements),
   (d) any consultation required with State or Commonwealth public authorities that will or may be adversely affected by the proposed instrument,
   (e) whether a public hearing is to be held into the matter by the Planning Assessment Commission or other specified person or body,
   (f) the times within which the various stages of the procedure for the making of the proposed instrument are to be completed.
5. Planning Proposal exhibited for public comment.
6. Planning Proposal reviewed following public submissions and submissions from relevant State and Commonwealth authorities.
7. Final Local Environmental Plan with proposed amendments drafted.
8. Amending Local Environmental Plan made by the Minister and gazetted.

3.5.2 Voluntary Purchase of Residential Properties

Removal of housing from high hazard floodway areas in the floodplain is generally accepted as a cost effective means of correcting previous decisions to build in such areas. The Voluntary Purchase of residential property in hazardous areas has been part of subsidised floodplain risk

management programs in NSW for over 20 years.[12] After purchase, land is subsequently cleared and the site re-developed and re-zoned for public open space or some other flood compatible use. A further criterion applied by State Government agencies in assessing eligibility for funding is that the property must be in a high hazard floodway area, that is, in the path of flowing floodwaters where the depth and velocity at the peak of the flood are such that life could be threatened, damage of property is likely and evacuation difficult.

Under a Voluntary Purchase scheme the owner is notified that the body controlling the scheme, Council in the present case, is prepared to purchase the property when the owner is ready to sell. There is no compulsion whatsoever to sell at any time. The price is determined by independent valuers and the Valuer General, and by negotiation between Council and the owners. Valuations are not reduced due to the flood affected nature of the site.

Prior to progressing to the purchase of a property, it would first be necessary to hold discussions with each eligible and agreeable property owner, as well as a detailed assessment of each property to determine a priority order and costing for each.

There are eleven (11) existing dwellings in Yass that are subject to between 1 m and 4 m depth of above-floor inundation in a 1% AEP flood on the Yass River. All of the properties are located on the southern side of the river on land that has a flood hazard vulnerability classification of H5. While the acquisition of these properties cannot be justified on economic grounds due to an estimated cost of about $7.0 Million, the hazardous nature of the flooding and the associated risk to life should people become trapped in the affected dwellings warrants their consideration for inclusion in the NSW Government's Voluntary Purchase Scheme.

A confidential report was prepared as part of the present study which highlighted the flood risk in each of the eleven properties. The confidential report then formed the basis of discussions which were held by the FRMC prior to the finalisation of the draft *Yass FRMP*. Based on the outcome of the discussions it was decided the eleven properties should not be recommended for inclusion in the NSW Government's Voluntary Purchase Scheme and rather the risk to life in these properties should be managed through the implementation of the following measures:

i) Design and implementation of an integrated flood warning system for the Yass Valley (refer **Section 3.6.1** of this report for further details, noting this comprises Measures 5 and 6 of the *Yass FRMP*).

ii) Updating of the *Yass Valley Local Flood Plan* to ensure that these properties are identified as needing to be evacuated in the early stages of a major flood on the Yass River (refer **Section 3.6.2** of this report, noting this forms part of Measure 3 of the *Yass FRMP*).

iii) Council to liaise directly with the eleven property owners (and tenants if applicable) advising them of the flood risk and the need for them to evacuate in a safe and orderly manner during the early stages of a major flood on the Yass River (refer **Section 3.6.3** of this report, noting this forms part of Measure 4 of the *Yass FRMP*).

iv) Council to investigate altering the zoning of one or more of the affected properties from a residential to a commercial land use.

[12] State government funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted. Properties built after this date should have been constructed in accordance with the principles in the manual.

The effectiveness of the above measures at reducing the risk to life in the eleven properties should be reviewed when the *Yass FRMS&P* is next updated, as by this time they should have been implemented and possibly tested in a real flood situation.

3.5.3 Raising Floor Levels of Residential Properties

The term “house raising” refers to procedures undertaken, usually on a property by property basis, to protect structures from damage by floodwaters. The most common process is to raise the affected house by a convenient amount so that the floor level is at or above the MHFL. For weatherboard and similar buildings this can be achieved by jacking up the house, constructing new supports, stairways and balconies and reconnecting services. Alternatively, where the house contains high ceilings, floor levels can be raised within rooms without actually raising the house. It is usually not practical to raise brick or masonry houses. Most of the costs associated with this measure relate to the disconnection and reconnection of services. Accordingly, houses may be raised a considerable elevation without incurring large incremental costs.

State and Federal Governments have agreed that flood mitigation funds will be available for house raising, subject to the same economic evaluation and subsidy arrangements that apply to other structural and non-structural flood mitigation measures. In accepting schemes for eligibility, the Government has set out the following conditions:

- House raising should be part of the adopted Floodplain Risk Management Plan.
- The scheme should be administered by the local authority.

State government funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted. Properties built after this date should have been constructed in accordance with the principles in the manual. The Government also requires that councils carry out ongoing monitoring in areas where subsidised voluntary house raising has occurred to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level. In addition, it is expected that councils will provide documentation during the conveyancing process so that subsequent owners are made aware of restrictions on development below the design floor level.

Council’s principal role in subsidised voluntary house raising would be to:

- Define a habitable floor level, which it will have already done in exercising controls over new house building in the area.
- Guarantee a payment to the builder after satisfactory completion of the agreed work.
- Monitor the area of voluntary house raising to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level.

Prior to progressing to the raising of a dwelling, it would be necessary to hold discussions with each eligible and agreeable property owner, as well as a detailed assessment of each property to determine a priority order and costing for each.

The current cost to raise a medium sized (150 m^2) house is about $100,000 based on recent experience in other centres.

While there are three existing dwellings that are subject to above-floor inundation due to surcharge of the local stormwater drainage system, the relatively shallow depth, short duration and low hazard nature of the flow would not warrant their inclusion in a voluntary house raising scheme.

While there are two existing dwellings that are located in high hazard flood storage areas on the Yass River, only one would qualify for voluntary house raising given its weatherboard type construction. As the depth of above-floor inundation in a 1% AEP flood is presently 0.4 m, it would be necessary to raise the floor level of the dwelling by 0.9 m, noting that the current floor level is presently set about 0.7 m above the adjacent ground level. While the raising of the floor level of the dwelling could not be justified on economic grounds (i.e. because the *Present Worth Value* of the damages saved by raising it above the peak 1% AEP flood level would be negligible), there is merit in raising its floor level above the peak 1% AEP flood level on social grounds.

The inclusion of the single dwelling in the NSW Government's Voluntary House Raising Scheme was discussed at the FRMC meeting which was held prior to the finalisation of the draft *Yass FRMP*. Given the ongoing damages that would be incurred in the eleven residential properties that were identified for potential inclusion in the NSW Government's Voluntary Purchase Scheme, it was decided that there was no justification for the inclusion of the single dwelling in the NSW Government's Voluntary House Raising Scheme.

3.6 Response Modification Measures

3.6.1 Improvements to Flood Warning System

Improvements to the flood warning and response procedures were strongly favoured by the community during the community consultation process. An effective flood warning system has three key components, i.e. a flood forecasting system, a flood warning broadcast system and a response/evacuation plan. All systems need to be underpinned by an appropriate public flood awareness program.

Presently warnings regarding the potential for flooding to occur at Yass are limited to BoMs *Severe Thunderstorm Warning* and *Severe Weather Warnings for Flash Flooding* alert services which are publically available via the internet or on smart phones via free Apps.

Funding to establish local flash flood warning systems has traditionally been made available on the basis of no Council contribution to the initial capital cost in recognition of the high maintenance costs which Council would have to meet. The costs of maintaining the system would include such items as rain and river gauges, warning communication systems and ongoing public awareness/education programs. The maintenance obligations need to be identified and included in any initial funding grant. An operation and maintenance manual would need to be prepared for the system. Reference to the system would also need to be incorporated into the *Yass Valley Local Flood Plan*.

BoM has indicated that it would be supportive of improvements to the flood warning system for the Yass Valley, noting that WMAwater, 2016b and WMAwater, 2016c include recommendations for improvements to be made to the flood warning systems for the villages of Gundaroo and Sutton. It is envisaged that improvements to the flood warning system for the Yass Valley which take into account the recommendations of WMAwater, 2016b and WMAwater, 2016c would comprise:

- The installation of a network of pluviographic rain gauges both within and adjacent to the Yass Valley which would allow BoM to monitor rainfall depths and intensities in real time.

- The installation of alarms on the Macks Reef Road, Gundaroo and Yass stream gauges which would be triggered when key water levels are reached during a flood event. In the case of Gundaroo and Yass, an automated public announcement system could be linked to the key trigger levels, warning residents and business owners that a key trigger level(s) has been reached in the river and to monitor and take action where required.
- The installation of two new stream gauges upstream of Yass, one on the Yass River and the other on Murrumbateman Creek. While locating a single stream gauge on the Yass River downstream of its confluence with Murrumbateman Creek would control a large portion of the catchment which lies upstream of Yass, its location only a short distance upstream of the town would not provide sufficient advance warning of the magnitude of an approaching flood. Rather, the provision of a gauge on Murrumbateman Creek a short distance upstream of its confluence with the Yass River (Catchment Area = 184 km^2) in combination with another gauge which could be located further upstream at say the Greenwood Road crossing of the Yass River (Catchment Area = 800 km^2) would provide sufficient coverage of the catchment and advance warning time of an approaching flood.
- Installation of manual read water level gauges at Sutton, Gundaroo and Yass.
- Installation of warning signs and self-deploying boom gates on river and creek crossings.

Given the potential for hazardous flooding to impact existing development at Yass, coupled with the recommendations set out in WMAwater, 1016b and WMAwater, 2016c, the development of a comprehensive flood warning system for the Yass Valley has been included in the *Yass FRMP*.

3.6.2 Improved Emergency Planning and Response

As mentioned in **Section 2.16**, the *Yass Valley Local Flood Plan* provides detailed information regarding preparedness measures, conduct of response operations and coordination of immediate recovery measures for all levels of flooding.

NSW SES should ensure information contained in this report on the impacts of flooding on urban development, as well as recommendations regarding flood warning and community education are used to update Volume 2 of the *Yass Valley Local Flood Plan*. Volume 2 should include the following sections:

Annex A – The Flood Threat includes the following sub-sections:

Land Forms and River Systems – ref. **Sections 2.1** and **2.2** of the report for information on these topics.

Characteristics of Flooding – Indicative extents of inundation for the 1% AEP and PMF events and the typical times of rise of floodwaters at key locations on the major watercourses are shown on **Figures 2.2**, **2.3** and **2.5**. The location of vulnerable development and critical infrastructure relative to the flood extents is shown on **Figure 2.6**.

Flood History – Recent flood experience at Yass is discussed in **Section 2.3** of the report.

Design Flood Heights – The design flood heights for the Yass stream gauge should be updated based on the design peak flood levels set out in **Table 2.4** of the report.

Flood Mitigation Systems – Apart of two stormwater detention basins that have been constructed in the upper reaches of the Chinamans Creek catchment as part of two relatively new residential subdivisions, there are no other formal flood mitigation measures in Yass.

Extreme Flood Events – The PMF was modelled and the indicative extent and depth of inundation presented on **Figure 2.3**.

Annex B – Effects of Flooding on the Community

Information on the properties affected by the 1% AEP design flood are included in this report (**Figure 2.2**), noting that the floor level data used in this assessment were a combination of field survey and estimates which were made from the LiDAR survey and "drive by" survey. A separate confidential report was also issued to the FRMC identifying the eleven dwellings that are subject to hazardous flooding conditions and which would need to be evacuated in the early stages of a major flood on the Yass River.

Figure 2.5 shows stage hydrographs at road crossings at Yass, the locations of which are shown on **Figure 2.2**, sheets 2 and 3.

Figure 2.6 shows the location of vulnerable development and critical infrastructure in Yass relative to the flood extents ranging between 20% and 0.2% AEP, as well as the PMF. Refer **Section 2.7** for details of affected infrastructure.

Figures 3.6, **3.7** and **3.8** show the flood emergency response planning classifications for the 5% AEP, 1% AEP and PMF events, respectively, based on the definitions set out in AIDR, 2017.

Figures 3.9, 3.10 and **3.11** show the indicative extent and depth of inundation associated with flooding on the Yass River corresponding to NSW SES's interim Minor (4.6 m), Moderate (6.0 m) and Major (8.0 m) flood levels on the Yass stream gauge, while **Table 3.7** over provides a description of the flood related consequences at each level.

3.6.3 Public Awareness Programs

Community awareness and appreciation of the existing flood hazards in the floodplain would promote proper land use and development in flood affected areas. A well informed community would be more receptive to requirements for flood proofing of buildings and general building and development controls imposed by Council. Council should also take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplains of the flood risk.

One aspect of a community's preparedness for flooding is the "flood awareness" of individuals. This includes awareness of the flood threat in their area and how to protect themselves against it. The overall level of flood awareness within the community tends to reduce with time, as memories fade and as residents move into and out of the floodplain. The improvements to flood warning arrangements described above, as well as the process of disseminating this information to the community, would represent a major opportunity for increasing flood awareness in Yass.

Means by which community awareness of flood risks can be maintained or may be increased include:

- displays at Council offices using the information contained in the present study and photographs of historic flooding in the area; and
- talks by NSW SES officers with participation by Council and longstanding residents with first-hand experience of flooding in the area.
- preparation of a *Flood Information Brochure* which could be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with rate notices.

The community should also be made aware that a flood greater than historic levels or the flood planning level can, and will, occur at some time in the future.

In addition to the above, Council and/or NSW SES should liaise with the owners (and also the tenants if applicable) of the eleven residential properties that were identified for possible inclusion in the NSW Government's Voluntary Purchase Scheme and advise them of the existing flood risk and the need for them to evacuate their properties during the early stages of a major flood on the Yass River.

TABLE 3.7
IMPACTS RELATING TO INTERIM FLOOD LEVEL CLASSIFICATIONS
YASS RIVER FLOODING AT YASS

Flood Level Classification	Gauge Height (m)	Consequence
Minor	4.6	• Flat Rock Crossing inundated to a depth of about 4.4 m.
Moderate	6.0	• Flat Rock Crossing inundated to a depth of about 5.8 m. • Floodwater surcharges the left bank of Yass River immediately upstream of Comur Street and inundates Riverbank Park to depths of up to 1 m.
Major	8.0	• Flat Rock Crossing inundated to a depth of about 7.8 m. • Riverbank Park inundated to depths of up to 3 m. • Rossi Street inundated to a depth of about 1.4 m at the low point between Church Street and Comur Street. • Banjo Patterson Park inundated to depths of up to 1.6 m. • Low point in Comur Street 80 m north of its intersection with Rossi Street inundated to a depth of about 1.1 m.(1) • Wargeila Road on the verge of being inundated at a location about 160 m north of its intersection with Yass Valley Way. • Three dwellings and six commercial buildings in undated above-floor level.

1. Note: Comur Street will commence to be inundated at this location when the water level reaches 6.9 m on the Yass stream gauge.

4 SELECTION OF FLOODPLAIN MANAGEMENT MEASURES

4.1 Background

NSWG, 2005 requires a Council to develop a Floodplain Risk Management Plan based on balancing the merits of social, environmental and economic considerations which are relevant to the community. This chapter sets out a range of factors which need to be taken into consideration when selecting the mix of works and measures that should be included in the *Yass FRMP*.

The community will have different priorities and, therefore, each needs to establish its own set of considerations used to assess the merits of different measures. The considerations adopted by a community must, however, recognise the State Government's requirements for floodplain management as set out in NSWG, 2005 and other relevant policies. A further consideration is that some elements of the *Yass FRMP* may be eligible for subsidy from State and Federal Government sources and the requirements for such funding must, therefore, be taken into account.

Typically, State and Federal Government funding is given on the basis of merit, as judged by a range of criteria:

- The magnitude of damage to property caused by flooding and the effectiveness of the measure in mitigating damage and reducing the flood risk to the community.
- Community involvement in the preparation of the Floodplain Risk Management Plan and acceptance of the measure.
- The technical feasibility of the measure (relevant to structural works).
- Conformance of the measure with Council's planning objectives.
- Impacts of the measure on the environment.
- The economic justification, as measured by the benefit/cost ratio of the measure.
- The financial feasibility as gauged by Council's ability to meet its commitment to fund its part of the cost.
- The performance of the measure in the event of a flood greater than the design event.
- Conformance of the measure with Government Policies (e.g. NSWG, 2005 and Catchment Management objectives).

4.2 Ranking of Measures

A suggested approach to assessing the merits of various measures is to use a subjective scoring system. The chief merits of such a system are that it allows comparisons to be made between alternatives using a common "currency". In addition, it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). The system does not, however, provide an absolute "right" answer as to what should be included in the *Yass FRMP* and what should be left out. Rather, it provides a method by which Council can re-examine the measures and if necessary, debate the relative scoring given to aspects of the *Yass FRMP*.

Each measure is given a score according to how well the measure meets the considerations discussed above. In order to keep the scoring simple, the following system is proposed:

+2 Measure rates very highly

+1 Measure rates well

0 Measure is neutral

- 1 Measure rates poorly

- 2 Measure rates very poorly

The scores are added to get a total for each measure.

Based on considerations outlined in this chapter, **Table 4.1** presents a suggested scoring matrix for the measures reviewed in **Chapter 3**. This scoring has been used as the basis for prioritising the components of the *Yass FRMP*.

4.3 Summary

Table 4.1 indicates that there are good reasons to consider including the following elements into the *Yass FRMP*:

- An update of e *Yass LEP 2013* to allow better management of the floodplain
- Improved planning controls through the development of a Development Control Plan for the Yass Valley which incorporates the recommendations set out in this report.
- Incorporation of the catchment specific information on flooding impacts contained in this report in NSW SES Response Planning and Flood Awareness documentation for the study area.
- Improvements to the flood warning system for the Yass Valley through the installation of a number of telemetered pluviographic rain gauges, as well as a number of telemetered stream gauges upstream of the town.
- Improved public awareness of flood risk in the community.
- Development and implementation of a *Vegetation Management Plan* for Chinamans Creek.

TABLE 4.1
ASSESSMENT OF POTENTIAL FLOODPLAIN MANAGEMENT MEASURES FOR INCLUSION IN YASS FLOODPLAIN RISK MANAGEMENT PLAN

Measure	Impact on Flooding/ Reduction in Flood Risk	Community Acceptance	Technical Feasibility	Planning Objectives	Environ. Impacts	Economic Justification	Financial Feasibility	Extreme Flood	Government Policies and TCM Objectives	Score
Flood Modification										
Cobham Street to Shaw Street Stormwater Drainage Upgrade	-1	+2	+1	+1	0	-2	0	0	-1	0
Lead Street Stormwater Drainage Upgrade	+1	+2	+2	+1	0	-2	0	0	+1	+5
Browne Street Trunk Drainage Upgrade	+1	+2	+2	+1	+1	-2	0	0	+1	+6
Yass Railway Museum Detention Basin Option 1	+1	+1	+2	+1	0	-2	0	0	+1	+4
Yass Railway Museum Detention Basin Option 2	+1	+1	+2	+1	0	-2	0	0	+1	+4
Vegetation Management	+1	+2	+2	+2	+2	-1	0	0	+2	+10
Property Modification										
Controls over Future Development (via a new Development Control Plan for the Yass Valley)	+2	+2	+2	+2	0	0	0	+1	+2	+11
Voluntary Purchase of Residential Property Subject to Highly Hazardous Flooding Conditions	+2	-1	+2	+2	0	-2	-2	+2	+2	+7
House Raising in Areas Subject to Less Hazardous Conditions	+1	-2	+2	+2	0	+1	+1	0	+1	+6
Response Modification										
Improvements to Flood Warning System	+2	+2	+2	+1	0	0	0	+2	+2	+11
Improved Emergency Planning and Response	+2	+2	+2	+1	0	0	0	+2	+2	+11
Public Awareness Programs	+1	+2	+2	+1	0	0	0	+1	+2	+9

5 YASS FLOODPLAIN RISK MANAGEMENT PLAN

5.1 The Floodplain Risk Management Process

The *Yass Floodplain Risk Management Study (**Yass FRMS**)* and *Yass Floodplain Risk Management Plan* (***Yass FRMP***) have been prepared for the township of Yass (**study area**) as part of a Government program to mitigate the impacts of major floods and reduce the hazards in the floodplain. The *Yass FRMP* which is set out in this Chapter has been prepared as part of the Floodplain Risk Management Process in accordance with the NSW Government's Flood Prone Land Policy.

The first steps in the process of preparing the *Yass FRMP* were the collection of flood data and the review and update of the *Yass Flood Study* (WMAwater, 2016a) (***Updated Flood Study***), details of which are set out in **Appendix B** of the *Yass FRMS* report.

5.2 Purpose of the Plan

The overall objectives of the *Yass FRMS* were to assess the impacts of flooding, review policies and measures for the management of flood affected land and to develop the *Yass FRMP* which:

- Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding and establishes a program and funding mechanism for the *Yass FRMP*.
- Proposes amendments to Yass Valley Council's (**Council's**) existing policies to ensure that the future development of flood affected land in the study area is undertaken so as to be compatible with the flood hazard and risk.
- Ensures the *Yass FRMP* is consistent with NSW State Emergency Services (**NSW SES's**) local emergency response planning procedures.
- Ensures that the *Yass FRMP* has the support of the community.

5.3 The Study Area

The study area for the *Yass FRMP* applies to areas that are affected by the following two types of flooding at Yass:

- **Main Stream Flooding**, which occurs when floodwater surcharges the inbank area of the existing river and creek system. Main Stream Flooding is typically characterised by relatively deep and fast flowing floodwater, but may be shallower and slower moving in flood fringe areas.
- **Major Overland Flow** which occurs during storms which result in the surcharge of the existing stormwater drainage system. It is also present in the upper reaches of the study catchments.

Figure 1.1 (2 sheets) is a location and catchment plan, while **Figure 2.1** (4 sheets) shows the key features of the existing stormwater drainage system at Yass.

5.4 Community Consultation

The Community Consultation process provided valuable direction over the course of the investigations, bringing together views from key Council staff, other departments and agencies, and importantly, the views of the community gained through:

- the delivery of a *Community Newsletter and Questionnaire* to property occupiers in the study area which allowed the wider community to gain an understanding of the issues being addressed as part of the study;
- meetings of the Floodplain Risk Management Committee to discuss results as they became available;
- a community "drop-in" session which was held during the exhibition of the draft *Yass FRMS&P* report.; and
- a one-on-one meeting with a concerned resident in Browne Street.

A summary of the responses to the questions contained in the *Community Questionnaire* is contained in **Appendix A** of the *Yass FRMS&P report*.

5.5 Existing Flood Behaviour

Yass has experienced several large floods that have inundated the floodplain and isolated parts of the town since settlement occurred in the 1830s. While stream gauge records only extend back to 1915, archival information indicates that major flood events occurred in July 1852, July 1864, April 1870, June 1891 and July 1900.

