Nundle and Woolomin Flood Study and Floodplain Risk Management Study & Plan

Nundle, with Peel River flowing right to left

Woolomin, with Peel River flowing from Chaffey Dam at top

Revised Final Draft Report

May 2012

Report of Tamworth Regional Council's Floodplain Management Committee

Bewsher

TAMWORTH REGIONAL COUNCIL

Nundle and Woolomin Flood Study and Floodplain Risk Management Study & Plan

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FOREWORD

In New South Wales the prime responsibility for local planning and the management of flood liable land rests with local government. To assist local government with floodplain management, the NSW Government has adopted a Flood Prone Land Policy in conjunction with the *Floodplain Development Manual*.

The Policy is directed at providing solutions to existing flood problems and to ensure that new development is compatible with the flood hazard and does not create additional flood problems.

The Policy sets out four sequential stages in the process of floodplain management:

1. Flood Study	Assessment to define the nature and extent of the flood problem.
2. Floodplain Risk Management Study	Evaluation of management options for the floodplain with respect to both existing and proposed development.
3. Floodplain Risk Management Plan	Formal adoption by Council of a management plan for floodplain risks.
4. Implementation of the Plan	Measures undertaken to reduce the impact of flooding on existing development, and implementing controls to ensure that new development is compatible with the flood hazard.

Tamworth Regional Council commissioned Bewsher Consulting to prepare this report. It has been prepared with financial assistance from the NSW Government through the Office of Environment and Heritage (OEH). This document does not necessarily represent the opinions of the NSW Government or OEH.

The assistance of Tamworth Regional Council's Floodplain Management Committee and officers from Council and OEH in preparing this document is acknowledged.

A draft report was prepared in May 2011. Subsequently as a result of improvements to the hydrological model's calibration, minor changes were made to the simulation of the 20 year, 50 year and 100 year ARI design floods. Public exhibition of the draft report was undertaken in March and April 2012. This report was then updated in April and May 2012 to reflect the revised modelling and the feedback received from the exhibition.

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EXECUTIVE SUMMARY

Bewsher Consulting Pty Ltd are specialist flood risk management consultants who were commissioned by Tamworth Regional Council, with financial assistance from the Office of Environment and Heritage (OEH), to prepare a Flood Study and Floodplain Risk Management Study and Plan for the small township of Nundle and the village of Woolomin. Nundle and Woolomin were severely impacted by flooding in November 2000.

The *Nundle and Woolomin Flood Study* and *Floodplain Risk Management Study & Plan* have been overseen by Council's Floodplain Management Committee, which comprises councillors and officers from Council, OEH and the State Emergency Service (SES), plus representatives of the Nundle and Woolomin communities.

Principal Outcomes

The principal outcomes of this study include:

- Consultation with the Nundle and Woolomin communities (**Chapter 3**);
- Preparation of a Flood Study which defines flood behaviour in the Peel River and tributaries at Nundle and Woolomin, for the 20 year, 50 year and 100 year average recurrence interval (ARI) events and the probable maximum flood (PMF). The November 2000 flood is estimated as about a 100 year ARI event at Nundle and about a 20 year ARI event at Woolomin. A sensitivity test was also conducted to assess the potential impacts of climate change (**Chapter 4**);
- Definition of the flood problem by construction of a property database, which records information on existing potentially flood affected properties within the study area up to the PMF. Some 10 dwellings in Nundle and 37 dwellings in Woolomin are expected to be flooded above floor level in the 100 year flood. The average annual cost of flood damages is assessed as $130K for Nundle and $270K for Woolomin (**Chapter 5**);
- A detailed evaluation of potential floodplain management measures to reduce flood damages to existing and future development, including flood mitigation dams, levees, a bypass channel, creek clearing, voluntary house purchase, voluntary house raising or redevelopment, infrastructure protection, planning controls, improvements to the flood warning system, improvements to emergency management capability and plans, and improvements to public flood readiness (**Chapter 6**);
- A recommended Floodplain Risk Management Plan (FRMP) (**Chapter 7**).

The Floodplain Risk Management Plan

The draft Nundle and Woolomin FRMP is presented in **Table 7.1**. The recommended measures have been selected after an assessment of the impacts of flooding, as well as environmental, social and economic considerations.

The recommended measures have been categorised into high and medium priorities, which reflects the ease with which the measure can be implemented and the value for money:

<u>High Priority</u>

- Council and State Water to consider Woolomin's flood mitigation requirements as part of the design of the Chaffey Dam augmentation;
- Council to invite the owners of 5 properties exposed to intolerable flood risks at Nundle to participate in a voluntary house purchase scheme, as funds permit;
- Council to investigate option for debris removal along Duncans Creek in order to mitigate flood risk;
- Council to consider the proposed revisions to the flood risk management controls in *TRDCP 2010*, as outlined in **Section 6.2.4.6** of this report;
- Council to promote the reduction of flood risk to existing buildings as part of the redevelopment process;
- Considering the pros and cons of further residential development on vacant lots, Council should not permit new development on high hazard land in Nundle, but could permit the development of such land in Woolomin for a limited period of time under a 'sunset provision' (for say 2-5 years) provided the risks to life and property can be adequately managed;
- Council, SES and the Nundle caravan park manager to improve the flood warning system in the manner described in **Section 6.3.1**;

- Council, SES and the Nundle caravan park manager to improve emergency management capability and plans in the manner described in **Section 6.3.2**; and
- Council, SES and the Nundle caravan park manager to improve the public's flood readiness in the manner described in **Section 6.3.3**.

<u>Medium Priority</u>

- Council to review the Flood Study for Woolomin when ALS topography becomes available and/or if the Chaffey Dam stage-storage-discharge relationship changes;
- Council to undertake preliminary designs to assess the suite of levee and accompanying offset works which would be required to reduce damages and the frequency of outages at the Nundle Water Treatment Plant, and then to implement the works if feasible;
- Council to invite the owners of 1 property at Nundle and (at least) 7 properties at Woolomin to participate in a voluntary house raising/redevelopment scheme, with a maximum $60K/house Government subsidy to raise the dwelling floors to above the 100 year ARI flood level (or higher, plus make other improvements to reduce the risk); and
- Council to raise the water pumps in Hall and Oakenville Streets, Nundle.

Funding

The total capital cost of implementing the FRMP is $2.5M. This would reduce the number of houses flooded above floor level in the 100 year ARI flood by at least 13 (6 Nundle, 7 Woolomin). Important infrastructure such as the Nundle Water Treatment Plant would be afforded protection from frequent floods. There would be significantly reduced risks to life through the recommended improvements to flood warning systems, emergency management capability and plans, and community flood readiness.

1. INTRODUCTION

1.1 BACKGROUND

Flooding of Nundle and Woolomin in November 2000 caused significant damage and threats to human life. Following the process set out in the NSW Government's *Floodplain Development Manual* (see **Section 1.3**), Tamworth Regional Council commissioned the *Nundle and Woolomin Flood Study* and the *Nundle and Woolomin Floodplain Risk Management Study and Plan*, in order to:

- better understand flood behaviour;
- assess the flood risks, which are understood as a combination of probabilities and consequences;
- manage existing flood risks;
- identify, evaluate and recommend structural and non-structural measures to reduce the flood risks;
- apply appropriate flood planning controls to new developments (e.g. minimum floor levels).

No previous detailed flood studies or flood management studies for Nundle or Woolomin have been identified.

1.2 STUDY AREA

The study area consists of the small township of Nundle (population 289) and the village of Woolomin (population ~200) within the Tamworth Regional Council Local Government Area (**Figure 1.1**). Nundle is located on the right bank of the Peel River about 45 kilometres south-east of Tamworth (**Figure 1.2a**). Woolomin is located on the right bank of the Peel River at its junction with Duncans Creek about 32 kilometres south-east of Tamworth (**Figure 1.2b**). River flows at Nundle are unregulated, but Peel River flows at Woolomin have been regulated by Chaffey Dam since its construction in 1979. The dam comprises an earth and rockfill embankment and a concrete lined morning glory spillway, and has an existing water supply capacity of 62 GL (**Figure 1.2c**, **d**). With a growing understanding of the risk posed by extreme floods, interim works involving a 1.8m parapet wall were completed in 2004, and an auxiliary spillway was completed in 2011. In February 2011, the Federal and State Governments announced funding for the augmentation of Chaffey Dam to increase capacity to 100 GL, providing improved water security for Tamworth City and the Peel River irrigation industry. Construction is scheduled to commence in 2012.

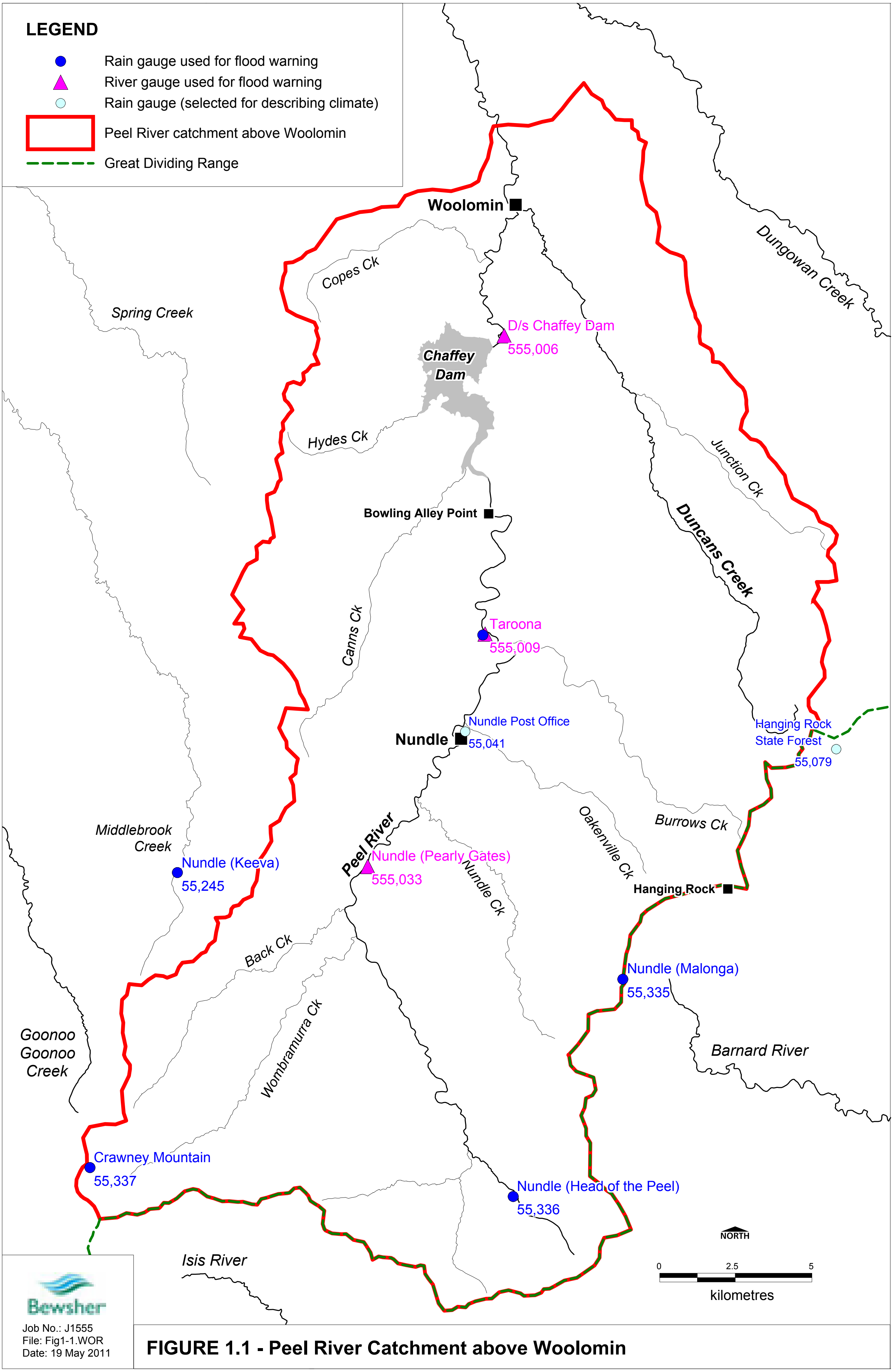
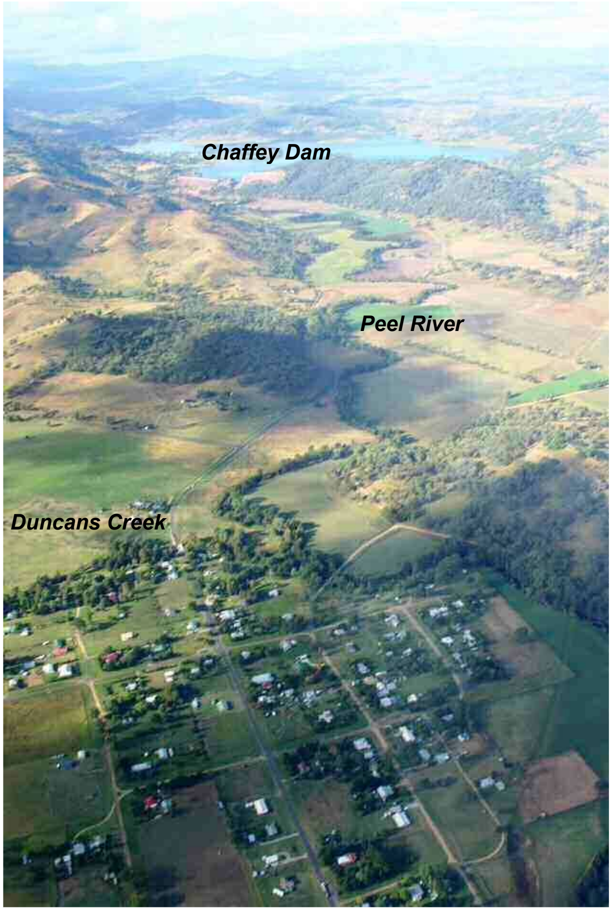


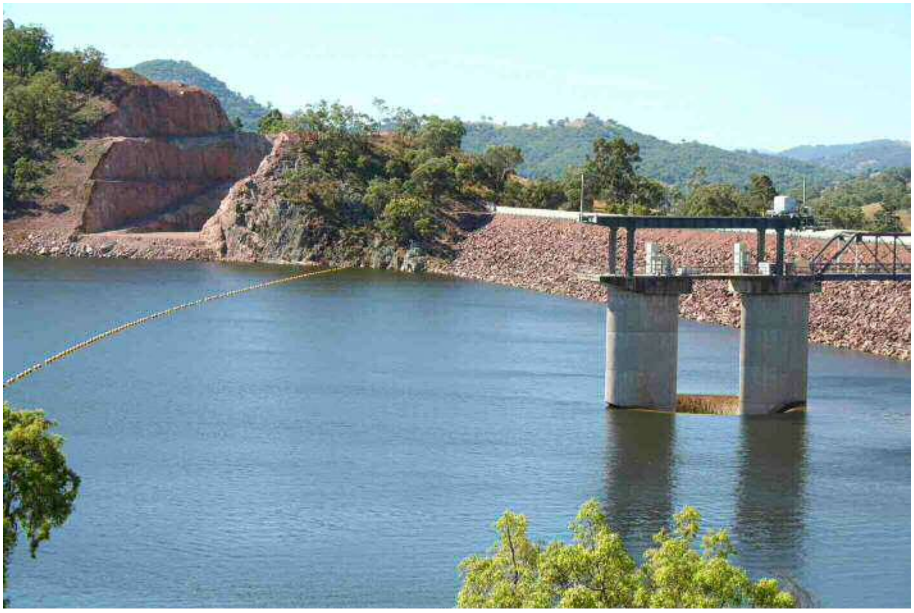
FIGURE 1.1 - Peel River Catchment above Woolomin

a. Nundle, with Peel River flowing right to left



b. Woolomin, with Peel River flowing from Chaffey Dam at top

c. Looking upstream to Chaffey Dam wall and auxiliary spillway



d. Chaffey Dam “morning glory” spillway on right and auxiliary spillway on left

FIGURE 1.2 – Views of Nundle, Woolomin and Chaffey Dam
Source: Bewsher Consulting, February 2011

1.3 THE GOVERNMENT'S FLOODPLAIN MANAGEMENT PROCESS

The NSW Government's Flood Prone Land Policy and a *Floodplain Development Manual* (NSW Government, 2005) form the basis of floodplain management in NSW. The main responsibility for managing flood prone lands in NSW rests with local councils. The NSW Government's Floodplain Management Program is administered by the Office of Environment and Heritage (OEH) and provides councils with technical and financial assistance to undertake flood studies and floodplain risk management studies, and for the implementation of works identified in those studies. The Department of Planning and Infrastructure is responsible for assisting councils on land use planning matters consistent with the *Floodplain Development Manual* (NSW Government, 2005).

The primary objective of the Flood Prone Land Policy is: to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.

For existing developed areas, the impacts of flooding shall be reduced by flood mitigation works and measures, including on-going emergency management measures, the raising of houses where appropriate and by development controls. For areas proposed for development or redevelopment, the potential for flood losses shall be contained by the application of ecologically sensitive planning and development controls.

The implementation of the Flood Prone Land Policy generally culminates in the preparation and implementation of a Floodplain Risk Management Plan (FRMP) by Council, which is the ultimate objective of the current study. Community consultation is an important part of the process and this has been undertaken via Council's Floodplain Management Committee and public displays and questionnaires with the local community.

The steps in the floodplain management process are summarised in **Figure 1.3**.

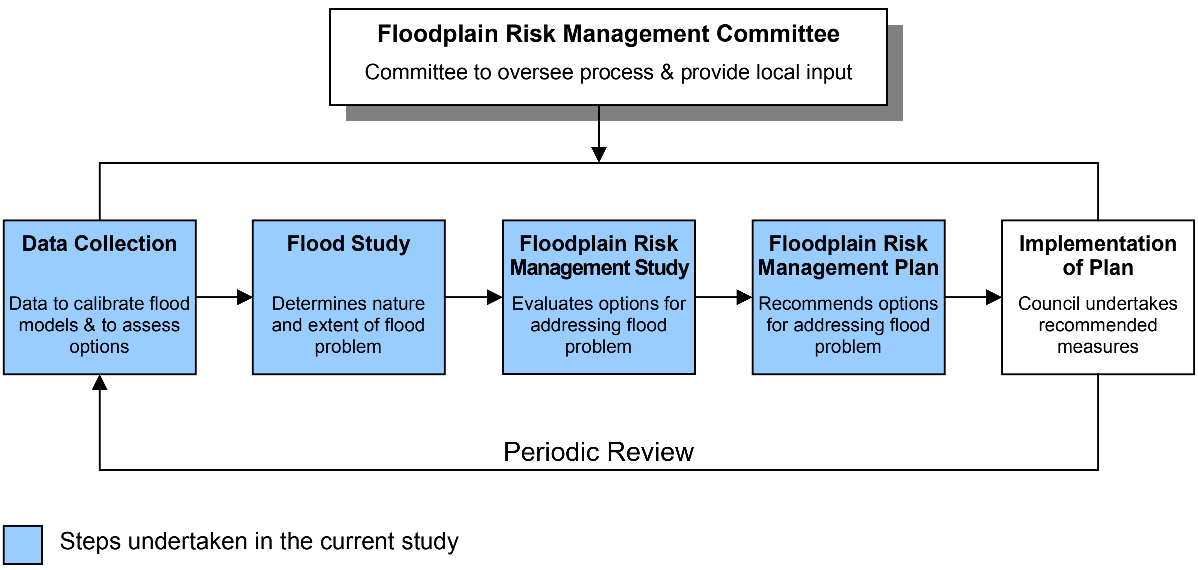


FIGURE 1.3 – The Floodplain Risk Management Process

2. BACKGROUND INFORMATION

2.1 CATCHMENT DESCRIPTION

Nundle and Woolomin are located in the upper Peel River catchment, which is part of the Namoi River basin within the Murray-Darling system. **Figure 2.1** shows the main topographic features of the catchment above Woolomin. Nundle is located on the right bank of the Peel River, about 27 km (by river) downstream from the start of the Peel River below the Great Dividing Range. Elevations at the catchment boundary exceed 1400m, the highest at Crawney Mountain in the south-western corner. Nundle township is also affected by very flashy flows in creeks draining the Hanging Rock area to the east, including Oakenville Creek which rises at an elevation of almost 1300m, flowing 9 km to the Peel River through Nundle (elevation 590m). The total catchment area to Nundle is about 234 km^2 of which Oakenville Creek contributes 14 km^2.

Woolomin is located at the junction of the Peel River and Duncans Creek, about 7 km downstream from Chaffey Dam. The catchment area at Woolomin is about 539 km^2, 76% of which is regulated by the dam. The Peel River catchment downstream of the dam, including Copes Creek, contributes an area of 29 km^2. Duncans Creek contributes an area of 101 km^2, rising in the Great Dividing Range (elevation about 1300m) and travelling about 25 km (by river) to the Peel River at Woolomin (elevation 470m).

Charts showing average monthly rainfall for two long-term rain gauges near Nundle are presented in **Figure 2.2**. The mean annual rainfall at Nundle Post Office (elevation 595m) is 844mm whereas the mean annual rainfall at the significantly higher Hanging Rock State Forest (elevation 1253m) is 1432mm. At the latter station, the wettest months have occurred in January and February, typically when summer cyclonic weather systems move south from the tropics (and most known floods at Nundle and Woolomin have occurred in these months). However, the winter months may also be quite wet, as occurred in 1998 through the passage of several cold fronts from the south (SES, 2002).

Most of the land in the Peel River catchment above Woolomin has been cleared, where the dominant land use is grazing (Green et al., 2011). There is a substantial forest cover in the upper Duncans Creek area (near the Hanging Rock State Forest) and on the south-eastern fringe of the catchment at Ben Halls Gap State Forest.

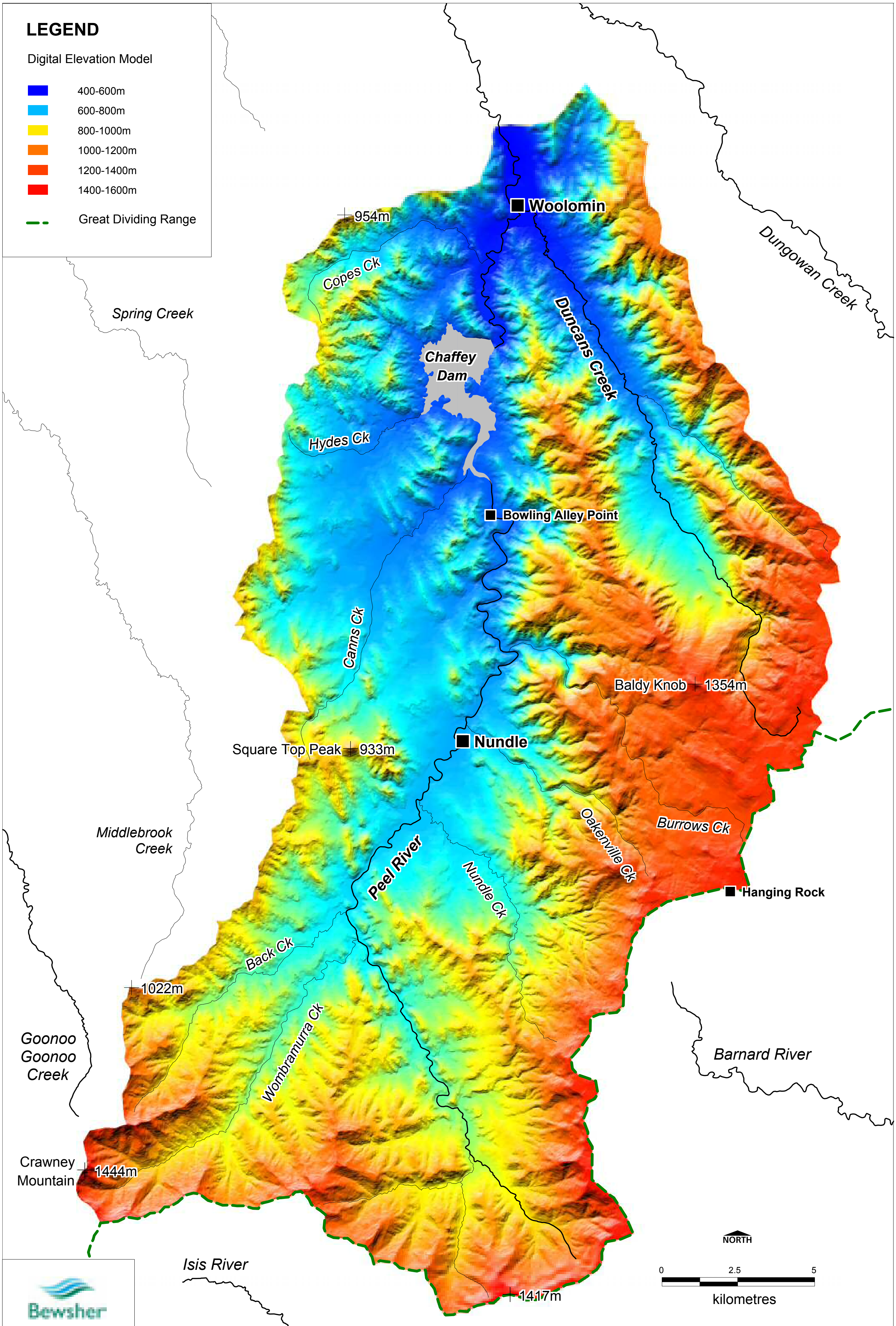


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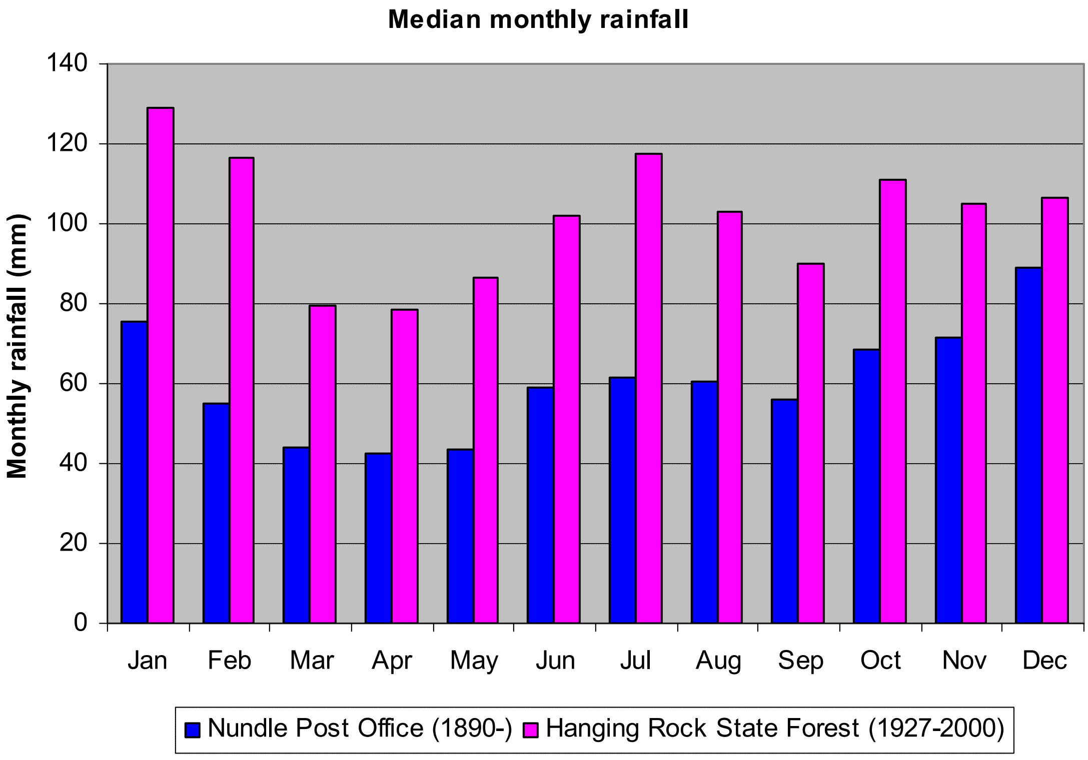
FIGURE 2.1 - Topography of the Peel River catchment above Woolomin



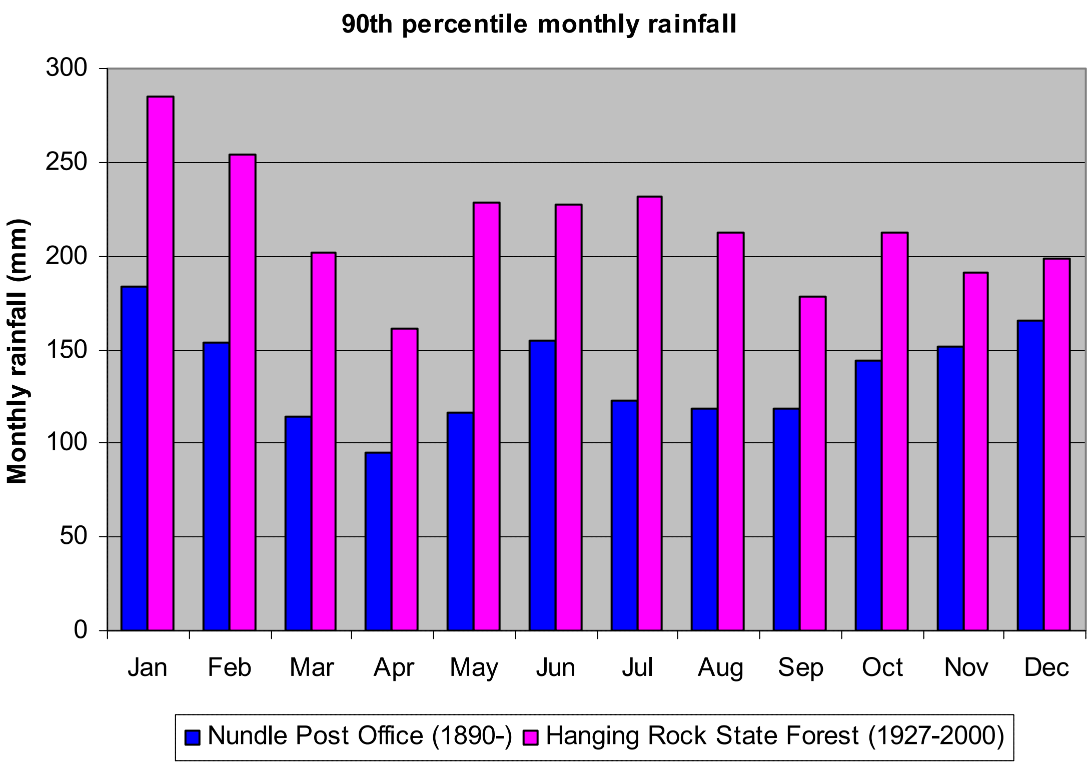


FIGURE 2.2 – Monthly Rainfall Statistics for Nundle Post Office and Hanging Rock State Forest

Data source: Bureau of Meteorology

Note: see Figure 1.1. for locations

2.2 FLOOD HISTORY

2.2.1 Pre-2000

A list of floods known to have affected Nundle and/or Woolomin is assembled from various sources in **Table 2.1**, with newspaper extracts and photos provided in **Appendix A**. Large floods occurred in January 1910, February 1955, February 1971 and January 1976, prior to the construction of Chaffey Dam. The flood of January 1984 is evidence that Woolomin can be flooded from Duncans Creek despite negligible flows from the Peel River below Chaffey Dam.

2.2.2 November 2000

The flood of November 2000 is regarded as a record flood at Nundle (see **Figure 2.3**). Even though Chaffey Dam was at over 100% of its Effective Full Storage Volume prior to the flood, **Figure 2.4** demonstrates the mitigating effect of the flood storage space in the dam on flows downstream – the peak discharge at the gauge downstream of the dam was only 37% compared to that at Taroona upstream of the dam. Nevertheless, Woolomin also experienced a serious flood.

