BOMBALA COUNCIL

BOMBALA FLOODPLAIN RISK MANAGEMENT STUDY AND FLOODPLAIN RISK MANAGEMENT PLAN

Issue 2 - Final

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Project: 4093 BOMBALA FLOODPLAIN RISK MANAGEMENT STUDY

REV	DESCRIPTION	AUTHOR	REVIEWER	WORLEY-PARSONS APPROVAL	DATE
0	Draft Report – Issue for Internal Review	GR/ ARM A. Morris	ARM A. Morris		
1	Draft Report – Issue for Client Review	ARM A. Morris	CRT C Thomas		11-2-2013
2	Final Report – Updated to Incorporate Public Exhibition	ARM A. Morris	CRT C Thomas	CRT C Thomas	14-05-2013

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ACKNOWLEDGEMENTS

The following report was prepared by WorleyParsons Services Pty Ltd (*incorporating the former Patterson Britton & Partners*) on behalf of Bombala Council's Floodplain Risk Management Committee.

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It has been prepared by incorporating contributions from individuals from the local community and a range of key stakeholders. Contributions from the NSW Office of Environment & Heritage (*formerly DECCW*) and the Bombala Floodplain Risk Management Committee have been essential to the formation of management strategies for the Study and are greatly appreciated.

FOREWORD

The NSW State Government's Flood-Prone Land Policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Policy and practice are defined in the Government's Floodplain Development Manual (*2005*).

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

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

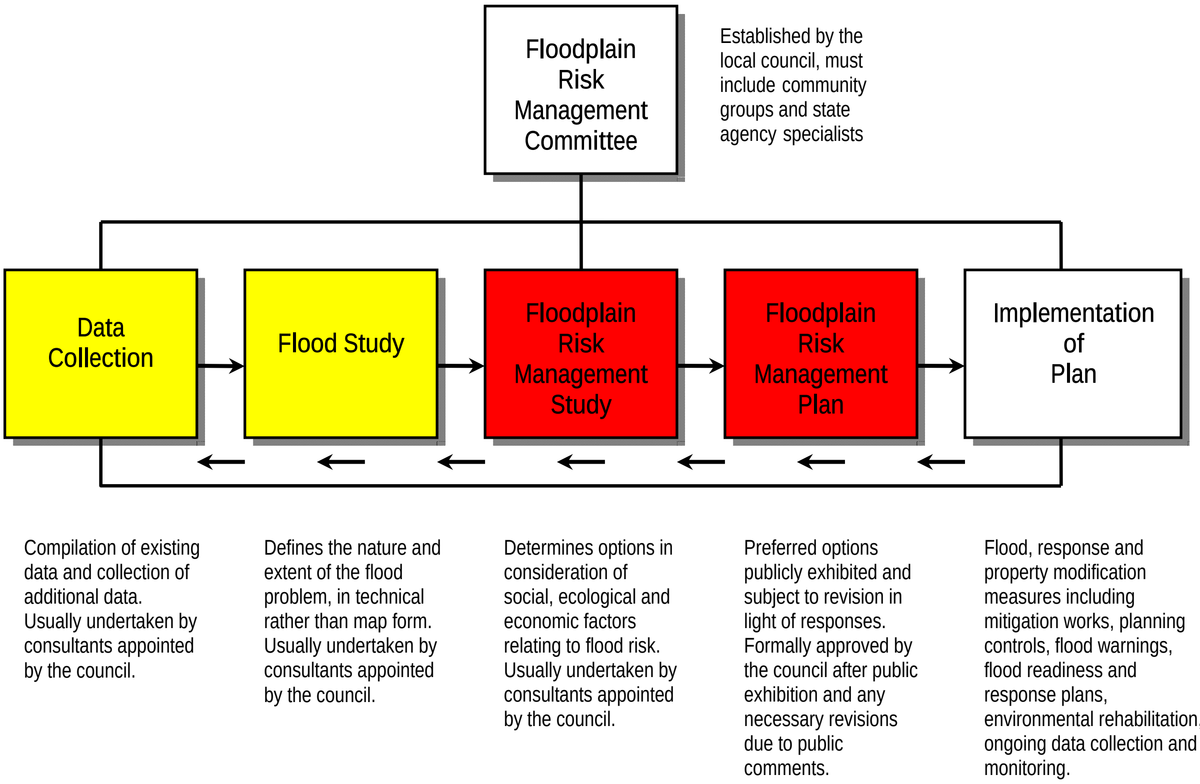
STAGES OF FLOODPLAIN RISK MANAGEMENT

STAGE	DESCRIPTION
1. Flood Study	Determines the nature and extent of the flood problem.
2. Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed developments.
3. Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4. Implementation of Plan	Results in construction of flood mitigation works to protect existing development and the application of environmental and planning controls to ensure that new development is compatible with the flood hazard.

A detailed description of the inter-relationship between these stages is provided overleaf. The link between the various outcomes of the studies involved in the floodplain risk management process and the implementation of measures (*both planning and structural*) to reduce flood damages is also shown.

Bombala Council commenced this process, when it formed its own shire wide Floodplain Risk Management Committee. Council and the Committee, with the technical and financial support of the NSW Department of Environment, Climate Change and Water, subsequently commissioned the Flood Study for Bombala.

The Bombala Flood Study and Overland Flows Investigation (December, *2010*) represented the first of the four stages. It has been prepared to assist Bombala Council and the local community in understanding the extent and characteristics of flooding that could occur at Bombala. The results from the Flood Study have been used as a base for investigations undertaken to prepare this Floodplain Risk Management Study for the town.



Source: *'Floodplain Development Manual'* (*2005*)

GLOSSARY

Source: '*Floodplain Development Manual*' (*2005*).

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. E.g., if a peak flood discharge of 500 m³/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m3/s or larger events occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
average annual damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time. Refer Appendix M.
average recurrence interval (ARI)	The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the council, however legislation or an EPI may specify a Minister or public authority (other than a council), or the Director General of DIPNR, as having the function to determine an application.

development	Is defined in Part 4 of the EP&A Act: - infill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development - new development: refers to development of a completely different nature to that associated with the former land use. E.g., the urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. - redevelopment: refers to rebuilding in an area. E.g., as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.

flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage (refer Section C6) before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (ie) land susceptible to flooding by the PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
flood planning area	The area of land below the FPL and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.
flood planning levels (FPLs)	Are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
flood readiness	Readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. - existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. - future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. - continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
freeboard	Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. (See Section K5). Freeboard is included in the flood planning level.
habitable room	in a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	a source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in Appendix L.
hydraulics	term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	a graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

local drainage	smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purposes of this manual major drainage involves: - the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or - water depths generally in excess of 0.3m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or - major overland flowpaths through developed areas outside of defined drainage reserves; and/or the potential to affect a number of buildings along the major flow path.
mathematical/computer models	the mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	the merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into council plans, policy, and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local flood risk management policy and EPIs.

minor, moderate and major flooding	both the SES and the BoM use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: - minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level ridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. - moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. - major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	measures that modify either the flood, the property or the response to flooding. Examples are provided in Table 2.1 with further discussion in Appendix J.
peak discharge	the maximum discharge occurring during a flood event.
probable maximum flood	the PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snowmelt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
probable maximum precipitation	the PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	a statistical measure of the expected chance of flooding (see AEP).

risk	chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	the amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	equivalent to water level (both measured with reference to a specified datum).
stage hydrograph	a graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	a plan prepared by a registered surveyor.
water surface profile	a graph showing the flood stage at any given location along a watercourse at a particular time.

1. INTRODUCTION

Bombala is located on the Bombala River about 80 kilometres south of Cooma. The town is located downstream of the confluence of the Bombala and Coolumbooka Rivers (*refer* **Figure 1**), which collectively drain a catchment area of 537 km^2 (*refer* **Figure 2**).

Bombala has experienced major floods in the past, most notably in 1971, 1952 and 1983. As a consequence of these experiences, Council has adopted a policy of restricting development in low lying areas that are potentially vulnerable to flooding.

Nonetheless, current predictions of the extent of inundation in the 1% annual exceedance probability (*AEP*) flood indicate that most businesses on the northern or river side of the main street of Bombala (i.e., Maybe Street) would experience inundation. Residential dwellings in Caveat, Young and Therry Streets would also be flood affected. Hence, there is an existing flood problem that needs to be addressed.

Bombala has a population of about 1500, but has insufficient existing housing stock to accommodate growth. Most of the additional development is to occur within the existing town boundaries (*pers comm Grantley Ingram*). As Council is aware of the potential for some areas within the town boundaries to be inundated in major floods, it is keen to further investigate the flood problem so that more informed planning decisions can be made in assessing the likely increase in development applications.

In recognition of these issues, Bombala Council decided to proceed with the development of a floodplain risk management plan for the township. In accordance with procedures outlined in the NSW Government's *'Floodplain Development Manual'* (*2005*), Council commissioned Consulting Engineers, Patterson Britton & Partners (*now a part of WorleyParsons*), to undertake a combined flood and floodplain risk management study for the township.

The first stage in this process involved the preparation of the '*Bombala Flood Study and Overland Flows Investigation*' (*Issue No.3, December 2010*). The Flood Study defined the flood behaviour in and around the township, including information on flood flows, velocities, levels and flood extents, for a range of flood events under existing floodplain and catchment conditions. It confirmed that the existing flooding problem at Bombala is real and has the potential to threaten life and cause damages to property.

Accordingly, it is appropriate, under the NSW Government's *Floodplain Management Program*, to consider options for reducing the flood damages that could be experienced by residents of Bombala and to reduce the risk for loss of life. Specifically, the assessment should address the existing flood risk, along with considering planning measures to manage the flood risk to future development and any residual, or continuing flood risk which exists at Bombala.

FIGURE 1

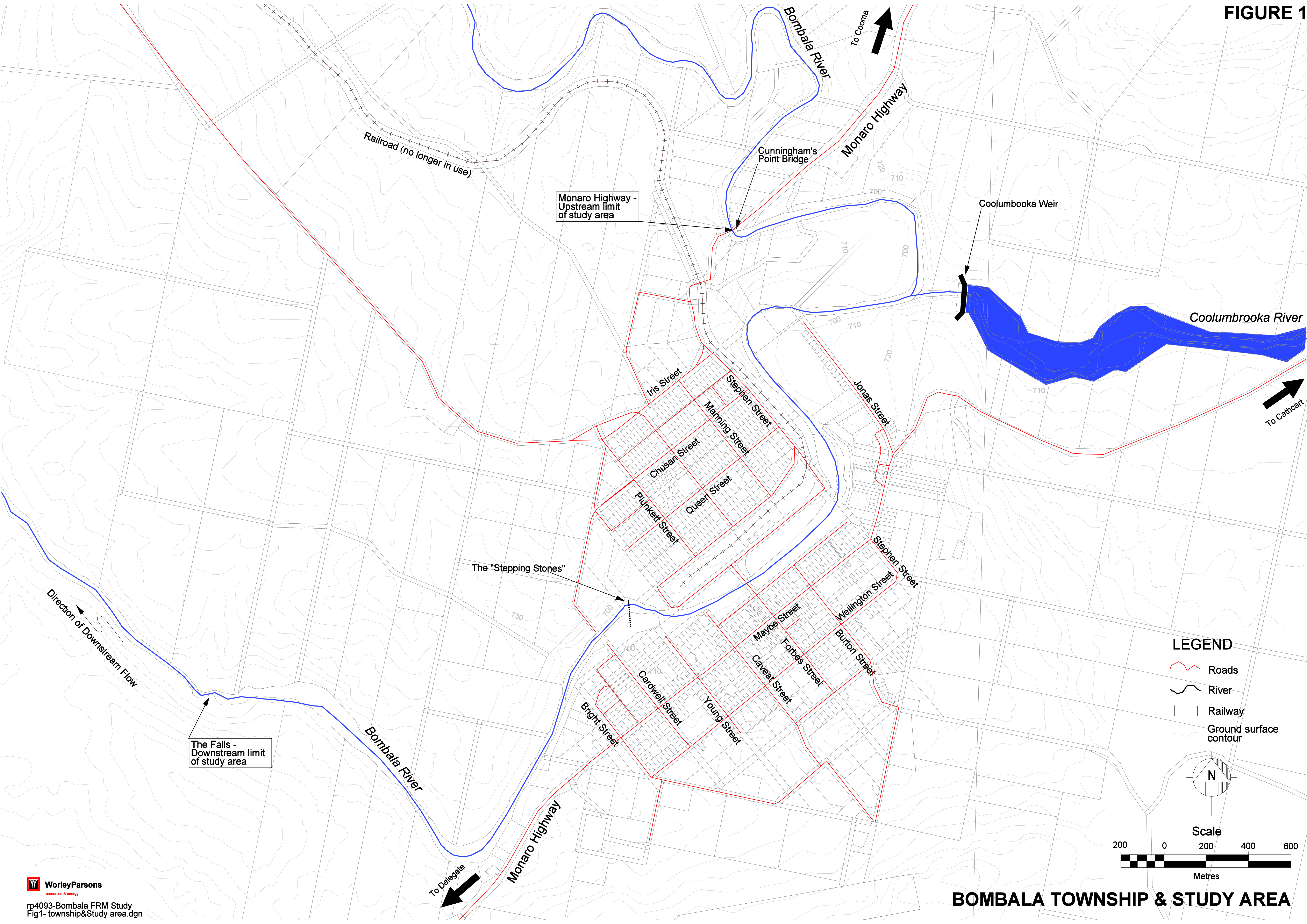


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Fig1- township&Study area.dgn

BOMBALA TOWNSHIP & STUDY AREA

The associated assessment involves consideration of the flood damages that residents and the broader community may experience as a consequence of the existing flood problem. These damages are a measure of the cost of flooding under existing conditions. As outlined above, the NSW Government's *Floodplain Management Program* is targeted toward determining measures that can be cost effectively implemented to reduce existing flood damages.

The DECC's '*Floodplain Development Manual*' (*2005*) classifies floodplain risk management options into three categories: *property modification*, *response modification* and *flood modification*. To assist with communicating these concepts to a general audience, the floodplain risk management options presented are classified as either *structural* or *non-structural* measures. A breakdown of the proposed measures and their classification is presented in **Section 6**.

Typically, the first step in the assessment is to identify potential flood damage reduction measures (*structural measures*) and to identify potential planning controls (*non-structural measures*) that could reduce the impact of floods. These are tested to establish their relative benefit, which is usually measured in terms of the potential reduction in flood damages, or the potential for additional future development that can occur at no increased risk to the community. The measures are also costed and their respective costs compared to their net benefit, thereby allowing a benefit-cost ratio to be determined for each measure.

Measures with a high benefit-cost ratio are typically recommended for inclusion within a Floodplain Risk Management Plan, which is the fourth phase in the floodplain risk management process (*refer to flow chart in Foreword*).

Therefore, this Floodplain Risk Management Study sets out to:

- identify and evaluate management options (*structural and non-structural*) for the floodplain in terms of their capacity to reduce existing and potential future flood risks;
- provide information on flood behaviour and flood hazard, so that community aspirations for future land use can be assessed; and,
- provide a framework for revisions to planning instruments such as Local Environmental Plans (*LEPs*), so that land use controls are consistent with flood risk and flood hazard.

2. THE FLOOD RISK

The contemporary flood risk at Bombala can be broken up into three major components, namely:

- the *existing* flood risk;
- the potential *future* flood risk; and,
- the continuing flood risk.

Each component of the flood risk is discussed further in the following sections.

2.1 EXISTING FLOOD RISK

The existing flood risk relates to those areas where flood damages are likely to arise as a consequence of flooding. It concerns existing dwellings and commercial premises that would be inundated during a flood, as well as all associated infrastructure within the floodplain, including roads, railways and utility services. In this context, the existing flood risk is usually addressed by flood modification measures which aim to modify flood behaviour and thereby reduce flood damages and response modification measures to reduce social impacts.

The extent of the catchment draining to Bombala is presented in **Figure 2**. The extent of inundation for the 1% AEP flood event is shown on **Figure 3**.

Investigations undertaken as part of the *Bombala Flood Study and Overland Flows Investigation*, involved detailed flood modelling of these processes to define the existing behaviour of flooding and drainage in the vicinity of the township.

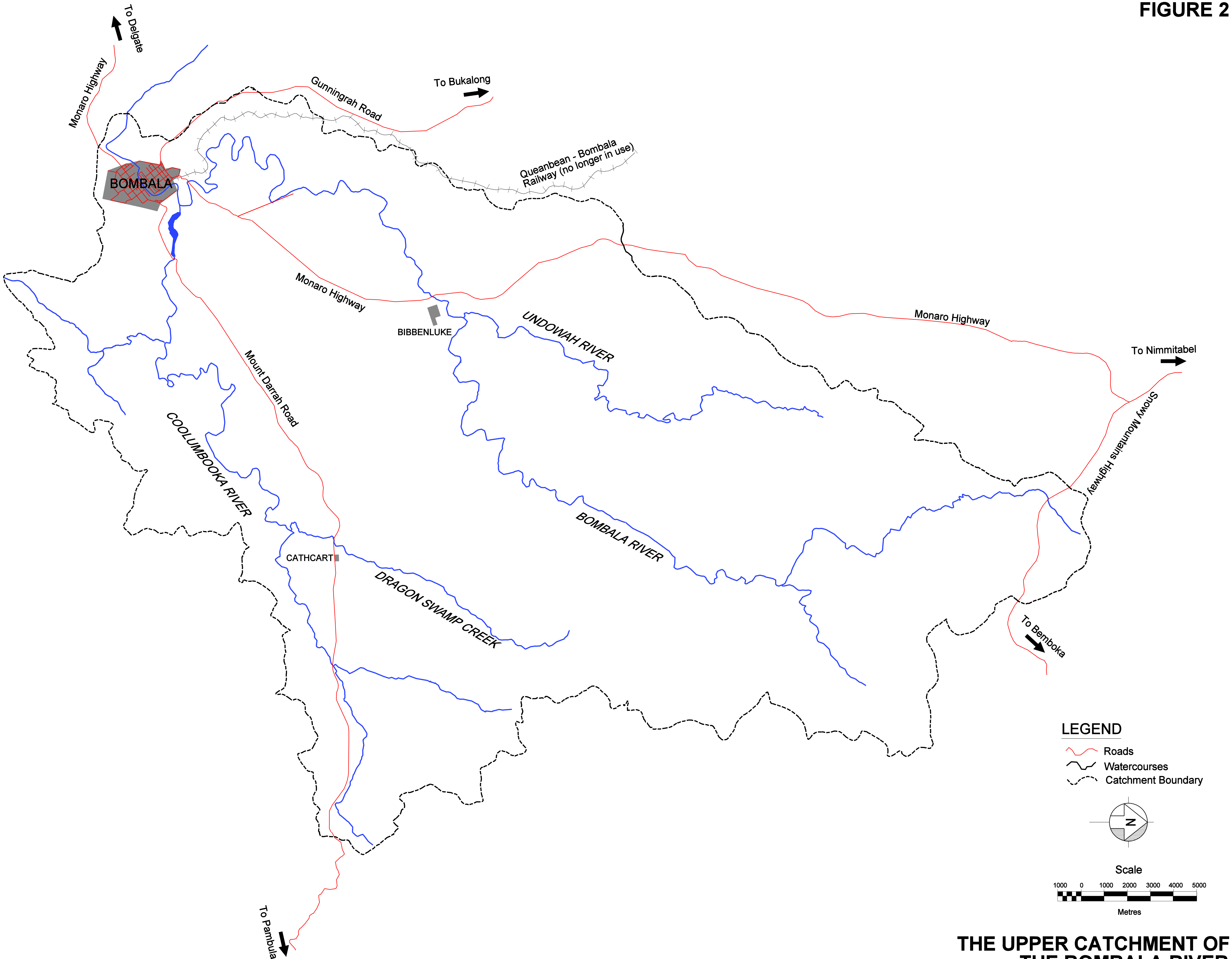
The Flood Study established the following:

(1) In a 1% AEP flood, the Bombala River catchment has a critical storm duration of 36 hours. That is, a design storm with a 36 hour duration will generate the highest peak 1% AEP discharge at Bombala.

(2) Flooding in the town appears to be exacerbated by the constriction in the channel / floodway downstream of Bright Street (*refer* **Figure 1**). In major floods, floodwaters "back-up" above Bright Street, leading to more rapid inundation of the town. Water surface profiles documented in the Flood Study confirm this, showing a sudden increase in water surface gradient downstream of Bright Street.

(3) Overland flows, which can lead to significant nuisance flooding in the local area of Bombala were also investigated. This refers to run-off which is generated by a local storm cell that may or may not coincide with Bombala River flooding. The Overland Flows Investigation established that Trouble Spots 1 and 3 are the location of the most significant problem for run-off in the township. These trouble spots are locations where the results of hydraulic modelling predict stormwater will enter premises during the 5% AEP flood event.

FIGURE 2



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THE UPPER CATCHMENT OF THE BOMBALA RIVER

FIGURE 3

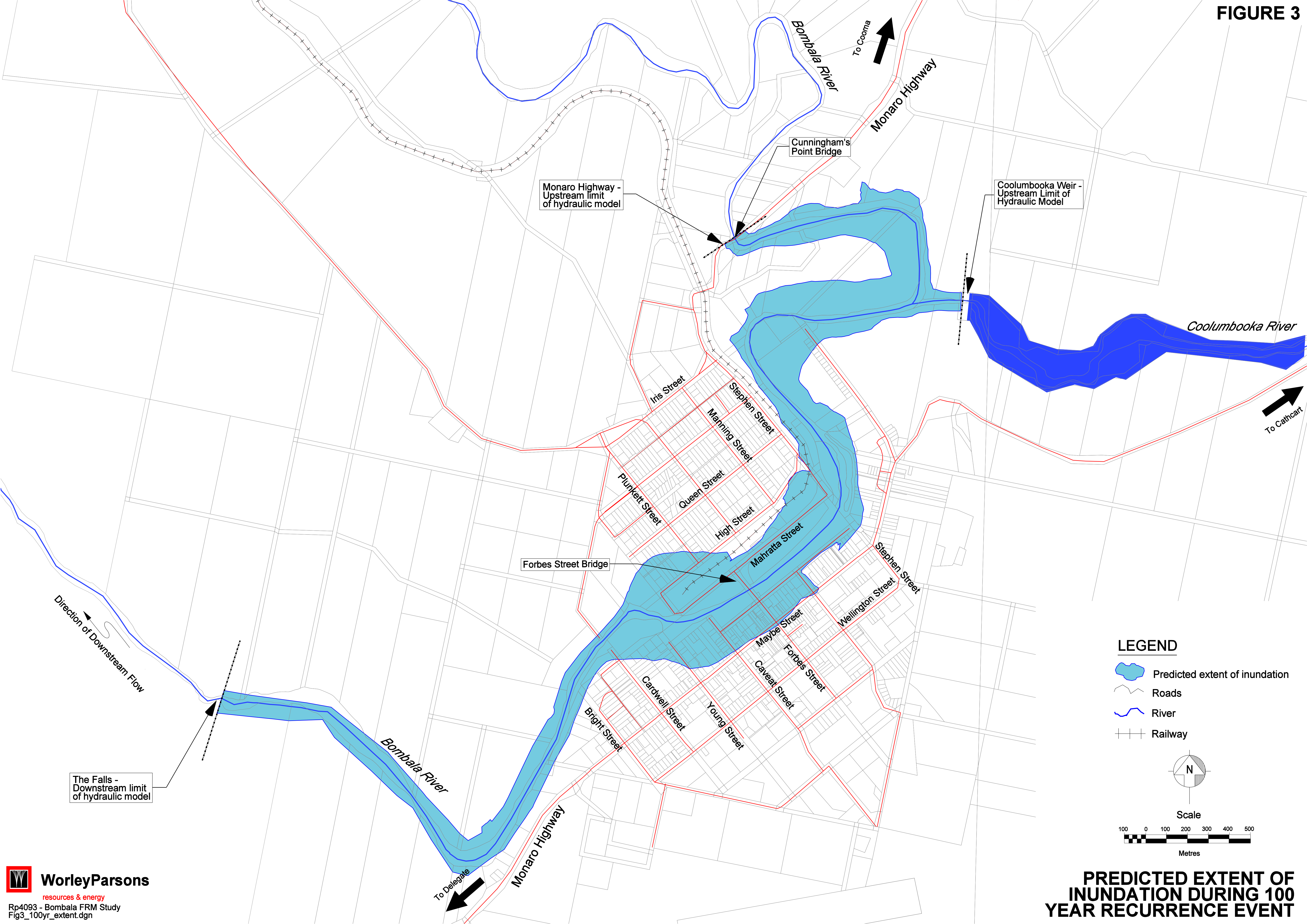

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Fig3_100yr_extent.dgn

PREDICTED EXTENT OF INUNDATION DURING 100 YEAR RECURRENCE EVENT

(4) The results of modelling the sub-surface drainage lines established that the lines have very limited capacity. The existing capacity of the system is estimated to be less than the 20% AEP storm event.

(5) Flood hazard mapping for the 1% AEP flood along Bombala River is presented in **Figure 4** and **Figure 5** and shows the potential flood risk to which residents of Bombala could be exposed. As shown, a significant number of properties on the northern side of Maybe Street between Burton Street and Young Street are exposed to High to Very High hazard at the peak of the 1% AEP flood.

(6) As a result, it can be considered that flooding up to the 1% AEP event can be considered to pose a significant risk to life. In addition, as shown in **Figure 6**, the Probable Maximum Flood (*PMF*) is expected to inundate a significant proportion of the town located on the southern floodplain of the Bombala River, which has potentially serious implications for flood emergency response.

2.2 FUTURE FLOOD RISK

The potential *future* flood risk relates to those areas of the floodplain that are likely to be proposed for future development or to be the subject of rezoning applications.

As land resources for development become increasingly scarce, pressures mount to allow development within floodplain areas where it might otherwise be avoided.

Council has a duty of care to ensure that its current planning instruments recognise the associated flood risk. Council also has a responsibility to ensure that a Floodplain Risk Management Plan is in place and that this Plan or an associated *Flood Policy*, can be used to support decisions to approve or reject development proposals on flood affected sections of the LGA.

