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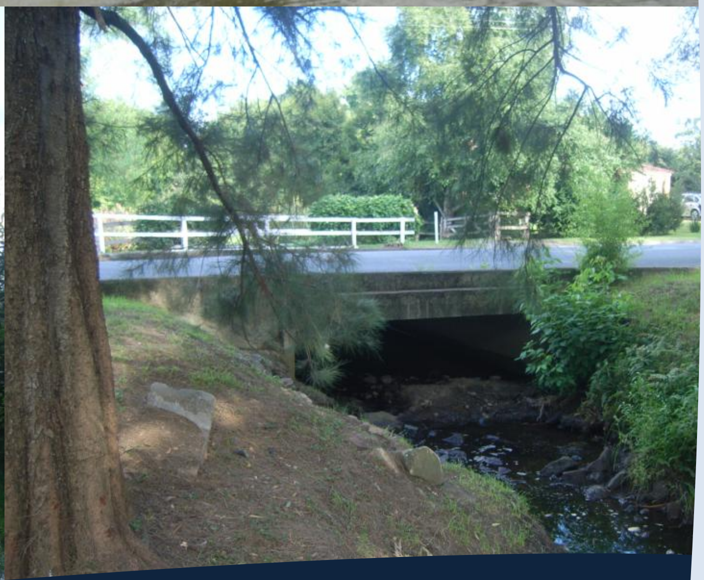

Broughton Creek Stage 1 Report

W4858

Prepared for Shoalhaven City Council

February 2011

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Report No:_____

Document Control

Version	Status	Date	Author		Reviewer	
1	Draft	8 / 09 / 2011	Luke Evans	LRE	Rhys Thomson	RST
2	Final	28 / 09 / 2011	Luke Evans	LRE	Rhys Thomson	RST

Foreword

The NSW Government Flood Prone Land Policy is directed towards providing solutions to existing flood 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.

Under the policy, the management of flood prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain management measures.

The Policy identifies the following floodplain management 'process' for the identification and management of flood risks:

1. Formation of a Committee	Established by a Local Government Body (Local Council) and includes community group representatives and State agency specialists.
2. Data Collection	The collection of data such as historical flood levels, rainfall records, land use, soil types etc.
3. Overland Flow/ Flood Study	Determines the nature and extent of the floodplain.
4. Overland Flow/ Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
5. Overland Flow/ Floodplain Risk Management Plan	Involves formal adoption by Council of a management plan for the floodplain.
6. Implementation of the Plan	This may involve the construction of flood mitigation works (e.g. culvert amplification) to protect existing or future development. It may also involve the use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard.

The process is iterative, and following the implementation of the plan, it is important that ongoing monitoring and evaluation is undertaken.

This Floodplain Risk Management Study and Plan has been prepared for Shoalhaven City Council by Cardno.

Executive Summary

Shoalhaven City Council commissioned Cardno to undertake a Floodplain Risk Management Study and Plan for the Broughton Creek Catchment.

This report details the investigations completed as part of Stage 1 of the study, namely;

- Establishment of the TUFLOW model
- Results of the community consultation
- Calibration and Verification of the TUFLOW model
- Determination of flood extend, levels and hazard
- Determination of the existing flood damages
- Sensitivity analysis of the TUFLOW model

Table of Contents

List of Tables

List of Figures

NOTE: * indicates figures located in body of report. Other figures are attached separately

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Appendices

Glossary

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Creek Rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
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 overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.

Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the "Standard flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is

	necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
NPER	National Professional Engineers Register. Maintained by the Institution of Engineers, Australia.
Overland Flow	The term overland flow is used interchangeably in this report with “flooding”.

Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedance Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

* Terminology in this Glossary have been derived or adapted from the NSW Government *Floodplain Development Manual*, 2005, where available.

Abbreviations

AAD	Average Annual Damage
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Intervals
BoM	Bureau of Meteorology
DCP	Development Control Plan
DECCW	Department of Environment, Climate Change & Water (now Office of Environment & Heritage)
DHI	Danish Hydraulics Institute
EPI	Environmental Planning Instrument
ESD	Ecologically Sustainable Development
FPL	Flood Planning Levels
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
GSDM	Generalised Short Duration Method
ha	Hectare
HAT	Highest Astronomical Tide
IEAust	Institution of Engineers, Australia (now referred to as Engineers Australia)
IFD	Intensity Frequency Duration
km	Kilometres

km^2	Square kilometres
LAT	Lowest Astronomical Tide
LEP	Local Environment Plan
LGA	Local Government Area
LIC	Land Information Centre
m	Metre
m^2	Square metre
m^3	Cubic Metre
mAHD	Metres to Australian Height Datum
MHWL	Mean High Water Level
MHWN	Mean High Water Neaps
MHWS	Mean High Water Spring
MIKE11	MIKE11 Proprietary Software Package
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Spring
mm	Millimetre
m/s	Metres per second
MSL	Mean Sea Level
NPWS	National Parks and Wildlife Service (within the Department of Environment and Conservation)
NRFMC	Natural Resource and Floodplain Management Committee
NSW	New South Wales

OEH	Office of Environment & Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
REP	Regional Environmental Plan
RL	Reference Level
RTA	Roads and Traffic Authority
SEPP	State Environmental Planning Policy
SES	State Emergency Service

1 Introduction

This report details the Stage 1 investigations of the Broughton Creek Floodplain Risk Management Study and Plan (FRMSP).

This report details the creation, calibration and verification of the TUFLOW model, and the flood details, hazard categorisation and flood damages for the existing scenario.

1.1 Study Context

The Floodplain Management process progresses through 6 stages, in an iterative process:

1. Formation of a Floodplain Management Committee
2. Data Collection
3. Overland Flow / Flood Study
4. Overland Flow / Floodplain Risk Management Study
5. Overland Flow / Floodplain Risk Management Plan
6. Implementation of the Overland Flow / Floodplain Risk Management Plan

This report addresses Stages 2 and 3.

1.2 Study Objectives

The Stage 1 report details:

- Establishment of the TUFLOW model
- Results of the community consultation
- Calibration and Verification of the TUFLOW model
- Determination of flood extend, levels and hazard
- Determination of the existing flood damages
- Sensitivity analysis of the TUFLOW model

2 Catchment Description

Broughton Creek and its tributaries rise in the ranges to the north and west of the town of Berry, flowing through farming areas and forest to the Shoalhaven River downstream of Nowra. Of particular interest are the flood prone parts of the Berry Township.

The catchment and study area are shown in **Figure 2.1**

The Broughton Creek catchment area is approximately 518 km^2. Agricultural industry is the major land use within the catchment, with extensive areas utilised for dairy and beef cattle grazing in private pasture production. The township of Berry is the only urban area within the catchment.

The area downstream of Berry is flat and swampy and is generally below the level of the natural Broughton Creek levees. This floodplain has an elevation generally between 1mAHD and 2mAHD. Tidal influence extends approximately 12km upstream of the Broughton Creek and Shoalhaven River confluence to the vicinity of the Coolangatta Road Bridge (SMEC, 2008).

The main tributaries to Broughton Creek, upstream of the Coolangatta Road bridge include Broughton Mill Creek, Bundewallah Creek, Connollys Creek and an unnamed watercourse locally know as Town Creek. Other tributaries include Anderson Lane Creek, Anderson Lane Tributary, Hitchcock's Lane Creek and Hitchcock's Lane Tributary.

The key features of the study area are shown in **Figure 2.2**.

The lower reaches of the Broughton Creek catchment, downstream of the Coolangatta Road bridge, forms part of the Shoalhaven River floodplain, and as such has previously been considered in the Lower Shoalhaven River Floodplain Risk Management Study and Plan (WMA, 2002).

The significant recorded historical flood events for the Broughton Creek catchment were the August 1974, April 1988, February 2002 and June/July 2005 events, and were detailed in the Broughton Creek Flood Study (SMEC, 2008). Of these, the 2005 event was the largest recorded.

3 Available Data

3.1 Previous Studies and Reports

A number of studies have been conducted concerning the Broughton Creek catchment and the wider Shoalhaven River catchment. These studies have been reviewed as part of this study and relevant information incorporated.

Previous studies are summarised in **Table 3.1**.

Table 3.1: Summary of Previous Studies and Reports

Study	Description
Lower Shoalhaven River Flood Study (Web McKeown & Associates, 1990)	The flood study for the region was undertaken in 1990 using the WBNM hydrological model, and the CELLS hydraulic model. The models were calibrated to yearly historical floods from 1974 – 1979, and the 1988 flood event. The study determined downstream conditions at Shoalhaven Heads for 20yr, 50yr, 100yr and PMF. Different levels were determined depending on if the heads were open or closed.
Shoalhaven City Local Flood Plan Draft (State Emergency Services, 2003)	The SES investigation covered the Shoalhaven City Council area. It was concerned with flood preparedness, response and recovery.
Lower Shoalhaven River Floodplain Risk Management Study (Webb McKeown & Associates, 2008)	The study built on the initial 1990 study, further investigating key flooding issues and possible solutions. The model used had Shoalhaven Heads closed, but scouring out as the flood progressed. Key issues identified included blockage at Shoalhaven Heads, evacuation access, and urban development and expansion. It also stated that Broughton Creek and Bolong Rd Bridge had insufficient capacity to manage flood waters. An economic analysis was undertaken which estimated AAD at $1.8M, with 734 properties affected in the 100yr event. A variety of management measures were discussed including flood modifications (basins, levees), property modifications (raising, voluntary purchase) and response modifications (evacuation planning). Property and response initiatives were considered to be more applicable.