The July 1900 flood event is estimated to be the flood of record at Yass, while the October 1959 flood event is the largest to have occurred since official records began in 1915. The July 1900 flood reached about 10.3 m on the Yass stream gauge, while the October 1959 reached about 10.0 m. The October 1959 flood was equivalent to about a 1% (1 in 100) Annual Exceedance Probability (**AEP**) flood event.

Appendix B of the *Yass FRMS* report contains a series of photos which show the flooding that was experienced in parts of Yass during the major floods that occurred in 1900, 1925 and 1959, while **Figures 2.2** and **2.3** show the indicate extent and depth of inundation for the 1% AEP and Probable Maximum Flood (**PMF**) events, respectively. **Figure 2.4** shows design water surface profiles along the Yass River, Chinamans Creek and Bango Creek, **Figure 2.5** shows the time of rise of floodwaters at a number of key locations at Yass. **Figure 2.6** shows the indicate extent of flooding at Yass for floods of between 20% and 1% AEP, as well as the PMF event.

The relatively confined nature of the Yass River at Yass results in a relatively large difference in peak flood levels for floods of varying magnitude. For example, the peak 1% AEP flood level on the river is over 5 m higher than the corresponding peak 20% AEP flood level, while the peak PMF level is about 15 m higher than the corresponding peak 1% AEP flood level.

This large flood range in combination with the relatively rapid response time of the catchment to flood producing rain and the absence of an effective flood warning system for Yass poses a significant risk to life for occupiers of those areas that are subject to Main Stream Flooding. It also poses problems for agencies such as NSW SES given the relatively short period of time that is available to evacuate people from areas that could, depending on the intensity of the storm event, be subject to hazardous flooding conditions.

In addition to parts of Yass being impacted by relatively deep and potentially fast flowing floodwater which surcharges the Yass River and its tributaries (i.e. as a result of Main Stream Flooding), it is also subject to relatively shallow and slower moving overland flow which occurs during storms which result in the surcharge of the existing stormwater drainage system, principally within the Chinamans Creek catchment (i.e. as a result of Major Overland Flow).

5.6 Existing Flood Mitigation Measures

Apart from two stormwater detention basins that have recently been constructed in the upper reaches of the Chinamans Creek catchment as part of two new residential subdivisions, there are no other formal flood mitigation measures in Yass.

5.7 Economic Impacts of Flooding

Table 5.1 shows the number of properties that would be flooded to above-floor level and the damages experienced in residential and commercial/industrial development, as well as public buildings in the study area.

At the 1% AEP level of flooding, 23 dwellings and 34 commercial/industrial buildings are subjected to above-floor inundation, noting that no public buildings are above-floor inundated during a flood of this magnitude. The maximum depth of above-floor inundation in the worst affected residential and commercial property increases from about 4 m for a 1% AEP flood event to about 17 m for the PMF.

The total flood damages in Yass amounts to $6.59 Million in the event of a 1% AEP flood, increasing to about $154 Million in a PMF event. For a discount rate of 7% pa and an economic life of 50 years, the *Present Worth Value* of damages for all flood events up to the 1% AEP flood is about $3.5 Million.

TABLE 5.1
ECONOMIC IMPACTS OF FLOODING IN STUDY AREA

Design Flood Event (% AEP)	Properties Flooded Above-Floor Level						Total Flood Damages
	Residential		Commercial/Industrial		Public		
	No.	$ Million	No.	$ Million	No.	$ Million	$ Million
20%	0	0.13	1	0.06	0	0.02	0.21
10%	1	0.31	3	0.23	0	0.02	0.56
5%	3	0.64	14	0.70	0	0.02	1.36
2%	12	1.76	18	2.04	0	0.02	3.82
1%	23	3.14	34	3.39	0	0.06	6.59
0.5%	32	4.62	60	5.67	3	0.21	10.50
0.2%	44	6.40	80	10.50	7	1.27	18.17
PMF	276	35.22	152	91.99	32	26.67	153.88

5.8 Structure of Yass Floodplain Risk Management Plan

A summary of the *Yass FRMP* proposed for the study area along with broad funding requirements for the recommended measures are shown in **Table S1** at the commencement of the *Yass FRMS* report. These measures comprise preparation of planning documentation by Council, improvements to the flood warning system and community education on flooding by Council and NSW SES to improve flood awareness and response, and the management of vegetation along sections of Chinamans Creek. The measures will over time achieve the objectives of reducing the flood risk to existing and future development for the full range of floods.

The *FRMP* is based on the following mix of measures which have been given a provisional priority ranking according to a range of economic, social, environmental and other criteria set out in **Table 4.1** of the report:

- **Measure 1** – Update wording in the Yass Local Environmental Plan, 2013 (***Yass LEP 2013***)
- **Measure 2** – Improvements to planning and development controls for future development in flood prone areas
- **Measure 3** – Improvements to emergency response planning
- **Measure 4** – Increase public awareness of the risks of flooding in the community
- **Measure 5** – Investigation and design of an integrated flood warning system for the Yass Valley
- **Measure 6** – Implementation of an integrated flood warning system for the Yass Valley
- **Measure 7** – Development and implementation of a *Vegetation Management Plan* for Chinamans Creek

5.9 Planning and Development Controls

The results of the *Yass FRMS* indicate that an important measure for Council to adopt in the floodplain would be strong floodplain risk management planning applied consistently by all of its branches.

5.9.1 Revision of Yass LEP 2013

Clause 6.2 of *Yass LEP 2013* entitled “Flood planning” outlines its objectives in regard to development of flood prone land. The Flood Planning Level (**FPL**) referred to is the 1% AEP flood plus an allowance for freeboard of 0.5 m. The area encompassed by the FPL is known as the Flood Planning Area (**FPA**) and denotes the area subject to flood related development controls, such as locating development outside high hazard areas and setting minimum floor levels for future residential development.

The NSW Government recently finalised reforms of the *NSW Flood Prone Land Package* which included an update of the flood planning clause in all NSW Council Local Environmental Plans which will come into effect on 14 July 2021. While the wording of the flood planning clause in the *Yass LEP 2013* will be automatically updated on this date, it is recommended that the new special flood considerations clause set out in the *NSW Flood Prone Land Package* also be included in *Yass LEP 2013* (**Measure 1**). The objectives of the new clause are as follows:

- in relation to development with particular evacuation or emergency response issues (e.g. group homes, residential care facilities, etc.) to enable evacuation of land subject to flooding in events exceeding the flood planning level; and
- to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

The new clause would apply to land identified as FPCC4 (i.e. land which lies between the FPA and the extent of the PMF). Wording in relation to this new clause is given in **Section 3.5.1.4**.

5.9.2 Yass Valley Development Control Plan

The recommended approach to managing future development in the study area uses the concepts of *flood hazard* and *hydraulic categorisation* to develop controls for future development in flood prone land (**Measure 2**). **Figure E1.1** in **Appendix E** is an extract from the *Flood Planning Map* relating to the study area. The extent of the FPA has been defined as follows:

- In areas subject to Main Stream Flooding on the Yass River at Yass, the FPA is based on the area inundated by the 1% AEP plus 1.2 m freeboard, while in other areas it is based on the traditional definition of the area inundated by the 1% AEP plus 0.5 m freeboard.
- In areas subject to Major Overland Flow, the FPA is defined as the extent of floodway areas, as well as areas where depths of inundation in a 1% AEP event exceed 0.1 m.

It is proposed that properties intersected by the extent of the FPA would be subject to S10.7 flood affectation notification and planning controls graded according to flood hazard and hydraulic categorisation. **Annexures 2A** and **2B** in **Appendix E** set out the graded set of flood related planning controls which apply to development in areas that are affected by Main Stream Flooding and Major Overland Flow, respectively. **Figure E1.1** in **Appendix E** shows the areas where the graded set of flood related planning controls set out in **Annexures 2A** and **2B** apply.

Minimum habitable floor level (**MHFL**) requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on **Figure E1.1**. The MHFLs for residential land use types is the level of the 1% AEP flood event plus freeboard, whereas for commercial and industrial land use types the MHFL is to be as close to the 1% AEP flood level plus freeboard as practical, but no lower than the 5% AEP flood level plus freeboard. In situations where the MHFL is below the 1% AEP flood level plus freeboard, a mezzanine area equal to 30% of the total habitable floor area is to be provided, the elevation of which is to be set no lower than the 1% AEP flood level plus freeboard.[13]

Figure E1.2 in **Appendix E** is an extract of the *Flood Planning Constraint Category Map* for Yass. The figure shows the subdivision of the floodplain into the following four categories which have been used as the basis for developing the graded set of planning controls:

- **Flood Planning Constraint Category 1 (FPCC 1)**, which comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding.

[13] Freeboard is equal to 0.5 m for development being assessed in areas affected by Main Stream Flooding and 0.3 m for development being assessed in areas affected by Major Overland Flow.

- **Flood Planning Constraint Category 2 (FPCC 2)**, which comprises areas which lie within the extent of the FPA where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
- **Flood Planning Constraint Category 3 (FPCC 3)**, which comprises areas which lie within the extent of the FPA but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
- **Flood Planning Constraint Category 4 (FPCC 4)**, which comprises the area which lies between the extent of the FPA and the PMF. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to "critical uses and facilities" which are critical for response and recovery.

A *Special Flood Consideration Zone* has also been included which relates to areas where the flood risk is considered to be high enough to require additional controls to be applied to future development which is located on land that lies above the FPL. The *Special Flood Consideration Zone*, the extent of which is shown on **Figures E1.1** and **E1.2**, has been defined as the extent of land where the flood hazard vulnerability classification for the PMF is H3 or higher, noting that the resulting extent was further refined in order to improve its definition in a number of places. The additional controls in this area relate to the safe and orderly evacuation of people who would be occupying the floodplain at the time of a flood event.

5.10 Improvements to Flood Warning, Emergency Response Planning and Community Awareness

Three measures are proposed in the *Yass FRMP* to improve flood warning, emergency response planning and community awareness to the threat posed by flooding.

Measure 3 involves the update by NSW SES of the *Yass Valley Local Flood Plan* using information on flooding patterns, peak flood levels, times of rise of floodwaters and flood prone areas identified in this report. Figures have been prepared showing indicative extents of flooding, high hazard areas, expected rates of rise of floodwaters in key areas and locations where flooding problems would be expected. **Section 3.6.2** references the locations of key data within this report.

Council should also take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplains of the flood risk (included as **Measure 4** of the *Yass FRMP*). This information could be included in a *Flood Information Brochure* to be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with the rate notices. The community should also be made aware that a flood greater than historic levels or the planning level can, and will, occur at some time in the future.

Measure 5 involves the investigation and design of an integrated flood warning system for the Yass Valley which would include the installation of a network of pluviographic rain gauges, along with a series of telemetered stream gauges. An automated alarm and public announcement system should be linked to the telemetered stream gauges warning residents and business owners that a key trigger level(s) has been reached and to monitor and take action where

required. Other improvements include the installation of manual read water level gauges at Sutton, Gundaroo and Yass, as well as the installation of warning signs and self-deploying boom gates on river and creek crossings. **Measure 6** involves the implementation of an integrated flood warning system for the Yass Valley.

5.11 Flood Modification Works

While several potential flood modification works in the form of upgrades to the existing stormwater drainage system and the construction of a detention basin in publically owned land were assessed as part of the *Yass FRMS*, none were considered to provide sufficient benefit in terms of a reduction in flood affectation and hazard in existing development to justify their inclusion in the *Yass FRMP*. The assessed measures could also not be justified on economic grounds.

The *Yass FRMS* concluded that there is merit in developing and implementing a *Vegetation Management Plan* for Chinamans Creek where it runs through the urbanised parts of Yass, noting that while the removal of dense vegetation from inbank areas would not have a significant impact on peak 1% AEP flood levels, it would reduce the frequency of nuisance flooding and the risk of blockage of hydraulic structures (**Measure 7**).

5.12 Implementation Program

The steps in progressing the floodplain management process from this point onwards are:

1. Council adopts *Yass FRMP* and submits an application for funding assistance.
2. Assistance for funding qualifying projects included in the *Yass FRMP* may be available upon application under the Commonwealth and State funded floodplain management programs, currently administered by the Department of Planning, Industry and Environment.
3. As funds become available from Government agencies and/or Council's own resources, implement the measures in accordance with the established priorities.

The *Yass FRMP* should be regarded as a dynamic instrument requiring review and modification over time. The catalysts for change could include new flood events and experiences, legislative change, alterations in the availability of funding, reviews of Council's planning strategies and importantly, the outcome of some of the studies proposed in this report as part of the *Yass FRMP*. In any event, a thorough review every ten years is warranted to ensure the ongoing relevance of *Yass FRMP*.

6 GLOSSARY OF TERMS

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government Floodplain Development Manual, 2005.

TERM	DEFINITION
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, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
Floodplain	Area of land which is subject to inundation by floods up to and including the Probable Maximum Flood (**PMF**) event, that is, flood prone land.
Flood Planning Area	The area of land that is shown to be in the Flood Planning Area on the *Flood Planning Map*.
Flood Planning Map	The *Flood Planning Map* shows the extent of land on which flood related development controls apply in a given area, noting that other areas may exist which are not mapped but where flood related development controls apply.
Flood Planning Constraint Category 1 (FPCC 1)	Comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding
Flood Planning Constraint Category 2 (FPCC 2)	Comprises areas which lie below the *Flood Planning Level* where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
Flood Planning Constraint Category 3 (FPCC 3)	Comprises areas which lie below the *Flood Planning Level* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
Flood Planning Constraint Category 4 (FPCC 4)	Comprises the area which lies above the *Flood Planning Level* (**FPL**) but within the extent of the PMF. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to “critical uses and facilities” which are critical for response and recovery.
Flood Planning Level (FPL)	Flood levels selected for planning purposes, as determined by the relevant adopted floodplain risk management study and plan, or as part of a site specific study In the absence of an adopted floodplain risk management study and plan for a particular location, the FPL is defined as the peak 1% AEP flood level plus the addition of a 0.5 m freeboard.

TERM	DEFINITION
Flood Prone/Flood Liable Land	Land susceptible to flooding by the PMF. Flood Prone land is synonymous with Flood Liable land.
Floodway	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 flow, or a significant increase in flood levels.
Flood Storage Area	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the *Flood Planning Level* 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, 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.
Local Drainage	Land on an overland flow path where the depth of inundation during the 1% AEP storm event is less than 0.1 m.
Main Stream Flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Major Overland Flow	Where the depth of overland flow during the 1% AEP storm event is greater than 0.1 m.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location. 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.

7 REFERENCES

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APPENDIX A

COMMUNITY CONSULTATION

TABLE OF CONTENTS

ATTACHMENTS

A1. INTRODUCTION

At the commencement of the *FRMS,* the Consultants prepared a *Community Newsletter* and a *Community Questionnaire*, both of which were distributed by Council to the residents and business owners in Yass (refer to **Attachment 1**). A media release was also prepared that introduced the project and encouraged the community to provide input to the study by responding to the Community Questionnaire. The media release was placed on Council's website and advertised in the local newspaper and radio station.

The purpose of the *Community Newsletter* was to introduce the objectives of the study and set the scene on flooding conditions so that the community would be better able to respond to the *Community Questionnair*e and contribute to the study process.

The *Newsletter* contained the following information:

- A plan showing the extent of the study area.
- A statement of the objectives of the FRMS&P; namely the development of a strategy for reducing the flood risk and minimising the long-term impact of flooding on the community.

The *Community Questionnaire* was structured with the objectives of:

- Determining residents' and business owners' attitudes to controls over future development in flood liable areas.
- Inviting community views on possible flood management options which could be considered for further investigation in the *FRMS* and possible inclusion in the resulting *FRMP*.
- Obtaining feedback on any other flood related issues and concerns which the residents and business owners cared to raise.

This **Appendix** to the *FRMS&P* report discusses the responses to the nine questions that were included in the *Community Questionnaire* and comments made by respondents.

Chapter A2 deals with the residents' and business owners' views on the relative importance of classes of development over which flood-related controls should be imposed by Council.

Chapter A3 identifies residents' and business owners' views on the suitability of the various options which could be considered in more detail in the *FRMS.*

Chapter A4 discusses the best methods by which the community could provide feedback to the consultants over the course of the study.

Chapter A5 summarises the findings of the community consultation process.

A2 RESIDENT PROFILE AND FLOOD AWARENESS

A2.1 General

Residents were requested to complete the *Community Questionnaire* and return it to the Consultants by 31 August 2018. The deadline was extended to include any submissions that were received after this date. The Consultants received 92 responses in total out of the 2950 that had been distributed.

The Consultants have collated the responses, which are shown in graphical format in **Attachment 2**.

A2.2 Respondent Profile

The first four questions of the *Community Questionnaire* canvassed resident information such as whether the respondent was a resident or business owner, length of time at the property, the type of property (e.g. house, unit/flat).

Of the 92 responses, 87 were residents and one was the principal of Yass Public School. A further six respondents were business owners, while one was a property developer (**Question 2**).

The majority of respondents occupied residential type property (**Question 3**), which included houses (77 respondents), units/flats/apartments (4), villas/townhouses (3) and semi-rural farms (2). Two responses received were concerned with property which is vacant land. Seven respondents owned non-residential type property, which included shops/commercial premises (2 respondents), industrial units (2), community buildings (2) and one warehouse or factory. Note that some responses were included in more than one property classification type.

The length of time respondents had been at the address was found to be varied, with approximately 24% of respondents having lived at the residence for between '1-5 years', 41% for '5 to 20 years', and 27% for 'more than 20 years' (**Question 4**). Note that 8% of respondents did not answer this question.

A2.3 Controls over Development in Flood Prone Areas

The respondents were asked to rank from 1 to 4 the classes of development which they consider should receive protection from flooding (**Question 5**). Rank 1 was the most important and rank 4 the least.

The classes in decreasing order of importance to respondents ranged from:

- vulnerable residential (e.g. aged persons accommodation);
- residential property;
- essential community facilities (e.g. schools, evacuation centres); and
- commercial/business type development.

These results gave a guide to the Consultants as to the appropriate location of future development of the various classes within the floodplain. For example, on the basis of community views, vulnerable residential type development would receive the highest level of protection by locating future development of this nature outside the floodplain.

In **Question 6**, respondents were asked what notifications Council should give about the flood affectation of individual properties. The community was strongly in favour of advising existing residents (47) and prospective purchasers (51) of the known potential flood threat, while 12 respondents favoured only advising those who enquire to Council about the known potential flood risk. No respondents favoured not providing any notification.

Respondents were also asked in **Question 7** about the level of control Council should place on new development to minimise flood-related risks. The most popular responses were to place restrictions on developments to reduce the potential for flood damage (e.g. minimum floor level controls or the use of compatible building materials) and prohibit all development on land with any potential to flood. The next most favoured response was to advise of the flood risks, but allow the individual the choice as to whether they develop or not provided they take steps to minimise the potential flood risks. Fourteen respondents felt that Council should prohibit all new development only in those locations that would be extremely hazardous to persons or property during floods.

A3 POTENTIAL FLOOD MANAGEMENT MEASURES

The respondents were asked for their opinion on potential flood management measures which could be evaluated in the *FRMS* (and if found to be feasible included in the *FRMP*), by ticking a "yes" or "no" to the eleven potential options identified in **Question 8**.

The options comprised a range of *structural flood management measures* (e.g. programs by Council to manage vegetation in the creek system to maintain hydraulic capacity; widening of watercourses; construction of detention basins; improving the stormwater system; levees to contain floodwaters, as well as various *non-structural management measures* (e.g. voluntary purchase of residential properties in high hazard areas; raising floor levels of houses in low hazard areas; flood related controls over new developments; improvements to flood warning and evacuation procedures; community education on flooding; flood advice certificates). The options were not mutually exclusive, as the adopted *FRMP* could, in theory, include all of the options set out in the *Community Questionnaire*, or indeed, other measures nominated by the respondents or the FRMC.

The most popular structural measures were the management of vegetation along the creek corridor and improving the stormwater system in the town. The construction of detentions basins was another popular structural measure.

Of the non-structural measures, improvement of flood warning and evacuation procedures, provision of a Planning Certificate to purchasers in flood prone areas, specifying controls on future development in flood-prone areas and community flood-awareness programs all received strong support.

A mostly negative response was given to the widening of watercourses and the construction of permanent levees. Providing subsidies for raising the floor level of properties and the implementation of a residential Voluntary Purchase scheme were also unpopular.

A4 INPUT TO THE STUDY AND FEEDBACK FROM THE COMMUNITY

In **Question 9,** residents were asked for their view on the best methods of their providing input to the Study and feedback to the Consultants over the course of the investigation. Newsletters and mail-outs were the most popular methods, followed by articles in the local media (newspaper, radio and TV) and via Council's website. Other suggestions raised by respondents include:

- Community meetings.
- Provide information on the legal rights and responsibilities of councils and land owners regarding stormwater management.
- Support an independent review process of the *Flood Study* that affected property owners can access.
- Engage with affected property owners directly to co-operatively formulate outcomes for the study.

A5 SUMMARY

Ninety-two responses were received to the *Community Questionnaire* which was distributed by Council to residents and business owners in Yass. The responses amounted to about 3 per cent of the total number of questionnaires that were distributed to the community.

The issues identified by the responses to the *Community Questionnaire* support the objectives of the study as nominated in the attached *Community Newsletter,* and the activities nominated in the Study Brief. Of interest is that about one-third (28) of the respondents to the questionnaire were in favour of prohibiting all new development on land with any potential to flood. This was matched by an almost equal number of respondents (27) who were in favour of Council advising of the flood risks, but allowing the individual a choice to develop so long as potential flood risks are minimised.

Of the *structural measures* which could be incorporated in the *FRMP*, the most popular were management of vegetation along creek corridors, improving the capacity of the stormwater system and the construction of detention basins. The construction of permanent levees along the banks of the Yass River and the widening of the watercourse received a mostly negative response.

Improvements of flood warning and evacuation procedures, provision of a Planning Certificate to purchasers in flood prone areas, specifying controls on future development in flood-prone areas and community flood-awareness programs were the most popular of the potential *non-structural measures* set out in the *Community Questionnaire*.

There were no new measures identified by the respondents to the questionnaire.

ATTACHMENT A1

COMMUNITY NEWSLETTER
AND QUESTIONNAIRE

YASS
FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

Community Newsletter

Yass Valley Council has engaged consultants to undertake a Floodplain Risk Management Study and Plan for the township of Yass. The Floodplain Risk Management Study will assess options which are aimed at reducing the impacts of flooding on existing development and the establishment of a framework to manage flood liable land in accordance with current best floodplain management principles. The Plan will set out a recommended program of works and measures which will over time reduce the social, environmental and economic impacts of flooding at Yass.

The preparation of the Study and Plan is being jointly funded by Council and the NSW Office of Environment & Heritage. Council has established a Floodplain Risk Management Committee which is comprised of relevant council members, state government agencies and community representatives.