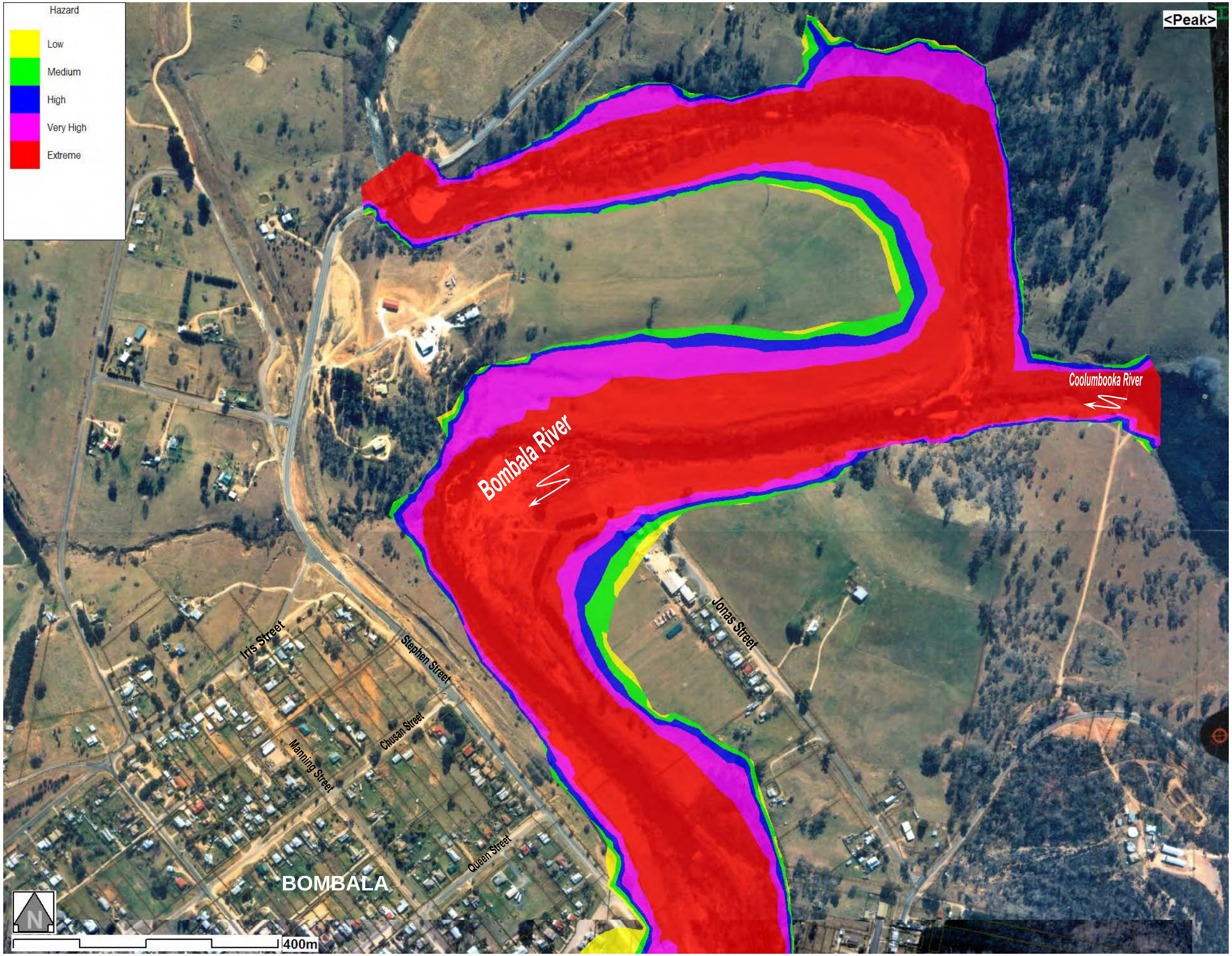
2.3 CONTINUING FLOOD RISK

Unless the Probable Maximum Flood (*PMF*) is adopted as the basis for determining structural and planning measures aimed at reducing flood impacts, there will always be a residual or continuing flood risk.

However, the adoption of the PMF as the ‘planning flood’ is often not realistic or practical because it would sterilise a large area of land, thereby forcing development to areas of higher ground which may not historically be serviced or which could introduce unrealistically high infrastructure costs.

Hence, a lesser flood standard is usually adopted. As a result, measures that are put in place to control flood impacts will ultimately be overwhelmed by a flood that is larger than that adopted as the threshold for the planning control of land use, or as the limiting flood for the design of structural measures. Accordingly, it is incumbent upon Council to consider the implications of floods greater than the adopted planning flood and to work with the State Emergency Services (*SES*) to develop a contingency response plan for such events.

FIGURE 4



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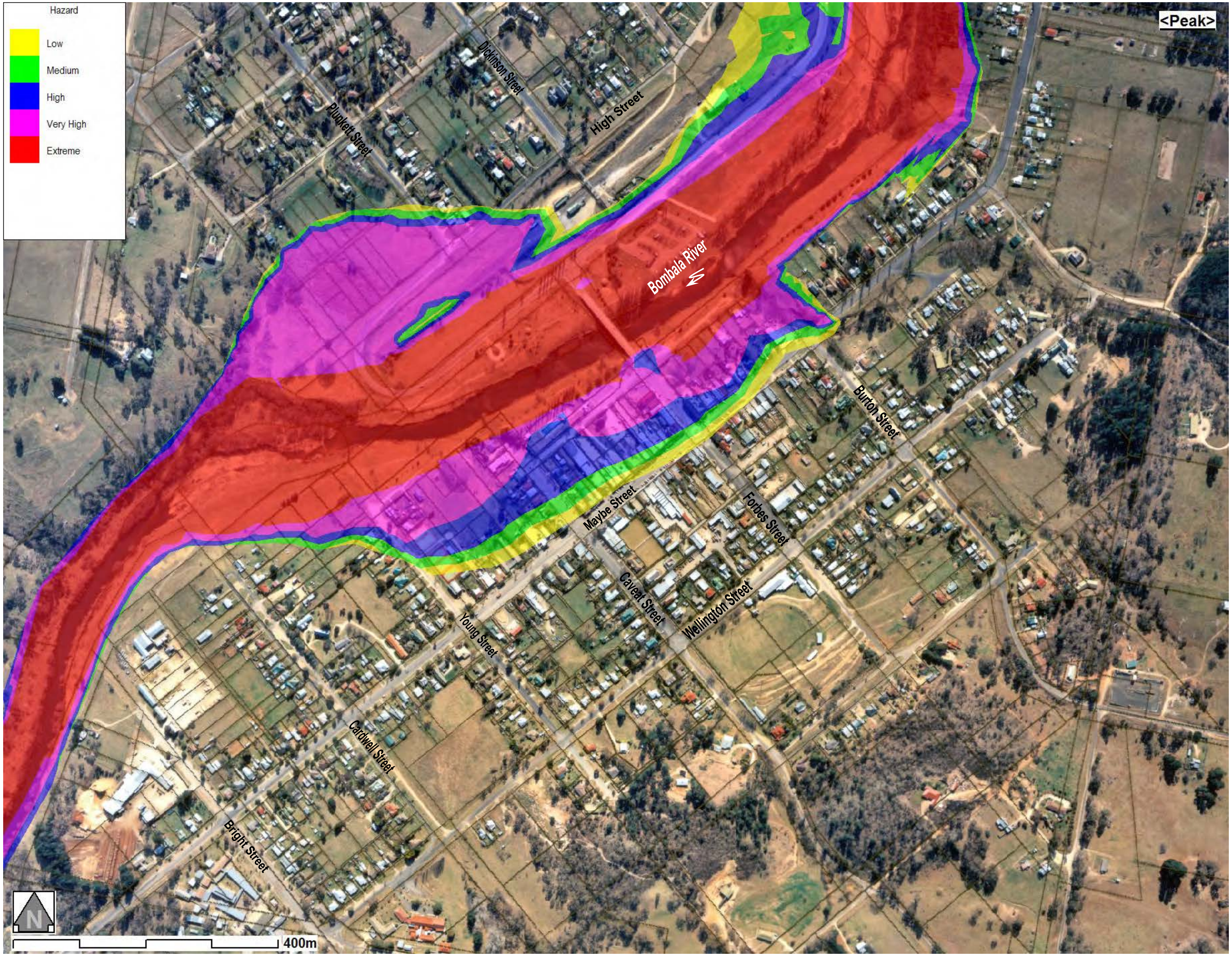
PROVISIONAL FLOOD HAZARD MAPPING FOR THE BOMBALA RIVER 100 YEAR ARI EVENT (1 of 2)

FIGURE 5



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PROVISIONAL FLOOD HAZARD MAPPING FOR THE BOMBALA RIVER 100 YEAR ARI EVENT (2 of 2)

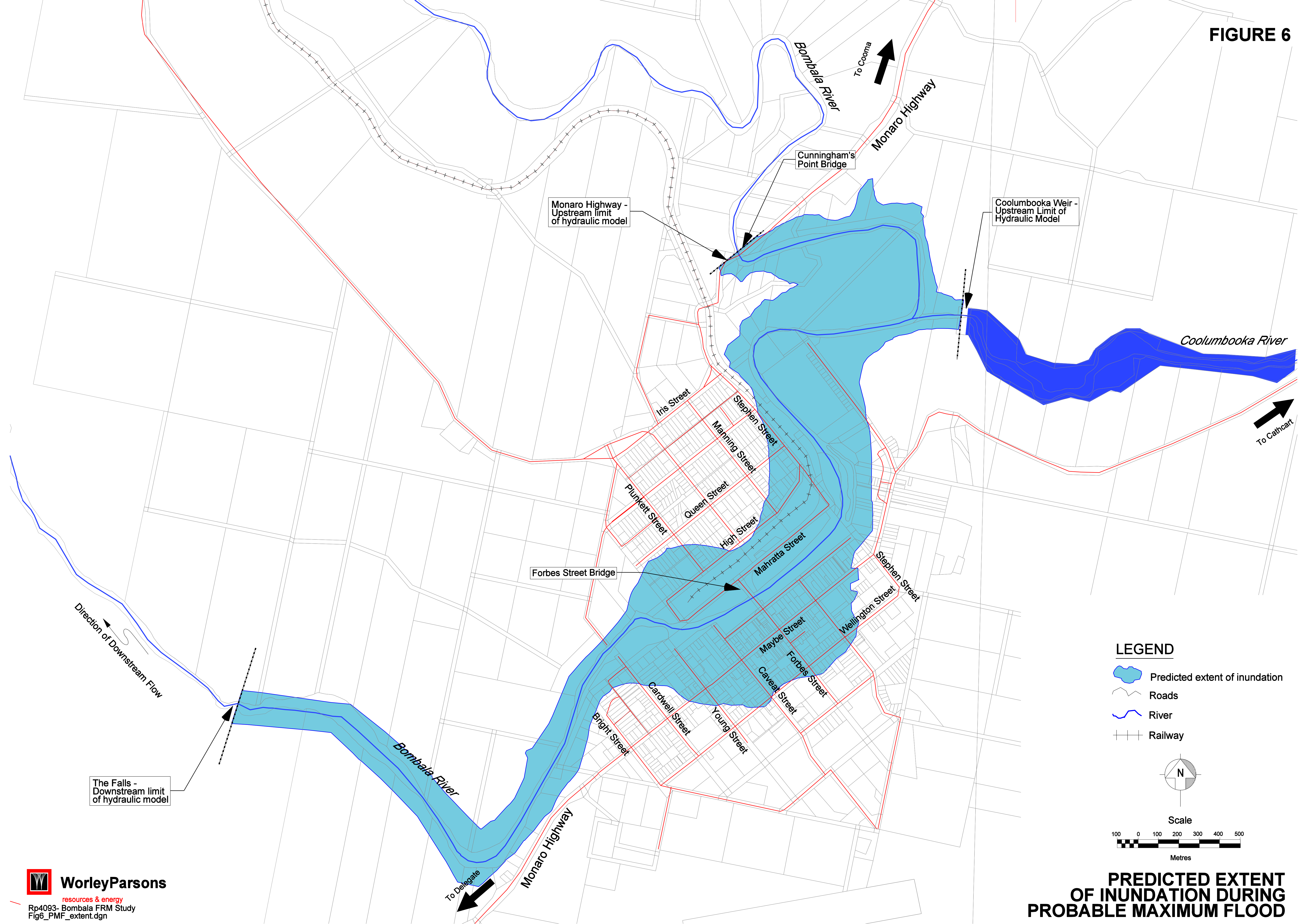


FIGURE 6

PREDICTED EXTENT OF INUNDATION DURING PROBABLE MAXIMUM FLOOD

3. CONSULTATION

Development of Bombala Floodplain Risk Management Study has involved consultation with the following key stakeholders:

- Bombala Council officers – provision of available data and technical information.
- The NSW Office of Environment and Heritage – technical advice and study review.
- Bombala Floodplain Risk Management Committee – anecdotal flood information and technical advice provided during Committee meetings
- State Emergency Services (*Southern Highlands Region and Bombala Flood Controller*) – provision of existing Local Flood Plans for emergency management and advice on procedures implemented during past flood events.
- The local community at Bombala – provision of historic flood information during the Flood Study phase as well as feedback on the proposed flood damage reduction measures and suggestions of alternative measures (*refer* **Appendix C** and **Appendix D**).

4. EXISTING FLOODPLAIN RISK MANAGEMENT MEASURES

4.1 EXISTING FLOOD MITIGATION WORKS

It is understood that no major flood mitigation works have been previously undertaken in the vicinity of Bombala. Notwithstanding, Council has endeavoured to address local drainage issues by upgrading existing drainage infrastructure through the town.

4.2 CURRENT PLANNING INSTRUMENTS

The existing Bombala Local Environmental Plan 2012 includes the following provisions (*Clause 6.2*) for the regulation of works that are proposed on flood prone land:

6.2 Flood Planning

1) *The objectives of this clause are as follows:*
    a) *to minimise the flood risk to life and property associated with the use of land,*
    b) *to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,*
    c) *to avoid significant adverse impacts on flood behaviour and the environment.*

2) *This clause applies to:*
    a) *land identified as "Flood planning area" on the Flood Planning Map, and*
    b) *other land at or below the flood planning level.*

3) *Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:*
    a) *is compatible with the flood hazard of the land, and*
    b) *is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and*
    c) *incorporates appropriate measures to manage risk to life from flood, and*
    d) *is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and*
    e) *is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.*

4) *A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.*

5) *In this clause:*

- ***flood planning area*** *means the land shown as "Flood planning area" on the Flood Planning Map.*
- ***flood planning level*** *means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.*

Bombala Council also has in place an existing policy titled *'3.7 Town Planning & Development Control, Flood Prone Land or Floodway Lands – Minimum Floor Levels'*. The policy is quite brief and effectively refers all development applications at flood prone land to Council for an individual assessment of floor level requirements, as per the following:

3.7 Floodprone Land or Floodway Lands – Minimum Floor Levels

POLICY NO: 3.7 Town Planning & Development Control

POLICY STATEMENT

Council set minimum floor levels for residential/ dwelling development as being a minimum of 500mm and for commercial/industrial development as being a minimum 250mm above 1971 flood level respectively

Min No: C. 142/84

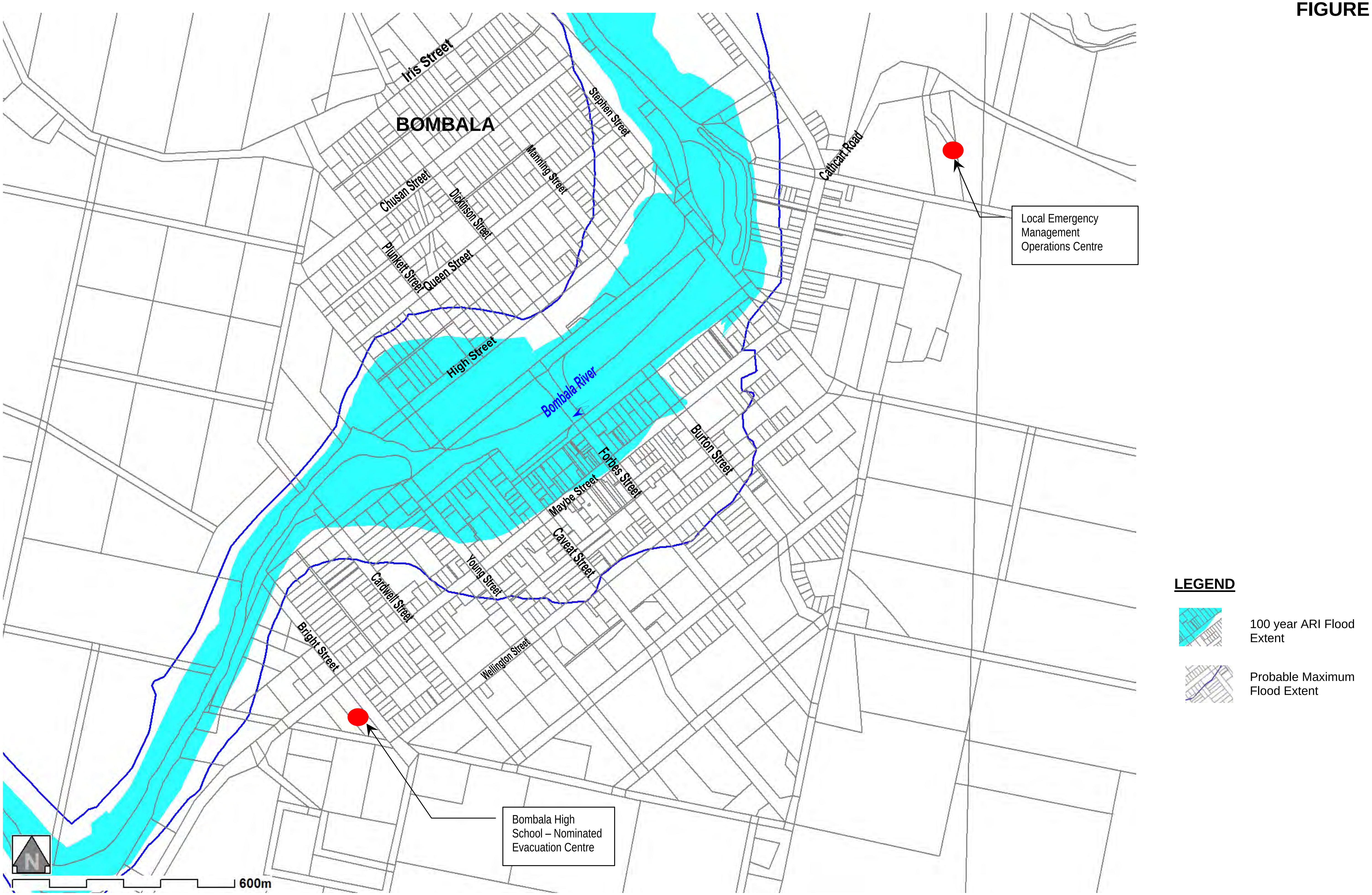
Date: 25/6/84

4.3 LOCAL FLOOD PLAN AND EMERGENCY RESPONSE PROTOCOLS

The existing flood emergence response protocols for Bombala are outlined in the *'Bombala Local Flood Plan' (2008)*, which is a sub-plan of the Bombala Local Disaster Plan, prepared by State Emergency Services (*SES*) and Bombala Council.

The key features of the existing Local Flood Plan are summarised in the following:

- The Bureau of Meteorology (*BOM*) issues Flood Watches and severe weather warnings to the Southern Highlands SES Region Headquarters.
- Southern Highlands SES Region Headquarters liaises with Bombala SES Local Controller regarding flood warnings and potential road closures. It also issues general SES Flood Bulletins to media organisations and agencies for public dissemination.
- Bombala Council also provides information on road closures within the Council area.
- Bombala SES Local Controller is based in Urana Street (*refer* **Figure 7**) and issues all local warnings to residents of Bombala.
- Bombala SES Local Controller monitors the Bombala Gauge (*222019*), together with any weather forecasts warning of potential storm activity including severe weather warnings and severe thunderstorm warnings for the Bombala district. In addition, the staff gauge at Coolumbooka (222012) is also be monitored to provide information on expected flood levels.



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EMERGENCY MANAGEMENT REFERENCE POINTS INCLUDING SES OPERATIONS CENTRE AND NOMINATED EVACUATION CENTRE

- Evacuations are overseen by Bombala SES Local Controller and conducted by SES, Police, Rural Fire Service and NSW Fire Brigade personnel.
- The designated flood evacuation centres for Bombala are currently the Bombala multi purpose hall and Bombala High School (*refer* **Figure 7**).
- Bombala SES Local Controller is responsible for issuing the "All Clear" message to the community to signify that the danger to life and property has passed.

5. FLOOD DAMAGES ASSESSMENT

5.1 WHAT ARE FLOOD DAMAGES

Flood damages are adverse impacts that private and public property owners experience as a consequence of flooding. They can be both tangible and intangible and are usually measured in terms of a dollar cost.

Tangible damages include direct damages such as the damage to property as a consequence of inundation (*e.g., the cost of replacing carpets and removing mud from houses in the aftermath of a flood*). Tangible damages can also be indirect damages such as the cost to the community of individuals being unable to get to work because they are isolated due to flooding. These costs can usually be measured and data has been gathered over many years to provide a reliable indication of the likely damage costs that can be incurred by residential, commercial and industrial property owners.

It is more difficult to quantify intangible damages. Intangible damages include less 'concrete' impacts such as the trauma felt by individuals as a result of a major flood and the associated health related impacts. Only limited data is available, but it has been stated that intangible damages could be as much or more than the tangible damage cost.

As part of a Floodplain Risk Management Study, it is necessary to determine the total damages that could be incurred as a consequence of flooding. If the total damage cost is significant, it can be argued that works or planning measures to reduce the cost can be justified. The justification process involves determining an estimate of the flood damage that could be expected to occur over the design life of the works (*say 30 years*). This damage cost is then compared to the damage cost if no works were undertaken. The difference defines the reduction in flood damage cost, or the net benefit. The net benefit of the works is compared against the cost of the works, thereby generating a benefit-cost ratio for the works.

If the benefit-cost ratio is sufficiently high (*i.e., ideally greater than 1*), it is likely that the works will attract State Government funding and could proceed.

5.1.1 Flood Damage Categories

Flood damage costs for Bombala were determined based on consideration of the different types of land use within the township. The predominant land uses are:

- residential; and,
- commercial/ industrial.

There are also fringing areas of farmland which could experience agricultural flood damages. However, as this study is specific to the town of Bombala, no consideration of rural flood damages has been made.

Residential and commercial flood damages include damage to structures (*e.g., buildings, houses, shops, offices*) and damage to the items within those structures. They also include damages to outdoor facilities and associated infrastructure, and to the land on which the structures are sited.

Damage to infrastructure as a result of flooding includes losses associated with damage caused by inundation of roads, water supply and sewerage services, and damage to utilities such as electricity, gas and telecommunications systems.

Residential and commercial damages can be separated into direct and indirect damages. Direct damages are the result of the physical contact of floodwaters with the structure and may include the costs associated with repair, replacement or the loss in value of inundated items. Indirect damages represent all other costs not associated with physical damage to property and typically include the loss of income incurred by residents affected by flooding, as well as flood recovery items such as clean-up costs.

The approach developed to calculate residential flood damages for Bombala is based upon the development of a representative damage curve for a typical house in the village. A damage curve is a numerical relationship that correlates the depth of flooding to the cost of damages that would result from that flooding. The cost of the damages associated with the flooding increases as the depth of flooding increases.

The approach employed applies procedures outlined in the Department of Environment, Climate Change's (*DECC*) Floodplain Risk Management Guideline titled, *'Residential Flood Damages'* (*2007*). It involves the application of the damage curves documented in the literature with flood data documented in *Bombala Flood Study and Overland Flows Investigation* (*2010*). These curves incorporate an allowance for direct and indirect damage costs for <u>residential</u> dwellings and properties. In other words, the data available on flood damages typically only applies to residential properties.

Therefore, an estimate of the direct damages associated with the inundation of the limited <u>commercial</u> premises at Bombala was based on recorded damage costs for similar premises reported in the literature. This literature includes a range of previous floodplain risk management studies and recorded data presented in intergovernmental reports. DECCW advises that this approach is suitable, provided that the damage curve data is updated to reflect current day Average Weekly Earnings (*AWE*) and GST (*if applicable*)

Indirect damages for commercial premises were assumed to be 50% of the corresponding direct damages. The higher proportion was assumed to account for the greater impact of indirect influences such as the slowdown that a business could experience due to employees being unable to get to work due to inundation of roads.

There is no data available to define the extent of the public and corporate infrastructure that could be damaged as a result of flooding. Accordingly, infrastructure damages were determined to be 30% of the total direct and indirect residential (*including dwellings and property damages*) and commercial costs. This is in keeping with approaches employed for other areas of NSW.

5.1.2 Stage – Damage Relationships

DECCW's guideline *'Residential Flood Damages'* (*2007*) outlines the method for determining stage-damage curves for residential dwellings. This procedure is recommended as the basis for derivation of average annual damages and net present values of damages to enable the comparison of management options.

Standard stage-damage curves have also been developed from records of damages gathered from interviews with residents and landowners in flood affected communities. For example, Smith et al (*1979*) determined stage-damage relationships for different land use types based on data gathered during and following the Lismore floods in 1974.

Accordingly, stage-damage curves were developed for residential properties and commercial sites based on consideration of the available stage-damage relationships in the literature. The adopted stage-damage curves for Bombala are included within **Appendix A**.

5.1.3 Average Annual Damage

The relative cost of the potential flood damages is typically expressed in terms of the Average Annual Damages (*AAD*). The AAD is the average damage per year that would occur from flooding over a very long period of time.

In understanding this concept, there may be periods where no floods occur or the floods that do occur are too small to cause significant damage. On the other hand, some floods will be large enough to cause extensive damage.

The average annual damage is equivalent to the total damage caused by all floods over a long period of time divided by the number of years in that period (*DECCW, 2007*). It provides a measure for comparing the economic benefits of potential flood damage reduction options.

5.2 FLOOD DAMAGES ANALYSIS FOR BOMBALA

In order to calculate the potential flood damages, it is necessary to have data that defines the floor levels of structures that could potentially be flooded and details of the type of structure; e.g., residential dwelling, commercial or industrial premises. This data can be used with peak flood levels generated from modelling completed for the 'Bombala Flood Study and Village Overland Flows Investigation' (2010) to determine the depth of 'over floor' flooding for each residential, commercial and industrial property.

Damage costs can then be assigned to individual buildings according to the depth of inundation and the associated "damage" as reflected in stage-damage curves that have been developed from data gathered following major floods (*refer* **Appendix A**).

