Allans Creek Floodplain Risk Management Plan

Report Prepared For

Wollongong City Council

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REPORT STATUS

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It is the responsibility of the reader to verify the currency of the version number of this report. All subsequent releases will be made directly to the Client.

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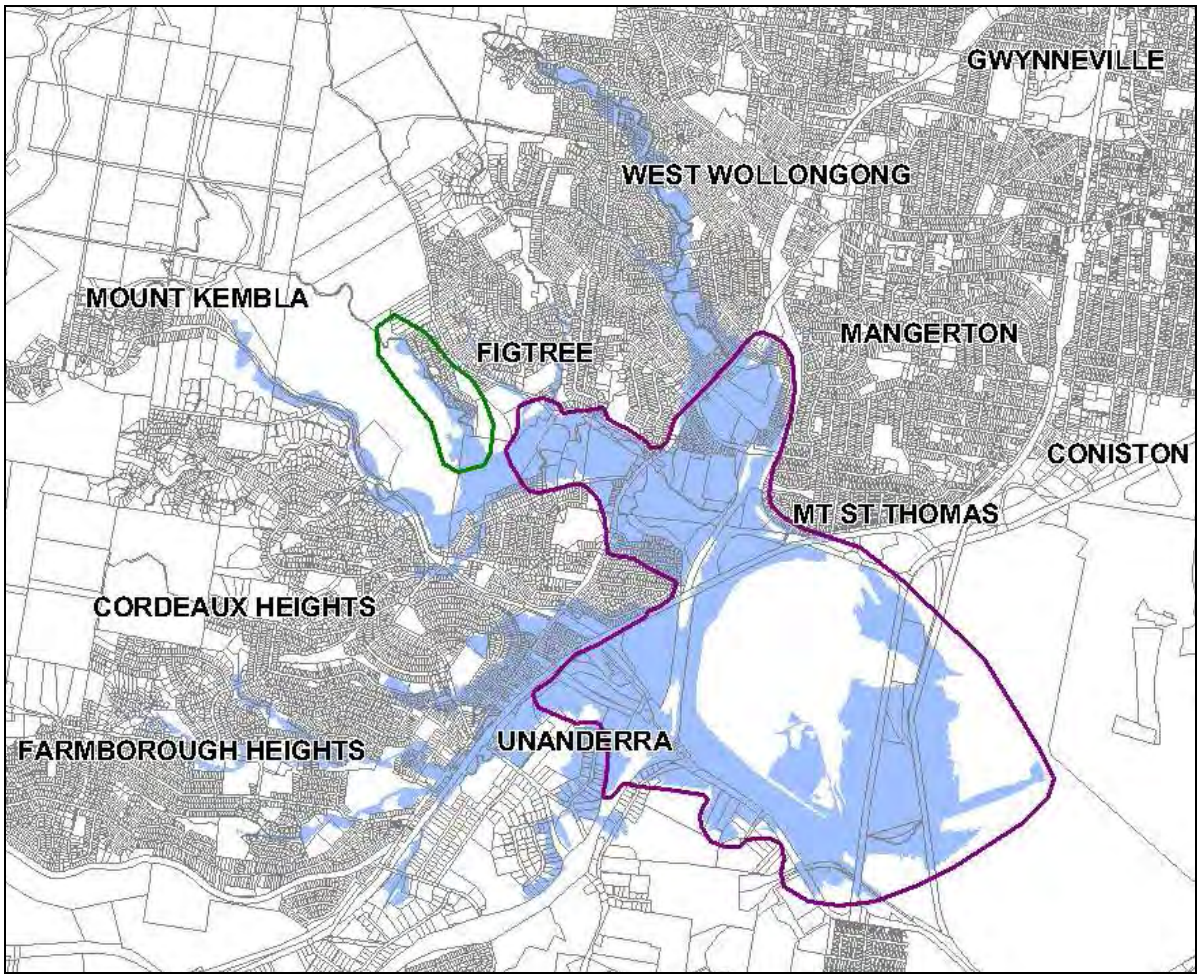
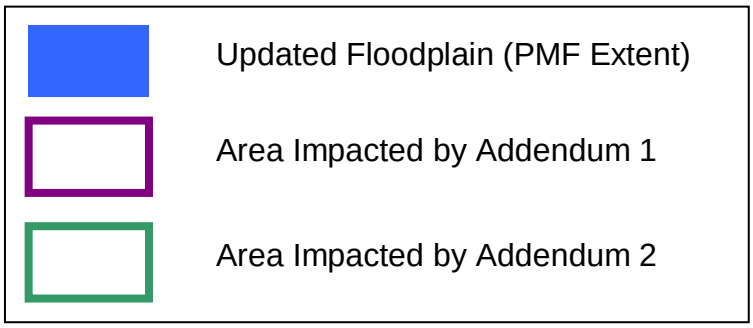
IMPORTANT INFORMATION

Due to the implementation of actions from the Allans Creek Floodplain Risk Management Plan and subsequent detailed investigations, the Allans Creek Flood Study (2006) has been updated to represent the current catchment conditions. These updates have resulted in two Addendum reports (Cardno Lawson Treloar, 2008, ref: R2346v3 and Cardno Lawson Treloar, 2009 ref: W4789v4), which supersedes a number of results presented in this Plan. It is therefore imperative that this Floodplain Risk Management Plan is read in conjunction with the Addendum reports. Figures showing flood extents have been superseded for the entire floodplain and must be read from the Addendum reports. It is the responsibility of the reader to ensure they have read the Addendum reports before using the presented data.

The areas impacted by the Addendum reports are shown on the following page.

Area Impacted by Addendum 1 (Cardno Lawson Treloar, 2008, Ref: R2346v3) and Addendum 2 (Cardno Lawson Treloar, 2009, Ref: W4789v4)





NOTE: Flood levels, velocities and flows have been updated within the area shown above. Flood extents for the entire floodplain have been updated in Addendum 1, except for flood extents for the Darragh Drive area, which have been updated in Addendum 2.

FOREWORD

The State Government's Flood 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 liable land is the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

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

1. Formation of a Committee	Established by Council and includes community group representatives and State agency specialists.
2. Data Collection	Past data such as flood levels, rainfall records, land use, soil types etc.
3. Flood Study	Determines the nature and extent of the floodplain.
4. Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
5. Floodplain Risk Management Plan	**Involves formal adoption by Council of a plan of management for the floodplain.**
6. Implementation of the Plan -	Construction of flood mitigation works to protect existing development. Use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard.

The Allans Creek Floodplain Management Committee was formed in 1995. Data Collection, the Flood Study and the Floodplain Risk Management Study were carried out concurrently with the development of this Plan. This report forms the fifth stage of the management process for the Allans Creek Floodplain.

This Plan has been prepared for Wollongong City Council by Lawson & Treloar Pty Ltd (now Cardno Lawson Treloar) to outline floodplain risk management actions to be implemented.

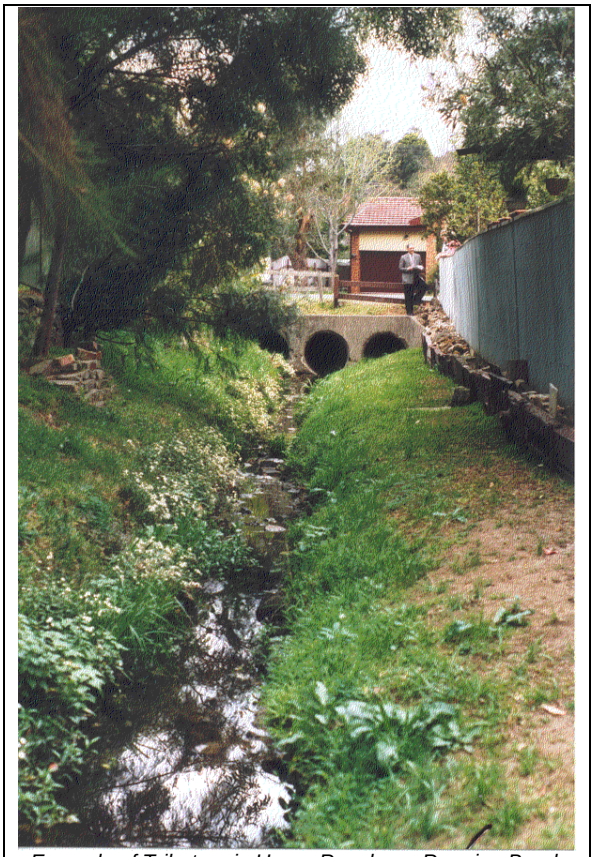
EXECUTIVE SUMMARY

Wollongong City Council commissioned Lawson and Treloar (now Cardno Lawson Treloar) to undertake a *Floodplain Risk Management Plan* for Allans Creek.

The Allans Creek catchment and floodplain is a highly urbanised area within the Wollongong City Council local government area. The catchment of 42 km^2 lies to the south west of the Wollongong CBD and rises up to the Illawarra escarpment.

The main natural tributaries that drain the catchment are:

- Allans Creek
- American Creek
- Brandy and Water Creek (and tributary)
- Branch Creek (and tributary)
- Byarong Creek
- Charcoal Creek (and tributaries)
- Ghost Creek
- Jenkins Creek
- Nudjia Creek
- Running Brook.



Example of Tributary in Upper Reaches - Running Brook Looking downstream to Uralba Street, Property Development on either side of Creek

A series of urbanised drainage systems also feed into these main tributaries along with a series of road areas and parks that act as floodways during rare and extreme events. These include:

- Arrow Avenue
- Bellevue Road
- Berkeley Road
- Blackman Parade
- Cleverdon Crescent
- Cordeaux Heights
- Cummins Creek
- Figtree Park
- Five Islands Road
- F6 Freeway (and tributary)
- Govett Crescent
- Grace Street
- Hargreaves Street
- Princes Highway (and tributary)
- O'Briens Road
- Railway
- Resolution Drive
- Rickard Road
- Various Drains in the Unanderra area
- Sheringa Grove
- Springhill Road
- Tresnan Road
- Wallawa Street/Bellevue Road
- Westfield (Figtree).