Lower Shoalhaven River Floodplain Risk Management Plan (Webb McKeown & Associates, 2008)	The study outlines which of the mitigation options put forward above are most likely to have benefits, and how council could implement these programs. An example of the mitigation measures proposed are: • Develop a post-flood evaluation and review program to further refine models • Implement stormwater management plan for local drainage flooding issues • Finalise and implement Council's Shoalhaven River Entrance Management Plan for Flood Mitigation (EMPFM) • Update flood polices such as FPL's property set-backs, and improve resident flood awareness
Broughton Creek Flood Study (SMEC Australia Pty Ltd, 2008)	The study determined the flood behaviour for the Broughton Creek catchment for a range of design events including PMF, 200yr, 100yr, 50yr, 20yr, 10yr and 5yr events. Hydrologic modelling was undertaken in RAFTS and hydraulic modelling in Mike-11. Downstream boundary conditions were taken from the CELLS model. Calibration was undertaken using historical events from 1974, 1988, 2002 and 2005. Historical flood levels were included in the report and utilised in the current investigations.
Berry Town Creek Flood Study (MacDonald International, 2009)	The study investigated the flooding of Town Creek in Berry between Queen Street and Prince Alfred Street. The investigation was undertaken using HEC-RAS and DRAINS for the 1%, 5%, 10%, 20% and 50% AEP events. The study recommended the upgrades of pipes and culverts at Princess Street, Victoria Street and Albany Street. The report included flood levels and extents which were utilised in the current investigations.
Lower Shoalhaven River Floodplain Management Study & Plan: Climate Change Assessment (WMAwater, 2011)	An amendment to the 2008 study to incorporate the predicted impacts of climate change. The study adopted NSW Government sea level rise estimates of 0.4m by 2050 and 0.9m by 2100, and increases in precipitation of 10%, 20% and 30% in line with DECC Guidelines. Based on these values, the findings of the previous study (Webb McKeown & Associates, 2008) were updated including planning levels, damages, flood mitigation options and evacuation procedures.

3.2 Survey Information

Council provided a substantial amount of the existing data of the study area. Additional survey was commissioned for the areas not covered by existing survey.

3.2.1 Existing survey

Survey information was obtained from a number of sources. The following summarises the information received:

- Airborne Laser Scanning (ALS) – Council provided aerial survey across the catchment. The survey was conducted in 2004 and is indicative of the catchment at this time. Generally, accuracy of ALS data is +/- 0.15m to one standard deviation on hard surfaces.
- Culvert Cross Sections – Culverts within Berry were surveyed by ESG group in 2002-2005
- Creek Cross Sections – Cross sections for Andersons Lane Creek, Broughton Mill Creek, Bundewallah Creek, Bundewallah Tributary, Hitchcocks Lane Creek, Hitchcocks Lane Tributary and Town Creek were taken from the Mike11 model
- Drainage Survey – survey of pits, pipes, culverts and bridges were supplied by Council
- Historical levels – historical levels identified from the SMEC (2008) and Webb McKeown Associates (2008) flood studies for Broughton Creek and the Lower Shoalhaven River respectively.

3.2.2 Additional Survey

Additional survey was collected for parts of the study area where existing survey did not exist or did not provide sufficient information.

The following survey details were obtained:

- Retirement Village – Design plans of the access road detailing the culverts and bridge crossing, and the road crest level (Dwg Ref: 05001-C1B-01 to 09)

3.2.3 Floor Level Property Survey

A detailed floor level survey was carried out by Peter Smith Surveyors. Floor levels and property descriptions of all the properties within the SMEC PMF extent (SMEC, 2008) were obtained. This information has been provided separately to Council for privacy reasons.

3.3 GIS Data

The following Geographic Information System (GIS) data was provided by Council as a part of the study:

- Cadastre
- Drainage Layers: pits, pipes, easements
- 2m contours
- Aerial photography: undertaken by Council prior to the commencement of the current study. The imagery is centred on Berry, and extends for approximately 10km, reaching the Pacific Ocean in the East, and the Shoalhaven River in the South
- Environmental and social characteristics: acid sulphate soils, vegetation zones, LEP zones, and areas of ecological sensitivity

3.4 Site Inspection

A site inspection was conducted on 11 February 2011.

3.5 Historic Flood Information

The study area has experienced a number of large flood events, with the most recent being in 2002, 2005 and 2011. Previous studies include flood levels at certain locations for the 2002 and 2005 events, and Council has provided photographs taken during and after the 2005 and 2011 events.

3.6 Historical Rainfall Data

There are numerous rainfall stations around the study area. Not all of these however were operational during the identified storm events. Rainfall gauges identified in and around the study area are listed in **Table** 3.2. Isohyetal maps were produced for historic events as part of the SMEC study (SMEC, 2008).Daily totals for each historical storm event are summarised in **Table 3.3 and Table 3.4.**

Table 3.2: Rain Gauges

Station No.	Station Name	Type	Source	Operation
068003	Berry Masonic Village	Daily	BOM	1886-current
068218	Wattamolla (Griffiths)	Daily	BOM	1982-current
68190	Wattamolla (Tamol)	Daily	BOM	1970-current
068197	Foxground Road	Daily	BOM	1972-current
068175	Toolijooa (Nyora)	Daily	BOM	1967-current
068247	Beaumont (The Cedars)	Daily	BOM	1993-current
068209	Jamberoo (Druewalla)	Daily	BOM	1963-2007
068035	Jamberoo (The Ridge)	Daily	BOM	1992-current

BOM = Bureau of Meteorology

Table 3.3: Rainfall Totals for May 2003 Flood Event

Station No.	Station Name	Total Daily Rainfall (mm to 9am)
		July 2005
068003	Berry Masonic Village	220.8
068218	Wattamolla (Griffiths)	198.6
68190	Wattamolla (Tamol)	163.2
068197	Foxground Road	170.0
068175	Toolijooa (Nyora)	74.4
068247	Beaumont (The Cedars)	83.6
068209	Jamberoo (Druewalla)	212.0
068035	Jamberoo (The Ridge)	137.0

The storm event occurred on 1st July 2005.

Table 3.4: Rainfall Totals for March 1975 Flood Event

Station No.	Station Name	Total Daily Rainfall (mm to 9am)
		February 2002
068003	Berry Masonic Village	170.2
068218	Wattamolla (Griffiths)	159
68190	Wattamolla (Tamol)	131.2
068197	Foxground Road	171.6
068175	Toolijooa (Nyora)	143.6
068247	Beaumont (The Cedars)	185.0
068209	Jamberoo (Druewalla)	122.0
068035	Jamberoo (The Ridge)	146.2

The storm event occurred on 5th Feb 2002

4 Consultation

Community consultation is proposed to be undertaken in three key phases over the course of the project:

- Resident Survey
- Community Forums
- Public Exhibition

As of Stage 1, the resident survey has been completed and is discussed below. The Community Forum and Public Exhibition will take place during later stages of the study.

4.1 Community Information Brochure/Questionnaire

Community consultation was undertaken in December 2010. An information brochure and questionnaire were distributed to those properties identified in the SMEC investigation (SMEC, 2008) as being within the PMF extent. The brochure and questionnaire are attached in **Appendix A**. The brochure provided an outline of the floodplain risk management process and the objectives of the study. The questionnaire sought information about historical flooding events and feedback on possible floodplain management options.

The brochure and questionnaire were delivered to approximately 550 property owners within the floodplain. These properties were selected as being in or near the PMF extent, and as such, they may have experienced or witnessed flooding in the catchment. A summary was also advertised in the local newspaper, the Berry Town Crier, informing residents of the study and advising that the survey was being undertaken.

From the distribution, 82 responses were received, representing a return of approximately 14% of direct distribution. An average response rate for these types of surveys is in the order of 10%, and so this represents a reasonable return rate.

A summary of the findings of the resident survey are presented below.

4.1.1 Years at Address

One of the questions in the survey related to the length of time that residents had resided at their current address. The majority of the responses were from owner occupiers (87%) with the remainder made up of tenants, businesses and farmland.

Of the 83 respondents, 52% had been at their property longer than 10yrs, and 65% were living in Berry at the time of the 2005 flood event. **Figure 4.1** provides an overview of the periods of residency.