The Study and Plan will build on the results of the *Yass Flood Study* (completed in 2016) which defined flooding patterns and flood levels in Yass under present day conditions (an electronic copy of the *Yass Flood Study* can be accessed at https://www.yassvalley.nsw.gov.au).

The figure on the back of this questionnaire shows the indicative extent of the 1 in 100 annual exceedance probability (AEP) flood along the Yass River, Chinaman's Creek, Bango's Creek and Fairy Hole Creek, as well as the extent of flood prone land at Yass (as defined by the extent of the Probable Maximum Flood). The 1 in 100 AEP flood is a flood which has a 1% chance of occurrence in any one year, while the Probable Maximum Flood is the largest flood that could conceivably occur at Yass.

Have Your Say on Floodplain Management

An important first step in the preparation of a Floodplain Risk Management Study and Plan is to determine the flood issues which are important to the community. The attached **questionnaire** has been provided to residents and business owners to assist the consultants in gathering this important information. The questionnaire may also be completed online via Council's website (https://www.surveymonkey.com/r/YassFRMSP). All information provided will remain confidential and for use in this study only. Please return the completed questionnaire in the reply paid envelope provided by **Friday 31 August 2018**.

Contact: Yass Valley Council

Joseph Cleary | Design Engineer
Phone: (02) 6226 1477
Email: Council@yass.nsw.gov.au

yass valley council
the country the people

YASS
FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

Community Questionnaire

This questionnaire is part of the *Yass Floodplain Risk Management Study and Plan*, which is currently being prepared by Yass Valley Council with the financial and technical support of the NSW Office of Environment & Heritage. Your responses to the questionnaire will help us determine the flood issues that are important to you.

Please return your completed questionnaire in the reply paid envelope provided by **Friday 31 August 2018**. No postage stamp is required. If you have misplaced the supplied envelope or wish to send an additional submission the address is:

Lyall & Associates Consulting Water Engineers
Reply Paid 85163
NORTH SYDNEY NSW 2060

Alternatively, the questionnaire can be completed online via the following link:

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

1. Your Details:

Name (optional):_____

Address:_____

Email Address (optional):_____

Phone Number (optional):_____

About your property

2. Please tick as appropriate:

- ☐ I am a resident
- ☐ I am a business owner
- ☐ Other (please specify _____)

3. What is your property?

- ☐ House
- ☐ Villa/Townhouse
- ☐ Unit/Flat/Apartment
- ☐ Vacant land
- ☐ Industrial unit in larger complex
- ☐ Stand alone warehouse or factory
- ☐ Shop
- ☐ Community building
- ☐ Other (_____)

4. How long have you been at this address?

- ☐ 1 year to 5 years
- ☐ 5 years to 20 years
- ☐ More than 20 years (___ years)

Your attitudes to Council's development controls

5. Please rank the following development types according to which you think are the most important to protect from floods

(1=highest priority to 4=least priority)

Development Type	Rank
Commercial/Business	
Residential	
Vulnerable residential development (e.g. aged persons accommodation)	
Essential community facilities (e.g. schools, evacuation centres)	

6. What notifications do you consider Council should give about the potential flood affectation of individual properties?
(Tick one or more boxes)

- ☐ Advise every resident and property owner on a regular basis of the known potential flood threat
- ☐ Advise only those who enquire to Council about the known potential flood threat
- ☐ Advise prospective purchasers of property of the known potential flood threat.
- ☐ Provide no notifications
- ☐ Other (please specify)

_____

_____

7. What level of control do you consider Council should place on new development to minimise flood-related risks?

(Tick only one box)

(In addition to being favoured by the community, these options would also need to comply with legislation)

- ☐ Prohibit all new development on land with any potential to flood.
- ☐ Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties.
- ☐ Place restrictions on future developments to reduce the potential for flood damage (e.g. impose minimum floor level controls or the use of flood compatible building materials).
- ☐ Advise of the flood risks, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
- ☐ Provide no advice regarding the potential flood risks or measures that could minimise those risks.
- ☐ Other (please specify)

_____

_____

Your opinions on floodplain risk management measures

8. Below is a list of possible options that may be looked at to try to minimise the effects of flooding in the study area (see plan attached).

This list is not in any order of importance and there may be other options that you think should be considered. For each of the options listed, please indicate "yes" or "no" to indicate if you favour the option. Please leave blank if undecided.

Option	Yes	No
Management of vegetation along creek corridors to provide flood mitigation, stability, aesthetic and habitat benefits.		
Widening of watercourses.		
Construction of detention basins to temporarily store stormwater runoff and reduce the impacts of flooding on existing development.		
Improve the stormwater system within the town area.		
Construct permanent levees along the rivers and creeks to contain floodwaters.		
Voluntary scheme to purchase residential property in high hazard areas.		
Provide funding or subsidies to raise houses above major flood level in low hazard areas.		
Specify controls on future development in flood-liable areas (eg. controls on extent of filling, minimum floor levels.)		
Improve flood warning and evacuation procedures both before and during a flood.		
Community education, participation and flood awareness programs.		
Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.		
Other: _____ _____		

Other Information

9. What do you think is the best way for Council to get input and feedback from the local community about the results and proposals from this study?

(Tick one or more boxes)

- ☐ Council's website / social media pages
- ☐ Articles in local newspaper
- ☐ Announcements on local radio
- ☐ Through Council's Floodplain Risk Management Committee
- ☐ Mail outs / newsletters
- ☐ Other (please specify)

  (_____
  _____)

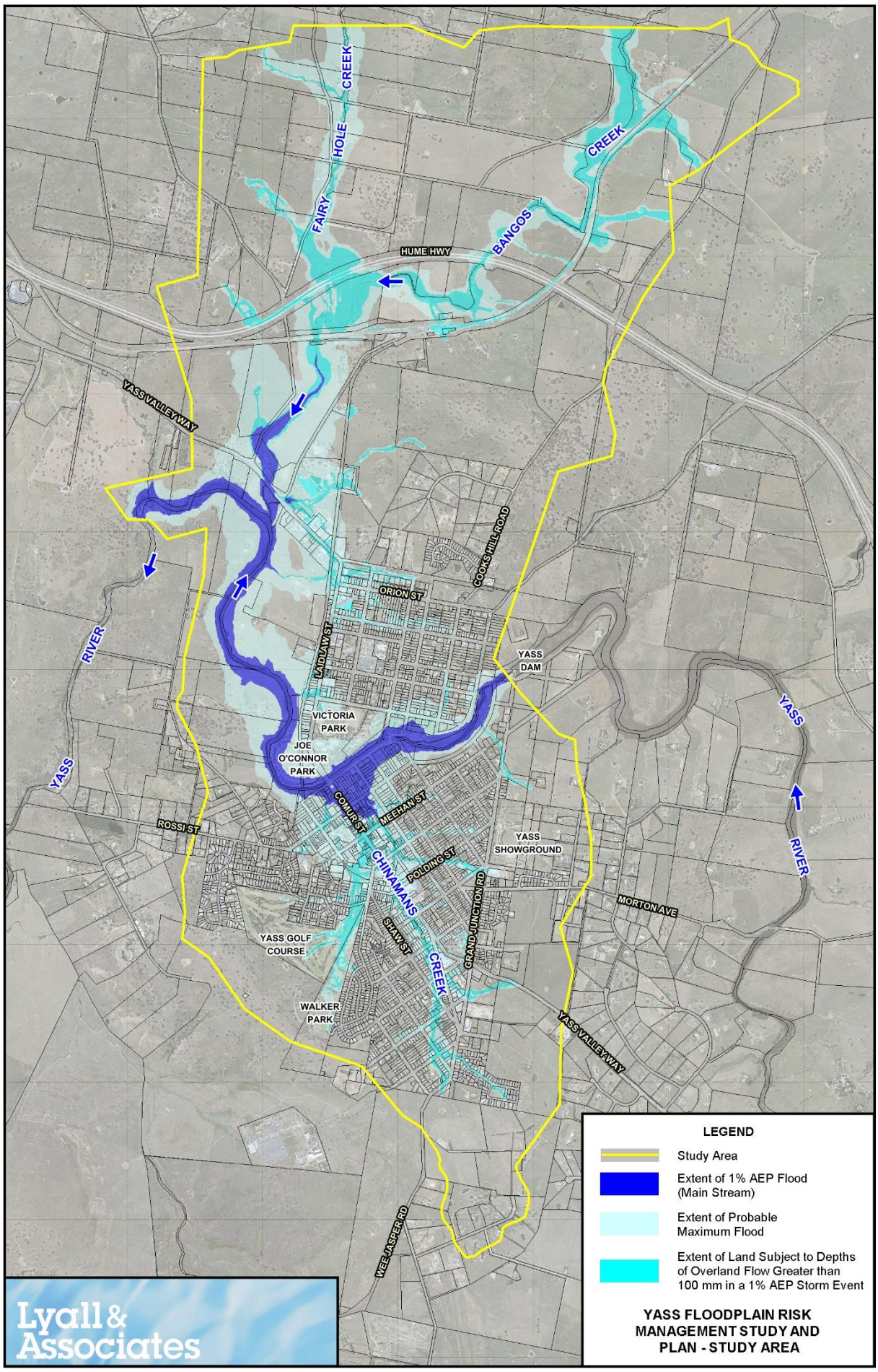
Who can I contact for further information?

Yass Valley Council
Joseph Cleary | Design Engineer
Phone: (02) 6226 1477
Email: Council@yass.nsw.gov.au

yass valley council
the country the people

Additional Comments

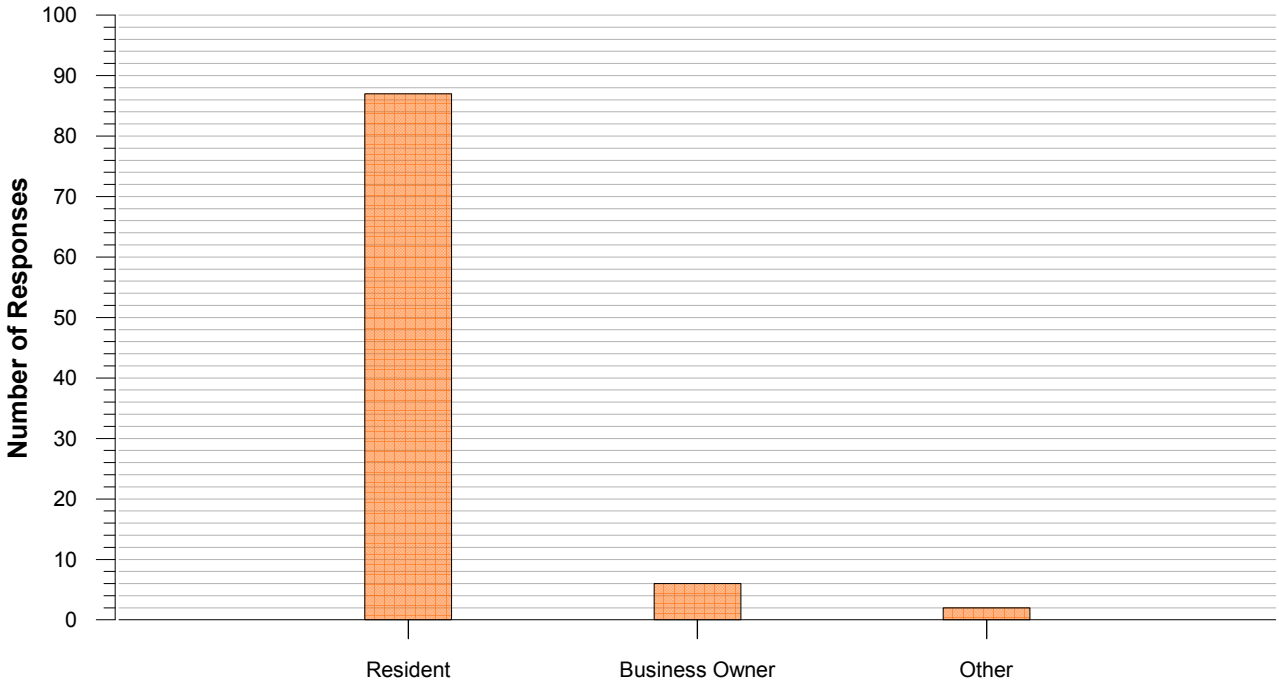
Please write any additional comments here:


FAIRY HOLE CREEK
BANGOS CREEK
HUME HWY
YASS VALLEY WAY
COOKS HILL ROAD
ORION ST
LAIDLAW ST
YASS DAM
RIVER
VICTORIA PARK
JOE O'CONNOR PARK
YASS
COMUR ST
MEEHAN ST
ROSSI ST
YASS SHOWGROUND
POLDING ST
CHINAMANS CREEK
GRAND JUNCTION RD
MORTON AVE
SHAW ST
YASS GOLF COURSE
WALKER PARK
YASS VALLEY WAY
WEE JASPER RD
LEGEND
Study Area
Extent of 1% AEP Flood (Main Stream)
Extent of Probable Maximum Flood
Extent of Land Subject to Depths of Overland Flow Greater than 100 mm in a 1% AEP Storm Event
YASS FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN - STUDY AREA
Lyall & Associates

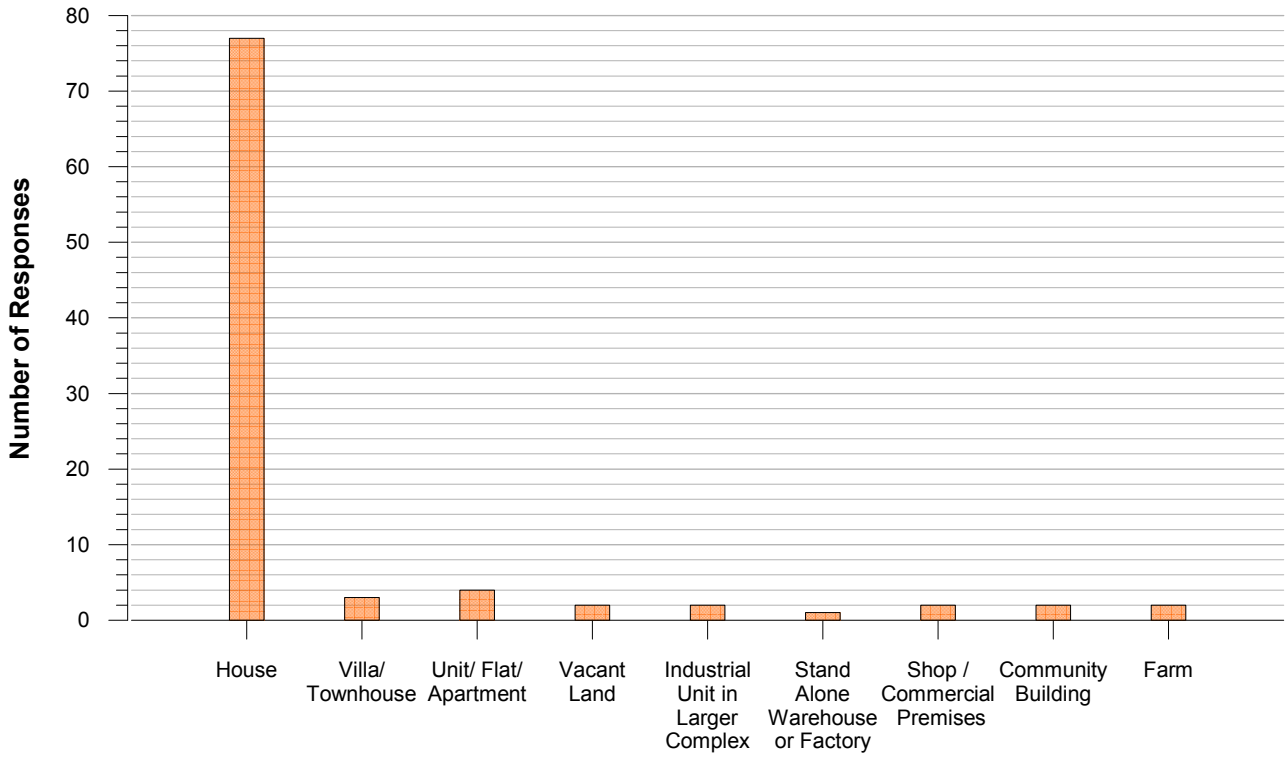
ATTACHMENT A2

RESPONSES TO COMMUNITY QUESTIONNAIRE

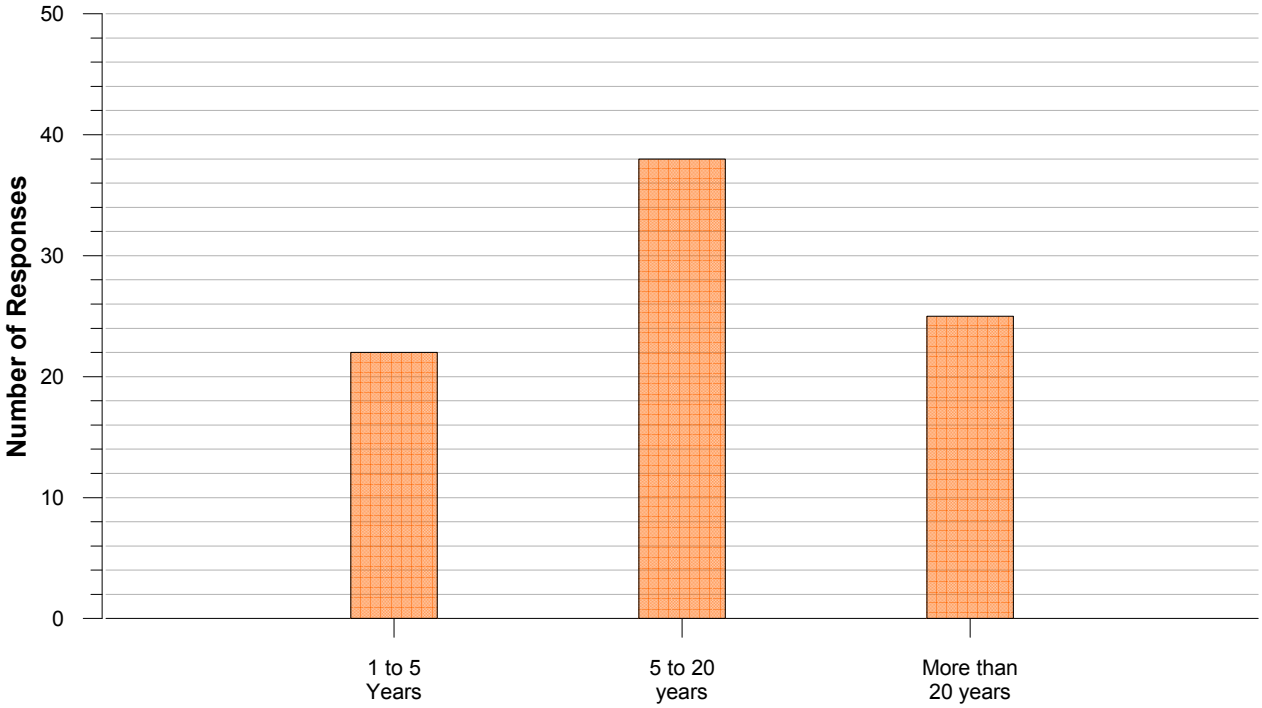
Q2. Residential Status



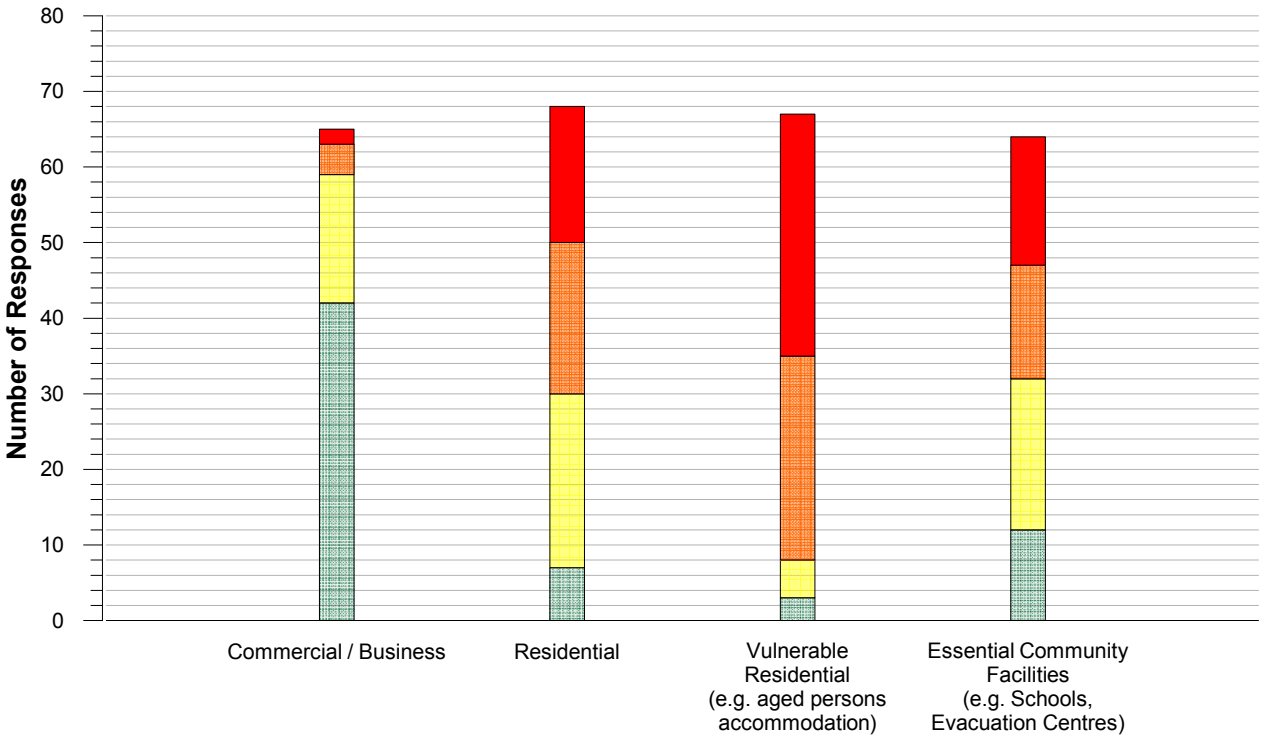
Q3. Type of Property



Q4. How long have you been at this address?