The Catchment and Creeks

The catchment is characterised by steep upper slopes with limited development and a floodplain with a mix of residential, commercial and industrial development. The Creek systems are highly modified in locations, consisting of concrete pipes and open channels draining ultimately to the Port Kembla Inner Harbour.

Example of a Steep Concrete Lined Channel

Development of Port Kembla Harbour in the mid 1900s has resulted in the lowland and former estuarine areas of the Allans Creek catchment being more modified than in any other catchment of the Illawarra region (Forbes Rigby, 2002).

In the majority of other areas the creeks are in a natural condition but their integrity is compromised by the impacts of catchment development.

Major transport routes through the catchment include the F6 Freeway, the Princes Highway and the Illawarra Railway Line. These major links cross the various tributary creeks with bridges and/or culverts, which are major controls to flooding.

South Coast Rail Line Bridge Across Charcoal Creek

The Issue of Flooding

In the past, flooding within the Allans Creek catchment has caused property damage and posed a high hazard to the residents living in close proximity to major watercourses in the catchment. Additionally major transport links and local roads have been inundated by flood waters making evacuation and emergency access difficult.

Flooding at Intersection of Bellevue Road and Princes Highway, August 1983
(Source: Wollongong City Council)

Flooding of developed areas within the catchment has been reasonably frequent in recent times. Over the past decades, Allans Creek has experienced significant flood events including those in March 1975, March 1978, March 1983, October 1983, February 1984, June 1991, August 1998 and October 1999.

Due to the large nature of the catchment and the significant variation in the amount of rainfall across the catchment, the August 1998 and October 1999 events were of varying magnitudes depending on the locality. For example, the August 1998 event was most severe in the northern parts of the catchment, whilst the October 1999 event was most severe in the southern parts of the catchment. During both of these events a number of properties were affected and a substantial cleanup operation was required following the flood.

In the 1998 and 1999 flood events, significant blockage of culverts was observed throughout the floodplain. These blockages resulted in flood levels being elevated in areas upstream of structures that blocked and in some cases, the creation of flow diversion paths.

Bank Collapse and Associated Culvert Blockage, Byarong Creek Crossing of Princes Highway, August 1998 Event
(Source: Wollongong City Council)

Flood Behaviour - Existing Conditions

The rainfall characteristics of the Illawarra Escarpment, the steep topography and the high probability of culverts blocking during flood events exacerbate the flood behaviour of the area in comparison to other urban areas in New South Wales (Lawson and Treloar, 2006a).

Design flows for the catchment were calculated using a hydrological model (RAFTS). To calculate design flood levels and velocities, a MIKE11 hydraulic model was established and calibrated to available

historical flood information. This included the use of information relating to the blockage of culverts. The information available on culvert blockage was utilised, along with information from other catchments, to develop a blockage policy (Council's *Conduit Blockage Policy*).

Design flood events were considered using the hydrologic and hydraulic models. These events included the 5, 10, 20, 50, 100 year ARI and the Probable Maximum Flood (PMF) in accordance with current practice.

The findings of the study indicate that a number of properties within the floodplain are susceptible to above-floor flooding even in the 5 year ARI event.

Floodplain Management Study

The *Floodplain Risk Management Study* (Lawson and Treloar, 2006b) has investigated what can be done to minimise the effects of flooding in the Allans Creek catchment. This *Floodplain Risk Management Plan* recommends a strategy to meet this objective.

Specific objectives of the study included:

- the implementation of a community consultation strategy, to ensure community input is obtained at key times throughout the study
- a description and quantification of the flood issues in the Allans Creek catchment including the likely cost of flooding to the community
- the identification and assessment of potential floodplain risk management measures to reduce the risks and hazards of flooding
- a review of issues relating to planning and development control within both the catchment and floodplain
- the assessment of options on a common basis to outline the best measures to reduce flood risk based on environmental, social, economic, financial and engineering considerations.

Impacts and Costs of Flooding

The following table summarises the number of properties that would be flooded in different design flood events together with the flood damage that is likely to occur.

Impacts and Costs of Flooding - Total Number of Properties with Above Floor Flooding

Flood (ARI)	Res.	Com.	Indus.	Flood Damage ($'000,000)
5 yr	44	12	4	10
10 yr	65	13	7	16
20 yr	230	18	29	111
50 yr	276	21	33	130
100 yr	317	25	34	146
PMF	507	64	64	378
Average Annual Damage				13.5
Present Worth of Damage (50 yr, 7%)				186

Options to Manage Flooding

Using the merits-based approach advocated in the NSW State Government's Floodplain Development Manual (2005) and in consultation with the community, Council and state agency stakeholders, a number of potential options for the management of flooding were identified.

These options included:

- flood modification measures,
- property modification measures, and
- emergency response modification measures.

An extensive list of options was assessed against a range of criteria (technical, economic, environmental and social).

Flood Risk Precincts

Wollongong City Council has adopted an approach of classifying areas of the floodplain by the potential risk associated with these areas referred to as 'flood risk precincts'. This is in accordance with the draft development control plan - *Managing Our Flood Risks* (DCP 54, 2004). This document specifies the following definitions for the application of flood risk precincts for the Local Government Area:

- **High Flood Risk Precinct** - Most development should be restricted in this precinct. Stringent development controls are applied.

- **Medium Flood Risk Precinct** - In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls, and

- **Low Flood Risk Precinct** - The Low Flood Risk Precinct is that area above the 100 year flood (plus 0.5m freeboard) and most land uses would be permitted within this precinct.

Options Assessment

Hydraulic modelling of the flood modification options was undertaken along with an assessment of the economic, social, environmental, land use, heritage and planning issues.

Actions for Implementation

Flood modification works to be implemented as part of this Plan include:

- Upgrade of the American Creek F6 Freeway Culverts
- Upgrade of The Avenue Culverts
- Creek modification works at various locations
- Debris control structures at various locations
- Ring levees at various locations.
- Further investigation and implementation of lowering of the floodplain on the west bank of Brandy and Water Creek at the southern end of Darragh Drive.

Action for Implementation - Amplification of The Avenue Culverts from existing configuration (shown above)

Property modification measures to be implemented as part of this Plan include:

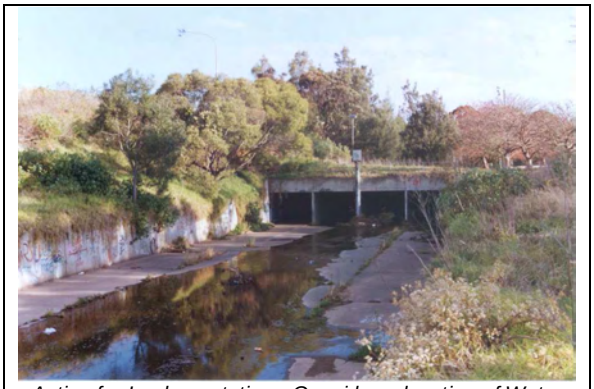
- Implementation of Development Control Matrix
- Voluntary House Raising of selected properties
- Voluntary Purchase of selected properties.

Emergency response modification measures considered and recommended for the floodplain include:

- Preliminary investigations for a trial SMS service for flood alerts
- Issue of Public Awareness information.

Other actions include the collection of additional data (eg rainfall data) and relocation of existing water level recorders.

The total estimated capital cost of implementating of the Allans Creek Floodplain Risk Management Plan is $42,928,000 and the recurrent cost is estimated to be $229,500.



Action for Implementation - Consider relocation of Water Level Recording Station on Byarong Creek (Shown here adjacent to F6 Freeway Culverts)

The Next Step

The next step in the Floodplain Management process is the implementation of the Plan. For major capital works this will require application to appropriate bodies for funding, further investigations, detailed design (in the case of flood modification options) prior to actual construction of works.

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GLOSSARY*

Annual Exceedence 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 Reccurance 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, the 100 year ARI flood event will occur on average once every 100 years.
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.
Creek Modification	Widening or altering the creek channel in an environmentally compatible manner (i.e. including weed removal and stabilisation with suitable native endemic vegetation) to allow for additional conveyance.
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.
High Flood Risk Precinct	This has been defined as the area within the envelop of land subject to a high hydraulic hazard (in accordance with the provisional criteria outlined in the Floodplain Development Manual) in a 100 year flood event together with all land within a corridor 10m from the top of the creek bank. The high flood risk precinct is where high flood damages, potential risk to life, evacuation problems would be anticipated or development would significantly and adversely effect flood behaviour. Most development should be restricted in this precinct. In this precinct, there would be a significant risk of flood damages without compliance with flood related building and planning controls.
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.
Integrated survey grid (ISG)	ISG is a global co-ordinate system based on a Transverse Mercator Projection. The globe is divided into a number of zones, with the true origin at the intersection of the Central Meridian and the Equator.
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.
Low Flood Risk Precinct	This has been defined as all other land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified within either the High Flood Risk (and Interim Riverine Corridor) or the Medium Flood Risk Precinct, where risk of damages are low for most land uses. The Low Flood Risk Precinct is that area above the 100 year flood (plus 0.5m freeboard) and most land uses would be permitted within this precinct.
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.
Medium Flood Risk Precinct	This has been defined as land below the 100 year flood level (plus 0.5m freeboard) that is not within the High Flood Risk (and Interim Riverine Corridor) Precinct. It is land subject to low hydraulic hazard (in accordance with the provisional criteria outlined by the Floodplain Development Manual). In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.
NPER	National Professional Engineers Register. Maintained by the Institution of Engineers, Australia.
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 Exceedence 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.