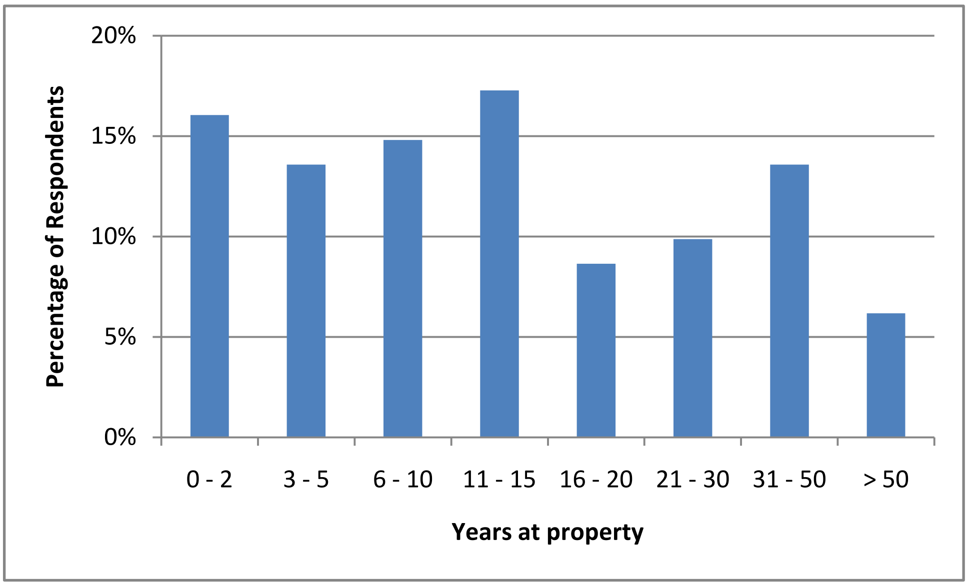

Figure 4.1: Years respondents have spent at current address

4.1.2 Flood Awareness & Information

Included in the questionnaire were a series of questions to determine resident's previous experiences of flooding. Of the 83 respondents, 39% state that flood waters entered their property, though only 2% experienced over-floor flooding. 45% of the respondents had not experienced flooding in Berry.

Approximately 30% of respondents had incurred some form of financial costs due to flooding. A further 20% reported being affected in other ways, such as restricted movement and forced relocation of live stock.

Residents were also asked to comment on how likely they thought future flood events would impact them. 81% believed that they would be unaffected or that flooding would only impact a small part of their yard. 17% believed that significant portions of their outdoor space would be flooded, whilst 5% believed that they would experience over-floor flooding.

It was also asked of residents if they had sought out information on flooding issues in the catchment. Nearly 30% had received information from relatives, friends, neighbours or the previous owner, and a further 12% had received information from the real estate agent when purchasing their property. Approximately 30% reported having sourced info from Council, either via customer service, or from the website.

It is important that when information is disseminated, that it be done in such a way that it reaches the population. Residents were asked to comment on which possible options of providing information they saw as the most effective. The responses have been ranked below in **Figure 4.2**.

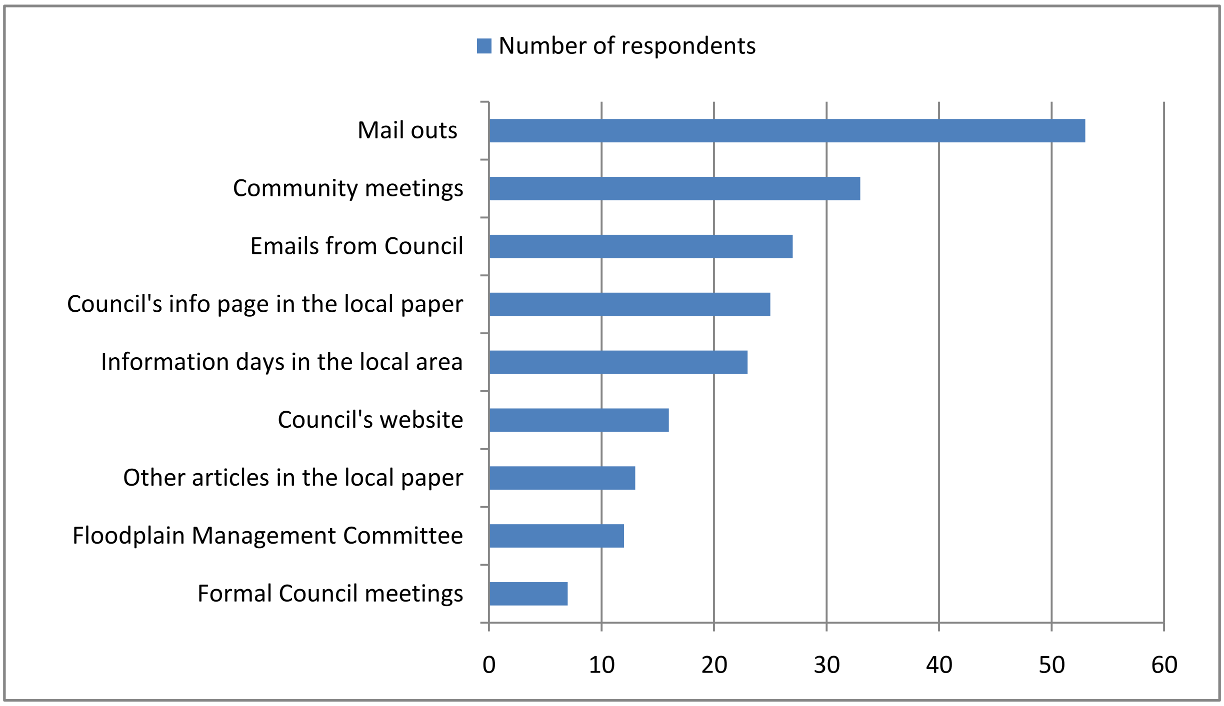

Figure 4.2: Preferred Channel for Information Distribution

4.1.3 Flood Management Options

A question in the questionnaire asked respondents to give a mark of 1 – 5 to a variety of potential management options, with 5 being the more preferred and 1 not preferred. By taking an average of the marks given to each option, it was possible to rank the options based on resident preference. The ranking is shown in **Figure 4.3**.

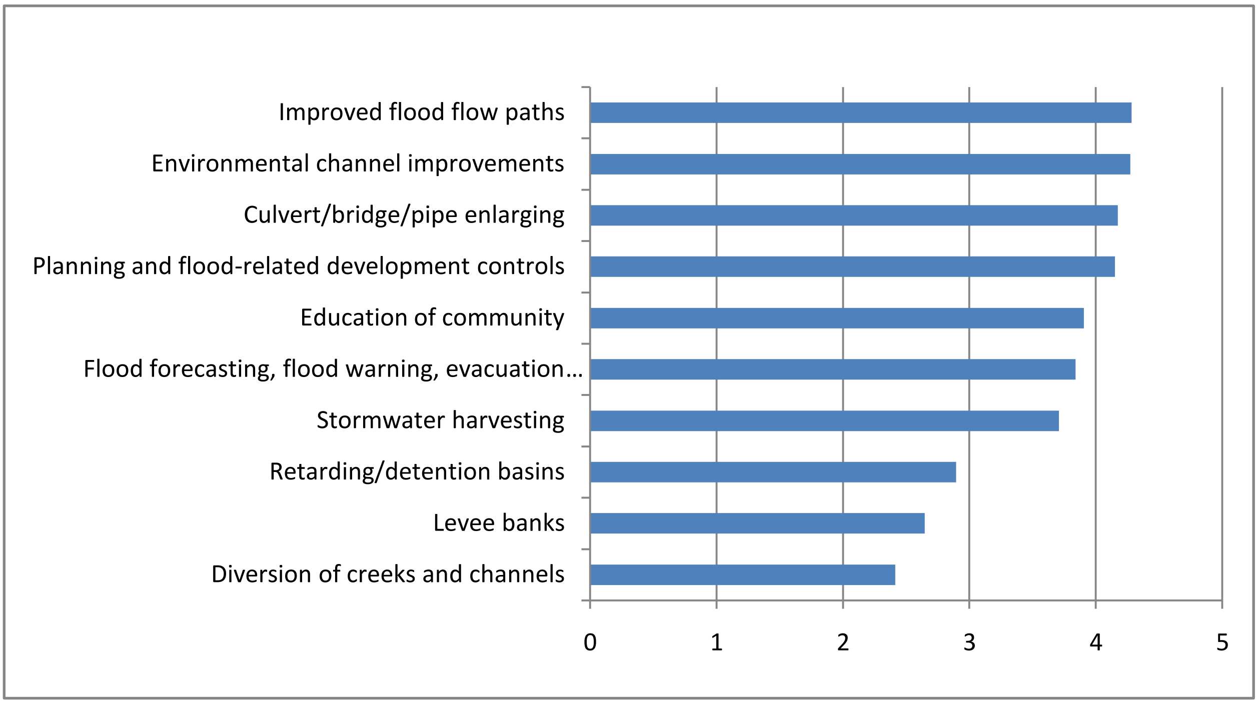

Figure 4.3: Resident Ranking of Possible Options

Improved flow paths and environmental channel improvements were the most preferred flood management options. It was noted by some residents that a number of waterways are clogged with weeds.

Planning and flood related development controls, flood forecasting, flood warning, evacuation planning and emergency response, education and stormwater harvesting were all ranked approximately equal.

Larger structural options such as detention basins, levees and diversions were least preferred.

5 Flood Study Modelling

The TUFLOW 1D/2D hydraulic model used to define the flood behaviour in the Broughton Creek study area. The hydrological model XP-RAFTS used to generate inflow hydrographs while the Direct Rainfall method was adopted for areas within the 2D model domain.

The intention of the TUFLOW model is to provide a better definition of the flood behaviour from the previous MIKE11 model that was adopted. The 2D component of the model allows for a better definition of the overbank and floodplain flows. This is particularly important in the areas near the township, where there are both complicated local flows along Town Creek as well as cross catchment flows which occur near Broughton Mill Creek.

For areas downstream of the railway line, the flood levels are primarily influenced by the backwater from the Shoalhaven River. These areas tend to be outside of the main focus of this study. As such, the TUFLOW model boundary was set a few hundred metres downstream of the railway line. For areas downstream of this, the MIKE11 model should still be adopted to define the flood behaviour.