Floor level information is available for the majority of properties in Bombala located within the extent of flooding resulting from the 1% AEP flood. However, in order to develop a reliable flood damage estimate, it is necessary to establish floor level and property data for all properties that have the potential to be inundated during all floods up to and including the adopted extreme event.

Therefore, floor levels for residential, commercial and industrial properties affected by the 1% AEP flood event have been based on floor level survey data. This floor level data was surveyed by registered surveyors (Williams & Lightfoot) in 2002 and 2009.

For properties affected by floods up to and including the extreme event which fall outside the 1% AEP flood extent, floor levels were estimated by assuming that they were elevated 0.3 metres above the existing ground surface. The existing ground surface was defined from a digital terrain model which has been developed from data collected over the course of several topographic surveys to provide the most comprehensive definition of floodplain topography. These investigations include:

- River cross-section survey data collected as part of the *'Bombala Flood Study* (*1987 DWR*)*'*
- River cross-section survey data collected by Williams and Lightfoot in 2000; and,
- Additional river cross-section data collected by Williams and Lightfoot in 2002 for the *'Bombala Flood Study'* (*2003*).

Residential and commercial/industrial property types were defined from field observations.

Estimates of the tangible flood damages associated with each of the 0.5%, 1%, 2%, 5% and 20% AEP floods and the adopted extreme flood are outlined in the following sections for mainstream flooding of the Bombala River.

The corresponding flood damages database is provided in **Appendix B**, which comprises all properties that were included in the damages analysis.

5.3 FLOOD DAMAGE RESULTS

5.3.1 Flooded Properties

The floor level dataset was combined with peak design flood level estimates generated from the modelling that was completed for the *Bombala Flood Study and Village Overland Flow Investigation* (*2010*). The two data-sets were used to determine the number of residential and commercial/industrial properties that may be subject to over-floor flooding for each design flood.

The results of the analysis indicate that <u>48 properties would potentially be flooded during a design 1% AEP event</u>.

A summary of the distribution of the types of properties that would be flooded during the range of design floods investigated is provided in **Table 1**. As shown in **Table 1**, the distribution in the type of properties affected varies depending on the flood event. **Table 1** also shows that 238 properties would potentially be flooded during the extreme flood.

Table 1 ESTIMATED NUMBER OF PROPERTIES FLOODED ABOVE FLOOR LEVEL

FLOOD EVENT	RESIDENTIAL	COMMERCIAL/INDUSTRIAL	CARAVAN SITE
20% AEP	0	0	1
5% AEP	8	3	1
2% AEP	15	4	1
1% AEP	23	24	1
0.5% AEP	31	61	1
Extreme	170	67	1

5.3.2 Damage Costs

Table 2 shows the break-up of flood damages that would by incurred by the various property types. The total flood damages cost resulting from inundation by a flood equivalent to the 1% AEP event is estimated to be about $4.7M. Roughly half of this cost (approximately $2.4M) is attributed to damage to residential dwellings and property.

As shown in **Table 2**, both direct and indirect damage costs were estimated as part of the flood damage assessment. Direct damages are the result of physical contact of floodwaters with property and may include the costs of repair, replacement or loss in value of inundated items. Indirect damages represent all other costs not associated with physical damage to property and typically include the loss of income of those residents affected by flooding and flood recovery items such as clean-up costs.

Standard stage-damage curves have been developed from records of damages gathered from flood affected communities for a range of different property types. The OEH (formerly DECC) has used this data to develop stage-damage curves for residential dwellings. These curves are documented in the DECC Draft Guideline titled, *'Residential Flood Damages'*, and have been adopted for this assessment.

No definitive information is currently available to calculate indirect damages. Therefore, indirect residential damages were estimated as 5% of the direct residential house and property damage costs. This estimate was adopted from the value quoted in a report prepared by Water Studies titled, *'The Sydney Floods of August 1986'* (*1986*).

Indirect commercial and industrial damages were determined as 50% of the direct commercial and industrial damage costs. This was based on recommendations in the 'Flood Damage User Manual' (*Water Studies, 1992*) to adopt a value of 5% of direct damages for every day of lost trading and an estimated 2 weeks (*10 days*) of lost trading.

Infrastructure damages were estimated as 30% of the total direct and indirect residential, commercial and industrial damage cost. This was based on the comparison of actual flood damage costs from floods in Lithgow, Bathurst, Hawkesbury-Nepean, Inverell, Nyngan and Narrabri.

Table 2 DIRECT AND INDIRECT FLOOD DAMAGES FOR BOMBALA

FLOOD EVENT	RESIDENTIAL		COMM & INDUST		INFRASTRUCTURE	TOTAL
	Direct	Indirect	Direct	Indirect		
20% AEP	-	-	57,106	28,553	25,698	$111,400
5% AEP	571,721	28,586	179,628	89,814	260,925	$1,130,700
2% AEP	1,308,886	65,444	296,183	148,092	545,581	$2,364,200
1% AEP	2,281,604	114,080	826,496	413,248	1,090,628	$4,726,100
0.5% AEP	3,232,029	161,601	2,684,597	1,342,299	2,226,158	$9,646,700
Extreme	22,318,541	1,115,927	5,115,152	2,557,576	9,332,159	$40,439,400

The total flood damages for each design event were combined with their probability of occurrence to determine an Average Annual Damage (*AAD*) cost. **The AAD for the township of Bombala is estimated to be $375,300**. This incorporates all events up to and including the extreme flood.

5.4 INTANGIBLE FLOOD DAMAGES

Intangible flood damages are those that are unable to be quantified in monetary terms. These damages are related to the physical and mental health of individuals, environmental concerns, the ability to undertake necessary evacuation measures and disruption to essential community services and operations.

Based on past experiences with floods at Bombala and the results of the Flood Study, it is considered that there would generally be sufficient warning time to facilitate evacuation of flood affected residents and businesses located in the Central Bombala.

Notwithstanding, emotional stress and mental illness can stem from a number of experiences associated with damage to family homes and businesses. These include:

- destruction of memorabilia (i.e., family photos);
- death of pets;
- financing the replacement of damaged property;
- living in temporary accommodation;
- children attending a different school;
- loss of business income and potential clients;
- loss of wages; and,
- anxiety experienced by young children.

According to the Bombala FRMS Community Consultation Report, residents are generally aware of the possibility of flooding and the associated risks. Also a number of residents would have experienced flooding in the past (such as in 1971 and 1983). Even so, it is possible that the intangible damage cost could be equivalent to the total tangible damage cost.

5.5 CONCLUSION

Flood damage estimates for Bombala during a flood equivalent to a 1% AEP event are significant. The analysis presented in this report indicates that the total direct and indirect damage could exceed **$4.7M** during the occurrence of a 1% AEP flood. This damage cost does not account for intangible damages, which have the potential to be as much as the direct and indirect cost.

The results of the analysis also indicate that the Average Annual Damage for all events up to the extreme flood is in the order of **$375,300**.

6. FLOODPLAIN RISK MANAGEMENT OPTIONS

6.1 POTENTIAL FLOODPLAIN RISK MANAGEMENT OPTIONS

Information presented in the *Bombala Flood Study and Overland Flows Investigation* (*2010*) and the damages analysis outlined in **Section 5**, indicates that there is potential for damages and loss to be incurred by the residents of Bombala should major flooding of Bombala occur, or should high-intensity rainfall cause runoff from the local catchment area.

These damages would include financial losses to individual property owners and losses to the overall community as a result of damage to infrastructure and disruption to everyday life.

Accordingly, it was considered appropriate to identify a range of measures that could potentially be implemented to reduce the flood damages that the community could be exposed to in the future.

A list of options was originally developed in consultation with representatives from Council, the NSW Office of Environment and Heritage (*OEH*) and the Bombala Floodplain Risk Management Committee. The measures were devised with a view to reducing the existing flood damages that could be incurred by the community and with a view to providing a mechanism for ensuring that the existing, future and continuing flood risk faced by future development was minimised.

The potential floodplain management options comprised a combination of property modification, response modification and flood mitigation measures. For the purpose of providing an easy to understand explanation of the proposed measures to a general audience, the floodplain risk management options were classified as 'flood damage reduction options' (*structural measures*) and 'planning options' (*non-structural measures*) in consultation brochures and questionnaires.

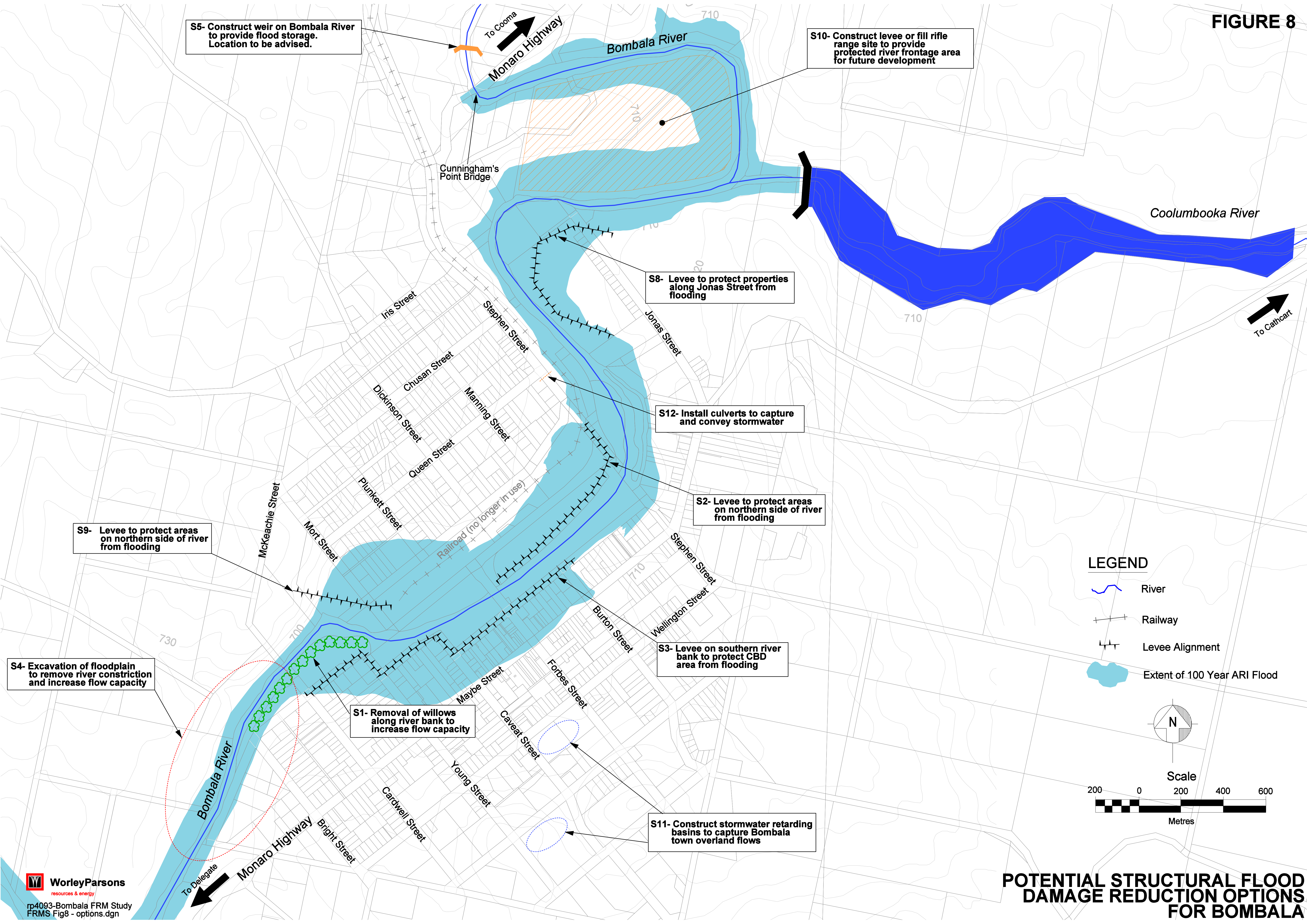
Flood damage reduction options have been identified which are targeted towards managing the existing flood risk at Bombala due to mainstream flooding of the Bombala River. In addition, two options have been identified which are targeted towards managing overland flows which may occur as a result of an intense local catchment storm event.

The floodplain risk management options that were considered are listed in **Table 3** and **Table 4**, together with their classification according to the categories defined by the Floodplain Development Manual. The "structural" options are shown graphically in **Figure 8**.

6.2 CONSULTATION

A consultation program was undertaken to determine the views of the community on the suitability of the floodplain management options that were proposed for consideration. The consultation involved the preparation of information brochures and questionnaires that were distributed to all residents within the Bombala township and consideration of feedback provided by this review. The brochure and questionnaire provided to the community is included within **Appendix C**.

FIGURE 8



POTENTIAL STRUCTURAL FLOOD DAMAGE REDUCTION OPTIONS FOR BOMBALA

Responses to the questionnaires were compiled and processed to determine the most suitable combination of flood damage reduction options. A total of 76 responses were received from the Bombala community. A report summarizing the responses is enclosed within **Appendix D**.

TABLE 3 POTENTIAL FLOOD DAMAGE REDUCTION OPTIONS

OPTION	DESCRIPTION OF WORKS / ACTIONS ASSOCIATED WITH OPTION	Floodplain Development Manual Classification
S1	Removal of trees (*willows*) along river bank between Young and Bright Streets.	Flood modification
S2	Construction of a levee along the right bank extending from the Forbes Street bridge upstream to the Apex Park, and linking with Stephen Street.	Flood modification
S3	Construction of a levee along Therry Street between Young Street and Burton Street.	Flood modification
S4	Excavation of the Bombala River floodplain in the area of “necking” downstream of Young Street.	Flood modification
S5	Construct weir on Bombala River to provide flood storage	Flood modification
S6	Voluntary house raising of flood affected properties, such as residential dwellings in Caveat Street.	Property modification
S7	Installation of floodgates on all stormwater outlets to the river	Flood modification
S8	Construction of a levee to prevent flooding of land between the river and Jonas Street	Flood modification
S9	Construction of a levee from the end of Mort Street across the low lying land to McKeachie Street.	Flood modification
S10	Construction of a levee / filling of the rifle range site located north-east of Stephen Street	Flood modification
S11	Construction of stormwater retarding basins in the town area	Flood/ Stormwater modification
S12	Installation of culverts to capture and divert stormwater	Flood/ Stormwater modification

TABLE 4 CONSIDERED FLOOD PLANNING OPTIONS

OPTION	DESCRIPTION OF ACTIONS ASSOCIATED WITH OPTION	Floodplain Development Manual Classification
P1	Review of flood related planning instruments, including Council policies related to flooding, infill development and existing land use zones.	Property modification
P2	Voluntary house purchase of flood affected properties	Property modification
P3	Development/review of existing Flood Warning System including possible replacement of damaged/off-line streamflow gauges	Response modification
P4	Establishment of a database listing flood affected properties	Response modification
P5	Review of stormwater drainage infrastructure maintenance program	Property modification

7. ASSESSMENT OF SELECTED FLOOD DAMAGE REDUCTION OPTIONS

7.1 OPTIONS FOR INVESTIGATION

A floodplain risk management study is a multi-disciplinary process that needs to consider a number of different factors to develop an appropriate mix of management options to deal with the flood risk (*NSW Government, 2005*). Each floodplain risk management option will have both advantages and disadvantages. The purpose of the floodplain risk management study is to quantify the relative merits of each option, giving consideration to any flooding, social, economic and environmental consequences.

To assess the merits of each of the options identified for further investigation in **Section 7.2**, hydraulic modelling and a cost benefit analysis was completed.

The damage assessment documented in **Section 5** established that the single occurrence of the design 1% AEP flood would lead to damages amounting to **$4.7M**. This damage cost does not account for intangibles, which have the potential to be as much again.

The flood damages database, which provides the basis for estimating damages is included at **Appendix B**.

The results of the analysis also indicate that the Average Annual Damage for all events up to the extreme flood is in the order of **$375,300**. That is, funds in the order of $375,300 would need to be put aside each year on average, in order to cover the damage bills that could be incurred as a consequence of flooding.

The preferred options include a range of structural works and planning options. The structural (*flood modification*) options are shown indicatively in **Figure 8**.

The following chapter details the investigation of each structural option, including the benefits and dis-benefits arising from their installation and the cost to implement. This has been undertaken for the purpose of identifying those structural options that provide the greatest cost-benefit to Bombala. The methodology employed to undertake this assessment is discussed in **Section 7.2**.

7.2 PRELIMINARY ASSESSMENT OF STRUCTURAL OPTIONS

A preliminary assessment of the proposed flood damage reduction options was undertaken during a Floodplain Management Committee Meeting on 20th June 2012. During the meeting, the feasibility and qualitative benefits associated with the various options were considered in the context of the projected damage for existing conditions and the response to the community consultation. This led to a refinement of the list of options, which is discussed following.

7.2.1 Options Not Included for Further Investigation

The right-bank levee which extends parallel and south of Mahratta Street (*Option S2*), Jonas Street levee (*Option S8*), Mort Street levee (O*ption S9*) and filling of the rifle range (*option S10*) are targeted towards either protecting a small number of existing developments from flooding or else raising land to facilitate creation of new development (*refer* **Table 3** *and* **Figure 8**).

However, in the case of the right-bank levee (*optionS2*), Jonas Street levee (*option S8*) and Mort Street levee (*option S9*), significant civil works which involve importing large quantities of fill are required to install a flood damage reduction measure which will protect at most 2 of 3 properties. Therefore, it was agreed that other flood protection measures such as voluntary house raising might be better suited to achieving economic flood protection of these areas. Conversely, the filling of the rifle range (*Option S10*) was associated with creating potential future development scenarios. The Floodplain Management Committee agreed that a full assessment of this option was not warranted at this time.

Similarly, it was decided that while the installation of floodgates (*option S7*) may be a worthwhile to investigate to prevent nuisance flooding from occurring, in the absence of a levee structure, floodgates alone would not make a notable reduction to existing flood levels.

Therefore, these particular flood damage reduction options were not considered for further assessment.

7.2.2 Options Included for Further Investigation

Through consideration of the distribution of flood damages within Bombala, including a qualitative consideration of flood damages associated with run-off from local storm events within the town area, and the response provided by the local community during the consultation phase of the Floodplain Risk Management Study, it was decided that removal of Willow Trees along the right bank downstream of the township (O*ption S1*), Therry Street levee (O*ption S3*), excavation of the Bombala River (*Option S4*), a flood storage weir on the Bombala River (*Option S5*), Voluntary House Raising (O*ption S6*), stormwater retarding basin (*option S11*) and installation of culverts (*Option S12*) warranted further investigation. A detailed investigation of each of these options is provided in **Section 7.4** and **Section 7.5**.

7.3 METHODOLOGY FOR ASSESSMENT OF STRUCTURAL OPTIONS

7.3.1 Hydraulic Assessment

The hydraulic benefit and dis-benefit that would be afforded by each option was determined using the RMA-2 flood model that was originally developed as part of the *'Bombala Flood Study and Overland Flows Investigation'* (*2010*). Different versions of the RMA-2 flood model were developed for each option and each was used to simulate flooding for the scenario where each of the proposed option is in place.

In some cases, the RAFTS hydrologic model that had been used to analyse the flood hydrology for the Flood Study was employed to determine the impact of the proposed structural option. This approach was appropriate where storage is a consideration, such as Option S5.

The impact of each option was then quantified by developing flood level and flow velocity difference mapping. Difference maps are created by comparing peak flood level and flow velocity estimates at each node in the RMA-2 flood model from simulations undertaken for both existing and post-development (*i.e., incorporating the proposed management options*) scenarios. This effectively creates a contour map of predicted changes in peak flood levels and flow velocities and allows easy determination of the impact that each proposed management option is likely to have on existing flood behaviour and characteristics.

The impact of each option on peak flood levels (*measured as increases and decreases in peak flood level*) are shown in **Figures 9** to **12**. It should be noted that velocity difference mapping has not been prepared. An assessment of the modelling results established that changes in velocity for each of the options were relatively minor. Therefore, velocity difference mapping was not warranted.

In addition, a RAFTS hydrologic model which represents run-off from the local catchment that falls within the Bombala township was used to assess the effectiveness of Option S11 and S12, which are targeted towards managing local overland flows.

7.3.2 Benefit - Cost Assessment

A benefit-cost analysis was also undertaken to assess the economic viability of implementing the proposed flood management options. The cost of construction works was estimated and compared with the predicted monetary benefit offered by each option in terms of the potential reduction in flood damages. Direct and indirect costs were included in the damage cost estimates. All damage costs are expressed in 2012 dollars.

An initial assessment of the viability of each of the options was undertaken by simulating the 1% AEP event and comparing the reduction in flood damages associated with the 1% AEP event with existing conditions, in the context of the cost of the proposed works. Where the results indicated that a reduction in damages had been achieved which was comparable to the cost of the works, a complete cost benefit analysis was undertaken for the option.

However, in some instances, the preliminary assessment established that it was apparent the option either generated negligible reductions, or else would cost an excessively large amount to warrant further investigation.

Where a complete cost-benefit analysis has been carried out, the reduction in flood damages has been determined on the basis of the reduced level of flooding that would occur if the respective options were implemented over the full range of design floods; that is, for all standard floods between the 20% AEP event and the PMF.

7.4 INVESTIGATION OF STRUCTURAL OPTIONS WHICH ADDRESS MAINSTREAM FLOODING OF THE BOMBALA RIVER

7.4.1 Option S1 – Removal of Willow trees along the river bank

Option Description

A copse of Willow trees line the northern bank of the Bombala River downstream of the Bombala town centre. There is concern that the dense foliage of the trees decreases the capacity of the main channel of the Bombala River during flooding, thereby raising flood levels upstream.

Option S1 involves the removal of the Willow trees between Young Street and Bright Street. The trees identified for removal are shown in **Figure 9**. For Option S1 any Willow trees with foliage below the level of the 1% AEP event would be removed.

Hydraulic Assessment

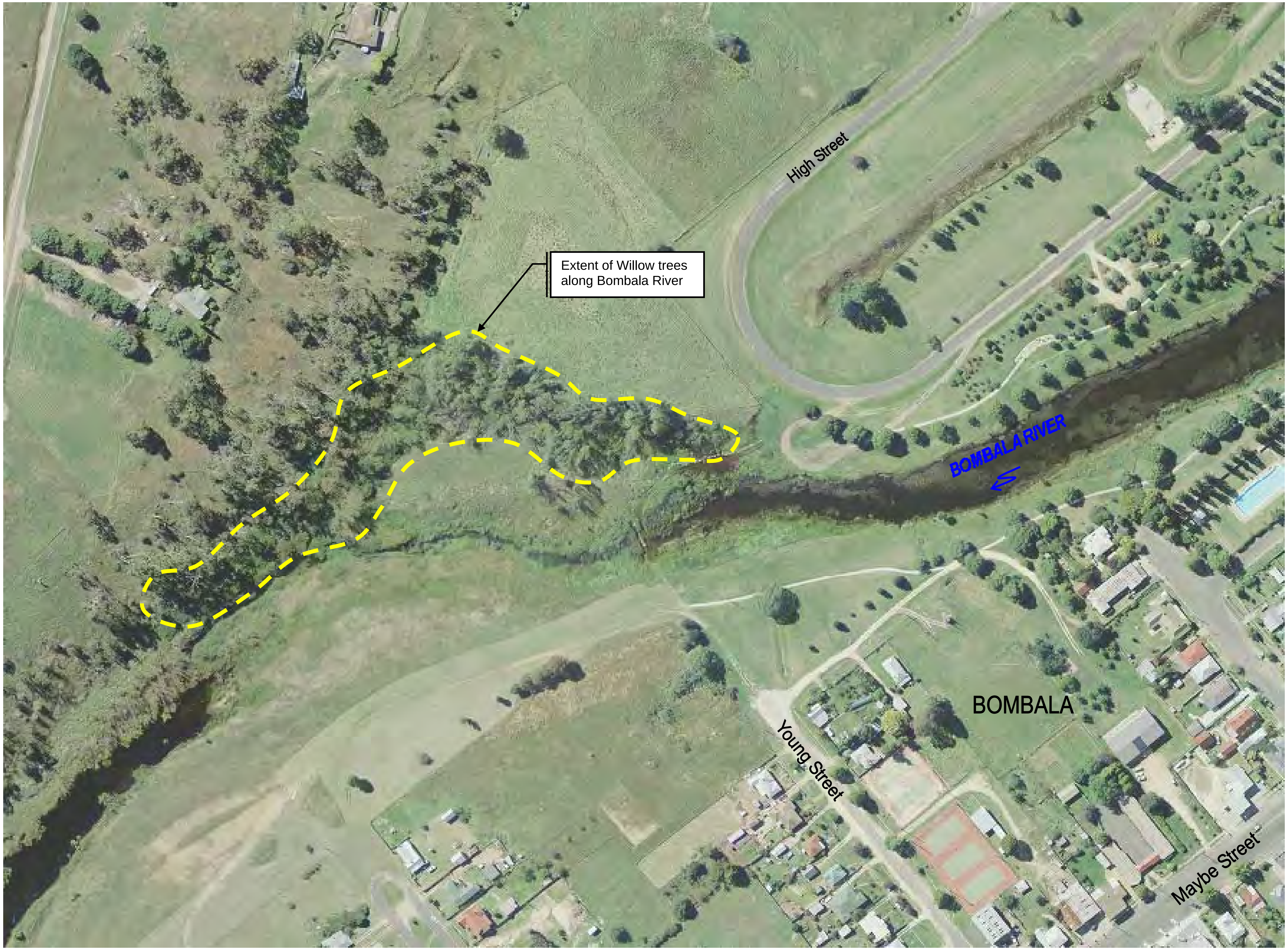
In the RMA-2 hydrodynamic model a Manning's 'n' value is assigned to different types of land use. The Manning's 'n' is a measure of the "roughness" of the floodplain and represents the extent to which a particular type of land use will impede flow. The adopted values for Manning's 'n' were previously determined by calibrating the RMA-2 hydrodynamic model to historical flood events. This process is described in detail in the '*Bombala River Flood Study and Overland Flows Investigation*' (*2010*).

To assess the impact of Option S1 on flooding in the Bombala River, the adopted value for Manning's 'n' was modified to reflect the roughness of the channel with the trees removed. The RMA-2 model was then used to re-simulate the 1% AEP flood event with the adopted terrain roughness.