* Many terms in this Glossary have been derived or adapted from the NSW Government *Floodplain Development Manual*, 2005.

LIST OF ABBREVIATIONS

AAD	Average Annual Damage
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AMG	Australian Mapping Grid
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
CMB	Catchment Management Board
DCP	Development Control Plan
DHI	Danish Hydraulics Institute
DIPNR	Department of Infrastructure, Planning and Natural Resources (now Department of Natural Resources and Department of Planning)
DLWC	Department of Land and Water Conservation (now Department of Natural Resources)
DNR	Department of Natural Resources
DoP	Department of Planning
DPWS	Department of Public Works and Services (now Department of Commerce)
DUAP	Department of Urban Affairs and Planning (now Department of Planning)
EPA	Environmental Protection Authority (now Department of Environment and Conservation)
EPI	Environmental Planning Instrument
ESD	Ecologically Sustainable Development
FPL	Flood Planning Level
FRMC	Floodplain Risk Management Committee
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

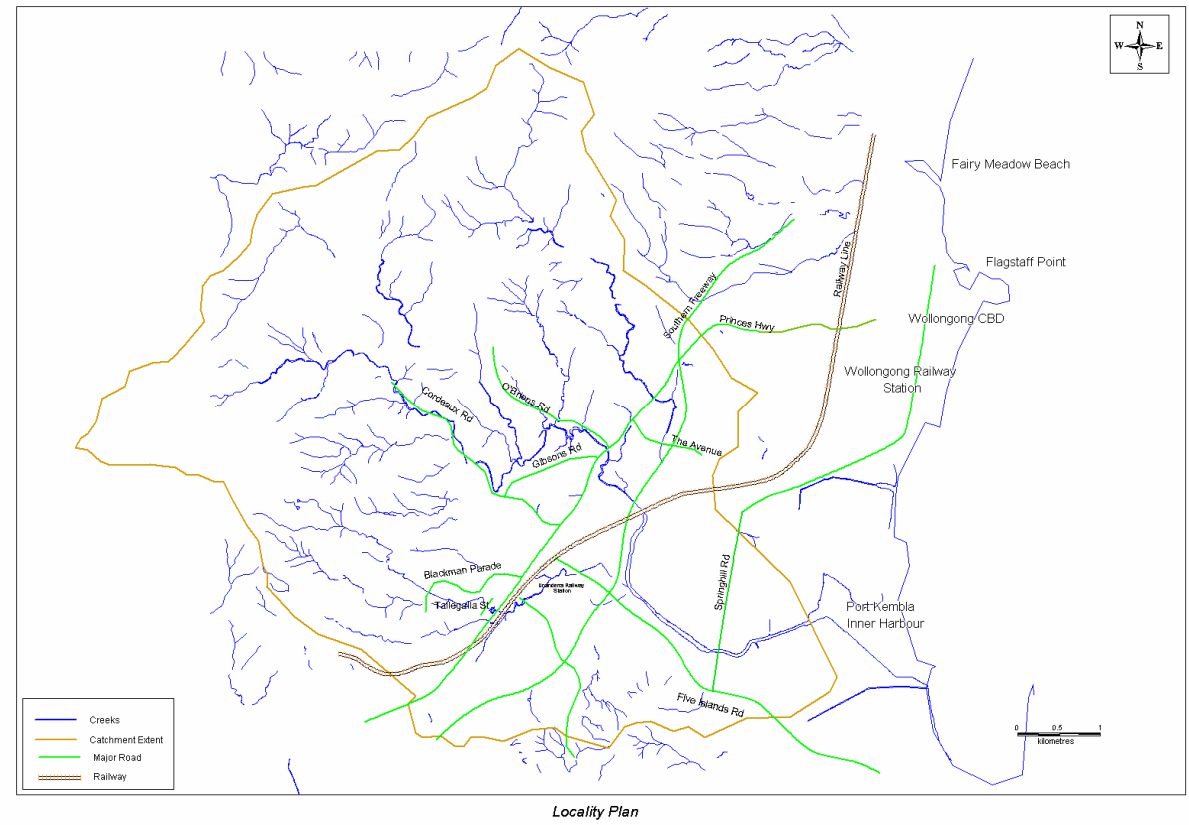
IEAust	Institution of Engineers, Australia (now referred to as Engineers Australia)
IFD	Intensity Frequency Duration
km	kilometres
km^2	Square kilometres
L&T	Lawson & Treloar
LAT	Lowest Astronomical Tide
LEP	Local Environment Plan
LGA	Local Government Area
LIC	Land Information Centre
m	metre
m^2	Square metres
m^3	Cubic metres
mAHD	Metres to Australian Height Datum
MHIs	Maximum Height Indicators
MHL	Manly Hydraulics Laboratory
MHWL	Mean High Water Level
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MIKE11	MIKE11 proprietary software package
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
mm	millimetre
m/s	metres per second
MSL	Mean Sea Level
NPWS	National Parks and Wildlife Service (now within the Department of Environment and Conservation)
NSW	New South Wales
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PWD	Public Works Department New South Wales

RAFTS	RAFTS proprietary software package
REP	Regional Environmental Plan
RTA	Roads and Traffic Authority
SCA	Sydney Catchment Authority
SCARM	Standing Committee on Agriculture and Resource Management
SEPP	State Environmental Planning Policy
SES	State Emergency Service
SRA	State Rail Authority (now RailCorp)
WBNM	Watershed Bounded Network Model
WCC	Wollongong City Council

LIST OF APPENDICES

1. INTRODUCTION

Wollongong City Council, through the Allans Creek Floodplain Management Committee, is developing a Floodplain Risk Management Plan for the Allans Creek Floodplain in accordance with the New South Wales Government's flood prone land policy. Lawson and Treloar were commissioned to prepare the Plan in accordance with the NSW Floodplain Development Manual (2005). The area of interest is shown below in a Locality Plan.



Locality Plan

1.1 Plan Context

The preparation of this plan follows on from the Flood Study (Lawson and Treloar, 2006a) and Floodplain Risk Management Study (Lawson and Treloar, 2006b) and forms the fifth stage of the Floodplain Risk Management Process which includes:

- Formation of a Committee
- Data Collection
- Flood Study
- Floodplain Risk Management Study, and
- **Floodplain Risk Management Plan**
- Implementation of the Plan.

As prescribed in the floodplain management process, the Allans Creek Floodplain Management Committee was formed in 1995. Wollongong City Council, under the direction of this Committee, commissioned the Flood Study, Floodplain Risk Management Study, and Floodplain Risk Management Plan in 1996. To develop the

plan, the findings of the Floodplain Risk Management Study (Lawson and Treloar, 2006b) were extensively utilised.

1.2 Plan Objectives

The objectives of this plan are to:

- be consistent with the NSW State Government Flood Prone Land Policy and the Floodplain Development Manual (2005)
- identify actions for implementation to reduce the existing risk of flooding, minimise future risk of flooding and manage the residual risk of flooding,
- identify time frames, costs and responsibilities for the actions listed, and
- ensure integration of proposed actions with related plans of management.

1.3 Related Plans of Management and Strategies

There are a wide range of related plans of management and strategies that have been considered during the preparation of this plan. These include:

- Catchment Blueprint (South Coast Catchment Management Board, 2003)
- Allans Creek Riparian Management Strategy (Forbes Rigby, 2002)
- Riparian Corridor Strategy (DIPNR, 2004)
- Stormwater Management Plan (Forbes Rigby, 2000)
- Estuary Management Plan (to be prepared)
- Local Environment Plan (Wollongong City Council, 1990)
- Wollongong DISPLAN (SES, 2004).

1.4 Community Consultation

An exhibition of the Draft Plan was available at Wollongong Library and Unanderra Library from 18 April 2005 to 13 May 2005. The exhibition was advertised in *The Advertiser* and letters were sent to all residents within the floodplain advising of the exhibition with a newsletter and feedback questionnaire.

Council's floodplain management personnel fielded queries from the community at a community stall and a poster display of the Draft Plan at Westfield Figtree on both Saturday 30 April 2005 and Saturday 7 May 2005 between 10am - 2pm. All interested persons were welcome to view the display and discuss the draft plan.

A total of 26 written comments in the form of correspondence or completed feedback questionnaires were received from the community. Comments were used to refine the Plan prior to its completion. Comments from Council and State Agencies were also included in this final version of the Floodplain Risk Management Plan.

1.5 Plan Outline

This Plan covers the following details:

- summary of catchment characteristics (Section 2)
- description of flood behaviour and impacts (Section 3)

- summary of flood modification actions for implementation (Section 4)
- summary of property modification actions for implementation (Section 5)
- summary of emergency response modification actions for implementation (Section 6)
- summary of data collection and further investigations for implementation (Section 7)
- implementation action plan (Section 8).

2. ALLANS CREEK CATCHMENT CHARACTERISTICS

Key characteristics of the Allans Creek catchment are shown in the following table.