A description of the behaviour and consequences of the November 2000 flood is provided in various SES documents (SES, 2000, 2002). Further information was derived from the community questionnaire issued for this study in 2006 (see **Section 3.5**). It is noted that about 70% of respondents from each of Nundle and Woolomin had experienced the November 2000 flood (**Figure 2.5**). A summary of the nature and consequences of the flood is provided here.

At about 10 p.m. on Sunday 19th November 2000, floodwaters from the Peel River began to flow across the floodplain at Nundle. The Nundle Caravan Park was inundated by water backing up Oakenville Creek at about 10.30 p.m., resulting in the evacuation of the park and relocation of vans to higher ground. However, the caravan park manager's residence was inundated and two caravans were destroyed and several others damaged. Shortly after midnight on 20th November 2000, backup flooding from Oakenville Creek inundated Nundle Café and Nundle Garage to a depth of about one metre. At about the same time, high velocity flood waters began to inundate the low-lying areas of Nundle. Two houses at the intersection of Herring and Innes Streets were inundated and both families had to be rescued under extremely dangerous conditions. In the process of this rescue, three emergency service vehicles became trapped by the force and volume of the water. Large trees, animals, bales of hay, caravans, motor vehicles and other debris were seen in the river at this time.[1] A house in Buchanan Street was flooded to waist high but the family could not be rescued due to the flooded gully between their house and the street. According to the SES (2000) flood report, "They were very lucky not to have been washed away". Four houses located in the Jenkins Lane ("Ratters Flat") area and another house in Buchanan Street were also inundated requiring evacuation of the residents. In Hall Street, two caravans were washed away and a holiday home was inundated. Houses on the lower side of Jenkins Street had water under them, which damaged belongings. Houses on the upper side of Jenkins Street suffered water damage from local overland flows travelling from the high ground towards the Peel River. Large debris damaged two cabins in the River Glen Cottages in Jenkins Street, and riverbank erosion threatened all four cabins. The pump station and water treatment works were flooded and badly damaged, depriving residents of water for about 24 hours. Fences were damaged extensively, and the brick toilet block at

[1] For a description of the flood and its consequences at one of these houses, refer to the article, 'Heartbreak for Nundle family' in **Appendix A**.

Nundle Recreation Ground was damaged. Three wooden bridges were washed away: the Peel River Bridge at Pearly Gates on Crawney Road; the Peel River Bridge at Bowling Alley Point on the Nundle-Tamworth Road; and a bridge across Oakenville Creek near the antimony mine on the Nundle-Hanging Rock Road. Based on the hydrograph at Taroona (**Figure 2.4**), it is likely that the flood peaked upstream at Nundle at about 1 a.m. on 20th November. The questionnaire responses indicate that people became aware of the flood only a short time before feeling its effects, and in some cases, with no forewarning whatsoever (**Figure 2.6)**. Newspaper and SES reports show that whilst some people were advised of the rising flood, the loss of power and telephone communications was problematic for the flood response.

According to the SES Local Flood Plan, Chaffey Dam commenced spilling via the morning glory spillway at about midnight on 20th November. The outflows coincided with high flows in Duncans Creek, which started to break out of its banks and threaten Woolomin about 12.30 a.m. Shortly afterwards the power in Woolomin failed, telephone services were cut and floodwaters inundated the Nundle Road Bridge. Water from Duncans Creek crossed Duncan Street at about 2 a.m. and by 3.30 a.m. floodwaters were running down Frederick Street, Nundle Road and all cross streets to Henry Street. Floodwaters were later observed to be one to two metres deep at the northern end of Nundle Road in Woolomin. The floodwaters below the dam peaked at 5.40 a.m. (**Figure 2.4**), ceased rising at Woolomin at 7.10 a.m., and had receded 50mm by 8 a.m. During the flood, SES volunteers woke residents from low-lying (older) houses and evacuated people to a private residence located on a hillside on the northern side of the village, or to the school. The original plan to move people to the tennis club (on the eastern side of the village) was abandoned due to the volume of water coming down Nundle Road. A number of houses in Woolomin were reportedly flooded to depths over floor of 0.3-0.6m. The type of damages sustained is described in newspaper reports in **Appendix A**. Flooding caused septic tanks to overflow, fouling the wells which supplied domestic water to many homes. It is understood that about 60 persons evacuated Woolomin as a result, whilst the remainder relied on bottled water and 'portaloos' until the wells were pumped out. As at Nundle, about half the questionnaire respondents indicated they had negligible advance warning time (**Figure 2.6**).

2.2.3 January 2010

A hydrograph of the flood of Saturday 2nd January 2010 is provided in **Figure 2.7**. The peak discharge at Taroona was significantly lower than the November 2000 flood (**Table 2.1**). The flood peaked at the Pearly Gates gauge (located 8.1 km upstream of Nundle) at 1.17 p.m. and peaked at the Taroona gauge (located 4.8 km downstream of Nundle) at 2.15 p.m., which yields a remarkably high flood travel time of 13.3 km/hr (3.7 m/s). This points to the very flashy nature of Peel River floods upstream of Chaffey Dam. As stated in the Local Flood Plan, Nundle is subject to dangerous flash floods due to the rapid rate-of-rise, high velocity flows and very high debris loads.

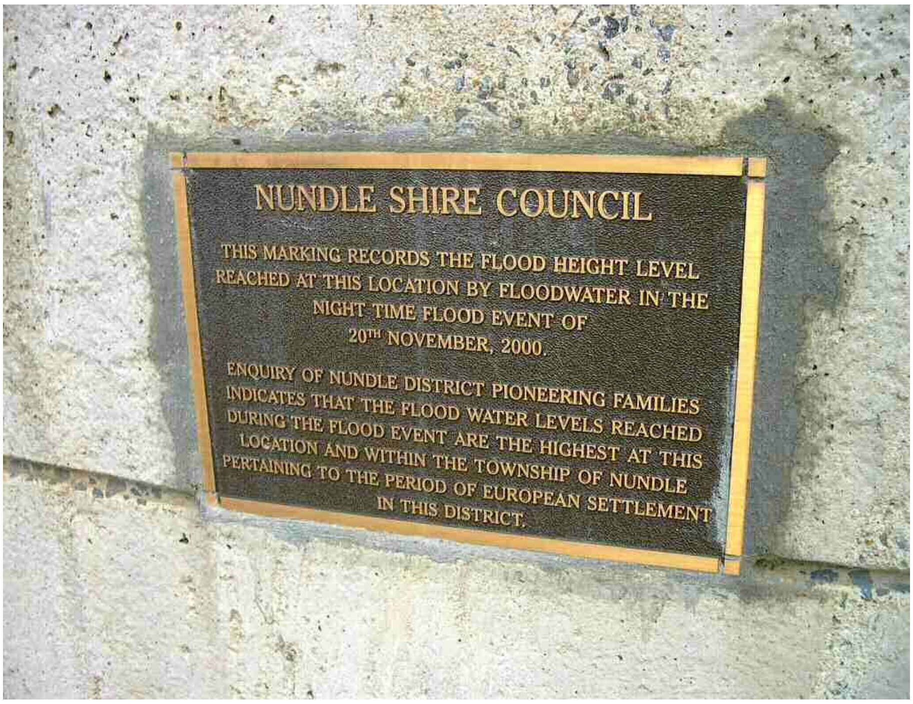
As **Figure 2.7** implies with negligible flows downstream of Chaffey Dam, the flood was absorbed into Chaffey Dam which began the event at 86% of its Effective Full Storage Volume. Woolomin did not experience the flood.

TABLE 2.1 – Flood History at Nundle and Woolomin

Date	Pearly Gates*	Taroona* Site no.: 419081 Catch't area: 280km^2		Bowling Alley Point* Site no.: 419004 Catch't area: 310km^2		D/s Chaffey Dam*[a] Site no.: 419045 Catch't area: 407km^2		Nundle (above Chaffey Dam)	Woolomin (flows regulated by Chaffey Dam since 1979)
	m	m	ML/day	m	ML/day	m	ML/day		
1874 Jan					85,600[b]				
1910 Jan					24,500[b]				0.15m higher than 1955 peak at one site.[c]
1924 Feb					57,500[d]			Overflowed banks.	
1955 Feb					75,900[b]	4.95[e]	73,400[e]	Flood rose to bottom of bridge over Peel River – worst for 45 years. Five families evacuated.	Severe damage with mud in nearly every home; carpet and lino ruined. Bridge over Peel River damaged beyond repair when flood reached 5.7m. Woolomin Hall washed off its piers and floated 25m downstream.
1971 Feb					68,500[b]	6.37[e]	71,700[e]		
1976 Jan					31,800[b]	5.82[e]	46,000[e]		
						Post-Chaffey Dam			Post-Chaffey Dam
1984 Jan				5.24[b]	88,100[b]	0.99[f]	400[f]	One house near water treatment plant affected.	0.44m lower than 1955 peak at one site.[c] Localised flooding from Duncan's Creek. Peel River flows mitigated by Chaffey Dam, which filled for first time.
1996 Jan		4.65[f]	41,900[f]			0.96[f]	100[f]	0.13m below 1984 peak. Pearly Gates Bridge damaged.	
2000 Nov		6.38[f]	126,200[f]			7.21[f]	46,300[f]	See text	See text
2001 Mar		4.89[f]	56,800[f]				4,000[f]		
2010 Jan	6.13[g]	5.33[g]	71,400[h]					Brick public toilets at Nundle Recreation Ground damaged. Nundle Caravan Park flooded. Oakenville Street surface damaged. Water treatment plant flooded, supply disrupted. Nundle Bridge closed for ~2 hours.	

Notes:

* Refer to Figure 1.1 for locations
[a] Formerly known as Bowling Alley Dam Site. The inconsistency between reported stage and discharge is noted, which may reflect errors in the source documents or altered gauge zeroes or rating tables.
[b] Water Resources Commission, 1984
[c] DWR, no date
[d] Flow record supplied by NSW Office of Environment and Heritage
[e] Water Resources Commission, 1980, Tables 7, 10, 14
[f] Flow record supplied by NSW Office of Water
[g] Bureau of Meteorology
[h] Derived from rating table from NSW Office of Water



a. Flood plaque, River Road, downstream of Nundle

b. Site of flood plaque, River Road, downstream of Nundle

FIGURE 2.3 – November 2000 Flood Plaque, River Road, Nundle

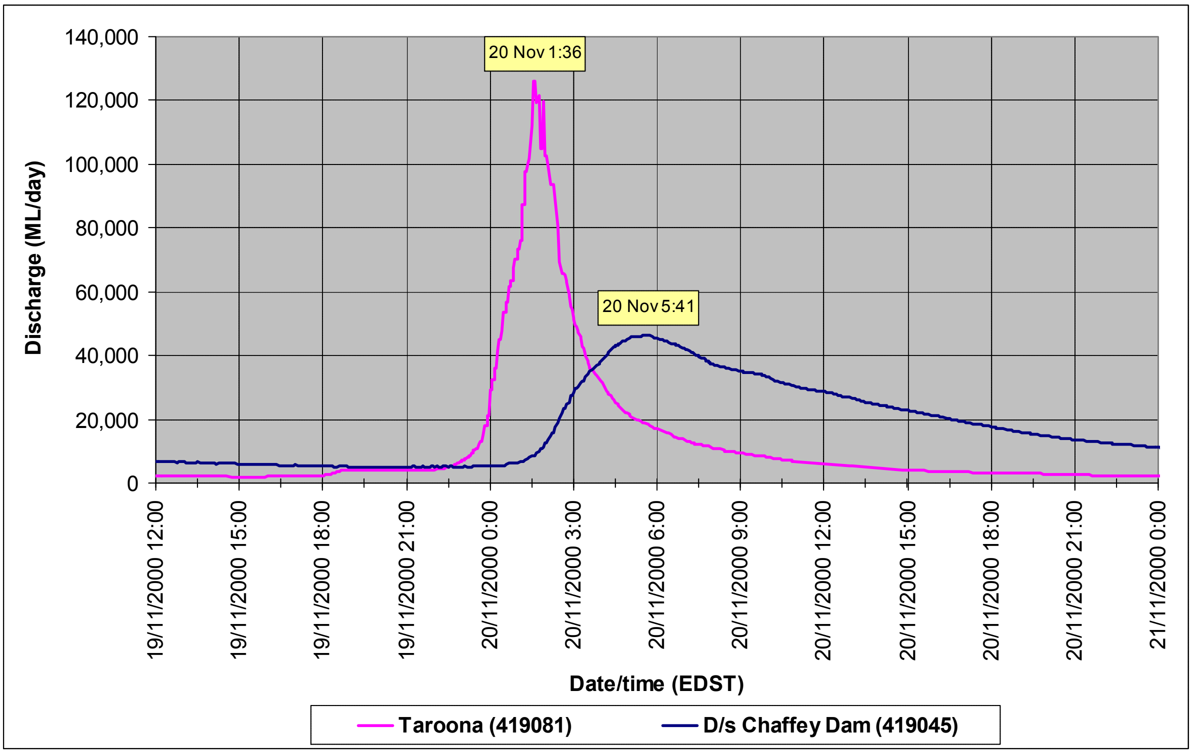


FIGURE 2.4 – November 2000 Flood Hydrographs

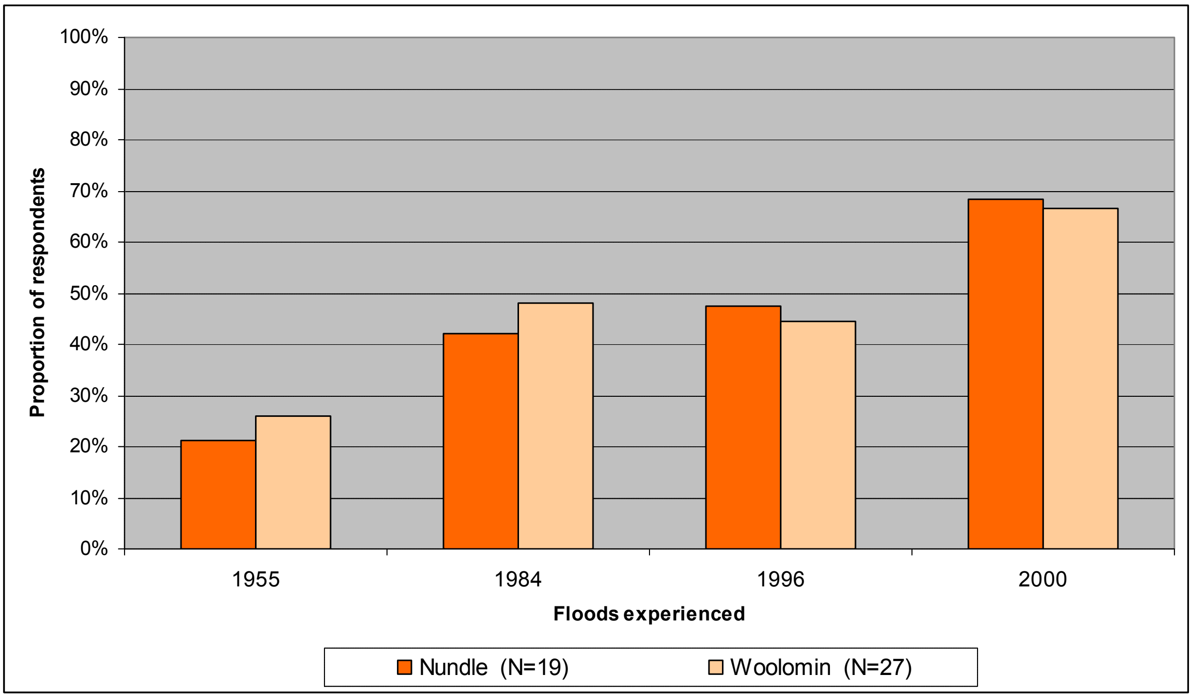


FIGURE 2.5 – Floods Experienced by Community (assessed in 2006)

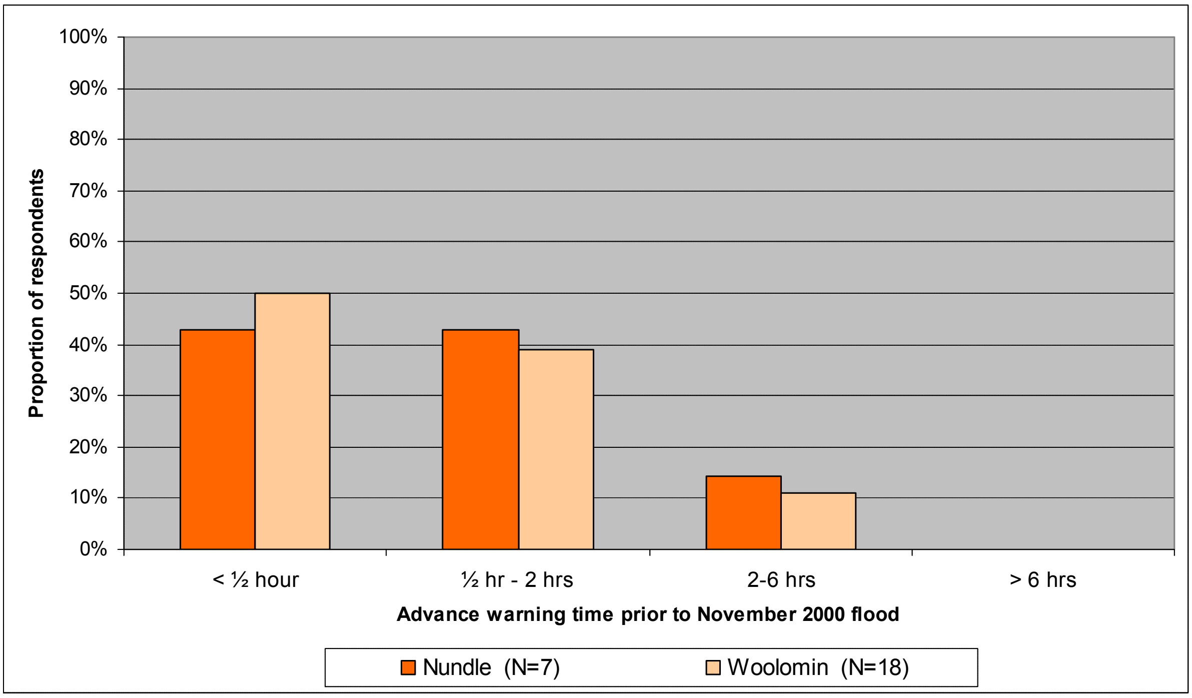


FIGURE 2.6 – Warning Time Available to Community, November 2000 Flood

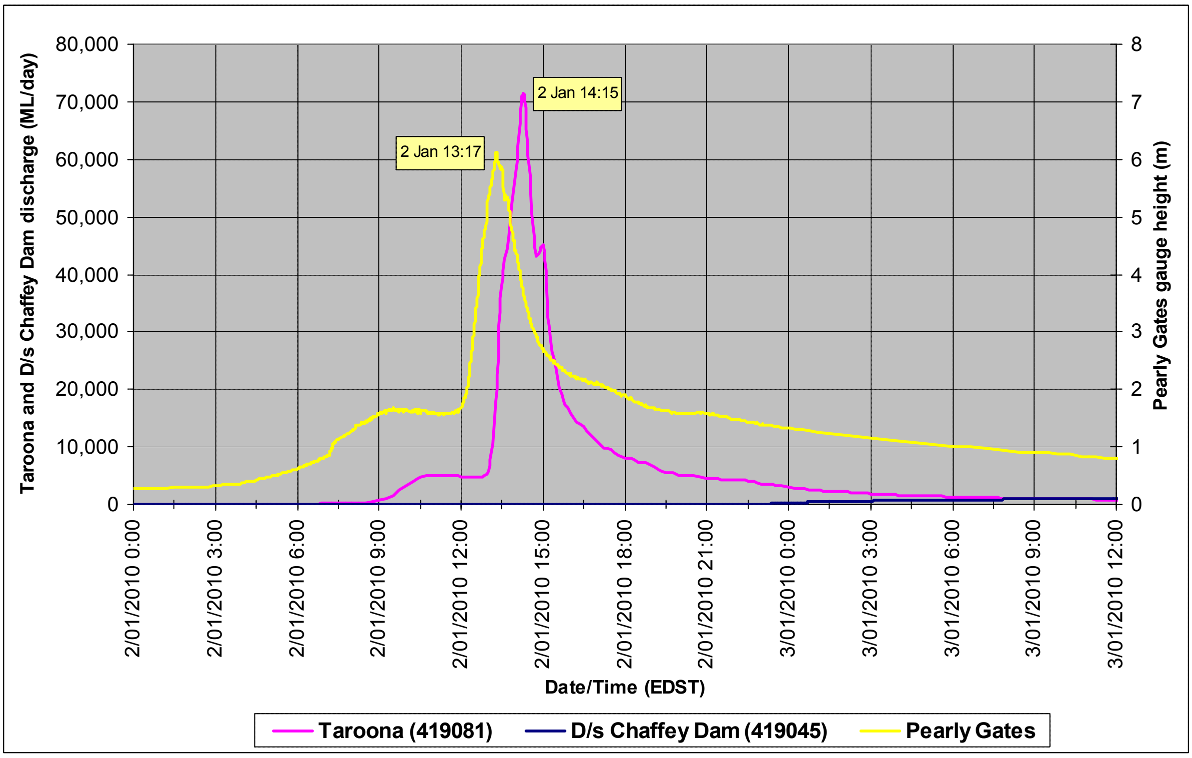


FIGURE 2.7 – January 2010 Flood Hydrographs

2.3 SOCIAL PROFILE

An understanding of social characteristics is an important consideration for floodplain risk management studies. Data from the 2006 Census was extracted for Nundle and Woolomin. Some key points are summarised in **Table 2.2** and discussed below.

- Based on the average household sizes, and the number of dwellings located within the modelled PMF floodplain, it is estimated that about 130 people live in the floodplain at Nundle and 220 people live in the floodplain at Woolomin;
- Nundle has a relatively high proportion of people aged over 65, a high median age and smaller average household size compared to Woolomin and NSW;
- At both communities, very few people speak a language other than English;
- The median household income at Woolomin and especially Nundle is much less than NSW;
- Almost 10% of residents at Nundle and 5% of residents at Woolomin do not have a motor vehicle;
- Over 90% of occupied private dwellings are separate houses, whilst there is also a higher than average proportion of "other dwellings", including caravans;
- A high proportion of dwellings at Woolomin have mortgagee owners;
- Woolomin and especially Nundle have a high proportion of dwellings without an internet connection; and
- Almost half the population at Woolomin did not live at the same address 5 years ago.

Potential implications for floodplain management are:

- Low incomes mean that people may not be able to participate in any voluntary house raising schemes which require substantial co-contributions from the homeowner;
- A high proportion of older residents at Nundle, and dwellings without motor vehicles, represent potential challenges should evacuation be required as a result of flooding;
- The provision of flood educational materials in English would be sufficient for these communities;
- The lack of internet take-up (and the nature of its use requiring *residents* to be proactive) means that this would have limited benefits as a means of flood education; and
- The high turnover of population—and the infrequency of floods—suggest that any educational initiatives will need to be sustained.

TABLE 2.2 – Census Data for Nundle and Woolomin
Source: 2006 Census Basic Community Profiles, www.censusdata.abs.gov.au/

	Nundle (locality)	**Woolomin** (suburb)[1]	**NSW**
SELECTED PERSON CHARACTERISTICS [B01]: % of persons			
Total persons	289	469	6,549,177
Aged 14 years and under	16.3%	19.8%	19.8%
Aged 65 years and over	22.5%	13.3%	13.8%
Aboriginal/Torres Strait Islander	4.8%	6.8%	2.1%
Australian born	90.0%	90.2%	69.0%
Born overseas	4.5%	6.0%	23.8%
Speaks English only	96.2%	97.0%	74.0%
Speaks language other than English	0%	1.8%	20.1%
Australian citizen	94.8%	92.8%	85.8%
SELECTED MEDIANS AND AVERAGES [B02]:			
Median age	48	38	37
Median individual income ($/week)	$283	$358	$461
Median household income ($/week)	$512	$675	$1,036
Median housing loan repayment ($/month)	$577	$1,020	$1,517
Median rent ($/week)	$100	$100	$210
Average household size	2.0	2.7	2.6
NUMBER OF MOTOR VEHICLES BY DWELLINGS [B29]: % of occupied private dwellings			
Dwellings with 0 motor vehicles	9.2%	4.5%	11.6%
Dwellings with 1 motor vehicle	46.2%	27.3%	38.3%
Dwellings with 2 motor vehicles	32.3%	45.5%	33.1%
Dwellings with 3+ motor vehicles	6.9%	19.9%	13.0%
Average number of motor vehicles per occupied private dwelling	1.4	1.9	1.5
DWELLING STRUCTURE [B31]: % of occupied private dwellings			
Separate house	91.6%	93.8%	71.4%
Semi-detached, row or terrace house, townhouse etc	0%	0%	9.7%
Flat, unit or apartment	6.1%	0%	17.7%
Other dwelling	2.3%	6.2%	1.1%

	Nundle (locality)	**Woolomin** (suburb)[1]	**NSW**
TENURE TYPE BY DWELLING STRUCTURE [B32]: % of occupied private dwellings			
Fully owned	59.5%	40.9%	34.8%
Being purchased	13.0%	38.6%	31.9%
Rented	22.9%	20.5%	29.5%
TYPE OF INTERNET CONNECTION [B35]: % of occupied private dwellings			
No internet connection	56.2%	42.1%	35.1%
POPULATION CONTINUITY [B37,B38]: % of persons aged 1 or 5 years and over			
Persons enumerated same address 1 year ago	89.4%	84.1%	79.5%
Persons enumerated same address 5 years ago	57.9%	51.6%	55.0%

Notes:
[1] Woolomin 'suburb' extends beyond the village of Woolomin.

2.4 HERITAGE ISSUES

2.4.1 Aboriginal Cultural Heritage

Prior to European settlement, most of the Tamworth region was inhabited by the Kamilaroi people. Kamilaroi was not a tribe in itself, but a grouping of tribes which all used a common language known as Gamilaraay. In the east of the region, along the Moonbi Ranges and up onto the New England Tablelands were the Anaiwan people (TRC, 2010).

The *National Parks and Wildlife Act* protects Aboriginal objects and places in NSW. The location of known Aboriginal objects and places is listed on a register known as the Aboriginal Heritage Information Management System. Information on this register can be inspected. Any proposed floodplain management works that might disturb or damage an Aboriginal object or place require a permit under the *National Parks and Wildlife Act*, as well as development consent (Tamworth Regional LEP 2010, Section 5.10).

2.4.2 European Heritage

Following the discovery of gold at Hanging Rock in 1851, Nundle was gazetted as a township in 1854 (Bolleau, 2007). The village of Woolomin appears to have been partitioned into lots in 1861. The Tamworth Regional LEP 2010 lists a number of heritage items in both Nundle and Woolomin (see **Figure 2.8** and **Table 2.3**). By comparison with **Figure 5.2** and **Figure 5.3**, it is noted that the only heritage items subject to above floor inundation in the 100 year flood are “I536” and “I538” at Woolomin. Under the LEP, any proposed floodplain management works that might alter or demolish a heritage item require special consideration including development consent.

Nundle   Woolomin

FIGURE 2.8 – Heritage Items
Source: Tamworth Regional LEP 2010 Heritage Maps

TABLE 2.3 – Heritage Items in Nundle and Woolomin
Source: Tamworth Regional LEP 2010, Schedule 5 (dated 21 Jan 2011)

Locality	Item name	Address	Property description	Significance	Item no
Nundle	Church	63 Gill St	Lot 1, DP 770383	Local	I268
Nundle	St Peter's Catholic Church	15 Innes St	Lot 1, DP 786993	Local	I269
Nundle	Former Courthouse/ Museum and Police Station and Residence	38–40 and 41–43 Jenkins Street	Lot 701, DP 96508	Local	I270
Nundle	Nundle Shire Office	58 Jenkins Street	Lot 1 and Part Lot 2, Sec 21, DP 758798	Local	I271
Nundle	All Saints Church of England	70 Jenkins Street	Part Lot 4, Sec 3, DP 758798	Local	I272
Nundle	Residence	79 Jenkins Street	Lot 2, DP 591822; Lots 12 and 13, Sec 2, DP 758798	Local	I273
Nundle	Odgers and McClelland Exchange Stores	81 Jenkins Street	Lot 172, DP 1072542	Local	I274
Nundle	Jenkins St Antiques, Odgers and McClelland General Store	83 Jenkins Street	Lot 101, DP 598667	Local	I275
Nundle	Jenkins St Guest House (Former Bank of New South Wales)	85 Jenkins Street	Lot 171, DP 1072542	Local	I276
Nundle	Peel Inn	89 Jenkins Street	Lot A, DP 369396; Lots 1–3, DP 997480	Local	I277
Nundle	Old Church Boutique Primitive Methodist Church	90–92 Jenkins Street	Lots 6 and 13, Sec 31, DP 758798	Local	I278
Nundle	Nundle Post Office	91 Jenkins Street	Lot 1, DP 714004	Local	I279
Nundle	Nundle Public School	93–97 Jenkins Street	Lot 1, DP 123390; Lot 9, Sec 30A, DP 758798	Local	I280
Nundle	Nundle Memorial Hall and Library	101 Jenkins Street	Lots 8 and 10, Sec 30A, DP 758798	Local	I281
Nundle	Nundle Cemetery	Nundle Creek Road	Lot 7001, DP 1030464	Local	I282
Woolomin	St Mary's Anglican Church	50–52 Frederick Street	Lot 3, Sec 8, DP 759117	Local	I536
Woolomin	Residence	Corner Munro Street and Gap Road	Lot 222, DP 755350	Local	I537
Woolomin	Residence	86–88 Nundle Road	Lot 1, DP 127996; Lots 1 and 14, Sec 14, DP 759117	Local	I538

3. COMMUNITY CONSULTATION

3.1 CONSULTATION PROCESS

The success of any floodplain management plan hinges on its acceptance by the local community and other stakeholders. This can only be achieved by involving the local community at all stages of the decision-making process.

Community consultation has been an important component of the current study, through meetings of the Floodplain Management Committee, questionnaires and public exhibition of the draft report. The consultation has aimed to inform the community about the development of the floodplain management study and its likely outcomes, and provided an opportunity to collect feedback and ideas on potential floodplain management measures.

The key elements of the consultation process have been as follows:

- Meetings of the Floodplain Management Committee;
- Project web-site;
- Community information sheet;
- Community questionnaire;
- Agency and interest group questionnaire; and
- Public exhibition of the draft FRMP.

3.2 FLOODPLAIN MANAGEMENT COMMITTEE

The study has been overseen by Tamworth Regional Council's Floodplain Management Committee. This committee comprises representatives from:

- Tamworth Regional Council;
- Office of Environment and Heritage (OEH), formerly DECCW;
- State Emergency Service (SES); and
- the Nundle and Woolomin communities.

The Committee has met to hear progress reports by the consultant, and to provide direction as the study progressed. The main agenda items are summarised in **Table 3.1**.

TABLE 3.1 – Meetings of Tamworth Regional Council's Floodplain Management Committee

DATE OF MEETING	MAIN AGENDA ITEMS
8 Nov 2006	Inception meeting
20 Dec 2010	Flood model calibration; community consultation; options
16 Jun 2011	Presentation of first draft report
28 May 2012	Presentation of revised draft report and recommendation to Council for adoption of report

3.3 PROJECT WEB-SITE

A study web-site was developed, containing information and contact details. The site was located at www.bewsher.com.au/studies-nundlewool.html.

3.4 COMMUNITY INFORMATION SHEET

A newsletter was sent to property owners in Nundle and Woolomin in November 2006 (see **Appendix B**). The newsletter performed a variety of functions: it introduced readers to the study; it reminded them that flooding has been problematic; it flagged potential management strategies; and it encouraged residents to participate in the study.

3.5 COMMUNITY QUESTIONNAIRE

Accompanying the information sheet was a community questionnaire (see **Appendix B**), from which 46 responses were received (19 Nundle, 27 Woolomin).

