1. INTRODUCTION

1.1 Study Background

A Floodplain Risk Management Study and Plan (FRMS and FRMP) are to be prepared for the Whartons, Collins and Farrahars Creeks, Bellambi Gully and Bellambi Lake catchments as part of a Government program to manage the flood related risks of human occupation of floodplains. Figure 1.1 shows the location of the study area north of Wollongong.

An important first step in the process of preparing a FRMP (Figure 1.2) is the undertaking of a flood study for the study area. The flood study is the formal starting point of defining management measures for flood liable land and represents a detailed technical investigation of flood behaviour.

Using flood data collected for the purpose of this study, airborne laser survey data covering the study area, plus detailed field surveys of existing structures and the inbank areas of the streams, mathematical models were developed and interpreted to present a comprehensive picture of flooding on the creeks under current conditions.

The study objective was to define flood behaviour in the creeks in terms of flows, levels and velocities for floods ranging between 5 and 500 years Average Recurrence Interval (ARI), as well as for the Probable Maximum Flood (PMF).

Flood behaviour was defined using computer based hydrologic models of the catchments and hydraulic models of the various creeks and their respective floodplains. The hydrologic models were based on a runoff routing approach. The models were tested and tuned using flood and tidal data which were collected for the historic flood of 17 August 1998. Two other floods of some significance occurred in October 1987 and April 1988. However, a general lack of flood related data coupled with significant changes to the level of development within the study catchments meant that these storms were of limited use in the model tuning process.

Design storms were applied to the hydrologic models to generate discharge hydrographs within the study area. These hydrographs constituted the upstream boundaries and internal inflow inputs to the hydraulic models.

A dynamic hydraulic modelling approach was adopted for the analysis to account for the time varying effects of flow in the creeks, the routing effects of the floodplain storage and the potential impact of entrance and storm tidal conditions on flooding in the lower reaches of the creeks. A depth-averaged, one and two-dimensional free surface flow modelling approach was chosen which allowed for the interaction of flows between the channels and the floodplains, flow through culverts and flow over control structures such as road embankments and the sand berms which form at the ocean outlets.

After testing, the models were used to prepare plans showing the indicative extent and depth of flooding, water surface elevation contours and flow velocity vectors for the design events. The models were also used to prepare water surface profiles along each study reach.
In accordance with current engineering practice and documentation provided by the Department of Environment, Climate Change and Water (DECCW), a “Flood Envelope” approach was adopted for defining design water surface levels and flow velocities. The requirements of Wollongong City Council’s (WCC’s) Conduit Blockage Policy (WCC, 2009) were also incorporated into the development of the design flood envelopes.

The procedure involved running the model for a range of scenarios to define the upper limit of expected flooding for each design flood frequency. The scenarios were as follows: catchment runoff derived from the design storm events, in conjunction with a normal semi-diurnal tidal hydrograph at the downstream boundary and the entrance of each creek in either a shoaled or scoured condition; or storm tide hydrographs of each design frequency in conjunction with catchment runoff from a minor storm event and the entrance of each creek in its shoaled condition.

It was found that when shoaling of the entrance exceeds inshore ocean levels, the height of the sand berm controlled flood levels in the lower reaches of the creek systems, whilst catchment runoff controlled flooding in the middle to upper reaches of the creek systems.

1.2 Study Tasks

The flood study had three components:

- **Review of available hydrologic and hydraulic data and previous investigations.** The Bureau of Meteorology (BOM), Manly Hydraulics Laboratory (MHL), Sydney Water (SW) and the NSW Roads & Traffic Authority (RTA) provided rainfall data for a number of historic storm events. Rainfall and flood level data collated for historic floods which occurred in the 1980’s and 1990’s were initially assessed for their adequacy in the model testing process.

  A brief was prepared for inbank cross sectional survey of the streams in the study area. Gallagher Odell & Garey Consulting Surveyors & Engineers undertook the survey.