The results of the modelling have established that the removal of the trees will result in no discernable change on peak 1% AEP flood levels in the Bombala River. It is generally expected that the benefits would be more notable during a rarer flood event. However, in recognition that potential benefits may be gained for a smaller flood event, the revised model was used to simulate the benefits to flooding associated with the 20% AEP event. This also established that there was no discernible reduction in flood levels associated with this option.

The trees are located in a section of the Bombala River where the channel diverges and subsequently converges. The trees line the northern bank of the river covering a relatively small area of the section of river channel affected by the 1% AEP flood. The results of the modelling suggest that the influence of the trees on channel capacity is relatively minor.

FIGURE 9



LOCATION OF WILLOW TREES BETWEEN YOUNG AND BRIGHT STREET IDENTIFIED FOR REMOVAL IN OPTION S1

Benefit - Cost Assessment

The removal of Willow trees from the banks of the Bombala River is not expected to affect flood levels in Bombala for the 1% AEP flood. The estimated cost of removing the Willow trees is approximately **$16,000**. While there is no apparent benefit to flooding associated with removal of the Willow trees, there may still be merit in the selective removal of the riparian vegetation when considered in the context of sustainable catchment management principles.

7.4.2 Option S3 – Flood Protection Levee Along Therry Street

Option Description

The Bombala town centre is located along Maybe Street on the southern side of the Bombala River. Flood modelling presented in the '*Bombala River Flood Study and Overland Flows Investigation*' (*2010*) indicates that most properties located between Maybe Street and the River will be inundated in the event of a 1% AEP flood.

Option S3 involves the construction of a levee along the southern bank of Bombala River. The levee is proposed to extend between Burton Street at the upstream end down to Cardwell Street. The length of the proposed levee would be approximately 1000 metres. The alignment and extent of the proposed levee is shown in **Figure 10**. At the location where the levee crosses Forbes Street, some type of flood gate would be required.

The crest of the proposed levee would be constructed to a nominal elevation of 704.0 mAHD. This would afford protection during floods up to and including the 1% AEP flood event, with provision of a freeboard of 500 mm. The proposed levee would prevent floodwaters from inundating properties along the southern river bank during events up to and including the 1% AEP flood.

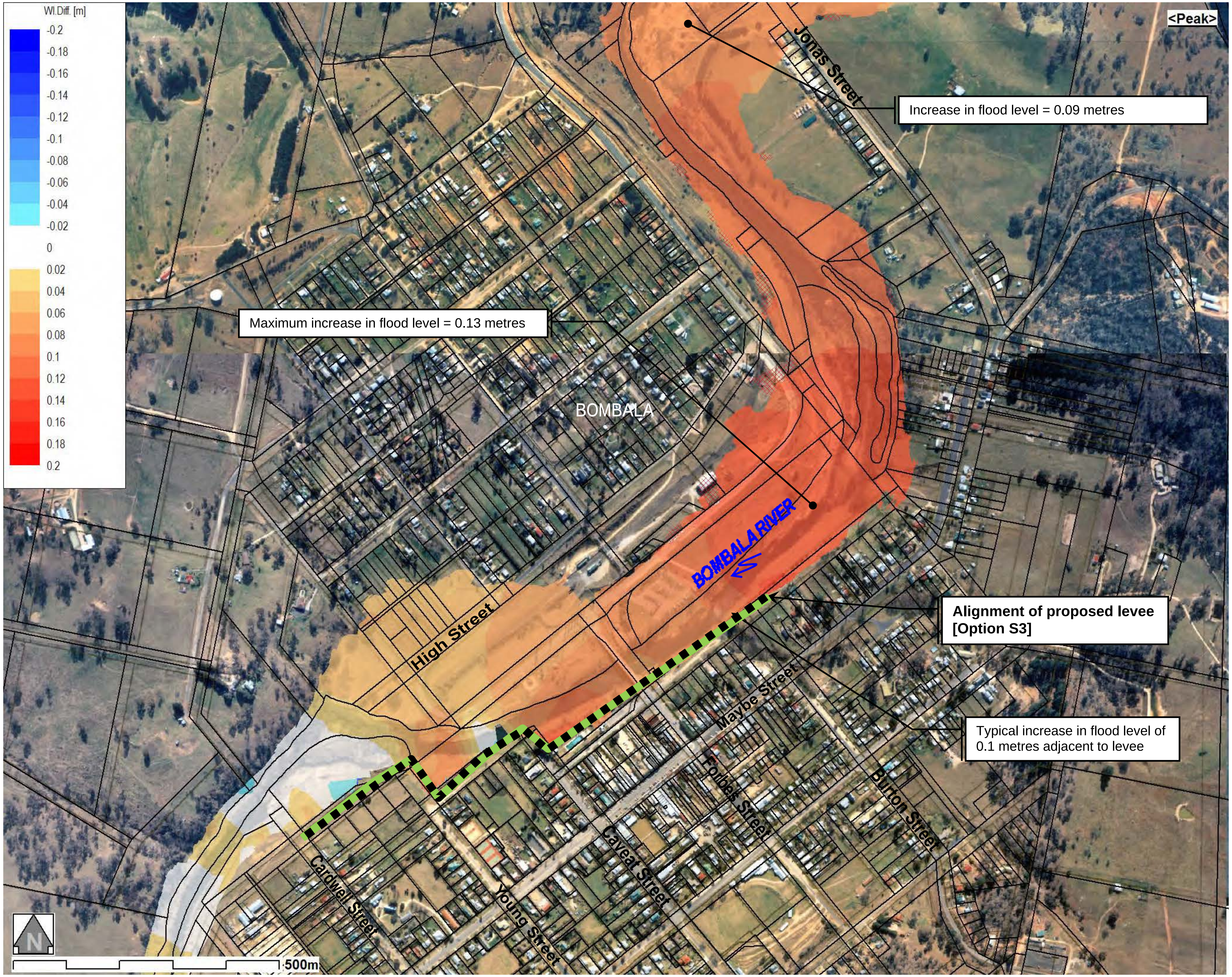
Hydraulic Assessment

The results of the flood modelling confirm that a levee constructed to a crest elevation of 704.0 mAHD will not be overtopped during all floods up to and including the 1% AEP flood event. The difference in flood levels generated by the proposed levee is shown in **Figure 10**.

The following conclusions can be drawn from the results of the flood modelling (*refer* **Figure 10**):

- The proposed levee would generate a maximum increase in peak 1% AEP flood level of about 0.13 metres. This is predicted to occur approximately 500 metres upstream of the Forbes Street Bridge (*refer* **Figure 10**).
- Typical increases in the order of 0.1 metres in the peak 1% AEP flood level are predicted for the township upstream of the levee. The impact on flood levels associated with the levee gradually decreases upstream of Jonas Street (*refer* **Figure 10**).

FIGURE 10



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PREDICTED CHANGES IN PEAK 100 YEAR RECURRENCE FLOOD DEPTHS FOR OPTION S3 [Levee along Therry Street]

- Construction of the proposed levee would result in a maximum localised increase in peak flow velocity of approximately 2.5 m/s. The maximum increase is predicted to occur adjacent to the levee near Caveat Street.
- Typical increases in the peak flow velocity of 1.8 m/s are also predicted near the Forbes Street Bridge. These increases in the flow velocity are contained within the river channel. Elsewhere, the increase in flow velocity is not considered to be significant.

Benefit - Cost Assessment

The results of the hydraulic analysis indicate that construction of the proposed Option S3 levee would result in a significant reduction in peak 1% AEP flood levels for sites along the southern side of the Bombala River.

The levee would result in relatively low increases in peak flood levels for the 1% AEP flood in areas upstream of the proposed alignment. The increase is generally constrained to areas within the river channel away from residential and commercial property. Notwithstanding, there is predicted to be an increase in 0.09 metres at a single property.

An assessment of the benefits associated with implementing Option S3 was undertaken and compared to the estimated capital works cost. The assessment was based on consideration of the benefits and dis-benefits of the 20%, 5%, 2%, 1% and 0.5% AEP flood events and the probable maximum flood (*PMF*). The outcomes are summarised in the following:

- Option S3 would cost about $3,400,000 to construct. This does not allow for life cycle costs including maintenance and repairs due to damage during a flood. However, there may be opportunities to significantly reduce the amount of fill required to construct the levee if sections were situated on private property in contrast to the crown land on the river bank.
- With Option S3 in place, the annual average flood damage in the township of Bombala will reduce to $212,720. This represents a reduction of about $162,620 in the average annual cost of flood damages for Bombala. Considered over a design life of 30 years, this equates to a total benefit of $2,500,000. Therefore, the benefit – cost ratio for this option is approximately 0.71.

The results of the flood modelling indicate that implementation of Option S3 would result in increases in peak 1% AEP flood level of up to 0.13 metres. Increases of this magnitude, while significant, would need to be considered in the context of the adversely affected property and the potential means to mitigate this impact.

In addition, there may be opportunities to increase the cost benefit ratio of this option. One alternative may involve optimising the length of the levee in a manner that affords maximum protection to flood affected properties. This may involve truncating the levee at Young Street, beyond which it does not afford protection to a significant number of properties.

However, this would need to be undertaken in a manner such that the levee continues to protect the remaining at risk properties.

7.4.3 Option S4 – Excavation of the Bombala River Floodplain

Option Description

The Bombala River floodplain straightens through an area of necking approximately 1000 metres downstream of the Forbes Street bridge crossing. During major flood events, the channel capacity through this section of the floodplain causes floodwaters to partially back up through the township. The location of the channel section is shown on **Figure 11**.

For Option S4 an increase in the channel capacity which currently constricts flow is proposed. This will involve excavating the floodplain to increase the flow capacity of the channel and reduce flood levels upstream.

The proposed option will involve widening of the floodplain along a 600 metre long section of channel, requiring excavation of approximately 42,000 cubic metres of bank material. The location of the proposed cut is shown on **Figure 11**. This is equivalent to increasing the width of the floodplain channel (i.e. that section of the floodplain which will convey flood events greater than the 20% AEP flood), by approximately 10 metres on either side of the channel.

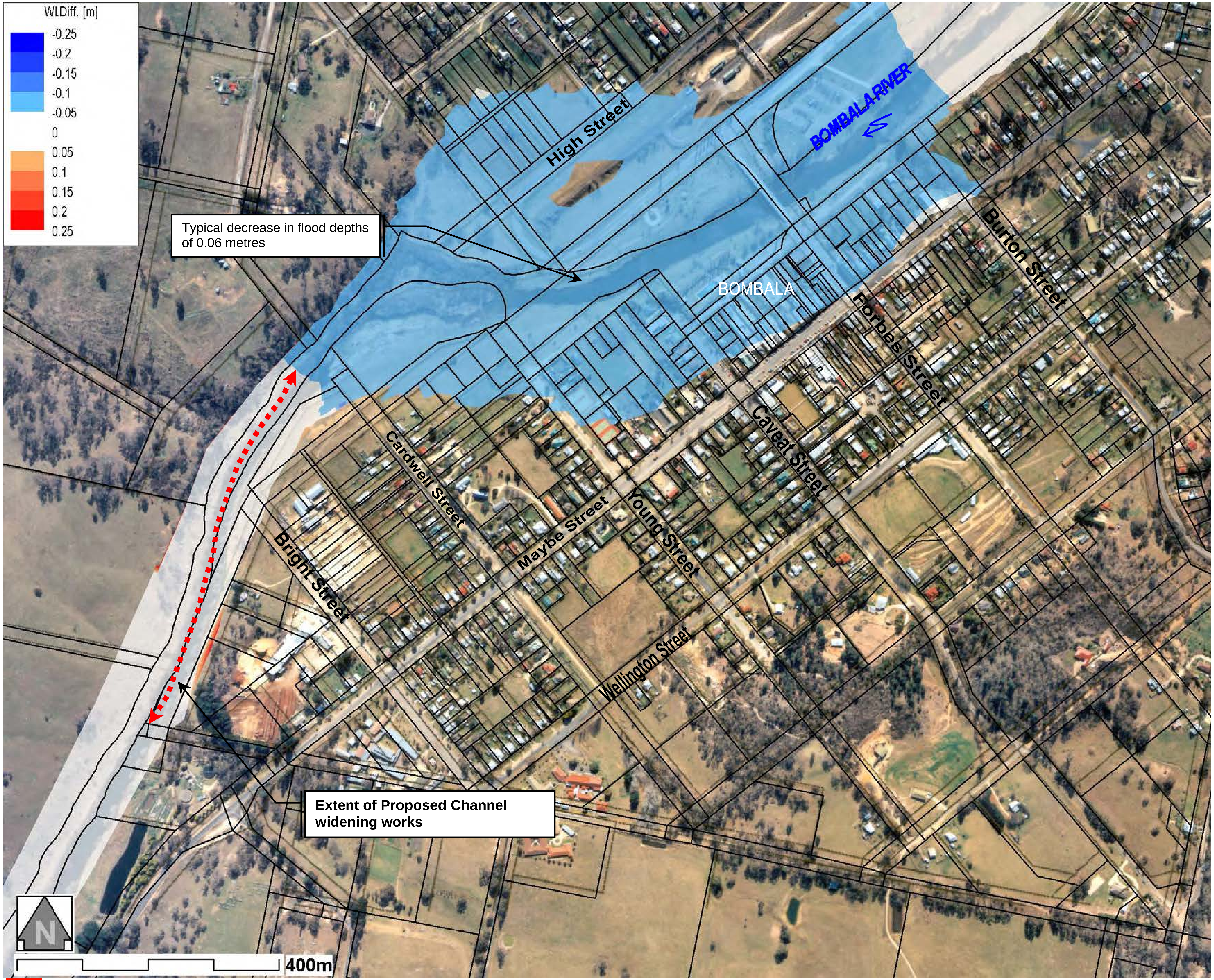
Altering the flow characteristics of a natural channel may result in unforseen changes to the channel section due to the changes in the regime of the river. By restricting the extent of excavation to the overbank area, the impacts to normal flow conditions are minimised. The proposed channel upgrade in Option S4 would limit such that the flow capacity of the channel is increased with minimal impact on more frequent flood events.

Impact on Flooding

The results of hydraulic analysis indicate that the proposed widening of the Bombala River channel would result in decreased peak flood levels extending up to 4 kilometres upstream from the proposed channel widening works. Implementation of Option S4 would result in a maximum decrease in the peak 1% AEP flood level of approximately 0.07 metres, occurring adjacent to Young Street.

Benefit-Cost Assessment

The cost of undertaking Option S4 is estimated to be approximately **$3,200,000**. This figure is based on construction costs outlined in *Rawlinson's Australian Construction Handbook Edition 29, 2012*.



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PREDICTED CHANGES IN PEAK 100 YEAR RECURRENCE FLOOD DEPTHS FOR OPTION S4 [Excavation of Bombala River Channel]

The construction of Option S4 would result in a decrease in damages resulting from the 1% AEP flood of approximately **$88,380**. While a detailed cost – benefit analysis considering all flood events has not been calculated, this suggests that this option is unlikely to be cost effective. At such a low payoff, Option S4 is not considered a viable flood risk management measure.

One of the significant costs associated with Option S4 involves off-site disposal of any excavated material. It is likely that some portion of the cost of disposing of the excavated bank material could be offset if both Options S3 and S4 were implemented. This is because material cut from the banks in Option S4 could be deposited as fill for the levee in Option S4. This option has not been investigated in detail, but it could be considered as a potential measure to improve the cost effectiveness of the Option S3.

7.4.4 Option S5 – Flood Detention Structure on the Bombala River

Option Description

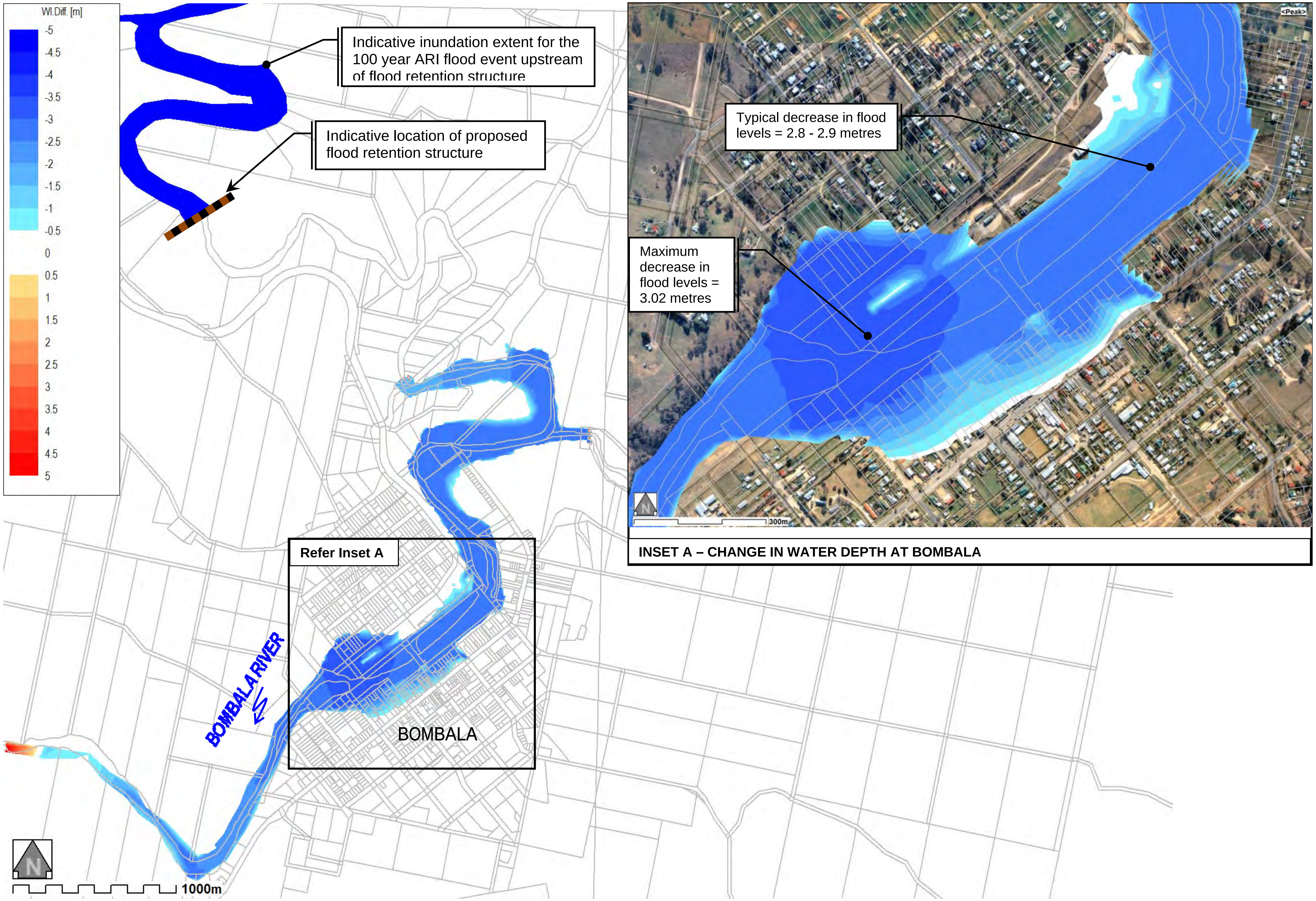
Option S5 involves the construction of a flood detention structure on the Bombala River upstream of the Bombala township. The structure would operate at low storage levels under normal operating conditions in order to provide capacity to retain floodwaters in the event of a large flood. The structure would best be described as a dam, given the volume of flow required to be stored.

An indicative location was adopted for the proposed dam, which is shown on **Figure 12**. It was necessary to adopt an indicative location since it is necessary to understand the likely potential for the dam to store water.

However, the location of the dam would be contingent upon a comprehensive investigation of the upstream river reach to identify the most cost effective location to build the structure. This would include geological field surveys to identify appropriate base and abutments for the weir/dam structure, locations where storage could be optimised for a minimum height and consideration of suitable crown land.

The proposed dam was investigated assuming a Full Supply Level (FSL) of 720.0 mAHD. The proposed FSL is approximately 13 metres above the current minimum level of the river bed at the proposed location. This proposed FSL corresponds to a storage volume of approximately 5,475.0 ML, which would be sufficient to capture run-off from the sub-catchment draining to the dam site which is equivalent to a 20% AEP storm event. The approximate length of the crest of the dam is 165 metres.

FIGURE 12



PREDICTED CHANGES IN PEAK 100 YEAR RECURRENCE FLOOD DEPTHS FOR OPTION S5 [Flood Retention Structure on Bombala River]

Impact on Flooding

The proposed dam would normally operate with a low storage volume. Since the purpose of the dam is to store floodwater during extreme flood events, the dam must operate with sufficient excess storage capacity to retain significant volumes of flow from the Bombala River.

The hydrologic model of the Bombala River catchment upstream of the township was refined to include the retention capacity of the proposed dam. The updated RAFTS model was used to re-simulate the 1% AEP flood with the proposed dam in place. From the results of the modelling, the new discharge hydrograph for the 100 year design flood in the Bombala River sub-catchment was extracted from the model, included as an upstream boundary condition in the hydraulic model. The model was then used to re-simulate the 1% AEP flood event.

The results of the modelling show that the dam would significantly reduce the flood impacts in the Bombala. The results of the modelling suggest that only the rear of particular properties along Maybe Street would continue to be affected by flooding during the peak of the 1% AEP event.

Benefit-Cost Assessment

The cost of constructing the flood detention structure at the indicative location to a maximum level of 720 mAHD is estimated to be in the order of $15 to $30 million. This estimate is based on the actual construction costs of several comparably sized dam structures together with an estimate of the volume of fill required to construct the proposed structure.

Construction of the proposed dam is estimated to result in a decrease in 1% AEP damage from $4,730,000 to $16,300. While all the flood events have not been modelled, it is estimated that the reduction in annual average damages would be in the order of at least $225,000 per year, meaning the proposed structure will provide significant benefit. The present value of the reduction in annual average damage is in the order of $3.6 million (*assuming a discount rate of 5% over 50 years*).

However, given the cost associated with construction, this suggests the cost-benefit ratio for Option S5 is between 0.1 and 0.2 (*assuming a cost of $15 million and $30 million respectively*).

For this reason, this option does not appear to be viable. It is noted that a smaller structure, could be constructed, however this would lead to a reduction in the effectiveness of flood damages. Due to the nature of the cost of constructing major river works, it is expected that a smaller structure would lead to a comparatively lower cost benefit to flooding. However, there may be merit in this option if it were considered in conjunction with another objective, for example improving water security for Bombala and/or other towns.

7.4.5 Option S6 – Voluntary house raising of flood affected properties

Option Description

House raising is a process in which an existing structure is separated from its foundation and elevated by hydraulic jacks to a desired elevation. In general, an increase in the floor level of 3 metres (equivalent to one floor) is targeted. A new foundation is then constructed beneath the raised structure. The cost of raising a structure depends on several factors, such as the size of the building, construction material and the type of foundation. For example, the cost of raising a single storey, non-brick house on a pier foundation to a height of roughly 3 metres is typically in the order of $40,000-$50,000. Other types of houses become more complicated, however there is still potential to raise these houses also.

House raising is an option offered to residents on a voluntary basis. Council subsidies are offered to residents based on the severity of the risk of flooding for each property. Even if this option is not pursued by a particular resident, the ongoing offer of a subsidy by council may influence the future saleability of the property, as prospective purchasers consider potential flood risks. Government grants are also sometimes available for house raising.

Impact on Flooding

House raising will reduce the damages associated with flooding for a particular property by elevating the dwelling above the level of flooding. The raised floor level of the dwelling is typically elevated above the 1% AEP flood level.

House raising does not entirely mitigate flood risks at individual properties. Residents are more likely to remain in a raised house during flood events and therefore are exposed to the hazards inherent during major flooding. Potential for flood damages still remains during extreme flood events where peak levels exceed the floor level of the raised structure.

Benefit-Cost Assessment

As discussed in **Section 5**, potential damages to individual properties in Bombala during a range of flood events were estimated. This assessment of flood damages was used to compile an average estimate of the average annual damage (*AAD*) for each structure.

A preliminary cost assessment was prepared for Option S6 based on the estimated cost of raising dwellings located within the influence zone of the probable maximum flood (*PMF*). The estimated cost of raising each building was compared to the reduction in annual average damage resulting from undertaking voluntary house raising.

Twelve residential dwellings were estimated to have a positive net present value in undertaking voluntary house raising above the 100 year flood level. The total cost of raising all twelve dwelling approximately 3 metres above existing levels is in the order of **$600,000**. The estimated reduction in AAD achieved by undertaking Option S6 is **$96,000**. Assuming a remaining life of 30 years for each building and a discount rate of 5%, the estimated net present value of undertaking Option S6 is **$888,000**.

7.5 INVESTIGATION OF STRUCTURAL OPTIONS TO MANAGE OVERLAND FLOWS

In addition to the flood risk posed by riverine flooding, the issue of run-off which is generated during short duration high intensity storm events was also investigated as part of the *Bombala Flood Study and Overland Flows Investigation*. This included investigating a number of "trouble spots", which were identified in the local township.

Two particular trouble spots were nominated for further investigation as part of the Bombala Floodplain Risk Management Study. These trouble spots are identified as "Trouble Spot 1", which relates to local catchment flooding of the area in the vicinity of the intersection of Forbes and Maybe Streets, and "Trouble Spot 3", which relates to an overland flow path that drains an area between Young Street and Cardwell Street. The location of these trouble spots is identified on **Figure 13**.

Investigations undertaken for the Flood Study established that the existing drainage system had limited capacity to convey run-off. Significant surcharging would occur during both the 5% and 1% AEP events. This indicates that improving the existing drainage problem by augmenting the capacity of the sub-surface drainage system would be cost prohibitive.

For this reason, it was decided a more viable option would be to investigate the effectiveness of installing stormwater detention basins within the local township, which could act to reduce the peak of the run-off which arrives at the bottom of the township. This is discussed in more detail in the following sections.

In addition, the effectiveness of installing additional culverts at the end of Queen Street has also been considered.

7.5.1 Option S11A – Construction of a Stormwater Detention Basin At Bombala Showground

Option Description

The area of land which falls within the catchment area of Forbes and Maybe Street was investigated. The location of the detention basin proposed of Option S11A is shown graphically in **Figure 13**. The proposed detention basin would be designed to capture and store runoff from the local catchment draining to Wellington Street.

It would involve the construction of a 230 metre long bund along the lower, north-west perimeter of the Bombala Exhibition Ground. The bund would have a maximum height of 1.2 metres. The corresponding crest level of the bund would be 714.0 mAHD. A crest width of 1 metre and side-slopes of 1(V) in 3(H) have been adopted for the proposed embankment.