5.1 Model Area

A 3m grid was developed to cover the township of berry and its immediate surrounds. The size of the model area is approximately 8.95 km^2, represented by approximately 995,000 grids cells.

5.2 Topography (2D)

A terrain grid was generated to represent surface elevations from ALS data supplied by Shoalhaven City Council. **Figure 5.1** shows the elevations of the Broughton Creek model area.

5.3 1D Network

Pipes drainage systems and selected open channels were modelled in TUFLOW as distinct 1D elements connected to the 2D terrain grid via pits.

The location and size of pipes and culverts were determined from Shoalhaven City Council database information, and additional survey. The majority of the catchment had detailed information on the piped drainage network. Where invert data did not exist, a standard cover depth was assumed and surface levels were estimated from the ALS data. Where no pipe sizes were found, pipe size was assumed to be equal to the largest pipe connected to the upstream pit.

Town Creek was modelled as a distinct 1D element, while other creeks were represented in the 2D domain. This was because the width of Town Creek was generally too small to be accurately represented by the 3m 2D grid. Town creek cross sections were taken from the previous MIKE11 model, and additional survey.

Figure 5.2 shows the 1D elements in the model. The lengths of the drainage system components for the model are:

- Pipes 6.5km
- Box Culverts 0.1km
- 1D Open Channels 1.1km

5.4 Roughness

5.4.1 2D Roughness

Each of the 2D grid cells has a roughness value applied to model the influence of flow behaviour of the particular land use. The adopted roughness layout, shown in **Figure 5.3** was based on aerial photographs, site inspections and Council's land-use zonings. The roughness value for each land-use is listed in **Table 5.1**.

Table 5.1: 2D Roughness Values

Land Use	Roughness Parameter
Roads	0.015
Medium Residential	0.11
Low Residential	0.09
Medium – High Density Vegetation (bush)	0.1
Low Density Vegetation (open space, pasture)	0.06
Waterways	0.05

5.4.2 1D Roughness

Each 1D element in the model – pipes, culverts, open channels – was also given a roughness parameter. Where possible, roughness values were taken from the previous SMEC MIKE11 model (see Volume 1). Where elements did not form a part of the previous model, roughness values were determined from photographs and site inspections. The roughness values for 1D elements are listed in **Table 5.2**.

Table 5.2: 1D Roughness Values

1D Element	Roughness Parameter
Concrete Pipes	0.015
Concrete Box Culverts	0.015
Town Creek – Max	0.16
Town Creek – Min	0.07
Town Creek - Average	0.14

5.5 Hydrology

There were two hydrological methods used in this model – one for upstream flows, and one for the 2D domain. The hydrological model XP-RAFTS was used to generate the inflow hydrographs to the study area. A XP-RAFTS model was constructed as part of the previous SMEC (2008) study. The model required minor adjustments to catchment areas due to the new 2D domain, but all other parameters remained unchanged. These changes are shown in **Figure 5.4**, and the area changes summarised in **Table 5.3**.

Table 5.3: RAFTS Model Changes

RAFTS Catchment ID	Previous Area (ha)	Updated Area (ha)
BC_HL1	71.5	39.1
BC_CP1	64.5	10.3
BC_BW3	5.4	4.9
BC_CN1	597.3	508.9
BC_BM4	461.6	302.1
BC_BC7	231.4	201.7
BC_BCTrib1	455.2	128.8

For the 2D domain, the Direct Rainfall Methodology was adopted. In this procedure, rainfall is applied directly to the 2D grid, and the resultant flows routed through model. As such, no separate hydrological model was required for the study area.

A schematisation of the hydrological set up is shown in **Figure 5.5**.

The design Intensity-Frequency-Duration (IFD) parameters were taken from the previous RAFTS model, and confirmed with data from the Bureau of Meteorology. Due to the large size of the total catchment area (approximately $184km^2$) the areal distribution of rainfall is variable. The IFD parameters for the regions covering the Broughton Creek catchment, adopted in the SMEC (2008) study, are shown in **Table 5.4**.

The loss rates applied to the rainfall based on the soil conditions of the catchment are listed in **Table 5.5**.

Table 5.4: Design IFD Parameters

Parameter	Berry	Berry East	Berry North	Berry North East
50% AEP 1-hour Intensity	47	50	50	52
50% AEP 12-hour Intensity	10.5	11	11.5	12.5
50% AEP 72-hour Intensity	3.5	3.5	4	4.5
2% AEP 1-hour Intensity	105	110	115	120
2% AEP 12-hour Intensity	25	27.5	29	32
2% AEP 72-hour Intensity	9	9	10.5	12
Skew	0	0	0	0
F2	4.274	4.274	4.274	4.274
F50	15.78	15.78	15.78	15.78
Temporal Pattern Zone	1	1	1	1

Table 5.5: Rainfall Loss Parameters

Land Use	Initial Loss (mm)	Continuing Loss (mm/hr)
Roads	1	0
Medium Residential	10	2
Low Residential	12	3
Medium – High Density Vegetation (bush)	15	5
Low Density Vegetation (open space, pasture)	15	5
Waterways	0	0

5.6 Boundary Conditions

The downstream boundary was modelled as a constant water level. The downstream boundary conditions were taken from the MIKE11 model (SMEC, 2008).

The boundary conditions for the SMEC (2008) study were based on a previous study of the Shoalhaven River and Shoalhaven Heads (Webb McKeown & Associates, 2002).

The downstream level accounts for the combined effects of flooding in the Shoalhaven River and ocean tide levels.

The downstream boundary of the TUFLOW model is approximately 2.6km upstream of the MIKE11 boundary, and therefore the boundary levels adopted in this study differ to those adopted in the SMEC study (SMEC, 2008). Downstream levels for the TUFLOW model were taken from the MIKE11 model at the point where the TUFLOW model ends.

The downstream boundary water level for each event is shown in **Table 5.5**. The values shown are the downstream value from the MIKE11 model, and the water level 2.6km upstream, which was adopted as the downstream value in the TUFLOW model.

Table 5.5: Downstream Boundary Conditions

Event	MIKE11 Downstream Boundary Water Level (mAHD)	TUFLOW Downstream Boundary Water Level (mAHD)
2002 Historical Event	3.9	5.23
2005 Historical Event	3.9	5.23
50% AEP	2.9	4.44
20% AEP	3.3	4.65
10% AEP	3.6	4.8
5% AEP	3.9	4.97
2% AEP	4.5	5.2
1% AEP	5.0	5.97
PMF	7.0	7.6

6 Model Calibration and Verification

The TUFLOW model was calibrated against the 2005 and 2002 historical flood events and verified against the MIKE11 model for the 100yr design flood event.

6.1 Calibration Results

A comparison of the model peak water levels and the historic flood levels for the 2002 and 2005 events are summarised in **Table** 6.1 and **Table 6.2** respectively. The location of these points is shown in **Figure 6.1** and **Figure 6.2** respectively.

A comparison of the model peak water levels and the MIKE11 model results for the 1% AEP event is summarised in **Table 6.3.** The location of these points is shown in **Figure 6.3**.

Table 6.1: Comparison of Tuflow and Historic 2002 Flood Levels

Location	Tuflow Peak Level (mAHD)	Historic Peak Level (mAHD)	Difference (m)*
Town Creek 1	6.13	5.95	0.18
Town Creek 2	12.07	12.05	0.02
Town Creek 3	17.31	17.27	0.04
Town Creek 4	17.22	17.22	0.00
Town Creek 5	17.63	17.43	0.20
Bundewallah Creek 1	7.30	7.23	0.07
Bundewallah Creek 2	7.52	7.44	0.08

***Positive numbers represent a higher level for the numerical model, compared to the historic levels**

Table 6.2: Comparison of Tuflow and Historic 2005 Flood Levels

Location	Tuflow Peak Level (mAHD)	Historic Peak Level (mAHD)	Difference (m)*
Broughton Mill Creek 1	7.01	6.91	-0.10
Broughton Mill Creek 2	6.04	5.93	-0.11
Broughton Mill Creek 3	9.19	9.13	-0.06
Town Creek 1	6.61	6.92	0.31
Town Creek 2	9.21	9.21	0.00
Town Creek 3	9.27	9.34	0.07
Town Creek 4	9.74	9.73	-0.01
Town Creek 5	9.52	9.39	-0.13
Town Creek 6	9.46	9.46	0.00
Town Creek 7	9.82	9.66	-0.16
Town Creek 8	9.64	9.54	-0.10
Town Creek 9	9.68	9.59	-0.09
Town Creek 10	15.82	15.52	-0.30
Town Creek 11	17.81	17.64	-0.18
Town Creek 12	17.45	17.66	0.21
Town Creek 13	17.82	17.66	-0.17
Town Creek 14	17.96	17.90	-0.06

***Positive numbers represent a higher level for the numerical model, compared to the historic levels**

Table 6.3: Comparison of Tuflow and 1% AEP Mike11 Flood Levels

Location	Tuflow Peak Level (mAHD)	Mike11 Peak Level (mAHD)	Difference (m)*
BC_TRIB_1	6.4	6.21	-0.19
BMC_1	5.8	5.69	-0.11
BMC_2	7.79	7.73	-0.06
BMC_3	10.14	10.08	-0.06
BMC_4	11.42	11.26	-0.16
BMC_5	15.21	15.2	-0.01
BW_1	12.95	12.82	-0.13
BW_2	16.05	15.89	-0.16
BW_3	25.36	25.27	-0.09
Nth_Rd_1	11.76	11.97	0.21
STH_1	5.03	5.01	-0.02
STH_2	5.21	5.41	0.2
STH_3	9.05	9.11	0.06
STH_TRIB_1	5.21	5.42	0.21
STH_TRIB_2	10.31	10.35	0.04
TC_1	5.8	5.72	-0.08
TC_2	6.75	6.58	-0.17
TC_3	12.81	12.58	-0.23
TC_4	16.52	16.6	0.08
TC_5	20.2	20.43	0.23
TC_6	29.98	30.09	0.11

***Positive numbers represent a higher level for the numerical model, compared to the Mike11 levels**

For the 2002 historical event, the TUFLOW model reports values within +/-0.2m of the recorded historical values, with the majority within +/-0.1m.