  WCC provided Airborne Laser Scanning (ALS) data covering the study area, as well as detailed survey of existing structures located along the study reaches. This information was used to define the sub-catchments for the development of the catchment model and also as input to the two-dimensional component of the hydraulic model.

- **A hydrologic component** which included preparation of hydrologic models (RAFTS) of the study catchments, tuning of the models to a historic flood and adoption of model parameters for design flood estimation, derivation of design storms and their application to the models to define design discharge hydrographs.

- **A hydraulic component** which comprised the preparation and testing of hydraulic models (TUFLOW) of the main streams and floodplain areas and the application of discharge hydrographs to the models to define water surface profiles, flows and velocities for the design floods.
1.3 Overview of Report

This Report (Volume 1) summarises the investigations and presents plans showing water surface contours and the extents of flooding for the 100 year ARI event. The extent of flood prone land in the study area is also presented. The Report is supported by five Appendices, which provide additional details relating to the study. Figures referred to in the five Appendices are bound in Volume 2 of the report.

Chapter 2 of the Report contains background information including a brief overview of the study catchments, a review of the data base available for the study and a discussion on the history of flooding in the study catchments. A detailed description of the watercourses which drain the study area is contained in Appendix A, whilst a summary of the responses to two Community Questionnaires which were distributed by WCC during the course of the study is contained in Appendix B.

Chapter 3 deals with the development of the computer based catchment models which were used to generate discharge hydrographs for input to the hydraulic model. The RAFTS runoff-routing modelling program was adopted for this study. Details on the RAFTS model calibration process are presented in Appendix C. This chapter of the report also deals with the derivation of design runoff hydrographs from the study catchments using the RAFTS program. This step involved the determination of design storm rainfall depths over the study catchments for a range of storm durations, and conversion of the rainfall hyetographs to discharge hydrographs. The results of the modelling are presented in Appendix D.

Chapter 4 deals with the development of the two-dimensional (in plan) hydraulic models which were used to analyse flood behaviour in the study area. The TUFLOW hydraulic modelling program was adopted for this study. Further details of the TUFLOW model development are presented in Appendix C.

Chapter 5 details the results of the hydraulic modelling of the design floods using the TUFLOW hydraulic model. Also summarised in this chapter of the report are the findings of several sensitivity studies. The impact of climate change in terms of sea level rise and increased rainfall intensities are also discussed. Appendix E presents further details on the derivation of design flood information. Results are presented as plans showing indicative extents and depths of inundation. Water surface profiles along each study reach are also presented. Details of the sensitivities studies and the basis for assessing climate change impacts are also contained in this Appendix.

Chapter 6 contains a list of definitions of flood related terms used in the study.

Chapter 7 contains a list of References.
Figure 1.1
LOCATION PLAN

SOURCE: WOLLONGONG CITY COUNCIL

NOT TO SCALE

FLOODPLAIN MANAGEMENT COMMITTEE AREAS

WHARTONS, COLLINS AND FARRAHARS CREEK,
BELLAMBI GULLY AND BELLAMBI LAKE FLOOD STUDY
Several flood study investigations have been carried out which define the nature and extent of flooding in specific locations throughout the Study Area. A review of these investigations will be carried out as part of this present study.

Involves the compilation of existing data and the collection of additional data. The collection of flood related data was carried out largely by Council following the August 1998 flood event.

Involves detailed hydrologic and hydraulic modelling of the catchments and their tributaries in the Study Area.

The Floodplain Risk Management Study will determine options which will seek to reduce the impact of flooding on the community in consideration of social, ecological and economic factors.

Preferred floodplain management options will be publicly exhibited and the responses from the community incorporated in the Plan. The Plan will then be formally approved by Council following the public exhibition period.