A 10 metre long spillway is proposed at the north-eastern corner of the showground with a crest elevation of 713.8 mAHD. The spillway would direct any overflow from the basin to the existing drainage channel which runs along Caveat Street. Suitable scour protection measures would need to be incorporated into the design, such as gabion mattresses.

FIGURE 13

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INDICATIVE LOCATION OF THE PROPOSED STORMWATER DETENTION BASINS IN OPTION S11 AND SUB-SURFACE DRAINAGE IN OPTION S12

Runoff from Burton Street drains into stormwater pits located at the intersection of Maybe Street and Forbes Street, which convey the runoff through a 750 mm diameter pipe to Bombala River. However, during extreme rainfall events, runoff has the potential to exceed the flow capacity of the pipe, which will run-off to back up and overflow. The *'Bombala Flood Study and Overland Flow Investigation'* (*2010*) identifies two structures at this intersection which experience inundation due to overland flow. The proposed detention basin would be constructed with the intention of reducing peak overland flows at the intersection of Maybe and Forbes Street.

Impact on Flooding

The proposed detention basin was incorporated into the local catchment RAFTS-XP hydrologic model that was developed as part of the Flood Study. The design parameters of the proposed basin were based on consideration of the topography in the vicinity of the Bombala Exhibition Ground.

The maximum volume of run-off that could be retained by the basin would be approximately 1,800 m^3. The corresponding peak level of ponding is expected to be 713.8 mAHD, meaning that a nominal freeboard of 200 mm will be provided between this level and the bund crest. Given the length of the crest, overtopping, if it occurs, will not be to a substantial depth.

The proposed detention basin has a capacity to retain runoff such that the peak discharge for the 1% AEP event which arrives at the intersection of Maybe and Forbes Street is reduced from approximately 13.4 m^3/s to 11.7 m^3/s. This is a reduction in peak discharge of 1.7 m^3/s (*or approximately 13%*). For the 5% AEP event, the peak discharge arriving at this location is predicted to reduce from 9.9 m^3/s to 8.8 m^3/s.

The limited reduction in the peak flow associated with the Option S11A can be attributed to the location of the proposed detention basin relative to the overall sub-catchment area draining to the intersection of Maybe Street and Forbes Street. That is, the location of the proposed detention basin only intercepts approximately one third of the total catchment area draining to the Forbes Street/ Maybe Street intersection. Therefore, it has no potential to intercept flows downstream, which are also more significant since it represents a more urbanised catchment. Ideally, the detention basin would be located further closer to the affected areas, however this is limited by existing development.

The peak flow capacity of the sub-surface drainage, located along Forbes Street, is in the order of 1.5 m^3/s. This represents the flow conveyance capacity of the pipeline prior to surcharge of the stormwater pits. Therefore, there will remain a significant proportion of run-off which is conveyed by the overland flow paths during major flood events.

It is estimated that the cost of Option S1(A) would be **$140,000**. A break-down of this estimate is provided in **Appendix E**.

7.5.2 Option S11B – Construction of a Stormwater Detention Basin adjacent to Caveat Street

The potential to reduce run-off through Trouble Spot 3 was also investigated. This involved investigating the effectiveness of a detention basin in the upper catchment area draining to Maybe Street.

Option Description

Initially, a number of different locations were considered for the proposed detention basin. It was decided to investigate the effectiveness of a detention basin located near the intersection of Caveat Street and Alma Street. The location of the proposed detention basin for Option S11B is shown graphically in **Figure 13**. The detention basin would have the potential to pick up run-off from slightly more than half of the total local catchment draining to Maybe Street

It would involve the construction of an embankment across a natural drainage path. The proposed location of the detention basin is shown in **Figure 13**. The crest level of the embankment would be 740.0 mAHD.

A crest width of 1 metre and side-slopes of 1(V) in 3(H) have been adopted for the embankment. The maximum base width would be about 25.0 metres.

Construction of the embankment would also involve the excavation of the basin base down to 736 mAHD in some areas of the basin (*refer* **Figure 13**). The volume of excavations will be approximately 7,000 m^3, with the intention of balancing cut and fill requirements. The proposed basin is estimated to have a storage capacity of approximately 14,000 m^3.

A spillway be installed with a crest elevation of 739.8 mAHD to convey excess run-off downstream and avoid overtopping of the embankment. The spillway would direct any overflow from the basin to the existing drainage channel along Caveat Street. The design would also include appropriate scour protection, such as gabion mattresses.

Impact on Flooding

The proposed detention basin is predicted to reduce the volume of run-off which arrives at Trouble Spot 3 during the 1% AEP event from 25.0 m^3/s to 20.8 m^3/s. This represents a reduction in peak discharge of 4.2 m^3/s, equivalent to a 17 % reduction. During the 5% AEP event, the proposed detention basin is predicted to reduce the peak discharge from 17.2 m^3/s to 14 m^3/s. This equates to a reduction in peak run-off of 3.2 m^3/s, equivalent to 18%.

The detention basin would be designed with a configuration that would limit the peak discharge down Caveat Street. The *'Bombala Flood Study and Overland Flow Investigation'* (*2010*) identifies a low point on Wellington Street from which runoff is conveyed toward Maybe Street. During heavy rainfall, runoff in this overland flow path has been known to inundate properties including the Toyota dealership on Maybe Street.

It is estimated that the cost of Option S1(A) would be **$420,000**. A break-down of this estimate is provided in **Appendix E**.

7.5.3 Option S12 – Install Additional Culverts at the Intersection of Queen Street and Stephen Street

Option Description

Option S12 would involve constructing additional sub-surface drainage infrastructure to convey overland flow from the intersection of Queen Street and Stephen Street into the Bombala River.

Under the present configuration, twin 600 mm diameter pipes convey runoff from the northern side of Queen Street beneath Stephen Street and into the Bombala River.

The *'Bombala Flood Study and Overland Flow Investigation'* (*2010*) identified that during heavy rainfall, runoff overtops the gutters on the southern side of Queen Street, inundating properties on Stephen Street, near Queen Street.

Option S12 would involve the installation of a swale which connects to an additional stormwater pit on the southern side of Queen Street to capture runoff before it enters the properties on Stephen Street. Two 600 mm diameter pipes would convey the run-off beneath Stephen Street.

The proposed pipe system would have sufficient capacity to reduce the overland flow along Queen Street during the 5% AEP storm to below the level of the street gutters. This would greatly reduce the potential for nuisance flooding of properties on the southern side of Queen Street.

The installation of a stormwater inlet pit and associated piping would be required on the southern side of Queen Street to capture runoff that flows along Queen Street (*refer* **Figure 13**). Construction involves the excavation and backfilling of trenches for the pits and pipes, including resurfacing the Monaro highway for the section under which the pipes would pass.

Impact on Flooding

As discussed, Option S12 would be configured in such a way as to capture and convey run-off, thereby limiting the peak overland which discharges across properties on Stephen Street. The peak flow carried by the additional pipe system would be about 1.2 m^3/s (*not allowing for blockages*). The configuration and design of the surcharge pits at Queen Street should be such that the potential impact of any discharges on nearby properties are minimised.

The implementation of Option S12 is estimated to cost about **$45,000**. A break-down of this cost is provided in **Appendix E**.

7.6 DISCUSSION

As discussed, a preliminary assessment of each of the structural damage reduction measures was undertaken, using the 1% AEP damage reduction as a reference point. Where there a reduction in the damages was generated which was comparable to the cost, the item was nominated for further investigation. The summary of the reduction in 1% AEP damages is provided in **Section 7.6.1**. A complete benefit – cost analysis for selected options is provided in **Section 7.6.2**.

7.6.1 Preliminary Assessment of Flood Damage Reduction Options for Bombala River Flooding

A summary of the predicted damages and associated reduction in damages for each of the options investigated which relate to riverine flooding is provided in **Table 5**. It is noted that the results presented in **Table 5**, are based on an assessment of the 1% AEP event only. This provides an indication of whether an option is considered to be viable or not.

Of the options investigated, the results indicate that further investigation of the removal of Willow Trees along the right river bank (O*ption S1*)and the excavation of the Bombala River (O*ption S4*) is not warranted since the reduction in flood levels and the associated damage reduction is relatively insignificant. Conversely, although the Bombala River flood storage structure (*option S5*) generates a significant reduction in flooding throughout Bombala, the comparative cost involved in building the required structure is considered too great to warrant further investigation.

The results also suggest that both the Therry Street levee (*Option S3*), involving construction of a levee along Therry Street, and targeted Voluntary House Raising (*Option S6*), associated with voluntary house raising both achieve significant reductions in the cost of flooding in combination with a reasonable capital works cost. Therefore, a cost benefit assessment, taking into account the reduction in flood damages across the full range of flood damages and calculating the reduction in Annual Average Damages associated with flood modelling has been undertaken. The results of this investigation are reported in **Section 7.6.2**.

Table 5 COMPARISON OF RIVERINE FLOOD DAMAGE REDUCTION OPTIONS FOR THE 1% AEP EVENT

OPTION (*refer* Figure 8)	PREDICTED DAMAGE ASSOCIATED WITH 1% AEP EVENT	PREDICTED REDUCTION IN DAMAGES ASSOCIATED WITH 1% AEP EVENT	CAPITAL COST OF WORKS	COMMENT
Option S1 Removal of Willow trees along river bank	$4,726,100	$0	$16,000	This option generates no discernible reduction in flood levels.
Option S3 Flood Protection Levee Along Therry Street	$905,000	$3,821,000	$3,400,000	The comparison between the reduction in damages and the cost of the capital works indicates this option merits further investigation
Option4 Excavation of the Bombala River Floodplain	$4,637,720	$88,380	$3,200,000	The small reduction in flood damages suggests this option is not viable
Option S5 Construction of flood detention basin on Bombala River	$16,300	$4,710,000	$15,000,000	The significant cost associated with construction of this option indicates it is not viable.
Option S6 Voluntary house raising of flood affected properties	$3,226,100	$1,500,000	$600,000	Relates to properties identified with a benefit cost above 1. Merits assessment of full AAD

7.6.2 Full Cost Benefit Assessment for Selected Options

As discussed in **Section 7.6.1**, two options are considered to merit a full cost benefit assessment. These options are Option S3, which involves construction of a levee along Therry Street and Option S6, which involves voluntary house raising.

The results of the full cost – benefit assessment is summarised below in **Table 6**.

Table 6 FULL BENEFIT-COST ANALYSIS FOR SELECTED FLOOD DAMAGE REDUCTION OPTIONS

OPTION (*refer* Figure 8)	REDUCTION IN ANNUAL AVERAGE DAMAGES ASSOCIATED WITH PROPOSED WORKS	NET PRESENT VALUE OF PROPOSED WORKS	CAPITAL COST OF WORKS	BENEFIT – COST RATIO
THERRY STREET LEVEE (OPTION S3)	$163,600	$2,500,000	$3,400,000	0.71
SELECTED VOLUNTARY HOUSE RAISING (OPTION S6)	$88,00	$888,000	$600,000	1.48

The results presented in **Table 6** indicate that Option S6 is economically viable, where appropriate properties are targeted. That is, there will be some properties within the township for which house raising is a cost effective measures. The results also suggest that Option S3 is not viable when considered purely from an economic perspective. However, there may be opportunity to review the existing alignment of the levee, which is currently located on crown land and allow sections of the levee to be constructed on higher ground, requiring less fill and thereby reducing the cost. This would be subject to consultation with the community.

Another alternative would be to limit the extent of the levee, which currently extends as far downstream as Cardwell Street. However, the majority of flood affected properties lie between Burton and Young Street and the cost effectiveness of the levee could be improved by reducing the total length. However, this would need to be considered in the context of the potential future development of the blocks directly affected by a reduction in the length of the levee.

Notwithstanding, both these options are considered appropriate to include as part of the Bombala Floodplain Risk Management Plan.

7.6.3 Flood Damage Reduction Options for Local Overland Flows

A full flood damages analysis has not been completed for the nuisance flooding experienced from run-off within the local catchment. However, a broad scale estimate of the benefit cost of the options which considers a qualitative assessment of the damages associated with overland flooding has been calculated in consideration of the appropriate guidelines.

Table 7 COMPARISON OF FLOOD DAMAGE REDUCTION OPTIONS WHICH ADDRESS NUISANCE FLOODING WITHIN THE LOCAL TOWNSHIP

OPTION (*refer* Figure 8)	EXISTING DAMAGES WITHIN THE LOCAL AREA AFFECTED BY FLOODING	PREDICTED REDUCTION IN DAMAGES ASSOCIATED WITH 1% AEP EVENT	CAPITAL COST OF WORKS	COMMENT
Option S11A	\$25,000 - \$50,000	\$5,000 - \$10,000	\$140,000	The cost to construct the basin would appear difficult to justify, based on the limited no. of properties directly inundated by flooding.
Option S11B	\$25,000 - \$50,000	\$5,000 - \$10,000	\$420,000	The cost to construct the basin would appear difficult to justify, based on the limited no. of properties directly inundated by flooding.
Option S12	\$10,000 - \$20,000	negligible	\$42,500	Could be undertaken as part of a drainage improvement program.

The results associated with the investigation indicate that on a benefit- cost basis, implementation of each of the above options could not be justified. However, there may be opportunities to pursue each of these options separately as part of a drainage improvement program.

8. HYDRAULIC AND HAZARD CLASSIFICATION

The personal danger and physical property damage caused by a flood varies both in time and place across the floodplain. Accordingly, the variability of flood patterns across the floodplain over the full range of floods, needs to be understood by flood prone landholders and by floodplain risk managers.

Representation of the variability of flood hazard across the floodplain provides floodplain risk managers with a tool to assess the existing flood risk and to determine the suitability of land use and future development. The hazard associated with a flood is represented by the static and dynamic energy of the flow, which is in essence, the depth and velocity of the floodwaters. Therefore, the flood hazard at a particular location within the floodplain, is a function of the velocity and depth of the floodwaters at that location.

The NSW Government's *'Floodplain Development Manual'* (*2005*), characterises hazards associated with flooding into a combination of three hydraulic categories and two hazard categories. Hazard categories are broken down into high and low hazard for each hydraulic category as follows:

- Low Hazard – Flood Fringe
- Low Hazard – Flood Storage
- Low Hazard – Floodway
- High Hazard – Flood Fringe
- High Hazard – Flood Storage
- High Hazard - Floodway

As a result, the manual effectively divides hazard into two categories, namely, high and low. An interpretation of the hazard at a particular site can be established from **Figure L1** and **L2** on the following page, which have been taken directly from the manual.

The first of these graphs shows approximate relationships between the depth and velocity of floodwaters and resulting hazard. This relationship has been used to define the provisional low and high hazard categories represented in the second of these plots.

8.1 UPDATED FLOOD HAZARD

Hazard mapping had previously been prepared for the Bombala River floodplain as part of investigations for the '*Bombala Flood Study and Overland Flows Investigation*' (*2010*). The flood hazard mapping was based on the Floodplain Development Manual (2005) and has been considered as part of the investigations for the Floodplain Risk Management Study. The adopted hazard criteria and hazard mapping is discussed in the following.

8.1.1 Adopted Provisional Hazard Categorisation

As shown in the **Figures L1** and **L2**, flood hazard is a measure of the degree of difficulty that pedestrians, cars and other vehicles will have in egressing flooded areas, and the likely damage to property and infrastructure. At low hazard, passenger cars and pedestrians (*adults*) are able to move out of a flooded area. At high hazard, wading becomes unsafe, cars are immobilised and damage to light timber-framed houses would occur.

Flood hazard is categorised according to a combination of the flow velocity and the depth of floodwater. The categories are defined by lower and upper bound values for the product of flow velocity and floodwater depth.

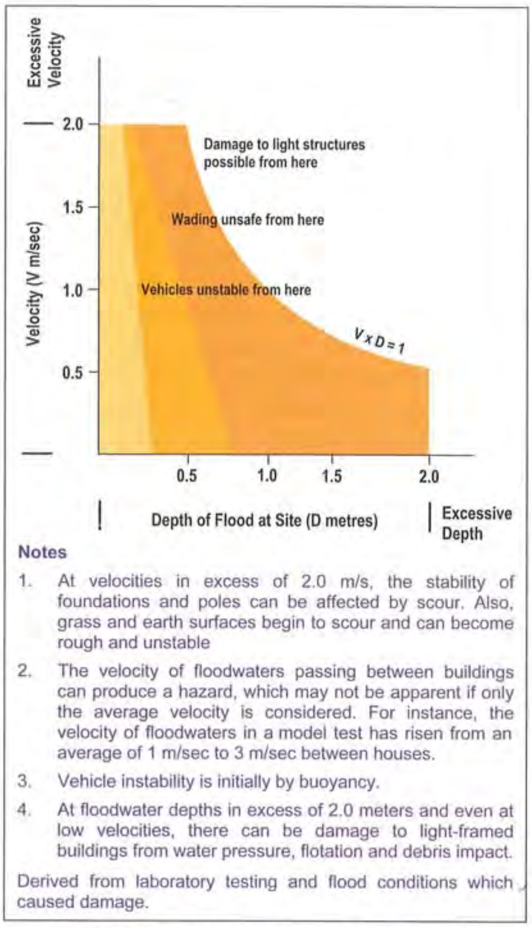

FIGURE L1 - Velocity & Depth Relationships

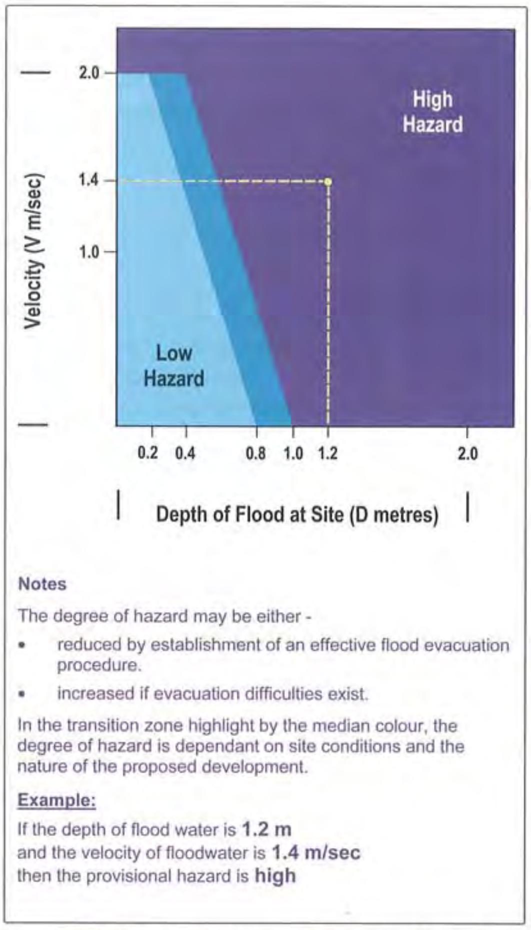

FIGURE L2 - Provisional Hydraulic Hazard Categories

Spatial and temporal distributions of flow, velocity and water level determined from the computer modelling undertaken as part of this study, were used to determine the flood hazard along the Bombala River floodplain.

Hence, for the purpose of understanding how the flood hazard affects existing development and areas of potential future development, it is useful to further subdivide areas falling within the high hazard category, into High Hazard, Very High Hazard and Extreme Hazard.

Similarly, the low hazard category defined in the manual has been subdivided to create a Low Hazard and a Medium Hazard category.

A summary of the criteria adopted for each hazard category is listed in **Table 8**.

Table 8 ADOPTED HAZARD CRITERIA

HAZARD CATEGORY	CRITERIA	PRACTICAL APPLICATION
Low	Depth (*d*) < 0.4 m & velocity (*v*) < 0.5 m/s	Suitable for cars
Medium	exceeding Low criteria, and $d \leq 0.8$ m, $v \leq 2.0$ m/s, and $v \times d \leq 0.5$	Suitable for heavy vehicles and wading by able bodied adults
High	exceeding Medium criteria, and $d \leq 1.8$ m, $v \leq 2.0$ m/s, and $v \times d \leq 1.5$	Suitable for light construction, timber frame, brick veneer etc.
Very High	exceeding High criteria, and 0.5 m/s < velocity < 4 m/s & $v \times d \leq 2.5$	Suitable for heavy construction, steel frame, concrete etc.
Extreme	exceeding Very High criteria and v > 4 m/s	Unsuitable for development – indicates significant conveyance of flow or floodway

8.1.2 Provisional Flood Hazard

The criteria presented in **Table 8** were used to develop provisional hazard mapping (*refer* **Figures 4** *and* **5**) for the floodplain of the Bombala River in the vicinity of Bombala. Results from the flood modelling that was undertaken for this study were combined with the hazard category criteria listed in **Table 8** to generate the flood hazard mapping.

Provisional flood hazard mapping generated for the 1% AEP flood is discussed in **Section 2.1**. The mapping indicates that a large proportion of the floodplain north of Maybe Street, between Young and Burton Street would be subject to a high to very high flood hazard. This includes a significant number of dwellings which are located within this section of the floodplain.

Only localised parcels of the floodplain and the main river channel are predicted to be classified as extreme hazard. An example of this is located at the very northern end of Young Street, where an extreme hazard classification coincides with a number of undeveloped parcels of land.

The hazard represented in this mapping is provisional only. This is because it is based only on an interpretation of the flood hydraulics and does not reflect the effects of other factors that influence hazard (*see clause L6 to Appendix L of the Floodplain Development Manual*). For example, access to an otherwise low hazard area may be through a high hazard area and this may present an unacceptable risk to life and limb and as such the provisional low hazard area may be changed to high hazard.

However, in this instance, all of the properties affected by flooding are located close to the edge of the floodplain. Due to the topography of Bombala, which is characteristic of a typical river valley, any evacuation would occur along a rising road access, for example evacuation along any of the roads which are aligned north –west to south- east such as Caveat Street or Forbes Street.

Furthermore, during the 1% AEP event, there is typically around 20 hours from the commencement of the rainfall event to when properties begin to be inundated. Similarly, there is approximately 3 hours between the river beginning to rise above cease to flow level and when these properties are inundated.

For these reasons, provisional hazard is considered to provide a reasonable representation of the “true” flood hazard at Bombala.

8.2 HYDRAULIC CATEGORIES

8.2.1 Adopted Hydraulic Categorisation

The NSW Government’s *‘Floodplain Development Manual’* (*2005*) also characterises flood prone areas according to the hydraulic categories presented in **Table 9**. The hydraulic categories provide an indication of the potential for development across different sections of the floodplain to impact on existing flood behaviour.

Unlike for the hazard categorisation outlined on the previous page, the *‘Floodplain Development Manual’* (*2005*) does not provide explicit quantitative criteria for defining hydraulic categories. This is because the extent of floodway, flood storage and flood fringe areas is largely dependent on the geomorphic characteristics of the floodplain in question.

Although there are no specific procedures for identifying or determining hydraulic categories, a rigorous methodology involving several stages of analytical analysis in conjunction with flood modelling has been developed by Thomas & Golaszewski (*2012*). This methodology has been applied with success to similar floodplains in NSW and has been shown to provide a robust procedure for defining floodway extent.

Most recently, this methodology was applied to the Lower Hastings River floodplain as part of investigations for the *‘Hastings Floodplain Risk Management Study*’ (*2012*),‘*Camden Haven River Flood Study*’ (*Final Draft, 2012*) and ‘*Bungendore Floodplain Risk Management Study*’ (*Final Draft, 2012*).

The hydraulic category mapping that was prepared for the Bombala River floodplain as part of the Bombala Floodplain Risk Management Study investigations is shown in **Figure 14** to **Figure 15**.

The following sections describe the methodology that was employed to determine the hydraulic category mapping.

Table 9 HYDRAULIC CATEGORY CRITERIA

HYDRAULIC CATEGORY	DESCRIPTION
FLOODWAY	• those areas where a significant volume of water flows during floods • often aligned with obvious natural channels • they are areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which may in turn adversely affect other areas • they are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.
FLOOD STORAGE	• 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	▪ 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.

8.2.2 Adopted Methodology for Determination of Floodway Corridors

The adopted methodology for determination of hydraulic categories for the study area involved several stages of assessment that relied on rigorous analytical analysis of all available hydraulic, topographic, cadastral and geomorphic data-sets.

Once the detailed investigations to determine the extents of floodway corridors were completed, an analytical assessment was also undertaken to determine the extent of flood storage and flood fringe areas. Each of these hydraulic categories was then combined to develop hydraulic category mapping for the study area which can be incorporated into future mapping layers linked to Council's Local Environmental Plan.

A detailed breakdown of the methodology applied to determine the hydraulic category mapping is outlined in the following sections.