3.5.1 Flood Experience

A section of the questionnaire sought information about residents' previous flood experience, especially the November 2000 flood. This material is summarised in **Section 2.2.2**. A surveyor was engaged to survey flood marks where residents indicated they had a precise flood mark indicating the level reached by the November 2000 event. As well as flood marks provided by OEH, the community's flood marks were used for calibration of the flood models (see **Chapter 4**).

3.5.2 Floodplain Management Measures

A particular goal of the questionnaires was to canvass the community's ideas about how to manage the flood problem. One question allowed respondents to indicate support (or otherwise) in relation to a range of general floodplain management measures. The results are presented for Nundle in **Figure 3.1** and for Woolomin in **Figure 3.2**.

At Nundle, of the measures that attempt to modify flood behaviour, there was a high level of support (>50%) for enlarging bridges and culverts (note, the Nundle Road Bridge over the Peel River was replaced by a new bridge in 2008) and clearing the watercourse of debris. Of the measures that modify property in order to reduce flood damage, there was good support for voluntary house raising and the use of planning controls for new buildings. All the measures related to improving people's response to floods were well supported, especially the need to improve flood warning systems. There was a relatively high level of opposition to two measures: filling low-lying land, and voluntary purchase.

At Woolomin, six measures relating to modifying flood behaviour received high levels of support (>50%): constructing bypass channels/floodways, enlarging bridges and culverts, creek widening and/or dredging, clearing creeks of debris, removing floodplain obstructions and constructing permanent levees. There was a very high level of support for the use of planning controls for new buildings. All the measures related to improving people's response to floods were well supported, especially promoting flood readiness. There was a relatively high level of opposition to the filling of low-lying land, voluntary purchase and 'flood-proofing' buildings.

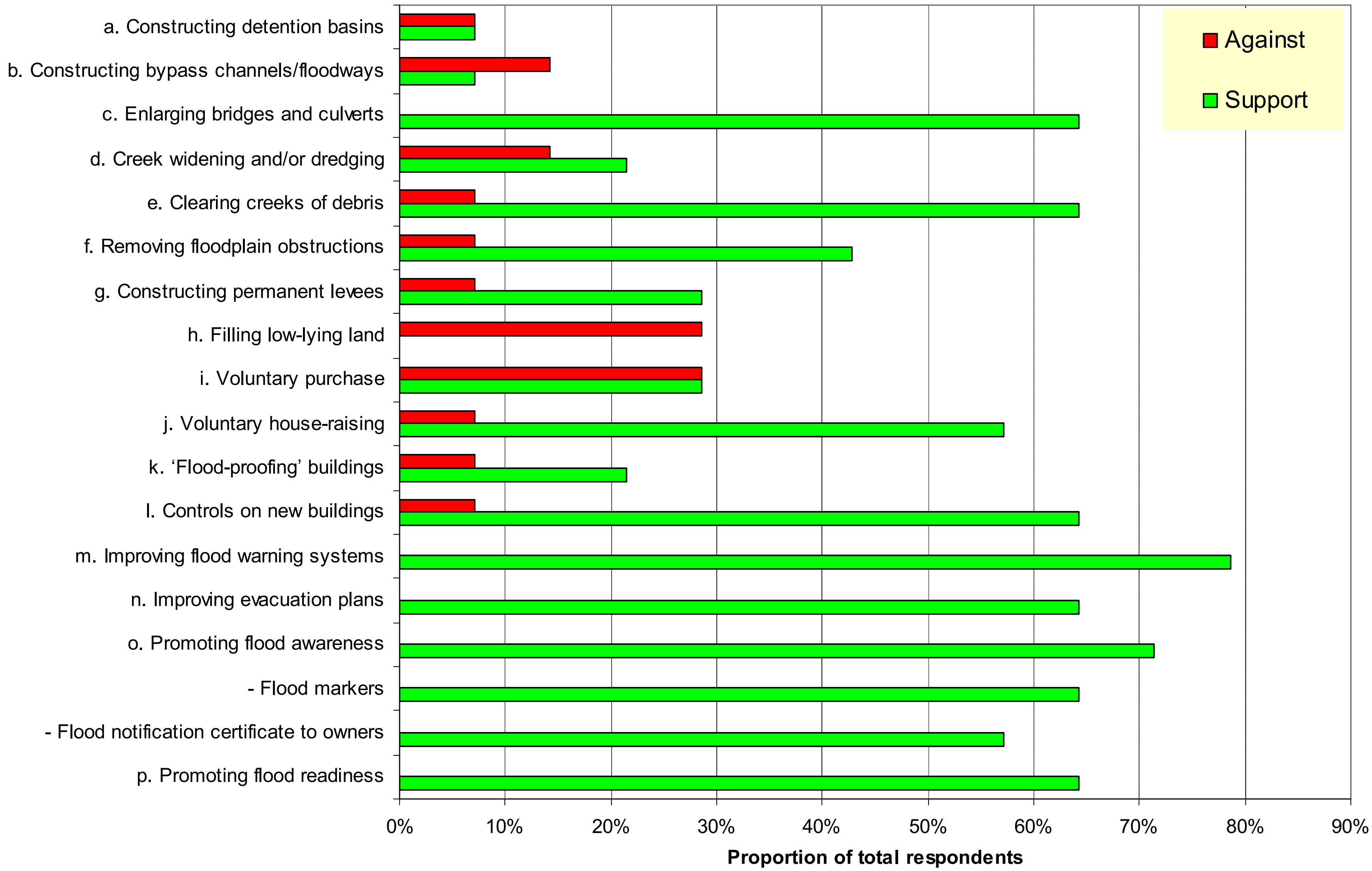


FIGURE 3.1 – Nundle Community Views on Management Options (N=14)

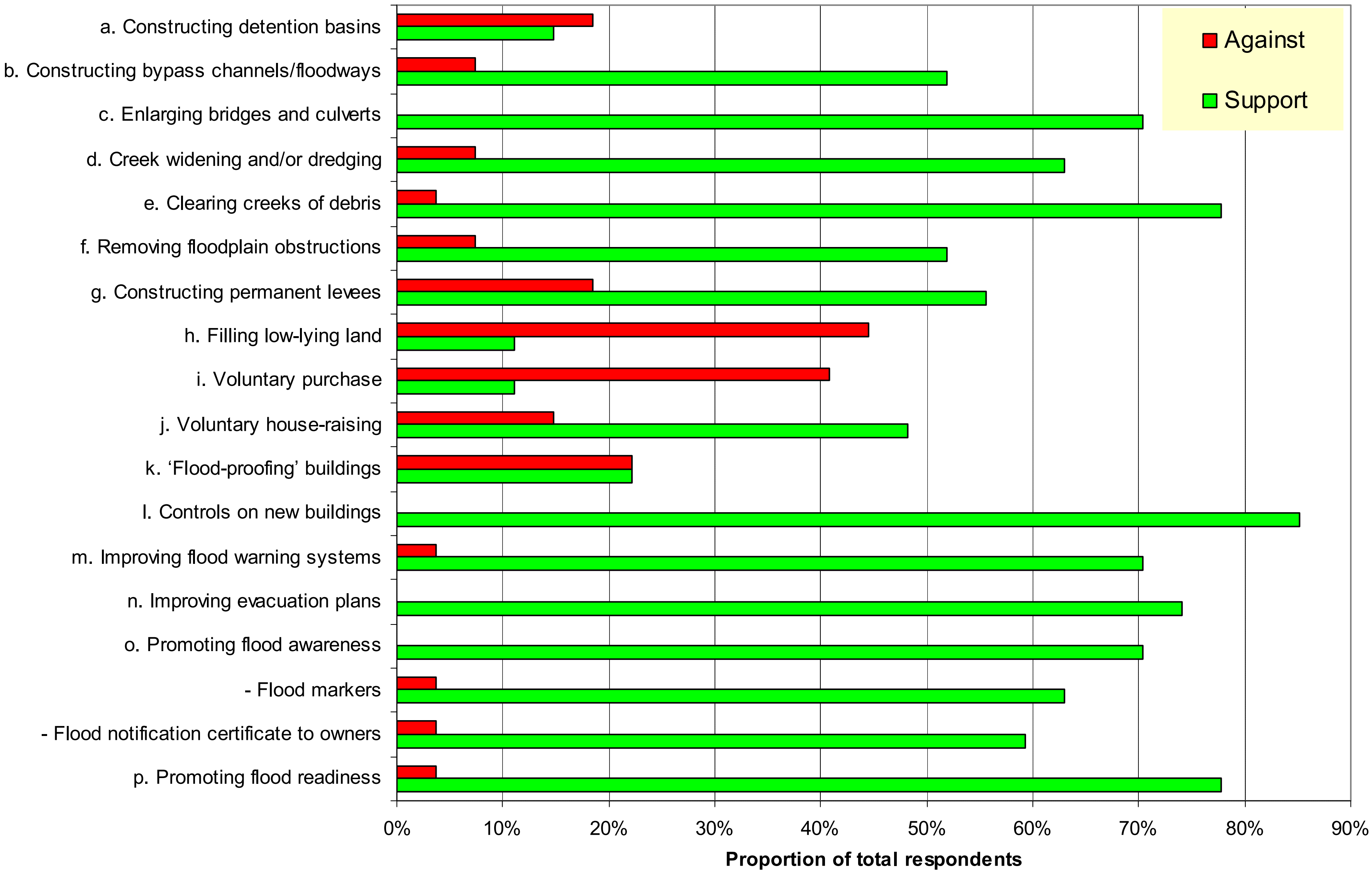


FIGURE 3.2 – Woolomin Community Views on Management Options (N=27)

A very useful indication of floodplain management measures supported by the community is obtained from Question 6 of the questionnaire, which was an open question. The answers have been summarised in **Table 3.2**, which is arranged according to location, category of floodplain management measure, and decreasing frequency of the response.

TABLE 3.2 – Floodplain Management Measures Suggested by Community

Nundle	**Woolomin**
Modify the flood	Modify the flood
▸ Clear debris from creek (x3) ▸ Detention basin upstream ▸ Tree-planting in catchment ▸ Levees	▸ Creek dredging/widening/realignment (x6) ▸ Clear debris from creek (x5) ▸ Levee banks, along Duncans Creek and above and below Peel River bridge (x4) ▸ Construct shallow bypass channels, including through eastern side of Woolomin from Duncans Creek, through Recreation Ground to northern side of village (x3) ▸ Improve local drainage of floodwaters in Woolomin (x3) ▸ Increase Chaffey Dam storage volume (x3) ▸ Operate Chaffey Dam so as to mitigate flooding in Woolomin (x2) ▸ Ensure Chaffey Dam is safe (x2) ▸ Appropriate design of bridges and bridge approaches to allow free flow of floodwater (x2)
Modify property	Modify property
▸ Development control for floodplains (x3) ▸ Design bridge and approaches to be above flood level, to ensure Nundle Road remains open for benefit of businesses and schools ▸ Voluntary purchase for old houses and voluntary house raising for strong houses	▸ Enhance flood immunity/quality of evacuation route, including larger box culverts on Gap Road (x3) ▸ Subsidies for voluntary house raising
Modify response	Modify response
▸ Early warning (x3)	▸ Improve flood warning systems and evacuation plans (x5)

At Nundle, the repeated responses related to clearing debris from the creek, development controls for buildings located in the floodplain, and the need for early flood warning. It is noted that the Fisheries Management Division does not support the removal of riparian vegetation (see **Section 3.6.2**), and its removal is not expected to significantly mitigate flood levels for the large events under consideration in this study.

At Woolomin, there was vocal support for creek dredging/widening/realignment and for clearing debris from the watercourses. These measures are not supported by the Fisheries Management Division (see **Section 3.6.2**). Ideas to construct levee banks along Duncans Creek and near the Peel River (Frederick Street) Bridge, and to construct a bypass channel through the eastern side of Woolomin are worthy of further consideration. There was considerable comment in relation to Chaffey Dam. It is noted that since the questionnaire was issued, the Chaffey Dam Safety Upgrade works have been completed, and plans to upgrade the storage volume to 100 GL have been announced (see **Section 1.2**). There is no scope to mitigate flooding in Woolomin through the *operation* of Chaffey Dam, since spills are uncontrolled. Flood warning systems, evacuation capability and plans are all worthy of further consideration in this FRMS&P.

3.5.3 Controls on New Development

Another question sought to gauge the community's views on the appropriateness of development within the floodplain. The results are presented in **Figure 3.3**. As expected, an increasing proportion of respondents, for each of Nundle and Woolomin, considered that a more conservative approach was required for the rezoning of land for new development when compared to subdivision of land, and for subdivision of land when compared to "all new development". The interesting result from this question is that respondents from Woolomin appear to be more tolerant of flood risks (or pro-development?) when compared to the respondents from Nundle. However, a high proportion of the respondents to this question for Woolomin (91%) favoured placing restrictions on development such as minimum floor levels (cf. 63% for Nundle). So whilst there was a greater acceptance of the *use* of flood-prone land in Woolomin for residential uses, there was also recognition that the *style* of development required controls.

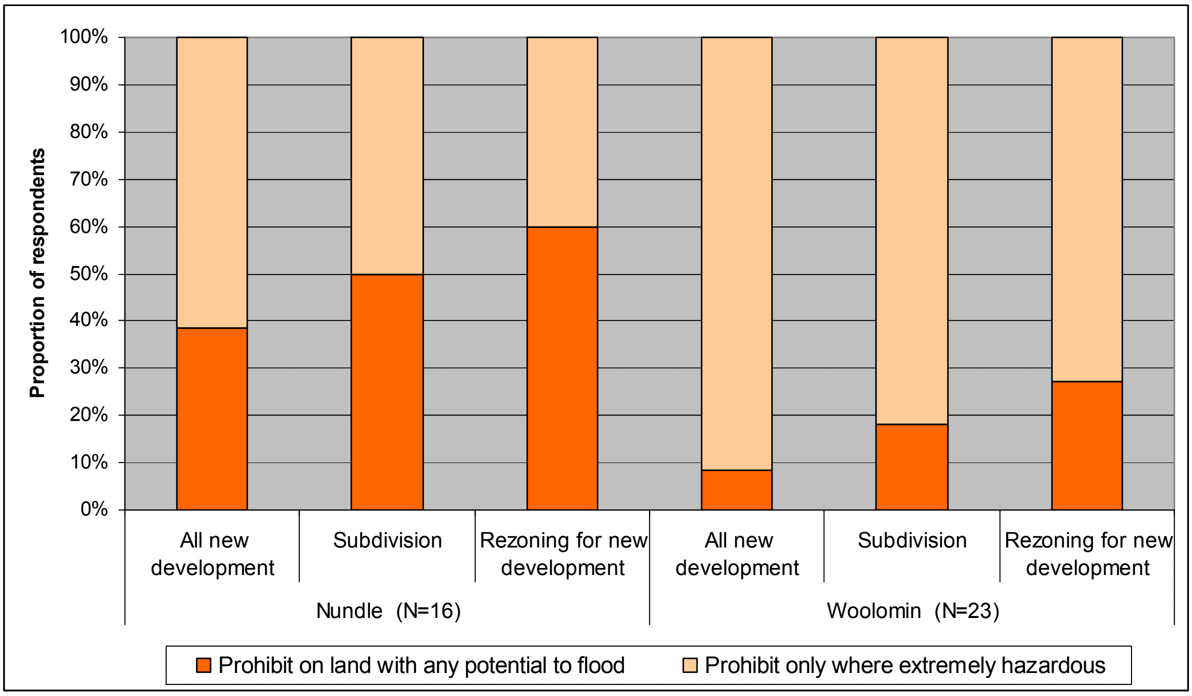


FIGURE 3.3 – Community Views on Controls on New Development

3.5.4 Disclosure

Another question sought to gauge the community's views about methods of disclosing flood risk to the public. The results are shown in **Figure 3.4**. Caution is needed in interpreting the results because the question allowed only for indicating support (not opposition) to each disclosure method. No one was of the view that Council should not provide information. An idea of *regularly* issuing a flood certificate to residents gained little support. But there was good support for issuing flood certificates to prospective purchasers, putting flood marks on telegraph poles and especially for making flood maps available at the Council office and/or on the internet.

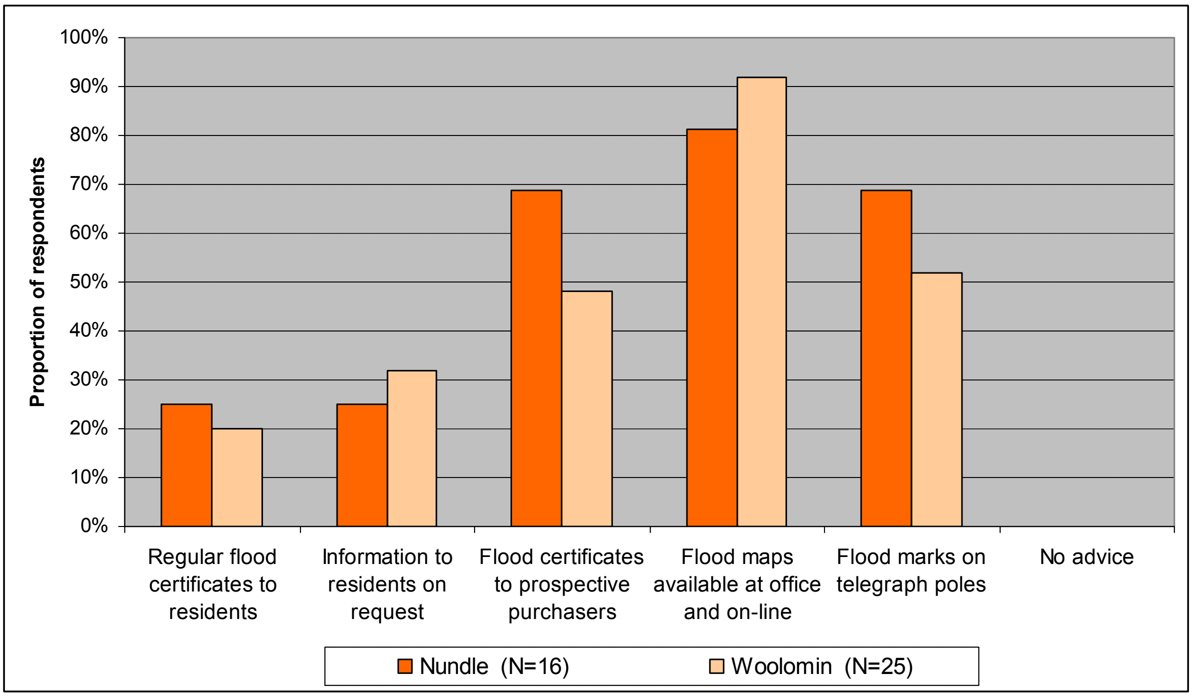


FIGURE 3.4 – Community Views on Disclosure of Flood Information

3.6 AGENCY QUESTIONNAIRE

In February 2007, separate questionnaires, along with a copy of the newsletter, were issued to selected agencies and interest groups listed in **Table 3.3**. The questionnaire and some key responses are attached at **Appendix B**.

3.6.1 Potential Damage to Assets

Assets identified as subject to damage from flooding are:

- Country Energy: A ground mounted voltage regulator, Nundle Road, Woolomin (190m south of Duncans Creek Road turnoff); this is located with the modelled PMF extent but not within the 100 year extent;
- Tamworth Regional Council, roads: An extended inundation could damage about 2 km of bitumen on MR 105 at Woolomin (cost $200K), and require gravel resheeting to 2 km of streets in Woolomin (cost $50K);
- Tamworth Regional Council, water directorate: Inundation of the Water Pump Station at Hall Street, Nundle, could cause damages of $40K, inundation of the Water Treatment Plant at Hall Street could cause damages of $200K, and inundation of the Water Pump Station bore at Oakenville Street, Nundle, could cause damages of $20K; the directorate proposed protecting the water treatment plant with a levee and raising the two pump stations.

3.6.2 Other Comments

The Bureau of Meteorology described the upgrading of the Peel Valley flood warning network (to Tamworth) with radio telemetry, as well as the installation of additional rain gauges and the Pearly Gates river level gauge upstream of Nundle. No formal, local flash flood warning procedures have been developed for Nundle or Woolomin.

The Department of Planning stated that flood-related issues should be addressed in Council's strategic planning work and through development controls.

The Fisheries Management Division (Aquatic Habitat Protection Unit) highlighted the importance of maintaining the connectivity between the floodplain and the river to allow for spawning of certain species. Attention was also drawn to the *Fisheries Management Act 1994*, which makes it an offence to perform unauthorised dredging and reclamation works in 'water land' (i.e. land that may be permanently or intermittently submerged by water), stipulates that the passage of fish must not be blocked, and requires consideration of threatened species of fish during the planning process. Fisheries expressed the following opinion on the general flood modification options outlined in the newsletter:

- Constructing detention basins: may be supported so long as these do not result in blockage of fish passage or result in the net loss of fish habitat;
- Constructing bypass channels or floodways: the flood study should define a system of floodways that conforms to the natural drainage pattern;
- Enlarging bridges and culverts: generally supported where hydraulic capacity increased (but need to consider fish passage);
- Creek widening and/or dredging: not supported as likely to result in loss of habitat (but possible if adverse effects are compensated by creation of new habitat);
- Clearing creeks of debris: not supported because riparian vegetation is a key component of fish habitat;
- Removing floodplain obstructions: support the removal of artificial floodplain obstructions so that the natural drainage pattern is maintained;
- Constructing permanent levees: should be constructed only where there is a compelling need such as around a town; and
- Filling low-lying land: not supported since these usually comprise of 'water land' and can include important aquatic habitats.

Namoi Catchment Management Authority supports an approach of proactive vegetation management between flood events to minimise the potential damage caused to channel banks by flooding. This involves identifying riparian bank areas prone to damage and establishing native trees and shrubbery in these areas.

The State Emergency Service indicated that they would like to see the FRMS&P consider the following issues:

- Nundle: improvement of the flood warning system (both in terms of river level monitoring and communication to the affected community); community education including improved flash flooding signage along the river near camping grounds.
- Woolomin: understanding of the flood risk; planning controls appropriate to that risk; the potential for flood warning systems; suitable emergency response planning including appropriate evacuation centres; public education.

State Water described the flood mitigating function of Chaffey Dam due to its 15m airspace. The outlet valves used for irrigation supply and environmental flows have a capacity of only about 1,400 ML/day and so have negligible effect on flood volumes. They do not intend to retain the sirens installed at Woolomin after the Chaffey Dam Safety Upgrade is completed.

TABLE 3.3 – Liaison with Agencies and Interest Groups

ORGANISATION	RESPONSE
Bureau of Meteorology	Email
Country Energy (Northern Regional Office)	Survey
NSW Dept of Environment and Conservation (EPA)	Letter
NSW Dept of Environment and Conservation (NPWS)	Letter
NSW Dept of Planning (Western Region)	Survey
NSW Dept of Primary Industries, Fisheries Management Division (Tamworth)	Letter
NSW Office of Environment and Heritage (OEH), formerly DECCW	Discussion
NSW Police (Nundle)	
Roads and Traffic Authority	
Namoi Catchment Management Authority	Survey
Nundle Community Development Committee	
State Emergency Services (Namoi Region)	Discussion
State Water	Discussion
Tamworth Regional Council (Roads; Water Services Directorate)	Email
Telstra Country Wide (North West NSW)	

3.7 PUBLIC EXHIBITION

The draft *Nundle and Woolomin FRMS&P* was placed on public exhibition in March-April 2012 and redistributed to OEH, the SES and internally within Council. Eight submissions were received from the public, a detailed submission from the SES and a number from within Council. The comments were generally supportive of both the recommended measures included in the draft FRMP and the decisions to exclude other measures from the draft FRMP.

Supported measures included:

- Considering the provision of additional flood mitigation capacity in the design of the Chaffey Dam Augmentation (with Council requested to lobby for such);
- Constructing a 100 year ring levee around the Nundle water treatment plant in Hall Street (but without any elevation of Hall Street to provide access);
- Raising of the water pumps in Hall and Oakenville Streets, Nundle
- Offering voluntary house purchase (two of the affected houses in Nundle indicated their strong support, given past difficulty in securing purchasers for their properties);
- Providing a formal flood warning system for Woolomin;
- Providing flood education for new residents at Woolomin.

Several respondents expressed opposition to the idea of a flood levee or floodway at Woolomin, which in any case were not supported in this study. In the case of the Woolomin Recreation Ground Committee, new facilities have been built on the flat.

Four respondents called for clearing of watercourses especially Duncans Creek. Although this is not supported by Fisheries, it is noted that removal of flood debris blockages, Willows and nominated Eucalypts has occurred in other areas of the State, under the supervision of Catchment Management Authorities (CMAs). The potential for funding for this work could be explored through the Namoi CMA.

Advice was also received of a house on the banks of Duncans Creek being flooded during the 2010 event from break-out flows initiated by a debris dam. (This house had not been flooded in the 2000 event). An additional request was then made at the May 2012 Committee meeting for Council to investigate options to remove such debris.

The SES expressed concern about allowing increased development in high hazard areas particularly at Woolomin. If Council chooses to allow development of vacant residential lots at Woolomin (see Option C under **Section 6.2.5.3**), the SES suggests putting a sunset clause on the right to develop, say for a period of 5 years, which enables current owners to build a home but also acts to limit future risk.

A thorough review of the planning proposals in the draft report was also carried out by Council's Manager of Development and Approvals.

4. FLOOD BEHAVIOUR SUMMARY

4.1 EXISTING FLOOD BEHAVIOUR

The *Nundle and Woolomin Flood Study* was prepared as the first phase of investigations for this project and is reported in **Appendix C** of this report. The flood study provides an assessment of flood behaviour under existing catchment conditions. Flood levels, flood velocities and the extent of flood inundation have been determined for floods with different probabilities of occurrence. This helps to determine the magnitude of the flood problem within the catchment, and to identify the main problem areas. It also provides the necessary flood models to examine the effectiveness of undertaking various floodplain management measures within the catchment, which is further examined in this report.

The flood model is comprised of a *hydrologic* model (RORB) and a *hydraulic* model (TUFLOW).

The *hydrologic* model determines the runoff resulting from a particular rainfall event. The primary outputs from the model are hydrographs at various locations along the waterways to describe the quantity, rate and timing of stream flow that results from rainfall events. The model covers the entire catchment.

The *hydraulic* model consists of a linked two-dimensional/one-dimensional (2D/1D) model using a 3 metre grid to define the topography of the floodplain. The model simulates the movement of floodwaters through the waterway reaches, storage elements and hydraulic structures. The model calculates flood levels and flow patterns and also models the complex effects of backwater, roughness, overtopping of embankments, waterway confluences, bridge constructions and other hydraulic structures across the study area.

The hydrologic and hydraulic models were calibrated to a historical flood event to demonstrate the validity of the models. The November 2000 flood was chosen as the main calibration event for Nundle and Woolomin, while the smaller January 2010 flood was used as a verification event for Nundle (but was not felt at Woolomin). Comparing flood levels surveyed after the events with modelled levels shows that the models satisfactorily replicate the observed floods.

Design floods are hypothetical floods used for floodplain management studies. Design floods with the following average recurrence intervals (ARI) were modelled: 20 year, 50 year, 100 year and the probable maximum flood (PMF) (see the glossary for definitions). Design floods are modelled by applying design rainfall totals which are derived from *Australian Rainfall and Runoff* (2000). For Nundle, the 1 hour and 48 hour storm durations were chosen as best defining the critical durations for all events up to the 100 year ARI event, the short duration for the short, steep tributaries flowing through the village towards the river, and the long duration for Peel River flows. For Woolomin, the 3 hour storm duration and the 72 hour storm duration were chosen for all events up to the 100 year ARI event, the short duration to model Duncans Creek flows, and the long duration for Peel River flows. Flood mapping at each location represents an envelope of the *maximum* flood levels across each model simulation. Further information about methods is provided in **Appendix C**.

Figure 4.1 plots the 100 year flood depths, extents and levels for Nundle, whilst **Figure 4.2** plots the same information for Woolomin. **Figure 4.3** plots 100 year stage hydrographs for the two storm durations for each of Nundle and Woolomin.

The flood study has found that the November 2000 flood which impacted both Nundle and Woolomin was a particularly large flood approximating a 100 year ARI event. The 2010 flood at Nundle has also been assessed to have been somewhat smaller than a 20 year ARI event.

Due to the relatively narrow widths of the valleys at both Nundle and Woolomin there is no significant difference in the widths of the 20 year to 100 year floods. That is, the larger flows are reflected in increased flood depths rather than broader flow patterns. This situation results in extreme flood levels being much higher than the 100 year flood levels especially at Nundle where the floodplain is further constricted just downstream of the township.

The potential for longer duration flooding at Woolomin is due to the routing of the flood wave through Chaffey Dam. Woolomin flooding is also influenced by flows emanating from Duncans Creek and the relative timing of the flood peak in the Peel River downstream of Chaffey Dam and the flood peak from Duncan Creek, can have a significant impact on flood behaviour in the town.

4.2 CLIMATE CHANGE

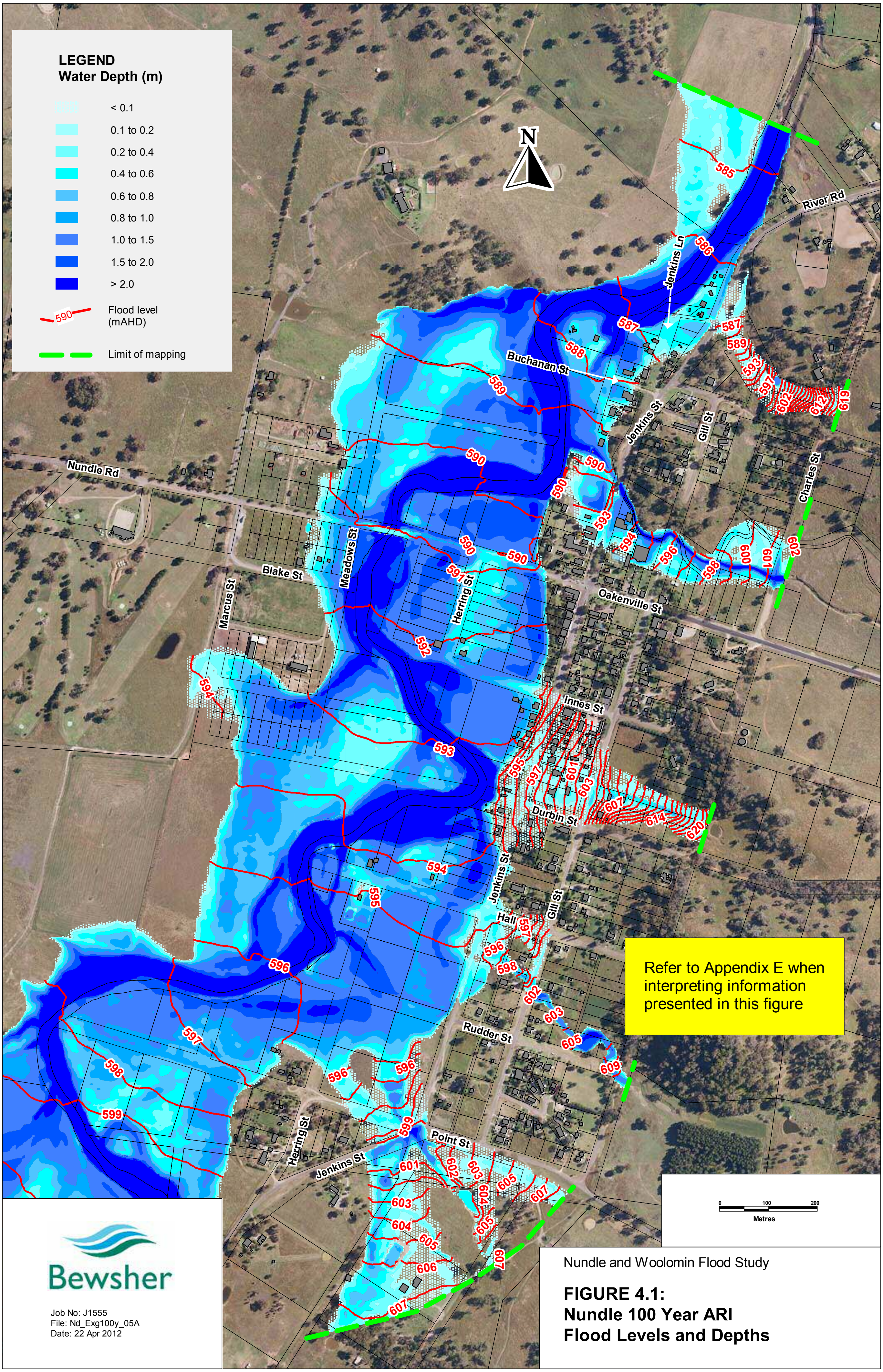
Climate change can potentially affect flood behaviour in the study area through an increased severity of flood producing storms. The degree to which rainfall intensities could increase is uncertain. An investigation by CSIRO (2006) reported that extreme rainfall (40 year 1 day rainfall total) could increase by 10% for the Namoi catchment by 2070. Based on advice from OEH, a 15% increase in 100 year ARI rainfall intensities was modelled as a sensitivity test. The flood study shows that flood levels at Nundle would typically increase by 0.2-0.3m whilst flood levels at Woolomin would typically increase by 0.1-0.2m (see **Figures C20** and **C25**).