Catchment Area	42km^2	
Maximum Ground Level in Catchment	530m AHD at Mt Kembla	
Minimum Ground Level in Catchment	0 m AHD at Port Kembla	
Land Use	Non Urban	10%
	Low Density Residential	24.7%
	Medium Density Residential	1.5%
	Business	0.4%
	Light Industrial	2.5%
	Heavy Industrial	14.7%
	Special Uses	4.7%
	Recreation	5.3%
	Tourism	0.1%
	Environmental Protection	20.6%
	State Recreation	15.7%
Number of Culvert and Bridge Crossings in Study Area	Over 70	
Social Characteristics	Aged 15 years and over	79.9%
	Aged 65 years and over	14.2%
	Median Age	36 years
	Total Indigenous Persons	1.47%
	Australian born	71.1%
	Main Other Countries of Origin	UK, Macedonia, Italy
	English Speaking Only	77.7%
	Living in a Private Dwelling	97.7%
	Average Household Size	2.7 persons
Number of properties affected by 1998 event	334	
Number of properties with reported above-floor flooding in 1998 event	89	
Estimate Number of Greenfield Lots for Future Development within Catchment	450 (UDIA, reported in Forbes Rigby, 2002)	

3. FLOOD BEHAVIOUR IN THE ALLANS CREEK CATCHMENT

3.1 Historical Flooding

Flooding of developed areas within the catchment has been reasonably frequent in recent times. Over the past decades, Allans Creek has experienced significant flood events including those in March 1975, March 1978, March 1983, October 1983, February 1984, June 1991, August 1998 and October 1999. In the 1998 and 1999 flood events, significant blockage of culverts was observed throughout the floodplain. These blockages resulted in flood levels being elevated in areas upstream of structures that blocked and in some cases, the creation of flow diversion paths.

Byarong Creek, Koloona Avenue, Figtree Post Flood Clean-up, October, 1983

American Creek, Govett Crescent, October 1983

Unanderra Drain Catchment, October 1999 Event

Byarong Creek, Thames Street, Property Inundation, August 1998

Brandy and Water Creek, O'Briens Road February 1984

Unanderra Drain, Chapman Street, Unanderra, August 1983

Photographs Courtesy Wollongong City Council

3.2 Flood Processes

The process of flooding is natural and is driven by rainfall processes and antecedent conditions. Rainfall in the Allans Creek catchment has been observed to be highly variable and influenced significantly by the presence of the Illawarra escarpment.

The action of flooding can result in changes to the creeks where the creeks are in a relatively natural state. For example, in the 1975 event (below), bankfull flows on Byarong Creek mobilised and transported bed sediment and cobbles downstream. Flows can also result in bank undercutting, slumping and erosion and loss of bank and bed stabilising vegetation, particularly where some or all of the riparian vegetation has been cleared. These processes are often exacerbated by urban development as structures (such as culverts and bridges) intercept the transported material.

Byarong Creek During March 1975 Event

Byarong Creek Following March 1975 Event

Photographs Courtesy Sandra Smart

Bank Erosion and Loss of Stabilising Vegetation as a result of August 1998 Flood Event

Debris Blocking the Coal and Co Railway Bridge in Upper American Creek

Photographs Courtesy Wollongong City Council

Floods in the Allans Creek catchment are primarily caused by intense rainfall over a short duration (typically less than 6 hours). Typical design event intensity of rainfall for the lower catchment is of the order of 140 mm/hr for durations of 30 minutes for the 100 year ARI event. The upper catchment has a higher rainfall intensity with typical design event intensity of rainfall of the order of 170 mm/hr for durations of 30

minutes for the 100 year ARI event. As a comparison, the Probable Maximum Precipitation is of the order of 400 mm/hr for the same duration event.

3.3 Culvert Blockage

Culvert blockage has been shown to have a major effect on the flooding mechanisms of the catchment (Rigby and Silveri, 2001). Culvert blockages in both the 1998 and 1999 floods caused flood flow diversion leading to new flood paths and increased flood plain flood damage. Critical culverts in the Allans Creek catchment that were shown to block are:

- the Princes Highway Culverts on all major crossings
- Byarong Creek at Koloona Avenue
- Byarong Creek at Uralba Street
- Byarong Creek at The Avenue
- Byarong Creek at the F6 Freeway
- American Creek at the F6 Freeway.

No culvert has blocked to the same degree for each flood event observed. Generally very high levels of blockage were experienced for the 1998 and 1999 storms with some blockages occurring during the 1991 storm and little evidence of blockage occurring for the 1984 storm.

In the storms where culverts blocked, many culverts blocked completely leading to the embankment above the culvert to act as a weir and in some cases water was diverted around the bridge or culvert. The water levels in the area upstream of the culvert and embankment were therefore elevated and caused worse flooding than if the culvert had been unblocked.

Extensive consultation between Wollongong City Council, the Department of Natural Resources, Lawson and Treloar and other consultants preparing similar studies for adjacent areas, led to the development of a design blockage policy (Council's *Conduit Blockage Policy*) to be used in the modelling of peak water levels for design storms.

The policy adopted by Council to represent blockage throughout the catchment is as follows:

i. 100% blockage for structures with a major diagonal opening width of <6m

ii. 25% bottom up blockage for structures with a major diagonal width of >6m.

    For bridge structures involving piers or bracing, the major diagonal length is defined as the clear diagonal opening between piers/bracing, not the width of the channel at the cross section.

iii. 100% blockage for handrails over structures covered in (i) and for structures covered in (ii) when overtopping occurs.

iv. Culvert blockage criteria applies only to exceedence probabilities greater than 10% AEP. That is, there are no culverts blocked in the determination of 10% AEP and 20% AEP flood levels.

The impact of blockage of any culvert/bridge in the catchment is manifold. The blockage causes an increase in the flood levels upstream of the culvert and a decrease downstream. Depending on the steepness of the creek, the impact of the culvert may or may not be transferred to a downstream culvert. For example, blocking the Koloona Avenue culvert would not have any significant impact on flood levels downstream at the Uralba Street Bridge. On the other hand, blocking The Avenue culverts on Byarong Creek would have an appreciable impact on flood levels at the F6 Freeway culverts.

The blockage can also have significant impact on the timing of the hydrographs at the confluence of major creeks. This in turn can have either a beneficial impact if the timing of various hydrograph peaks are staggered or an adverse impact if the peaks coincide. Thus a number of culvert blockage combinations are possible, which may result in the coincidence of flood peaks at the confluence that may result in further adverse flooding conditions.

In addition, in the lower reaches of the creeks, a combination of blocked/unblocked culverts can have significant adverse impacts. For example, on Byarong Creek various blockage combinations for the Princes Highway Bridge, The Avenue culverts and the F6 Freeway culverts will have different impacts.

After careful review of the hydraulic behaviour of all the creeks in the catchment, eight different combinations of blockages were assessed as part of the Flood Study (Lawson and Treloar, 2006a). The criterion for selection for these blockage scenarios was to establish the highest possible flood level primarily to ensure that the flood planning level is set accordingly.

3.4 Flood Impact

Flood impact can be measured by water levels and velocities, which can be translated to impacts in economic and social terms for various design flood events for varying recurrence intervals.

Under the existing conditions, the flood impact in terms of number of properties affected and estimated economic impacts were estimated within the Floodplain Risk Management Study (Lawson and Treloar, 2006b) and are shown below.

Number of Properties with Above Floor Flooding and Total Damage Costs

Flood (ARI)	No of Res.	No of Com.	No of Indus.	Total	Flood Damage ($'000,000)
5 yr	44	12	4	60	10
10 yr	65	13	7	85	16
20 yr	230	18	29	277	111
50 yr	276	21	33	330	130
100 yr	317	25	34	376	146
PMF	507	64	64	635	378
Average Annual Damage					13.5
Present Worth of Damage (50 years, 7%)					186

The above table indicates that under present conditions, the average annual damage, i.e. the cost each year of the impact of floods to the community is $13.5 million.

3.5 Flood Risk Precincts

Wollongong City Council has adopted an approach of classifying areas of the floodplain by the potential risk associated with these areas referred to as 'flood risk precincts'. This is in accordance with the flood-related development control plan - *Managing Our Flood Risks* (DCP 54, 2004). This document specifies the following definitions for the application of flood risk precincts for the Local Government Area:

- **High Flood Risk Precinct** - This has been defined as the area within the envelop of land subject to a high hydraulic hazard (in accordance with the provisional criteria outlined in the Floodplain Development Manual) in a 100 year flood event together with all land within a corridor 10m from the top of the creek bank. The high flood risk precinct is where high flood damages, potential risk to life, evacuation problems would be anticipated or development would significantly and adversely effect flood behaviour. Most development should be restricted in this precinct. In this precinct, there would be a significant risk of flood damages without compliance with flood related building and planning controls.