FIGURE 14

LEGEND

Floodway

Flood Storage

Flood Fringe

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4093 - Bombala Floodplain Risk Management Study
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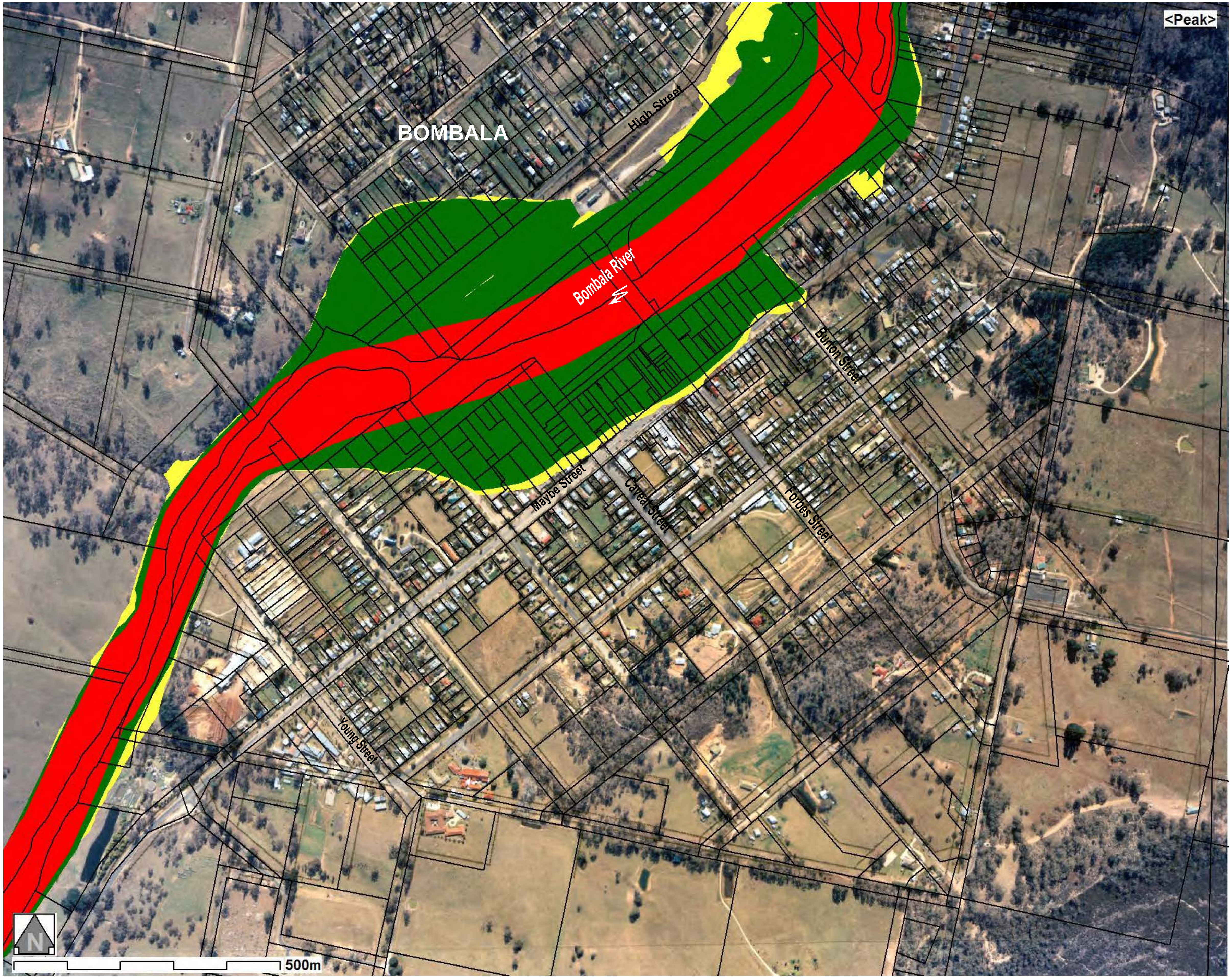
HYDRAULIC CATEOGRY MAPPING FOR THE BOMBALA RIVER (1 of 2)



LEGEND

- Floodway
- Flood Storage
- Flood Fringe

WorleyParsons
resources & energy

4093 - Bombala Floodplain Risk Management Study
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HYDRAULIC CATEOGRY MAPPING FOR THE BOMBALA RIVER (2 of 2)

8.2.3 Determination of Floodway Extent

The floodway extent was determined based on an assessment of aerial photography, topographic data and existing hydraulic modelling results. Determination of this extent or "line" considered the following:

- the location of flood storages that are readily identifiable from aerial photography;
- the location and potential impact of hydraulic controls and geomorphic features that could influence floodwater movement and flood characteristics (*e.g., velocity*);
- mapping of contours of 'velocity-depth' product (*V x D*); and,
- mapping of the variation in peak flow velocity.

Because of the complex nature of flooding at the confluence of Coolumbooka River and Bombala River and the varied floodplain types encountered across the study area, establishment of a standard set of criteria was not considered appropriate for the determination of all floodway extents. For example, definition of the floodway extent based on a single target value for velocity or velocity-depth product (*V x D*) would limit the reliability of the investigation findings.

Accordingly, to ensure the assessment of floodway extent was completed reliably, the study area was divided into numerous precincts to enable assessment on a '*local*' scale.

A set of interactive flood maps was produced for each of these precincts to show key hydraulic data including the variation in V x D, peak flow velocities and peak flood depths. The results of modeling of the design 1% AEP flood were used as the benchmark for the analysis.

The interactive flood maps were used to identify areas of the floodplain representing:

- high depth and high velocities; i.e., high V x D (*generally considered floodway*);
- high depth and low velocities (*generally considered flood storage*); and,
- low depth and low velocity (*generally considered flood fringe*).

In this regard, an analysis of the floodway extents was undertaken to identify areas where the velocity-depth product is greater than 4 m^2/s and where flow velocities are greater than 1 m/s. The location of significant blockages across the floodplain was also considered in determining the preliminary floodway extents.

Due consideration was also given to the full range of design flood events; that is, the assessment was not solely reliant on hydraulic data for the 1% AEP event. Particular attention was paid to identifying floodways that could emerge during varying stages of the Probable Maximum Flooding scenario i.e., the PMF was 'stepped through' to establish any flow paths that emerged above and beyond those determined for the 1% AEP event.

This methodology was applied to generate a "Preliminary" Floodway Extent.

The Preliminary Floodway Extent was further verified by comparison with mapping of the width of the floodplain that would be required to convey 80% of the peak flow. Trial analyses for this project and similar floodplain risk management studies have shown a good correlation between the transitions in velocity-depth product contour mapping, geomorphic characteristics and the width of the floodplain that conveys about 80% of the flood flow. A discussion of this criteria and its appropriateness for defining floodway extent is provided in Thomas et al (*2012*).

The width occupied by 80% of the flow was readily determined for any location within the lower reaches of the floodplain using the *Flow Extraction* tool within waterRIDE™. This width was then used to verify and adjust the Preliminary Floodway Extent.

Prior to finalising the floodway corridor a further review was undertaken to apply a practical "*common sense*" check of the floodway extent against cadastral and property constraints. The review relied on flood engineer judgment and experience to "*fine tune*" the floodway extent mapping. Consideration was also given to property boundaries and land use zoning boundaries. For example, in some cases it was found that the floodway extent could be adjusted by a short distance, of up to 10 metres, to line-up with the property boundaries without having any significant impact on the conveyance capacity of the floodway corridor. This ensured a practical common sense approach which avoided unnecessary constraints being placed on particular properties near the edge of the floodway corridor.

Application of this process led to the determination of those areas of the floodplain that would be classified as floodway.

8.2.4 Adopted Methodology for Determining Flood Storage and Flood Fringe

Following determination of those areas of the floodplain categorised as floodway, investigations were focused towards identifying the remaining hydraulic categories, namely flood storage and flood fringe. As outlined in the NSW *'Floodplain Development Manual'* (*2005*), flood storage and flood fringe make up the remainder of the floodplain outside of the floodway corridor.

Flood storage areas are defined in the '*Floodplain Development Manual*' (*2005*) as "those parts of a floodplain that are important for the temporary storage of floodwaters during the passage of a flood". If filled or obstructed (*through the construction of levees or road embankments*) the reduction in storage would be expected to result in a commensurate increase in flood levels in nearby areas. The remaining flood prone areas not classified as floodway or flood storage are termed flood fringe.

In order to determine the boundary between flood storage and flood fringe, the variation in peak flood depths in areas outside of the floodway extent was mapped to identify areas inundated to depths of approximately 0.3 metres. A depth of 0.3 metres was selected as it is considered to be the transitional point between flood storage and flood fringe.

In terms of the study area, peak depths below 0.3 metres are generally considered to correspond to areas where negligible floodwater is stored and represent a relatively small proportion of storage for floodwaters.

In accordance with the Floodplain Development Manual (*2005*), this represents areas which are unlikely to have any significant impact on the pattern of floodwater distribution through a river and floodplain system and associated flood levels.

Accordingly, the boundary between flood storage and flood fringe was defined by a peak 1% AEP flood depth of 0.3 metres.

Flood storage and flood fringe mapping for the floodplain of Bombala River is presented as **Figure 14** to **Figure 15**.

9. ASSESSMENT OF FLOOD PLANNING OPTIONS

One of the major objectives of the Bombala Floodplain Risk Management Study is to identify and assess opportunities for reducing the impact of floods on flood affected areas of Bombala. These opportunities can be structural works to redirect floodwaters or to protect vulnerable areas, or can be related to proactive planning measures.

The development of suitable planning measures is critically important for the management of future flood events and for ensuring future development is compatible with the flood risk. Planning measures aim to mitigate the flood risk for existing areas and provide strategies that will minimize the impact that flood could have on areas where development is proposed. It is also possible to manage floods by implementing planning measures that aim to prevent property and people from being placed at risk during floods. As a result, planning or non-structural measures can be targeted toward improving flood emergency response and toward identifying land uses for the floodplain that are consistent with the flood hazard.

9.1 POTENTIAL PLANNING OPTIONS

A community consultation process was undertaken as part of the initial stages of the Bombala Floodplain Risk Management Study. A set of potential planning options was identified and developed as an outcome of this community consultation process in 2011. The planning options that were identified include:

P1 Review of flood related planning instruments, including Council policies related to flooding, infill development and existing land use zones

P2 Voluntary house purchase of flood affected properties

P3 Development/review of existing Flood Warning System including possible replacement of damaged/off-line streamflow gauges

P4 Establishment of a database listing flood affected properties

P5 Review of stormwater drainage infrastructure maintenance program

A discussion of each of these planning options is provided in the following sections.

In terms of the definitions adopted by the manual, the above "planning" options represent a combination of property modification measures (*P1, P2 and P5*), and response modification measures (*P3 and P4*).

9.2 OPTION P1 – REVIEW OF FLOOD RELATED PLANNING INSTRUMENTS

Council's existing policy titled '*Floodprone Land or Floodway Lands – Minimum Floor Levels*' is quite brief and effectively refers all development applications to Council for an individual assessment of floor level requirements. The existing policy requires that residential floor levels be located a minimum of 500 millimetres above the 1971 flood level and commercial properties be located a minimum 250 millimetres above the 1971 flood level.

Accordingly, it is recommended that a new Development Control Plan (*DCP*) for floodprone land be developed for Bombala that considers the results of modelling undertaken as part of *Bombala Flood Study and Village Overland Flows Investigation (2010)* and the associated mapping of peak flood levels, hydraulic categories and flood hazard prepared as part of this study.

It is envisaged that the DCP/ Policy could be incorporated into Council's existing policy register as a sub-section of Policy 3.7. The DCP should incorporate the following requirements:

- Building development on flood prone areas shall be restricted to single dwelling or non-residential development permissible within the zone, except where specifically permitted.
- Building development proposals on flood prone land for all sites provisionally classified as High Hazard/Floodway by the Manual 2005 or the relevant Floodplain Risk Management Plan should not be supported.
- Council will only support building developments on flood prone land provided the applicant can demonstrate to Council's satisfaction that the development will not adversely impact on flooding across adjoining properties. The applicant is also required to show that flooding will not adversely impact on the development proposal. Such applications are to be prepared by a suitably qualified civil engineer/surveyor/hydrologist with a demonstrated experience in flood assessment of land development proposals.
- The finished floor levels of habitable rooms shall be at least equal to the Flood Planning Level (*FPL*), which is to be defined as 500 mm above the 1% AEP flood level determined by investigations for the '*Bombala Flood Study and Village Overland Flows Investigation*' (*2010*).
- Renovations including re-cladding or re-roofing and floor extensions greater than 60 m^2 in flood prone sites are classified in accordance with the 2005 Manual as "major additions". Council will support applications provided the applicant can demonstrate to Council's satisfaction that flood proofing measures have been considered in accordance with guidelines presented in Appendix J of the 2005 Manual. Such applications are to be prepared by a suitably qualified civil engineer with demonstrated experience in floodplain management.
- Council will not support habitable floor extensions greater than 20 m^2 where the dwelling is located in a high hazard area.
- Council should only support residential or commercial building developments in flood prone land where effective warning time and reliable access is available for evacuation. Evacuation should be consistent with flood evacuation strategies detailed in the SES Local Flood Plan.

- Council will not support new building development on flood prone land where emergency evacuation can only occur through high hazard floodway or high hazard flood storage areas.
- Developments that can demonstrate effective evacuation through low hazard conditions during the early warning phases of a flood may be supported. Applicants are to provide details of the evacuation route and likely flood conditions encountered during an effective evacuation.
- The DCP should include a map which shows the residential flood planning area for Bombala.
- Hydraulic category mapping (*refer* **Figure 14** and **Figure 15**) prepared as part of the Bombala Floodplain Risk Management Study should be referenced in the DCP. Furthermore, it is preferable if the mapping is included in the Bombala LEP.

A new DCP for flood prone land will complement Council's updated Bombala Local Environmental Plan 2012.

9.3 OPTION P2 – VOLUNTARY PURCHSE OF FLOOD AFFECTED PROPERTIES

The purchase of properties may be considered in certain high hazard areas of the floodplain where it is potentially impractical or uneconomical to mitigate against the risk posed by flooding. In this circumstance, it may be appropriate for the property to be purchased voluntarily and the risk posed by the property removed, potentially through demolition.

At Bombala, a total of 47 properties are inundated by the 1% AEP flood event. The majority of these are concentrated along the section of Maybe Street and cross roads between Burton Street and Young Street. It is estimated that purchase of all properties inundated by the 1% AEP flood would cost in the order of $10 million dollars and would effectively require re-creation of the town centre elsewhere. In general, the NSW Government funding of the Voluntary Purchase Scheme is available only where other alternatives (*e.g. levees*) are not considered viable.

The results of the community consultation undertaken in 2011 established that the voluntary purchase of properties was the least popular planning measure proposed, with only 24% of people who responded to the survey supporting the measure.

Therefore, in consideration of the concentration of properties, the cost associated with voluntary purchase in comparison to the structural options investigated and the response of the community to the proposed measure, voluntary house purchase is in general, not considered to be a feasible proposal for Bombala.

Notwithstanding, there may be certain isolated properties affected by the 100 year flood that are remote from the town centre where, with the support of the landowner, this may be considered.

9.4 OPTION P3 – DEVELOPMENT/ REVIEW OF EXISTING FLOOD WARNING SYSTEM

In any developed floodplain area, unless the risk posed by flooding is removed up to the level of the Probable Maximum Flood, a "continuing" or "residual" flood risk will exist. In order to manage the continuing flood risk, it is necessary to include appropriate provisions to evacuate areas of the floodplain placed at risk by flooding. This will include consideration of appropriate evacuation routes, identification of suitable evacuation centres and provision of sufficient available warning time, where possible.

The Bombala township is situated at the base of relatively steep river valley, with a number of roads running perpendicular to the river. In general, each of these roads "rises" as they continue away from the river. This means that areas of high ground which become surrounded by floodwater, also referred to as "flood islands" are not a feature of the Bombala Floodplain. Therefore, it is unlikely people evacuating from flooded areas will become trapped by floodwater.

Accordingly, the most significant factor for instigating effective evacuation from flood affected areas, for the general population is associated with providing sufficient available warning time to the community.

During the 1% AEP flood event, approximately 27 hours available warning time exists for the critical 36 hour duration storm from the commencement of the rainfall event to the peak of the flood at the Bombala township. However, there is approximately 22 hours between the commencement of the storm and subsequent inundation of properties. Therefore, provided that an appropriate warning system is in place, opportunity exists to undertake safe evacuation and to implement measures (e.g. sandbagging) to reduce the damages to property.

9.4.1 Existing Rainfall and Streamflow Gauging Stations

In order to provide adequate flood warning, there needs to exist a network of rainfall and streamflow gauges which can be used to forecast the potential for flooding to occur as a consequence of a particular rainfall event. Where sufficient rainfall and streamflow gauges exist within the upper catchment areas, they can be used to predict the timing and level of the flood peak in downstream areas.

In this context, the available rainfall and streamflow gauges which have the potential to form part of a flood warning system are described below. It is noted that not all rainfall gauges which exist are included. In areas where two gauges are located in close proximity to each other, a preference has been given to including any pluviometer whose record is already linked to the Bureau of Meteorology's online rainfall and streamflow data base (http://www.bom.gov.au/nsw/flood/).

The current rainfall gauges which are operated within or adjacent to the Bombala River catchment are listed in **Table 10** while the available streamflow gauging stations are listed in **Table 11**.

Table 10 OPERATIONAL STREAMFLOW GAUGE STATIONS IN THE UPPER BOMBALA RIVER CATCHMENT

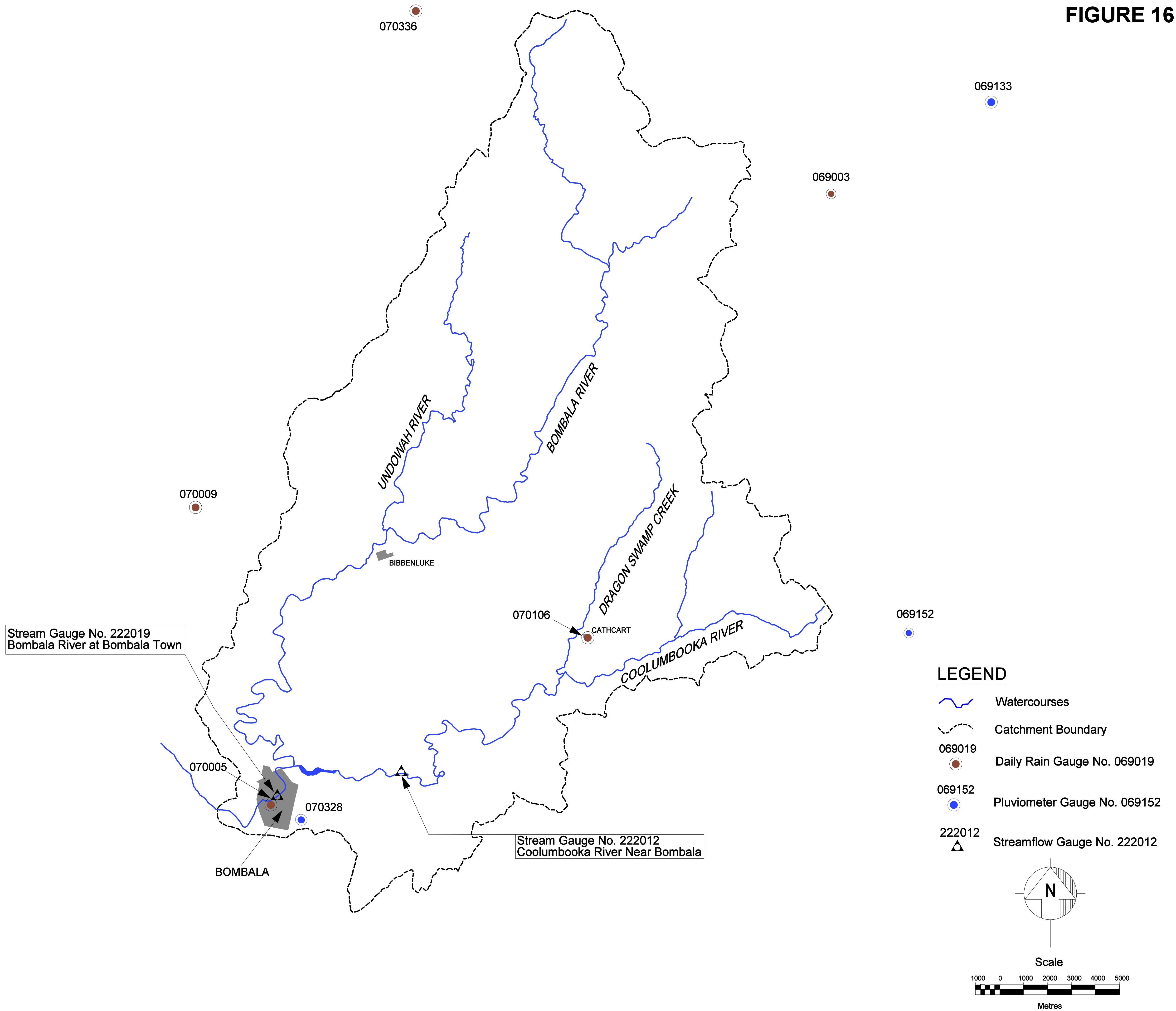
Gauge No.	NAME	CATCHMENT LOCATION	CURRENT METHOD OF READING	RELEVANCE TO FLOOD WARNING
222019	Bombala River at Bombala Town	Lower Bombala River	Telemetered streamflow gauge	Provides real time recording of actual flood levels in town
222012	Coolumbooka River at Coolumbooka Bridge	Lower Coolumbooka River	Staff read streamflow gauge	Provides an indication of river levels short distance upstream.

Table 11 OPERATIONAL RAINFALL GAUGE STATIONS IN OR ADJACENT TO THE UPPER BOMBALA RIVER CATCHMENT

Gauge No.	NAME	CATCHMENT LOCATION	CURRENT METHOD OF READING	RELEVANCE TO FLOOD WARNING
070106	Cathcart (Old Post Office)	Upper Coolumbooka River (Dragon Swamp Creek)	Daily Read rainfall gauge, not telemetered	Provides a measure of rainfall in the upper Coolumbooka River catchment
069152	Cathcart (Mount Darragh)	Bega River (approximately 10 kilometres from Bombala River catchment boundary)	Telemetered pluviometer – updated at BoM website	Rainfall record in the upper Coolumbooka River catchment
069133	Bemboka (the knob)	Upper Bega River (approximately 4 kilometres from Bombala river catchment boundary)	Telemetered pluviometer – updated at BoM website	Provides a measure of rainfall in the upper Bombala River catchment
070009	Bukalong Station	Cambalong Creek catchment (immediately west of Bombala River catchment)	Daily Read rainfall gauge, not telemetered	Rainfall record in the mid Bombala River catchment (e.g., near Bibbenluke)
070336	Holts Flat (Bellevue)	Cambalong Creek catchment (immediately west of Undowah River catchment)	Daily Read rainfall gauge, not telemetered	Rainfall record in upper Undowah River catchment
070328	Bombala AWS	Lower Bombala River	Telemetered pluviometer – updated at BoM website	Provides a measure of rainfall at Bombala

The location of the identified rainfall and streamflow gauges is shown on **Figure 16**.

FIGURE 16



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LOCATION OF RAIN AND STREAMFLOW GAUGES

9.4.2 Adequacy of Existing Network for Providing Effective Flood Warning

Although a reasonably good distribution of rainfall gauges exists currently across the upper Bombala River catchment, the current network of rainfall gauges has a number of limitations when considered in the context of effective flood warning.

One of the features of the catchment is that there is a significant change in the expected rainfall intensity across the catchment. This is due to the effects on rainfall that are associated with the proximity of the catchment to the Great Dividing Range. In general, those areas at the eastern extent of the catchment are likely to experience more intense rainfall, with rainfall intensity reducing in a westward direction.

This variation can be observed in a comparison of the 1% AEP 36 hour design rainfall depths. In the east of the catchment, to the area east of Cathcart the predicted depth of rainfall is 370 millimetres. However, for the same storm event at Bombala, the predicted rainfall depth is 277 millimetres, approximately 100 millimetres less. This spatial variation in rainfall depth is reflected in the depths of rainfall recorded for both the 1971 and 1978 storm events, which were used to calibrate the hydrologic and hydraulic models developed for the *Bombala River and Overland Flows Investigation*.

Although pluviometers are located at the western and eastern extremities of the catchment, at present no telemetered rainfall gauge is available to provide a real time record of rainfall in the mid part of the catchment. Including an additional gauge (e.g. at Bibbenluke) will provide an important additional reference for understanding the intensity, magnitude and distribution of a particular storm event.

Secondly, the only location where a telemetered streamflow gauge exists within the catchment is at the Bombala township. Although this is important for monitoring the rate of river rise at Bombala, this is of limited use in terms of effective flood warning, since this gauge provides little/ no warning time.

A manually read staff gauge is also located at the Coolumbooka Bridge on the Coolumbooka River. However, due to its close proximity to the township, this gauge is of limited use in providing appropriate flood warning. In addition, this gauge only records flows from one of the two main tributaries which drain to Bombala, further limiting its usefulness.

9.4.3 Recommended Additions to the Flood Warning System

In consideration of the current distribution of rainfall and streamflow gauges and the identified limitations associated with using the existing gauges to effect flood warning, it is recommended that consideration be given to the following:

- Installation of an additional telemetered pluviometer in the mid-catchment area. Bibbenluke or Cathcart may be an appropriate location for the gauge.

- Installation of an additional telemetered streamflow gauge at Bibbenluke. Approximately 40 % of the total catchment area draining to Bombala drains to this location. In addition, it is estimated that the travel time for flow between Bibbenluke and Bombala is in the order of 8 hours, which will allow adequate time to safely evacuate people.
- Installation of a streamflow gauge further upstream on the Coolumbooka River. Consideration should also be given to automating the existing gauge at Coolumbooka.

If installed, these gauges could ultimately be used to develop an intelligent flood warning system, which could be operated by the SES in consultation with Bombala Council. The flood warning system would use predicted estimates as well as real time records of rainfall and streamflow to predict the timing and peak level of flooding in Bombala.

It is estimated that the installation of each gauge would cost in the order of $10,000. There would be ongoing maintenance costs. However, these need to be understood in the context of a tool which will provide for more effective flood management of the township during times of significant flooding.

9.4.4 Additional Recommendations for Flood Warning and Readiness

It is also recommended that an evacuation centre be identified for the area of town north of the Bombala River. This is particularly important for any persons who are staying at the caravan park at the onset of major flooding.

9.5 OPTION P4 – ESTABLISHMENT OF A DATABASE OF FLOOD AFFECTED PROPERTIES

Through the floodplain management process, a complete list of all properties inundated up to the Probable Maximum Flood has been developed. This will inform Council's statutory planning obligations (e.g. the generation of flood information for Section 149 certificates) and also provide a basis for effecting evacuation from flood prone properties during times of flooding.

It is recommended that a complete listing be developed for the township which identifies properties which are affected by over floor flooding for the 5%, 2%, 1% and 0.5% AEP flood events as well as the Probable Maximum Flood. This list should be kept confidential and held by Council for consultation with the SES.

It is estimated that this could be produced and maintained at a relatively nominal cost to Council, for example in the order of $5,000 with minimal ongoing costs.

9.6 OPTION P5 – REVIEW OF STORMWATER DRAINAGE INFRASTRUCTURE MAINTENANCE PROGRAM

During the community consultation phase of the investigation, a number of respondents noted that various elements of the stormwater drainage infrastructure within the township are partially and/or fully blocked by sediment and other debris. This has reduced the hydraulic efficiency of the subsurface drainage system.

It is therefore recommended that Council institute a drainage maintenance program. The program should in the first instance involve updating the records of existing stormwater infrastructure within Bombala, with a view to developing a database of all the pits and pipes in town.

Following this, inspections of each of the main drainage channels should be undertaken by Council, their condition documented and a program developed to periodically remove any debris which is blocking the infrastructure. It is envisaged that the program would prioritise those sections of the drainage network which are most important for effective stormwater management, together with any areas where capacity is significantly compromised.

It is anticipated that ongoing maintenance of the stormwater infrastructure would also assist in identifying areas where the system could be augmented to reduce the potential for blockage, for example by the use of a sediment trap.