4.3 FUTURE WORK

All flood studies are subject to periodic revision for reasons that include:

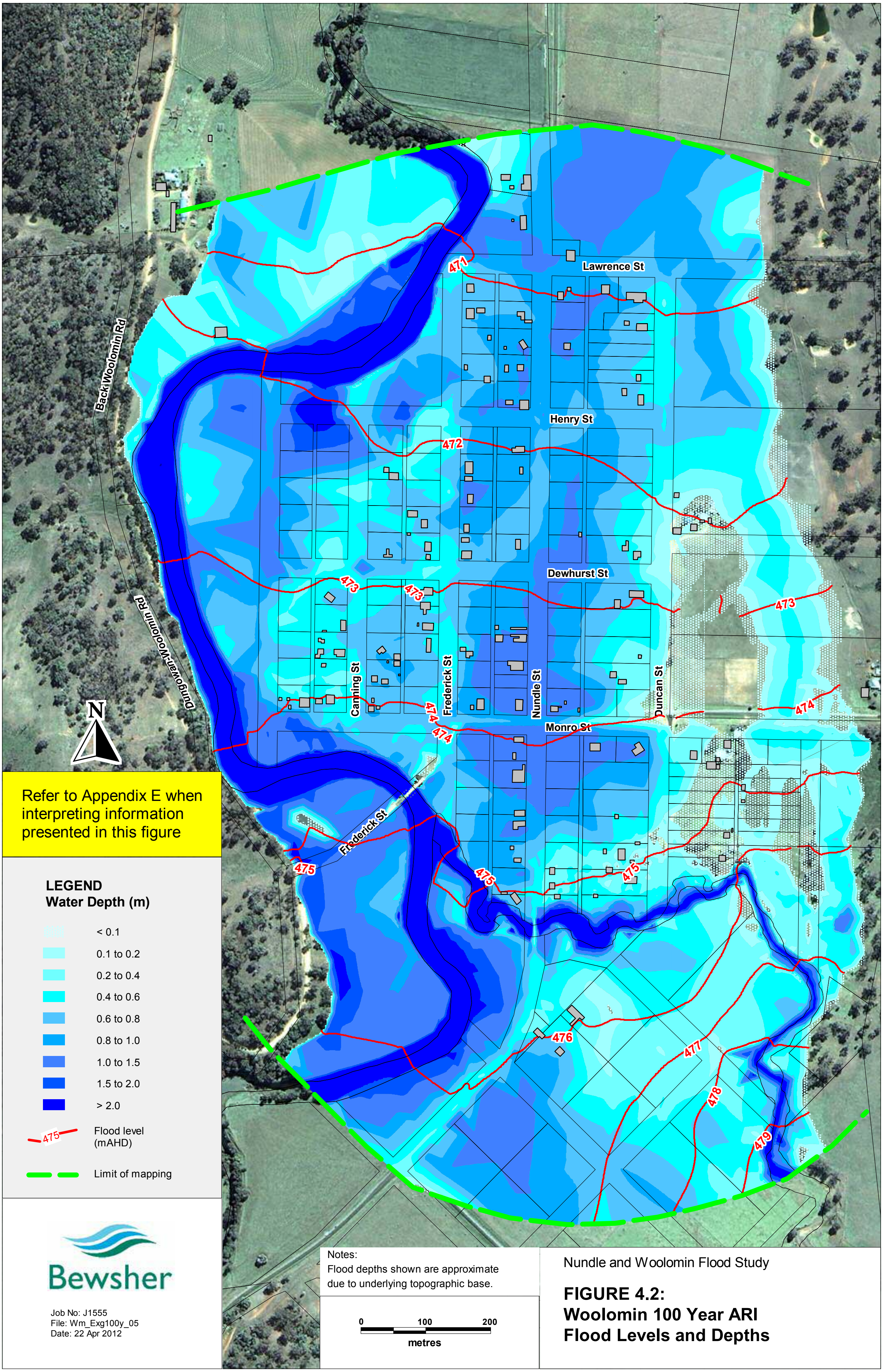
- The availability of new rainfall or ground topography information;
- The occurrence of new floods which provide additional data;
- The availability of better computer models as the science of flood modelling improves and computer capabilities increase; or
- The implementation of flood mitigation works, or development within the catchment that was not previously simulated in the models.

For Nundle and especially Woolomin, it is recommended that Council review the flood study should a high quality topographic surface be made available (e.g. survey from Airborne Laser Scanning or ALS). Also, if the Chaffey Dam augmentation currently being planned results in an altered storage-stage-discharge relationship, this will need to be incorporated into a revised flood study for Woolomin.



Nundle and Woolomin Flood Study

FIGURE 4.1:
Nundle 100 Year ARI
Flood Levels and Depths



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Notes:
Flood depths shown are approximate due to underlying topographic base.

Nundle and Woolomin Flood Study

FIGURE 4.2:
Woolomin 100 Year ARI
Flood Levels and Depths

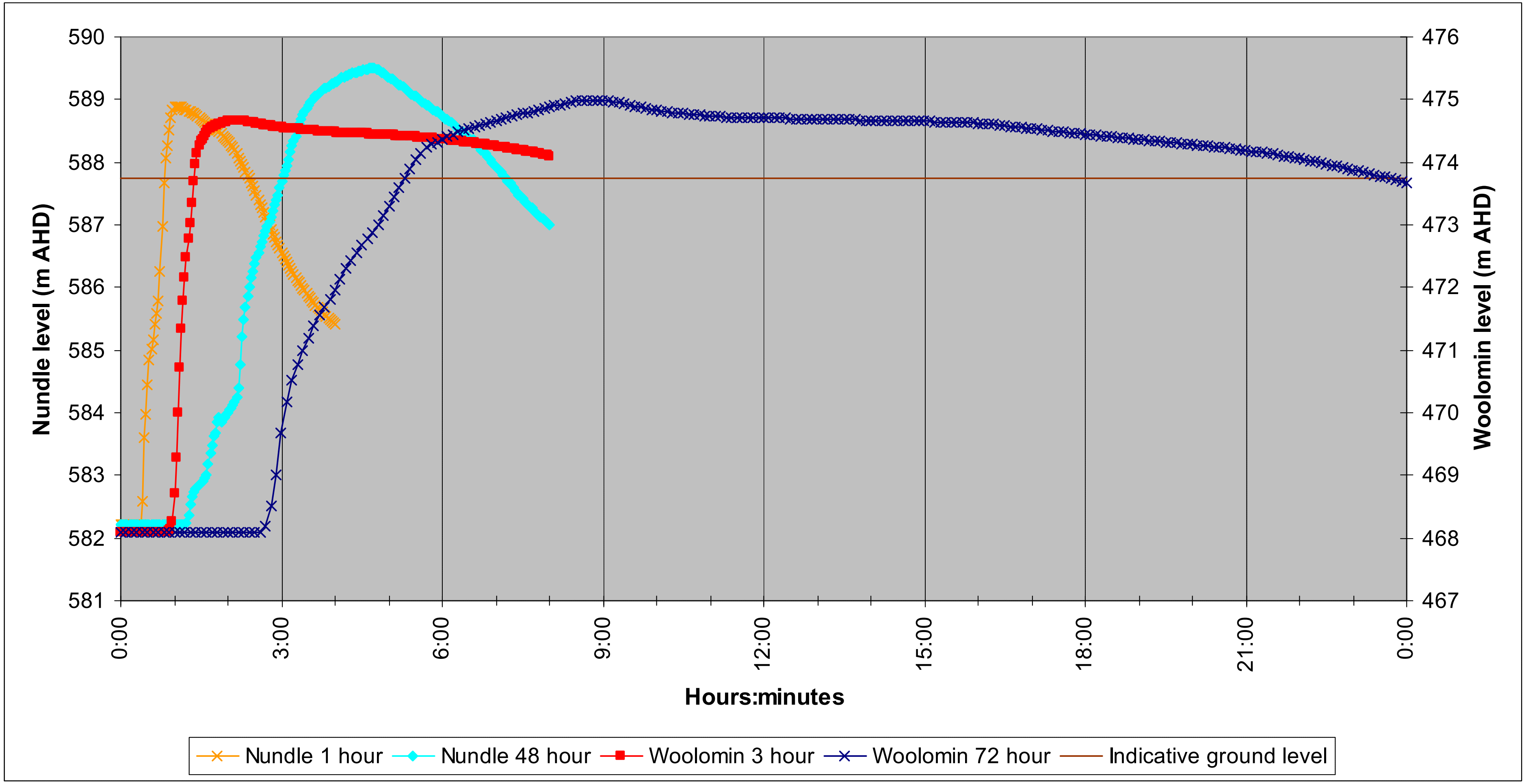


FIGURE 4.3 – 100 Year Flood Stage Hydrographs, Nundle and Woolomin

Notes: Nundle hydrograph at junction Peel River and Oakenville Creek, Woolomin hydrograph at Peel River @ Frederick Street Bridge

5. DEFINING THE FLOOD PROBLEM

5.1 FLOOD DAMAGES DATABASE

A flood damages database was assembled for Nundle and Woolomin. The database allows assessment of the potential impacts of flooding, including the number of buildings inundated. It also allows economic assessments of the existing flood problem and various flood mitigation measures.

For Nundle, 95 buildings are within the modelled PMF extent, comprising 63 residential and 32 commercial/industrial/public sector. For Woolomin, 87 buildings are within the PMF extent, comprising 81 residential and 6 others. Early in the study, surveyors were engaged to survey building floor levels and record other information about buildings in the floodplain. This resulted in 56 buildings being surveyed in Nundle and 87 in Woolomin. For the small number of buildings without surveyed information, levels were estimated using the Digital Elevation Models developed for the Flood Study. Ground levels were extracted at a point near the building and floor levels were estimated by adding an assumed 0.5m “height above ground” to each ground level estimate. Google StreetView was used to estimate the land use and style of construction of buildings that were not surveyed.

Flood surfaces for the 20 year, 50 year and 100 year ARI floods and the PMF were used to extract flood levels for each building in the database.

Table 5.1 summarises the attributes and sources of information included in the Nundle and Woolomin flood damages database.

TABLE 5.1 – Attributes Recorded in Flood Damages Database

Attribute	Comment/Source
Land use	Residential or commercial/other/public sector land use.
Property no.	Council cadastre.
Address	Council cadastre. Note discrepancies with address info provided by surveyor.
Legal description (Lot/DP)	Council cadastre.
Building wall material	Surveyor.
Building sub-structure	Surveyor.
No. of storeys	From photos provided by surveyor.
Residential type	From photos provided by surveyor.
Residential code	Refers to the categories used for residential flood damage calculation (DECC, 2007).
Commercial type/name	Surveyor. Some estimated from Google Street View.
Commercial code	Refers to categories used for commercial damage calculation (Bewshers).
Photo filename	Surveyor.
Comment	
Ground level and source	Surveyed or estimated.
Floor level and source	Surveyed or estimated.
Existing design flood levels (20 year, 50 year, 100 year, PMF)	Flood Study.

5.2 TYPES OF FLOOD DAMAGE

The definitions and methodology used in estimating flood damages are well established. **Figure 5.1** summarises all the types of flood damages considered in this study. The two main categories are "tangible" and "intangible" damages. Tangible flood damages are those that can be more readily evaluated in monetary terms. Intangible damages relate to the social cost of flooding and therefore are much more difficult to quantify.

Tangible flood damages are divided further into direct and indirect damages. Direct flood damages relate to the loss or loss in value of an object or a piece of property caused by direct contact with floodwaters, flood-borne debris or sediment deposited by the flood. Indirect flood damages relate to loss in production or revenue, loss of wages, additional accommodation and living expenses, and any extra outlays that occur because of the flood.

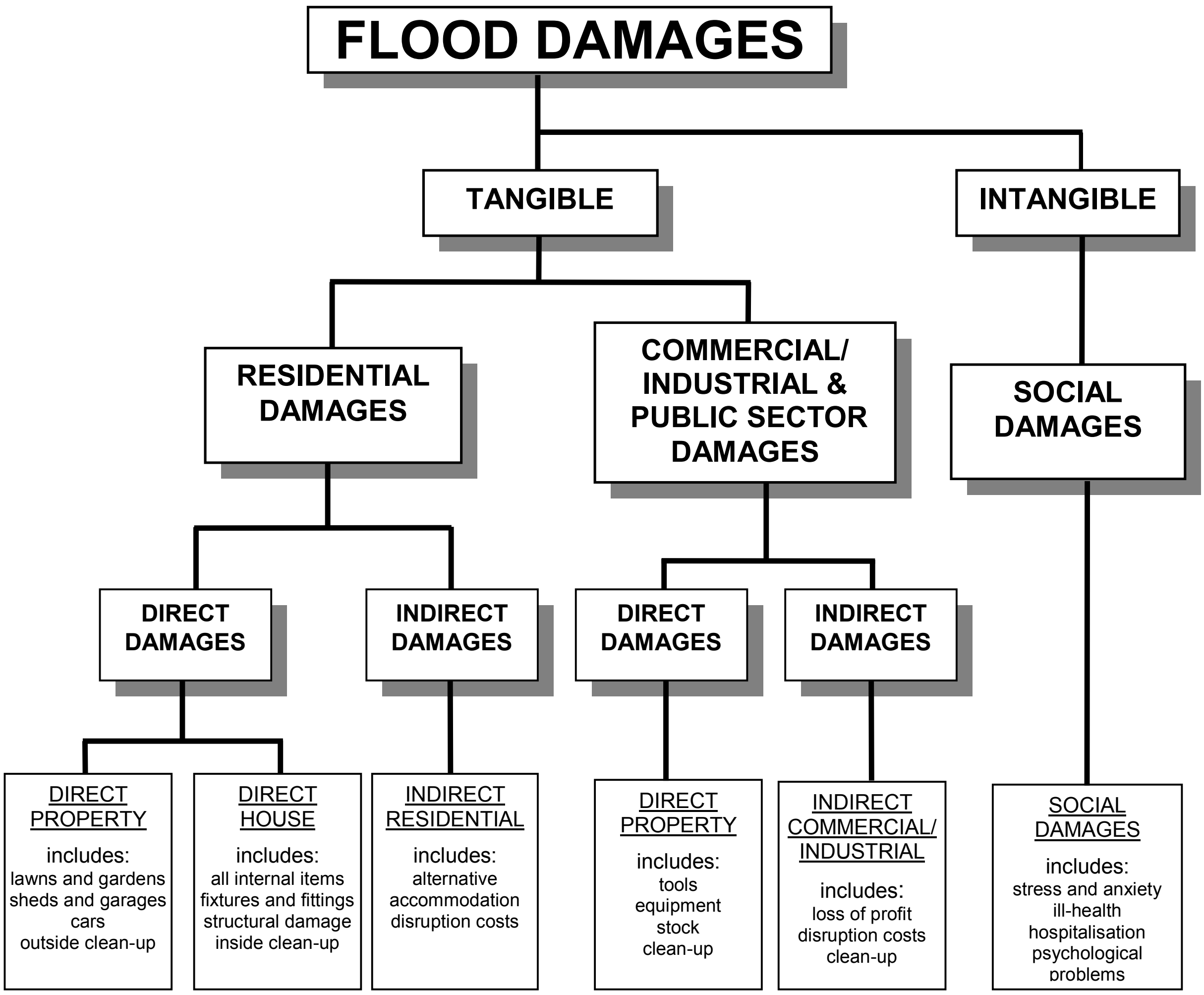


FIGURE 5.1 – Types of Flood Damage

5.3 BASIS OF FLOOD DAMAGES CALCULATIONS

Flood damages have been calculated by applying one of several stage-damage curves to every property included in the database. These curves relate the amount of flood damage that would potentially occur at different depths of inundation, for a particular property type, whether residential or commercial/industrial.

5.3.1 Residential

The *Residential Flood Damages* Floodplain Risk Management Guideline (DECC, 2007) is the key reference for assessing residential flood damages in NSW. This provides a standard method for deriving site-specific residential stage-damage curves. The inputs and outputs to the Nundle and Woolomin stage-damage curve are presented in **Appendix D**. The potential damage to cabins in Nundle Caravan Park and the River Glen cottages[2] in Nundle was assessed on a basis of half the damages of a single storey low set house.

5.3.2 Commercial

No standard stage-damage curves have been issued for commercial and industrial damages. The stage-damage relationships used to estimate these damages in this study are based on a collation of information from investigations following floods in Sydney (1986), Bathurst (1986), Nyngan (1990), Forbes (1990), Inverell (1991) and Coffs Harbour (1996). Indirect commercial/industrial losses were estimated as 20% of direct actual commercial/industrial damages, in accordance with advice previously received from the Office of Environment and Heritage (OEH).

5.3.3 Building Failure

It is noted that an allowance is made in the DECC (2007) stage-damage data for structural damage but not for actual building failure, which could be significant in the study area in extreme floods. Middleman-Fernandes (2010) demonstrated that where buildings fail, stage-damage functions underestimate loss.

5.3.4 Infrastructure

In accordance with advice previously received from OEH, the actual value of damage to infrastructure (including roads and bridges, water supply and sewerage, electricity and telephone supplies, natural gas supplies) was estimated at 15% of the total damages.

5.3.5 Motor Vehicles

Census data indicate an average motor vehicle ownership rate of about 1.7 per household in the study area (**Table 2.2**). Not all cars will be present during working hours, but others may travel to the study area for work. Vehicles were assumed to be at the same ground level as the residences with which they are associated.

Based on insurance data from the Katherine flood (Jan 1998), Wollongong flood (Aug 1998) and Canberra bushfire (Jan 2003), it is assumed that the average cost of a written-off motor vehicle is in the order of $12,000. Damage is expected to begin at a depth over the ground of 0.3m, and a write-off is assumed to occur at a depth of 0.6m over the ground.

[2] The Committee was advised at its May 2012 meeting that some of these cottages had since been removed from the site.

5.3.6 Social

Intangible, or social, flood damages are not readily quantifiable in monetary terms. Physical contact with floodwaters can cause residents to suffer physical and mental impacts to their health. Evacuation, the loss of personal property and cleaning up can trigger significant stress and trauma. While difficult to quantify, in keeping with advice received from OEH, social damages were estimated as 25% of total damages, which are interpreted as the sum of direct residential damages and direct commercial/industrial damages.

5.4 ECONOMIC ANALYSIS

An economic appraisal is required for all proposed capital works in NSW, including flood mitigation measures, in order to attract funding from the State Government's Capital Works Program. The NSW Government has published two Treasury Policy Papers to guide this process: *NSW Guidelines for Economic Appraisal* (NSW Treasury, 2007) and a summary in *Economic Appraisal Principles and Procedures Simplified* (NSW Treasury, 2007).

An economic appraisal is a systematic means of analysing all the costs and benefits of a variety of proposals. In terms of flood mitigation measures, benefits of a proposal are generally quantified as "the avoided costs associated with flood damages". The avoided costs of flood damage are then compared to the capital (and on-going) costs of a particular proposal in the economic appraisal process.

Average annual damage (AAD) is a measure of the cost of flood damage that could be expected each year by the community, on average. It is a convenient yardstick to compare the economic benefits of various proposed mitigation measures with each other and the existing situation.

The "present value" of flood damage is the sum of all future flood damages that can be expected over a fixed period (usually 20 years) expressed as a cost in today's value. The present value is determined by discounting the future flood damage costs back to the present day situation, using a discount rate of 7%.

A flood mitigation proposal may be considered to be potentially worthwhile if the benefit–cost ratio (the present value of benefits divided by the present value of costs) is greater than 1.0. In other words, the present value of benefits (in terms of flood damage avoided) exceeds the present value of (capital and on-going) costs of the project.

However, whilst this direct economic analysis is important, it is not unusual to proceed with urban flood mitigation schemes largely on social grounds, that is, on the basis of the reduction of intangible costs and social and community disruption. In other words, the benefit–cost ratio could be calculated to be less than 1.0.

Net present value is a useful tool to complement the benefit–cost ratio in the economic appraisal process. A flood mitigation proposal may be considered to be potentially worthwhile if the net present value (the present value of benefits minus the present value of capital and on-going costs) is greater than zero.

5.5 SUMMARY OF INUNDATION PATTERNS

A summary of the predicted number of dwellings in Nundle and Woolomin flooded above habitable floor level in each design event is provided in **Table 5.2**. An indication of likely flood depths in the 100 year ARI event is provided in **Table 5.3**. The distribution of buildings expected to be flooded above floor level in the 20 year and 100 year events is shown in **Figure 5.2** for Nundle and **Figure 5.3** for Woolomin.

Key results for Nundle are:

- 4 dwellings would be flooded above floor level in the 20 year ARI flood, including isolated houses in Hall Street, Herring Street and Buchanan Street;
- 10 dwellings would be flooded above floor level in the 100 year ARI flood (but none to depths greater than 0.5m);
- 7 dwellings are located on land subject to high hydraulic hazards in the 100 year flood (5 of these flooded above floor);
- Depths are very much greater in the PMF, with 54 dwellings inundated above floor level to a median depth of 5.2m (and maximum of >10m);
- 2 commercial/industrial/public sector buildings would be flooded above floor level in the 20 year ARI flood, including Nundle Woollen Mill;
- 7 commercial/industrial/public sector buildings would be flooded above floor level in the 100 year ARI flood, including the café and garage in Jenkins Street;
- At Nundle Caravan Park (a.k.a. Fossickers Way Tourist Park), the lower tier north of Oakenville Creek would be entirely flooded in the 20 year event; most of the upper tier near the cabins would also be inundated in the 100 year event, but the surveyed cabins would not be flooded above floor level (see **Figure 6.14**);
- Road inundation depths may be assessed from **Figure 4.1**. Oakenville Street (Nundle Road) would be flooded to a maximum depth of almost 1.5m in the 100 year flood.

Key results for Woolomin are:

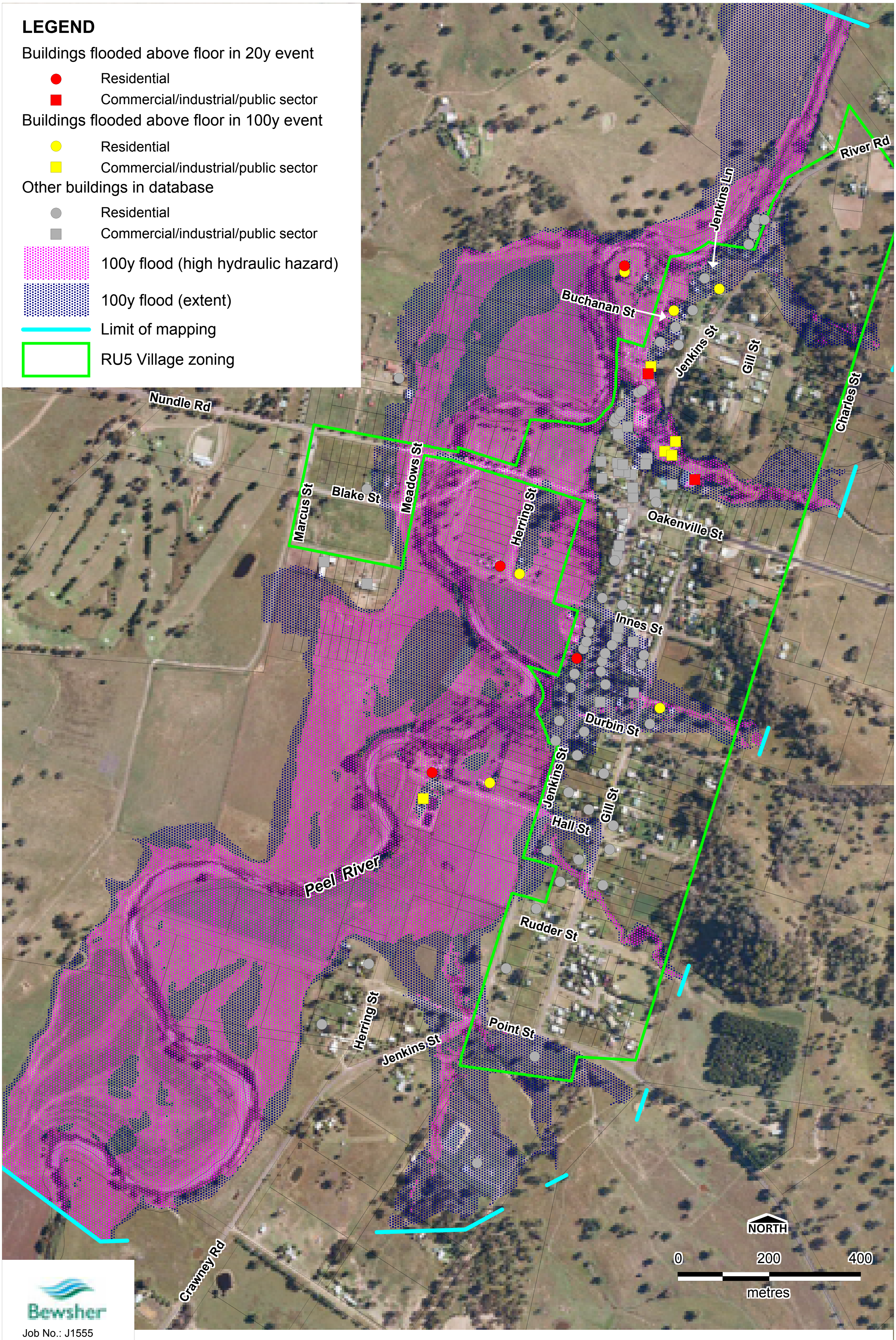
- Almost all the "yards" in the village are flooded even in the 20 year ARI flood, showing that the width of the floodplain is almost the same for all design floods;
- 19 dwellings would be flooded above floor level in the 20 year flood; these are dispersed throughout the village;
- 37 dwellings would be flooded above floor level in the 100 year ARI flood (none to depths greater than 1.0m), but another 47 dwellings would not be inundated;
- 23 dwellings are located on land subject to high hydraulic hazards in the 100 year flood (18 of these flooded above floor);
- Every dwelling in the main area of the village would be inundated above floor level in the PMF, to a median depth of 2.6m (and maximum of 4m);
- 4 commercial/industrial/public sector buildings would be flooded above floor level in the 20 year ARI flood, including the RFS and SES depots to depths of 0.4m;
- 6 commercial/industrial/public sector buildings would be flooded above floor level in the 100 year ARI flood, including Woolomin Primary School;
- Road inundation depths may be assessed from **Figure 4.2**. Nundle Street (within the village) would be flooded to a maximum depth of about 1.2m in the 100 year flood.

TABLE 5.2 – Number of Dwellings Inundated

Location	20 year		50 year		100 year		PMF	
	Yard	Floor	Yard	Floor	Yard	Floor	Yard	Floor
Nundle	25	4	32	8	36	10	63	54
Woolomin	75	19	77	26	78	37	81	80
TOTAL	100	23	109	34	114	47	144	134

TABLE 5.3 – Dwelling Inundation Depths in the 100 Year Flood

Location	Below Floor Flooding (Number of Buildings)		Above Floor Flooding (Number of Buildings)				
	-0.5 to -0.2	-0.2 to 0.0	0.0 to 0.2	0.2 to 0.5	0.5 to 1.0	> 1.0m	TOTAL
Nundle	10	5	3	7	0	0	10
Woolomin	22	12	15	11	11	0	37
TOTAL	32	17	18	18	11	0	47



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Date: 24 Apr 2012

FIGURE 5.2 - Distribution of Buildings Inundated in Design Floods, Nundle

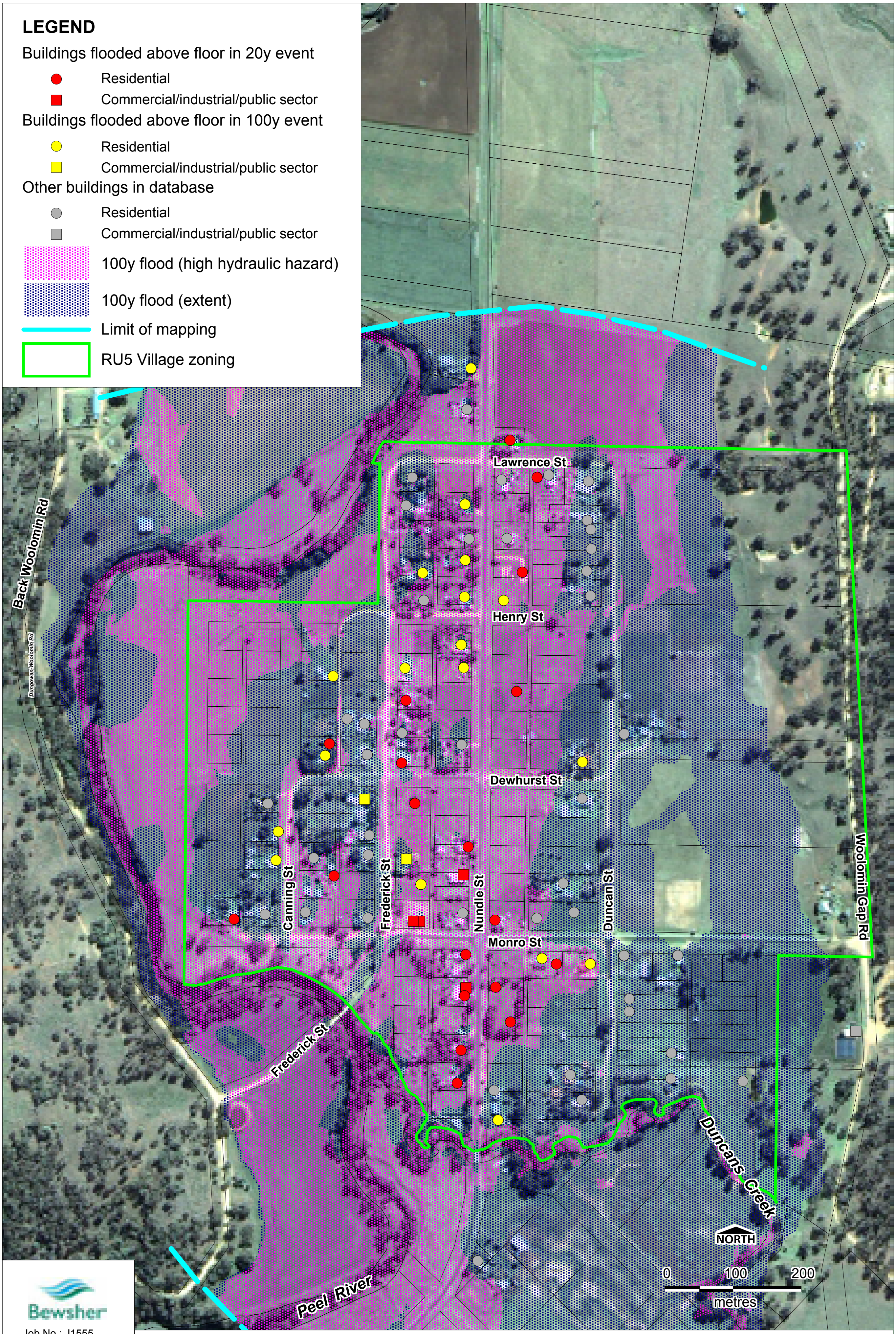

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FIGURE 5.3 - Distribution of Buildings Inundated in Design Floods, Woolomin

5.6 SUMMARY OF CALCULATED DAMAGES

Calculated flood damages are reported in **Table 5.4**, with a breakdown of the components contributing to average annual damages shown in **Table 5.5**.