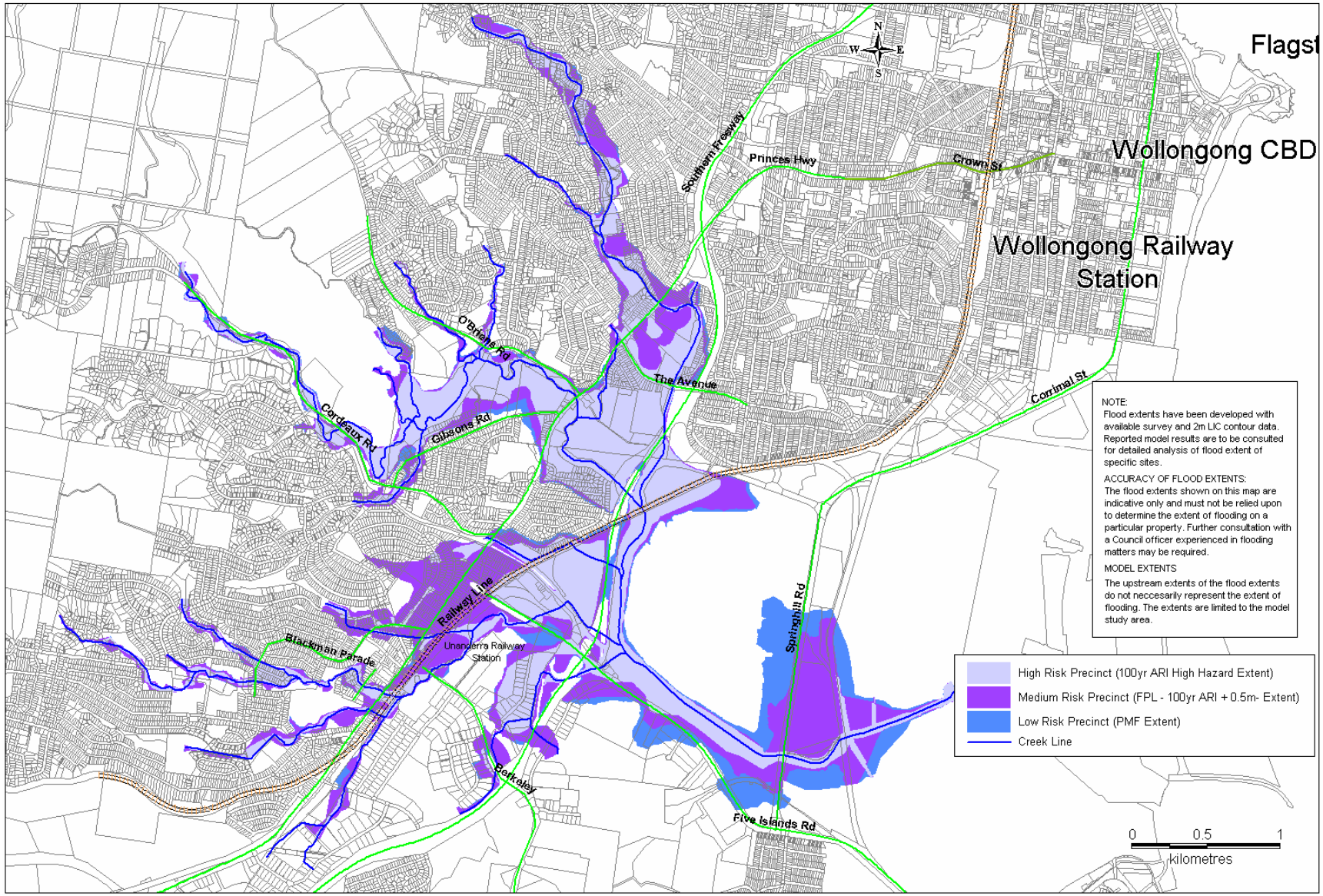
- **Medium Flood Risk Precinct** - This has been defined as land below the 100 year flood level (plus 0.5m freeboard) that is not within the High Flood Risk (and Interim Riverine Corridor, defined as 10m from the top of bank) Precinct. It is land subject to low hydraulic hazard (in accordance with the provisional criteria outlined by the Floodplain Development Manual). In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls, and

- **Low Flood Risk Precinct** - This has been defined as all other land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified within either the High Flood Risk (and Interim Riverine Corridor) or the Medium Flood Risk Precinct, where risk of damages are low for most land uses. The Low

Flood Risk Precinct is that area above the 100 year flood (plus 0.5m freeboard) and most land uses would be permitted within this precinct.

It should be noted that the hazard-related portion of the definition of high risk (i.e. velocity-depth product of 1.0) is appropriate for able-bodied adults only. In the case where children, elderly or disabled persons are affected by floodwaters, velocity-depth products less than 1.0 are likely to be hazardous. Thus, portions of the medium risk precinct may be high risk for children, elderly or disabled persons.

The flood risk precincts for Allans Creek are shown on the following page.


Flagst
Wollongong CBD
Wollongong Railway Station
Southern Freeway
Princes Hwy
Crown St
O'Briens Rd
The Avenue
Cordeaux Rd
Gilligans Rd
Corrimal St
Railway Line
Springhill Rd
Blackman Parade
Unanderra Railway Station
Berkeley
Five Islands Rd
N
W
E
S
NOTE:
Flood extents have been developed with available survey and 2m LIC contour data. Reported model results are to be consulted for detailed analysis of flood extent of specific sites.
ACCURACY OF FLOOD EXTENTS:
The flood extents shown on this map are indicative only and must not be relied upon to determine the extent of flooding on a particular property. Further consultation with a Council officer experienced in flooding matters may be required.
MODEL EXTENTS
The upstream extents of the flood extents do not neccesarily represent the extent of flooding. The extents are limited to the model study area.
High Risk Precinct (100yr ARI High Hazard Extent)
Medium Risk Precinct (FPL - 100yr ARI + 0.5m- Extent)
Low Risk Precinct (PMF Extent)
Creek Line
0
0.5
1
kilometres

4. FLOOD MODIFICATION MEASURES

To manage the existing flood risk defined in Section 3, a range of flood modification measures were considered as part of the Floodplain Risk Management Study (Lawson and Treloar, 2006b).

These options were reviewed and those identified to be the most effective in reducing the incidence of above floor flooding and the economic impact of flooding were selected. Additionally, options to reduce the risk of overfloor flooding at the 100 year ARI across the entire floodplain were also included, even where they did not rank highly in the multi-criteria matrix assessment to ensure an appropriate spatial coverage of actions to address the very wide range of issues across the floodplain. The reference identification details (ID) from the Floodplain Risk Management Study (Lawson and Treloar, 2006b) is shown within the table and further details of the measures proposed can be found in the Study.

ID	Creek	Locality	Action
FM55	American	Culverts under F6 Freeway	Bridge construction
FM20	Byarong	The Avenue, Figtree	Bridge construction
FM15	Byarong	Upstream of Princes Highway Bridge	Improvements of flow entry to bridge, placing a debris control structure upstream in Harry Graham Park, modification of creek system at rear of Arrow Avenue Properties
FM58	Byarong	Upstream of The Avenue	Debris Control Structure(s)
FM21	Byarong	Entire system	Corridor Management and Maintenance
FM41	American	Entire system	Corridor Management and Maintenance
FM54	Charcoal	Entire system	Corridor Management and Maintenance
FM3	Byarong	Upstream of Koloona Avenue, Mt Keira	Creek modification works
FM2	Byarong	Upstream of Koloona Avenue, Mt Keira	Debris Control Structure(s)
FM46	Charcoal	Between d/s of Lindsay Maynes Park and Upstream of Railway, Unanderra	Creek modification works
FM48	Charcoal	Between Tallegalla Street and Princes Highway, Unanderra	Creek modification works and flood detention area
FM43	Charcoal	Between Blackman Pde and Tallegalla Street	Creek modification works
FM30	American	Between Gibsons Road and Princes Highway	Creek modification works
FM24	American	Along length in Upper Reaches	Creek modification works
FM18	Byarong	Channel Between Princes Hwy and The Avenue	Channel Widening
FM38	American/ Byarong	Between The Avenue and Freeway	Creek modification works
FM37	American/ Byarong	Between Lysaght Oval and Freeway Bypass	Formalise channel for flow
FM56	Allans	Upstream of Princes Highway Bridge	Debris Control Structure
FM57	Freeway/ Industrial Area	Unanderra Industrial area – Upstream of Berkeley Road (two crossings)	Debris Control Structure(s)

ID	Creek	Locality	Action
FM60	American	Upstream of Alukea Road Culverts	Debris Control Structure(s)
FM4	Byarong	Park on left bank Upstream of Koloona Avenue, Mt Keira	Detention Basin
FM1	Byarong	Upstream of Koloona Avenue, Mt Keira	Pipe outlet realignment
FM16	Byarong	Arrow Avenue/Bellevue Road	Stormwater Drainage and Overland flow path modifications
FM59	Byarong/ American	F6 Freeway	Removal of a portion of the F6 median strip
FM25	American	Upstream of Govett Crescent	Levee Embankment on western side of Govett Crescent
FM61	Byarong Creek	Casuarina Place and Whelan Avenue	Ring levee in association with additional flood storage
FM35	Allans	O'Donnell Drive	Ring levee (Cobblers Park)
FM34	American	Figtree Gardens Caravan Park	Access Road Culvert Amplification
FM66	Brandy & Water	West Bank at Southern End of Darragh Drive	Further investigation and implementation of lowering the floodplain on the west bank
FM62	American	Baker Crescent	A small levee to prevent flow ingress to properties just upstream of culvert
FM23	American	Upstream of Cordeaux Road	Debris Control Structure(s)

A range of flood storage areas were identified for consideration as part of an Upper Byarong Creek scheme (Options FM63, 64, 65). These options are contingent on a suitable Voluntary Purchase agreements being met and further studies. They would best proceed in a scheme that includes Options FM61, FM3 and FM4 and it is recommended that the overall scheme for the area be considered as a priority for concept analysis.

These options or further studies are included in Section 8 within the Implementation Action List.

5. PROPERTY MODIFICATION MEASURES

To manage the future risk as a result of development within the floodplain, a range of property modification measures were considered as part of the Floodplain Risk Management Study (Lawson and Treloar, 2006b).

Those options that were found to be the most effective in reducing the risk of the incidence of above floor flooding and the future economic impact of flooding selected for inclusion in this plan are listed below with their reference ID from the Floodplain Risk Management Study:

- Updating of DCP54 with Development Control Matrix for Allans Creek (PM1)
- Updating Relevant Council documents to include Guidelines for Public Domain Infrastructure (PM2)
- House Raising Program (PM3)
- Voluntary Purchase Program (PM4)
- Provision of a Flood Refuge within the Figtree Gardens Caravan Park (PM5)
- Detailed Investigation of Possible Zoning Modifications (PM6)
- Revision of Section 149(5) Certificate Wording (PM7)
- Adapt Towradgi Creek Flood Certificate for Allans Creek (PM8)
- Caravan Park/Manufactured Home Estate Policy (PM9)
- Cumulative Impact Study and Review of On-Site Detention Policy (PM10)
- Public Awareness and Education for Property matters (Creek Maintenance in Private Property) (PM13)
- Additional Property Survey (PM14).