Implementation of the Plan will allow Council to reduce the impact of flooding on the community through flood, property, and response modification measures. The measures include structural works, planning controls, flood warnings, flood readiness and response plans, ongoing data collection and monitoring.
2. BACKGROUND

2.1 Brief Catchment Overview

The contiguous catchments of Whartons, Collins, Farrahars Creeks, Bellambi Gully and Bellambi Lake are located between 6 and 10 km north of the Wollongong Central Business District. The streams which drain these catchments run through the suburbs of Bulli, Woonona, Woonona East, Russell Vale, Bellambi, Corrimal and Corrimal East. The Whartons Creek catchment defines the northern limits; and the Bellambi Lake catchment the southern limits, of the study area (Figure 2.1).

Each catchment extends over a distance of approximately 3.5 km in a westerly direction from the South Pacific Ocean up to the Illawarra Escarpment. The average elevation of the escarpment is between 350-400 m AHD, with the highest point in the study area located in the headwaters of the Whartons Creek catchment, where the elevation of the ridgeline exceeds 425 m AHD.

The upper reaches of the streams that drain the study catchments are fed by runoff which originates from the heavily wooded escarpment area where gradients in excess of 50 percent are common place.

The middle to lower reaches of the streams flow through the developed parts of the study catchments. The gradient of the streams in these parts flattens from around 20 per cent where they drain developed areas west of the Princes Highway, to less than 1 per cent where they discharge to the South Pacific Ocean.

At their outlets, the streams are examples of Intermittently Closed and Open Lakes and Lagoons (ICOLLS). Many of the coastal estuaries of NSW fall into this category, whereby the coastal entrance experiences a cyclical process of entrance filling and berm building as a result of wave action and the littoral movement of sand, followed by berm breaching and entrance scour which is commonly associated with runoff producing rain falling on the catchment.

Figures 2.2 to 2.4 show the network of drainage lines which comprise the study reaches and the names which have been assigned to each.

Table 2.1 summarises the catchment areas which contribute runoff to the major drainage structures which cross the Princes Highway, Northern Distributor and Illawarra Railway Line corridors. Also given in Table 2.1 is the total area of the study catchments at their point of discharge to the South Pacific Ocean.

Table 2.2 gives details of the major drainage structures which cross the Princes Highway, Northern Distributor and Illawarra Railway Line corridors.

Five major flood retarding basins have been constructed in the study area in the past two decades. Details on these structures are given in Table 2.3.

A detailed description of the network of streams which drain the study catchments is contained in Appendix A.
### TABLE 2.1
**SUMMARY OF CONTRIBUTING CATCHMENT AREAS (ha)**

<table>
<thead>
<tr>
<th>Study Catchment</th>
<th>Watercourse</th>
<th>Location</th>
<th>Princes Highway</th>
<th>Northern Distributor</th>
<th>Illawarra Railway Line</th>
<th>Ocean Outlet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whartons Creek</td>
<td>Main Arm</td>
<td>140</td>
<td>-</td>
<td>158</td>
<td>211</td>
<td></td>
</tr>
<tr>
<td>Collins Creek</td>
<td>Main Arm</td>
<td>190</td>
<td>295</td>
<td>321</td>
<td>413</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tributary 2</td>
<td>62</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tributary 4</td>
<td>-</td>
<td>16</td>
<td>34</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tributary 5</td>
<td>-</td>
<td>4</td>
<td>14</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Bellambi Gully/</td>
<td>Main Arm</td>
<td>71</td>
<td>92</td>
<td>110</td>
<td>583</td>
<td></td>
</tr>
<tr>
<td>Farrahars Creek</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tributary 1</td>
<td>11</td>
<td>41</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tributary 2</td>
<td>81</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tributary 3</td>
<td>72</td>
<td>95</td>
<td>108</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tributary 4</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tributary 5</td>
<td>7</td>
<td>31</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tributary 6</td>
<td>-</td>
<td>13</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Bellambi Lake</td>
<td>Main Arm</td>
<td>56</td>
<td>71</td>
<td>97</td>
<td>266</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 2.2
MAJOR DRAINAGE STRUCTURES IN THE STUDY AREA