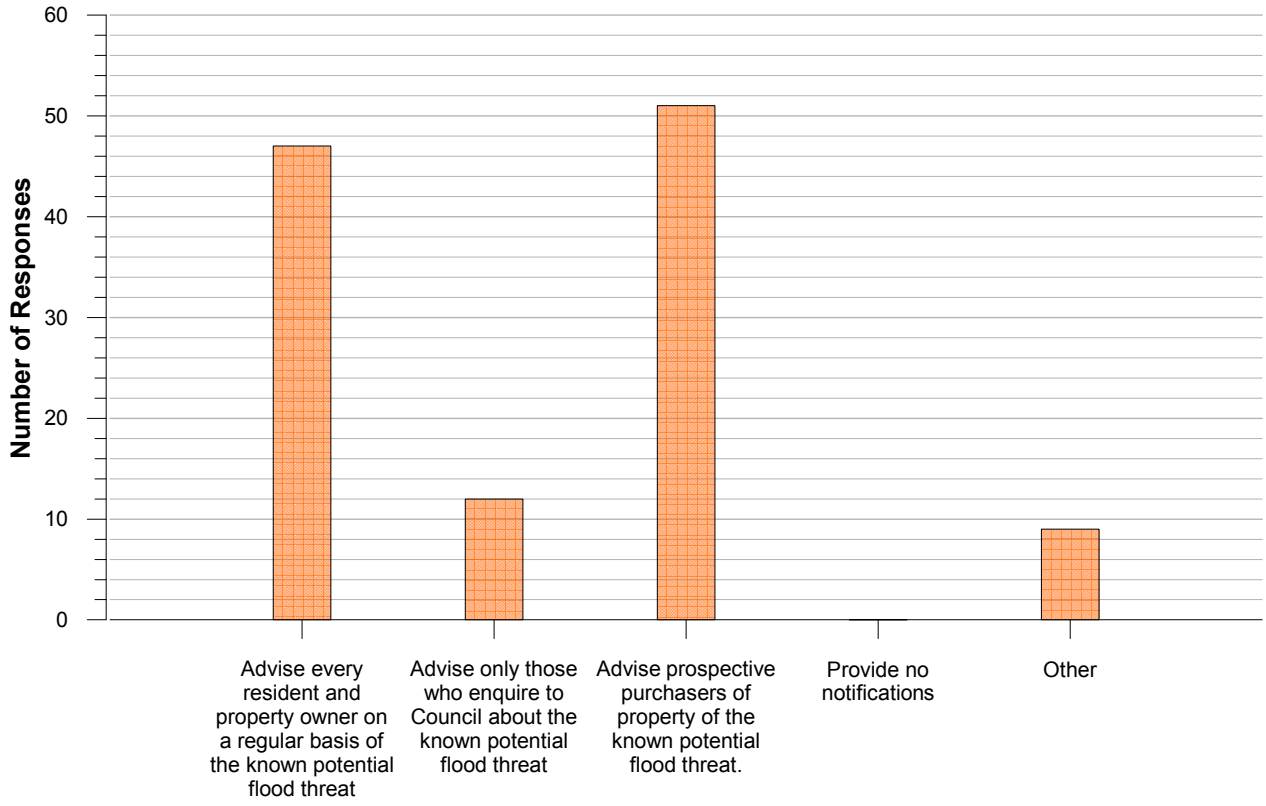
Q5. Ranking of development types by importance to protect from floods



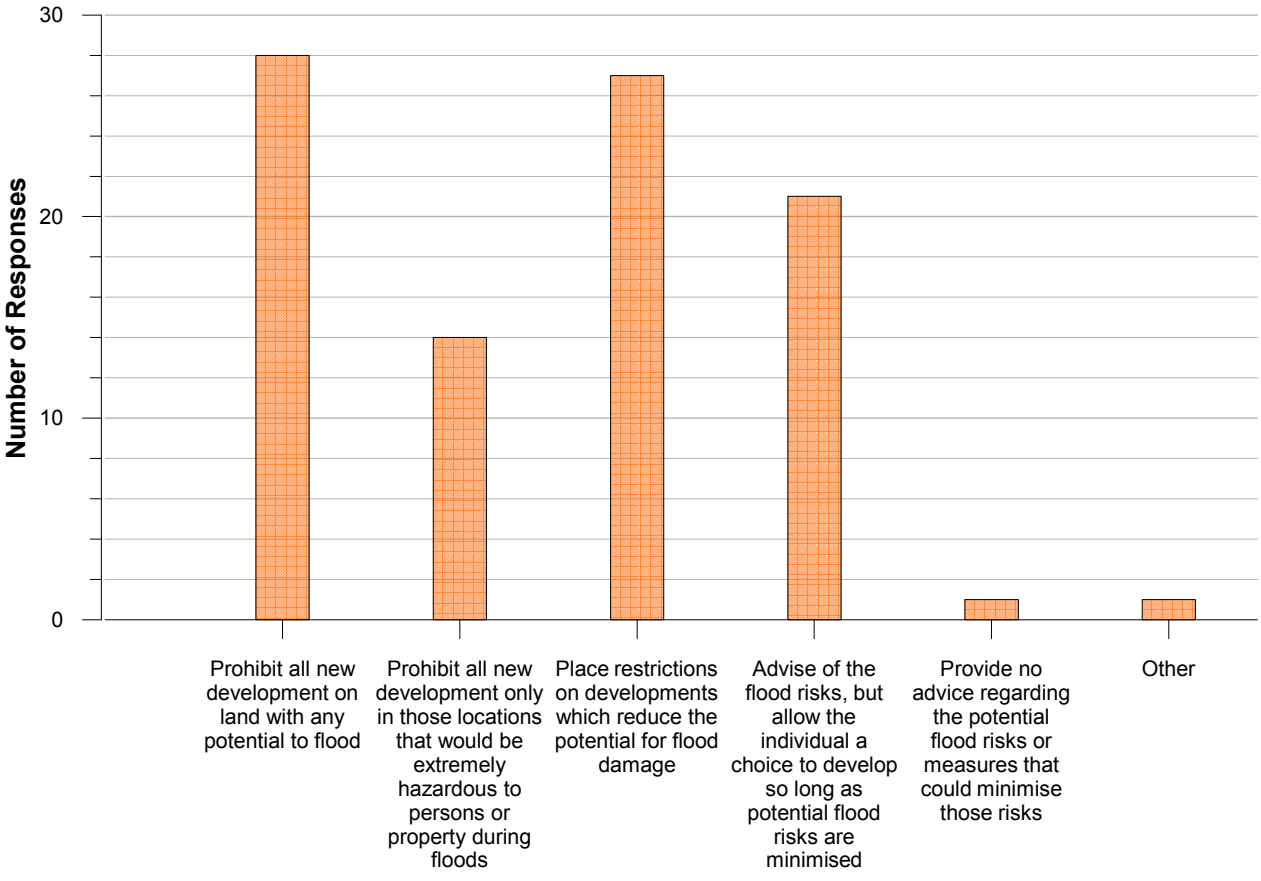
LEGEND

- 1 (Highest Priority)
- 2
- 3
- 4 (Lowest Priority)

Q6. What notifications should Council give about the potential flood affectation of properties?

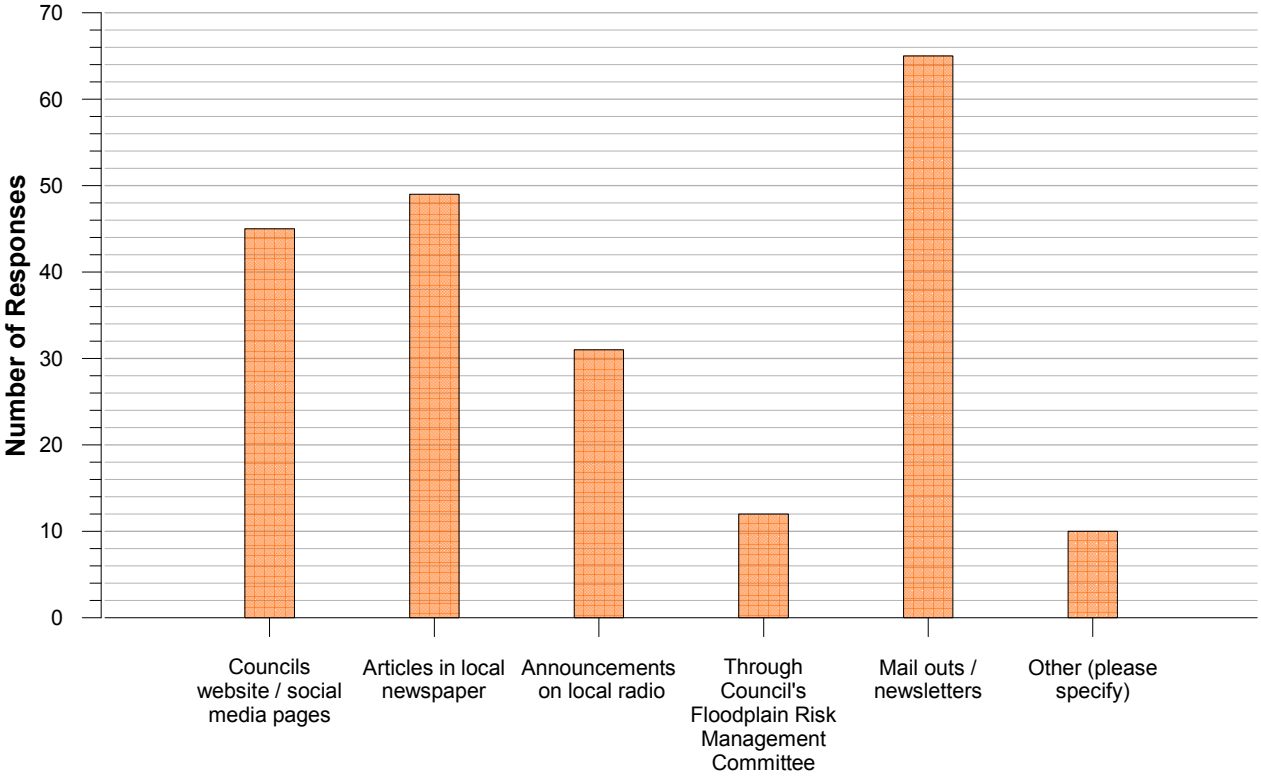


Q7. What level of control should Council place on new development to minimise flood-related risks?



Q8. Possible Floodplain Management Measures

Q9. Best methods to get input and feedback from the local community



APPENDIX B

PHOTOGRAPHS SHOWING HISTORIC FLOODING AT YASS

YASS – July 1900

(Source: Yass Tribune, https://www.yasstribune.com.au/story/5879732/a-flood-of-rainy-memories/ , 2019)

Plate B1.1 – *"The major flood in 1900 saw people having to be rescued from their homes at night. Photo: Yass & District Historical Society Collection."*

YASS – May 1925

(Source: Yass Tribune, https://www.yasstribune.com.au/story/5879732/a-flood-of-rainy-memories/ , 2019)

Plate B2.1 – *"The flood of 1925, with people sheltering on the Courthouse steps. Photo: Yass & District Historical Society Collection."*

Plate B2.2 – *"The main thoroughfare underwater in 1925. Photo: Yass & District Historical Society Collection."*

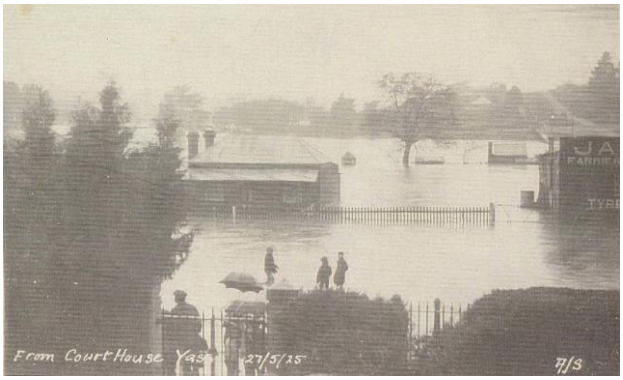


Plate B2.3 – "*The view from the Courthouse in 1925. Photo: Yass & District Historical Society Collection."*

YASS – October 1959

(Source: Yass Tribune, https://www.yasstribune.com.au/story/5879732/a-flood-of-rainy-memories/ , 2019)

Plate B4.1 – *"Travelling by boat on the corner of Rossi and Comur Street, 1959. Photo: Yass & District Historical Society Collection."*

Plate B4.1 – *"Only the top of this cobblestone cottage was visible during the flood of 1959. Photo: Yass & District Historical Society Collection."*

YASS – October 1959

(Source: Yass Tribune, https://www.yasstribune.com.au/story/2800345/have-a-say-on-flood-studies/, 2015)

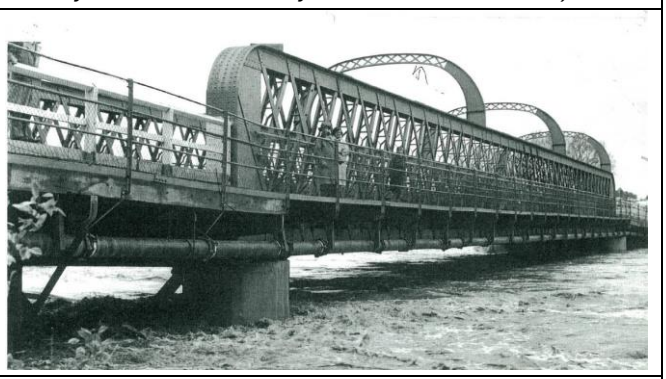


Plate B5.1 – *"The 1959 flood devastated Yass' main street. Locals now have the chance to help with studies on this and other floods that have occurred in the region."*

YASS – 9 August 2020

(Source: NSW SES – Yass Unit, 2020)

Plate B6.1 – Walmsley Crossing 9:15am

Plate B6.2 – In vicinity of 680 Yass River Road

Plate B6.3 – Buckmaster's Bridge 10:28am

Plate BC6.4 – Manton's Creek

Plate B6.5 – "*3:11pm road under bridge at riverbank park started flooding"*

Plate B6.6 – Buckmaster's Bridge 4:00pm

APPENDIX C

FLOOD STUDY UPDATE

TABLE OF CONTENTS

ATTACHMENTS

FIGURES
(BOUND IN VOLUME 2)

C1. HYDROLOGIC MODEL DEVELOPMENT AND CALIBRATION

C1.1. Updates to Yass River Hydrologic Model

A hydrologic model of the Yass River (**Yass River Hydrologic Model**) was developed as part of Lyall & Associates, 2019, the sub-catchment layout of which is shown on **Figure C1.1**. The RAFTS sub-model within the DRAINS software was used to convert rainfall to runoff and to route the discharge hydrographs to the location of the Yass stream gauge.

The outlets of each sub-catchment were linked, with the lag time derived by dividing the stream length by an assumed flow velocity of 3.5 m/s.[1] The following PERN values were adopted for the two principal land uses in the catchment:[2]

- wooded slopes = 0.08
- cleared pastoral land = 0.045

Design rainfall data, temporal patterns, aerial reduction factors and Probability Neutral Burst Initial Loss (**PNBIL**) values were input to the Yass River Hydrologic Model based on the procedures set out in ARR 2019. A copy of the data extracted from the ARR Data Hub for Yass is contained in **Attachment C1**.[3]

Continuing loss rates and the storage coefficient (**Bx**) were adjusted until a good match was achieved with the design peak flow estimates that were derived by way of the flood frequency analysis undertaken as part of WMAwater, 2016a for the Yass stream gauge. **Table C1.1** over shows that applying the continuing loss values shown in **Column B** along with a constant Bx of 0.8 to the Yass River Hydrologic Model provided a good fit with the design peak flow estimates derived as part of WMAwater, 2016a (refer **Column D**).

The recalibrated Yass River Hydrologic Model was used to derive the peak flow in the Yass River for the PMF as part of the present study (refer **Section B3.1.3** for details), while the peak flow in the Yass River for design flood events ranging between 50 and 0.5% AEP were taken from WMAwater, 2016a.

C1.2. Updates to Yass Town Hydrologic Model

The hydrologic (DRAINS) model that was developed as part of WMAwater, 2016a was updated using the ensemble approach to design flood estimation that is set out in ARR 2019. The following adjustments were also made to its structure:

[1] Preliminary runs of the TUFLOW model that was developed as part of the present study showed that flow velocities ranged between 2.5-4.5 m/s in the reach of the Yass River between the Yass Dam and the Railway Weir.

[2] A PERN value of 0.06 was applied to those sub-catchments which comprised a mixture of both wooded and cleared pastoral land

[3] The Yass River Hydrologic Model was originally developed using the procedures set out in the 2016 draft edition of Australian Rainfall and Runoff when the advice was to apply pre-burst rainfall loss values for design flood estimation. The model was subsequently updated as part of the present study using the NSW specific guidance on application of losses for design flood estimation.

- rural sub-catchments in the Bango Creek catchment and in the headwaters of the Chinamans Creek catchment were modelled in the DRAINS software using the RAFTS modelling approach, while the urbanised sub-catchments in the study area were modelled using the IL-CL modelling approach.
- additional sub-catchments were added to the model to more accurately define patterns of major overland flow in a number of areas; and
- the outlets of the sub-catchments in the upper reaches of the study catchments were linked and the lag times between each assumed to be equal to the distance along the main drainage path divided by an assumed flow velocity of 2 m/s.

Figure C1.2 (2 sheets) shows the layout of the sub-catchments which comprise the updated hydrologic model (**Yass Town Hydrologic Model**).

TABLE C1.1
COMPARISON OF PEAK FLOW ESTIMATES
YASS STREAM GAUGE

AEP (%) [A]	Adopted Continuing Loss (mm/hr) [B]	Peak Flow (m^3/s)	
		WMAwater, 2016a [C]	Yass River Hydrologic Model [D]
1	2.8	1,570	1,570
2	2.2	1,160	1,174
5	2.8	730	739
10	3.1	490	499
20	3.4	310	317
50	3.4	110	117

C2. HYDRAULIC MODEL DEVELOPMENT AND CALIBRATION

C2.1. Updates to Yass TUFLOW Model

The TUFLOW hydraulic model that was developed as part of WMAwater, 2016a was reviewed and updated in order to refine several aspects of its structure and to improve the accuracy of the flood mapping. The following adjustments were made to its structure as part of the present study:

- The grid spacing was reduced from 5 m to 2 m to more accurately define the key features which influence patterns of major overland flow (e.g. crown in the road, kerb and gutter etc.).
- The model boundary was extended upstream to incorporate details of recent residential subdivisions.
- Revised inflow boundaries which reflected the revised sub-catchment layout that was incorporated in the Yass Town Hydrologic Model (refer **Section B1.2** for details).
- Detailed ground survey data in the vicinity of the intersection of Browne Street and Demestre Street that were captured as part of the present study (refer **Figure C2.1**, sheet 2 for extent of survey).
- Details of 41 culvert and bridge structures that were surveyed as part of the present study (refer **Figure C2.1**, sheets 3 and 4 for location).
- Up-to-date details of the existing stormwater drainage system, whereby pipe invert levels were reviewed and updated to ensure the drainage system was positively graded.
- The downstream boundary of the model was extend about 1 km further downstream on the Yass River.
- Material layers representing the various surface types along the major overland flow paths were revised based on detailed aerial photography. Hydraulic roughness parameters were also updated.

Figure C2.1 (4 sheets) shows the layout of the updated TUFLOW model (**Yass TUFLOW Model**). The Yass TUFLOW Model was run for the full range of events that were assessed as part of WMAwater, 2016a. While the Yass TUFLOW Model provides improved definition of major overland flow at Yass, as shown in **Table C2.1** it generates peak flood levels on the Yass River that are very similar to those derived as part of WMAwater, 2016a.

TABLE C2.1
COMPARISON OF MODELLED PEAK GAUGE HEIGHT
AT YASS RIVER STREAM GAUGE

AEP (%) [A]	Gauge Height[1] (m)		Difference[2] (m) [D]
	WMAwater, 2016a [B]	Yass TUFLOW Model [C]	
1	11.30	11.32	0.02
2	9.98	10.08	0.10
5	8.74	8.84	0.10
10	7.09	7.18	0.09
20	5.86	5.94	0.08
50	4.62	4.67	0.05

1. Gauge zero = RL 475.52 m AHD.
2. A positive difference indicates the Yass TUFLOW Model generates peak flood levels that are higher than those presented in WMAwater, 2016a.

C3. DERIVATION OF DESIGN DISCHARGE HYDROGRAPHS

C3.1. Yass River Hydrology

C3.1.1. Previous Studies

Yass Dam 3.0 m Raising Concept Design Report (NSW Department of Commerce (DoC), 2010)

A calibrated RORB model that was originally developed as part of the *Yass Dam Flood Study* undertaken NSW Public Works in 1994 was used to derived design peak flow estimates at Yass dam. DoC, 2010 found that there was a significant variation in storage routing (Kc) parameters required to calibrate the RORB model.

Column B in **Table C3.1** sets out the design peak flow estimates that were generated by the RORB model using the procedures set out in ARR 1987. A peak flow estimate of 15,500 m^3/s was derived for the PMF based on application of both the Generalised Southeast Australia Method (**GSAM**) and Generalised Short Duration Method (**GSDM**), the procedures for which are set out in BoM, 2006 and BoM, 2003, respectively. The peak flow estimate was derived based on the lowest storage routing (Kc) parameter that formed part of the RORB model calibration process, hence providing a conservative estimate of the PMF at Yass.

TABLE C3.1
COMPARISON OF DESIGN PEAK FLOW ESTIMATES
YASS STREAM GAUGE

AEP (%)	DoC, 2010	WRM, 2015		WMAwater, 2016a	Present Study	
	RORB Model	Flood Frequency Analysis	XP-RAFTS Model	Flood Frequency Analysis	Flood Frequency Analysis	Yass River Hydrologic Model
[A]	[B]	[C]	[D]	[E]	[F]	[G]
20	130	Not Documented	Not Assessed	310	280	317
10	240			490	480	499
5	610			730	725	739
2	1,010			1,160	1,160	1,174
1	1,350	955	1,018	1,570	1,560	1,570
0.5	Not Assessed	Not Documented	Not Assessed	2,060	2,080	1,767
0.2			1,900	Not Assessed	2,950	2,243
PMF	15,500		8,459(1) 13,217(2)	15,500(3)	-	12,100

1. Based on adopted flow velocity of 1.5 m/s.
2. Based on adopted flow velocity of 3.5 m/s.
3. Based on peak PMF flow derived as part of DoC, 2010.

Extreme Flood Discharge Estimate for Yass Dam (WRM Water + Environment, 2015)

A flood frequency analysis was undertaken as part of WRM, 2015 for the Yass stream gauge using 95 years of annual peak flows. **Table C3.1** shows that WRM, 2015 found that the peak flow for the 1% AEP flood event at Yass was 995 m^3/s (Column C), which is about 25% lower than the corresponding peak flow derived as part of DoC, 2010.

A hydrologic (XP-RAFTS) model of the Yass River was developed as part WRM, 2015. The XP-RAFTS model was calibrated to flood events that occurred in August 1974, December 2010 and March 2012. An assumed flow velocity of 1.5 m/s was needed to achieve a good match between the modelled and recorded discharge hydrographs at the Yass stream gauge for the December 2010 and March 2012 flood events (equivalent to a 14 and 25% AEP flood event, respectively), while a flow velocity of 3.5 m/s was required to achieve a good match for the August 1974 flood event which was equivalent to a 4% AEP flood event. Based on the above, a flow velocity of 1.5 m/s was adopted for design flood estimation purposed as part of WRM, 2015.