Key results are:

- Flooding at Woolomin is expected to cost more than twice as much as flooding at Nundle for the 20 year, 50 year and 100 year events, but a similar amount in the PMF;
- The annual average damage is about $130K for Nundle and $270K for Woolomin (total $400K), which is a measure of the cost of flood damage that could be expected each year, on average, by the community;
- The present value of damages is about $1.3M for Nundle and $2.8M for Woolomin (total $4.2M), which represents the maximum sum that could be spent on flood mitigation measures if a benefit/cost ratio of 1.0 is required and all flood damages can be avoided;
- Given the nature of the communities, it is not surprising that the residential sector contributes most to flood damages – 49% for Nundle, 72% for Woolomin (total 67%).

TABLE 5.4 – Summary of Flood Damages by Event (excluding motor vehicles)

Location	Predicted Actual Damage in Flood Event ($2011)				Average Annual Damage ($2011)*	Present Value of Damage ($2011)*
	20 year	50 year	100 year	PMF		
Nundle	$0.6M	$1.3M	$1.8M	$11.8M	$127K	$1.3M
Woolomin	$2.5M	$3.2M	$3.9M	$13.1M	$268K	$2.8M
TOTAL	$3.1M	$4.5M	$5.7M	$24.9M	$395K	$4.2M

* Based on treasury guidelines of a 7% discount rate and expected life of 20 years

TABLE 5.5 – Components of Flood Damage for Nundle and Woolomin (Average Annual Damage, $2011)

	Damage Component	Method Assessed	Nundle		Woolomin		Total	
A.	Direct Residential Dwelling Damage	DECC (2007) curves	$35,000	24%	$103,000	38%	$138,000	35%
B.	Direct Residential Property Damage	DECC (2007) curves	$25,000	17%	$59,000	22%	$84,000	21%
C.	Indirect Residential Damage	20% of (A + B)	$12,000	8%	$32,000	12%	$44,000	11%
D.	Direct Commercial Damage	BC curves	$20,000	14%	$6,000	2%	$26,000	7%
E.	Indirect Commercial Damage	20% of D	$4,000	3%	$1,000	0%	$5,000	1%
F.	Infrastructure Damage	15% of (A + B + D)	$12,000	8%	$25,000	9%	$37,000	9%
G.	Social Damage	25% of (A + B + D)	$20,000	14%	$42,000	16%	$62,000	16%
	TOTAL		**$147,000**	100%	**$268,000**	100%	**$395,000**	100%
H.	Motor Vehicle Damage	BC curves	$20,000		$84,000		$104,000	

6. EVALUATION OF FLOODPLAIN MANAGEMENT OPTIONS

Floodplain management measures can be divided into three general groups:

1) those that modify flood behaviour;
2) those that modify property in order to minimise flood damage; and
3) those that modify people's response to flooding.

Measures that modify flood behaviour usually include structural works that attempt to lower flood levels, or to divert floodwaters away from areas that would otherwise flood. These types of measures are often favoured by the community.

Measures that modify property in order to minimise flood damage include voluntary house purchase, voluntary house raising or house reconstruction, "flood-proofing" and controls on new development.

Measures that modify people's response to flooding include measures that provide additional warning of flooding, improve emergency management planning and improve public awareness of the flood risk.

A range of assessment criteria have been used for evaluating potential floodplain management measures within the study area. These are described below. A qualitative assessment has been undertaken for each floodplain risk management option according to these criteria. **Table 6.1** provides the scores used for each criterion for this qualitative assessment.

- **Number of buildings protected in the 100 year flood**

  A prime indicator of the effectiveness of a measure in reducing the potential for flood damage and the risk to life is the reduction in the number of buildings that are affected by significant floods.

- **Financial feasibility**

  Measures proposed within the FRMP must be capable of being funded. There are various sources of funding that may be utilised, including funding related to the development of new release areas (Section 94 Contributions) and funding from Council, with assistance from the Government's Floodplain Management Program administered by OEH, for the alleviation of existing flood problems.

- **Economic merit**

  The ratio of the benefit divided by the cost (i.e. the benefit/cost ratio) is a common measure of assessing economic feasibility. Theoretically, no investment should be made on a measure if the benefit/cost ratio does not exceed one (i.e. if the benefits do not exceed the costs). However, traditionally many floodplain risk management measures have been undertaken where this is not the case because the intangible benefits (i.e. social benefits and reduced risks to life, which are not readily quantified) are considerable. Benefit/cost ratios can also be useful in ranking competing options.

- **Community acceptance**

  An understanding of community attitudes towards any proposed floodplain management measures is essential. Strongly negative community attitudes often would be enough to deter the implementation of a proposal which otherwise had merit. Community views on potential floodplain management measures were assessed early in the study through distribution of the community questionnaire. These results were discussed in **Section 3.5**. Further opportunity for comment was provided during public exhibition of the draft Nundle and Woolomin FRMP (**Section 3.7**).

- **Environmental impact**

  Floodplain management measures involving structural works may often have significant environmental impacts. Impacts such as those on vegetation, Aboriginal heritage, visual amenity and soil erosion/sedimentation must be considered when evaluating works within floodplains.

- **Impact on flood behaviour**

  The impact on flood behaviour caused by any measure needs to be considered for upstream and downstream locations. These impacts can include changes in flood levels, changes in velocities or alteration of flow directions. Reducing impacts in one location can lead to adverse impacts elsewhere.

- **Performance during rare floods**

  All measures must be assessed in the knowledge that rare floods, i.e. higher than the 100 year flood, or higher than any known historical flood, will happen at some time in the future. It is vital that the options do not expose the community to unacceptable risks by providing a false sense of security.

- **Technical feasibility**

  If the proposed measures involve structural works, these works must be able to be constructed and be free from major technical constraints.

- **Political/administrative feasibility**

  Any recommended measure will have more chance of success if it involves little if any disruption to current political and administrative structures, attitudes and responsibilities. Council and other authorities also have various strategic objectives concerning development within the study area.

Potential floodplain management measures for the study area are discussed below. Each measure is included in a qualitative assessment matrix (**Table 6.2**) to assess its relative merits, thereby determining whether it should be included in the draft Nundle and Woolomin FRMP.

TABLE 6.1 – Explanation of Assessment Scores for Qualitative Assessment Matrix

CRITERIA	RANKING SCORE				
	– –	–	Ω	+	+ +
REDUCTION IN NUMBER OF HOUSES FLOODED ABOVE FLOOR LEVEL IN 1% AEP FLOOD	number of houses flooded above floor in 1% AEP flood would increase	number of houses flooded above floor in 1% AEP flood could increase	no existing houses protected from over-floor flooding in 1% AEP flood	1 or 2 existing houses protected from over-floor flooding in 1% AEP flood	more than 2 existing houses protected from over-floor flooding in 1% AEP flood
FINANCIAL FEASIBILITY	Very unlikely to receive funding	May not receive funding	Neutral	Would possibly receive funding	Very likely to receive funding
ECONOMIC MERIT	Benefit–Cost Ratio less than 0.1	Benefit–Cost Ratio = 0.1–0.3	Benefit–Cost Ratio = 0.3–0.7	Benefit–Cost Ratio = 0.7–1.0	Benefit–Cost Ratio greater than 1.0
COMMUNITY ACCEPTANCE	Strongly against in community survey and community workshop	Not supported in community survey and community workshop	Neutral	Supported in community survey and community workshop	Strongly supported in community survey and community workshop
ENVIRONMENTAL IMPACT AND ECOLOGICAL ENHANCEMENT	Significant negative environmental impact	Some negative environmental impact	No environmental impact and no opportunity for ecological enhancement	Some opportunity for ecological enhancement	Significant opportunity for ecological enhancement
IMPACT ON FLOOD BEHAVIOUR	Significantly increase flood levels and/or velocities	Some increase in flood levels and/or velocities	No change	Some reduction in flood levels and/or velocities	Significantly reduces flood levels and/or velocities
CONSEQUENCES IN EXTREME FLOODS	Significantly increases risk	Some increase in risk	No change in risk	Some reduction in risk	Significant reduction in risk
TECHNICAL FEASIBILITY	Very difficult	Difficult	Neutral	Easy	Very easy and straight forward
POLITICAL/ ADMINISTRATIVE / LEGAL IMPACT	Significant changes required which are very unlikely to be supported	Some changes required which may not be supported	No changes or impact	Some changes required are likely to be supported	Significant changes required which are likely to be strongly supported

TABLE 6.2 – Qualitative Matrix Assessment of Floodplain Risk Management Options

Note: Decisive factors for recommending or not recommending an option are highlighted in tan

MEASURE NO.*	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	REDUCTION OF DWELLINGS FLOODED ABOVE FLOOR LEVEL IN 1% AEP FLOOD		FINANCIAL FEASIBILITY		ECONOMIC MERIT		COMMUNITY ACCEPTANCE	ENVIRON-MENTAL IMPACTS AND ECOLOGICAL ENHANCE-MENTS	IMPACTS ON FLOOD BEHAVIOUR	CONSE-QUENCES IN EXTREME FLOODS	TECHNICAL FEASIB-ILITY OR DIFFICULTY	ADMINIS-TRATIVE / POLITICAL / LEGAL IMPACTS	RECOMMENDED FOR FURTHER CONSIDERATION
				NO. DWELLINGS		CAPITAL COST		BENEFIT–COST RATIO							
1	**FLOOD MODIFICATION MEASURES**														
1.1.1	**Mitigation Dam**	Peel River above Nundle	++	6	– –	>$50M	– –	< 0.1	?	– –	+	Ω	–	– –	No
1.1.2		Duncans Creek above Woolomin	++	5	– –	>$20M	– –	< 0.1	?	– –	+	Ω	–	– –	No
1.1.3		Consider Woolomin's flood mitigation requirements as part of Chaffey Dam augmentation design	N/a												Yes
1.2.1	**Levee**	Water treatment plant, Nundle	Ω	0	–	$300K	+	>0.5#	+	Ω	–	Ω	Ω	–	Yes (study first)
1.2.2		River Glen Cottage Development, Nundle	Ω	0	+	$80K	–	0.1	?	Ω	– –	Ω	Ω	–	No
1.2.3		Woolomin	++	37	–	$4M	Ω	0.5	– –	–	– –	– –	– –	– –	No
1.3	**Bypass channel**	Eastern Woolomin	+	1	–	$2M	–	0.1	– –	+?	+	Ω	Ω	– –	No
1.4	**Creek clearing**	Nundle and Woolomin	Ω	0	–	$100K	– –	< 0.1	++	– –	Ω	Ω	+	– –	No
		Council to investigate debris removal options to mitigate the flood risk particularly along Duncans Creek.	N/a												Yes
2	**PROPERTY MODIFICATION MEASURES**														
2.1	**Voluntary house purchase**	5 properties at Nundle (TRC)	++	5	+	$1.4M	–	0.2	+	Ω	Ω	++	+	+	Yes
2.2	**Voluntary house raising/ redevelopment**	1 property at Nundle, 7 properties at Woolomin, with $60K/house Government subsidy (TRC)	++	8	+	$480K (part subsidy)	+	0.8 (part subsidy)	+	Ω	Ω	–	–	–	Yes
2.3	**Infrastructure protection**	Raise two water pumps at Nundle (TRC)	Ω	0	+	$50K	++	>1#	+	Ω	Ω	+	+	Ω	Yes
2.4	**Existing planning controls**	Consider proposed revisions to the flood risk management controls in *TRDCP 2010* (TRC)	Ω	0	++	Low	++	>1#	+	Ω	Ω	++	++	Ω	Yes
2.5	**Manage future development**	Do not permit further residential development on high hazard land at Nundle (TRC)	Ω	0	++	Low	++	>1#	+	Ω	Ω	++	++	–	Yes
3	**RESPONSE MODIFICATION MEASURES**														
3.1	**Improve flood warning system**	Alarm key rainfall and river level gauges above Nundle (TRC, Bureau)	Ω	0	+	Bureau staff costs	++	>1#	+	Ω	Ω	+	+	–	Yes
		Analyse rain/river levels to inform selection of appropriate gauge triggers for alarming (SES)	Ω	0	+	SES staff costs	++	>1#	+	Ω	Ω	+	+	Ω	Yes
		Install a telemetered river level gauge and rain gauge in Duncans Creek catchment (TRC, Bureau)	Ω	0	+	<$30K (+ $6K pa)	++	>1#	+	Ω	Ω	+	–	+	Yes
		Prepare a rainfall based flood intelligence tool for Nundle (SES) and install manual river gauge at accessible location in Nundle (TRC)	Ω	0	+	$10K	++	>1#	+	Ω	Ω	+	+	–	Yes
		Pre-prepare a range of simple warning messages for Nundle and Woolomin (SES)	Ω	0	+	SES staff costs	++	>1#	+	Ω	Ω	+	+	Ω	Yes
		Establish automated telephone dial-out systems for Woolomin and Nundle (TRC)	Ω	0	+	$50K	++	>1#	+	Ω	Ω	+	+	–	Yes
		Negotiate with State Water to retain the siren infrastructure at Woolomin and transfer to SES (TRC)	Ω	0	+	$20K	++	>1#	?	Ω	Ω	+	+	–	Yes
		Install a public address system at Nundle Caravan Park (park manager)	Ω	0	+	$5K	++	>1#	+	Ω	Ω	+	+	–	Yes
		Arrange to personally warn any campers below Nundle and at Woolomin (SES)	Ω	0	+	Nil	++	>1#	+	Ω	Ω	+	–	Ω	Yes

MEASURE NO.*	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	REDUCTION OF DWELLINGS FLOODED ABOVE FLOOR LEVEL IN 1% AEP FLOOD		FINANCIAL FEASIBILITY		ECONOMIC MERIT		COMMUNITY ACCEPTANCE	ENVIRON-MENTAL IMPACTS AND ECOLOGICAL ENHANCE-MENTS	IMPACTS ON FLOOD BEHAVIOUR	CONSE-QUENCES IN EXTREME FLOODS	TECHNICAL FEASIB-ILITY OR DIFFICULTY	ADMINIS-TRATIVE / POLITICAL / LEGAL IMPACTS	RECOMMENDED FOR FURTHER CONSIDERATION
				NO. DWELLINGS		CAPITAL COST		BENEFIT–COST RATIO							
3.2	**Improve emergency management capability and plans**	Update Local Flood Plan and other flood intelligence documents from this study (SES)	Ω	0	+	SES staff costs	++	>1#	+	Ω	Ω	+	++	Ω	Yes
		Prepare flood emergency management plan for Nundle Caravan Park using template (park manager)	Ω	0	+	$5K (if consultant required)	++	>1#	+	Ω	Ω	+	++	Ω	Yes
		Seal alternative evacuation route from Nundle Caravan Park to Jenkins Street (TRC)	Ω	0	+	$20K	++	>1#	+	Ω	Ω	Ω	+	Ω	Yes
		Ensure any on-site vans on lower tier of Nundle Caravan Park remain mobile (park manager)	Ω	0	Ω	Nil	++	>1#	+	Ω	Ω	Ω	++	Ω	Yes
		Conduct audit of use of camping grounds downstream of Nundle over summer; assess evacuation capability; prepare evacuation strategy (SES)	Ω	0	+	SES staff costs	++	>1#	+	Ω	Ω	+	+	Ω	Yes
		Prepare evacuation strategy for Woolomin and resource the SES appropriately (SES)	Ω	0	+	SES staff costs	++	>1#	+	Ω	Ω	+	–	Ω	Yes
3.3	**Improve public flood readiness**	Prepare and distribute flood certificates to residents within the floodplain (TRC)	Ω	0	+	$2K pa	++	>1#	+	Ω	Ω	+	+	–	Yes
		Prepare and distribute a FloodSafe Guide for Woolomin (SES, TRC)	Ω	0	+	$10K	++	>1#	+	Ω	Ω	+	+	Ω	Yes
		Enhance the flood information available at Council's web-site (TRC)	Ω	0	+	$20K	++	>1#	+	Ω	Ω	+	+	–	Yes
		Display flood marker and poster describing flood evacuation procedures at Nundle Caravan Park, and mark extent of flood-prone land on site maps (park manager)	Ω	0	+	$10K	++	>1#	+	Ω	Ω	+	+	Ω	Yes
		Install additional signage at informal camping grounds downstream of Nundle (TRC)	Ω	0	+	$20K	++	>1#	+	Ω	Ω	+	+	Ω	Yes
		Install flood marker at the Riverside Park in Woolomin (TRC)	Ω	0	+	$10K	++	>1#	+	Ω	Ω	+	+	Ω	Yes
		Establish an annual flood education "outreach" program across the Local Government Area (TRC, SES)	Ω	0	+	$10K pa	++	>1#	?	Ω	Ω	+	+	–	Yes
		Encourage business owners to use Business FloodSafe toolkit to assess and reduce their flood exposure (SES)	Ω	0	+	Nil	++	>1#	+	Ω	Ω	+	+	Ω	Yes

Notes:
* To locate the report section in which the measure is described, for Measure No. 1.1.4 read Section 6.1.1.4, and so on.
\# It has not been possible to carry out a full economic analysis as some of the benefits are intangible. Accordingly the BCR has been estimated.

6.1 FLOOD MODIFICATION MEASURES

6.1.1 Flood Mitigation Dams

Recommendation: *That the potential to improve flood mitigation performance be examined as part of the design of the soon-to-be-augmented Chaffey Dam*

Flood mitigation dams are storages that which collect and store floodwaters for release at a controlled rate. They reduce peak flows and levels downstream of the dam sites.

6.1.1.1 Peel River above Nundle

A flood mitigation dam on the Peel River would be solely for flood mitigation purposes. This means that most of the time it would be empty (and hence does not have the potential to provide regulated flows for water supply purposes). It would be a very major structure with a likely height in excess of 20 metres in order to achieve reasonable reductions in flood levels at Nundle (e.g. reducing 100 year flood levels to 20 year flood levels).

It is noted that reducing 100 year flood levels to 20 year flood levels would see 100 year flood levels at Nundle being lowered by between 0.3m and 0.5m. This would result in ten dwellings no longer experiencing above floor level flooding in the 100 year event.

It is estimated that the required storage volume would be of the order of 10 million cubic metres and therefore the dam would be a very large structure with a likely height in excess of 20 metres. It would need to be a fully engineered structure since it would have to withstand overtopping in floods larger than a 100 year event.

Its construction cost would exceed $50 million and to this would need to be added the cost of acquiring land. The benefits in terms of reduced flood damages are far outweighed by the cost.

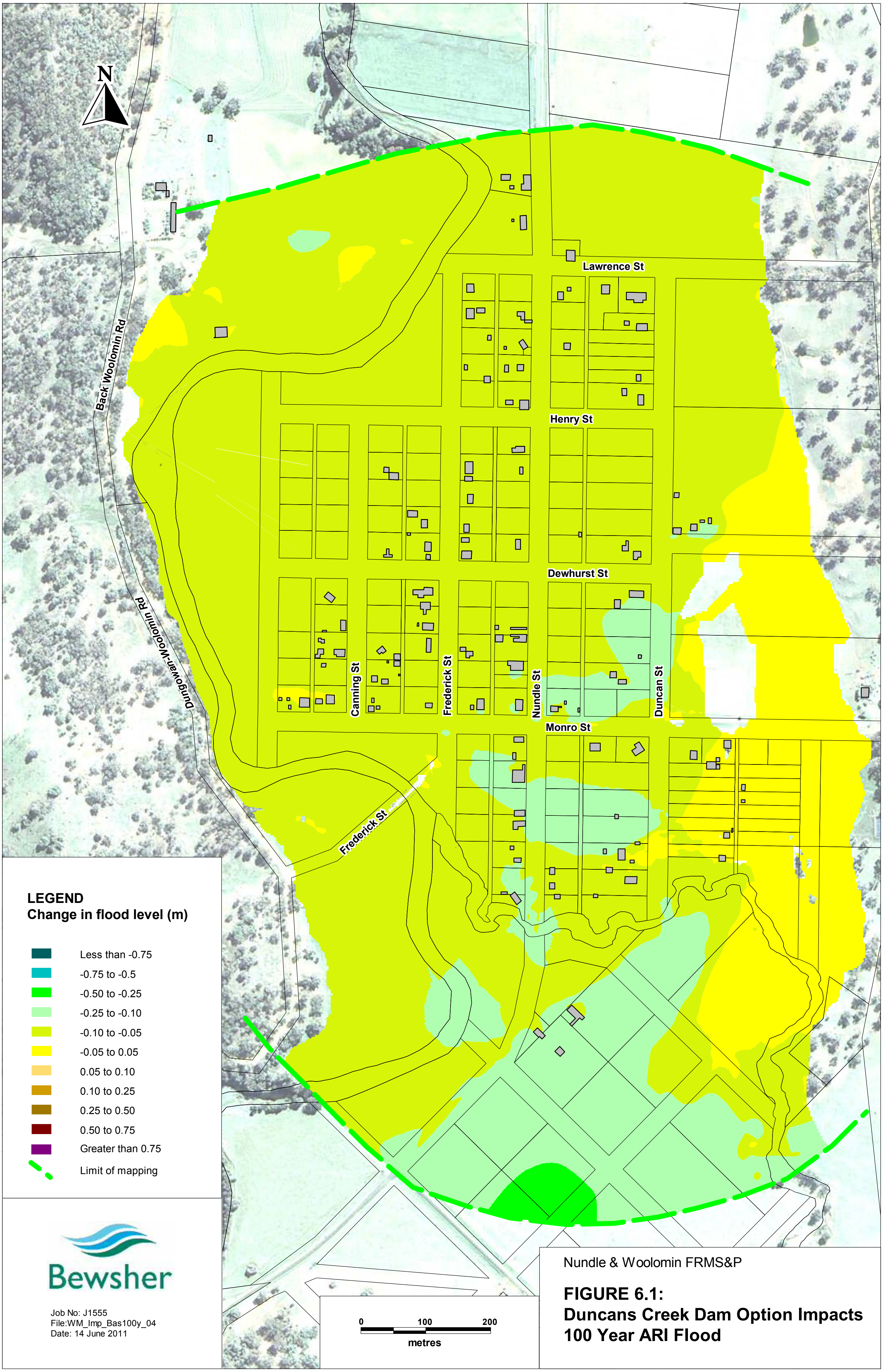
The Fisheries Management Division has also expressed reservations about flood mitigation dams unless steps are taken to ensure no blockage of fish passage or net loss of fish habitat (**Section 3.6.2**).

The dam is not recommended.

6.1.1.2 Duncans Creek above Woolomin

The potential to construct a flood mitigation dam on Duncans Creek just upstream of Woolomin was examined. Since the dam would be solely for flood mitigation purposes it follows that most of the time it would be completely empty (and hence does not have the potential to provide regulated flows for water supply purposes). The dam has been assessed on the basis of assuming that the Duncans Creek 100 year peak flow would be able to be reduced to the 20 year peak flow. **Figure 6.1** shows the resultant changes in 100 year flood levels at Woolomin – a small reduction in flood levels, typically between 0.05m and 0.10m. This would free five dwellings from above floor flooding in the 100 year event.

It is estimated that the required storage volume would be of the order of 3 million cubic metres and therefore the dam would be a large structure with a height in excess of ten metres. It would need to be a fully engineered structure since it would have to withstand overtopping in floods larger than a 100 year event.



LEGEND
Change in flood level (m)

- Less than -0.75
- -0.75 to -0.5
- -0.50 to -0.25
- -0.25 to -0.10
- -0.10 to -0.05
- -0.05 to 0.05
- 0.05 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- 0.50 to 0.75
- Greater than 0.75
- Limit of mapping

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FIGURE 6.1:
Duncans Creek Dam Option Impacts
100 Year ARI Flood

Its construction cost would be likely to exceed $20 million and to this would need to be added the cost of land acquisition. The benefits in terms of reduced flood damages are far outweighed by the cost.

The Fisheries Management Division has also expressed reservations about flood mitigation dams unless steps are taken to ensure no blockage of fish passage or net loss of fish habitat (**Section 3.6.2**).

The dam is not recommended.

6.1.1.3 Chaffey Dam augmentation

Chaffey Dam is a dedicated water supply reservoir. As such it has no capacity to control the release of flood waters which are passing through it. While typically those flows will have their peak values reduced by virtue of their routing through the dam (as detailed in the Flood Study report, **Appendix C**), provision of such items as a dedicated flood storage "compartment" within the dam would enhance its capacity to further reduce those peak flows.

It is therefore recommended that flood mitigation at Woolomin (and communities further downstream including Tamworth) be considered as part of the design of the soon-to-be-augmented Chaffey Dam.

6.1.2 Levees

Recommendation:
That a preliminary design study be undertaken to assess the suite of levee and accompanying offset works which would be needed to limit flood damages at the Nundle water treatment plant, and then implement the works if feasible

6.1.2.1 Ring levee around water treatment plant, Hall Street, Nundle

One Nundle public asset which has experienced significant flood damage is the water treatment plant located in Hall Street and quite close to the river. As reported in **Section 3.6.1**, due to the magnitude of those damages Tamworth Regional Council has been considering constructing a levee to limit the risk of damage to the plant.

This proposal has been tested by looking at a conceptual ring levee around the plant which would serve to exclude 100 year ARI floodwaters. The results of including such a levee in the hydraulic model and re-running the 100 year ARI flood event are shown in **Figure 6.2**. As expected, the figure shows that such a levee would have a small adverse impact on flood levels at and upstream of the levee. The adverse impacts are a maximum of 0.4m immediately adjacent to the levee but more generally are less than 0.1m. It can be seen that the impact extends to the western overbank area of the Peel River floodplain, where the maximum impact is 0.11m.

Associated works such as localized raising of Hall Street (possibly required to provide vehicular access into the plant) would also potentially increase impacts beyond those which are reflected in **Figure 6.2**.

Complementary works – including having a less obstructive south, or upstream-facing, wall alignment and offsetting excavation works beyond the levee footprint – would be needed to reduce the modelled impacts.

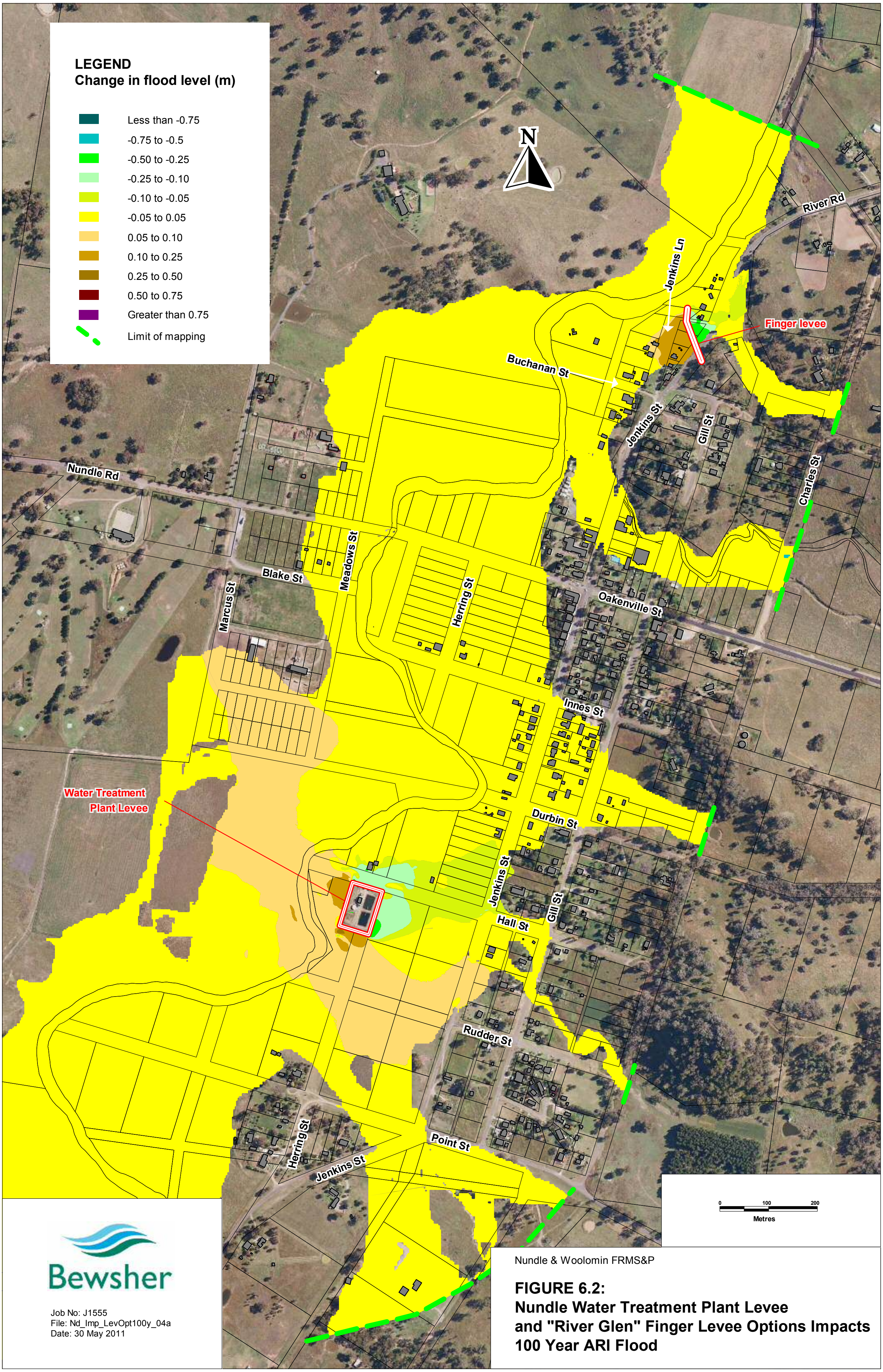

FIGURE 6.2:
Nundle Water Treatment Plant Levee and "River Glen" Finger Levee Options Impacts 100 Year ARI Flood

Including allowance for a 0.3m freeboard relative to the 100 year flood levels would result in a levee whose height would vary between 0.7m and 1.3m.

The cost of the works would be of the order of $300K. To this would need to be added the purchase of adjacent lands for the siting of the levee and the offsetting excavation works.

It is recommended that a preliminary design study be undertaken to assess the suite of levee and accompanying offset works which would be needed to limit flood damages at the Nundle water treatment plant.

6.1.2.2 Finger levee to protect "River Glen" Cottage Development, River Road, Nundle

One area with hazardous flow conditions in major flood events is in the area north (i.e. downstream) of Buchanan Street. Since the properties are located in the area where the Peel River floodplain narrows, it follows that any proposal to build a conventional levee to protect those properties would have a significant and adverse impact on upstream flood levels. This would be unacceptable since there are flood prone properties and dwellings in that upstream area.

The option of potentially constructing one or more "finger" levees – that is, structural mounds or walls which would serve to protect properties from the worst hydraulic conditions – has been assessed using the hydraulic model. The results of testing a finger levee which would be located immediately upstream of the "River Glen" Cottages in River Road are presented in **Figure 6.2**. Whilst the levee would reduce flood levels (and hazardous conditions) at the downstream properties there would be a significant adverse impact on upstream properties.

The construction cost of a one metre high levee is estimated to be $80K. To this would need to be added the cost of acquiring land for the levee.

Because of its low economic merit and the unacceptable adverse impacts on upstream properties, this and/or similar finger levee schemes are not recommended[3].