This should be formalised into a Stormwater Drainage Asset Management Plan.

10. FLOODPLAIN RISK MANAGEMENT PLAN

It is recommended that Bombala Council proceed toward the development of a *Floodplain Risk Management Plan* for Bombala.

The Plan should, subject to the provision of funding considerations, incorporate the following:

- Inclusion of mapping for Bombala River hydraulic categorisation zones into Council's Local Environmental Plan (*LEP*)
- Preparation of an up to date Flood Planning Area Map, using the results developed for the Bombala Flood Study, which shows the area of floodplain that falls within the 1% AEP event with a freeboard of 500 millimetres.
- Preparation of a Development Control Plan (*DCP*)/ flood policy for flood prone land, for inclusion within Council's existing Policy Register. The DCP should refer to the recommendations made in **Section 9.2**.
- Documentation of warning times for flooding of Bombala relative to known rainfall depths within the upper catchment (*refer* **Table 7**), and inclusion of this information within the Bombala Local Flood Plan.
- Liaison with the Bureau of Meteorology to install additional rainfall and streamflow gauges in the upper catchment, to provide effective flood warning for the Bombala township.
- Development of an intelligent flood forecasting system, which can use recorded and predicted rainfall and/ or streamflow depths to predict the peak flood level at Bombala.
- Maintenance of a database listing all flood affected properties and the depths of inundation at each property for a range of floods up to and including the Probable Maximum Flood.
- Preparation of a Stormwater Drainage Asset Management Plan, which a particular focus on rehabilitating any infrastructure which is currently blocked.
- A feasibility level investigation of Option S3, which involves construction of a levee along Therry Street, particularly with a view to identifying potential cost saving measures and/or alternative materials which may make this option more cost effective.
- Further consideration of the costs associated with voluntary house raising, in the context of those properties where the process is considered to be viable economically.

11. REFERENCES

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APPENDIX A

FLOOD DAMAGE CURVES

Appendix A - Floodplain Specific Damage Curves for Individual Residences

Steps in Curve 0.1 m

	Residential	Commercial	Commercial
Type	**R**	**C**	**CZ**
AFD from Modelling	**Damage**	**Damage**	**Damage**
0.00	$0	$0	$0
0.05	$32,208	$0	$18,817
0.10	$63,337	$6,443	$19,652
0.20	$66,368	$12,886	$20,486
0.30	$69,398	$19,329	$21,319
0.40	$72,429	$24,483	$22,155
0.50	$75,460	$29,637	$22,610
0.60	$78,490	$34,791	$23,819
0.70	$81,521	$41,663	$24,653
0.80	$84,552	$45,960	$25,486
0.90	$87,582	$47,677	$26,322
1.00	$96,053	$52,831	$51,634
1.10	$99,356	$56,053	$54,317
1.20	$102,658	$59,274	$57,000
1.30	$105,961	$63,913	$59,686
1.40	$109,264	$65,459	$62,369
1.50	$112,566	$67,006	$65,052
1.60	$115,869	$68,552	$67,735
1.70	$119,172	$70,098	$70,420
1.80	$122,474	$71,644	$73,101
1.90	$125,777	$73,190	$75,784
2.00	$129,080	$74,737	$78,472
2.10	$129,934	$74,737	$81,153
2.20	$130,789	$74,737	$83,836
2.30	$131,643	$74,737	$86,519
2.40	$132,498	$74,737	$89,202
2.50	$133,352	$74,737	$91,885
2.60	$134,207	$74,737	$94,568
2.70	$135,062	$74,737	$97,254
2.80	$135,916	$74,737	$99,937
2.90	$136,771	$74,737	$102,620
3.00	$137,625	$74,737	$105,303
3.10	$141,445	$74,737	$106,136
3.20	$146,886	$74,737	$106,970
3.30	$152,326	$74,737	$107,805
9.90	$154,717	$74,737	$107,805

APPENDIX B

FLOOD DAMAGES DATABASE

Table B1: FLOOD DAMAGES DATABASE FOR BOMBALA FLOODPLAIN RISK MANAGEMENT STUDY

Property Identifier	Ground Level (mAHD)	Building Type	5 Year ARI Flood Damages	20 Year ARI Flood Damages	100 Year ARI Flood Damages	200 Year ARI Flood Damages	Flood Damages in Adopted Extreme Flood Event
1	703.58	C	0	0	0	45540	74737
2	703.489	C	0	0	2332	47398	74737
3	703.403	C	0	0	7956	51318	74737
4	703.289	C	0	0	15624	55670	74737
5	703.106	C	0	0	25906	62641	74737
6	704.857	C	0	0	0	0	74737
7	703.831	C	0	0	0	32053	74737
8	703.682	C	0	0	0	41106	74737
9	704.168	C	0	0	0	12859	74737
10	704.004	C	0	0	0	22210	74737
11	704.092	C	0	0	0	16945	74737
12	704.002	C	0	0	0	21902	74737
13	703.663	C	0	0	0	40825	74737
14	703.426	C	0	0	3854	48735	74737
15	703.434	C	0	0	3197	48229	74737
16	703.556	C	0	0	0	45348	74737
17	704.044	C	0	0	0	18955	74737
18	704.075	C	0	0	0	16835	74737
19	703.947	C	0	0	0	23622	74737
20	704.083	C	0	0	0	15569	74737
21	704.041	C	0	0	0	18027	74737
22	703.656	C	0	0	0	39043	74737
23	703.474	C	0	0	0	46704	74737
24	703.312	C	0	0	9147	53069	74737
25	703.214	C	0	0	15718	56363	74737
26	703.113	C	0	0	22219	60203	74737
27	702.93	C	0	0	31880	65558	74737
28	703.095	C	0	0	23484	61271	74737
29	702.978	C	0	0	29832	64914	74737
30	703	C	0	0	28750	64584	74737
31	703.101	C	0	0	23824	61429	74737
32	703.07	C	0	0	25554	62950	74737
33	703.098	C	0	0	24362	61809	74737
34	702.886	C	0	0	35989	66574	74737
35	702.649	C	0	0	46939	70250	74737
36	701.634	C	0	19652	72720	74737	74737
37	701.558	C	0	23676	73875	74737	74737
38	701.383	C	0	32591	74737	74737	74737
39	702.857	C	0	0	39089	67181	74737
40	703.856	C	0	0	0	27564	74737
41	704.213	C	0	0	0	6285	74737
42	704.551	C	0	0	0	0	74737
43	704.775	C	0	0	0	0	74737
44	703.893	C	0	0	0	24283	74737
45	703.647	C	0	0	0	38011	74737
46	703.853	C	0	0	0	26677	74737
47	703.674	C	0	0	0	36488	74737
48	704.039	C	0	0	0	16870	74737
49	703.448	C	0	0	0	46987	74737
50	703.443	C	0	0	177	47124	74737
51	703.497	C	0	0	0	46262	74737
52	704.805	C	0	0	0	0	74737
53	703.767	C	0	0	0	30354	74737
54	704.831	C	0	0	0	0	74737
55	704.562	C	0	0	0	0	74737
56	704.091	C	0	0	0	11585	74737
57	703.95	C	0	0	0	20105	74737
58	703.097	C	0	0	19206	58276	74737
59	702.988	C	0	0	24978	62955	74737
60	703.551	C	0	0	0	42663	74737
61	703.697	C	0	0	0	33865	74737
62	704.054	C	0	0	0	13524	74737
63	704.148	C	0	0	0	7268	74737
64	708.38	R	0	0	0	0	136672

Building Type
C = Commercial
CZ = Commercial (Special)
I = Industrial
R = Residential

Table B1: FLOOD DAMAGES DATABASE FOR BOMBALA FLOODPLAIN RISK MANAGEMENT STUDY

Property Identifier	Ground Level (mAHD)	Building Type	5 Year ARI Flood Damages	20 Year ARI Flood Damages	100 Year ARI Flood Damages	200 Year ARI Flood Damages	Flood Damages in Adopted Extreme Flood Event
65	708.677	R	0	0	0	0	133900
66	708.929	R	0	0	0	0	131659
67	709.527	R	0	0	0	0	118374
68	703.683	R	0	0	63553	87724	153786
69	702.909	R	0	0	82553	115072	154061
70	702.74	R	0	0	87442	120361	154116
71	703.219	C	0	0	24538	61186	74737
72	700.622	R	0	108093	136896	152491	154717
73	703.09	R	0	0	73773	105467	153995
74	704.994	R	0	0	0	0	153302
75	704.487	R	0	0	0	0	153485
76	704.285	C	0	0	0	6001	74737
77	703.657	C	0	0	0	42590	74737
78	703.201	C	0	0	21100	58573	74737
79	703.311	R	0	0	63825	94771	153891
80	702.314	R	0	0	99276	128062	154250
81	701.492	R	0	69709	125925	135718	154538
82	701.176	R	0	79309	130964	141195	154654
83	701.805	R	0	33139	115630	133065	154429
84	702.036	R	0	0	108081	131111	154348
85	702.149	R	0	0	104394	130156	154308
86	702.458	R	0	0	91426	123081	154197
87	702.749	R	0	0	80219	113530	154093
88	704.713	R	0	0	0	0	153380
89	704.582	R	0	0	0	0	153412
90	703.262	R	0	0	63900	95422	153887
91	701.932	R	0	0	110807	131807	154364
92	700.905	R	0	86460	133110	152342	154717
93	701.623	R	0	64875	121131	134485	154484
94	701.05	R	0	82150	131889	146936	154686
95	701.155	R	0	79198	131041	141554	154654
96	705.885	R	0	0	0	0	152936
97	702.844	R	0	0	76738	109704	154037
98	703.184	R	0	0	66518	98528	153914
99	699	CZ	16551	31262	34614	34831	36000
100	709.66	R	0	0	0	0	103054
101	708.46	R	0	0	0	0	132587
102	711.97	R	0	0	0	0	0
103	710.35	R	0	0	0	0	76063
104	708.25	R	0	0	0	0	134375
105	707.24	R	0	0	0	0	152445
106	705.1	R	0	0	0	0	153220
107	709.17	R	0	0	0	0	119015
108	710.52	R	0	0	0	0	70732
109	711.28	R	0	0	0	0	0
110	711.47	R	0	0	0	0	0
111	712.16	R	0	0	0	0	0
112	710.71	R	0	0	0	0	66784
113	710.81	R	0	0	0	0	63826
114	707.55	R	0	0	0	0	152354
115	706.99	R	0	0	0	0	152558
116	706.78	R	0	0	0	0	152646
117	704.53	R	0	0	0	43304	153474
118	704.37	R	0	0	0	66523	153533
119	704.43	R	0	0	0	65027	153512
120	704.64	R	0	0	0	0	153454
121	705.21	R	0	0	0	0	153263
122	706.07	R	0	0	0	0	152940
123	707.99	R	0	0	0	0	141939
124	711.05	R	0	0	0	0	36084
125	709.65	R	0	0	0	0	110403
126	711.25	R	0	0	0	0	0
127	707.92	R	0	0	0	0	146893
128	708.49	R	0	0	0	0	134720

Building Type
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R = Residential

Table B1: FLOOD DAMAGES DATABASE FOR BOMBALA FLOODPLAIN RISK MANAGEMENT STUDY

Property Identifier	Ground Level (mAHD)	Building Type	5 Year ARI Flood Damages	20 Year ARI Flood Damages	100 Year ARI Flood Damages	200 Year ARI Flood Damages	Flood Damages in Adopted Extreme Flood Event
129	709.22	R	0	0	0	0	127614
130	710.24	R	0	0	0	0	96212
131	710.67	R	0	0	0	0	78501
132	711.32	R	0	0	0	0	0
133	711.89	R	0	0	0	0	0
134	703.65	R	0	0	82513	114895	154012
135	705.74	R	0	0	0	0	153184
136	706.34	R	0	0	0	0	152946
137	709.14	R	0	0	0	0	129540
138	709.27	R	0	0	0	0	126346
139	709.69	R	0	0	0	0	112187
140	717.85	R	0	0	0	0	0
141	713.1	R	0	0	0	0	0
142	706.48	R	0	0	0	0	152832
143	720.12	R	0	0	0	0	0
144	720.62	R	0	0	0	0	0
145	708.9	R	0	0	0	0	131425
146	714.28	R	0	0	0	0	0
147	713.04	R	0	0	0	0	0
148	711.37	R	0	0	0	0	0
149	710.28	R	0	0	0	0	84205
150	703.93	R	0	0	0	80282	153734
151	707.98	R	0	0	0	0	140705
152	705.87	R	0	0	0	0	153008
153	706.34	R	0	0	0	0	152836
154	706.71	R	0	0	0	0	152691
155	706.56	R	0	0	0	0	152732
156	705.7	R	0	0	0	0	153042
157	706.25	R	0	0	0	0	152837
158	705.21	R	0	0	0	0	153218
159	704.35	R	0	0	0	40606	153530
160	710.09	R	0	0	0	0	88706
161	708.47	R	0	0	0	0	133643
162	706.81	R	0	0	0	0	152648
163	707.41	R	0	0	0	0	152430
164	708.07	R	0	0	0	0	137006
165	708.13	R	0	0	0	0	136492
166	708.65	R	0	0	0	0	132049
167	708.76	R	0	0	0	0	131109
168	704.2	R	0	0	0	65678	153591
169	704.36	R	0	0	0	37547	153533
170	704.44	R	0	0	0	0	153504
171	704.2	R	0	0	0	65658	153593
172	705.45	R	0	0	0	0	153140
173	706.29	R	0	0	0	0	152836
174	707.49	R	0	0	0	0	152401
175	708.61	R	0	0	0	0	132387
176	710.43	R	0	0	0	0	77502
177	710.32	R	0	0	0	0	80824
178	710.21	R	0	0	0	0	84109
179	709.93	R	0	0	0	0	98180
180	710.26	R	0	0	0	0	82520
181	710.1	R	0	0	0	0	87339
182	709.72	R	0	0	0	0	104989
183	709.92	R	0	0	0	0	98333
184	708.64	R	0	0	0	0	132128
185	708.59	R	0	0	0	0	132554
186	708.67	R	0	0	0	0	131862
187	708.66	R	0	0	0	0	131941
188	708.61	R	0	0	0	0	132362
189	708.56	R	0	0	0	0	132780
190	708.59	R	0	0	0	0	132515
191	708.56	R	0	0	0	0	132762
192	708.45	R	0	0	0	0	133689

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Table B1: FLOOD DAMAGES DATABASE FOR BOMBALA FLOODPLAIN RISK MANAGEMENT STUDY

Property Identifier	Ground Level (mAHD)	Building Type	5 Year ARI Flood Damages	20 Year ARI Flood Damages	100 Year ARI Flood Damages	200 Year ARI Flood Damages	Flood Damages in Adopted Extreme Flood Event
193	708.53	R	0	0	0	0	132997
194	707.15	R	0	0	0	0	152520
195	705.27	R	0	0	0	0	153200
196	705.08	R	0	0	0	0	153270
197	704.71	R	0	0	0	0	153404
198	710.42	R	0	0	0	0	77480
199	708.77	R	0	0	0	0	130922
200	708.48	R	0	0	0	0	133395
201	708.1	R	0	0	0	0	136637
202	707.7	R	0	0	0	0	151409
203	707.22	R	0	0	0	0	152493
204	706.29	R	0	0	0	0	152829
205	705.17	R	0	0	0	0	153234
206	709.44	R	0	0	0	0	113871
207	709.84	R	0	0	0	0	100625
208	709.95	R	0	0	0	0	96882
209	710.02	R	0	0	0	0	91813
210	710.36	R	0	0	0	0	78652
211	710.52	R	0	0	0	0	73662
212	710.84	R	0	0	0	0	63856
213	710.17	R	0	0	0	0	83924
214	709.55	R	0	0	0	0	109222
215	709.31	R	0	0	0	0	117156
216	708.85	R	0	0	0	0	129924
217	707.75	R	0	0	0	0	146773
218	706.54	R	0	0	0	0	152726
219	709.89	R	0	0	0	0	97920
220	709.63	R	0	0	0	0	106481
221	709.37	R	0	0	0	0	115068
222	709.08	R	0	0	0	0	124633
223	708.2	R	0	0	0	0	135437
224	707.51	R	0	0	0	0	152374
225	706.79	R	0	0	0	0	152634
226	706.15	R	0	0	0	0	152865
227	710.38	R	0	0	0	0	77350
228	710.51	R	0	0	0	0	73375
229	711.03	R	0	0	0	0	0
230	709.84	R	0	0	0	0	98891
231	708.56	R	0	0	0	0	132207
232	705.93	R	0	0	0	0	152940
233	707.22	R	0	0	0	0	152473
234	704.59	R	0	0	0	0	153427
235	704.72	R	0	0	0	0	153379
236	709.24	R	0	0	0	0	118714
237	707.83	R	0	0	0	0	141270
238	709.91	R	0	0	0	0	96497
239	710.74	R	0	0	0	0	65647
240	709.83	R	0	0	0	0	99002
241	709.05	R	0	0	0	0	124832
242	707.88	R	0	0	0	0	139257
243	706.4	R	0	0	0	0	152769
244	705.91	R	0	0	0	0	152945
245	705.23	R	0	0	0	0	153188
246	704.78	R	0	0	0	0	153347
247	704.43	R	0	0	0	0	153471
248	709.26	R	0	0	0	0	110129
249	708.63	R	0	0	0	0	129232
250	707.12	R	0	0	0	0	152385
251	710.12	R	0	0	0	0	69785
252	709.55	R	0	0	0	0	78662
253	709.77	R	0	0	0	0	0
254	706.04	R	0	0	0	0	137232

Building Type
C = Commercial
CZ = Commercial (Special)
I = Industrial
R = Residential

APPENDIX C

COMMUNITY CONSULTATION BROCHURE AND QUESTIONNAIRE

Potential Flood Damage Reduction Options for Bombala

During a recent meeting of Council's Floodplain Management Committee, several strategies were identified as potential structural flood mitigation options for Bombala. These strategies are outlined in the following table.

The location of each structural strategy/option is shown on the central pages of this brochure, along with its principal objective.

Due to your local knowledge of flooding in the area, you may know of other options equally worthy of consideration. Council would be interested to hear of these. Please note, the potential solutions listed below are by no means an exhaustive list.

Furthermore, at this stage, Council has no immediate plans to implement any of the options and would need to undertake further investigations as part of a Floodplain Risk Management Study in order to secure government funding to undertake the associated capital works.

Potential Structural Flood Mitigation Options

OPTION	DESCRIPTION
S1	Removal of trees (*willows*) along river bank between Young and Bright Streets.
S2	Construction of a levee along the right bank extending from the Forbes Street bridge upstream to the Apex Park, and linking with Stephen Street.
S3	Construction of a levee along Therry Street between Young Street and Burton Street.
S4	Excavation of the Bombala River floodplain in the area of "necking" downstream of Young Street.
S5	Construct weir on Bombala River to provide flood storage
S6	Voluntary house raising of flood affected properties, such as residential dwellings in Caveat Street.
S7	Installation of floodgates on all stormwater outlets to the river
S8	Construction of a levee to prevent flooding of land between the river and Jonas Street
S9	Construction of a levee from the end of Mort Street across the low lying land to McKeachie Street.
S10	Construction of a levee / filling of the rifle range site located north-east of Stephen Street
S11	Construction of stormwater retarding basins in the town area
S12	Installation of culverts to capture and divert stormwater

Apart from aiming to address existing flood problems, the NSW Government's Flood Prone Land Policy also endeavours to prevent inappropriate development that could cause flooding problems in the future.

Accordingly, the Committee wants to consider any potential planning measures that could be implemented to allow better management of flood liable lands.

A provisional list of potential planning options is provided in the following table. Council would welcome any comments you may have on these measures.

Potential Planning Based Flood Mitigation Options

OPTION	DESCRIPTION
P1	Review of flood related planning instruments, including Council policies related to flooding, infill development and existing land use zones.
P2	Voluntary house purchase of flood affected properties
P3	Development/review of existing Flood Warning System including possible replacement of damaged/off-line streamflow gauges
P4	Establishment of a database listing flood affected properties
P5	Review of stormwater drainage infrastructure maintenance program

Where to from here?

Council intends to proceed toward the development of a floodplain risk management study and plan for Bombala.

However, in the meantime, and to help with the scoping of that investigation, Council is interested to learn of your views on the options presented in this brochure. It would be appreciated if you could answer the enclosed questionnaire and return it to Council.

Any comments or written submissions that you may have regarding these options would also be welcome

It must be remembered that flooding cannot be prevented, but that the options described here would help to reduce the impact of flooding. It would also help the community to prepare for major floods.

Any comments or written submissions that you may have regarding these proposed strategies should be directed to:

Mr Grantley Ingram
Director of Regulatory Services
Bombala Council
PO Box 105
BOMBALA NSW 2632
Ph (02) 6458 3555

Bombala Floodplain Risk Management Study

Community Information Brochure

Background

Bombala has experienced major floods in the past, most notably in 1971, 1952 and 1983. As a consequence of these floods, Council has adopted a policy of restricting development in low lying areas that are potentially vulnerable to flooding.

Nonetheless, current predictions, which are based on detailed flood modelling, indicate that most businesses on the northern or river side of Maybe Street, Bombala would experience inundation during the 100 year recurrence flood event. Residential dwellings in Caveat, Young and Therry Streets would also be flood affected. Hence, there is an existing flood problem that needs to be addressed.

Overland flow in the town area has also been observed inundating dwellings and roads.

In recognition of the flood hazard, Bombala Council is developing a Floodplain Risk Management Plan which will serve as a "blueprint" for management of the River and adjoining floodplain lands. The Study aims to provide a basis for future planning decisions that will help to reduce the impacts of flooding by ensuring appropriate development in floodplain areas.

The Floodplain Risk Management Study follows the Bombala Flood study and Overland Flow Investigation undertaken by WorleyParsons.

Purpose of this Brochure

The purpose of this brochure is to enable residents and businesses within the township of Bombala to comment on flooding issues that affect them, and to help identify possible solutions to problems caused by flooding.

The brochure outlines a range of potential flood damage reduction options being considered by the Bombala Floodplain Management Committee. These are shown overleaf and are discussed in the following sections.

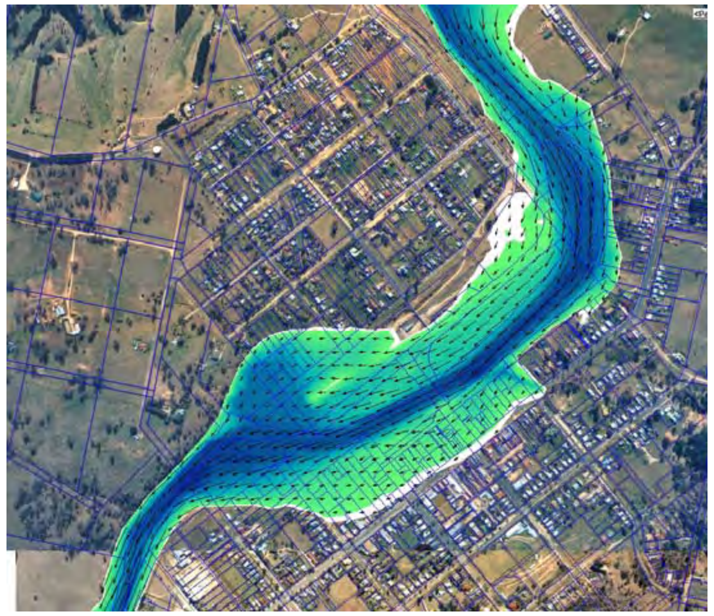
Accordingly, Bombala Council welcomes your comments on the options that are presented. Alternatively, you may feel that there are other options that you believe need to be considered. Council welcomes your ideas on these also.

Progress to Date

The first stage in the floodplain management process was recently completed with the submission of a draft of the Bombala Flood Study and Overland Flows Investigation Report.

The Flood Study was prepared by consulting engineers, Patterson Britton & Partners (*now part of WorleyParsons*), and details the extent to which inundation is predicted throughout the town. It also provides an assessment of stormwater flows in the local town area resulting from localised rainfall events.

Mapping has been prepared showing the depth of floodwaters and the flood hazard across the town for floods of differing severity, up to and including the Probable Maximum Flood (PMF).



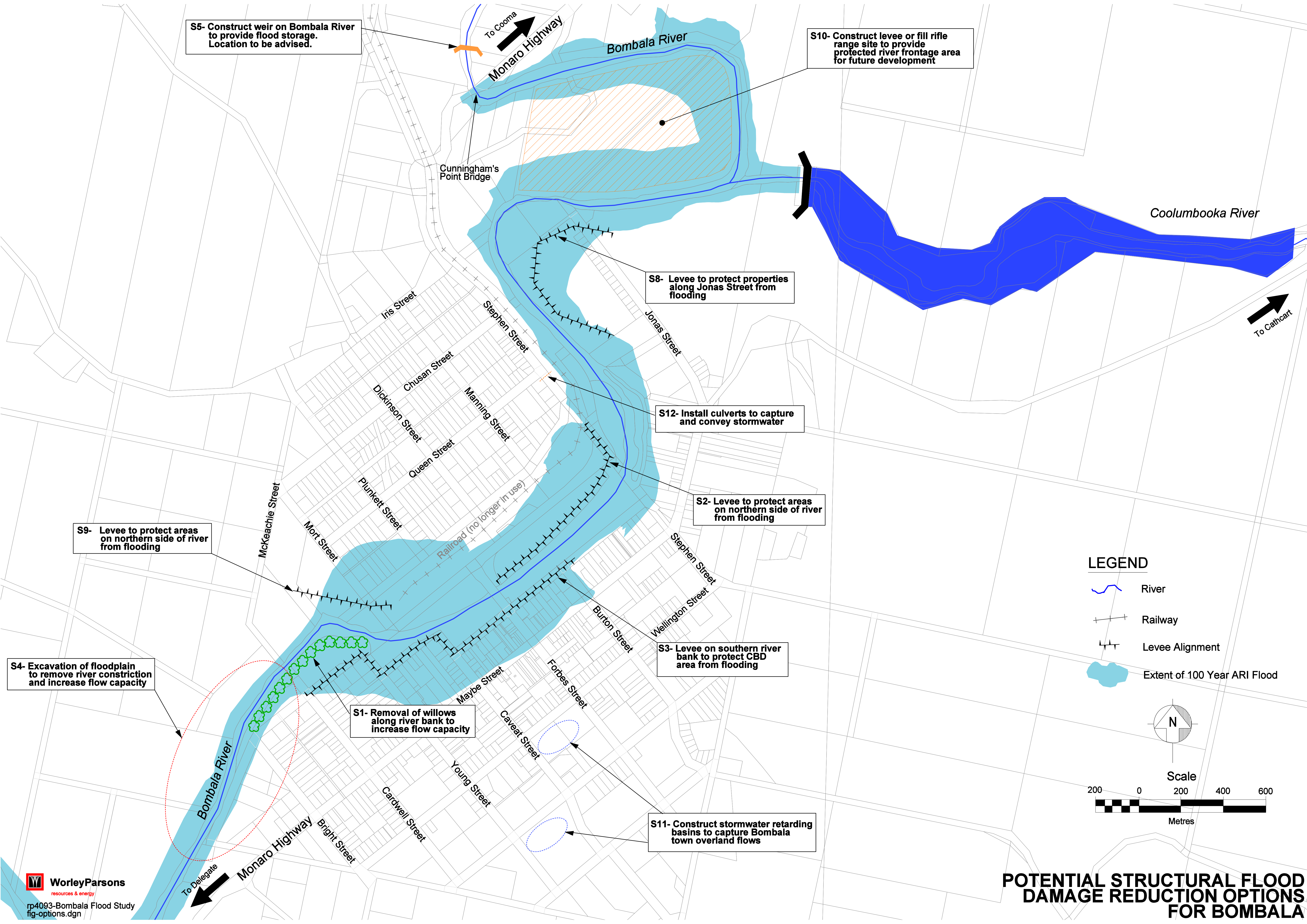
Modelled Extent of the 100 Year Recurrence Flood in Central Bombala (*enlarged image available for viewing at Council Offices*)

Where are we Now?