Design rainfall data were input to the XP-RAFTS model using the procedures set out in ARR 1987, while the Probable Maximum Precipitation (**PMP**) data were input to the XP-RAFTS model for the GSAM (BoM, 2006). **Table C3.1** shows that the peak 1% AEP flow estimate generated by the XP-RAFTS model (Column D) is similar to results of the flood frequency analysis (Column C) and that the peak PMF flow at the Yass stream gauge was 8,459 m^3/s, which is 45% lower than the flow rate that was derived as part of DoC, 2010.

A sensitivity analyses was undertaken as part of WRM, 2015 whereby the XP-RAFTS model was run assuming a flow velocity of 3.5 m/s, which was required to calibrate the model to the 1974 flood event. The peak PMF flow at Yass using the higher flow velocity was 13,217 m^3/s.

Yass Flood Study (WMAwater, 2016a)

A review of the WaterNSW derived rating curve for the Yass stream gauge undertaken as part of WMAwater, 2016a found that the rating curves that were used to derive peak flow estimates prior to 1969 underestimated the flow for gauge heights higher than RL 5.0 m. Based on this finding, the peak flow estimates for the eleven historic floods that reached a gauge height higher than RL 5.0 m between 1915 (i.e. when the gauge was first established) and 1969 were revised using the most recent WaterNSW derived rating curve.

WMAwater, 2016a also found that there were five flood events that occurred between 1835 and 1915 which exceeded RL 6.0 m on the Yass stream gauge, including the 1900 flood which is considered to be the flood of record at Yass.

A log-Pearson Type 3 (**LP3**) distribution was fitted to the annual series of flood peaks for the period between 1915 and 2014 as part of WMAwater, 2016a. The period of record was extended to incorporate the flood of record in 1900. Column E of **Table C3.1** shows that the design peak flow estimates that were derived as part of WMAwater, 2016a, noting that the peak PMF flow of 15,500 m^3/s that was originally derived as part of DoC, 2010 was adopted.

The design discharge hydrographs that were used as input to the hydraulic model that was developed as part of WMAwater, 2016a at the location of the Yass Dam were derived by factoring the ordinates of the discharge hydrograph that was recorded by the Yass stream gauge for the March 1989 flood event so that their peaks matched the design peak flow rates that were derived as part of the flood frequency analysis.

C3.1.2. Review of Flood Frequency Analysis

A flood frequency analysis was undertaken as part of the present study using the annual series of flood peaks for the period between 1915 and 2019, as well as the flood of record in 1900. Column F of **Table C3.1** shows that incorporating the five additional years of data between 2015 and 2019 does not significantly alter the design peak flow estimates that were derived as part of WMAwater, 2016a.

Based on the above, the design discharge hydrographs for 20 to 0.5% AEP flood events that were originally derived as part of WMAwater, 2016a were utilised for the present investigation. The design discharge hydrograph for a flood event with an AEP of 0.2 per cent was derived as part of the present study by factoring the ordinates of the recorded March 1989 discharge hydrograph at the Yass stream gauge so that the peak matched the design peak flow rate that was derived as part of the flood frequency analysis that is presented in Column F of **Table C3.1**.

Figure C3.1 shows the design discharge hydrographs that were used as input to the Yass TUFLOW Model that was developed as part of the present study.

Table C3.1 shows that application of design rainfall data to the Yass River Hydrologic Model for the 0.5% and 0.2% AEP flood events results in design peak flow estimates that are substantially lower than those that were derived from the flood frequency analysis and input to the Yass TUFLOW Model as part of the present investigation. The design peak flows derived from the Yass River Hydrologic Model for the 0.5% and 0.2% are equivalent to an increase in the peak 1% AEP flow of 12% and 42%, respectively which is generally consistent with the percentage increase in rainfall intensity between these and the 1% AEP design storm events.

C3.1.3. Review of PMF Estimate

PMP data were input the Yass River Hydrologic Model based on the GSAM, procedures for which are set out in BoM, 2006. PMP rainfall depths for storm durations between 24 and 96 hours in duration were derived using the GSAM, while PMP rainfall depths for storm durations ranging between 9 and 24 hours were interpolated between the GSAM derived depth for the 24 hour duration storm and the GSDM derived depth for the 6 hour duration storm (refer **Figure C1.1** for extent of GSDM PMP ellipses).

As set out in BoM, 2006, the GSAM temporal patterns were adopted for all storm durations while the GSDM temporal patterns were also adopted for storm durations between 9 and 18 hours.

The peak PMF flow at the Yass stream gauge that was derived as part of the present study is 12,100 m^3/s, which is about 40% higher than the peak flow that was derived as part of WRM, 2015 and about 20% lower than the flow rate that was derived as part of DoC, 2010 and later adopted by WMAwater, 2016a.

The peak PMF flow of 8,459 m^3/s that was derived as part of WRM, 2015 is considered an under-estimate as the XP-RAFTS model was tuned to the results of a flood frequency that underestimated the peak 1% AEP flow by assuming a flow velocity of 1.5 m/s. The peak PMF flow derived as part of WRM, 2015 using a flow velocity of 3.5 m/s was 13,217 m^3/s which is comparable to that derived as part of the present study.

The peak PMF flow of 15,500 m^3/s derived as part of DoC, 2010 and later adopted as part of WMAwater, 2016a is considered an overestimate due to the high variance in storage routing (Kc) parameters that were required to calibrate the RORB model at the time.

Based on the above, a peak PMF flow of 12,100 m^3/s has been adopted as part of the present study for defining the extent of the floodplain at Yass.

C3.2. Local Catchment Hydrology

C3.2.1. Rainfall Intensity

The procedures used to obtain temporally and spatially accurate and consistent Intensity-Frequency-Duration (**IFD**) design rainfall curves for the assessment of local catchment flooding at Yass are presented in ARR 2019. Design storms for frequencies of 20, 10, 5, 2, 1, 0.5 and 0.2% AEP were derived for storm durations ranging between 30 minutes and 36 hours. The IFD dataset was downloaded from BoMs *2016 Rainfall IFD Data System*.

C3.2.2. Areal Reduction Factors

The rainfalls derived using the processes outlined in ARR 2019 are applicable strictly to a point. In the case of a catchment of over tens of square kilometres area, it is not realistic to assume that the same rainfall intensity can be maintained. An Areal Reduction Factor (**ARF**) is typically applied to obtain an intensity that is applicable over the entire catchment.

While ARFs ranging between 0.96 and 1.0 are applicable on the Chinamans Creek catchment and between 0.75 and 1.0 on the Bango Creek catchment, a good match was achieved between the flows derived by the Yass Town Hydrologic Model and those derived by the Regional Flood Frequency Estimation (**RFFE**) Model, the procedures for which are set out in ARR 2019 using a single value of 1.0. As the purpose of the study was to also define the nature of major overland flow which is typically associated with smaller catchments, where point rainfall is more applicable, a global ARF value of 1.0 was adopted for design flood estimation purposes.

C3.2.3. Temporal Patterns

ARR 2019 prescribes the analysis of an ensemble of 10 temporal patterns per storm duration for various zones in Australia. These patterns are used in the conversion of a design rainfall depth with a specific AEP into a design flood of the same frequency. The patterns may be used for AEPs down to 0.2 per cent where the design rainfall data is extrapolated for storm events with an AEP less than 1 per cent.

The temporal pattern ensembles that are applicable to Frequent (more frequent than 14.4% AEP), Intermediate (between 3.2 and 14.4% AEP) and Rare (rarer than 3.2% AEP) storm events were obtained from the ARR Data Hub.[4]. A copy of the data extracted from the ARR Data Hub for the Yass Town Hydrologic Model is contained in **Attachment C2**.

C3.2.4. Probable Maximum Precipitation

Estimates of PMP were made using the GSDM as described in BoM, 2003. This method is appropriate for estimating extreme rainfall depths for catchments up to 1,000 km^2 in area and storm durations up to six hours.

The steps involved in assessing PMP for study catchments are briefly as follows:

- Calculate PMP for a given duration and catchment area using depth-duration-area envelope curves derived from the highest recorded US and Australian rainfalls.

[4] It is noted that the temporal pattern data set for the *Murray Basin* region is suitable for use at Yass.

- Adjust the PMP estimate according to the percentages of the catchment which are meteorologically rough and smooth, and also according to elevation adjustment and moisture adjustment factors.
- Assess the design spatial distribution of rainfall using the distribution for convective storms based on US and world data, but modified in the light of Australian experience.
- Derive storm hyetographs using the temporal distribution contained in BoM, 2003, which is based on pluviographic traces recorded in major Australian storms.

Figures C1.2, sheet 1 shows the location and orientation of the PMP ellipses that were used to derive the rainfall estimates at Yass, noting that two orientations were adopted to more accurately define the upper limit of flooding in both the Chinamans Creek and Bango Creek catchments.

C3.2.5. Design Rainfall Losses

The initial and continuing loss values to be applied in flood hydrograph estimation were derived using the NSW jurisdictional specific procedures set out in the ARR Data Hub. A copy of the raw ARR Data Hub data, which includes the Probability Neutral Burst Initial Loss values that were adopted for design flood estimation purposes is contained in **Attachment C2** of this Appendix. The continuing loss values set out in **Table C3.2** were adopted design flood estimation purposes (refer **Section B3.2.6** for further discussion).

C3.2.6. Derivation of Design Discharges

The Yass Town Hydrologic Model was run with the design rainfall data set out in **Sections C3.2.1** to **C3.2.5**, as well as the hydrologic parameters set out in **Section C1.2** in order to obtain design discharge hydrographs for input to the Yass TUFLOW Model.

Table C3.2 shows a comparison of design peak flow estimates derived from the Yass Town Hydrologic Model compared to those derived by the RFFE Model, while **Figure C1.2**, sheet 2 shows the location at which the comparisons were made. The peak flow comparison was undertaken for catchments that fit the following criteria:

- The total catchment area was greater than 0.5 km^2 and less than 1,000 km^2.
- The shape factor[5] and catchment area is comparable to those of the '*Nearby Catchments*' that are relied upon as part of the RFFE Model.[6]

Table C3.2 shows the Yass Town Hydrologic Model generally provides a good match to the RFFE Model for flood events with an AEP of less than 5 per cent, but provide a minor overestimate for more frequent flood events.

The storm duration of 30 minutes was generally found to be critical for maximising peak flows for individual sub-catchments where the catchment area is less than 30 ha, with the critical storm duration generally increasing with an increase in catchment area. Peak PMF flow rates for individual sub-catchments computed by the hydrologic model for the critical 15 minute PMP storm duration were generally between 11 and 13 times greater than the corresponding 1% AEP flow rates, with an upper and lower limit of 16.1 and 8.6, respectively. These values lie within the range of expected multiples for a small urban catchment.

[5] Defined as the shortest distance between catchment outlet and centroid divided by the square root of catchment area ARR 2019.

[6] *Nearby Catchments* are the 15 gauged catchments that are in close proximity to the study area and have been relied upon by the RFFE Model to estimate design peak flows at a given location.

TABLE C3.2
COMPARISON OF DESIGN PEAK FLOW ESTIMATES
YASS LOCAL CATCHMENTS

Identifier[(1)]	AEP (%)	RFFE Derived Peak Flow (m^3/s)	Model Derived Peak Flow (m^3/s)	Continuing Loss (mm/hr)	Discussion
RFFE_01 (Catchment Area = 25.8 km^2)	1	137	125	1.8	Achieves a good match between hydrologic and RFFE model derived design peak flows.
	2	106	106	1.8	
	5	71.8	71.6	3.1	
	10	51.2	50	4.4	
	20	34.3	35.7	4.4	
RFFE_02 (Catchment Area = 10.7 km^2)	1	68.1	68.6	1.8	Achieves a good match between hydrologic and RFFE model derived design peak flows.
	2	52.4	55.6	1.8	
	5	35.6	42.7	3.1	
	10	25.4	30.8	4.4	
	20	17.1	21.8	4.4	

1. Refer **Figure C1.2**, sheet 2 for location of peak flow comparison at Yass.

C4. HYDRAULIC MODELLING OF DESIGN STORMS

C4.1. Accuracy of Hydraulic Modelling

The accuracy of results depends on the precision of the numerical finite difference procedure used to solve the partial differential equations of flow, which is also influenced by the time step used for routing the floodwave through the system and the grid spacing adopted for describing the natural surface levels in the floodplain. The results are also heavily dependent on the size of the two-dimensional grid, as well as the accuracy of the LiDAR survey data, which have a design vertical accuracy of +/- 150 mm.

Given the uncertainties in the LiDAR survey data and the definition of features affecting the passage of flow, maintenance of a depth of flow of at least 100 mm is required for the definition of a "continuous" flow path in the areas subject to shallow overland flow. Lesser modelled depths of inundation may be influenced by the above factors and therefore may be spurious, especially where that inundation occurs at isolated locations and is not part of a continuous flow path. In areas where the depth of inundation is greater than the 100 mm threshold and the flow path is continuous, the likely accuracy of the hydraulic modelling in deriving peak flood levels is considered to be between 100 and 150 mm.

Use of the TUFLOW Model results when applying flood related controls to development proposals should be undertaken with the above limitations in mind. Proposals should be assessed with the benefit of a site survey to be supplied by applicants in order to allow any inconsistencies in results to be identified and given consideration. This comment is especially appropriate in the areas subject to shallow flow, where the errors in the LiDAR survey data or obstructions to flow would have a proportionally greater influence on the computed water surface levels than in the deeper flooded main stream areas.

Minimum floor levels for residential, commercial and industrial developments should be based on the 1% AEP flood level plus appropriate freeboard (i.e. the *FPL*), to cater for uncertainties such as wave action, effects of flood debris conveyed in the flow stream and precision of modelling. Note that a freeboard of 500 mm has been adopted for defining the *FPLs*.

The sensitivity studies and discussion presented in **Section B4.4** provide guidance on the suitability of the recommended allowance for freeboard under present day climatic conditions.

C4.2. Presentation of Results

Figures 2.2 and **2.3** of the Main Report show the nature of flooding at Yass for the 1% AEP and PMF events, respectively, while **Figures C4.1** to **C4.6** show similar information for the 20%, 10%, 5%, 2%, 0.5% and 0.2% AEP flood events. These diagrams show the indicative extent and depth of inundation along the Yass River, Chinamans Creek and Bango Creek, as well as along the major overland flow paths for the range of design flood events.

Figure 2.4 of the Main Report shows water surface profiles along the Yass River, Chinamans Creek and Bango Creek for the full range of design flood events, while **Table 2.1** of the Main Report sets out the design peak flood levels at the Yass stream gauge.

The key features of flooding at Yass are set out in **Section 2.4.3** of the Main Report.

C5. REFERENCES

Austroads, 1994. ***"Waterway Design. A Guide to the Hydraulic Design of Bridges, Culverts and Floodways"***

BoM (Bureau of Meteorology), 2003. ***"The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method"***

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DIPNR (Department of Infrastructure, Planning and Natural Resources), 2005. ***"Floodplain Development Manual – The Management of Flood Liable Land"***

Geoscience Australia, 2019. **"Australian Rainfall and Runoff, A Guide to Flood Estimation"**.

IEAust (The Institution of Engineers Australia), 1987. ***"Australian Rainfall and Runoff – A Guide to Flood Estimation"***, Volumes 1 and 2.

Howells et al, 2004, ***"Defining the Floodway – Can One Size Fit All?"***

Lyall & Associates, 2019. ***"Hydraulic Assessment at Location of Proposed Causeway Crossing of Yass River"***

NSW Public Works, 2016, ***"Dam Safety Emergency Plan for Yass Dam"***

WMAwater (**WMA**), 2016a. ***"Yass Flood Study"***

WRM Water + Environment (**WRM**), 2015. ***"Extreme Flood Discharge Estimate for Yass Dam"***

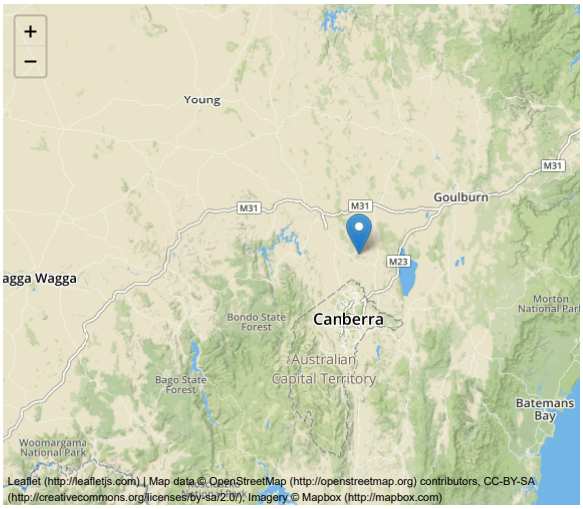
ATTACHMENT C1
DESIGN INPUT DATA FROM ARR DATA HUB
FOR YASS RIVER HYDROLOGIC MODEL

ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	149.154
Latitude	-35.013
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show



Data

River Region

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

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2016_v1

Short Duration ARF

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

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

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

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

ID	16929.0
Storm Initial Losses (mm)	24.0
Storm Continuing Losses (mm/h)	3.8

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/MB.zip)

code	MB
Label	Murray Basin

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_MB.zip)

code	MB
arealabel	Murray Basin

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-35.0125&longitude=149.1543&sdmin=true&s
to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	10 June 2020 05:12PM

Median Preburst Depths and Ratios

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.4 (0.021)	0.2 (0.009)	0.1 (0.004)	0.0 (0.000)	0.0 (0.000)	0.0 (0.001)
90 (1.5)	0.2 (0.009)	0.1 (0.004)	0.1 (0.002)	0.0 (0.001)	0.2 (0.004)	0.3 (0.006)
120 (2.0)	0.3 (0.013)	0.2 (0.007)	0.1 (0.004)	0.1 (0.002)	0.3 (0.006)	0.4 (0.008)
180 (3.0)	0.6 (0.022)	0.9 (0.027)	1.2 (0.029)	1.4 (0.030)	0.7 (0.012)	0.1 (0.002)
360 (6.0)	0.7 (0.020)	1.0 (0.023)	1.2 (0.023)	1.4 (0.023)	0.9 (0.013)	0.6 (0.007)
720 (12.0)	0.1 (0.002)	1.0 (0.018)	1.6 (0.024)	2.2 (0.028)	5.0 (0.053)	7.2 (0.066)
1080 (18.0)	0.0 (0.000)	0.6 (0.009)	0.9 (0.012)	1.3 (0.014)	5.4 (0.049)	8.5 (0.067)
1440 (24.0)	0.0 (0.000)	0.2 (0.003)	0.3 (0.004)	0.5 (0.005)	2.0 (0.017)	3.2 (0.023)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.3 (0.002)	0.6 (0.004)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.000)	0.1 (0.001)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

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

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

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

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

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

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	10.0 (0.559)	9.3 (0.384)	8.8 (0.310)	8.4 (0.256)	9.9 (0.261)	11.1 (0.263)
90 (1.5)	8.9 (0.435)	8.6 (0.312)	8.4 (0.259)	8.2 (0.220)	10.3 (0.236)	11.9 (0.245)
120 (2.0)	9.9 (0.440)	9.8 (0.324)	9.7 (0.273)	9.6 (0.235)	11.5 (0.239)	12.8 (0.240)
180 (3.0)	10.5 (0.408)	12.4 (0.360)	13.6 (0.335)	14.8 (0.316)	12.5 (0.226)	10.8 (0.174)
360 (6.0)	8.5 (0.260)	11.0 (0.253)	12.7 (0.246)	14.2 (0.238)	20.1 (0.279)	24.5 (0.298)
720 (12.0)	5.3 (0.127)	9.7 (0.175)	12.6 (0.191)	15.4 (0.198)	26.6 (0.282)	35.1 (0.322)
1080 (18.0)	3.4 (0.070)	7.4 (0.115)	10.0 (0.130)	12.5 (0.139)	22.5 (0.204)	29.9 (0.236)
1440 (24.0)	0.3 (0.006)	3.6 (0.051)	5.8 (0.068)	7.9 (0.079)	12.9 (0.106)	16.7 (0.120)
2160 (36.0)	0.0 (0.000)	1.5 (0.018)	2.5 (0.025)	3.4 (0.030)	7.3 (0.053)	10.3 (0.066)
2880 (48.0)	0.0 (0.000)	0.7 (0.008)	1.2 (0.011)	1.6 (0.013)	4.5 (0.031)	6.6 (0.040)
4320 (72.0)	0.0 (0.000)	0.1 (0.002)	0.2 (0.002)	0.3 (0.003)	0.3 (0.002)	0.3 (0.002)

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	22.7 (1.262)	20.4 (0.840)	18.8 (0.661)	17.4 (0.532)	22.9 (0.602)	27.1 (0.642)
90 (1.5)	20.6 (1.002)	21.4 (0.775)	21.9 (0.676)	22.4 (0.603)	22.4 (0.514)	22.3 (0.461)
120 (2.0)	21.5 (0.955)	23.4 (0.775)	24.7 (0.695)	25.9 (0.634)	29.5 (0.615)	32.2 (0.600)
180 (3.0)	21.8 (0.847)	24.1 (0.703)	25.7 (0.634)	27.2 (0.581)	25.9 (0.467)	24.9 (0.400)
360 (6.0)	19.1 (0.583)	28.1 (0.646)	34.0 (0.661)	39.7 (0.663)	52.2 (0.725)	61.6 (0.749)
720 (12.0)	22.6 (0.538)	31.9 (0.572)	38.0 (0.573)	43.9 (0.564)	64.7 (0.684)	80.3 (0.737)
1080 (18.0)	14.7 (0.301)	20.3 (0.315)	24.1 (0.314)	27.7 (0.307)	46.9 (0.427)	61.3 (0.484)
1440 (24.0)	10.5 (0.195)	18.4 (0.258)	23.6 (0.278)	28.6 (0.286)	34.8 (0.287)	39.4 (0.283)
2160 (36.0)	4.1 (0.068)	10.0 (0.123)	13.9 (0.144)	17.6 (0.155)	22.7 (0.166)	26.5 (0.169)
2880 (48.0)	1.5 (0.023)	7.5 (0.084)	11.4 (0.109)	15.2 (0.124)	22.5 (0.153)	28.1 (0.167)
4320 (72.0)	1.7 (0.023)	6.4 (0.065)	9.5 (0.082)	12.5 (0.093)	10.5 (0.066)	9.1 (0.050)

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

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

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	17.7	10.7	9.8	9.9	9.3	7.8
90 (1.5)	18.8	11.5	10.5	10.8	10.0	9.0
120 (2.0)	18.3	11.5	10.6	11.1	10.5	7.9
180 (3.0)	17.9	11.8	10.6	11.2	11.0	9.4
360 (6.0)	18.4	12.8	11.7	12.1	10.8	7.3
720 (12.0)	18.6	13.3	13.2	12.9	10.9	6.7
1080 (18.0)	20.4	15.5	15.5	16.0	12.4	6.4
1440 (24.0)	21.8	17.1	16.7	17.8	15.9	7.3
2160 (36.0)	23.7	19.2	19.2	21.8	17.9	12.1
2880 (48.0)	24.4	20.0	20.4	23.0	18.1	12.9
4320 (72.0)	24.6	20.7	21.6	24.2	22.9	17.6