For the 2005 historical event, the TUFLOW model reports values within +/-0.3m of the recorded historical values, with the majority within +/-0.1m

This is considered sufficiently accurate given the sources of the historical data which were generally flood marks, or resident observations, which were surveyed after the flood had past.

Most of the historical marks were focused on Town Creek and Broughton Mill Creek. In order to verify the accuracy of the wider model, locations were taken from across the study area from the 1% AEP Mike11 model, and compared to the TUFLOW results.

For the 1% AEP design event, TUFLOW predicted flood levels that were generally within +/-0.2m of the Mike11, with the majority within +/-0.1m.

7 Existing Case Results

Flood modelling of design storms was undertaken for the 50%, 20%, 10%, 5%, 2% and 1% AEP events and the PMF event. Each AEP was run for a series of durations; 1hr, 1.5hr, 2hr, 3hr, 6hr and 9hr storms. An envelope of different durations were taken to determine the peak extent, depth and water level in the study area.

Rainfall was applied directly to the 2D domain, using the Direct Rainfall approach. This approach effectively results in every 2D cell being inundated with some flood depth. In order to create model extents and provide reasonable results, a filter was applied to separate what is catchment runoff and what is flooding.

In this study, flood extents were drawn for depths greater than 0.15m. Isolated wet or dry regions smaller than 9 grid cells were also removed.

Flood extents with peak water level contours for the design storms are shown in **Figure 7.1** to **Figure** 7.**7**.

The peak flood depths for the design storms are shown in **Figure 7.8** to **Figure 7.14**.

8 Existing Flood Hazard

8.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations (Appendix L; NSW Government, 2005). The Floodplain Development Manual (NSW Government, 2005) defines two categories for provisional hazard – high and low.

The model results were processed using an in-house developed program, which utilises the model results of flood level and velocity to determine hazard. Provisional hazard was prepared for 6 design events, namely PMF, 1%, 2%, 5%, 10%, and 20% AEP. The provisional hazard is based on the envelope of the hazard at each location for each AEP.

Hazard is calculated for each grid cell at each time step based on velocity, depth and velocity x depth, with the highest value giving the hazard rating for the cell.

The provisional hazard is shown in **Figure 8.1** to **Figure 8.7**.

8.2 True Flood Hazard

Provisional flood hazard categorisation based around the hydraulic parameters described above in **Section 8.1**, does not consider a range of other factors that influence the "true" flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include the:

- Size of the flood
- Effective warning time
- Flood readiness
- Rate of rise of floodwaters
- Duration of flooding
- Ease of evacuation
- Effective flood access
- Type of development in the floodplain

True flood hazard will be assessed as part of the Floodplain Risk Management Study and Plan.

9 Current Economic Impact of Flooding

9.1 Background

The economic impact of flooding can be defined by what is commonly referred to as flood damages. Flood damages are categorised as various types; these types are summarised in **Table 9.1**.

Table 9.1: Types of Flood Damages

Type	Description
Direct	Building contents (internal) Structural damage (building repair) External items (vehicles, contents of sheds, etc)
Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible	Social (increased levels of insecurity, depression, stress) Inconvenience (general difficulties in post-flood stage)

The direct damage costs, as indicated in **Table 9.1**, are just one component of the entire cost of a flood event. There are also indirect costs. Together, direct and indirect costs are referred to as tangible costs. In addition to tangible costs, there are intangible costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDamage or ANUFLOOD, or via more generic methods using spreadsheets. For the purposes of this project, generic spreadsheets have been used based on a combination of OEH residential damage curves and FLDamage.

9.2 Floor Level and Property Survey

A floor level property survey was undertaken of properties within the flood extent; refer **Section 3.2**.

9.3 Damage Analysis

A flood damage assessment for the existing catchment conditions has been completed as part of this study.

The assessment is based on damage curves that relate the depth of flooding on a property to the likely damage within the property. Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments is not available and recourse is generally made to damage curves from other catchments.

OEH has conducted research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties. The OEH methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW.

The following sections set out our methodology for the determination of damages within the Broughton Creek catchment.

9.3.1 Residential Damage Curves

The draft DNR (now OEH) Floodplain Management Guideline No. 4 *Residential Flood Damage Calculation* (NSW Government, 2005) (NSW Government, 2005) was used in the creation of the residential damage curves. These guidelines include a template spreadsheet program that determines damage curves for three types of residential buildings, namely:

- Single story, slab on ground
- Two story, slab on ground
- Single story, high set

Damages are generally incurred on a property prior to any over floor flooding. The OEH curves allow for a damage of $10,023 (February 2011 dollars) to be incurred when the water level reaches the base of the house, with the base of the house assumed to be 0.3m below the floor level for slab on ground. We have assumed that this remains constant until overfloor flooding occurs. A nominal $3,000 has been allowed to represent damage to gardens where the ground level of the property is overtopped by more than 0.3m of depth but only up to 0.3m below the floor of the house.

There are a number of input parameters required for the OEH curves, such as floor area and level of flood awareness. The following parameters were adopted:

- A value of 150m^2 was adopted as a conservative estimate of the floor area for residential dwellings in the floodplain. With a floor area of 150m^2, the default contents value is $56,516 (May 2011 dollars)
- The effective warning time has been assumed to be zero due to the absence of any flood warning systems in the catchment. A long effective warning time allows residents to prepare for flooding by moving valuable household contents.
- The Broughton Creek catchment is a small part of the regional area, and as such is not likely to cause any post flood inflation. These inflation costs are generally experienced in regional areas where re-construction resources are limited and large floods can cause a strain on these resources.

Average Weekly Earnings

The OEH curves are derived for late 2001 and were updated to represent May 2011 dollars (as shown in **Table 9.2**). General recommendations by OEH are to adjust the values in residential damage curves by Average Weekly Earnings (AWE) rather than by the inflation rate as measured by the Consumer Price Index (CPI). OEH proposes that AWE is a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home. The most recent data from the Australian Bureau of Statistics at the time of this study was for May 2011. Therefore, all ordinates in the residential flood damage curves were updated to May 2011 dollars. In addition, all damage curves include GST as per OEH recommendations.

While not specified, we have assumed that the curves provided in OEH guidelines were derived in November 2001, which allows us to use the November 2001 AWE statistics (issued quarterly) for comparison purposes. May 2011 AWE values were taken from the Australian Bureau of Statistics website (ABS, 2011).

Consequently, damages have been increased by 51% and GST has been included compared to 2001 values.

Table 9.2: Average Weekly Earnings (AWE) Statistics for Residential Damage Curves

Month	Year	AWE
November	2001	$673.60
February	2011	$1,015.20

9.3.2 Commercial Damage Curves

Commercial damage curves were adopted from the FLDamage Manual (Water Studies Pty Ltd, 1992). FLDamage allows for three types of commercial properties:

- Low value commercial
- Medium value commercial
- High value commercial

In determining these damage curves, it has been assumed that the effective warning time is approximately zero, and the loss of trading days as a result of the flooding has been taken as 10.

These curves are determined based on the floor area of the property. The floor level survey provides an estimate of the floor area of the individual commercial properties. These have been used to factor these curves.

The Consumer Price Index (CPI) was used to bring the 1990 data to May 2011 dollars, using data from the Australian Bureau of Statistics (ABS, 2011). It was assumed that the FLDamage data was in June 1990 dollars. The CPI data is shown in **Table 9.3**.

Consequently, commercial damages have been increased by 73.8% and GST has been included compared to 1990 values.

Table 9.3: CPI Statistics for Commercial Damage Curves

Month	Year	AWE
June	1990	$102.50
May	2011	$178.30

9.3.3 Industrial Damage Curves

Cardno, as part of a previous floodplain management study (Cardno, 1998) conducted a survey of industrial properties in 1998 for Wollongong City Council. The damage curves derived from this survey are more recent than those presented in FLDamage and have been used in a number of previous studies. We therefore have used these damage curves for this study.

The curves were prepared for three categories:

- Low value industrial
- Medium value industrial
- High value industrial

Within the catchment, there are no properties considered to be representative of high value industrial properties, and hence these curves were not used.

The floor areas for the industrial properties were estimated during the floor level survey. To normalise the damages for property size, the curves have been factored to account for floor area.