Council now wishes to move on to the next step in the floodplain management process. This involves taking the findings from the Flood Study, identification of options to reduce the impacts of the flooding problem, and assessment of the effectiveness and cost of selected alternatives.

The aim is to prepare a floodplain risk management plan for the town that outlines proposed works and strategies that will reduce flood impacts and which can be implemented over the next five years.

The strategies may take the form of structural or planning options. For example, a structural option might be the construction of a levee whereas a planning option may be a voluntary house purchase program for houses located in high hazard areas of the floodplain. Ultimately, the floodplain risk management study will determine which of the strategies are feasible.



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rp4093-Bombala Flood Study
fig-options.dgn

POTENTIAL STRUCTURAL FLOOD DAMAGE REDUCTION OPTIONS FOR BOMBALA

Have Your Say about

POTENTIAL FLOOD DAMAGE REDUCTION OPTIONS FOR BOMBALA

If you wish to register your views or outline alternative flood damage reduction options for Bombala, please complete this form and return it in the envelope provided.

PERSONAL DETAILS

Your Name: ______________________________

Your Address: ______________________________

Your Telephone Number: ______________________________

QUESTIONS

		0 - 5	6 – 10	11 – 20	> 20
(1)	How many years have you lived in the Area?	☐	☐	☐	☐

		YES	NO	DON'T KNOW
(2)	Has your property been affected by flooding in the past? If so, when.	☐	☐	☐
(3)	Are you concerned that you could be flooded and incur property damage?	☐	☐	☐
(4)	Do you believe that work needs to be undertaken to reduce the flood risk to the community of Bombala?	☐	☐	☐
(5)	Do you support any form of flood mitigation structural works?	☐	☐	☐
(6)	Do you support any form of flood mitigation planning measures?	☐	☐	☐

(7) If you support flood mitigation structural works for Bombala, please mark the options you are in favour of (*refer brochure for additional details*).

Option S1

Removal of trees (willows) along river bank between Young and Bright Streets. ☐

Option S2

Construction of a levee extending from the Forbes Street bridge upstream to the Apex Park ☐

Option S3

Construction of a levee along Therry Street between Young Street and Burton Street. ☐

Option S4

Excavation of the Bombala River floodplain in the area of "necking" downstream of Young Street. ☐

Option S5

Construct weir on Bombala River to provide flood storage. ☐

Option S6

Voluntary house raising of flood affected properties, such as in Caveat Street. ☐

Option S7

Installation of floodgates on all stormwater outlets to the river. ☐

Option S8

Construction of a levee to prevent flooding of land between the river and Jonas Street ☐

Option S9

Construction of a levee from the end of Mort Street across the low lying land to McKeachie Street. ☐

Option S10

Construction of a levee / filling of the rifle range site located north-east of Stephen Street. ☐

Option S11

Construction of stormwater retarding basins in the town area. ☐

Option S12

Installation of culverts to capture and divert stormwater. ☐

(8) If you do not support flood mitigation structural works for Bombala, please explain why you are unsupportive:

____

____

____

____

(9) If you support flood mitigation planning measures for Bombala, please mark the options you are in favour of (*refer brochure for additional details*).

Option P1		Option P2		Option P3		Option P4		Option P5	
Review of flood related planning instruments.	☐	*Voluntary house purchase of flood affected properties.*	☐	*Development/review of existing Flood Warning System*	☐	*Establishment of a database listing flood affected properties.*	☐	*Review of stormwater infrastructure maintenance program*	☐

(10) If you do not support flood mitigation planning measures for Bombala, please explain why you are unsupportive:

____

____

____

____

(11) If you wish to, please outline the reasons for your preferred options and any suggestions that you may have for alternative flood mitigation solutions in the space provided below.

____

____

____

____

____

____

Please return your completed questionnaire to the following address by Monday 28th February 2011 in the envelope provided (no postage stamp required)

Contact: Mr Grantley Ingram
Bombala Council
Phone: (02) 6458 3555

Additional Contact: Mr Chris Thomas
WorleyParsons
Phone: (02) 8923 6866

APPENDIX D

COMMUNITY CONSULTATION SUMMARY REPORT

WorleyParsons
resources & energy

Infrastructure and Environment
Level 11, 141 Walker Street
North Sydney NSW 2060 Australia
Telephone: +61 2 8923 6866
Facsimile: +61 2 8923 6877
www.worleyparsons.com
WorleyParsons Services Pty Ltd
ABN 61 001 279 812

Ref: 4093/00
File: lr4093gr_arm120115-communityconsultation.doc

The General Manager
Bombala Council
PO Box 105
BOMBALA NSW 2632

3rd April 2012

Attention: Mr Grantley Ingram

Dear Grantley

**BOMBALA FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
COMMUNITY CONSULTATION SUMMARY REPORT**

I refer to the Community Information Brochure and Questionnaire for the Bombala Floodplain Risk Management Study and Plan that was prepared and distributed to the community of Bombala during February 2011.

The brochure outlined a total of twelve potential structural options and five potential planning options for implementation as part of the Bombala Floodplain Risk Management Plan. The questionnaire aimed to seek feedback regarding each of these options and also requested any suggestions for additional floodplain management options that could be further investigated.

As you are aware, a total of approximately 76 individual responses to the questionnaire have been received from the local community.

We have processed the responses and have prepared the following summary report, the findings of which will be considered in finalising the list of floodplain management options that will be further investigated as part of work to prepare the Floodplain Risk Management Study and Plan.

1. SUMMARY OF QUESTIONNAIRE RESPONSES

In total 76 questionnaire responses were received from residents. The majority (*72%*) of respondents have resided in the area for more than 20 years, indicating significant local experience including knowledge of past floods. Only 9% of respondents have been residents for between 11 and 20 years, 8% between 6 and 10 years and 11% for 5 years or less.

Flooding in the past had affected the property of 26% of respondents with 30% concerned about potential property damage from flooding in the future. A significant 67% of respondents believed further work should be undertaken by council to reduce flood risk with 64% in support of structural options and 73% in support of planning based options.

1.1 Support for Floodplain Risk Management Options

The following is a summary of the feedback received for the potential <u>structural</u> options:

- The greatest support was received for Option S1 (*removal of trees along river bank between Young and Bright Street*). 47 respondents (*62%*) were in favour of Option S1.

- 42 respondents (*55%*) were in favour of Option S5 (*construction of a weir on Bombala River*).
- Options S4 (*excavation of Bombala River in area of "necking"*) and S12 (*installation of culverts to capture and divert stormwater*) were each supported by 37 respondents (*49%*).
- Approximately 30% of respondents were in favour of each of the following options:
  - Option S3 (*construction of levee along Therry Street*)
  - Option S11 (*construction of stormwater retarding basins*)
  - Option S2 (*construction of a levee along the bank extending from the Forbes Street bridge upstream to Apex Park and linking with Stephen Street*).
- 19 respondents (25%) were in support of Option S8 (*construction of a levee to prevent flooding of land between the river and Jonas Street*).
- The least popular structural options were:
  - Option S7 (*installation of floodgates on all stormwater outlets to the river*) with 16 respondents in support (*21%*)
  - Option S10 (*construction of a levee / filling of the rifle range site*) with 14 in favour (*18%*)
  - Option S9 (*construction of a levee from the end of Mort St across the low-lying land to McKeachie Street*) and Option S6 (*voluntary house raising of flood affected properties*) with 13 in support (*17%*).
- 3 respondents supported all proposed structural options whilst 11 were opposed to all structural options. 5 respondents did not express any view on the proposed structural options.

The following is a summary of the feedback received for the potential planning options:

- The most popular planning option among the respondents was Option P5 (*review of stormwater drainage infrastructure maintenance program*).
- Approximately 40% of those surveyed supported Option P4 (*establishment of a database listing flood affected properties*) with 32 in support and Option P3 (*development/review of existing Flood Warning System*) with 31 in support.
- 27 respondents (*35%*) supported Option P1 (*review of flood related planning instruments, including council policies related to flooding, infill development and existing land use zones*).
- 18 respondents (*24%*) supported Option P2 (*voluntary house purchase of flood affected properties*).
- 9 respondents supported all proposed planning-based options and 19 respondents (*25%*) opposed all planning-based options. Every respondent expressed a view on planning options.

1.2 Negative Response for Floodplain Risk Management Options

The following is a summary of the negative feedback received for the potential floodplain management options:

- The proposals which received the least support from respondents were Options S6 (*voluntary house raising of flood affected properties*), S9 (*construction of a levee from the end of Mort St across the low-lying land to McKeachie Street*) and S10 (*construction of a* *levee / filling of the rifle range site*). Each only received support from approximately 18% of respondents.

- Other proposals involving the construction of levees (*Options S3, S2 and S8 – each with approximately 30% of respondents in support*) generally received less support than structural options which related to improving river flow capacity (*for example Option S1 and S4, with 62% and 49% in support respectively*).
- Some respondents left comments to the effect that levees would be expensive and ineffective at containing floodwater, with some respondents expressing concerns that the construction of levees might increase the damage associated with flooding downstream of the levee as floodwater was not allowed to disperse and instead carried downstream.

1.3 Identified Locations of Flooding

The following areas have been reported by the community as being susceptible to flooding:

- A number of respondents who resided on Maybe Street and parts of Caveat Street expressed concern that their property may be at risk from flooding. This is consistent with the predicted 100 year recurrence flood modelling results documented in the Bombala Flood Study & Village Overland Flow Investigation.
- Some comments left by respondents agreed that build-up at the narrowing "bottleneck" of the river (*in line with Young Street*) was a potential issue or had been in the past.
- One respondent claimed that the 1971 flood was a direct result of vegetation congestion (*especially willow trees*) at the "bottleneck".

1.4 Suggestions for Alternative Floodplain Risk Management Options

Of the comments suggesting alternative floodplain risk management options, many respondents suggested options which focus on improving river flow capacity rather than raising banks through levee construction:

- In addition to removing the willows between Young and Bright Street as proposed in Option S1 (*removal of trees along river bank between Young and Bright Street*), there were comments in support of dredging the river bed in other locations – particularly shallow sections and sections where vegetation and other debris inhibited flow, causing congestion. It is expected that Option S4 (*excavation of Bombala river in area of "necking"*) would contribute to easing congestion.
- Several respondents called for improvements to be made to the existing weir before consideration be given to the installation of a second weir. Respondents claimed the existing weir was clogged and required maintenance.
  - It was proposed that the riverbed surrounding the existing weir be dredged and that channels within the weir be cleared to bring the weir back to full functionality.
  - Capacity of the existing weir could be improved by excavating the riverbed and/or raising the height of the weir walls.
  - Additionally it was proposed that diversion channels be installed on the weir to carry water to additional storage basins to further improve capacity during times of heavy flow.

There were also comments calling for improvements to stormwater infrastructure maintenance, especially for more regular clearing of gratings at inlets. This falls under Option P5.

Some respondents expressed the view that some areas of Bombala are naturally prone to flooding since they are located in the Bombala River floodplain. Consequently, council should discourage development on flood-prone land – possibly purchasing existing flood affected properties as per planning-based Option P2 (*voluntary house purchase of flood affected properties*) rather than try to resist the surge of water with levees. Additionally, those who purchase land should be made aware of the possibility of flooding and develop “at their own risk”, should they elect to do so.

2. CONCLUSIONS AND RECOMMENDATIONS

2.1 Floodplain Management Options for Further Investigation

Based on the community response to the questionnaire, it is recommended that potential structural Floodplain Risk Management Options S1, S4, S5 and S12 be considered for further investigation in the development of the Floodplain Risk Management Study and Plan. Despite less support from residents, it is recommended that at least one levee alignment be included in the study, possibly S3 which will offer the greatest increase in the amount of flood protection afforded to the town. The remaining structural options relating to levee construction (*Options S2, S8, S9 and S10*) could still be investigated, particularly if they are considered to provide a substantial benefit to the community.

- It is recommended that Option S1 (*removal of trees along river bank between Young and Bright Street*) be given further consideration. The proposed option generated approval from 62% of survey respondents and further support in many comments.
- Option S4 (*excavation of the Bombala River in the area of “necking”*) is consistent with Option S1 in improving river capacity downstream of Young Street. Option S4 is expected to contribute to reducing the build-up of water riverside of Maybe Street and along the disused railroad during large flow events.
- Option S5 (*construction of an additional weir on Bombala River*) received strong support from residents. In addition to investigating an additional weir, it is recommended that the comments from residents relating to the existing weir also be considered (*refer to Section 1.5*).
- In addition to Option S12 (*installation of culverts to capture and divert stormwater*), it is recommended that options be investigated to improve maintenance protocols for stormwater infrastructure. Similarly it is recommended that the effectiveness of Option S11 be investigated.
- With 5 of the 12 structural options proposed involving the construction of a levee, and given the somewhat contentious responses from residents regarding levee construction, it is recommended that the Committee consider whether it is appropriate to investigate the various levee alignments proposed during the exhibition.

It is recommended that each of the planning options proposed be investigated as part of the study.

2.2 Addressing Community Concerns

As discussed, the response from the community has been considered in finalising the list of floodplain management. It is expected that investigation of some or all of the above options will inform the flooding concerns for particular locations that have been raised by the community. In particular, we see the following concerns being addressed through the options investigation:

- The potential to ease "congestion" or choking of the river in the vicinity of Young Street will be assessed via Options S1 & S4.
- The costs and benefits associated with upstream flood investigation will be assessed via Option S5.
- Improvements to existing stormwater infrastructure, including regular clearing and also additional drainage capacity (*Option S11, S12*).
- The issue of levee construction proved to be contentious among respondents and generally received less support than the options mentioned above. This appears to be due, in some part, to concerns about cost and the possible adverse flood impacts. It is recommended that these concerns be considered as part of the Floodplain Risk Management Study process.

We trust that the above report suitably summarises the response to the Community Information Brochure and Questionnaire and provides an appropriate direction for progressing the development of the Floodplain Risk Management Study and Plan.

Please feel free to contact myself on 8456 6955 should you have any queries.

Yours faithfully
WorleyParsons

Andrew Morris
Engineer, Water Resources

APPENDIX E

COST ESTIMATES FOR FLOOD DAMAGE REDUCTION OPTIONS

TABLE E1 - Cost Estimate for Structural Option 1, Removal of Willow Trees

BOMBALA FPMS Option S1

Project No.:	4093
Project Name:	Bombala FPMS
Date:	1-Jan-11

Disclaimer

This cost estimate is based on WorleyParsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes design fees, project management fees and authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 29, 2011

<u>Option Inputs</u>

Number of trees	12
Tree diameter (m)	0.5
Tree girth (m)	1.6
Distance alongside river (m)	500.0

Item	Description	Quantity	Rate	Unit	Total
1	Removal of trees and vegetation				
	- cut down tree, grub up stump and cart away	12	380.00	units	4,560
	- clear site of vegetation and cart away	5000	0.47	sqm	2,350
2	Landscaping of area alongside river				
	- loam spread and levelled sown with crouch grass	500	9.75	sqm	4,875
				TOTAL (SYDNEY)	$11,785
				TOTAL (EDEN, +12.0%)	$13,199
				TOTAL (BPI VARIATION, +10%)	
				TOTAL (+20% CONTINGENCY)	$15,839

TABLE E2 - Cost Estimate for Structural Option S3- Therry Street Levee

BOMBALA FPMS Option S3
Project No.:
Project Name: Bombala FPMS
Date: 1-Jan-12

Disclaimer
This cost estimate is based on WorleyParsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes design fees, project management fees and authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 29, 2011

Item	Description	Quantity	Rate	Unit	Total
1	Foundation Preparation				
	- remove top soil and vegetation	34969	1.96	sqm	68,539
	- compact foundation	34969	3.10	sqm	108,403
2	Cutoff Foundation Construction				
	- excavate foundation channel	2042	26.50	cum	54,108
	- shaping of batter slopes	5150	2.60	sqm	13,391
	- compact foundation	5150	3.10	sqm	15,966
	- excavate clay from borrow pit, deposit as fill & compact to 90%	2042	11.00	cum	22,460
	- lime stabilisation of zone 1 fill	2042	35.00	cum	71,464
3	Levee Core Construction				
	- excavate and stockpile clay from borrow pit and deposit as fill	98182	11.00	cum	1,080,000
	- lime stabilisation of zone 1 fill	5809	35.00	cum	203,304
	- shaping of batter slopes	37904	2.60	sqm	98,551
4	Levee Landscaping				
	- gravel pavement supply, placement and consolidation	117	93.00	cum	10,851
	- vapour barrier sand fill (100mm thick)	3790	37.00	cum	140,245
	- topsoil placement, raking and levelling	36737	9.40	sqm	345,331
	- turf layed, rolled and watered for 2 weeks	36737	8.00	sqm	293,898
		SUB TOTAL (SYDNEY) - Items 1-4			$2,526,510
		SUB TOTAL (EDEN, +12.0%)			$2,829,692
		SUB TOTAL (BPI VARIATION, +10%)			
		SUB TOTAL (+20% CONTINGENCY)			$3,395,630
5	Design & Miscellaneous Items (Contingency included in fee)				
	- Environmental Assessment	1	40,000	item	40,000
	- Survey	1	30,000	item	30,000
	- Geotechnical Testing	1	20,000	item	20,000
	- Detail Design	1	70,000	item	70,000
	- Land Acquisition	1	300,000	item	300,000
		SUB TOTAL (SYDNEY) - Items 5			460,000
		TOTAL (Items 1-5, including Contingency, and locality factors)			$3,856,000

TABLE E3 - Cost Estimate for Structural Option S4 - Bombala River Channel Widening

BOMBALA FPMS Option S4

Project No.:

Project Name: Bombala FPMS

Date: 27-Nov-12

Disclaimer

This cost estimate is based on WorleyParsons's experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes design fees, project management fees and authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 29, 2011

Item	Description	Quantity	Rate	Unit	Total
1	Site Preparation				
	- cut down tree, grub up stump and cart away	25	380.00	units	9,500
	- remove top soil and vegetation	16,500	1.96	sqm	32,340
2	Cutoff Foundation Construction				
	- excavate bank to terrance (berm) level	42,000	11.00	cum	462,000
	- dispose of excavated material	42,000	32.00	cum	1,344,000
	- shaping of bank batter slopes	16,500	2.60	sqm	42,900
4	Site Landscaping				
	- topsoil placement, raking and levelling	16,500	9.40	sqm	155,100
	- prepare soil and sew grass seed	16,500	8.41	sqm	138,765
	- plant shrubs (average size)	1,650	10.00	unit	16,500
	- trees	1,200	30.00	each	36,000
		SUB TOTAL (SYDNEY) - Items 1-4			$2,237,105
		SUB TOTAL (EDEN, +12.0%)			$2,505,558
		SUB TOTAL (BPI VARIATION, +10%)			
		SUB TOTAL (+20% CONTINGENCY)			$3,006,669
4	Design & Miscellaneous Items (Contingency included in fee)				
	- Environmental Assessment	1	40,000	item	40,000
	- Survey	1	30,000	item	30,000
	- Geotechnical Testing	1	20,000	item	20,000
	- Detail Design	1	70,000	item	70,000
	- Site access	1		item	
		SUB TOTAL (SYDNEY) - Items 5			160,000
		TOTAL (Items 1-5, including Contingency, and locality factors)			$3,167,000

TABLE E4 - Cost Estimate for Structural Option S11A - Showground Detention Basin

BOMBALA FRMS OPTION S11(A)

WorleyParsons
resources & energy

Project No.:	
Project Name:	Bombala FPMS
Date:	1-Jan-11

Disclaimer

This cost estimate is based on WorleyParsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes design fees, project management fees and authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 29, 2011

Levee Section Properties

Crest Width (m)	1.0
Base Width (m)	6.4
Side Slope (H:1V)	3.0
Height (m)	0.9
Rehab. Length (m)	230

Item	Description	Quantity	Rate	Unit	Total
1	Foundation Preparation				
	- remove top soil and vegetation	1472	2.02	sqm	2,973
	- compact foundation	1472	3.20	sqm	4,710
2	Cutoff Foundation Construction				
	- excavate foundation channel	403	27.30	cum	10,988
	- shaping of batter slopes	1015	2.70	sqm	2,741
	- compact foundation	1015	3.10	sqm	3,147
	- excavate clay from borrow pit, deposit as fill & compact to 90%	403	12.10	cum	4,870
	- lime stabilisation of zone 1 fill	403	35.00	cum	14,088
3	Levee Core Construction				
	- excavate and stockpile clay from borrow pit	894	12.10	cum	10,812
	- lime stabilisation of zone 1 fill	242	35.00	cum	8,453
	- shaping of batter slopes	1757	2.70	sqm	4,745
4	Levee Landscaping				
	- gravel pavement supply, placement and consolidation	23	90.00	cum	2,070
	- vapour barrier sand fill (100mm thick)	176	37.00	cum	6,502
	- topsoil placement, raking and levelling	1527	9.75	sqm	14,892
	- turf layed, rolled and watered for 2 weeks	1527	8.25	sqm	12,601
				TOTAL (SYDNEY)	$103,593
				TOTAL (EDEN, +12.0%)	$116,024
				TOTAL (BPI VARIATION, +10%)	
				TOTAL (+20% CONTINGENCY)	$139,229

Table E5 - Cost Estimate for Structural Option S11B - Detention Basin on Caveat Street

BOMBALA FRMS OPTION S11(B)
Project No.:
Project Name: Bombala FPMS
Date: 1-Jan-11

WorleyParsons
resources & energy

Disclaimer
This cost estimate is based on WorleyParsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes design fees, project management fees and authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 29, 2011

<u>Levee Section Properties</u>

Crest Width (m)	1.0
Base Width (m)	25.0
Side Slope (H:1V)	3.0
Height (m)	4.0
Rehab. Length (m)	130

Item	Description	Quantity	Rate	Unit	Total
1	Foundation Preparation				
	- remove top soil and vegetation	3250	2.02	sqm	6,565
	- compact foundation	3250	3.20	sqm	10,400
2	Cutoff Foundation Construction				
	- excavate foundation channel	228	27.30	cum	6,211
	- shaping of batter slopes	574	2.70	sqm	1,549
	- compact foundation	574	3.10	sqm	1,779
	- excavate clay from borrow pit, deposit as fill & compact to 90%	228	12.10	cum	2,753
	- lime stabilisation of zone 1 fill	228	35.00	cum	7,963
3	Levee Core Construction				
	- excavate and stockpile clay from borrow pit	7014	12.10	cum	84,863
	- lime stabilisation of zone 1 fill	540	35.00	cum	18,883
	- shaping of batter slopes	3542	2.70	sqm	9,564
4	Levee Landscaping				
	- gravel pavement supply, placement and consolidation	13	90.00	cum	1,170
	- vapour barrier sand fill (100mm thick)	354	37.00	cum	13,106
	- topsoil placement, raking and levelling	3412	9.75	sqm	33,268
	- turf layed, rolled and watered for 2 weeks	3412	8.25	sqm	28,150
4	Basin Excavation				
	- excavate to reduce levels and deposit in spoil heap within 1km (clay)	7014	9.95	cum	69,784
	- shaping of batter slopes	1625	9.75	sqm	15,844
				TOTAL (SYDNEY)	$311,850
				TOTAL (EDEN, +12.0%)	$349,272
				TOTAL (BPI VARIATION, +10%)	
				TOTAL (+20% CONTINGENCY)	$419,127

Table E6 - Cost Estimate for Structural Option S12 - Culvert Installation at Queen Street

BOMBALA FPMS Option S12

Project No.:	4093
Project Name:	Bombala FPMS
Date:	1-Jan-11

WorleyParsons
resources & energy

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<u>Levee Section Properties</u>

Distance from roadside to river (m)	130.0
Distance across road (m)	30.0
Diameter of culvert (mm)	0.6

Item	Description	Quantity	No.	Rate	Unit	Total
1	Site Establishment and Preparation					
	- Site setup	1		5.0	%	1,508
2	Removal of Existing Road Surface					
	- break up and remove bitumen paving with basecourse underneath	150	2	3.25	sqm	974.19
4	Laying culvert under The Monaro Highway					
	- culvert, precast concrete pipe Class 2	30	2	235.00	m	14,100.00
	- lintel	2	2		qty	-
5	Road Surface Reprofiling					
	- crushed rock basecourse	150	2	21.97	sqm	6,592.01
	- hot bitumous concrete incl tack coat	150	2	21.11	sqm	6,332.23
	- cast in situ concrete kerb incl reinforcement	15	2	71.87	m	2,156.20
6	Site Re-establishment and Ancillaries					
	- site clean-up	1		5.0	%	1,507.73

TOTAL (SYDNEY)	$31,662
TOTAL (EDEN, +12.0%)	$35,462
TOTAL (BPI VARIATION, +10%)	
TOTAL (+20% CONTINGENCY)	$42,554