6.1.2.3 Woolomin levee

The potential to protect Woolomin with a substantial levee was tested in the hydraulic model. As shown in **Figure 6.3**, the levee was modelled as being adjacent to the top of the near bank of Duncans Creek and the Peel River as far as Monro Street and then north of that street would follow an alignment close to existing village development. It was tested on the basis of being open-ended at the northern (or downstream) limit of the village in order to preserve a flowpath for the rare occasion that the levee would be overtopped. **Figure 6.3** shows that the impact of the levee on the local flood regime is very substantial. That is, it shows that there is a resultant very major increase in 100 year flood levels on the river side of the levee. Due to the worst constriction of flows occurring adjacent to Monro Street, the flood levels south of Monro Street would increase by up to 1.6m while within-channel and overbank flood velocities would typically slightly decrease (from about 2.6 m/s to 2.0 m/s and 1.2 m/s to 1.0 m/s, respectively). North of Monro Street, the flood level increases by between 0.2m and 1.0m adjacent to the levee alignment while increases of as much as 0.2m would extend at least a further 400 metres downstream of the end of the levee. North of Monro Street, the within-channel and overbank flood velocities would also increase from about 3.0 m/s to 4.0 m/s and 1.5 m/s to 2.2 m/s, respectively.

[3] Subsequent to the Committee recommending that the finger levee not receive further consideration, the Committee received advice in May 2012 that the cottages at River Glen had been removed from the site, although the manager's residence remains.

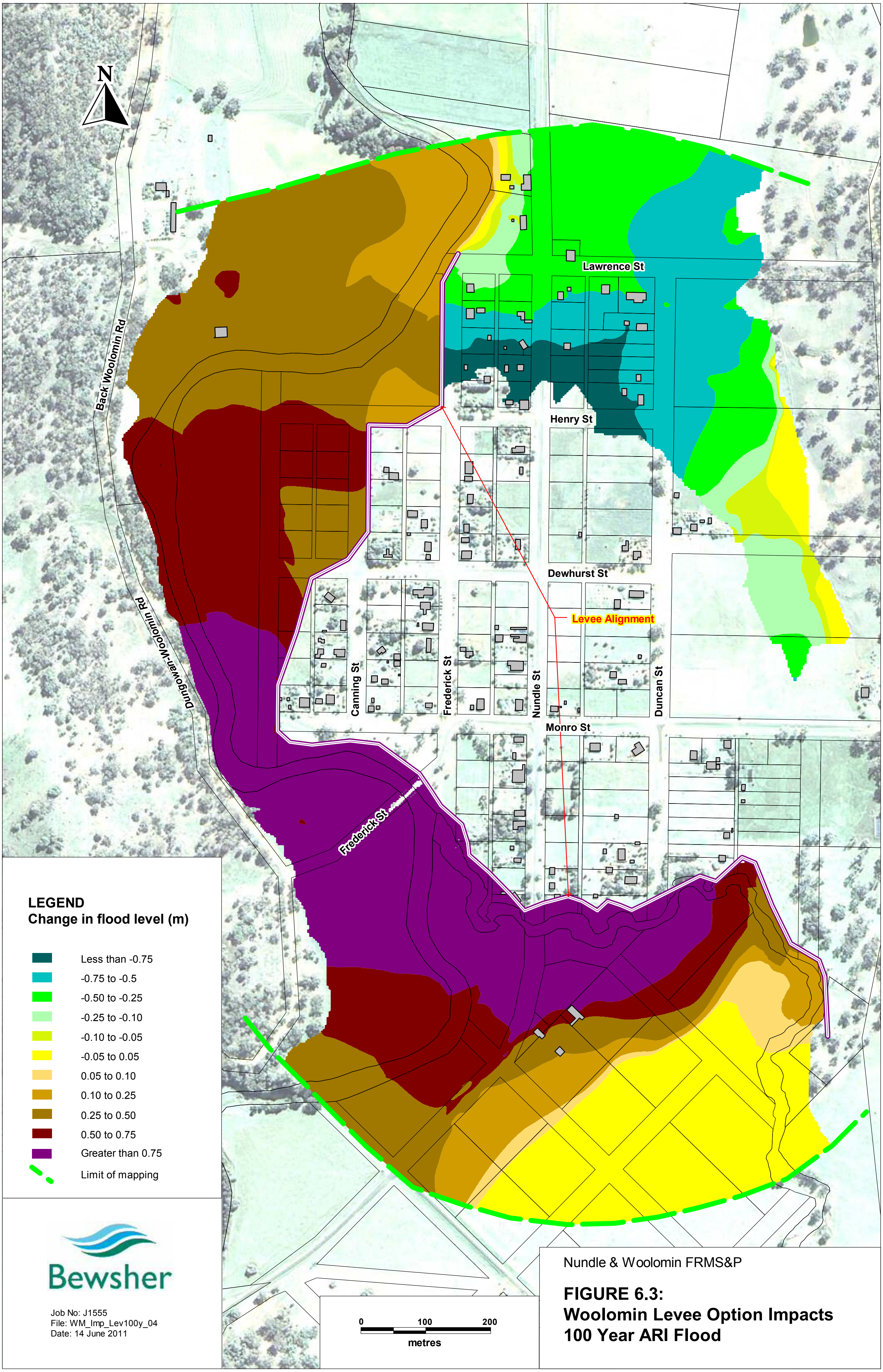

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FIGURE 6.3:
Woolomin Levee Option Impacts
100 Year ARI Flood

Assuming a crest level which equates to 500mm above the 100 year flood level, the height of the levee would vary between 1.1m and 2.7m south of Monro Street and between 1.5m and 2.7m north of Monro Street. Given the limited width available to construct the levee along much of its length, the majority of the levee would be in the form of a structural concrete or blockwork wall. Works equivalent to the levee construction would also be required at the Nundle Street bridge where the depth of water would be about 1.8m. It is anticipated that this would mean that the roadway itself would also need to be raised by as much as 2.3m and realistically this would mean replacing the only recently upgraded Nundle Street bridge over Duncans Creek with a much larger and higher structure.

The construction cost of the works would be of the order of $4 million to which would need to be added the cost of land acquisition.

A concrete or blockwall levee would not be welcomed by most residents of the village for aesthetic reasons.

Levee banks also tend to induce a false sense of security among the people they "protect". The common misperception that a levee solves all flood problems can result in catastrophic losses in the event of levee overtopping or failure, since people are unlikely to be prepared for these rarer events. In such events, water levels can change very quickly, and a levee bank also impacts upon people's ability to detect a rising flood.

The Fisheries Management Division has expressed reservations about levees because of the way they disrupt the connectivity between a river and its floodplain, which is important for some species (**Section 3.6.2**).

Given the very substantial range of adverse impacts and the community opposition that has been expressed, works similar to the modelled levee are not recommended.

6.1.3 Flood Bypass Channel through Eastern Woolomin

Finding: The building of a bypass channel would be expensive and the benefits would be quite limited in terms of reductions in major flood levels. The works are not recommended.

The potential to construct a bypass channel to alleviate flooding in Woolomin was considered. Since there is effectively no Peel River western overbank area, the only opportunity to construct some form of bypass channel is on the eastern edge of the village. Such a scheme – which would convey some of the Duncans Creek flows – was tested in the hydraulic model. As shown in **Figure 6.4** this consisted of modelling a 50 metre wide channel with a typical excavated depth of one metre. **Figure 6.5** shows the impact on 100 year ARI flood levels and it can be seen that typically the flood levels in the village are reduced by less than 0.10 metres east of Nundle Street and are essentially unchanged west of Nundle Street.

The channel works would involve the excavation and disposal of approximately 60,000 cubic metres of material and construction of a major culvert structure at Monro Street. The construction cost would be of the order of $2 million. To this would need to be added the cost of purchasing eight small lot properties south of Monro Street and purchase of easements/restriction-on-user corridors through five larger properties north of Monro Street.

Given the very limited benefits that would be generated by the modelled scheme – or some similar scheme – as well as the opposition voiced by the community, a bypass channel scheme is not recommended.

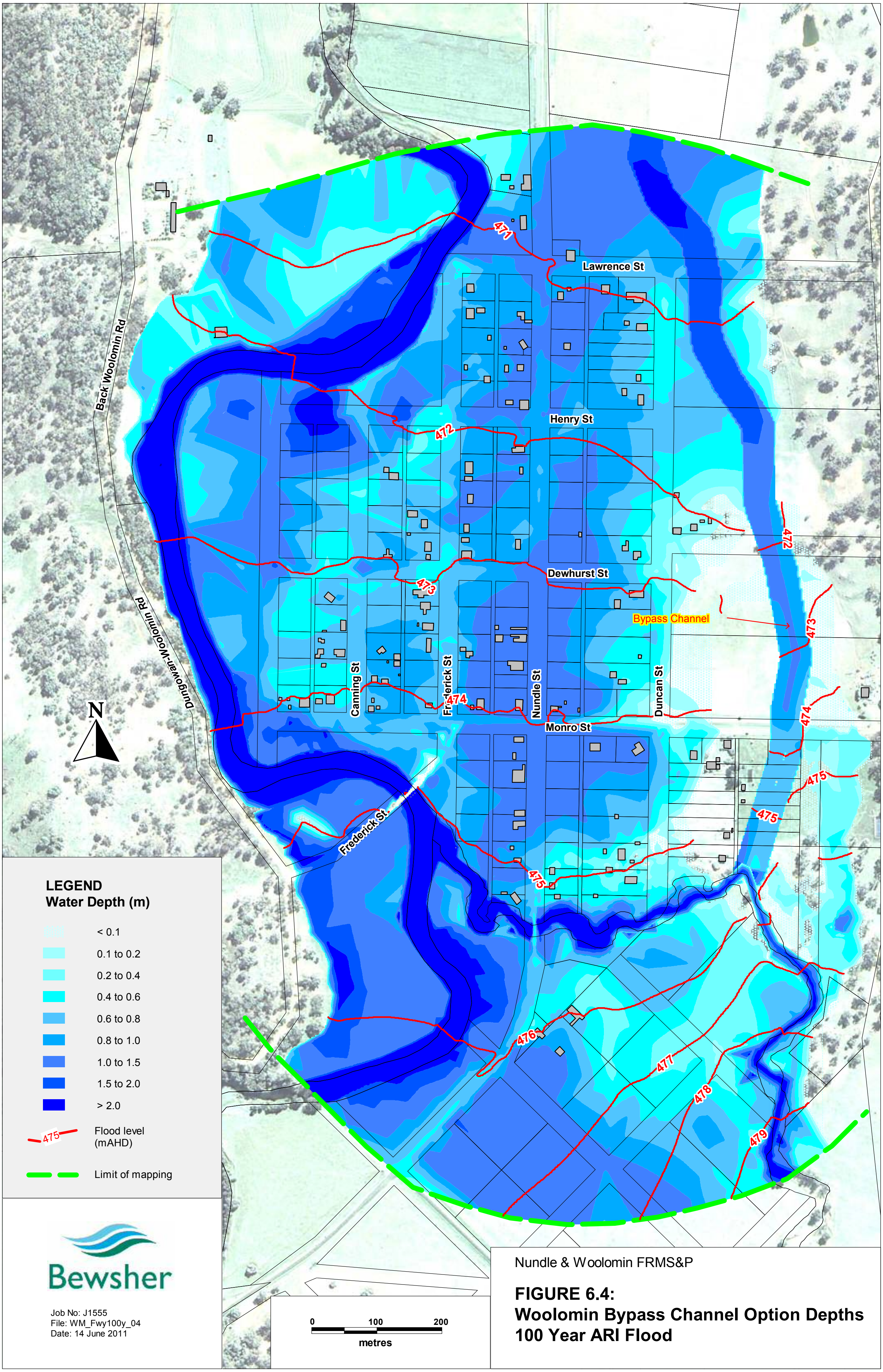

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FIGURE 6.4:
Woolomin Bypass Channel Option Depths
100 Year ARI Flood

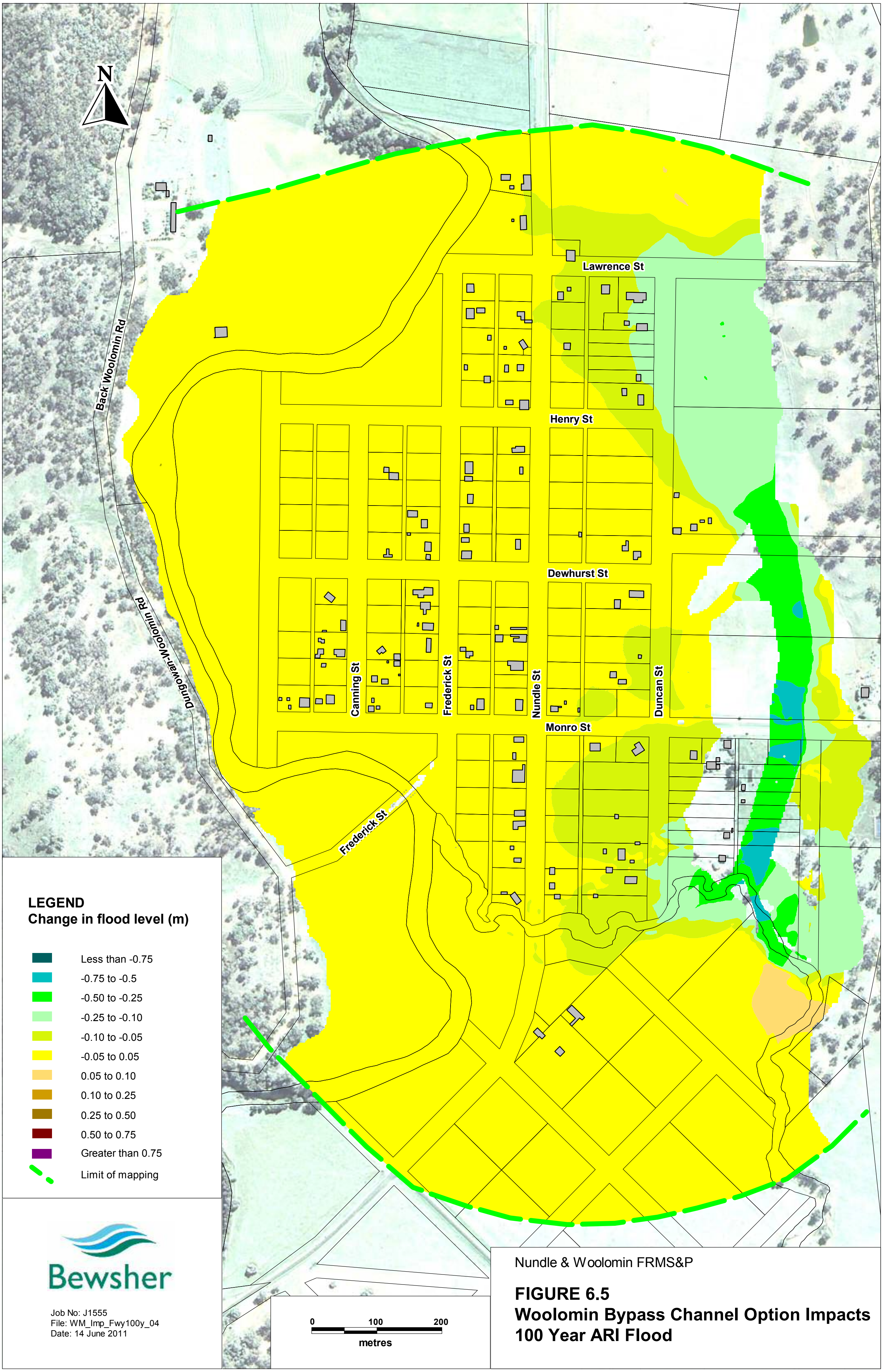

FIGURE 6.5
Woolomin Bypass Channel Option Impacts
100 Year ARI Flood

6.1.4 Channel Clearing

Finding: The clearing of dense vegetation, etc from the major channels has been found to generate only very small reductions in major event flood levels. Since the works would be expensive (and also need to be re-done on a regular basis) and have significant environmental impacts, they are not recommended. Nevertheless it was recommended that Council investigate options for debris removal along Duncans Creek as a means of mitigating existing flood risks.

Clearing the creeks of debris is a popular proposal for alleviating flooding, at both Nundle and Woolomin (**Figure 3.1**, **Figure 3.2**). Whilst removing any urban waste (e.g. car bodies) from the watercourses should be encouraged, managing riparian vegetation such as that seen in **Figure 6.6** is a more complex task because of the ecological and geomorphic functions of riparian vegetation. The Fisheries Management Division opposes this option because of the important role of vegetation as fish habitat (**Section 3.6.2**).

The impact on flood levels from removing vegetation in the Peel River channel at Nundle and both the Peel River and Duncans Creek channels at Woolomin has been examined. Reviews of the hydraulic models show that typically the river channel at Nundle carries about ten percent of the 100 year flood peak flow while the river and creek channels at Woolomin carry about fifteen percent. The removal of dense vegetation would achieve a slightly smoother conveyance system and hence the within channel flow capacity would also increase. It is however estimated that this would see the relative capacities of both sets of channels increasing by only several percent. This in turn represents a lowering of flood levels of only several centimetres.

With such limited benefits, the wide-scale works are not recommended.

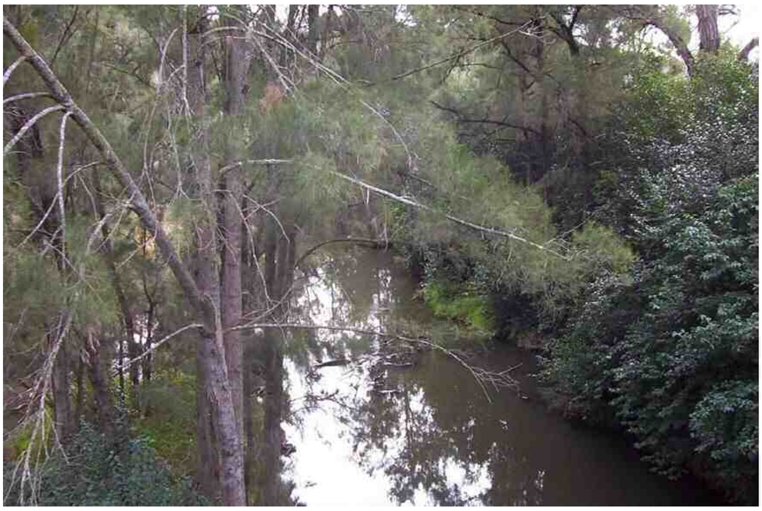

FIGURE 6.6 – Riparian Vegetation, Peel River at Woolomin

Following further consideration at the May 2012 meeting of Council's Floodplain Management Committee, there was considered merit in Council investigating options for debris removal along Duncans Creek as a means of mitigating flood risks. It was noted that a slab-on-ground house on the right bank of Duncans Creek had been inundated in the 2010 event by a break-out caused solely by debris build up in the Creek. This property had not been inundated in the 2000 flood (which had higher flood levels).

6.2 PROPERTY MODIFICATION MEASURES

6.2.1 Voluntary House Purchase

Recommendation: *Include five properties at Nundle on a voluntary purchase list, and implement as funds permit*

Some houses in the study area are exposed to such serious flood hazards that there is an intolerable risk of building failure and/or loss of life. Where this risk cannot be mitigated through flood modification options, it may be necessary to encourage the removal of that risk exposure via its inclusion in a voluntary house purchase (VP) scheme.

In an approved VP scheme, Council offers to purchase properties if and when they became available for purchase, subject to the availability of funds at the time. VP is not compulsory acquisition and affected property owners can expect to receive market values based on valuations by the NSW Government's Valuer General, assuming no VP scheme is in place and disregarding development constraints that may apply on that land due to its flood prone nature. Land purchased under a VP scheme is usually required to revert to open space.

An assessment of the flood risk exposure for dwellings at Nundle (excluding commercially operated cabins) subject to above-floor inundation in the 100 year event is presented in **Table 6.3**. Based particularly on the experience of the November 2000 flood, the hydraulic hazard in the 100 year ARI event, and the "flood emergency response planning (FERP)" classification[3] of each house, it is concluded that five houses are exposed to dangerous, intolerable flood risks. In November 2000, people from these houses had to be rescued under very dangerous conditions, posing risks to the rescuers as well as the residents (see **Section 2.2.2**). This reflects the "low flood island" FERP classification of these houses, which means that the evacuation route is cut by floodwater prior to inundation of the house (**Figure 6.7**). Profiles along the evacuation routes are presented in **Figure 6.8**. Residents from the two Hall Street houses would have to traverse a 0.9m low-point; residents from the two houses at the corner of Herring and Innes Streets would have to traverse a 0.4m low-point on Innes Street (the Herring Street and Oakenville Street route would be lower still); and residents from No. 3 Buchanan Street would have to cross a gully 2.5m lower than the ground level at the house. Four of the dwellings are inundated above floor level in the modelled 20 year flood. Whilst the modelled 100 year depths above floor level are no higher than 0.5m, the flow velocity is high and the hydraulic hazard is high. An extreme flood would be very much deeper.

House raising is not recommended for these five Nundle houses because of the high hydraulic hazard and the observed heavy debris loads during floods, which could impact upon a raised dwelling's sub-structure. The potential for floods of extreme depth also means it would not be safe for residents to remain in raised houses – they would need to evacuate *before* the flood, since evacuation routes are lost early. But whilst improvements to flash flood warning are required, the nature of the catchment at Nundle means that a "fail-safe" flash flood warning system cannot be guaranteed, so it is unlikely that people would always evacuate early enough to avoid disaster. People living in raised houses are believed to be less likely to evacuate, with a false sense of security in their raised dwellings. The intolerable risks at these five properties can only be addressed by voluntary purchase.

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[3] See *Flood Emergency Response Classification of Communities* (DECC, 2007).

At the time of an inspection in mid-2011, two of the five dwellings are for sale. Using the advertised prices, plus estimated prices of $250K/house for the other three properties, and a nominal sum of $20K/house for demolition, yields a total cost of $1.4M. The benefits in terms of flood damage savings produced by removing these dwellings are assessed at $260K. This yields a benefit-cost ratio of 0.2, which is fairly typical of VP schemes. However, the main rationale for VP is not to reduce tangible damages but to reduce the significant risk to life for the occupants of these houses and their potential rescuers. It is noted that at Nundle opposition to the general concept of VP was as great as support for VP in the community questionnaire (**Figure 3.1**). This, however, was based on a small sample that did not include responses from any of the occupants of these five dwellings. During public exhibition of the draft report, two of the affected owners indicated strong support for VP. They had both vacated their houses after the January 2010 flood, and both have experienced great difficulty selling their properties as this event had given prominence to their flood problems. One owner described the great stress felt during rain.

If Council adopts the recommendation for a VP scheme, it will need to consider whether to identify on Section 149 Certificates the recommendation of this *FRMP* that the property be acquired. It may also wish to consider rezoning the earmarked properties to an appropriate zone which does not permit residential uses (as well as extending this rezoning to vacant land with equivalent flood risk). Another issue is how to manage applications for building improvements or redevelopment at the properties earmarked for VP. Redevelopment will likely add value to the property and make its later purchase all the more difficult. It is suggested that only minor developments be approved.

An assessment of flood risk exposure for the 11 dwellings at Woolomin subject to depths of above-floor inundation exceeding 0.5m in the 100 year event is presented in **Table 6.4**. These houses are all located in areas subject to high hydraulic hazards in the 100 year flood (**Figure 5.3**), but on the whole the risk to life is less severe than for Nundle. Flow velocities exceeding 1.5 m/s are largely confined to the streets especially the south to north running Canning Street, Frederick Street and Nundle Street. There should be adequate flood warning time for Peel River floods (but not yet for Duncans Creek floods), though evacuation may be difficult if left too late (see **Section 6.3.2.4**). The overall flood risk profile for the village suggests that VP is not warranted. VP is also impractical given the large number of affected properties and is opposed by a large section of the community (**Figure 3.2**).

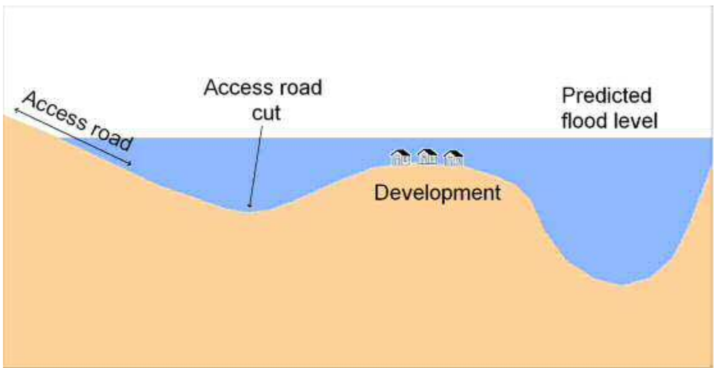

FIGURE 6.7 – Low Flood Island FERP Classification

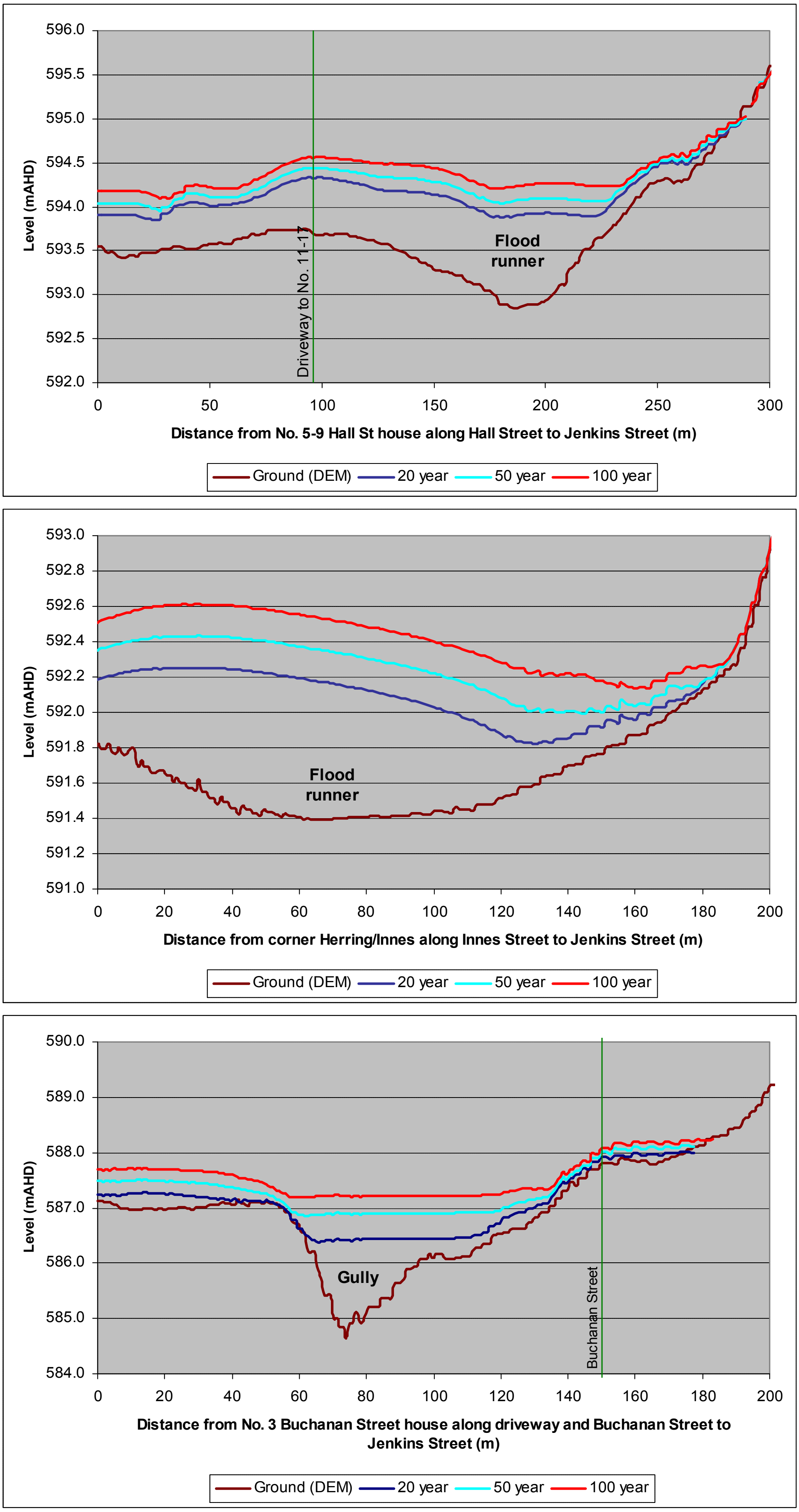

FIGURE 6.8 – Profiles along Evacuation Routes for Five Nundle Houses

TABLE 6.3 – Flood Risk Considerations for Houses Flooded Above Floor in 100 Year Event, Nundle

Address	Experience in Nov 2000 flood	Flood depth over floor				100y hydraulic hazard	Construction	100y FERP classification LFI = low flood island RRA = rising road access	Comment	VP (priority)	VHR (raise or redevelop) (priority)
		20y	50y	100y	PMF						
3 Buchanan Street	Flooded waist-high. Family trapped by gully, unable to be rescued. SES comment: 'very lucky not to have been washed away'.	0.0m	0.2m	0.5m	~10m	High	Metal clad/ slab and weatherboard/ piers	LFI	Isolated exposure. Likely to be trapped by gully.	Yes 1	No
8 Buchanan Street	Flooded?	N/a	0.2m	0.5m	~11m	Low-High	Fibro & hardi-plank/piers	RRA	Could be trapped by high vel flows across street.	No	Yes (raise) 1
58 Gill Street		N/a	0.0m	0.2m	~1m	Low-High	Vinyl & timber clad/piers	RRA	Shallow overland flow.	No	No
5-9 Hall Street	Flooded. Difficult rescue.	0.1m	0.2m	0.4m	~7m	High	Fibro sheeting/ piers	LFI	Isolated exposure.	Yes 2	No
11-17 Hall Street	Flooded. Difficult rescue.	0.0m	0.1m	0.2m	~6m	High	Fibro sheeting/ piers	LFI	Isolated exposure.	Yes 4	No
35-53 Herring Street	Flooded to ~ 0.7m above floor level. Very difficult rescue.	0.0m	0.2m	0.4m	~7m	High	Fibro sheeting/ piers	LFI	Isolated exposure. Dangerous rescue by neighbours in Jan 2010 flood. Unable to sell.	Yes 3	No
5-9 Innes Street	Flooded. Very difficult rescue.	N/a	N/a	0.1m	~7m	High	Weatherboard/ piers	LFI	Isolated exposure. Unable to sell property since vacated after Jan 2010 flood.	Yes 5	No
Lots 4 and 8 Jenkins Lane	Flooded to ~0.3m above floor level.	N/a	N/a	0.1m	~8m	Low	Fibro/slab (poor condition?)	RRA		No	No
63 Jenkins Street	Flooded to floor level.	0.3m	0.3m	0.4m	~6m	Low	Metal clad/slab	RRA		No	No

TABLE 6.4 – Flood Risk Considerations for Houses Flooded >0.5m Above Floor in 100 Year Event, Woolomin

Address	Flood depth over floor				100y hydraulic hazard	Construction	100y FERP classification LFI = low flood island RRA = rising road access	Comment	VP (priority)	VHR (raise or redevelop) (priority)
	20y	50y	100y	PMF						
42-44 Frederick Street (17-19 Dewhurst Street)	0.5	0.7	0.8	3.2	High	Metal cladding, slab	RRA	Metal shed	No	Maybe
13-15 Lawrence Street	0.6	0.7	0.8	3.5	High	Metal cladding, slab	RRA	Secondary, temporary dwelling	No	No
31-33 Monro Street	0.1	0.3	0.5	3.2	High	Metal cladding, pier	RRA	Secondary, temporary dwelling	No	No
22-40 Nundle Road	0.6	0.8	0.9	3.5	High	Concrete block, slab	RRA		No	Yes (redev) 3
41-51 Nundle Road	0.4	0.6	0.7	3.1	High	Fibro, pier	RRA		No	Yes (raise) 6
58-60 Nundle Road	0.3	0.5	0.6	3.3	High	Weatherboard, pier	RRA		No	Yes (raise) 7
61-63 Nundle Road	0.4	0.6	0.8	3.6	High	Weatherboard, pier	RRA		No	Yes (raise) 4
65-71 Nundle Road	0.4	0.6	0.8	3.7	High	Weatherboard, slab	RRA	Attached to shop	No	Maybe
70-72 Nundle Road	0.5	0.8	0.9	4.0	High	Metal clad, slab	RRA		No	Yes (redev) 1
73-75 Nundle Road	0.6	0.8	0.9	3.9	High	Weatherboard, slab	RRA		No	Yes (redev) 2
77-79 Nundle Road	0.4	0.6	0.8	3.5	High	Weatherboard, slab	RRA		No	Yes (redev) 5

6.2.2 Voluntary House Raising/Redevelopment

Recommendation:
Invite owners of 1 house in Nundle and ~7 houses in Woolomin to participate in a voluntary house raising/redevelopment scheme, with a maximum $60K/house subsidy, and implement as funds permit

Raising houses with low-set floor levels has proved to be an effective floodplain management measure at many locations throughout NSW. For example, Fairfield City Council has been implementing a successful house raising program in the Prospect Creek catchment for many years.