A range of properties are eligible for house raising. A total of 48 properties were specifically identified for house raising. These properties are outlined in Appendix A and remain ‘commercial in confidence’ until such time as Council has consulted with affected property owners. A range of properties are also eligible for voluntary purchase. A total of 18 properties were specifically identified for voluntary purchase. These properties are outlined in Appendix A and remain ‘commercial in confidence’ until such time as Council has consulted with affected property owners.

The proposed development control matrix to be implemented for Allans Creek is shown on the following page. This covers details such as flood planning levels and appropriate development control requirements to be applied within the catchment. This matrix should be read in the context of Council's Development Control Plan No 54, *Managing Our Flood Risks*.

These actions identified are included in Section 8 within the Implementation Action List.

Proposed Matrix for Inclusion in Managing Our Flood Risks (DCP 54)

Planning Consideration	Flood Risk Precincts (FRP's)																							
	Low Flood Risk^								Medium Flood Risk^								High Flood Risk^ (and Interim Riverine Corridor)							
	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
Floor Level		3										2, 6 or 7	1, 2 or 5	2	1	2,4					1		1	2,4,6
Building Components		2										1	1	1	1	1					1		1	1
Structural Soundness		3		3		3						3	2	3	2	2					1		1	1
Flood Affectation		2	2		2	2					1	1	1	1	1	2					1		1	1
Evacuation		2,4	*	3,4	4	3,4					*	3,4	1,4	3,4	1	1					*		1	1
Management & Design		4,5	1								1		2,3,5	2,3,5	2,3,5,6	2,3,5					2,3,5		2,3,5	2,3,5

	Not Relevant		Unsuitable Land Use	*	Refer to *'Management & Design'* planning consideration for subdivision	Industrial Only, Commercial Not Permitted

Floor Level

1	For industrial land use only - All Floor Levels to be equal to or greater than the 100 year flood unless justified by site specific assessment
2	Habitable floor levels to be equal to or greater than the 100 year flood plus 0.5m (freeboard)
3	All Floor Levels to be equal to or greater than the PMF level plus 0.5m (freeboard)
4	Floor levels to be as close to the design floor level as practical & no lower than the existing floor level when undertaking alterations or additions
5	Floor levels of shops to be as close to the design floor level as practical. Where below the design floor level, more than 30% of the floor area to be above the design floor level or premises to be flood proofed below the design floor level
6	Garage floor level to be no lower than 300 mm above finished adjacent ground
7	Garage floor level to be no lower than the 100 year ARI flood level minus 300 mm or 300 mm above the finished adjacent ground (whichever is the greater)

Building Components & Method

1	All structures to have flood compatible building components below or at the 100 year flood level plus 0.5m (freeboard)
2	All structures to have flood compatible building components below or at the PMF level plus 0.5m (freeboard)

Structural Soundness

1	IEAust NPER Structural Engineers report to certify that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a 100 year flood plus 0.5m (freeboard)
2	Applicant to demonstrate that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a 100 year flood plus 0.5m (freeboard)
3	IEAust NPER Structural Engineers report to demonstrate that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a PMF plus 0.5m (freeboard)

Flood Affectation

1	IEAust NPER Hydraulic Engineers report required to certify that the development will not increase flood affectation elsewhere, includes medium and high density residential proposals
2	The impact of the development on flooding elsewhere to be considered, includes low density residential

Evacuation	
1	Reliable access for pedestrians required during a 100 year flood
2	Reliable access for pedestrians and vehicles required during a PMF event
3	Reliable access for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF, or a minimum of 20 sq m of the dwelling/premises to be above the PMF level.
4	The development is to be consistent with any relevant flood evacuation strategy or similar plan
Management and Design	
1	Applicant to demonstrate that potential development as a consequence of a subdivision proposal can be undertaken in accordance with DCP54
2	Site Emergency Response Flood plan required (except for single dwelling-houses) where floor levels are below the PMF
3	Applicant to demonstrate that area is available to store goods above the 100 year flood plus 0.5m (freeboard)
4	Applicant to demonstrate that area is available to store goods above the PMF plus 0.5m (freeboard)
5	No external storage of materials below the design floor level which may cause pollution or be hazardous during any flood

* adapted from DCP54 for Towradgi Creek and modified for the Allans Creek Floodplain

^ Flood Risk Precinct Definitions for Allans Creek - see Section 3

See DCP 54 for a Schedule of Land Use Types Consistent with the Wollongong City Council LEP, 1990.

Any proposed development will also need to be consistent with Other Council requirements including Council's OSD Policy and Drainage Design Code.

6. EMERGENCY RESPONSE MODIFICATION MEASURES

To manage the residual risk, after the implementation of flood and property modification actions, a range of emergency response modification measures were considered as part of the Floodplain Risk Management Study (Lawson and Treloar, 2006b). Those options that were found to be the most effective in aiding to reduce the risk to life and property selected for inclusion in this plan are listed below with their reference ID from the Floodplain Risk Management Study:

- Periodic Revision Of Displan/Flood Sub Plan (EM 1)
- Preliminary Assessments for the establishment of a Trial SMS Service (EM 2)
- Enhancing Existing Flood Warning Systems (using additional rainfall gauges within the ALERT system) (EM 3)
- Electronic Information Transfer Agreement For Council Held Information To SES (EM 5)
- Issue Of Flood Study, Floodplain Risk Management Study and Plan Reports and Laminated Flood Extent Plans To SES (EM 6)
- Public Awareness and Education - Locality Based Floodsafe Brochure (EM 7)
- Public Awareness And Education - Fridge Magnets (EM 8)
- Public Awareness And Education - Annual Remembrance Day (17th August) (EM 9)
- Public Awareness And Education - Schools Package (EM 10).

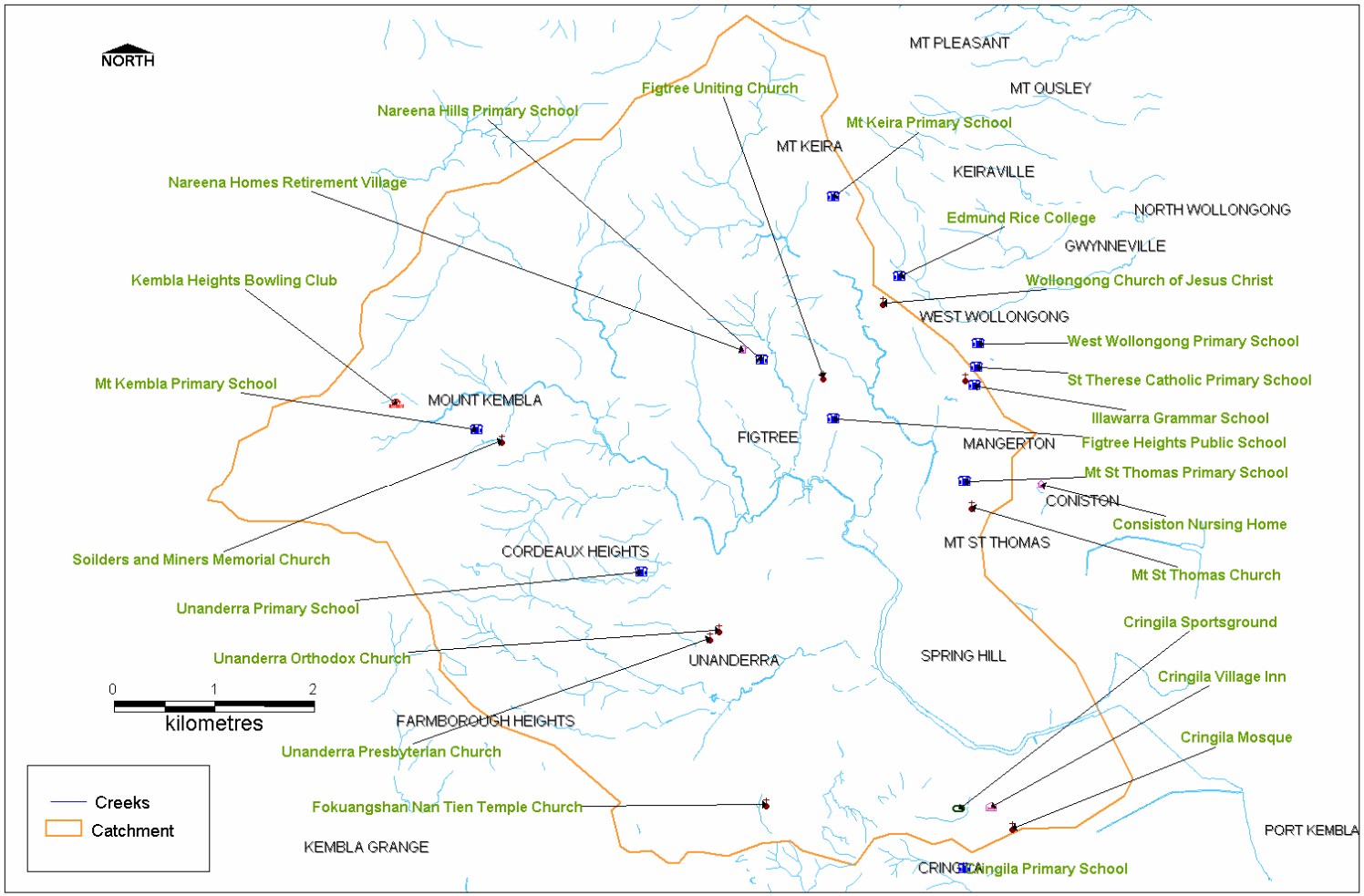
Further details for each action identified can be found within the Floodplain Risk Management Study (Lawson and Treloar, 2006b).

An example of potential public education materials to be localised is shown on the next page.

A map of the flood evacuation centres outside of the Allans Creek floodplain is also shown on the following page.