Layer Info

Time Accessed	10 June 2020 05:12PM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Download TXT (downloads/f8850093-8829-4423-afba-d3bb9a310132.txt)

Download JSON (downloads/a3ff81b2-985c-4a53-9752-4f8315b5d2ce.json)

Generating PDF... (downloads/5e2b9791-1310-4130-8d6c-e60d07381e98.pdf)

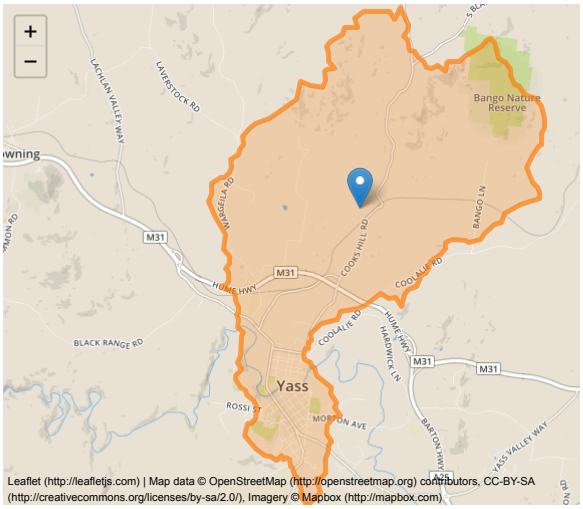
ATTACHMENT C2
DESIGN INPUT DATA FROM ARR DATA HUB
FOR YASS TOWN HYDROLOGIC MODEL

ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	148.939
Latitude	-34.786
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show



Data

River Region

Division	Murray-Darling Basin
River Number	12
River Name	Murrumbidgee River
Shape Intersection (%)	99.9

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2016_v1

Zone	a	b	c	d	e	f	g	h	i	Shape Intersection (%)
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0	100.0

Short Duration ARF

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

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

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

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

Storm Initial Losses (mm)	30.0
Storm Continuing Losses (mm/h)	4.4

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/MB.zip)

code	MB
Label	Murray Basin
Shape Intersection (%)	100.0

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_MB.zip)

code	MB
arealabel	Murray Basin
Shape Intersection (%)	100.0

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.786128399&longitude=148.938718071&sc to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	17 December 2019 04:39PM

Median Preburst Depths and Ratios

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.1 (0.004)	0.0 (0.002)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.5 (0.025)	0.3 (0.010)	0.1 (0.004)	0.0 (0.000)	0.1 (0.001)	0.1 (0.002)
120 (2.0)	0.4 (0.018)	0.2 (0.009)	0.1 (0.005)	0.1 (0.002)	0.2 (0.006)	0.4 (0.008)
180 (3.0)	3.6 (0.151)	2.3 (0.072)	1.4 (0.038)	0.6 (0.014)	0.3 (0.007)	0.1 (0.002)
360 (6.0)	0.5 (0.016)	0.9 (0.022)	1.2 (0.024)	1.4 (0.025)	1.0 (0.014)	0.7 (0.008)
720 (12.0)	0.0 (0.000)	1.2 (0.022)	2.0 (0.031)	2.7 (0.036)	6.3 (0.068)	8.9 (0.085)
1080 (18.0)	0.0 (0.000)	0.6 (0.009)	0.9 (0.012)	1.3 (0.014)	5.8 (0.055)	9.3 (0.076)
1440 (24.0)	0.0 (0.000)	0.3 (0.005)	0.5 (0.006)	0.7 (0.007)	1.8 (0.016)	2.7 (0.020)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.3 (0.002)	0.5 (0.004)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

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

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

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

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

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

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	7.9 (0.486)	6.7 (0.311)	5.9 (0.234)	5.2 (0.178)	6.3 (0.186)	7.2 (0.189)
90 (1.5)	10.5 (0.563)	9.4 (0.377)	8.6 (0.296)	7.9 (0.236)	9.8 (0.248)	11.2 (0.253)
120 (2.0)	13.1 (0.639)	12.3 (0.447)	11.7 (0.363)	11.2 (0.300)	11.9 (0.269)	12.4 (0.250)
180 (3.0)	15.0 (0.634)	13.4 (0.423)	12.4 (0.331)	11.4 (0.263)	10.5 (0.204)	9.9 (0.169)
360 (6.0)	7.9 (0.259)	11.9 (0.290)	14.6 (0.298)	17.2 (0.299)	20.4 (0.296)	22.9 (0.290)
720 (12.0)	2.9 (0.074)	8.8 (0.164)	12.7 (0.197)	16.5 (0.217)	28.1 (0.305)	36.8 (0.349)
1080 (18.0)	1.6 (0.035)	6.1 (0.097)	9.1 (0.121)	11.9 (0.135)	20.9 (0.195)	27.6 (0.225)
1440 (24.0)	1.2 (0.023)	4.6 (0.066)	6.8 (0.082)	9.0 (0.092)	11.4 (0.096)	13.1 (0.098)
2160 (36.0)	0.1 (0.002)	1.8 (0.022)	2.8 (0.030)	3.9 (0.035)	7.1 (0.054)	9.5 (0.064)
2880 (48.0)	0.0 (0.000)	0.2 (0.003)	0.4 (0.004)	0.5 (0.005)	4.4 (0.031)	7.2 (0.046)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.000)

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	19.0 (1.169)	21.5 (0.995)	23.1 (0.914)	24.7 (0.852)	25.1 (0.735)	25.3 (0.665)
90 (1.5)	22.0 (1.184)	21.9 (0.881)	21.8 (0.746)	21.7 (0.646)	22.3 (0.564)	22.8 (0.515)
120 (2.0)	27.9 (1.362)	26.9 (0.983)	26.3 (0.814)	25.7 (0.690)	25.7 (0.583)	25.7 (0.519)
180 (3.0)	33.5 (1.416)	30.0 (0.948)	27.8 (0.741)	25.6 (0.590)	25.0 (0.484)	24.6 (0.421)
360 (6.0)	18.9 (0.618)	27.4 (0.664)	33.0 (0.672)	38.4 (0.669)	50.5 (0.731)	59.6 (0.756)
720 (12.0)	17.5 (0.440)	29.8 (0.554)	38.0 (0.589)	45.9 (0.603)	63.9 (0.694)	77.4 (0.734)
1080 (18.0)	15.2 (0.330)	21.4 (0.343)	25.6 (0.340)	29.5 (0.333)	48.6 (0.454)	63.0 (0.514)
1440 (24.0)	11.7 (0.229)	18.6 (0.269)	23.2 (0.280)	27.6 (0.282)	31.1 (0.264)	33.7 (0.251)
2160 (36.0)	7.8 (0.134)	12.8 (0.163)	16.1 (0.172)	19.3 (0.175)	22.3 (0.170)	24.6 (0.165)
2880 (48.0)	1.4 (0.022)	5.7 (0.067)	8.5 (0.084)	11.2 (0.095)	20.7 (0.147)	27.8 (0.176)
4320 (72.0)	1.0 (0.015)	5.2 (0.056)	8.0 (0.073)	10.7 (0.084)	10.6 (0.070)	10.5 (0.062)

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

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

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	16.3	13.8	11.5	11.0	10.8	9.9
90 (1.5)	18.7	13.4	11.8	11.7	12.0	11.3
120 (2.0)	20.5	12.4	11.2	11.8	11.9	11.5
180 (3.0)	21.3	11.9	11.8	13.2	13.1	12.8
360 (6.0)	23.8	15.8	14.0	14.4	12.6	9.4
720 (12.0)	24.8	17.9	16.0	16.3	13.1	7.1
1080 (18.0)	25.7	19.8	18.9	19.6	15.6	10.3
1440 (24.0)	26.8	21.3	20.7	22.3	19.2	13.2
2160 (36.0)	28.3	23.2	23.6	25.6	23.1	15.1
2880 (48.0)	29.9	25.0	26.2	27.4	24.2	15.8
4320 (72.0)	30.5	25.5	27.0	28.6	25.3	22.1

Download TXT (downloads/817cc517-cba4-45ba-adeb-9e7839f2cd7e.txt)

Download JSON (downloads/4d2b8d03-be0b-47ea-8693-31940d6c9365.json)

Generating PDF... (downloads/aa2bf836-3aee-4fbb-8582-fa8a687366e6.pdf)

Layer Info

Time Accessed	17 December 2019 04:39PM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

ATTACHMENT C3
DESIGN PEAK FLOWS

TABLE C1
DESIGN PEAK FLOWS[1]

Peak Flow Location Identifier[2]	Tributary/Catchment	Location	Design Flood Events																						
			20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Storm Burst[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]	[P]	[Q]	[R]	[S]	[T]	[U]	[V]	[W]	[X]	[Y]	[Z]
Q01	Yass River	Downstream Dam	310	540	1	490	540	1	730	540	1	1160	540	1	1570	540	1	2060	540	1	2898	540	1	12,095	540
Q02		Flat Rock Crossing	310	540	1	490	540	1	730	540	1	1159	540	1	1569	540	1	2059	540	1	2896	540	1		
Q03		Hume Bridge	310	540	1	489	540	1	729	540	1	1158	540	1	1568	540	1	2057	540	1	2953	540	1		
Q04		Disused Railway Line	310	540	1	489	540	1	729	540	1	1158	540	1	1568	540	1	2057	540	1	2953	540	1		
Q05		Upstream Bango Creek	309	540	1	489	540	1	728	540	1	1157	540	1	1566	540	1	2055	540	1	2950	540	1	12,167	540
Q06		Downstream Bango Creek	309	540	1	488	540	1	728	540	1	1157	540	1	1566	540	1	2054	540	1	2948	540	1	12,208	540
Q07	Chinamans Creek	Green Street	1.6	180	3	2.5	60	9	3.5	60	9	4.2	270	1	5.5	270	5	6.2	270	2	7.2	30	6	43.2	30
Q08		Cobham Street	3.2	180	3	5.2	120	2	7.3	120	2	9.7	270	1	11.8	270	5	13.4	270	2	15.9	270	2		
Q09		Shaw Street	3.1	180	3	5.2	120	2	7.3	90	8	9.7	270	1	12.8	270	5	14.5	270	2	17	270	2		
Q10		Petit Street	3.5	180	4	6.5	120	2	9.7	90	8	13.3	270	1	18.4	270	5	21.1	270	2	25.2	270	2		
Q11		Browne Street	5.8	180	3	8.5	120	2	11.2	120	2	14.2	360	2	20.5	270	1	25	270	1	30.4	270	2		
Q12		Upstream Lead Street	6.5	180	3	9.1	120	9	11.7	120	2	14.3	360	2	16.1	270	1	17.6	270	1	19.8	270	1		
Q13		Yass Soldier Club	9.1	180	3	12.2	120	2	15.1	120	3	19.4	360	2	22.4	90	1	24.9	270	1	Subject to backwater flooding from the Yass River				
Q14		Rossi Street	5	180	3	14.2	120	2	Subject to backwater flooding from the Yass River																
Q15	Major Overland Flow	Grand Junction Road	1.7	180	3	3.2	60	9	4.5	120	2	5.6	60	6	6.6	30	6	8.1	30	6	10.1	30	6	54.9	30
Q16		Browne Street	1.3	90	5	2	120	2	2.7	120	2	3.4	60	6	4.2	30	6	4.9	30	6	5.9	30	6		
Q17		Church Street	1.2	30	4	2.1	30	2	3.1	30	5	4.3	270	1	5.5	270	2	6.5	30	3	8.3	30	6		
Q18		Walker Park	1	90	8	2	120	2	2.6	120	7	3.6	30	6	4.8	30	6	5.7	30	6	7.2	30	8	52.5	15
Q19		Yass Golf Course	0.5	90	7	0.9	120	7	1.2	30	6	1.5	30	6	1.9	30	6	2.1	30	6	2.5	30	6	13.6	15

Refer over for footnotes of Table.

TABLE C1 (Cont'd)
DESIGN PEAK FLOWS(1)

Peak Flow Location Identifier(2)	Tributary/Catchment	Location	Design Flood Events																						
			20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]	[P]	[Q]	[R]	[S]	[T]	[U]	[V]	[W]	[X]	[Y]	[Z]
Q20	Major Overland Flow	Yass Golf Course	1	90	7	1.7	60	9	2.3	60	6	2.8	30	6	3.5	30	6	4.2	30	6	5.1	30	6	13.6	15
Q21		Mont Street	3.6	90	7	6.6	120	2	8.7	120	7	10.5	30	6	13.4	30	6	15.8	30	6	19.5	30	6		
Q22		MOF	4.2	180	3	7.3	120	2	10.1	120	7	11.6	120	5	15.3	30	6	18.3	30	6	22.6	30	6		
Q23		DS Railway	1.3	180	3	4.4	120	2	7.3	120	2	8.9	270	5	12.2	30	6	15.2	30	6	19.6	30	6		
Q24		Comur Street	Not subject to flooding			0.1	30	7	0.4	30	7	0.7	270	1	3.7	270	1	6.5	270	1	11	270	5		
Q25		Comur Street	0	180	3	0.1	120	2	0.3	120	2	0.6	270	1	2.2	270	1	4.2	270	1	7.5	270	1		
Q26		Comur Street	0.1	30	2	1.1	120	2	2.5	120	2	4.4	270	5	6.6	270	5	Subject to backwater flooding from the Yass River							
Q27		Meehan Street	0.1	180	3	1.2	120	2	2.4	120	2	3.5	270	5	4.6	270	5	5.4	270	2	Subject to backwater flooding from the Yass River				
Q28		DS Railway	0.6	90	7	1	30	4	1.4	30	7	1.6	30	8	1.9	30	8	2.1	30	8	2.6	30	8		
Q29		DS Railway	0	90	7	0	60	1	0	30	5	0	30	6	0	30	6	0	30	6	Subject to backwater flooding from the Yass River				
Q30		DS Railway	2	30	1	2.9	120	7	3.5	30	7	3.8	30	6	4.1	30	6	4.5	30	8	5	30	8	23.3	30
Q31		Yass Valley Way	1.1	180	3	1.6	60	9	2	60	6	2.4	60	6	2.8	30	6	3.2	30	6	3.7	30	6		
Q32		US Glebe Street	0.5	120	8	0.8	60	7	1	90	8	1.4	60	7	1.7	270	1	2	270	1	2.6	270	5		
Q33		Yass Valley Way	4.6	180	3	7.1	90	8	9.6	90	8	12.2	270	1	Subject to backwater flooding from the Yass River										
Q34	Bango Creek		64.1	180	4	87.5	120	6	124	120	6	175	180	8	215	360	6	256	360	6	309	360	2	2,496	90
Q35			71.3	180	4	96.7	120	6	136	120	6	195	180	8	239	360	6	284	360	6	347	360	2	2,771	120
Q36		Hume Highway	71.8	180	4	97.7	120	6	137	120	6	196	180	8	241	360	6	287	360	6	351	360	2	2,804	120
Q37		Downstream Hume Highway	72.2	180	4	99.3	120	3	138	120	3	199	180	8	245	360	6	292	360	6	361	360	2		
Q38		Main Southern Railway	82.8	180	4	115	120	3	160	120	3	239	180	8	296	360	6	351	360	6	435	360	2	3,345	120
Q39		Yass Valley Way	82.7	180	4	116	120	3	161	120	3	Subject to backwater flooding from the Yass River													

Refer over for footnotes of Table.

TABLE C1 (Cont'd)
DESIGN PEAK FLOWS(1)

Peak Flow Location Identifier(2)	Tributary/Catchment	Location	Design Flood Events																						
			20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)	Critical Storm Burst(4)	Peak Flow (m^3/s)	Critical Storm Duration(3) (minutes)
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]	[P]	[Q]	[R]	[S]	[T]	[U]	[V]	[W]	[X]	[Y]	[Z]
Q40	Fairy Hole Creek		9.6	180	3	13.5	120	6	19.1	120	6	26.2	180	8	32.2	360	2	36.6	360	2	44.6	270	1	358	60
Q41			17.1	180	3	23.9	120	6	33.5	120	6	46.2	360	6	55.8	360	2	63	270	1	81.3	270	1	630	45
Q42		Fairy Hole Road	19.1	180	3	26.6	120	6	37.2	120	6	52.4	360	6	61.7	360	2	70.1	270	1	89.7	270	1		
Q43		Hume Highway	21.1	180	3	29.5	120	6	40.7	120	6	52.3	360	2	55.2	360	2	61.4	360	2	77.8	360	2		
Q44	Major Overland Flow	Hume Highway	4.9	180	3	7	120	6	9.8	120	6	13.1	360	6	15.8	360	2	18.4	270	1	23.9	270	1	178	45
Q45		Fairy Hole Road	2.6	180	3	4.4	60	9	6	60	9	7.3	270	1	8.2	270	5	12.2	270	1	15.5	270	1		
Q46		Yass River Stream Gauge	310	540	1	490	540	1	730	540	1	1159	540	1	1569	540	1	2059	540	1	2896	540	1	12,092	**540**

1. Peak flows less than 100m^3/s have been quoted to one decimal place in order to show minor differences.
2. Refer to relevant figures in **Volume 2** for location of Flow Location Identifiers.

APPENDIX D

FLOOD DAMAGES

TABLE OF CONTENTS

Page No.

FIGURES
(BOUND IN VOLUME 2)

D1. INTRODUCTION AND SCOPE

D1.1. Introduction

Damages from flooding belong to two categories:

- **Tangible Damages**
- **Intangible Damages**

Tangible damages are defined as those to which monetary values may be assigned, and may be subdivided into direct and indirect damages. Direct damages are those caused by physical contact of floodwater with damageable property. They include damages to commercial and industrial and residential building structures and contents, as well as damages to infrastructure services such as electricity and water supply. Indirect damages result from the interruption of community activities, including traffic flows, trade, industrial production, costs to relief agencies, evacuation of people and contents and clean up after the flood.

Generally, tangible damages are estimated in dollar values using survey procedures, interpretation of data from actual floods and research of government files.

The various factors included in the **intangible damage** category may be significant. However, these effects are difficult to quantify due to lack of data and the absence of an accepted method. Such factors may include:

- inconvenience
- isolation
- disruption of family and social activities
- anxiety, pain and suffering, trauma
- physical ill-health
- psychological ill-health.

D1.2. Scope of Investigation

In the following sections, tangible damages to residential, commercial / industrial and public properties have been estimated resulting from flooding in Yass. Intangible damages have not been quantified. The threshold floods at which damages may commence to infrastructure and community assets have also been estimated, mainly from site inspection and interpretation of flood level data. However, there is no data available to allow a quantitative assessment of damages to be made to this category.

D1.3. Terminology

Definitions of the terms used in this Appendix are presented in **Chapter D8** which also summarises the value of Tangible Flood Damages.

D2. DESCRIPTION OF APPROACH

The damage caused by a flood to a particular property is a function of the depth of inundation above floor level and the value of the property and its contents. The warning time available for residents to take action to lift property above floor level also influences damages actually experienced. A spreadsheet model which has been developed by DPIE for estimating residential damages and an in-house spreadsheet model which has been developed for previous investigations of this nature for estimating commercial, industrial and public building damages were used to estimate damages on a property by property basis according to the type of development, the location of the property and the depth of inundation.

Using the results of the updated flood modelling, a peak flood elevation for each event was interpolated at each property. The interpolated property flood levels were input to the spreadsheet models which also contained property characteristics and depth-damage relationships. The depth of above-floor inundation was computed as the difference between the interpolated flood level and the floor elevation at each property. The elevations of 2,068 building floors levels were based on information contained in the property database that was developed as part of WMAwater, 2016a, with adjustments made where necessary by adding the height of floor above a representative natural surface within the allotment (as estimated by visual inspection) to the natural surface elevation determined from LiDAR survey. The type of structure were also based on the WMAwater, 2016a for residential properties, while modifications were to the non-residential property database. The various factors relating to potential property damage were also updated as part of the present study.

The depth-damage curves for residential damages were determined using procedures described in *Guideline No. 4*. Damage curves for other categories of development (commercial and industrial, public buildings) were derived from previous floodplain management investigations.

Damages to the non-residential sector depend on the nature of the enterprise, the depth of inundation over the floor area and the time available for owners to take action to mitigate losses to contents. A spreadsheet model was used which was similar to the residential model in terms of estimation of depths of inundation, but used typical unit damage data which had been adopted in similar studies in NSW in recent years.

It should be understood that this approach is not intended to identify individual properties liable to flood damages and the value of damages in individual properties, even though it appears to be capable of doing so. The reason for this caveat lies in the various assumptions used in the procedure, the main ones being:

- the assumption that computed water levels and topographic data used to define flood extents are exact and without any error;
- the assumption that the water levels as computed by the hydraulic model are not subject to localised influences;
- the estimation of property floor levels by visual inspection rather than by formal field survey;
- the use of "average" stage-damage relationships, rather than a unique relationship for each property;
- the uncertainties associated with assessing appropriate factors to convert *potential damages* to *actual flood damages* experienced for each property after residents have taken action to mitigate damages to contents.

The consequence of these assumptions is that some individual properties may be inappropriately classified as flood liable, while others may be excluded. Nevertheless, when applied over a broad area these effects would tend to cancel, and the resulting estimates of overall damages, would be expected to be reasonably accurate.

For the above reasons, the information contained in the spreadsheets used to prepare the estimates of flood damages for the catchments should not be used to provide information on the depths of above-floor inundation of individual properties.

D3. SOURCES OF DATA

D3.1. General

To estimate A*verage Annual Flood Damages* for a specific area it is necessary to estimate the damages for several floods of different magnitudes, i.e. of different frequencies, and then to integrate the area beneath the damage – frequency curve computed over the whole range of frequencies up to the PMF. To do this it is necessary to have data on the damages sustained by all types of property over the likely range of inundation. There are several ways of doing this:

- The ideal way would be to conduct specific damage surveys in the aftermath of a range of floods, preferably immediately after each. An example approaching this ideal is the case of Nyngan where surveys were conducted in May 1990 following the disastrous flood of a month earlier (DWR, 1990). This approach would not be practicable at Yass given the limited data that are available on historic flood damages.
- The second best way is for experienced loss adjusters to conduct a survey to estimate likely losses that would arise due to various depths of inundation. This approach is used from time to time, but it can add significantly to the cost of a floodplain management study (LMJ, 1985). It was not used for the present investigation.
- The third way is to use generalised data such as that published by CRES (Centre for Resource & Economic Studies, Canberra) and used in the Floodplain Management Study for Forbes (SKM, 1994). These kinds of data are considered to be suitable for generalised studies, such as broad regional studies. They are not considered to be suitable for use in specific areas, unless none of the other approaches can be satisfactorily applied.
- The fourth way is to adapt or transpose data from other flood liable areas. This was the approach used for the present study. As mentioned, the *Guideline No 4* procedure was adopted for the assessment of residential damages. The approach was based on data collected following major flooding in Katherine in 1998, with adjustments to account for changes in values due to inflation, and after taking into account the nature of development and flooding patterns in the study area. The data collected during site inspection in the flood liable areas assisted in providing the necessary adjustments. Commercial and industrial damages were assessed via reference to recent floodplain management investigations of a similar nature to the present study.