Advantages of house raising include:
- reducing tangible flood damages and alleviating anxiety about future floods;
- providing under-house space for non-habitable uses such as garages and laundries; and
- an enhanced resale value.

Disadvantages of house raising include:
- an altered streetscape unless all the houses in an area are raised;
- difficult access for some people (e.g. elderly, people with a disability); and
- people living in raised houses are often less likely to evacuate, which can exacerbate risk to life in floods that overtop the raised floor or when people panic with water below the house.

Various forms of house raising schemes can be considered. The easiest form of house raising is for fibro or timber houses set on piers, and in a good condition. Fairfield Council's experience in Prospect Creek has shown that such houses can be raised by 1-2m for a cost of $60K.

Physically raising houses of brick veneer or full brick construction, or slab-on-ground, is more costly, and in most cases impractical. One solution for these dwellings is to completely rebuild the house at a higher level (and with other improvements, see **Section 6.2.5.2**). Based on the experience of Fairfield Council, net costs are about $100K.

The State and Commonwealth Governments provide financial subsidies for house raising schemes, depending on the relative priority of works on a State-wide basis. A *partial* subsidy scheme which requires the homeowner to make a financial contribution may be preferred to a full subsidy scheme because of the reduced administrative and financial burden on Council, which allows a greater number of flood-prone houses to be assisted in a shorter period of time. Partial schemes also engender homeowners' ownership of the scheme and are more flexible for owners of "difficult" houses (provided that the ultimate goal of raising habitable floor levels to the FPL is achieved).

An appropriate threshold for including houses in a voluntary house raising/redevelopment (VHR) scheme is considered to be where existing house floors are inundated to depths exceeding 0.5m in the 100 year flood. Other criteria for eligibility include:
- primary place of residence on the property (i.e. not a secondary or temporary structure);
- single storey; and
- not benefiting substantively from other floodplain management measures including VP.

Based on these criteria, it is assessed that one house at Nundle and (at least) seven houses at Woolomin would be eligible for inclusion in a VHR scheme (see **Tables 6.3** and **6.4**). A possible funding scheme is proposed in **Table 6.5**. This would cap Government contributions to $60K per house (irrespective of whether it is proposed to raise or redevelop the building structure), with any additional expenses borne by the homeowner. The economic benefits of raising or redeveloping these houses with the lowest habitable floor levels set at 0.5m above the 100 year flood level is assessed as $380K (note this is a conservative assessment including an allowance for the assets likely to be stored at ground level beneath the raised dwelling). Using the $60K subsidy, the total cost to Government would be $480K, yielding a benefit-cost ratio of 0.8. The scheme is recommended.

The concern about the effect of house raising on people's willingness to evacuate before a flood could be addressed by sustained community education and the use of word pictures in flood warning messages, emphasising the dangers and discomforts of failing to evacuate early (see **Section 6.3.3**). Another possibility is to include a PMF refuge in the redeveloped houses (see **Section 6.2.5.3**). This important issue is not regarded as a reason to reject house raising, which is primarily intended to reduce property losses in existing dwellings.

TABLE 6.5 – Proposed Funding Scheme for VHR Scheme

Contributor	**Cost per house**	**Nundle** 1 raise	**Woolomin** 3 raise, 4 redevelop	**Total** 4 raise, 4 redevelop
Commonwealth and/or State Government	Up to $40,000	$40K	$280K	$320K
Council	Up to $20,000	$20K	$140K	$160K
Owner	Remaining cost (for redevelopment or other works)	Nil*	$160K*	$160K*
TOTAL	Typical maximum $60K to raise or $100K to rebuild	$60K	$580K	$640K

* Remaining cost to owner will vary depending on actual cost of raising or rebuilding. Estimates here are based on $60K to raise and $100K to rebuild, per house.

6.2.3 Infrastructure Protection

Recommendation: *Raise susceptible components of water pumps at Hall Street and Oakenville Street, Nundle*

Council's Water Services Directorate suggested the possibility of raising the water pumps in Hall Street (**Figure 6.9**) and Oakenville Street, so that the susceptible components such as electrical equipment are less prone to damage from flooding (**Section 3.6.1**). These works are estimated to cost $50K and are recommended.

FIGURE 6.9 – Nundle Water Pump, Hall Street, after the January 2010 Flood

6.2.4 Existing Planning Controls

Recommendation: *Consider the proposed revisions to the flood risk management controls in Tamworth Regional Development Control Plan 2010, as outlined in Section 6.2.4.6*

This section briefly discusses Council's principal planning controls relating to the management of flood risk and implemented through its Local Environmental Plan (LEP) and its Development Control Plan (DCP).

6.2.4.1 Tamworth Regional Local Environmental Plan 2010 (TRLEP)

The Tamworth Regional Local Environmental Plan 2010 (TRLEP) came into effect in January 2011 and conforms to the "standard LEP template". Section 7.2 deals with flood planning. Its objectives comprise:

"(a) to minimise the flood risk to life and property associated with the use of land;
(b) to allow development on land that is compatible with the land's flood hazard taking into account projected changes as a result of climate change; and
(c) to avoid significant adverse impacts on flood behaviour and the environment."

6.2.4.2 TRLEP's Flood Planning Maps

The land to which the TRLEP clause applies is that shown on the "flood planning maps" attached to TRLEP. These maps show the extent of inundation produced by the flood planning level (FPL) which is the 100 year average recurrence interval (ARI) flood plus 0.5m freeboard.[4] The flood planning maps for Nundle and Woolomin have not been based on the flood modelling carried out as part of the present study but rather on previous historical information available to Council. For Woolomin, the TRLEP maps appear broadly consistent with the results of the current Flood Study, whilst for Nundle, the maps show vastly less inundation than the Flood Study (and are obviously inaccurate). Nevertheless it will be necessary for TRLEP's flood planning maps for both Nundle and Woolomin to be updated once the current study is adopted by Council.[5]

6.2.4.3 TRLEP's Development Consent Considerations

Clause 7.2 (3) of TRLEP lists a number of important considerations relating to floodplain developments. These require Council not to grant consent to development on land at or below the FPL unless they are satisfied that

> *"the development:*
> *(a) is compatible with the flood hazard of the land; and*
> *(b) is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties; and*
> *(c) incorporates appropriate measures to manage risk to life from flood; and*
> *(d) is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and*
> *(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding."*

Given the significant hazard which occurs in both Nundle and Woolomin in a 100 year flood event, it might be argued that new development on much of this land could not satisfy the requirements of this clause. This is particularly in relation to subclauses (a) and (e).

6.2.4.4 Tamworth Regional Development Control Plan 2010 (TRDCP)

TRDCP was adopted by Council in October 2010 and came into effect with TRLEP in January 2011.[6] The section of TRDCP that deals with "*Development on Flood Affected Land*" provides limited controls for the management of flood risk. The most significant controls include:

(a) a requirement to consider inundation that may occur due to breaching or overtopping of a levee. This is of little relevance in Nundle and Woolomin but will be of greater relevance in other parts of the LGA (e.g. Tamworth). The requirement to only consider land below the FPL or as shown on the "Flood Affected Lands" map may mean that that the flood risks in many areas behind levees may not be considered because the potential inundation is not shown on the maps;

(b) flood free access is required for all lots created by subdivision;

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[4] Whilst the intent of the definition of "flood planning level" in TRLEP is clear, unfortunately it is incorrectly worded. The wording used refers to "*1:100 ARI (average recurrent interval)"* and needs to be corrected to say either "*100 year ARI (average recurrence interval)*" or "*1:100 AEP (average exceedance probability)*". (The former is preferable).

[5] In the interim until the flood planning maps are updated, Clause 7.2 of TRLEP can still be applied to land at or below the more accurate flood planning level despite the failure of the current flood planning maps to correctly display the extent of inundation − refer Clause 7.2 (2)(b).

[6] Unfortunately the FPL adopted in TRDCP is inconsistent with that in TRLEP as the FPL in TRDCP does not include the 0.5m freeboard. Nevertheless TRLEP overrides the TRDCP definition of the FPL.

(c) for the development of existing lots, as a minimum, access by wading must be available.[7] As safe wading cannot be achieved within the high hazard areas of Nundle and Woolomin shown on **Figures 5.2** and **5.3** this control could be used to prevent any further development on a vacant lots within both villages;

(d) development should not obstruct the movement of flood water or cause concentration or diversion of flood waters;

(e) new buildings must be able to withstand the forces of floodwaters including debris and buoyancy forces;

(f) flood compatible building materials should be used in construction and in accordance with the flood proofing guidelines attached to the TRDCP;

(g) the level of residential floors shall be not less than the 100 year ARI flood level plus 0.5m. In the case of alterations and additions some concessions for lower floors levels are provided;

(h) there are no floor level requirements for commercial/retail/industrial developments although flood proofing measures are to be provided;

(i) residential subdivision (which creates potential for increased development intensity), is not permitted on lots fully inundated in the 100 year flood. Given that the majority of lots within the village area of Woolomin and some in Nundle are fully inundated in such a flood, this requirement could be used to prevent any further subdivision;

(j) various requirements related to land filling; and

(k) no non-residential rural buildings are to be permitted in "floodways" and their floors are to be located above the 100 year flood level.

6.2.4.5 TRDCP's Flood Affected Land Maps

There are Flood Affected Land maps in Appendix C of TRDCP. As with TRLEP's flood planning maps, the inundation extent shown for Woolomin is broadly similar to that determined from the new flood modelling in the current study. The Nundle TRDCP maps show much more inundation than the TRLEP maps but still have significantly less inundation than predicted by the current study. The wording of the TRDCP makes it clear that the maps to be used in the TRDCP are based on the "most current information available to Council" and should include "*Flood Studies … undertaken in accordance with the Floodplain Development Manual*" (as is the case for the current study). Consequently there should be no impediment to Council using the latest mapping available from the current study in preference to the maps in Appendix C, until such time as Appendix C is formally updated. Nevertheless it would be prudent for a note to be included in material accompanying TRDCP to indicate that more up to date maps are available for Nundle and Woolomin.

6.2.4.6 Potential Revisions to TRDCP's Flood Risk Management Controls

As TRLEP and TRDCP only came into effect in 2011 and the floodplains of Nundle and Woolomin are only a fraction of all the floodplains in the LGA, it has not been appropriate for this study to carry out any detailed review of the flood provisions within Council's existing planning instruments. Nevertheless the following matters are suggested for consideration by Council as part any future review of TRDCP, having regard to current best practice in floodplain risk management:

(a) adoption of a risk based approach that considers the probabilities and consequences of all possible floods (i.e. up to the probable maximum flood or PMF) and is not based solely on the consideration of the 100 year event. These flood risks comprise risks to property and risks to life. Their evaluation requires

[7] Whilst not specified in TRDCP, it is assumed that this requirement applies at the peak of the 100 year ARI flood.

detailed consideration of flood hazards, e.g. those caused by the depth and velocity of waters, evacuation safety risks, etc.

(b) preparation of flood risk maps. Such mapping would not only be based on the flood characteristics of one flood (e.g. 100 year flood), but would consider the potential consequences (and probabilities) of other flood events. For example, this might lead to a "high risk" classification being defined as all areas with a high hydraulic hazard in a 100 year event but might also include some dangerous areas behind existing levees which are not currently mapped as flood affected in a 100 year event but still have very significant flood risks (e.g. when overtopped and breached in a larger event). These maps would also recognise the serious personal safety risks which exist in some locations, e.g. "low flood islands"[8];

(c) introduction of a range of FPLs for different land uses depending on their sensitivity to the flood damage;

(d) greater consideration given to evacuation requirements and personal safety risks;

(e) measures to facilitate redevelopment of some flood affected properties. Throughout the LGA there will be flood affected buildings with serious risks to people and property. Where for whatever reason Council has decided not to move towards acquisition of these properties and no other practical measures have been endorsed to mitigate the risks, Council should be proactively encouraging redevelopment of the these properties in a manner which significantly reduces the flood risks. This could involve construction of a second storey refuge, raising of floor levels, use of flood compatible building materials and methods, etc. Where it is not possible for the redevelopment to meet the normal standards for new development, concessions to these standards should be allowed in order to facilitate the redevelopment (and thus reduce the current exposure to floods);

(f) modifications to existing mapping to facilitate applications of the Codes SEPP for Complying Development[9] (including the February 2011 amendments to the SEPP) so that better flood risk outcomes are achieved;

(g) in conjunction with the preparation of more detailed controls to manage flood risks, consider lodgement of an exceptional circumstances application in relation to the 2007 Guideline on Low Flood Risk areas[10];

(h) consideration of climate change impacts on rainfall intensities across the LGA's catchments; and

(i) consideration of stormwater and overland flow inundation as "flooding" consistent with the requirements of the Floodplain Development Manual.

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[8] A "low flood island" is an area of a floodplain which becomes surrounded by water and then as floodwaters continue to rise, eventually becomes overwhelmed (e.g. the western end of Hall Street in Nundle). See **Figure 6.7**.

[9] This refers to the *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008*, i.e. the "Codes SEPP", including its 2010 and 2011 Amendments. This is documented most recently in the Department of Planning & Infrastructure's Planning Circular PS 11-010 and related circulars.

[10] This was advised to Council in the Department of Planning & Infrastructure's Planning Circular PS 07-003 and comprised a new guideline to the Floodplain Development Manual and was accompanied by changes to the Environmental Planning and Assessment Regulation 2000 and Section 117 Direction on flood prone land.

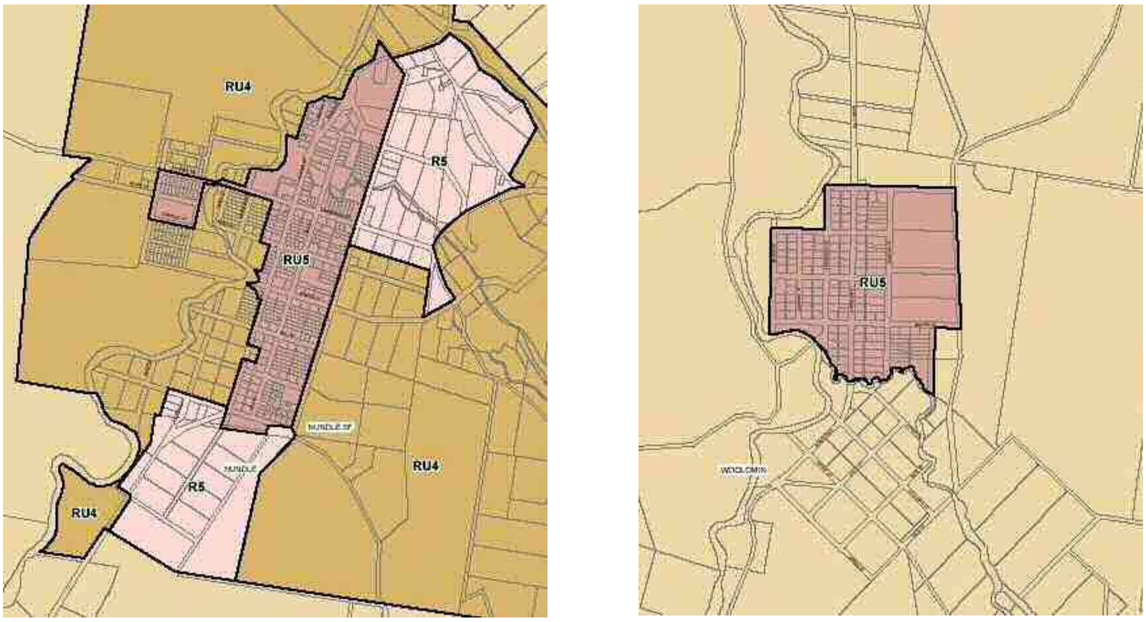
6.2.5 Management of Further Development in Nundle and Woolomin

Recommendations:
1) Use redevelopment to promote the reduction of flood risk to existing buildings
2) Considering the pros and cons of further residential development on vacant lots, do not permit development on high hazard land in Nundle, but permit the development of such land in Woolomin provided the risks to life and property can be adequately managed

6.2.5.1 Existing Potential for Further Development on Vacant Lots

Figure 6.10 below presents extracts of the zoning maps for Nundle and Woolomin from TRLEP. The RU5 zoning is the "village" zoning which has a minimum lot size of 2000m^2 which, in the case of Woolomin, is surrounded by the "primary production" zone RU1 with minimum lot sizes of 100−400ha. For Nundle the RU4 zone is the "rural small holdings" zone and R5 is the "large lot residential" zone. These latter zones have minimum lot sizes of 2−40ha typically.

The development of the existing lots within both villages can be ascertained from **Figures 5.2** and **5.3**. As can be seen, there is considerable potential for further development to occur on vacant lots within Nundle and Woolomin.[11] This is particularly the case in Woolomin where it is estimated that one third to one half of building lots within the village are currently un-developed.



Nundle Woolomin

FIGURE 6.10 − Land Zoning Maps for Nundle and Woolomin
Source: Tamworth Regional LEP 2010 Land Zoning Maps

[11] This assessment is based on a visual inspection of **Figures 5.2** and **5.3** as it has not been possible during the current study to determine the exact number of vacant lots with a "building right" (absent flood constraints). This is a complex task given that Nundle and Woolomin were previously under the control of other councils and some pre-existing rights from these previous administrations still exist.

A major concern is that the majority of the vacant lots are within the high hazard floodplain areas of both villages. Such high hazard areas are defined under the Floodplain Development Manual to be areas where there is "*possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings*". As a matter of normal practice, construction of new residential dwellings in such areas should not be permitted. In addition, any subdivision of existing vacant lots to intensify development potential should also not be permitted.

As noted above, Clauses 7.2(3)(a) and (e) of TRLEP (which deal with flood hazard and the sustainability of floodplain development), as well as the access and subdivision provisions within TRDCP, could be used to prevent any such future development occurring.

6.2.5.2 Redevelopment of Existing Dwellings

As noted in **Section 6.2.2**, redevelopment of existing severely flood affected dwellings in Nundle and Woolomin is seen as a key management measure in order to reduce the significant flood risks which currently occur. Such redevelopment needs to ensure that the flood risks to people and property are substantially reduced as result of the redevelopment. This could be achieved through the construction of a second storey refuge (or attic), strengthening of building structures to prevent damage and loss during a major flood, raising floor levels, reconstruction with flood compatible building materials and methods, etc. Because this redevelopment option is in many cases the only practical means available to reduce flood risks, it is the consultant's opinion that Council should be actively promoting such redevelopment wherever possible. In some circumstances this may mean making building concessions in order to facilitate a practical redevelopment which results in a substantial reduction to the existing flood risk.[12]

6.2.5.3 Options for Future Development of Vacant Lots

In considering various alternatives for the future development of vacant lots within Nundle and Woolomin, three options have emerged:

- **Option A**: − Disallow any development on existing vacant lots within the high hazard area. This option would be consistent with normal practice across many NSW floodplains as indicated in **Section 6.2.5.1** above. Nevertheless this would have a significant impost on existing property owners who purchased land in anticipation of being able to construct residential housing at an affordable price within the LGA. Further given the relatively low cost of land in the two villages, in some circumstances there may be little opportunity for owners to on-sell their holdings and then purchase and build elsewhere.

- **Option B**: − Allow development of all vacant land to proceed consistent with the limited development standards that may have been applied in the past. This would likely see a significant increase in risk to people and property within both villages. This outcome would be directly contrary to the primary objective of the Government's Flood Prone Land Policy which is "*to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods*".

[12] Where if such concessions were not made, redevelopment would not occur and an existing and intolerable flood risk at the site would continue.

- **Option C**: − Allow development to proceed with measures to manage risks to property and risk to life. With regard to risks to property, ensuring that development floors are constructed at or above the FPL and ensuring that buildings are constructed in a manner that was structurally resilient to the impacts of floodwaters, would likely contain property damage to acceptable levels. In regard to managing risk to life, two additional suites of measures might be incorporated to minimise these risks:
  - (i) for Woolomin, providing an improved flood warning system with the installation of an additional rain and river gauge on Duncans Creek (refer **Section 6.3.1.2**), provision of an automated telephone dial-out system and retention of the State Water siren system to warn occupants of the immediate need to evacuate the floodplain (refer **Section 6.3.1.5**); and
  - (ii) incorporating an on-site refuge in a second storey or attic above the reach of the PMF. In such instances the building would also need to be designed to withstand the forces of floodwaters in a PMF event. Whilst it might be practical on most lots in Woolomin to construct such an on-site refuge, within Nundle, given the very large flood range (i.e. up to about 8m for the Peel River floodplain) it is unlikely to be possible. (Consequently further development in Nundle on vacant high hazard lots cannot be supported).

Continued development of high hazard lots within the floodplain of either village, without recognition of the flood risks, i.e. Option B, is untenable and this option has not been considered further.

The choice between Options A and C is more difficult however. Whilst application of normal practice would see no more development on vacant lots with a high flood hazard, i.e. Option A, such an option would likely have a severe social impact and therefore may not be supported by the community or Council's elected officers.

The third alternative, i.e. Option C, may possibly receive the support of the community but is unlikely to receive the support of the SES. The SES' head office has voiced their opposition to on-site refuges because of the potential isolation and "entrapment" that may occur for residents who either choose not to evacuate, or are otherwise unable to evacuate. In the case of Woolomin this isolation could occur for up to about 20 hours. The SES also has concerns with potential medical or fire emergencies that may occur when people are isolated and unable to be safely reached by rescue vehicles or boats, and of the potential safety risks to which emergency services personnel might be exposed in trying to reach isolated individuals.

On balance it is the consultant's view that Option C may ultimately be preferred but recognises that both Options A and C will need further discussion with Council's Committee and all stakeholders, including the SES.

6.3 RESPONSE MODIFICATION MEASURES

6.3.1 Improve Flood Warning

Recommendations:
1) Alarm key rainfall and river level gauges above Nundle so that SES personnel are notified by mobile devices when designated rainfall intensities are recorded or critical stream levels are reached;
2) Analyse the rainfall duration-intensity plus river levels associated with historical floods and design floods to inform the selection of appropriate gauge triggers for alarming;
3) Install a telemetered rain gauge and river level gauge in the Duncans Creek catchment to provide flood warning to Woolomin
4) Prepare a rainfall based flood intelligence tool for Nundle and install a manual river gauge at an accessible location to quantify a relationship between the Pearly Gates gauge and Nundle
5) Pre-prepare a range of simple warning messages for Nundle and Woolomin
6) Establish automated telephone dial-out systems for Woolomin and Nundle
7) Negotiate with State Water to retain the siren infrastructure at Woolomin and transfer to SES
8) Install a public address system at Nundle Caravan Park
9) Arrange to personally warn any campers below Nundle and at Woolomin

6.3.1.1 General

Emergency Management Australia (EMA, 1999, p.2) defines the purpose of flood warning in the following way:

> *"…to enable and persuade people and organisations to take action to increase safety and reduce the costs of flooding. Generating appropriate responses, from the people and organisations at risk and from the agencies with responsibilities during flood times, is the goal of any flood warning system."*

Figure 6.11 summarises the total flood warning system. Flood *prediction* is not sufficient – *communication* of the threat in a way that prompts appropriate behaviour is vital.

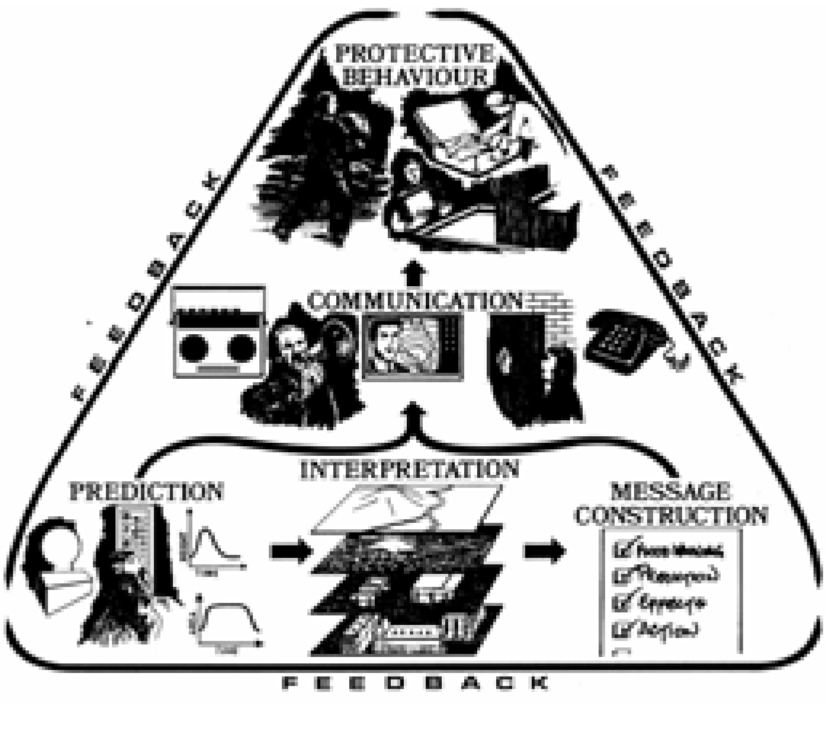


FIGURE 6.11 – The Total Flood Warning System
Source: EMA, 1999, p.8

Flooding at Nundle is characteristically flash flooding, with the river responding very quickly to rainfall on the surrounding hills. The November 2000 Peel River flood rose to peak at Taroona within about 3 hours (**Figure 2.4**), while the January 2010 flood rose to peak within only about 1½ hours (**Figure 2.7**). Design flood hydrographs at Nundle confirm the propensity for rapid rises, especially for the modelled short duration storm (**Figure 4.3**).

Floods at Woolomin may also rise quickly, especially for short duration storms centred over the unregulated Duncans Creek catchment, while longer warning should be available for floods travelling down the Peel River system through Chaffey Dam (**Figure 4.3**).

For flash flood catchments such as these, the provision of an effective flood warning service is problematic. This was borne out by the experience of the November 2000 flood (**Section 2.2.2**). Several challenges to an effective flood warning service have been identified for flash flood catchments (McKay, 2004, 2008):

a) Flash floods are less predictable than larger scale flooding. Rainfall over small catchments is usually not well predicted by numerical weather prediction models.

b) For flash floods, there is little time to develop reliable flood warnings and for effective dissemination and response to the flood warnings. More rapid user response is required, which necessitates specialised communication systems and a high level of public flood awareness.

c) A reliance on rainfall triggers increases the frequency of false alarms.

d) The use of water level triggers may not allow sufficient time for response.

For these reasons, the Bureau of Meteorology traditionally has not issued specific flood predictions for flash flood catchments. The Bureau does offer more general services that may be of some benefit in alerting the emergency services and community to the threat of flooding (**Table 6.6**).

TABLE 6.6 – Bureau of Meteorology Warning Services of Potential Benefit in Flash Flood Catchments

General Weather forecast
General weather forecasts may indicate the likelihood of heavy rain from synoptic scale events, typically with more than 24 hours notice.

Flood Watch
A Flood Watch is issued by the NSW Flood Warning Centre, typically providing 24 to 48 hours notice that flooding is *possible* based upon current catchment conditions and future rainfall, which is predicted by computer models of the atmosphere.

Severe Weather Warning
A Severe Weather Warning is issued for synoptic scale events when one or more of the following hazardous phenomena are forecast:

- Gale force winds (average 10-minute wind speed exceeding 62 km/h)
- Damaging winds (peak wind gusts exceeding 89 km/h)
- Destructive winds (peak wind gusts exceeding 124 km/h)
- Torrential rain and/or flash flooding
- Damaging surf conditions leading to significant beach erosion

Severe Thunderstorm Warning
A Severe Thunderstorm Warning is issued by the Severe Weather Team, typically providing 0.5 to 2 hours' notice of impending severe storms. These forecasts are based upon radar and, if available, data from field stations, reports from storm spotters, as well as an analysis of the synoptic situation.

6.3.1.2 Monitoring and prediction

Despite the above provisos, however, the flood warning infrastructure in the upper Peel River Valley has been significantly upgraded following flooding of Tamworth in January 2004 (McKay & Galvin, 2011). The upgrade includes:

- additional real-time rain and river level gauges (see **Figure 1.1** for those relevant to the current study);
- the replacement of the telephone telemetry network with ALERT (Automated Local Evaluation in Real Time) event reporting radio telemetry, which transmits each data increment such as 0.2 mm of rain or a 1 cm change in river level; and
- the installation of the Namoi Doppler weather radar in September 2010, which provides estimates of rainfall rates used for flood warning.

In addition to the informal prediction systems which were of value in the November 2000 flood event, this upgraded flood warning infrastructure does provide the emergency services (and the community) with a larger suite of tools to assess the threat of flooding. It is understood that the Nundle SES unit has an Enviromon base station to monitor the rain and river levels. A recommendation of this study is that some key rainfall and river level gauges above Nundle be alarmed so that SES personnel are notified by mobile devices when designated rainfall intensities are recorded or critical stream levels are reached. Such automatic notifications would provide something of a safety net. An analysis of rainfall duration-intensity associated with previous floods and the design floods is also recommended to inform selection of the rainfall intensity triggers. This analysis could yield a tool similar to that shown in **Figure 6.12**, which shows coarse relationships between rainfall duration-intensity and flood severities for a saturated catchment at Cootamundra. An analysis of river levels at Pearly Gates and Taroona associated with previous floods is also recommended to inform selection of the river level triggers. The triggers must also be sufficiently conservative to allow time for the SES to alert the public to the rapidly emerging flood threat. For example, a preliminary analysis of key timings during the January 2010 flood at Nundle in **Table 6.7** suggests that a trigger level of 3.0m at the Pearly Gates Bridge might represent an appropriate balance between likelihood of a flood and sufficient time to respond.

Advance notice of floods at Woolomin is made difficult by the current absence of telemetered rainfall or river level gauges in the Duncans Creek catchment (see **Figure 1.1**), which can produce flooding of the village independent of Peel River flows. It is recommended that the Tamworth flood warning network be upgraded with the addition of a telemetered river level gauge on Duncans Creek, probably at a suitable site just downstream of the confluence with Junction Creek, which is about 9 km upstream of Woolomin and would provide a short though valuable window for response prior to flooding (similar to the value of Pearly Gates for Nundle). As well as being of benefit to Woolomin during flood-time, a gauge here would fill in a noticeable data gap which meant that the size of the November 2000 Duncans Creek flow could not be confidently established for the flood model calibration. The site would also contribute to earlier flood prediction for Tamworth. It would also be prudent to install a telemetered rain gauge at the same site, taking advantage of any radio repeaters which might need to be installed to connect the gauge to the base station. The capital cost of the project is estimated to be no more than $30K. The Bureau of Meteorology has indicated that it would support any Council bid for additional capital funding for a river gauge (with Council to contribute either one-third or one-half of the costs depending whether Commonwealth funding can be secured), *provided that Council is willing to maintain it*.