<table>
<thead>
<tr>
<th>Study Catchment</th>
<th>Watercourse</th>
<th>Location of Major Cross Drainage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Princes Highway</td>
</tr>
<tr>
<td>Whartons Creek</td>
<td>Main Arm</td>
<td>4 off 2430 x 1950 RCBC’s</td>
</tr>
<tr>
<td></td>
<td>Tributary 2</td>
<td>2 off 1370 RCP’s (inlet)</td>
</tr>
<tr>
<td></td>
<td>Tributary 4</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Tributary 5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All dimensions are in millimetres unless otherwise noted. RCBC = Reinforced Concrete Box Culvert RCP = Reinforced Concrete Pipe (^1) Bridges are located on minor tributary of Whartons Creek north of Farrell Road. (^2) Based on survey of pipe outlet downstream of highway corridor.</td>
</tr>
<tr>
<td>Collins Creek</td>
<td>Main Arm</td>
<td>2 off 1800 x 2400 RCBC’s</td>
</tr>
<tr>
<td></td>
<td>Tributary 2</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Tributary 4</td>
<td>2 off 1830 RCP</td>
</tr>
<tr>
<td></td>
<td>Tributary 5</td>
<td>2 off 1500 RCP</td>
</tr>
<tr>
<td>Bellambi Gully/Farrahars Creek</td>
<td>Main Arm</td>
<td>1 off 2400 x 1600 RCBC</td>
</tr>
<tr>
<td></td>
<td>Farrahars Creek</td>
<td>1 off 1830 RCP</td>
</tr>
<tr>
<td></td>
<td>Tributary 1</td>
<td>1 off 900 RCP(^2)</td>
</tr>
<tr>
<td></td>
<td>Tributary 2</td>
<td>1 off 1830 RCP</td>
</tr>
<tr>
<td></td>
<td>Tributary 3</td>
<td>1 off 1500 RCP</td>
</tr>
<tr>
<td></td>
<td>Tributary 4</td>
<td>2 off 600 x 350 RCBC’s</td>
</tr>
<tr>
<td></td>
<td>Tributary 5</td>
<td>1 off 900 RCP</td>
</tr>
<tr>
<td></td>
<td>Tributary 6</td>
<td>-</td>
</tr>
<tr>
<td>Bellambi Lake</td>
<td>Main Arm</td>
<td>1 off 1600 x 1200 (inlet)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 off 1790 x 1950 (outlet)</td>
</tr>
</tbody>
</table>
## TABLE 2.3
DETAILS OF MAJOR FLOOD RETARDING BASINS IN THE STUDY AREA

<table>
<thead>
<tr>
<th>Study Catchment</th>
<th>Watercourse</th>
<th>Location</th>
<th>Outlet Structure</th>
<th>Elevation (m AHD) / Width (m)</th>
<th>Storage Volume (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dimensions</td>
<td>Primary Spillway</td>
<td>Secondary Spillway</td>
</tr>
<tr>
<td>Whartons Creek</td>
<td>Main Arm</td>
<td>Gordon Hutton Park</td>
<td>1 off 450 RCP</td>
<td>25.0 (approx.)</td>
<td>28.0 / 12</td>
</tr>
<tr>
<td>Collins Creek</td>
<td>Hollymount Creek</td>
<td>Edgewood Estate</td>
<td>1 off 2400 RCP</td>
<td>41.63</td>
<td>45.86 / 50</td>
</tr>
<tr>
<td>Bellambi Gully/ Farrahars Creek</td>
<td>Tributary 3</td>
<td>South of Edgewood Estate (Basin No. 1)</td>
<td>1 off 1500 RCP</td>
<td>33.47</td>
<td>36.0 / 18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>South of Edgewood Estate (Basin No. 2)</td>
<td>2180 wide x 910 high opening**(3)**</td>
<td>26.49</td>
<td>29.49 / 8.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>South of Edgewood Estate (Basin No. 3)</td>
<td>1 off 1500 RCP</td>
<td>21.28</td>
<td>26.4 / 30</td>
</tr>
<tr>
<td>Bellambi Lake</td>
<td>Main Arm</td>
<td>Corrimal High School</td>
<td>2 off 1800 RCP’s</td>
<td>6.04</td>
<td>9.13 / 18.5</td>
</tr>
</tbody>
</table>