The actions identified are included in Section 8 within the Implementation Action List.

Example of FloodSafe Brochure to be Localised for Allans Creek Catchment
(Source: State Emergency Service)



Evacuation Centres Outside of the Allans Creek Floodplain

7. DATA COLLECTION AND FURTHER INVESTIGATIONS

The ongoing collection of data to aid the assessment of the performance of implemented actions as well as aid in future revisions of this floodplain management plan is an integral part of the overall Plan.

A range of data collection actions were considered as part of the Floodplain Risk Management Study (Lawson and Treloar, 2006b). Those options that were found to be the most effective in achieving the above objectives are described below.

7.1 Data Collection Strategies

A series of data is currently collected including:

- peak flood height levels - maximum height indicators at various locations
- observed peak flood height levels - by resident report and interview (post-flood)
- continuous water level recorders - operated by Sydney Water Corporation (SWC) and Department of Commerce (DoC) at locations F6 Freeway Culverts on Byarong Creek and American Creek just upstream of the Princes Highway.

The current locations of stand-alone data collection systems are shown on page 23.

An action item within this Plan is that a series of additional maximum height indicators and rainfall gauges be installed. Proposed locations for these systems are also shown on page 23.

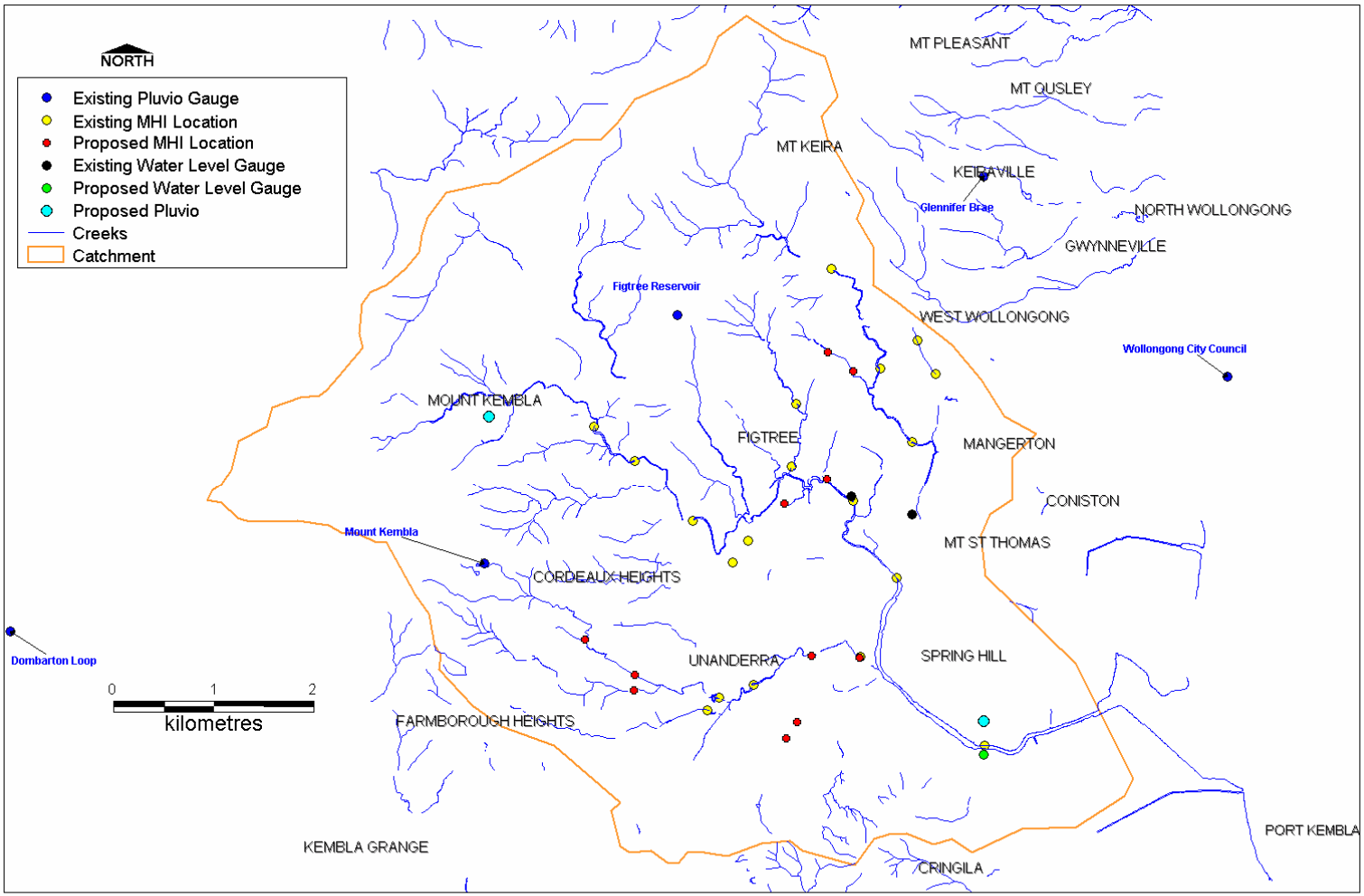
The Flood Study (Lawson and Treloar, 2006a) found that the current locations of continuous water level recorders resulted in reported stage hydrographs being compromised by the blockage of culverts. As a result, an action item in this plan is for these stations to be relocated to locations away from the culverts (commensurate with their locality also being suitable for other purposes, perhaps such as in association with water quality monitoring). However, given the considerable potential for blockage and backwater effects through the majority of the floodplain, only one location was suitable in the lower portion of the floodplain.

It is also recommended that, following significant flood events, a similar approach to the data collection post-flood be undertaken by Council as was undertaken for the 1998 and 1999 events as reported in Henshaw (1999). This involved the systematic collection of flood levels from residents using standardised forms and the entry of this data into Council's GIS.

Systems to detect rainfall amounts for intense rainfall events (referred to as an ALERT system) are currently in place in both Wollongong and the wider Illawarra area. This system draws upon the Bureau of Meteorology's rainfall gauge network and includes those gauges located as part of the network of Automatic Weather Stations (AWS) that report on a regular basis. Data from this network is available on real time at the Bureau of Meteorology Flood Forecasting Page for the 'Central NSW Coast' at www.bom.gov.au/hydro/flood/nsw/greatersyd.shtml. Details available

include 24 hour rainfall totals and rainfall from the last hour in graphical format. Details of depths of rainfall recorded at specific gauges are also available.

Given the significant spatial variation in the catchment and the existing coverage of the Bureau of Meteorology rainfall gauge network, an action item for this plan is that additional gauges be installed within the Allans Creek catchment. The locations of these are shown on page 23.



Current and Proposed Data Collection Locations

7.2 Further Investigations

Further investigations are recommended for all options once funding is secured for that option. For example, the creek modification options will require ongoing monitoring and maintenance through the preparation and implementation of a creek management plan for each creek system. This plan should include aspects such as a schedule of regular inspections and a means of identifying and rectifying issues. Detailed design should make reference to appropriate guidelines and manuals such as *A Rehabilitation Manual for Australian Streams* (CRC for Catchment Hydrology, 1999).

In general, all of the actions within this Plan lie within the area that is covered by the hydraulic model established for the Flood Study (Lawson and Treloar, 2006a). Some areas have been reported to be affected by flooding upstream of the model upper boundaries. Given that the model and therefore the definition of the floodplain does not extend to these areas, assessment was not undertaken of flood modification options for these areas. It is recommended that further investigations be undertaken as required for these areas.

These options are included in Section 8 within the Implementation Action List.

8. IMPLEMENTATION PROGRAM

The implementation program essentially forms the action list for this Plan. This action list is shown on the tables on the following pages and is divided into two parts:

- major works (substantial capital expenditure) (including the Lower Byarong and American Creek Floodplain Management Scheme and major independent tasks)
- minor works, planning tasks or further investigation actions.

In terms of staging of works, the order in which the actions are shown in the Action Plan should be viewed as a guide to the order in which works or studies should be undertaken.

In particular, the staging order of works for the Lower Byarong and American Creek Floodplain Management Scheme should be adhered to, to achieve the maximum benefit.

In other circumstances it is generally recommended that works proceed from downstream to upstream. However, concurrent works for other purposes may result in the undertaking of a specific action before or after another action identified in the Plan.

The implementation actions are also shown spatially in summary form on the accompanying figure 'Actions for Implementation'.

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

1. Floodplain Management Committee to consider and adopt recommendations of this Plan
2. Council considers the Floodplain Management Committee's recommendations,
3. Exhibit the draft Plan Report and seek community comment,
4. Consider public comment, modify the Plan if and as required, and submit the final Plan to Council,
5. Council adopt the Plan and submit an application for funding assistance to DNR and other agencies as appropriate,
6. As funds become available from DNR, other state government agencies and/or Council's own resources implement the measures in accordance with the established priorities.