The survey conducted only accounts for structural and contents damage to the property. Clean up costs and indirect financial costs were estimated based on the FLDamage Manual (Water Studies Pty Ltd, 1992). Actual internal damage could be estimated, along with potential internal damage, using various factors within FLDamage. Using both the actual and potential internal damages, estimation of both the cleanup costs and indirect financial costs could be made. The values were adjusted to June 2011 dollars using the CPI statistics show in

Consequently, damages have been increased by 47.4% and GST has been included compared to the 1998 values.

Table 9.4: CPI Statistics for Industrial Damage Curves

Month	Year	AWE
June	1998	$121.00
May	2011	$178.30

9.3.4 Adopted Damage Curves

The adopted damage curves are shown in **Figure 9.1**.The commercial and industrial damage curves are shown for a property with a floor area of 100m^2.

9.4 Average Annual Damage

Average Annual Damage (AAD) is calculated using a probability approach based on the flood damages calculated for each design event.

Flood damages (for a design event) are calculated by using the damage curves described above. These damage curves attempt to define the damage experienced on a property for varying depths of flooding. The total damage for a design event is determined by adding all the individual property damages for that event.

The AAD value attempts to quantify the flood damage that a floodplain would receive on average during a single year. It does this using a probability approach. A probability curve is drawn, based on the flood damages calculated for each design event. For example, the 1% AEP design event has a probability of occurring of 1% in any given year, and as such the 1% AEP flood damage is plotted at this point (0.01) on the AAD curve. AAD is then calculated by determining the area under the plotted curve. Further information of the calculation of AAD can be found in Appendix M of the Floodplain Development Manual (NSW Government, 2005).

The probability curve for the Broughton Creek damages is shown in **Figure 9.2**.

For this study, the damage resulting from events more frequent that a 50% AEP were assumed to be zero for the AAD analysis).

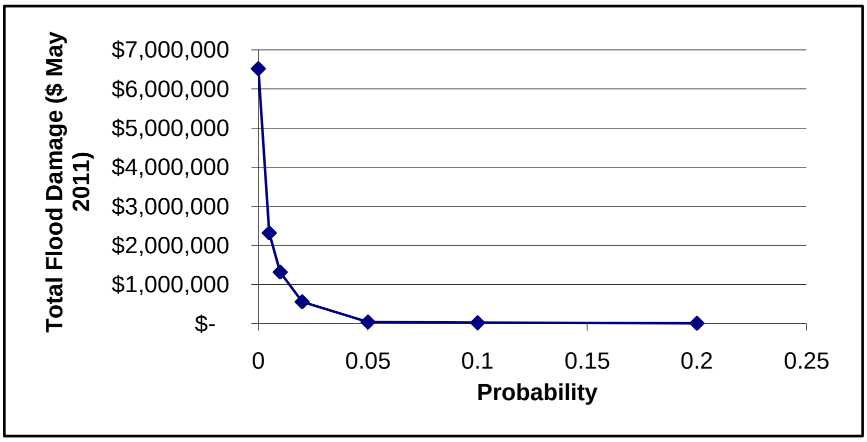

Figure 9.2: Broughton Creek Average Annual Damage Curve

9.5 Results

The results from the damage analysis are shown in **Table 9.5**. Based on the analysis described above, the average annual damage for the Broughton Creek floodplain under existing conditions is $109,926.

Table 9.5: Flood Damage Analysis Summary

Event / Property Type	Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Properties with overground flooding	Total Damage ($ May 2011)
PMF					
Residential	50	0.54	2.36	102	$ 3,451,255
Commercial	4	1.64	2.34	8	$ 2,173,869
Industrial	3	2.40	2.96	1	$ 762,987
PMF Total	57			111	$ 6,388,112
1% AEP					
Residential	11	0.66	0.74	40	$ 849,066
Commercial	3	1.09	0.81	3	$ 1,242,391
Industrial	2	0.82	1.27	2	$ 147,664
1% AEP Total	16			45	$ 2,239,120
2% AEP					
Residential	8	0.16	0.73	30	$ 547,417
Commercial	3	0.37	0.59	3	$ 711,943
Industrial	1	1.03	1.03	1	$ -
2% AEP Total	12			34	$ 1,259,360
5% AEP					
Residential	2	0.44	0.73	21	$ 304,893
Commercial	2	0.19	0.30	3	$ 222,142
Industrial	1	0.70	0.70	1	$ -
5% AEP Total	5			25	$ 527,035
10% AEP					
Residential	1	0.07	0.07	7	$ 42,293
Commercial	1	0.05	0.05	2	$ -
Industrial	1	0.29	0.29	1	$ -
10% AEP Total	3			10	$ 42,293
20%AEP					
Residential	0	-	0.00	3	$ 23,195
Commercial	0	-	-	2	$ -
Industrial	0	-	0.00	0	$ -
20%AEP Total	0			5	$ 23,195
50% AEP					
Residential	0	-	-	1	$ 10,098
Commercial	0	-	-	0	$ -
Industrial	0	-	-	0	$ -
50% AEP Total	0			1	$ 10,098

10 Sensitivity Analysis

10.1 Model Parameters

A sensitivity analysis was undertaken on the TUFLOW model for the 100 year ARI. The analysis was undertaken by:

- Varying 1D and 2D roughness values by +/- 20%
- Varying the inflows and rainfall by +/- 20%
- Varying the downstream boundary by +/- 20%

A large majority of the changes in flood levels occurred within creek systems and on farmland or parkland. To undertake a meaningful analysis of the sensitivity of the model, the differences of peak water levels were extracted within residential properties based on the floor level survey locations for each of the sensitivity analyses. Properties with a water level change of less than 5mm where classified as no change.

The sensitivity results are summarised in **Table 10.1**.

Table 10.1: Model Sensitivity Results Summary

	Roughness WL change		Inflow & Rainfall WL change		Boundary WL change	
	+20%	-20%	+20%	-20%	+20%	-20%
% of Properties with Increase	23%	2%	40%	0%	5%	1%
% of Properties with Decrease	1%	25%	0%	53%	0%	1%
Max Increase (m)	0.14	0.01	0.11	0.01	1.16	0.01
Max Decrease (m)	-0.01	-0.24	-0.01	-0.45	-0.02	-1.01
25th Percentile Increase (m)	0.00	0.00	0.00	0.00	0.00	0.00
90th Percentile Increase (m)	0.01	0.01	0.02	0.01	0.00	0.00
25th Percentile Decrease (m)	0.00	0.00	0.00	0.00	0.00	0.00
90th Percentile Decrease (m)	-0.01	-0.01	0.00	-0.11	0.00	0.00

10.2 Blockages

Stormwater pits can potentially block through a number of factors. A number of Councils in NSW adopt a "blockage policy" in undertaking design flood analysis. Shoalhaven City Council has not adopted a specific policy to date.

The culverts and bridges within the study area are primarily located along Town Creek and under the railway line. Blockages of these structures can occur by the accumulation of debris from upstream. Historical observations in other similar catchments have shown this debris to be diverse, and can include vegetation, tress, garbage bins and cars.

In the model, the blockages adopted were based on the SMEC investigation (SMEC, 2008), which had a blockage rate of 50% for culverts along Town Creek, while blockages throughout the rest of the catchment were kept unblocked, ie, a blockage of 0%.

The likely blockage of culverts can be difficult to predict. However, Wollongong Council have developed a Conduit Blockage Policy (Wollongong City Council, 2002) based on historical observations during major flooding in the urbanised portions of Wollongong in 1998 and 1999. The research behind this policy is probably the most complete to have been undertaken in NSW.

The policy adopts the following blockages:

- 100% blockage for structures with a major diagonal opening of less than 6m
- 25% blockage for structures with a major diagonal opening of greater than 6m
- 100% blockage for handrails over structures in both cases when overtopping occurs

The policy is more conservative than the approach adopted previously for Broughton Creek. In Broughton Creek, the above criteria mean that the majority of culverts are 100% blocked.

An analysis was undertaken in the model on the effects of this blockage.

The results of the blockage analysis are summarised in **Table 10.2**.

Table 10.2: Blockage Sensitivity Results Summary

	Blockage Sensitivity WL change (m)
% of Properties with Increase	10%
% of Properties with Decrease	1%
Max Increase (m)	1.12
Max Decrease (m)	-0.14
25th Percentile Increase (m)	0.00
90th Percentile Increase (m)	0.03
25th Percentile Decrease (m)	0.00
90th Percentile Decrease (m)	0.00

11 Discussion on Existing Flooding

11.1 Major Waterways

11.1.1 Broughton Creek

The major creek of the catchment is Broughton Creek. It passes through the south east corner of the model area. The majority of the flooding along this creek affects rural land, and generally does not impact on a significant number of houses or buildings. It does affect emergency access to David Berry Hospital, although it is noted that this hospital is not affected and is also not an emergency hospital.

11.1.2 Broughton Mill Creek

Broughton Mill Creek is a major tributary of Broughton Creek. It runs north to south past the east side of Berry, and crosses both the Princes Highway and the railway. Its overbank flooding affects the eastern side of Berry. Much of the floodplain is classed as high hazard in the 1% AEP, generally due to depth. Depths in this area are generally in excess of 1m along the rear of properties on Prince Alfred St and adjacent to Woodhill Mountain Road in the 1% AEP event. The flooding affects some of the commercial properties to the east of the main Berry Township and also the Bowling Club. This watercourse also affects the railway, and can cause overtopping of the railway embankment in events larger than the 5% AEP ARI event.