1. Spillway elevation is approximate only.
2. Volumes are approximate only.
3. Flow discharging through the outlet structure and over both the primary and secondary spillways in controlled by a second outlet structure which extends through the basin embankment. This structure is 6000 wide by 900 high.
2.2 Major Development in the Study Area

Several relatively large residential developments have been constructed in the study area in the past two decades. The developments which are of primary concern to this study are:

- The Magnolia Green development, which is located in the Whartons Creek catchment to the west (upstream) of the Princes Highway. The Magnolia Green development was constructed in the mid-1990's and was impacted upon by floodwaters which surcharged the major flood retarding basin in Gordon Hutton Park during the large storm which occurred in August 1998.

- The Bulli Spinners development, which is located in the Whartons Creek catchment at the intersection of Franklin Avenue and Ursula Street. Construction of this development commenced during the preparation of the flood study.

- Development to the west (upstream) of the Princes Highway on Tributary 2 of the Collins Creek drainage system. The subdivision of several relatively large parcels of land which lie to the west of the Princes Highway along Lang Street and Ball Street occurred in the 1990's.

- The Edgewood Estate development, which spans the catchment divide between the Collins Creek and Farrahars Creek/Bellambi Gully systems. Construction of this development did not commence until after the August 1998 storm. The major flood retarding basins which have been constructed as part of this development were also not operational at the time of the August 1998 event.

- A relatively large residential subdivision which is located to the east of Pioneer Drive in the Farrahars Creek/Bellambi Gully catchment. Construction of the residential subdivision, which is located on the left overbank of Tributary 3, had commenced prior to the August 1998 storm.

Many of the streams which drain the study catchments are crossed by the newly constructed Northern Distributor Extension. Details of the geometry of the new road, including the numerous bridges and culverts which convey flow from upslope catchments across the road corridor, were provided by the RTA.

Concerns were raised by the Floodplain Management Committee regarding the potential for a transfer of flow to occur out of the Slacky Creek catchment into the Whartons Creek catchment. The potential for this inter-catchment transfer of flow arises because a dam has been constructed in the upper reaches of the Slacky Creek catchment and its outlet lies on the catchment divide.

Survey carried out as part of this present study showed that during storms which result in the surcharge of the piped outlet from the dam, flow from the storage will cross into the Whartons Creek catchment where it will exacerbate flooding conditions (although only to a minor extent) in the middle and lower reaches of the creek system.

2.3 Community Consultation

At the commencement of this Flood Study, a community newsletter and questionnaire was distributed to occupiers and owners of property located on the floodplain of the study catchments. The newsletter introduced the study and invited the community to provide information relating to their experience of past flooding. A copy of the questionnaire component of the document and a summary of the community’s response is contained in Appendix B.
Council distributed a total of 6,714 questionnaires to occupiers of the floodplain, comprising:

- 4,710 to people who own a single property (both residents and businesses);
- 1,837 to occupiers of property (i.e. tenants of rented property); and
- 167 to people who own multiple properties on the floodplain of the study catchments.

A total of 763 people responded to the questionnaire, of which 193 noted that they had experienced flooding at the property. As a subset of the 193 people which have experienced flooding at the property, 170 were affected by the large flood which occurred on 17 August 1998.

Over 94 respondents noted that they had observed blockage of up to 110 culverts and bridges during the August 1998 storm. **Table B1 in Appendix B** gives the location of each of these structures.

A second community newsletter was distributed in August 2009 advising that the first phase of the study was nearing completion and that the draft Flood Study report would be placed on public exhibition over the month of September 2009.

A second questionnaire was attached to the newsletter seeking further input from the community on the study. Recipients of the questionnaire were asked to provide feedback on the draft Flood Study report, in particular the flood extents shown for the August 1998 flood. The questionnaire also contained a series of questions which were aimed at gauging the community’s attitudes to Council’s development controls, as well as seeking opinions on various floodplain risk management measures and controls.