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

Implementation Action List*

ID	Description	Reduction of Properties Flooded Above Floor Level**	Benefit-Cost Ratio	Estimated Cost		Funding Sources^	Priority
				Capital	Recurrent		
Lower Byarong and American Creek Floodplain Management Scheme							
FM55	Bridge Construction to replace culverts at American Creek crossing of the F6 Freeway	121	0.69#	$22.2 m#	$2,000#	RTA/Council/DNR	High
FM15	Improvements of flow entry to Princes Highway bridge, placing a debris control structure upstream in Harry Graham Park, modification of creek system at rear of Arrow Avenue Properties	121	0.69#	$22.2 m#	$2,000#	RTA/Council/DNR	High
FM18	Creek works on Byarong Creek between the Princes Highway and The Avenue	121	0.69#	$22.2 m#	$2,000#	Council/DNR	High
FM20	Bridge construction to replace The Avenue culverts	121	0.69#	$22.2 m#	$2,000#	RTA/Council/DNR	High
FM58	Debris Control Structure(s) Upstream of The Avenue	121	0.69#	$22.2 m#	$2,000#	Council/DNR	Medium
FM38	Creek modification works between The Avenue and Freeway	121	0.69#	$22.2 m#	$2,000#	Council/DNR	Medium
FM37	Formalise channel for flow between Lysaght Oval and Freeway Bypass	121	0.69#	$22.2 m#	$2,000#	Council/DNR	Medium
FM59	Removal of a portion of the F6 median strip	121	0.69#	$22.2 m#	$2,000#	RTA	Medium
Major Independent Works							
PM5	Provision of a Flood Refuge within the Figtree Gardens Caravan Park	NA	NA	$300,000	$5,000	Council/DNR	High
FM21/ FM41/ FM54	Corridor Management and Maintenance for All Creek Systems***	NA	NA	-	$150,000	Council/National LandCare Program/DNR	High
FM3	Creek modification works upstream of Koloona Avenue	NA	Note 1	$900,000	$5,000	Council/National LandCare Program/DNR	High
FM43	Creek works on Charcoal Creek between Blackman Pde and Tallegalla Street	NA	Note 1	$2,000,000	$2,000	Council/National LandCare Program/DNR	High
FM2/	Detention basin and debris control structure	NA	Note 1	$510,000	$4,000	Council/DNR	High

ID	*Description*	*Reduction of Properties Flooded Above Floor Level***	*Benefit-Cost Ratio*	*Estimated Cost*		*Funding Sources^*	*Priority*
				Capital	*Recurrent*		
FM4	for the park upstream of Koloona Avenue						
FM46	Creek modification works and flood detention area between Lindsay Maynes Park and Upstream of Railway, Unanderra	NA	Note 1	$350,000	$5,000	Council/National LandCare Program/DNR	Medium
FM30	Creek works for American Creek between Gibsons Road and Princes Highway	NA	Note 1	$2,300,000	$5,000	Council/National LandCare Program/DNR	Medium
FM35	Ring Levee O'Donnell Drive (Cobblers Park)	NA	NA	$1,000,000	$2,000	Council/DNR	Medium
FM16	Stormwater Drainage and Overland Flow Path Improvements Arrow Ave-Bellevue Road	NA	NA	$1,000,000	$2,000	Council/DNR	Medium
FM48	Creek works and flood detention area between Tallegalla Street and Princes Highway, Unanderra	NA	NA	$1,000,000	$2,000	Council/DNR	Medium
PM3/ PM4	Program of house raising and voluntary purchase	48 (VHR) 18 (VP)	6.25 0.57	$1.92 m VHR $7.2 m VP	-	Council/DNR	Medium
FM23	Debris Control Structure - Cordeaux Road	NA	NA	$10,000	$2,000	Council/DNR	Medium
FM34	Figtree Gardens Access Culvert Upgrade	NA	NA	$400,000	$2,000	Council/DNR	Medium
FM24	Creek Modification along length in Upper Reaches of American Creek	NA	NA	$250,000	$2,000	Council/DNR	Medium
FM56	Debris control structure upstream of Princes Highway Bridge on American Creek	NA	NA	$100,000	$2,000	Council/DNR	Medium
FM57	Debris Control Structure(s) - Unanderra Industrial area – Upstream of Berkeley Road (two crossings)	NA	NA	$100,000	$2,000	Council/DNR	Medium
FM60	Debris Control Structure upstream of Alukea Street culvert	NA	NA	$100,000	$2,000	Council/DNR	Medium
FM25	Levee Embankment on western side of Govett Crescent	NA	NA	$75,000	$1,000	Council/DNR	Medium
FM66	Further investigation and implementation of lowering floodplain of the western bank of Brandy and Water Creek.	NA	NA	$1,000,000	$2,000	Council/DNR	Medium
FM62	Minor levee upstream of Baker Crescent	NA	NA	$50,000	$500	Council/DNR	Medium

ID	*Description*	*Reduction of Properties Flooded Above Floor Level*	*Benefit-Cost Ratio*	*Estimated Cost*		*Funding Sources^*	*Priority*
				Capital	*Recurrent*		
Minor Works/Planning Tasks/Further Investigations							
FM21/ FM41/ FM54	Preparation of a Creek Management Plan to Identify Management and Maintenance Requirements	NA	NA	$100,000	-	Council/DNR	High
FM61/ FM63/ FM64/ FM65	Further investigations for Upper Byarong Creek Scheme	NA	NA	$50,000	-	Council/DNR	High
PM14	Additional Property Survey	NA	NA	$10,000	-	Council	High
EM5	Electronic Information Transfer Agreements between Council and the SES	NA	NA	$1,000	-	Council/SES	High
EM6	Issue Of Flood Study, Floodplain Risk Management Study and Plan Reports and Laminated Flood Extent Plans To SES	NA	NA	$2,000	-	Council/SES	High
PM1	Updating of DCP54 with Development Control Matrix for Allans Creek	NA	NA	$5,000	-	Council	High
PM2	Updating Relevant Council documents to include Guidelines for Public Domain Infrastructure	NA	NA	$5,000	-	Council	High
EM2	Preliminary Assessments for the establishment of a Trial SMS Service	NA	NA	$30,000	$10,000	Council/SES	High
PM7	Revision of Section 149(5) Certificate Wording	NA	NA	$5,000	-	Council	High
PM9	Caravan Park/Manufactured Home Estate Policy	NA	NA	$5,000	-	Council	High
EM8	Development and Issue of Fridge Magnets for Public Awareness And Education	NA	NA	$5,000	-	Council/SES	Medium
FM1	Realignment of the pipe outlet upstream of Koloona Avenue	NA	NA	$10,000	-	Council	Medium
PM13	Public Awareness and Education for Property matters (Creek Maintenance in Private Property)	NA	NA	$10,000	-	Council/DNR	Medium
PM6	Detailed Investigation of Possible Zoning	NA	NA	$10,000	-	Council	Medium

ID	*Description*	*Reduction of Properties Flooded Above Floor Level*	*Benefit-Cost Ratio*	*Estimated Cost*		*Funding Sources^*	*Priority*
				Capital	*Recurrent*		
	Modifications						
PM10	Cumulative Impact Study and Review of On-Site Detention Policy	NA	NA	$10,000	-	Council	Medium
EM10	Development of a Schools Package for Public Awareness And Education	NA	NA	$15,000	$1,000	Council/SES	Medium
EM7	Development of a Locality Based Floodsafe Brochure	NA	NA	$10,000	$1,000	Council/SES	Medium
EM9	Annual Remembrance Day	NA	NA	-	$5,000	Council/SES	Medium
EM1	Periodic Revision of Displan/Flood Sub Plan	NA	NA	$5,000	-	Council/SES	Medium
PM8	Adapt Towradgi Creek Flood Certificate for Allans Creek	NA	NA	$5,000	-	Council	Medium
PM11	Data Collection Strategies – Installation of Maximum Height Indicators, Rainfall Gauge(s), Relocation of Byarong Creek Water Level Recorder and Installation of Additional Water Level Recorders	NA	NA	$40,000	$5,000	Council/DNR/BoM	Medium
EM3	Enhancing Existing Flood Warning Systems (using additional rainfall gauges within the ALERT system)	NA	NA	$30,000	$10,000	Council/DNR/BoM	Medium
TOTAL (ex GST)				**$42,928,000**	**$229,500**		

*Implementation is dependent on the availability of funds and Council resources
** Flooded Above Floor Level at the 100 year ARI flood
# Option effectiveness evaluated as a combination of all of the marked options as part of Option 11 assessed within the Floodplain Risk Management Study (Lawson and Treloar, 2006b). FM55 was assessed alone as option 1 as well as in combination with Option 11.
^ Recurrent costs are not eligible for subsidy under the State/Commonwealth Floodplain Management Program.
Note 1 Creek modification options and detention options evaluated as a collective series of areas within the Floodplain Risk Management Study (Lawson and Treloar, 2006b) and require independent evaluation before implementation as stand-alone works.
***Works are dependent on Creek Management Plan to be prepared.
VP - Voluntary Purchase
VHR - Voluntary House Raising
NA - Not available.

9. REFERENCES

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10. ACKNOWLEDGEMENTS

This Plan has been undertaken and report prepared with the assistance of:

- Allans Creek Floodplain Management Committee
- Wollongong City Council - Design Division
- Department of Natural Resources
- Roads and Traffic Authority
- SRA (now RailCorp)
- SES
- Bureau of Meteorology
- Various resident groups and the community of the Allans Creek area
- Industrial proprietors who assisted with the development of flood damage curves
- Port Kembla Ports Corporation.

This study was funded under the State Government's Floodplain Management Program through the Department of Natural Resources on a 2:1 (State:Council) ratio.

11. QUALIFICATIONS

This plan has been prepared based on information within the Flood Study (Lawson and Treloar, 2006a) and the Floodplain Risk Management Study (Lawson and Treloar, 2006b) as well as information including:

- Wollongong City Council GIS information (various GIS layers including LEP, cadastre, 2m-contours, various environmental planning instruments, plans of management)
- Ground and Property Survey Details undertaken by Department of Public Works and Services (now Department of Commerce), HATCH and Wollongong City Council.

Cost estimates provided for options in this plan are preliminary only and more detailed cost estimates should be prepared during the detailed design phase.

APPENDICES

APPENDIX A

PROPERTIES FOR VOLUNTARY PURCHASE/VOLUNTARY HOUSE RAISING

Report Prepared For
Wollongong City Council

Allans Creek Floodplain Risk Management Plan

Report J1946/R2073
September, 2006