11.1.3 Bundewallah Creek

Bundewallah Creek flows west – east through pastureland to the north Berry. It joins Broughton Mill Creek immediately upstream of the Princes Highway crossing. This waterway is responsible for some minor property flooding near its confluence with Broughton Mill Creek, as well as inundation of some rural properties upstream, but generally does not significantly affect the Berry township.

11.2 Flowpaths

11.2.1 Town Creek

The major flowpath through the township of Berry is along the central watercourse, known locally as Town Creek. This flowpath originates in the north-west, and flows overland through pastureland before crossing North Road and entering a channel which winds through the centre of Berry. Town Creek passes under Prince Alfred Street near Victoria Street, and then flows south along side Prince Alfred Street before passing under the railway, and joining with Broughton Mill Creek downstream of the study area.

The Town Creek flowpath is responsible for the majority of flood damages in the study area.

It is generally slow moving, with velocities below 0.75m/s for the most part, but they can reach up to 1.5m/s along some sections of the channel where the channel has been rock lined. Flood depths adjacent to the main channel are generally 0.5 – 0.8m in the 1% AEP. Increased flood depths of up to 1.2m occur at some locations.

Town Creek flooding also causes the overtopping of roadways within Berry, which can affect access during a flood event. Peak water depths at key intersections along Town Creek are shown in for the 5% and 1% AEP events, and the PMF event.

Table 11.1: Peak Depths at Berry Intersections*

Intersection	5% AEP Peak Depth (m)	1% AEP Peak Depth (m)	PMF Peak Depth (m)
Albert Street & George Street	0.21	0.39	0.59
Princess Street & Edward Street	-	0.20	0.35
Princess Street & Albany Street	-	0.23	0.39
Princess Street & Alexandria Street	0.29	0.41	0.61

***note that depths are indicative and may vary across the road.**

11.2.2 North Street Overland Flowpath

A small flowpath conveys water along North Street and Albert Street in the north of Berry. The flowpath originates as an overland flowpath in pastureland adjacent to North Street. Shortly after Albany Street, the flowpath crosses North Street, and progresses through residential properties to emerge on the corner of Alexander and Albert Streets. Water is then conveyed down Albert Street to Broughton Mill Creek.

This flowpath conveys relatively little water. It causes flooding to some properties with depths of up to 0.5m, but velocities are low, and the flowpath is categorised as low hazard.

11.2.3 Hitchcocks Lane Creek

Two flowpaths cross the Princes Highway in the south-west. They are unnamed, but were referred to as Hitchcocks Lane Creek and Hitchcocks Lane Tributary in previous studies (SMEC, 2008). They combine immediately downstream of the retirement village, just prior to passing under the railway line.

Much of the flow between the Princes Highway and railway line is classified as high hazard, due to depths of up to 1.6m along the floodway, and up to 2.2m of ponding at the railway line in the 1% AEP.

Most of the affected area is pastureland with occasional residences, although the new retirement village has been built between these flowpaths. The properties within the retirement village have been raised above the 100yr level, and the access road is flood-free up to, and including, the 1% AEP event.

11.3 Critical Duration

As noted in **Section 7** each AEP was run for a series of durations. Generally, storm durations of 1 – 2 hours were critical throughout much of the catchment, including minor watercourses such as Town Creek, Bundewallah Creek and Broughton Mill Creek. Longer durations of 6 – 9 hours were found to be critical for Broughton Creek, where flooding is primarily driven by peak flood volumes rather than peak rainfall intensity.

11.4 Major Access Road/ Railway Overtopping

There are a number of major access routes within the Broughton Creek catchment. The most significant of these are:

- Princes Highway – Primary access to and from Berry in both directions
- Tannery Road – Access road to David Berry Hospital
- Railroad – Part of the Illawarra and Southern Highlands railroad track

Each of these locations are subject to flooding during storm events of sufficient magnitude, and the loss of access along these routes has consequences for emergency evacuation and access to medical treatment.

Approaching Berry from the north, the Princes Highway crosses Broughton Mill Creek shortly before entering Berry. There is a low point on this length of road at the corner out Albert Street, which experiences flooding from Broughton Mill Creek.

To the south of Berry, the Princes Highway crossed Hitchcocks Lane Creek, and a low point exists at this location which is also susceptible to flooding.

Tannery Road provides access to David Berry Hospital, and this access road crosses under the railway shortly before climbing up to the hospital located on a ridge. This underpass can be significantly flood affected.

The railway has a low point as it drops from the ridge near to Broughton Creek to the flatter plain near Berry. This low point is close to Broughton Mill Creek, and can affected by flooding of this watercourse.

Each of these locations are shown in **Figure 11.1** and the peak depths at these critical locations are shown in **Table 11.2** for the 5% AEP, 1% AEP and the PMF design events.

The timings, durations and emergency response implications of flooding at these locations will be examined in the Floodplain Risk Management and Study report.

Table 11.2: Major Access Road Flood Depths*

Location	5% AEP Peak Flooding Depth (m)	1% AEP Peak Flooding Depth (m)	PMF Peak Flooding Depth (m)
Princes Highway, corner of Albert St	0.31	0.74	2.31
Princes Highway, Hitchcock's Lane crossing	0.16	0.22	1.71
Tannery Road, railway underpass	1.87	2.59	4.52
11.4.1 Railway, Broughton Mill Creek crossing	-	0.21	1.87

***note that depths are indicative and may vary across the road.**

12 Qualifications

This report has been prepared by Cardno for Shoalhaven City Council and as such should not be used by a third party without proper reference.

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts.

Hence there will be a level of uncertainty in the results and this should be borne in mind in their application.

The report relies on the accuracy of the survey data and pit and pipe date provided by Council.

Study results should not be used for purposes other than those for which they were prepared.

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Figures

Appendix A

Community Consultation Brochure & Questionnaire

Floodplain Risk Management Options

The following list of Floodplain Risk Management options presents some preliminary strategies that could be considered to minimise the risk and reduce the impact of flooding throughout the Broughton Creek catchment. These options will be considered in further detail during the preparation of the Management Study and Plan.

Examples of Flood Management Options	
	Description
Flood Modification Options	• Construction of levees where properties are most at risk • Upgrading of drainage systems i.e. construction of detention/retarding basins • Stabilisation works of eroding foreshore areas and along drainage channels
Property Modification Options	• Building and development controls • Voluntary house raising program (for selected properties) • Voluntary house rebuilding subsidy scheme (for selected properties) • Voluntary property purchase program (for selected properties).
Emergency Response Modification Options	• Revision of the Local Disaster Plan (DISPLAN) • Public awareness and education—locality based flooding information for residents • Public awareness and education—flooding information for schools • Flood depth markers at major (flood affected) road crossings • Continuation of existing public awareness and education campaigns • Data collection strategies for future floods

Consultation

During the Floodplain Risk Management Study and Plan process, consultation will be undertaken with the community in order to establish a comprehensive list of management options.

In addition to the accompanying Questionnaire, which can also be found on Council's website, you will have further opportunities to comment on the direction of the project during the public exhibition periods of the Draft Risk Management Study and Plan. Any comments received during these periods will be taken into account before finalisation.

For further information regarding this project please see Council's website www.shoalhaven.nsw.gov.au, or contact either Shoalhaven City Council or Cardno via the details below.

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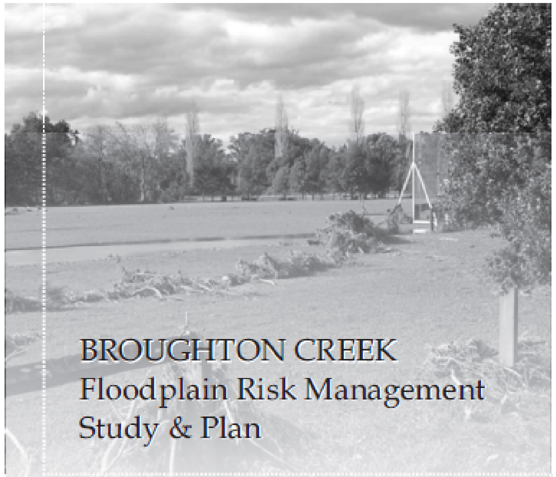


BROUGHTON CREEK Floodplain Risk Management Study & Plan

Information Brochure

Shoalhaven City Council has engaged Cardno to assist with the preparation of the Broughton Creek Floodplain Risk Management Study and Plan.

The Risk Management Study and Plan follows from the Flood Study, completed in 2007, which identified the existing flooding behaviour in the Broughton Creek catchment. The purpose of this Risk Management Study and Plan is to identify and recommend appropriate actions to manage flood risks in the Broughton Creek catchment.

This brochure provides an introduction to the Risk Management Study and Plan and informs you of the its objectives.

Your feedback on the accompanying questionnaire will play an important role in the project.

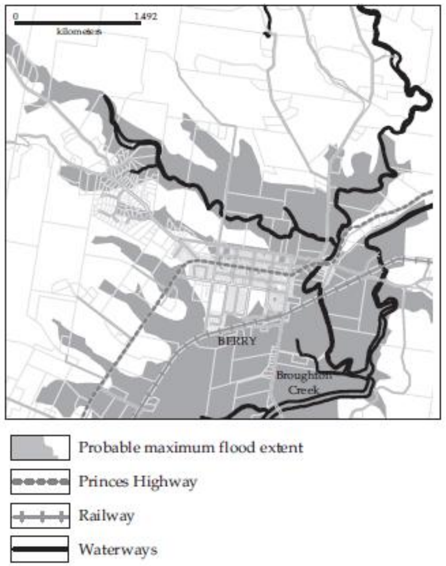
prepared for Shoalhaven City Council | prepared by Cardno

Existing Flooding Issues

As identified within the Flood Study (SMEC, 2007), Broughton Mill, Connollys, Bundewallah and Town Creeks are the main sources of flooding in Berry. Other locations affected by flooding include rural areas surrounding Berry and the Princes Highway.