Of the 6,307 questionnaires which were sent out, a total of 643 people responded in writing. Of those, about 50 provided comment on the August 1998 flood extents and/or details of observed flood behaviour. Based on a review of the comments, it was concluded that the hydraulic model reproduced observed flood behaviour in most areas, with the following exceptions:

- **Location**: Several residential allotments located on the left overbank of Whartons Creek between Franklin Avenue and Trinity Row. The hydraulic model predicted that shallow overland flow discharged through these properties during the August 1998 flood as a result of surcharging of the culvert located beneath Franklin Avenue, whereas respondents advised there was no flooding experienced in this area.

- **Location**: Several residential allotments located between Stanhope Street and Hollymount Park in the Bellambi Gully catchment. The hydraulic model predicted that a localised depression was inundated to a depth of over 1 m during the August 1998 flood as a result of floodwaters which surcharged the Princes Highway, whereas respondents advised there was no flooding experienced in this area.

Concerns were also raised with regard to predicted flood behaviour in the Edgewood Estate development. The hydraulic model was indicating that a portion of the flow which surcharges the spillway of the flood detention basin on Hollymount Creek during a 100 year ARI event will discharge overland through several residential allotments, rather than be contained by a defined overland flow path.

Whilst the difference in observed versus predicted flood behaviour can in most cases be linked to the problems associated with modelling shallow overland flow using a grid based model, several adjustments were made to the hydraulic model in order to improve its accuracy. Further discussion on the accuracy of the hydraulic model is contained in **Section 5.2.2**, whilst details of the adjustments which were made to the model as a result of community feedback are set out in **Section C5.2 in Appendix C and Section E2.1 in Appendix E**.
A copy of the second community newsletter and questionnaire is contained in Appendix B. Included in the Appendix is a graphical representation of the responses which were received to the various questions. A more rigorous review of the various responses will be undertaken during the next phase of the study, when the community’s attitudes and opinions will be incorporated into the Floodplain Risk Management Study.

2.4 Data Base

2.4.1 Rainfall Data

A number of pluviographic stations are in operation both within and immediately adjacent to the study catchments. Data from these stations were purchased for the October 1987, April 1988 and August 1998 events for which flood level data and anecdotal evidence was available. This data was used to assist in the tuning of the computer models.

2.4.2 Streamflow Data

No gauging stations are located on the study creeks to allow calibration of the hydrologic computer model to recorded streamflow data.

2.4.3 Tidal Data

Tidal data which were officially recorded at Port Kembla during the October 1987 and April 1988 flood events and at Port Hacking during the August 1998 flood event were obtained from various sources.

2.4.4 Flood Level Data

WCC maintains a database of historic flood level data for streams which drain its local government area. A review of the database shows that there are fifteen flood marks in the study area which relate to the storm which occurred in October 1987; five flood marks for the storm which occurred in April 1988 storm; and eighty seven flood marks for the storm which occurred in August 1998.

The responses to the first community questionnaire also provided anecdotal evidence which was used when tuning the computer models for this study.

2.4.5 Survey Information

Cross sectional survey of the inbank area of the streams in the study area was carried out by Gallagher Odell & Garey Consulting Surveyors & Engineers.

WCC provided ALS survey data covering the study area, as well as survey of existing structures located along the study reaches.

Information contained on several Work-As-Executed plans provided by WCC was also used to complement the survey data.
2.5 Historic Flooding in the Study Catchments

Historic flood data is available for storms which occurred on 20 October 1987, 30 April 1988 and 17 August 1998. The historic flood data comprises rainfall depths which were recorded at a number of pluviographic stations located both within and immediately adjacent to the study area, in addition to a number of flood marks which are contained in a database held by WCC.

Following is a brief description of the reported impact each storm had on the region at the time. The findings of analyses carried out on the recorded rainfall data (refer Section C2 of Appendix C for further details) are also summarised below.