D3.2. Property Data

The properties were divided into three categories: residential, commercial / industrial, and public buildings.

For residential properties, the data used in the damages estimation included:

- the location/address of each property
- an assessment of the type of structure
- natural surface level
- floor level

For commercial / industrial and public properties, the required data included:

- the location of each property
- the nature of each enterprise
- an estimation of the floor area
- natural surface level
- floor level

The property descriptions were used to classify the commercial and public developments into categories (i.e. high, medium or low value properties) which relate to the magnitude of likely flood damages.

The total number of residential properties, commercial / industrial and public buildings is shown in **Table D3.1**.

TABLE D3.1
NUMBER OF PROPERTIES INCLUDED IN DAMAGES DATABASE

Development Type	Number of Properties
Residential(1)	1,831
Commercial / Industrial	194
Public	43
Total	**2,068**

1. Includes individual residential units

D3.3. Flood Levels Used in the Analysis

Damages were computed for the design flood levels determined from the hydraulic model that was developed as part of the present investigation. The design levels assume that the drainage system is operating at optimum capacity. They do not allow for any increase in levels resulting from wave action, debris build-ups in the channels which may cause a partial blockage of bridges and which may result in conversions of flow from the supercritical to the subcritical flow regime, as well as other local hydraulic effects. These factors are usually taken into account by adding a factor of safety (freeboard) to the “nominal” flood level when assessing the “level of protection” against flooding of a particular property. Freeboard could also include an allowance for the future effects of climate change.

D4. RESIDENTIAL DAMAGES

D4.1. Damage Functions

The procedures identified in *Guideline No 4* allow for the preparation of a depth versus damage relationship which incorporates structural damage to the building, damage to internals and contents, external damages and clean-up costs. In addition, there is the facility for including allowance for accommodation costs and loss of rent. Separate curves are computed for three residential categories:

- Single storey slab on ground construction
- Single storey elevated floor
- Two storey residence

The level of flood awareness and available warning time are taken into account by factors which are used to reduce "potential" damages to contents to "actual" damages. "Potential" damages represent losses likely to be experienced if no action were taken by residents to mitigate impacts. A reduction in the potential damages to "actual" damages is usually made to allow for property evacuation and raising valuables above floor level, which would reduce the damages actually experienced. The ability of residents to take action to reduce flood losses is mainly limited to reductions in damages to contents, as damages to the structure and clean-up costs are not usually capable of significant mitigation.

The reduction in damages to contents is site specific, being dependent on a number of factors related to the time of rise of floodwaters, the recent flood history and flood awareness of residents and emergency planning by the various Government Agencies (BoM and NSW SES).

Flooding in Yass is "flash flooding" in nature, with surcharge of the Yass River occurring within five hours after water levels commence to rise. Consequently, there would be very limited time in advance of a flood event in which to warn residents and business owners, and for them to take action to mitigate flood losses.

Provided adequate warning were available, house contents may be raised above floor level to about 0.9 m, which corresponds with the height of a typical table/bench height. The spreadsheet provides two factors for assessing damages to contents, one for above and one for below the typical bench height. The reduction in damages is also dependent on the likely duration of inundation of contents, which would be limited to no more than an hour for most flooded properties.

Table D4.1 over shows total flood damages estimated for the three classes of residential property using the procedures identified in *Guideline No. 4*, for typical depths of above-floor inundation of 0.3 m and 1.0 m (The maximum depth of above-floor inundation in Yass is about 3.9 m at the 1% AEP level of flooding). A typical ground floor area of 240 m^2 was adopted for the assessment. The values in **Table D4.1** allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

D4.2. Total Residential Damages

Table D4.2 over summarises residential damages for the range of floods in Yass. The damage estimates were carried out for floods between the 20% AEP and the PMF, which were modelled hydraulically as part of the present study.

TABLE D4.1
DAMAGES TO RESIDENTIAL PROPERTIES

Type of Residential Construction	0.3 m Depth of Inundation Above Floor Level	1.0 m Depth of Inundation Above Floor Level
Single Storey Slab on Ground	$74,801	$102,386
Single Storey High Set	$68,074	$92,761
Double Storey	$47,652	$64,933

Note: These values allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

TABLE D4.2
RESIDENTIAL FLOOD DAMAGES IN YASS

Design Flood Event (% AEP)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	
20%	8	0	0.13
10%	18	1	0.31
5%	29	3	0.64
2%	48	12	1.76
1%	63	23	3.14
0.5%	84	32	4.62
0.2%	103	44	6.40
PMF	442	276	35.22

The threshold of above-floor flooding for residential type development in Yass is a 10% AEP flood, when a single dwelling which is located on Lead Street would be impacted by major overland flow.

An existing dwelling that is located on Lead Street would be subject to very minor above-floor inundation due to surcharge of the local stormwater drainage system during a 10% AEP storm event, while an additional two dwellings that are located on the southern overbank of the Yass River near the Hume Bridge would be subject to flooding during a 5% AEP flood event, when the depth of above-floor inundation would be a maximum of about 0.7 m.

A total of 23 dwellings would experience above-floor inundation at the 1% AEP level of flooding, increasing to 276 for the PMF event. The maximum depth of above-floor inundation in the worst affected dwelling would increase from about 4 m during a 1% AEP flood event to about 17 m in a PMF.

The total residential damages in Yass would increase from about $3.1 Million at the 1% AEP level of flooding to about $35 Million at the upper limit of flooding.

D5. COMMERCIAL / INDUSTRIAL DAMAGES

D5.1. Direct Commercial / Industrial Damages

The method used to calculate damages requires each property to be categorised in terms of the following:

- damage category
- floor area
- floor elevation

The damage category assigned to each enterprise may vary between "low", "medium" or "high", depending on the nature of the enterprise and the likely effects of flooding. Damages also depend on the floor area.

It has recently been recognised following the 1998 flood in Katherine that previous investigations using stage-damage curves contained in proprietary software tends to seriously underestimate true damage costs. DPIE are currently researching appropriate damage functions which could be adopted in the estimation of commercial and industrial categories as they have already done with residential damages. However, these data were not available for the present study.

On the basis of previous investigations the following typical damage rates are considered appropriate for potential external and internal damages and clean-up costs for both commercial and industrial properties. They are indexed to a depth of inundation of 2 metres. At floor level and 1.2 m inundation, zero and 70% of these values respectively were assumed to occur:

Low value enterprise	$280/m^2	(e.g. Commercial: small shops, cafes, joinery, public halls. Industrial: auto workshop with concrete floor and minimal goods at floor level, Council or Government Depots, storage areas.)
Medium value enterprise	$420/m^2	(e.g. Commercial: food shops, hardware, banks, professional offices, retail enterprises, with furniture/fixtures at floor level which would suffer damage if inundated. Industrial: warehouses, equipment hire.)
High value enterprise	$650/m^2	(e.g. Commercial : electrical shops, clothing stores, bookshops, newsagents, restaurants, schools, showrooms and retailers with goods and furniture, or other high value items at ground or lower floor level. Industrial: service stations, vehicle showrooms, smash repairs.)

The factor for converting potential to actual damages depends on a range of variables such as the available warning time, flood awareness and the depth of inundation. Given sufficient warning time, a well prepared business will be able to temporarily lift property above floor level. However, unless property is actually moved to flood free areas, floods which result in a large depth of inundation, will cause considerable damage to stock and contents.

For the present study, the potential damages described above were converted to actual damages using a multiplier which ranged from between 0.5 and 0.8 depending on the depth of above-floor inundation.

D5.2. Indirect Commercial and Industrial Damages

Indirect commercial and industrial damages comprise costs of removal of goods and storage, loss of trading profit and loss of business confidence.

Disruption to trade takes the following forms:

- The loss through isolation at the time of the flood when water is in the business premises or separating clients and customers. The total loss of trade is influenced by the opportunity for trade to divert to an alternative source. There may be significant local loss but due to the trade transfer this may be considerably reduced at the regional or state level.
- In the case of major flooding, a downturn in business can occur within the flood affected region due to the cancellation of contracts and loss of business confidence. This is in addition to the actual loss of trading caused by closure of the business by flooding.

Loss of trading profit is a difficult value to assess and the magnitude of damages can vary depending on whether the assessment is made at the local, regional or national level. Differences between regional and national economic effects arise because of transfers between the sectors, such as taxes, and subsidies such as flood relief returned to the region.

Some investigations have lumped this loss with indirect damages and have adopted total damage as a percentage of the direct damage. In other cases, loss of profit has been related to the gross margin of the business, i.e. turnover less average wages. The former approach has been adopted in this present study. Indirect damages have been taken as 50% of direct actual damages. A clean-up cost of $\$15/m^2$ of floor area of each flooded property was also included.

D5.3. Total Commercial and Industrial Damages

Table D5.1 over summarises estimated commercial and industrial damages in Yass.

The threshold of above-floor flooding in commercial and industrial type development in Yass is a flood that is slightly more frequent than 20% AEP, with one property located in Cobham Street shown to be impacted by major overland flow.

The floor level of an existing commercial/industrial type building that is located on Cobham Street would be inundated to a depth of about 0.2 m due to surcharge of the local stormwater drainage system during a 20% AEP storm event, while an additional two commercial/ industrial type buildings that are located in MacDonald Street and Warroo Road would be inundated to a similar depth during a 5% AEP storm event.

A total of 34 commercial/industrial type development would experience above-floor inundation at the 1% AEP level of flooding, increasing to 152 for the PMF event. Similar to the finding for residential development, the maximum depth of above-floor inundation in the worst affected property would increase from about 4 m during a 1% AEP flood event to about 17 m in a PMF.

The total commercial/industrial damages in Yass would increase from about $3.4 Million at the 1% AEP level of flooding to about $92 Million at the upper limit of flooding.

TABLE D5.1
COMMERCIAL AND INDUSTRIAL FLOOD DAMAGES IN YASS

Design Flood Event (% AEP)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	
20%	3	1	0.06
10%	9	3	0.23
5%	23	14	0.70
2%	42	18	2.04
1%	56	34	3.39
0.5%	80	60	5.67
0.2%	103	80	10.50
PMF	160	152	91.99

D6. DAMAGES TO PUBLIC BUILDINGS

D6.1. Direct Damages – Public Buildings

Included under this heading are government buildings, churches, swimming pools and parks. Damages were estimated individually on an area basis according to the perceived value of the property. Potential internal damages were indexed to a depth of above-floor inundation of 2 m as shown below. At floor level and 1.2 m depth of inundation, zero and 70% of these values respectively were assumed to occur.

Low value	\$280/m^2	
Medium value	\$420/m^2	(e.g. council buildings, NSW SES HQ, fire station)
High value	\$650/m^2	(e.g. schools)

These values were obtained from the Nyngan Study (DWR, 1990), as well as commercial data presented in the Forbes Water Studies report (WS, 1992) and adjusted for inflation. External and structural damages were taken as 4 and 10% of internal damages respectively.

D6.2. Indirect Damages – Public Buildings

A value of \$15/m^2 was adopted for the clean-up of each property. This value is based on results presented in the Nyngan Study and adjusted for inflation. Total "welfare and disaster" relief costs were assessed as 50% of the actual direct costs.

D6.3. Total Damages – Public Buildings

Table D6.1 over summarises estimated damages to public buildings in Yass.

The threshold of above-floor flooding for public buildings in Yass is equivalent to about a 0.5% AEP flood, with the floor level of the Yass Local Court inundated to a depth of between 0.1-0.3 m by floodwater which originates from the Yass River, while the floor levels of the Hamilton Hume and Yass District Museums are inundated to a similar depth by Major Overland Flow.

The number of public buildings in Yass that are above-floor inundated increases from three at the 0.5% AEP level of flooding to 32 at the upper limit of flooding, when the maximum depth of above-floor inundation in the worst affected property (i.e. the Yass Local Court) would be about 12 m.

TABLE D6.1
PUBLIC FLOOD DAMAGES IN YASS

Design Flood Event (% AEP)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	
20%	1	0	0.02
10%	1	0	0.02
5%	1	0	0.02
2%	1	0	0.02
1%	4	0	0.06
0.5%	8	3	0.21
0.2%	13	7	1.27
PMF	32	32	26.67

D7. DAMAGES TO INFRASTUCTURE AND COMMUNITY ASSETS

No data are available on damages experienced to infrastructure and community assets during historic flood events. However, a qualitative matrix of the effects of flooding on critical assets in Yass is presented in **Table 2.3** of the Main Report.

D8. SUMMARY OF TANGIBLE DAMAGES

D8.1. Tangible Damages

Floods have been computed for a range of flood frequencies from 20% AEP up to the PMF. From **Table D8.1**, the threshold for flood damages is a flood slightly smaller than a 20% AEP flood event. **Figure D8.1** shows the damage-frequency curves and cumulative distribution of above-floor depths of inundation at the 1% AEP flood level for residential, commercial and industrial and public buildings in Yass.

TABLE D8.1
TOTAL FLOOD DAMAGES IN YASS
$ MILLION

Design Flood Event (% AEP)	Residential	Commercial/ Industrial	Public	Total
20%	0.13	0.06	0.02	0.21
10%	0.31	0.23	0.02	0.56
5%	0.64	0.70	0.02	1.36
2%	1.76	2.04	0.02	3.82
1%	3.14	3.39	0.06	6.59
0.5%	4.62	5.67	0.21	10.50
0.2%	6.40	10.50	1.27	18.17
PMF	35.22	91.99	26.67	153.88

D8.2. Definition of Terms

Average Annual Damages (also termed “expected damages”) are determined by integrating the area under the damage-frequency curve. They represent the time stream of annual damages, which would be expected to occur on a year by year basis over a long duration.

Using an appropriate discount rate, average annual damages may be expressed as an equivalent “*Present Worth Value”* of damages and used in the economic analysis of potential flood management measures.

A flood management scheme which has a design 1% AEP level of protection, by definition, will eliminate damages up to this level of flooding. If the scheme has no mitigating effect on larger floods then these damages represent the benefits of the scheme expressed on an average annual basis and converted to the *Present Worth Value* via the discount rate.

Using the procedures outlined in *Guideline No. 4*, as well as current NSW Treasury guidelines, economic analyses were carried out assuming a 50 year economic life for projects and discount rates of 7% pa. (best estimate) and 11% and 4% pa. (sensitivity analyses).

D8.3. Average Annual Damages

The average annual damages for all flood events up to the PMF are shown below in **Table D8.2**. Note that values have been quoted to two decimal places to highlight the relatively small recurring damages.

TABLE D8.2
AVERAGE ANNUAL DAMAGES IN YASS
$ MILLION

Design Flood Event (% AEP)	Residential	Commercial/ Industrial	Public	Total
20%	0.02	0.01	0.00	0.03
10%	0.04	0.02	0.00	0.06
5%	0.06	0.05	0.00	0.11
2%	0.10	0.09	0.01	0.20
1%	0.13	0.11	0.01	0.25
0.5%	0.14	0.14	0.01	0.29
0.2%	0.16	0.16	0.01	0.33
PMF	0.20	0.26	0.04	0.50

D8.4. Present Worth of Damages at Yass

The *Present Worth Value* of damages likely to be experienced for all flood events up to the 1% AEP and PMF, for a 50 year economic life and discount rates of 4, 7 and 11 per cent are shown in **Table D8.3**.

For a discount rate of 7% pa, the *Present Worth Value* of damages for all flood events up to the 1% AEP flood is about $3.5 Million, for a 50 year economic life. Therefore one or more schemes costing up to this amount could be economically justified if they eliminated damages in Yass for all flood events up to this level. While schemes costing more than this value would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility. Flood management measures are considered on a multi-objective basis in **Chapter 3** of the Main Report.

TABLE D8.3
PRESENT WORTH VALUE OF DAMAGES IN YASS
$ MILLION

Discount Rate (%)	All Floods up to 1% AEP	All Floods up to PMF
4	5.4	10.8
7	3.5	6.9
11	2.3	4.5

D9. REFERENCES

DECC (Department of Environment and Climate Change, NSW) (2007) ***"Floodplain Management Guideline No 4. Residential Flood Damages"***.

DWR (Department of Water Resources, NSW) (1990) ***"Nyngan April 1990 Flood Investigation"***.

LMJ (Lyall, Macoun and Joy, Willing and Partners Pty Ltd) (1985) ***"Camden Floodplain Management Study"***.

SKM (Sinclair Knight Merz) (1994) ***"Forbes Floodplain Management Report and Draft Floodplain Management Plan, Volume 1"***.

WS (Water Studies) (1986) ***"The Sydney Floods of August 1986"***, Volume I Residential Flood Damage Survey, Report prepared for CRCE Water Studies Pty Ltd for the NSW PWD.

WS (Water Studies) (1992) ***"Forbes Flood Damage Survey, August 1990 Flood"***.

APPENDIX E

SUGGESTED WORDING FOR INCLUSION IN YASS VALLEY DEVELOPMENT CONTROL PLAN

TABLE OF CONTENTS

FIGURES
(BOUND IN VOLUME 2)

E1.1 Introduction

This section of the Plan sets out specific controls to guide development of flood liable land in the Yass Valley LGA. The approach to managing future development that is subject to flooding supports the findings of a series of location specific floodplain risk management studies and plans that have been prepared as part of the NSW Government's program to mitigate the impact of major floods and reduce the associated hazards in the floodplain.

E1.2 Objectives in Relation to Flood Risk Management

a) To minimise the potential impact of development and other activity upon the aesthetic, recreational and ecological value of the waterway corridors.

b) Increase public awareness of the hazard and extent of land affected by all potential floods, including floods greater than the 1% Annual Exceedance Probability (AEP) flood and to ensure essential services and land uses are planned in recognition of all potential floods.

c) Inform the community of Council's controls and policy for the use and development of flood prone land.

d) Reduce the risk to human life and damage to property caused by flooding through controlling development on land affected by potential floods.

e) Provide detailed controls for the assessment of applications lodged in accordance with the *Environmental Planning and Assessment Act 1979* on land affected by potential floods.

f) Provide different guidelines, for the use and development of land subject to all potential floods in the floodplain, which reflect the probability of the flood occurring and the potential hazard within different areas.

g) Apply a "merit-based approach" to all development decisions which takes account of social, economic and ecological considerations.

h) To control development and other activity within each of the individual floodplains within the LGA having regard to the characteristics and level of information available for each of the floodplains, in particular the availability of floodplain risk management studies and plans prepared in accordance with the *Floodplain Development Manual*, issued by the NSW Government.

i) Deal equitably and consistently with applications for development on land affected by potential floods, in accordance with the principles contained in the *Floodplain Development Manual*.

E1.3 Procedure for Determining What Controls Apply to Proposed Development

The procedure Council will apply for determining the specific controls applying to proposed development in flood liable areas is set out below. Upon enquiry by a prospective applicant, Council will make an initial assessment of the flood affectation and flood levels at the site using the following procedure:

- Assess whether the development is located on flood liable land from the **Flood Planning Map**.
- Determine which set of prescriptive flood related planning controls apply to the development from the **Flood Planning Map** (i.e. Main Stream Flooding or Major Overland Flow).

- Identify the category of the development from **Schedule1: Land Use Categories.**
- Determine the appropriate flood level at the site from the results of the location specific flood or floodplain risk management study.
- Determine which part of the floodplain the development is located in from the **Flood Planning Constraint Category Map**.
- Confirm that the development conforms with the relevant performance criteria, as well as the prescriptive controls set out in either **Schedule 2A** for Main Stream Flooding affected areas and **Schedule 2B** for Major Overland Flow affected areas.

With the benefit of this initial information from Council, the applicant will:

- Prepare the documentation to support the Development Application according to the requirements of **Section E1.9**.

A survey plan showing natural surface levels over the site will be required as part of the Development Application documentation. Provision of this plan by the applicant at the initial enquiry stage will assist Council in providing flood related information.

E1.4 Land Use Categories

The policy recognises seven different types of land use for which a graded set of flood related controls apply. They are included in **Schedule 1: Land Use Categories**.

E1.5 Flood Planning Constraint Categories

For those floodplains where Council has adopted a flood or floodplain risk management study, the identified flood liable land has been divided into the following four *Flood Planning Constraint Categories* (**FPCCs**):

- **Flood Planning Constraint Category 1 (FPCC 1)**, which comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding.
- **Flood Planning Constraint Category 2 (FPCC 2)**, which comprises areas which lie within the extent of the *Flood Planning Area* where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
- **Flood Planning Constraint Category 3 (FPCC 3)**, which comprises areas which lie within the extent of the *Flood Planning Area* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
- **Flood Planning Constraint Category 4 (FPCC 4)**, which comprises the area which lies between the extent of the *Flood Planning Area* and the Probable Maximum Flood (**PMF**). Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to “critical uses and facilities” which are critical for response and recovery.

A *Special Flood Consideration Zone* has also been included which relates to areas where the flood risk is considered to be high enough to require additional controls to be applied to future development which is located on land that lies above the FPL. The extent of the *Special Flood Consideration Zone* is shown on the Flood Planning and Flood Planning Constraint Category Maps. The additional controls in this area relate to the safe and timely evacuation of people who would be occupying the floodplain at the time of a flood event and only apply in areas categorised as FPCC4.

E1.6 Development Controls

The development controls have been graded relative to the severity and frequency of potential floods, having regard to the FPCCs determined by the relevant Floodplain Risk Management Study and Plan or, if no such study or plan exists, Council's interim considerations.

The objectives of the development controls are:

a) To require developments with high sensitivity to flood risk to be designed so that they are subject to minimal risk.

b) To allow development with a lower sensitivity to the flood hazard to be located within the floodplain, provided the risk of harm and damage to property is minimised.

c) To minimise the intensification of the high flood risk areas, and if possible, allow for their conversion to natural waterway corridors.

d) To ensure design and siting controls required to address the flood hazard do not result in unreasonable social, economic or environmental impacts.

e) To minimise the risk to life by ensuring the provision of reliable access from areas affected by flooding.

f) To minimise the damage to property arising from flooding.

g) To ensure the proposed development does not expose existing development to increased risks associated with flooding.

The performance criteria which are to be applied when assessing a proposed development are:

a) The proposed development should not result in any significant increase in risk to human life, or in a significant increase in economic or social costs as a result of flooding.

b) The proposal should only be permitted where effective warning time and reliable access is available to an area free of risk from flooding, consistent with any relevant Flood Plan or flood evacuation strategy.

c) Development should not significantly increase the potential for damage or risk other properties either individually or in combination with the cumulative impact of development that is likely to occur in the same floodplain.

d) Procedures would be in place, if necessary, (such as warning systems, signage or evacuation drills) so that people are aware of the need to evacuate are capable of identifying the appropriate evacuation route.

e) Development should not result in significant impacts upon the amenity of an area by way of unacceptable overshadowing of adjoining properties, privacy impacts (e.g. by unsympathetic house–raising) or by being incompatible with the streetscape or character of the locality.