Access to David Berry hospital and the rail line can also be affected during flood events.

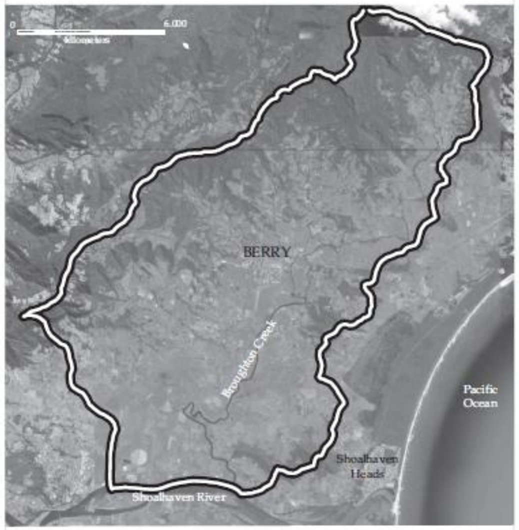
The probable maximum flood extent (extreme flood) for the Broughton Creek catchment is shown below. During this event, properties in Berry are affected by flooding primarily from Town Creek.



Study Area

The study area comprises the Broughton Creek catchment incorporating Berry and surrounding farmlands. Broughton Creek and its tributaries rise in the ranges to the north and west of the town of Berry, flowing through farmlands and forest to the Shoalhaven River downstream of Nowra. The catchment area of Broughton Creek covers approximately 104 square kilometres (see below).

Catchment Area



Floodplain Management Process

Council's Shoalhaven River Natural Resource and Floodplain Risk Management Committee (the Committee) oversees the Floodplain Management process. The Committee meets regularly and includes representatives from Council, Department of Environment, Climate Change and Water (DECCW), State Emergency Service (SES), Industry and Investment NSW, and representatives of the local community.

Floodplain Risk Management Study and Plan Objectives

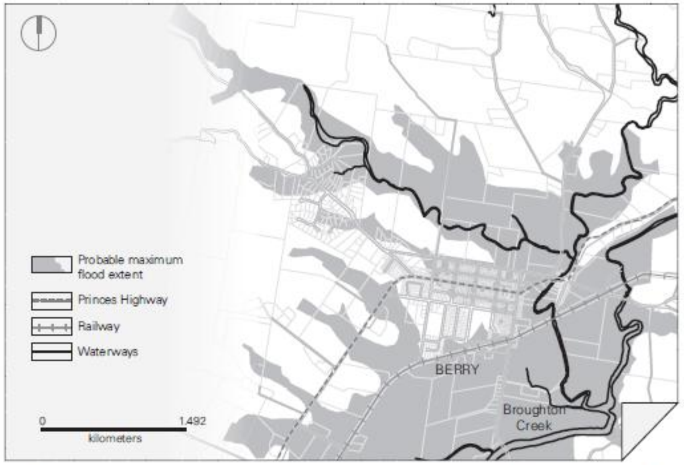
The objectives of the study and plan are:

Floodplain Risk Management Study

Find an appropriate mix of management measures and strategies to effectively manage the full range of flood risk in accordance with the NSW Government Floodplain Development Manual (2005) through an effective public participation and community consultation program. The information from this study will enable Council to formulate a Floodplain Risk Management Plan for the study area.

Floodplain Risk Management Plan:

Formulate a cost effective plan for the study area based on the findings of the Floodplain Risk Management Study and provide a priority program for implementation of the recommended works and measures in accordance with the Manual. The plan will detail how the existing and future flood risk within the study area will be managed.



If you have any further comments that relate to the Broughton Creek Floodplain Risk Management Study and Plan, please express them in the space below. Please feel free to attach additional pages if necessary.

Thank you for providing the above information. Please remember to put the pages back in the reply paid envelope by Friday 10 December 2010. A representative from Cardno may contact you in the near future to discuss your response.

YOUR PERSONAL INFORMATION WILL REMAIN CONFIDENTIAL

If you have any queries, please contact:

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OCTOBER 2010

BROUGHTON CREEK
Floodplain Risk Management Study & Plan

Local Resident/Land Owner Survey

*Note: information supplied will remain completely confidential.

Q1. Could you please provide us with the following details? We may wish to contact you to discuss some of the information you have provided us.

Name:
Address:
Daytime Ph:
Email:

Q2. Is your property (please tick)?

☐ Owner occupied ☐ Occupied by a tenant
☐ A business ☐ Farmland

Q3. How long have you lived, worked and/or owned your property? .... Months .... Years

Q4. How long have you lived in Berry? .... Months .... Years

Q5. How many people occupy your property? ....

Q 6. Please indicate the number of permanent residents at this address aged:

☐ 0 - 4 years ☐ 5 - 24 years
☐ 25 - 64 years ☐ 65+ years

prepared for Shoalhaven City Council

prepared by Cardno Shaping the Future

Our team appreciates the diverse effects of flooding – from its dynamic shaping of the environment through to its potential negative social and economic impact. With this knowledge we analyse and develop comprehensive plans.

Q 7. Have you ever experienced flooding since living/working/ owning your property? (please tick relevant boxes)

- ☐ Yes, floodwaters entered my house/business
- ☐ Yes, floodwaters entered my yard/surrounding property
- ☐ Yes, the road was flooded and I couldn't drive my car
- ☐ Yes, the creek broke its banks
- ☐ Yes, other parts of my neighbourhood were flooded
- ☐ No, I haven't experienced a flood (go to Q.9)
- ☐ Other (specify) ....

Q 8. If you have experienced a flood, how did the flooding affect you and your family/business? (please tick relevant boxes)

- ☐ Parts of my house/business building were damaged
- ☐ The contents of my house/business were damaged
- ☐ My garden, yard, and/or surrounding property were damaged
- ☐ My car(s) were damaged
- ☐ Other property was damaged (specify) ....
- ☐ I couldn't leave the house/business
- ☐ Family members/work mates couldn't leave/return to the house/business
- ☐ My family had to evacuate the house/business
- ☐ I had to move livestock/my livestock were threatened by flooding
- ☐ The flood disrupted my daily routine
- ☐ The flood affected me in other ways (specify) ....
- ☐ The flood didn't affect me

Q 9. Do you think your property would be flooded sometime in the future? (please tick relevant boxes)

- ☐ No
- ☐ Yes, but only a small part of my yard
- ☐ Yes, most of my yard/outdoor areas of business could be flooded
- ☐ Yes, my house/office/business could flood over the floor

Q10. Have you looked for information about flooding on your property? (please tick relevant boxes)

- ☐ Council's customer service centre
- ☐ Other information from Council (specify) ....
- ☐ Viewed a Property Planning (Section 149) Certificate
- ☐ Information from a real estate agent
- ☐ Information from relatives, friends, neighbours, or the previous owner
- ☐ Other information (specify) ....
- ☐ No information has been sought
- ☐ I do not believe my property is affected by flooding
- ☐ Council's website

If you answered yes to having looked for information on Council's website:

- ☐ What information have you looked for? (Please specify) ....
- ☐ Where were you able to find information? (Please specify) ....

Q11. What do you think are the best ways to get input and feedback from the local community about the options being considered to manage flooding and the results for this project? (please tick relevant boxes)

- ☐ Council's website
- ☐ Emails from Council
- ☐ Council's Floodplain Management Committee
- ☐ Formal Council meetings
- ☐ Council's information page in the local paper
- ☐ Other articles in the local paper
- ☐ Information days in the local area
- ☐ Community meetings
- ☐ Mail outs to all residents/business owners in the study area
- ☐ Other (specify) ....

Q12. What is the main language spoken at home?

- ☐ English
- ☐ Other (specify) ....

Q13. As a local resident who may have witnessed flooding/drainage problems, you may have your own ideas on how to reduce flood risks. Which of the following management options would you prefer for the Broughton Creek catchment (1=least preferred, 5=most preferred)? Please also provide comments as to the location where you think the option might be suitable.

Proposed Option	Preference (please circle)	Location/Other Comments?
Retarding or detention basins; these temporarily hold water and reduce peak flood flows	1 2 3 4 5	
Stormwater harvesting, such as rainwater tanks	1 2 3 4 5	
Improved flood flow paths	1 2 3 4 5	
Culvert/ bridge/pipe enlarging	1 2 3 4 5	
Levee banks	1 2 3 4 5	
Diversion of creeks and channels	1 2 3 4 5	
Environmental channel improvements, including removal of weeds & bank stabilisation	1 2 3 4 5	
Planning and flood-related development controls	1 2 3 4 5	
Education of community, providing greater awareness of potential hazards	1 2 3 4 5	
Flood forecasting, flood warning, evacuation planning and emergency response	1 2 3 4 5	
Other (please specify any options you believe are suitable). Please attach extra pages for other suggestions	1 2 3 4 5	