20 October 1987 Flood

Newspaper reports at the time (Weeks, 1992) reported that intense rain fell over a 12 hour period, with relatively shallow flooding being experienced in commercial property at Woonona.

"Unseasonal deluge and strong winds occurred yesterday, with many areas reporting flooding... Shops were flooded, fences and outhouses were washed away... when rainstorms pounded the Illawarra relentlessly for 12 hours yesterday."

"After an unseasonably wintry night of scattered heavy showers, the skies showed no mercy as heavy downpours bucketed more than 77 mm of rain on Wollongong from about 3am. The northern suburbs bore the storm's full vengeance... Main Street Woonona Shops were flooded, with shoppers wading shin deep in water at about 3.30pm." Residents blamed Wollongong Council. "Weather forecasts threatened more rain last night and today".

"The problem is being caused by an intense depression off NSW which is taking extremely warm, moist air from above the Tasman Sea and dumping it on the coast. The coastal depression registered 1005 hectopascals. This depression is moving slowly southeast. A high is located south of Tasmania, moving away from the continent."

Based on the rainfall records for the Bulli Pass, Russell Vale and Corrimal (Collins Street) pluviographic stations, bursts of rainfall embedded in the storm were equivalent to a 1 in 2 year event for periods of between 1 and 3 hours. For periods of less than 1 hour, rainfall was equivalent to only a 1 in 1 year event.

April 1988 Flood

Newspapers at the time (Weeks, 1992) reported that a family died at Coledale during the storm as a result of a landslide.

"A landslide, initiated by heavy rain, kills family at Coledale". "This has been a weekend of floods and landslides". Albion Park, Dapto and Macquarie Rivulet experienced flooding of some businesses and houses. The rain commenced on Friday night."
Based on the rainfall records at the above mentioned pluviographic stations, bursts of rainfall were equivalent to between a 3 and 5 year event for periods of up to 3 hours. Immediately to the north of the study catchments, the Bulli Pass pluviograph recorded a 3 hour period of rainfall which was equivalent to a 1 in 9 year event.

August 1998 Flood

During the 17 August 1998 storm, approximately 987 properties suffered above floor inundation. At least 144 properties amongst the 987 were considered unfit for occupation immediately following the event, with $1.5M spent in the urgent voluntary purchase of four of those houses. In addition to the damage to private homes, motor vehicles were also swept off roads during the flash flood.

The total tangible damage for the flood event has been estimate at $75M, comprising $49.8M to private property and $25.2M to public property. The total amount of money paid by insurance companies for the damages arising from the flood has been estimated at around $42M.

Apart from tangible loss, the 17 August 1998 storm also brought intangible loss, with one human life lost during the storm. Services were also disrupted which caused major inconvenience to local residents. Train services were limited due to damage done to rail tracks. Residents in the Wollongong area also experienced disruptions to fixed line services. The University of Wollongong, schools and shops were also closed for several days.

The heavy rainfall which was experienced on that day was a result of the interaction between a localised low pressure system and a much more extensive upper level trough. The storm was further enhanced and intensified by convergence into the localised low and uplift over the Illawarra Escarpment.

Wind speeds measured at the Bellambi automatic weather station averaged 25 knots during the day of 17 August 1998 and intensified to around 30 knots at 1800 hours on the same day. The storm was moving in an onshore direction during the day but turned offshore at the time where rainfall reached its peak. This change in wind direction may have further exacerbated flooding conditions in the study area as the storm followed the flood wave as it moved down the catchments.

Recorded rainfall depths exceeded a 1 in 100 year event at the Bulli and Rixons Pass gauge for periods of between 1 and 3 hours. Rainfall intensities recorded at gauges located east of the Bulli and Rixons Pass gauges were less. For example, the Russell Vale gauge recorded rainfall intensities equivalent to a 1 in 50 year event for periods of up to 3 hours and the Corrimal (Collins Street) gauge recorded rainfall intensities equivalent to a 1 in 40 year event for periods of up to 1 hour and only a 1 in 20 year event for periods of between 1 and 3 hours.
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