The prescriptive controls which apply to development that is proposed on land affected by Main Stream Flooding and Major Overland Flow are set out in **Schedules 2A** and **2B**, respectively.

E1.7 Proposals to Modify Flood Planning Constraint Categories

In certain situations it may be feasible to modify existing flood behaviour through engineering works which in turn would enable the extent of the FPCCs to be modified at a particular location. Proposals to modify an FPCC at a particular location would need to be supported by a detailed flooding investigation, further details of which are set out in **Section E1.9** below. Proposals would also need to demonstrate consistency with the flood related objectives and performance criteria of both the *Yass Local Environmental Plan* and the *Yass Valley Development Control Plan*.

E1.8 Special Requirements for Fencing

The objectives are:

a) To ensure that fencing does not result in the undesirable obstruction of the free flow of floodwater.

b) To ensure that fencing does not become unsafe during floods so as to threaten the integrity of structures or the safety of people.

c) Fencing is to be constructed in a manner which does not significantly increase flood damage or risk on surrounding land.

The performance criterion which is to be applied when assessing proposed fencing are:

a) Fencing is to be constructed in a manner that does not affect the flow of floodwater so as to detrimentally increase flood affection on surrounding land.

b) Fencing shall be certified by an engineer specialising in hydraulic engineering, that the proposed fencing is adequately constructed so as to withstand the force of floodwater, or collapse in a controlled manner to prevent the undesirable impediment of floodwater.

The prescriptive controls which apply to any proposed fencing on land designated FPCC 1, FPCC 2 and FPCC 3 are:

a) An applicant will need to demonstrate that the fence (new or replacement fence) would create no impediment to the flow of floodwater. Appropriate fences must satisfy the following:

- an open collapsible hinged fence structure or pool type fence, or louvre fencing;
- must not be constructed of non-permeable materials; or
- must allow floodwaters to equalised on both sides and minimise entrapment of flood debris.

E1.9 Explanatory Notes on Lodging Applications

Follow these major steps to lodge the application:

a) Check the proposal is permissible in the zoning of the land by reference to any applicable environmental planning instruments.

b) Consider any other relevant planning controls of Council (e.g. controls in any other relevant part of the DCP).

c) Check whether your property is located either partially or wholly within the Flood Planning Area or Outer Floodplain, as defined on the **Flood Planning Map**.

d) Determine which set of prescriptive flood related planning controls apply to the development from the **Flood Planning Map**.

e) Determine which Flood Planning Constraint Category (FPCC) applies to the developable portion of your property by reference to the **Flood Planning Constraint Category Map**. Enquire with Council regarding existing flood risk mapping or whether a site–specific assessment may be warranted. A property may be located in more than one FPCC and the assessment must consider the controls that apply in each. The flow diagram below summarises this consideration process.

f) Determine the land use category relevant to the development proposal, by firstly confirming how it is defined by the relevant environmental planning instrument and secondly by ascertaining the land use category from **Schedule 1: Land Use Categories**.

g) Assess and document how the proposal will achieve the performance criteria for proposed development and associated fencing set out in **Sections E1.6** and **E1.8**.

h) Check if the proposal will satisfy the prescriptive controls for different land use categories in different FPCCs, as specified in either **Schedule 2A** or **Schedule 2B**.

i) If the proposal does not comply with the prescriptive controls, determine whether the performance criteria are nonetheless achieved.

j) Illustrations provided in this plan to demonstrate the intent of development controls are diagrammatic only. Proposals must satisfy all relevant controls contained in this plan and associated legislation.

k) The assistance of Council staff or an experienced engineer or planner may be required at various steps in the process to ensure that the flood risk management related requirements of this Plan are fully and satisfactorily addressed.

Note that compliance with all the requirements of this plan does not guarantee that an application will be approved.

Information required with an application to address this plan is as follows:

a) Applications must include information which addresses all relevant controls listed above, and the following matters as applicable.

b) Applications for alterations and additions (see either **Schedule 2A** or **Schedule 2B**) to an existing dwelling on flood liable land shall be accompanied by documentation from a registered surveyor confirming existing floor levels.

c) Development applications affected by this plan shall be accompanied by a survey plan showing:

   i. The position of the existing building/s or proposed building/s;

   ii. The existing ground levels to Australian Height Datum around the perimeter of the building and contours of the site; and

   iii. The existing or proposed floor levels to Australian Height Datum.

d) Applications for earthworks, filling of land and subdivision shall be accompanied by a survey plan (with a contour interval of 0.25 m) showing relative levels to Australian Height Datum.

e) For large scale developments, or developments where an existing catchment based flood study is not available, a flood study using a fully dynamic one or two dimensional computer model may be required. For smaller developments the existing flood study may

be used if available and suitable (e.g. it contains sufficient local detail), or otherwise a flood study prepared in a manner consistent with the latest edition of *Australian Rainfall and Runoff* and the *Floodplain Development Manual*, will be required. From this study, the following information shall be submitted in plan form:

i. water surface contours;

ii. velocity vectors;

iii. velocity and depth product contours;

iv. delineation of flood risk precincts relevant to individual floodplains; and

v. show both existing and proposed flood profiles for the full range of events for total development including all structures and works (such as revegetation/ enhancements).

This information is required for the pre–developed and post–developed scenarios.

f) Where the controls for a particular development proposal require an assessment of structural soundness during potential floods, the following impacts must be addressed:

i. hydrostatic pressure;

ii. hydrodynamic pressure;

iii. impact of debris; and

iv. buoyancy forces.

Foundations need to be included in the structural analysis.

E1.10 Glossary of Terms

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government Floodplain Development Manual, 2005.

TERM	DEFINITION
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, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
Floodplain	Area of land which is subject to inundation by floods up to and including the Probable Maximum Flood (**PMF**) event, that is, flood prone land.
Flood Planning Area	The area of land that is shown to be in the Flood Planning Area on the *Flood Planning Map*.
Flood Planning Map	The *Flood Planning Map* shows the extent of land on which flood related development controls apply in a given area, noting that other areas may exist which are not mapped but where flood related development controls apply.
Flood Planning Constraint Category 1 (FPCC 1)	Comprises areas where factors such as the depth and velocity of flow, time of rise, and evacuation problems mean that the land is unsuitable for most types of development. The majority of new development types are excluded from this zone due to its potential impact on flood behaviour and the hazardous nature of flooding
Flood Planning Constraint Category 2 (FPCC 2)	Comprises areas which lie below the *Flood Planning Level* where the existing flood risk warrants careful consideration and the application of significant flood related controls on future development.
Flood Planning Constraint Category 3 (FPCC 3)	Comprises areas which lie below the *Flood Planning Level* but outside areas designated FPCC1 and FPCC2. Areas designated FPCC3 are more suitable for new development and expansion of existing development provided it is carried out in accordance with the controls set out in this document.
Flood Planning Constraint Category 4 (FPCC 4)	Comprises the area which lies above the *Flood Planning Level* (**FPL**) but within the extent of the PMF. Flood related controls in areas designated FPCC4 are typically limited to flood evacuation and emergency response, although additional controls apply to “critical uses and facilities” which are critical for response and recovery.
Flood Planning Level (FPL)	Flood levels selected for planning purposes, as determined by the relevant adopted floodplain risk management study and plan, or as part of a site specific study In the absence of an adopted floodplain risk management study and plan for a particular location, the FPL is defined as the peak 1% AEP flood level plus the addition of a 0.5 m freeboard.

TERM	DEFINITION
Flood Prone/Flood Liable Land	Land susceptible to flooding by the PMF. Flood Prone land is synonymous with Flood Liable land.
Floodway	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 flow, or a significant increase in flood levels.
Flood Storage Area	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the *Flood Planning Level* 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, 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.
Local Drainage	Land on an overland flow path where the depth of inundation during the 1% AEP storm event is less than 0.1 m.
Main Stream Flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Major Overland Flow	Where the depth of overland flow during the 1% AEP storm event is greater than 0.1 m.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location. 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.

SCHEDULE 1
LAND USE CATEGORIES

Land Use Category	Subdivision	LEP Land Uses
Critical Uses and Facilities	*Community facilities which may provide an important contribution to the notification or evacuation of the community during flood events.*	Health services facility; Electricity generating works; Emergency services facility.
Sensitive Uses and Facilities	*Uses which involve vulnerable members of the community;* *Uses which may cause pollution of a watercourse or town water supply;* *Uses which if affected, would significantly affect the ability of community to return to normal after flood event;*	Bio-solids treatment facility; Cemeteries; Child care centre; Correctional centre; Heavy industrial storage establishment; Heavy industries; Highway service centre; Group home; Passenger transport facilities; Respite day care centre; Schools; Seniors housing; Service Stations; Sewage treatment plant; Veterinary hospital; Waste or resource management facility; Water treatment facility.
Subdivision	*Subdivision of land which involves* *the creation of new allotments, with* *potential for further development;*	Camping grounds; Caravan parks; Eco-tourist facilities; Home business/ child care/occupations; Residential accommodation (excluding Group Home and Seniors housing); Tourist and visitor accommodation.
Residential		
Commercial and Industrial		Amusement centre; Commercial premises (excluding Market); Crematorium; Depots; Entertainment facility; Freight transport facilities; Function centre; General industries; Industrial retail outlet; Industrial training facility; Light industries; Mortuaries; Place of public worship; Public administration building; Recreation facility (indoor & major); Registered club; Research station;

		Restricted premises; Sex services premises; Storage premises; Transport depots; Truck depots; Warehouse or distribution centre; Wholesale suppliers; Vehicle body repair workshops; Vehicle repair stations;
Recreation and Non-Urban		Agriculture (excluding intensive livestock agriculture); Animal boarding and training establishment; Boat sheds; Charter & tourism boating facilities; Car park; Community facility; Extractive industry; Forestry; Jetties; Market; Open cut mining; Recreation area; Recreation facility (outdoor).
Alterations and additions		Residential development: i. An addition or alteration to an existing dwelling of not more than 50m² to the habitable floor area which existed at the date of commencement of this Plan; ii. The construction of an outbuilding with a maximum floor area of 30m² or Rebuilt dwellings which substantially reduce flood risk having regard to property damage and personal safety; or iii. A change of use which does not increase flood risk having regard to property damage and personal safety. iv. Alterations and additions: i. An addition to existing premises of not more than 10% of the floor area which existed at the date of commencement of this DCP; ii. Rebuilding of a development which substantially reduces the extent of flood effects to the existing development; iii. A change of use which does not increase flood risk having regard to property damage and personal safety; or iv. Subdivision which does not involve the creation of new allotments with potential for further development.

SCHEDULE 2A
PRESCRIPTIVE FLOOD RELATED DEVELOPMENT CONTROLS – MAIN STREAM FLOODING AT YASS

Planning considerations	Flood Planning Constraint Category 1 (FPCC 1)							Flood Planning Constraint Category 2 (FPCC 2)							Flood Planning Constraint Category 3 (FPCC 3)							Flood Planning Constraint Category 4 (FPCC 4)						
	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions
Minimum Habitable Floor Level						A1	A2 A5		A3		A2	A6	A1	A2 A5		A3		A2	A6	A1	A2 A5	A4	A3					
Building Components						B2	B2		B3		B2	B2	B2	B2		B3		B2	B2	B2	B2	B4	B3					
Structural Soundness						C3	C2		C4		C2	C2	C3	C2		C4		C2	C2	C3	C2	C5	C4					
Flood Affectation						D1	D1		D1	D1	D1	D1	D1	D2		D1	D1	D1	D1	D1	D2							
Emergency Response						E4	E2 or E3		E2 E4	E4 E5	E3 E4	E3 E4	E4	E2 or E3		E2 E4	E4 E5	E2 E4	E2 E4	E4	E2 or E3	E2 or E3	E2 E4	E4 E5	E2 E4	E2 E4		E2 E4
Management and Design						F2 F3	F2 F3		F2 F3 F4	F1	F2	F2 F3 F4	F2 F3	F2 F3		F2 F3 F4	F1	F2	F2 F3 F4	F2	F2 F3	F2 F3	F2 F3 F4	F1	F2	F2 F3 F4	F2	F2
Stormwater							G2		G1 G2	G1 G2	G1 G2	G1 G2		G2		G1 G2	G1 G2	G1 G2	G1 G2		G2	G1	G1	G1		G1		
Parking and Driveway Access						H2 H4 H6 H7	H6 H7 H8		H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H2 H4 H6 H7	H6 H7 H8		H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H2 H4 H6 H7	H6 H7 H8	H3	H3					

	Not Relevant		Unsuitable Land Use	Control only applies to development that is proposed on land which lies within the extent of the "Special Flood Considerations Zone" as defined on the Flood Planning and Flood Planning Constraint Category Maps

SCHEDULE 2B
PRESCRIPTIVE FLOOD RELATED DEVELOPMENT CONTROLS – MAJOR OVERLAND FLOW AT YASS

Planning considerations	Flood Planning Constraint Category 1 (FPCC 1)							Flood Planning Constraint Category 2 (FPCC 2)							Flood Planning Constraint Category 3 (FPCC 3)							Flood Planning Constraint Category 4 (FPCC 4)						
	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions	Critical Uses and Facilities	Sensitive Uses and Facilities	Subdivision	Residential	Commercial and Industrial	Recreational and Non-Urban	Alterations and Additions
Minimum Habitable Floor Level						A1	A2 A5				A2	A6	A1	A2 A5	A4	A3		A2	A6	A1	A2 A5	A4	A3					
Building Components						B1	B1				B1	B1	B1	B1	B4	B3		B1	B1	B1	B1	B4	B3					
Structural Soundness						C1	C1				C1	C1	C1	C1	C5	C4		C1	C1	C1	C1	C5	C4					
Flood Affectation						D1	D1			D1	D1	D1	D1	D2														
Emergency Response						E1	E1			E5					E2 orE 3	E2 E4	E5					E2 or E3	E2 E4	E4 E5	E2 E4	E2 E4		E2 E4
Management and Design						F2	F2			F1 F3	F2	F2 F4	F2	F2	F2 F3	F2 F3 F4	F1 F3		F4			F2 F3	F2 F3 F4	F1	F2	F2 F3 F4	F2	F2
Stormwater										G1	G1	G1			G1	G1	G1	G1	G1			G1	G1	G1				
Parking and Driveway Access						H2 H4 H6 H7	H6 H7 H8			H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H1 H3 H5 H6 H7	H2 H4 H6 H7	H6 H7 H8			H1 H3 H5 H6	H1 H3 H5 H6	H1 H3 H5 H6	H2 H4 H6	H6 H8	H3	H3					

	Not Relevant		Unsuitable Land Use		Control only applies to development that is proposed on land which lies within the extent of the "Special Flood Considerations Zone" as defined on the Flood Planning and Flood Planning Constraint Category Maps

Prescriptive controls for associated planning considerations under each FPCC

Minimum Habitable Floor Level

A1 Habitable floor levels to be set no lower than the 5% AEP flood level plus freeboard[1] unless justified by site specific assessment.

A2 Habitable floor levels to be set no lower than the 1% AEP flood level plus freeboard[1].

A3 Habitable floor levels to be set no lower than the 1% AEP flood level plus freeboard[1] or the PMF level associated with Major Overland Flow, whichever is the highest.

A4 Habitable floor levels to be set no lower than the PMF envelope level.[2]

A5 Habitable floor levels to be as close to the Minimum Habitable Floor Level as practical and no lower than the existing floor level when undertaking concessional development.

A6 Habitable floor levels to be as close to the 1% AEP flood level plus freeboard[1] as practical, but no lower than the 5% AEP flood level plus freeboard[1]. In situations where the habitable floor level is set below the 1% AEP flood level plus freeboard[1], a mezzanine area equal to 30% of the total habitable floor area is to be provided, the elevation of which is to be set no lower than the 1% AEP flood level plus freeboard[1].

Building Components & Method

B1 All structures to have flood compatible building components below the 1% AEP flood level plus freeboard[1] (refer **Schedules 3A** and **3B**).

B2 All structures to have flood compatible building components below the 1% AEP flood level plus freeboard[1] or the 0.2% AEP flood level, whichever is the highest (refer **Schedules 3A** and **3B**).

B3 All structures to have flood compatible building components below the 1% AEP flood plus freeboard[1] or the PMF level associated with Major Overland Flow, whichever is the highest (refer **Schedules 3A** and **3B**).

B4 All structures to have flood compatible building components below the 1% AEP flood plus freeboard[1] or the PMF envelope level[2], whichever is the highest (refer **Schedules 3A** and **3B**).

Structural Soundness

C1 Engineers report to certify that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard[1].

C2 Engineers report to certify that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard[1] or a 0.2% AEP flood, whichever is the greatest.

C3 Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard[1] or a 0.2% AEP flood, whichever is the greatest, alternatively PMF if required to satisfy emergency response criteria (see below).

C4 Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard[1] or the PMF associated with Major Overland Flow, whichever is the greatest.

C5 Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus freeboard[1] or the PMF envelope[2], whichever is the greatest.

Flood Affectation

D1 Engineers report required to certify that the development will not increase flood affectation elsewhere.

D2 The impact of the development on flooding elsewhere to be considered.

Note: When assessing flood affectation the following must be considered:
1. Loss of storage in the floodplain (Only for development being assessed under Schedule 2A).
2. Changes in flood levels and flow velocities caused by alteration of conveyance of flood waters.
3. Impacts of urbanisation on peak flood flows and volumes.

Emergency Response

E1 Reliable egress for pedestrians and vehicles required during a 1% AEP flood.

E2 Reliable egress for pedestrians and vehicles required during a PMF.

E3 Reliable egress for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF level, or a minimum of 20 m^2 of the dwelling to be above the PMF level.

E4 The development is to be consistent with any relevant flood evacuation strategy or similar plan.

E5 Applicant to demonstrate that there is rising road egress/access from all allotments internal to the subdivision to land which lies above the PMF.

Management and Design

F1 Applicant to demonstrate that potential development as a consequence of a subdivision or development proposal can be undertaken in accord with this Plan.

F2 Flood Safe Plan (home or business or farm houses) to address safety and property damage issues (including goods storage and stock management) considering the full range of flood risk.

F3 Site Emergency Response Flood Plan required considering the full range of flood risk

F4 No external storage of materials below the Minimum Habitable Floor Level which may cause pollution or be potentially hazardous during any flood.

Stormwater

G1 Engineers report required to certify that the development will not affect stormwater drainage.

G2 The impact of the development on local overland flooding to be considered.

Parking and Driveway Access

H1 The minimum surface level of open car parking spaces or carports shall be as high as practical, but no lower than the 5% AEP flood or the level of the crest of the road at the location where the site has access. In the case of garages, minimum surface level shall be as high as practical but no lower than the 5% AEP flood.

H2 The minimum surface level of open car parking spaces, carports or garages shall be as high as practical

H3 Garages capable of accommodating more than three motor vehicles on land zoned for urban purposes, or enclosed car parking, must be protected from inundation by floods up to the 1% AEP flood plus freeboard[1].

H4 The driveway providing access between the road and parking space shall be as high as practical and generally rising in the egress direction.

H5 The level of the driveway providing access between the road and parking space shall be no lower than 0.3 m below the 1% AEP flood or such that the depth of inundation during a 1% AEP flood is not greater than either the depth at the road or the depth at the car parking space. A lesser standard may be accepted for single detached dwelling houses where it can be demonstrated that risk to human life would not be compromised.

H6 Enclosed car parking and car parking areas accommodating more than three vehicles (other than on Rural zoned land), with a floor level below the 5% AEP flood or more than 0.8 m below the 1% AEP flood level, shall have adequate warning systems, signage and exits.

H7 Restraints or vehicle barriers to be provided to prevent floating vehicles leaving the site during a 1% AEP flood.

H8 Driveway and parking space levels to be no lower than the design ground/floor levels. Where this is not practical, a lower level may be considered. In these circumstances, the level is to be as high as practical, and, when undertaking concessional development, no lower than existing levels.

H9 Flood related parking and access requirements to be advised by Council if necessary. Contact Council for advice as early as possible.

1. Unless stated otherwise in an adopted location specific Floodplain Risk Management Study and Plan, freeboard is equal to 0.5 m for development being assessed under Schedule 2A and 0.3 m for development being assessed under Schedule 2B.
2. Note that this is a combination of peak flood levels arising from both Main Stream Flooding and Major Overland Flow.

SCHEDULE 3A
GENERAL BUILDING MATTERS

Electrical and Mechanical Equipment

For dwellings constructed on land to which this policy applies, the electrical and mechanical materials, equipment and installation should 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, shall be located above the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. Means shall be available to easily isolate the dwelling from the main power supply.

Wiring

All wiring, power outlets, switches, etc, should be, to the maximum extent possible, located above the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. All electrical wiring installed below this level should be suitable for continuous underwater immersion and should contain no fibrous components. Earth leakage circuit breakers (core balance relays) must be installed. Only submersible type splices should be used below the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. All conduits located below the relevant designated flood level should be so installed that they will be self-draining if subjected to flooding.

Equipment

All equipment installed below or partially below the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B** should 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 should 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 the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**. When this is not feasible, every precaution should be taken to minimise the damage caused by submersion according to the following guidelines:

i) Fuel

Heating systems using gas or oil as a fuel should have a manually operated valve located in the fuel supply line to enable fuel cut-off.

ii) Installation

The heating equipment and fuel storage tanks should 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 should be vented to the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B**.

iii) Ducting

All ductwork located below the relevant elevation referred to in control B1 or B2 of **Schedules 2A** and **2B** should 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 watertight wall or floor below the relevant flood level, a closure assembly operated from above the relevant elevation set out under B1 or B2 of **Schedules 2A** and **2B** should protect the ductwork.

Sewer

All sewer connections to properties in flood prone areas are to be fitted with reflux valves.

SCHEDULE 3B
FLOOD COMPATIBLE MATERIALS

Building Component	Flood Compatible Material	Building Component	Flood Compatible Material
Flooring and Sub Floor Structure	• Concrete slab-on-ground monolith construction. Note: clay filling is not permitted beneath slab-on-ground construction which could be inundated. • Pier and beam construction or • Suspended reinforced concrete slab	**Doors**	• Solid panel with waterproof adhesives • Flush door with marine ply filled with closed cell foam • Painted material construction • Aluminium or galvanised steel frame
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 chemical 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 • Removable rubber-backed carpet	**Wall and Ceiling Linings**	• Brick, face or glazed • Clay tile glazed in waterproof mortar • Concrete • Concrete block • Steel with waterproof applications • Stone natural solid or veneer, waterproof grout • Glass blocks • Glass • Plastic sheeting or wall with waterproof adhesive
Wall Structure	Solid brickwork, blockwork, reinforced, concrete or mass concrete	**Insulation**	• Foam or closed cell types
Windows	Aluminium frame with stainless steel or brass rollers	**Nails, Bolts, Hinges and Fittings**	• Galvanised • Removable pin hinges