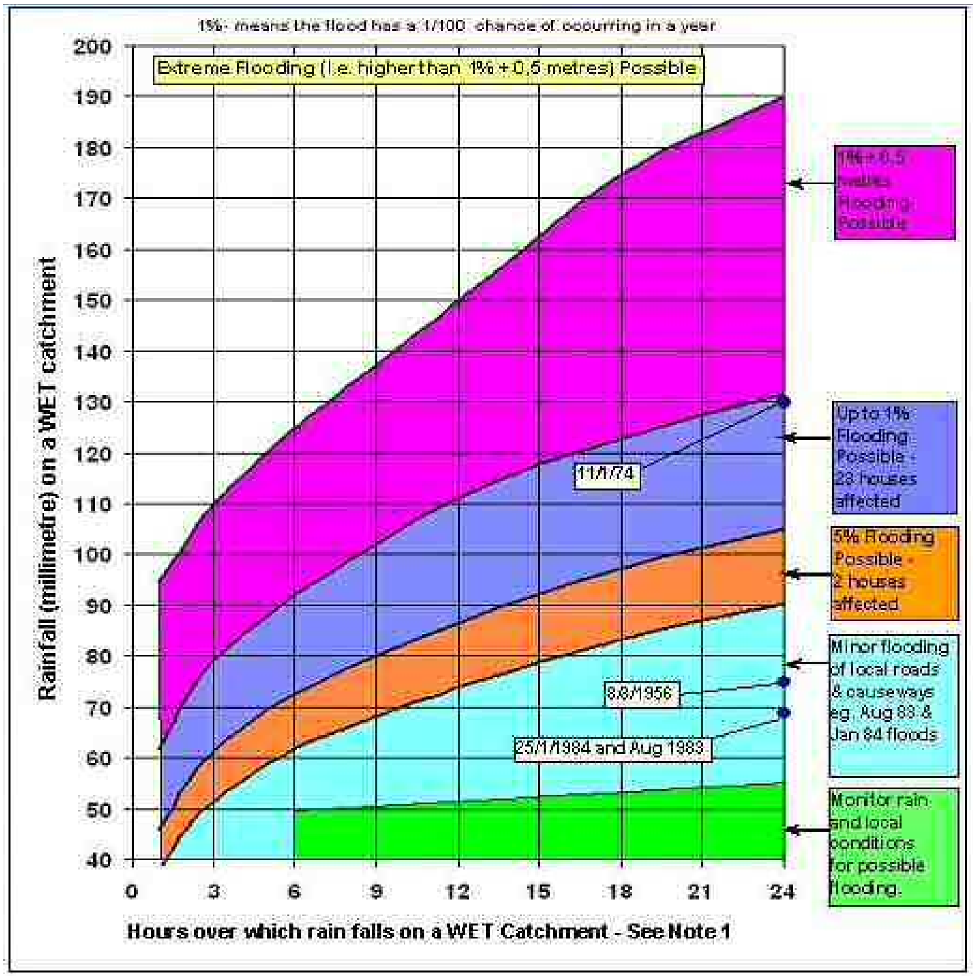


FIGURE 6.12 – Cootamundra Flash Flood Forecasting Diagram
Source: Bureau of Meteorology

TABLE 6.7 – Approximate Timeline, January 2010 Flood, Nundle

Note: Based on observed hydrograph at Pearly Gates, calibration model run and digital elevation model

	Pearly Gates river gauge	Nundle Caravan Park	Time between trigger and causeway cut
2 Jan 11.53 pm	Start of major rise (1.61m)		85 minutes
2 Jan 12.28 pm	3.0m		50 minutes
2 Jan 12.34 pm	3.5m		44 minutes
2 Jan 12.40 pm	4.0m		38 minutes
2 Jan 1.17 pm	Peak (6.13m)		1 minute
2 Jan 1.18 pm		Causeway flooded	
2 Jan 1.23 pm		Lower tier begins to flood	
2 Jan 1.55 pm		Peak	

6.3.1.3 Interpretation

Flood intelligence is the product of a process of reviewing information about the impacts of flooding on communities and allows the response agency to understand the implications of an observed or predicted flood level. Whilst the Nundle SES has a good appreciation for the main flood risk exposures in Nundle, there would be merit in developing a rainfall based intelligence tool (such as that shown in **Figure 6.12**) as well as flood intelligence linkages between the Pearly Gates gauge and Nundle. Because the gauge is about 8 km upstream of Nundle, the township is not strictly within the gauge's "reference area", plus some consequences will be related to flows in tributaries such as Oakenville Creek. Nevertheless, over time the Pearly Gates gauge could become quite valuable for the rapid assessments of likely consequences that are required for this flash flood catchment. A manual gauge at a location in Nundle where the river can be accessed before and during a flood would help to quantify a relationship between Pearly Gates and the township.[13]

6.3.1.4 Message construction

During historical floods in Nundle and Woolomin, where minimal or no warning time has been available and residents have been alerted by a personal telephone call or through a knock on the door, there has been little opportunity to consider the content of the warning messages. In this environment, sophisticated warnings are not required. However, the *Flood Warning* manual (AGD, 2009) makes the point that especially in flash flood situations, there is value in *setting up warning messages before flooding occurs*, for example:

- *46 mm of rain has fallen at the Head of the Peel gauge over the past two hours;*
- *Heavy rain is continuing;*
- *The Peel River at Pearly Gates gauge is at 3.0 metres and rising fast;*
- *Houses on the Peel River flat in Hall Street, Herring Street, Buchanan Street and Jenkins Lane could be flooded over the floor – residents should evacuate to high ground immediately – take your important papers and photographs, your medications and your pets with you – turn off the electricity, gas and water before you go – never drive, ride or walk through floodwater.*

A variety of messages could be prepared for Woolomin, allowing for flooding from Duncans Creek and/or the Peel River (though advance notice of Duncans Creek flooding may first require a telemetered gauge). Careful consideration is required for the actions that are advised – where to evacuate, or whether to take refuge (**Section 6.3.2.4**).

[13] Some historical information is available for a gauge previously located on the side of the old Nundle Road Bridge, but this was difficult to access and view during floods.

6.3.1.5 Communication

An important question is how the people affected by flooding can best be given the appropriate information. The potential for very fast rising floods means that door-knocking and telephone "trees" may be too slow to reach everyone in time, especially for Woolomin. An automated telephone dial-out system is recommended for owners of buildings in the Nundle floodplain and for Woolomin. The ability of such a system to quickly reach a large number of subscribers is highly beneficial for flash flood situations.

Alarms/sirens are also capable of reaching large numbers of people quickly, and Woolomin has had a siren system while the Chaffey Dam Safety Upgrade was being completed, in case of dam failure which would swamp Woolomin within minutes. It is recommended that negotiations with State Water be made to retain the siren infrastructure within Woolomin, with responsibility for the maintenance of the system passed to Council, and for triggering the siren passed to the local SES unit. A potential site for a siren at Nundle is at the caravan park, where due to the low-lying causeway, the northern side of the park may be quickly cut off from the southern side of the park where the manager resides, frustrating attempts to personally advise campers and caravanners occupying the low tier. A siren could also provide a warning to flood-prone residences in Buchanan Street nearby. As the *Flood Warning* manual (AGD, 2009) identifies, however, sirens may easily be misunderstood if not associated with an ongoing public education campaign regarding its use. In the case of a caravan park with a transient population, installation of a public address system that enables the manager to communicate to patrons on the low tier without crossing the causeway, is considered preferable. Speakers could be mounted at a high level outside the amenities block.

Some consideration must also be given to communicating flood warnings to the transient camping population which especially during the summer months can occupy camping sites on the banks of the Peel River below Nundle (e.g. **Figure 6.18a**) and at Riverside Park in Woolomin (**Figure 6.18b**). When a Flood Watch is issued, it is recommended that Nundle SES task a person to drive down River Road and to visit Riverside Park to inform any campers of the possibility of flooding and what to do in the event of a flood. If time allows, this action should also be triggered if the Pearly Gates river gauge (and proposed Duncans Creek river gauge) reach pre-determined trigger levels.

An automated telephone call or a siren will likely prompt members of the community to seek confirmation of the situation. Consideration needs to be given to providing them with the means to do so, possibly via the SES's general 132500 number or preferably through a regional flood information centre.

6.3.2 Improve Emergency Management Capability and Plans

Recommendations:
1) SES to update Local Flood Plan including flood intelligence from this study
2) Nundle Caravan Park manager to complete a flood emergency management plan template
3) Seal the alternative evacuation route from Nundle Caravan Park to Jenkins Street
4) Ensure that any on-site vans on the lower tier of Nundle Caravan Park remain mobile
5) Conduct an audit of the use of camping grounds between Nundle and Bowling Alley Point over the summer months, and assess evacuation capability from these areas to inform an evacuation strategy
6) Prepare an evacuation strategy for Woolomin and resource the SES appropriately in view of the discussion in Section 6.3.2.4

6.3.2.1 Local Flood Plan

Local Flood Plans should be routinely updated after significant floods or following the completion of Flood Studies and Floodplain Risk Management Studies. The *Nundle Local Flood Plan* is dated November 2002. It is in the process of being incorporated into a combined *Tamworth Regional Local Flood Plan*. It is recommended that the information from the *Nundle and Woolomin Flood Study and FRMS&P* be incorporated into the Local Flood Plan or other flood intelligence documents as appropriate, including:

- design flood levels, depths and extents for every property within the floodplain;
- surveyed or estimated ground and floor levels for every property within the floodplain;
- the location of buildings flooded above floor level (**Figures 5.2** and **5.3**);
- roads subject to inundation (**Figures 4.1** and **4.2**).

Should the recommendations of this study, such as voluntary purchase of severely at-risk properties, be implemented in due course, the Local Flood Plan will require further revision.

6.3.2.2 Nundle Caravan Park

One of the annexes to the Local Flood Plan contains evacuation arrangements for Nundle Caravan Park. Over recent years there has been a growing understanding of the vulnerability of caravan parks to flooding, with commensurate efforts to raise the quality of flood risk assessments and management plans. A flood emergency management plan template was prepared as part of the Shoalhaven *Caravan Parks Flood Safety Study* (Bewsher Consulting, 2008). It is recommended that the manager of Nundle Caravan Park, with assistance from the SES, prepare an up-to-date plan using this template, which contains sections for flood risk assessment, key priorities and triggers and flood response.

As arguably the worst single risk exposure within the study area, a high priority must be given to the provision of early warning from the SES to the park manager, and from the park manager to any patrons occupying the lower tier of the park. **Figures 6.7** and **6.8** show that an important contributing factor to the park's high flood risk is the Oakenville Creek causeway through the centre of the park, which can be cut very early in an event, preventing the manager from alerting patrons on the lower tier, and preventing evacuation of campers and caravanners via that route. For this reason, the installation of a public address system that could be used for issuing flood warnings is recommended in **Section 6.3.1.5**.

Early loss of the route across the causeway will require patrons from the lower tier to evacuate via the alternative egress route onto Buchanan Street. In heavy rain this route can become boggy so it is recommended that it be sealed through to Jenkins Street to enable the efficient shifting of caravans and vehicles . Cabins should not be installed on the lower tier of the park, and care is required to ensure that any on-site vans on the lower tier retain their mobile status (e.g. draw-bars attached, tyres inflated, not affixed to rigid annexes).

Ongoing efforts are also required to ensure that visitors to the park are aware of the potential for rapidly-rising floods. Under Clause 123(i) of the *Local Government (Manufactured Home Estates, Caravan Parks, Camping Grounds and Moveable Dwellings) Regulation 2005*, a caravan park manager is required to give written notice of the conditions of occupation to a prospective occupier, *including the location of flood liable land*. A handy means for this would be to indicate such on the site map distributed to visitors (see **Section 6.3.3**).

6.3.2.3 Camping areas downstream of Nundle

A potentially significant risk exposure over the summer months is campers occupying low-lying flats next to the Peel River between Nundle and Bowling Alley Point. The de facto emergency response strategy for this flood risk is self-evacuation. An audit of this informal camping sector was recommended in the *Flood Intelligence Collection and Review* prepared for the SES (Bewsher Consulting, 2009), and is confirmed here. There is also a need for a rudimentary evacuation capability assessment for these camping sites, including the identification of any potentially life-threatening "low flood islands" where access may be lost early. This should be used to inform an evacuation strategy incorporated into the Local Flood Plan, as well as signage used to direct campers to safe locations in a flood emergency.

a. Causeway over Oakenville Creek, Nundle Caravan Park

b. View from causeway to lower tier, Nundle Caravan Park

c. Looking down to Oakenville Creek causeway and amenities block

FIGURE 6.13 – Nundle Caravan Park photos

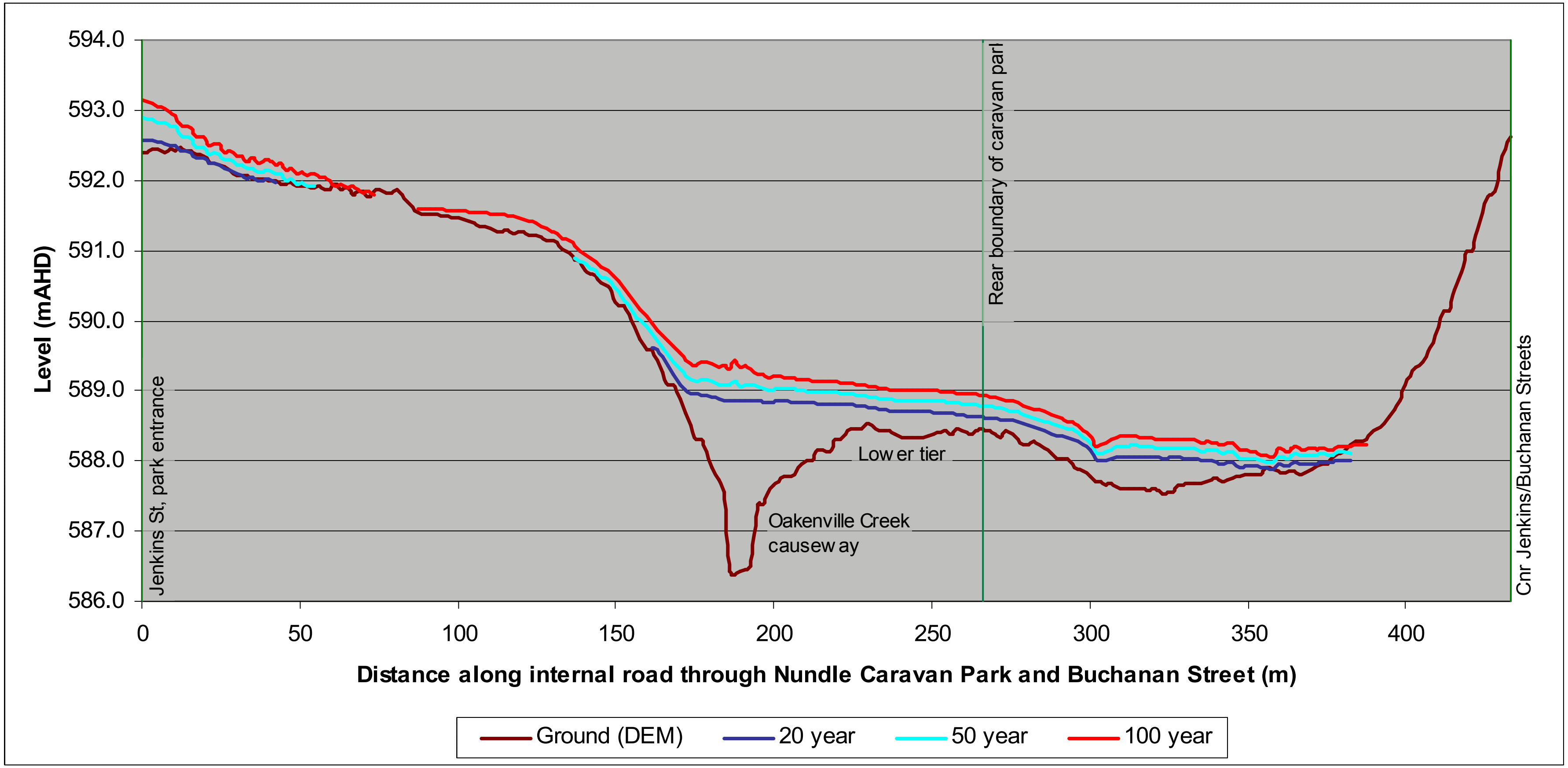


FIGURE 6.14 – Ground and Flood Profile through Nundle Caravan Park

6.3.2.4 Woolomin

Both the experience of the November 2000 flood and the Local Flood Plan suggest that the best evacuation strategy for the residents of Woolomin has yet to be determined. In November 2000, some people evacuated to a private residence on a hillside to the north of the village, others towards the tennis courts on high ground to the east of the village, while most went to the school in Frederick Street. An assessment of the merits of various emergency management responses is presented below:

- **Option A**: − evacuate to the Emergency Recovery Centre on Woolomin Gap Road (**Figure 6.15a**). The advantage of this site is its location beyond the floodplain. According to SES personnel, however, in the November 2000 event the site could not long be reached (**Section 2.2.2**). **Figure 6.16** shows that a 472.9m AHD low-point on the Monro Street evacuation route near its intersection with Nundle Road is about 0.8m below the level of the road west of Canning Street. Although a "rising road access" flood emergency response planning (FERP) classification is afforded to properties located close to Monro Street east of Nundle Road, the low-point effectively makes the area west of Nundle Road a "low flood island" (**Figure 6.7**). Consideration was given to raising the Monro Street low-point to enhance the evacuation route's flood immunity, but this is impractical given the degree of raising required, the need for commensurate raising at the intersections with cross streets including Nundle Road, and the difficulty of managing adverse flood effects upstream of the raised road, with significant expense. Accordingly, unless people evacuate early or there is sufficient boat rescue capability to shift people to this site, the designated Emergency Recovery Centre is not a practical place of refuge for much of the Woolomin community.

- **Option B**: − evacuate to the primary school in Frederick Street (**Figure 6.15b**). The advantage of this site is its proximity for several residences. Flood modelling indicates that its buildings are located in a small area of low hydraulic hazard in the 100 year event (**Figure 5.3**). However, the site would be inaccessible to people east of Nundle Road via Monro Street (**Figure 6.16**). Its buildings would be inundated above floor level in the 100 year flood, and without a higher floor level, any evacuees would be trapped and require rescuing. At present, then, the primary school is not an appropriate formal flood evacuation centre.

- **Option C**: − evacuate to private residences outside the floodplain. In the November 2000 flood, some people were evacuated to the Dawson residence on a hillside to the north of the village. This may well be the most pragmatic approach for residents living on the northern side of the village in future events too. If it is deemed that the wooden Frederick Street Bridge is capable of safely conveying evacuation traffic during a rising flood, there may well be accessible flood-free residences located west of the Peel River whose owners are willing to shelter evacuees until the flood subsides. It is noted that with low-points of 473.3m AHD at the intersection of Frederick Street and Monro Streets, and 473.6m AHD on Frederick Street west of the bridge, this evacuation route could be open for longer than the Monro Street evacuation route. However, it may be unwise to formalise evacuation to private residences when a future owner may not wish to participate in this process.

- **Option D**: − construct a community shelter with PMF refuge. It might be possible to build a multi-purpose community or school building with sufficient floor space above the PMF level to temporarily house the residents of Woolomin. This building could have an independent water supply and an effluent tank. A designated local evacuation centre of this nature would also facilitate resupply if required. If located at the school where the ground level is about 472.6m AHD, a two-storey building with the second storey above 475.6m AHD would provide space above the modelled PMF. Against the idea of a community shelter located within the floodplain is the difficulty of accessing the shelter for some residents (**Figure 6.16**) and concerns about the risk of fire and medical emergencies.

- <u>**Option E**: − construct houses with PMF refuges</u>. It is noted that 47 houses at Woolomin are not subject to above-floor inundation even in the modelled 100 year flood (**Section 5.6**). This number will increase if a voluntary house raising/redevelopment scheme is implemented (**Section 6.2.2**). An existing concern – that will be amplified if houses are raised – is the reluctance of residents to evacuate their raised dwellings before a flood, with a tendency to wait and see how severe the event is. This reticence should be targeted through sustained education about the dangers and discomforts of sitting out a flood in Woolomin (**Section 6.2.2**; **Section 6.3.3**). But *as a measure of last resort*, recognising the likelihood that some people will refuse to evacuate before the flood no matter how frequently and strongly expressed is the need to do so, it might also be advisable to ensure that any new dwellings in the village include their own PMF refuge (**Section 6.2.5.3**).

There are no easy answers to the emergency management dilemmas at Woolomin. Council as the development approval authority and the SES as the flood response agency need to liaise with the community to develop an agreed strategy to managing the risk to life from flooding. The Consultant suggests that the following measures be included:

- education so the community accepts the need to evacuate early (see **Section 6.3.3**);
- in an emerging flood situation, encourage early evacuation to the Emergency Recovery Centre on Woolomin Gap Road, and provide good facilities and community activities there as incentive for people to evacuate;
- based on the road low-points within the village, demarcate evacuation sectors to guide late evacuation decisions: the south-eastern sector evacuating to the Emergency Recovery Centre; the south-western sector to the primary school (or across the Frederick Street Bridge); and the northern sector to a private residence on a hillside on the northern side of the village;
- if in the future any community building is proposed at Woolomin public school (or elsewhere in Woolomin), make provision in the building design for a second storey which could also function as a PMF refuge for the residents of the village;
- ensure that the local emergency services have a strong boat rescue capability (with at least two boats and crews).

It is noted that the SES and RFS depots would be flooded in the 20 year event (**Figure 5.3**; **Figure 6.15c**). Ideally the emergency services should not be located in the floodplain, since inundation of their depots could compromise the quality of their response in the community. However, the advantage of the current SES site is its centrality and accessibility to most personnel during a flood. Also, it is understood that the depot is not used as an operations centre.

a. Emergency Recovery Centre adjacent to tennis courts, Woolomin Gap Road

b. Woolomin Public School, Frederick Street

c. Woolomin SES and RFS depots

FIGURE 6.15 – Woolomin photos

FIGURE 6.16 – Ground and Flood Profile along Monro Street, Woolomin

6.3.3 Improve Public Flood Readiness

Recommendations:
1) Prepare and distribute flood certificates to residents within the floodplain
2) Prepare and distribute a FloodSafe Guide for Woolomin
3) Enhance the flood information available at Council's web-site
4) Display a flood marker and poster describing the flood evacuation procedures at Nundle Caravan Park, and mark extent of flood-prone land on site maps
5) Install additional signage at informal camping grounds downstream of Nundle
6) Install a flood marker at Riverside Park in Woolomin
7) Establish an annual flood education "outreach" program across the Local Government Area, probably in about October since large floods have been most prevalent over the summer months
8) Encourage business owners within the floodplain at Nundle and Woolomin to use the Business FloodSafe toolkit to assess and reduce their flood exposure

Actual flood damages can be reduced, and safety increased, where communities are "flood-ready".

> *People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension… Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the [SES], with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced.* (Keys, 2002, p.52)
>
> *The challenge is not in gaining the attention of the community… but in changing the community's attitude and behaviour towards flooding.* (FEAC, 2006)

By 2006, about 70% of questionnaire respondents from each of Nundle and Woolomin had experienced the November 2000 flood (**Figure 2.5**). This figure may overestimate the proportion of the community who observed the flood, since those who responded may be those who are concerned about floods, and those who are concerned may be those who experienced the 2000 flood. Indeed, it is striking that six years after the event, the remaining 30% of the respondents had apparently not witnessed the 2000 flood in Nundle or Woolomin. The 2006 Census data (proportion of people enumerated at the same address 5 years ago) suggests that over a period of 10 years, only 34% of the residents of Nundle and 27% of the residents of Woolomin are likely to live at the same address (**Table 2.2**). Already, it is likely that more residents than not will have no memory of the 2000 flood.

Although some smaller floods have been experienced at Nundle since November 2000 (but not at Woolomin) (see **Section 2.2.3**), the flood readiness generated by the 2000 flood must be enhanced, and for many residents, flood readiness must be created. Broad community support for such activities was indicated by the questionnaires (**Figures 3.1** and **3.2**). This section explores measures for promoting community flood readiness in Nundle and Woolomin.

6.3.3.1 Certificates

In the Consultant's view, perhaps the key measure for raising a community's awareness of flooding is via the regular issuing of flood certificates to all occupiers of the floodplain. These flood certificates would inform individual property owners of the flood situation at their *particular property*. It is the site-specific nature of this advice (compared to a generic brochure) that offers the best chance of overcoming scepticism. Only after floodplain occupants accept that *they* could have a problem are they ready to take on board ideas about addressing that problem. A certificate would contain information such as the expected flood levels in a range of design floods and could also provide information on ground and floor levels where this information is available. This would allow an assessment of the depths of flooding over the property and building floor.

Flood certificates, such as the sample included as **Figure 6.17**, could be attached to Section 149 certificates. They could also be delivered with Council's rates notices every 2 years, along with advice about what people can do to prepare for flooding (e.g. brochures tailored to Nundle or Woolomin).

6.3.3.2 Brochures

As part of the current study, a newsletter was prepared and distributed in November 2006 to all properties in Nundle and Woolomin. As well as informing residents about the study, this newsletter endeavoured to raise the profile of floods as a serious threat (e.g., by providing a flashback to the 2000 flood). Especially for Woolomin where a relatively large number of houses are subject to flooding, there would be value in preparing a tailored FloodSafe Guide to accompany the others available for the Tamworth area.[14] This should describe the flood history at Woolomin and make clear that whilst Chaffey Dam does have flood mitigating benefits for Woolomin, it does not eliminate the threat of Peel River flooding (e.g. Nov 2000) and of course does nothing to mitigate Duncans Creek flooding (e.g. Jan 1984). It should also describe the dangers and discomforts of attempting to sit out a flood, persuading people to evacuate early (e.g. competing with snakes and spiders; septic tanks surcharging; being trapped as the water continues to rise, with the trauma that could cause).[15] The Guide should also describe the flood warning system (e.g. what does a sounding siren mean?), and the preferred evacuation strategy (e.g. what to do and where to go?).

6.3.3.3 Web-site

Tamworth Regional Council currently has some basic flood information on its web-site, including safety advice such as "don't drive through floodwaters".[16] A comparison with the flood information provided on other councils' web-sites suggests that there is significant scope for enhancing the current site.[17] Other information that could be added includes:

[14] www.ses.nsw.gov.au/community-safety/floodsafe/floodsafe-guides

[15] A good example of the fear a flash flood can engender is this footage from Postmans Ridge in the Lockyer Valley floods of January 2011: www.couriermail.com.au/news/queensland/charlotte-bull-22-captured-on-video-the-terrifying-moments-when-freak-flood-hit-her-parents-home-at-postmans-ridge/story-e6freoof-1225988428125

[16] www.tamworth.nsw.gov.au/Council/Emergency-Services/Flood-Management/default.aspx

[17] See Lismore City Council at www.lismore.nsw.gov.au (search for 'flood and emergency information) and Wollongong City Council at www.wollongong.nsw.gov.au (search for 'floodplain management').

FIGURE 6.17 – Sample Flood Certificate

Tamworth Regional Council

Flood Certificate

Certificate Issued for Property at: 25 River Street, Woolomin
Lot 25, DP 25252

Owners Name: Mr D. & Mrs I. Citizen

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1. Classification of Flood Risk

Council records indicate that the above property is located within a **High** Flood Risk area.

Land that is potentially subject to inundation is classified as low, medium or high flood risk. Council has prepared a development control plan that provides details of flood related development controls that may be applicable.

2. Known Floor and Ground Levels

The lowest habitable floor level of the main building on this property is: Source of information:	473.09m AHD Council Survey, March 2008
The lowest ground level on this property is: Source of information:	472.94m AHD Council Survey, March 2008

If the floor level and/or ground level are currently unknown and you would like to know what the levels are, this can be surveyed by a registered surveyor.

3. Estimated Flood Levels

Flood levels in the vicinity of the above property have been extracted from the Nundle and Woolomin Flood Study (Bewsher Consulting, 2011).

Size of Flood*	Flood Level	Depth over Lowest Floor Level	Depth over Lowest Ground Level
Probable Maximum Flood	476.7m AHD	3.6m	3.8m
100 Year Flood	474.0m AHD	0.9m	1.1m
50 Year Flood	473.8m AHD	0.7m	0.9m
20 Year Flood	473.7m AHD	0.6m	0.8m

**The Probable Maximum Flood (or PMF) is extremely rare.*
A 100 year flood is a large flood. It has a 1 in 100 (ie 1%) chance of occurring in any year.
A 50 year flood has a 1 in 50 (ie 2%) chance of occurring in any year.
A 20 year flood has a 1 in 20 (ie 5%) chance of occurring in any year.

Issued by Tamworth Regional Council
1st July 2011

- Information used during a flood including a list of local radio stations with their frequencies, links to flood warnings, guidelines of what to do, maps of evacuation routes and updated information about road closures;
- A brief description of each town and village's flood history and flood risk, together with a flood photo gallery; the *Towns and Villages* report (Bewsher Consulting, 2007) and *Flood Intelligence Collection and Review* (Bewsher Consulting, 2009) contain much useful information;
- Information about Council's floodplain management initiatives, including links to its various flood studies and floodplain risk management studies, when adopted; and
- Answers to frequently asked questions.

6.3.3.4 Flood markers/signs

The community questionnaire showed high levels of support for flood markers or signs as a way of promoting community flood awareness (**Figures 3.1** and **3.2**). One strategic location is Nundle Caravan Park, where a clear and permanent flood marker at the amenities block indicating the height of the November 2000 event, plus a poster describing the flood evacuation procedures, would be a valuable means for alerting the transient population of the park to the threat of flash flooding.

The use of semi-formal camping grounds along the banks of the Peel River downstream of Nundle is a seasonally significant risk exposure. Some signage alerting campers to the possibility of flash flooding has been mounted (**Figure 6.18a**), but the SES has indicated that there is a need for more such signage. It is also possible that some campers may not appreciate the significance of the message "Area subject to flash flooding". A more explicit sign would say "Area subject to fast rising, very dangerous flooding". There is also a need to provide campers guidance about what to *do* in the event of a flash flood, such as "Seek high ground immediately".

On the same principle of the vulnerability of campers unfamiliar with the local flood regime, there is also a need for signage at Riverside Park in Woolomin (**Figure 6.18b**).

6.3.3.5 Commemorations

The commemoration of severe floods has been an important means of raising flood awareness in many locations in NSW (Keys, 2002). The community would benefit if Council, with assistance from the SES, instituted an annual flood education week (or broader disaster awareness week) across the entire Local Government Area, with a concerted effort to publish relevant articles, give radio interviews, visit schools and other community groups, and have displays in local libraries.

6.3.3.6 Business FloodSafe

Few businesses are affected by floods in Nundle and Woolomin, but those that are would benefit by preparing a Business FloodSafe toolkit available on-line from the SES. In particular, flood modelling suggests that Nundle Woollen Mill may be at risk from frequent floods and should consider ways of managing its risk.

a. Camping area along Peel River downstream of Nundle

b. Riverside Park, Monro Street, Woolomin

FIGURE 6.18 – Peel River Camping Areas

6.3.3.7 Recommendations

A variety of techniques are available to build and maintain flood-ready communities. Education strategies need to be well conceived, with clear and realistic goals. For Nundle and Woolomin, short warning times limit the amount of property protection that can safely be achieved. Nevertheless, flood education can have an important role in making people alert to the threat of flooding and teaching safe actions during floods, thereby reducing the risk to human life.

For the purposes of the FRMP, a multi-faceted approach involving the following measures has been included:

- prepare and distribute flood certificates to residents within the floodplain;
- prepare and distribute a FloodSafe Guide for Woolomin;
- enhance the flood information available at Council's web-site;
- display a flood marker and poster describing the flood evacuation procedures at Nundle Caravan Park, and mark the extent of flood-prone land on the site maps (see **Section 6.3.2.2**);
- install additional signage at informal camping grounds downstream of Nundle;
- install a flood marker at Riverside Park in Woolomin;
- establish an annual "outreach" program across the Local Government Area, probably in about October since large floods have been most prevalent over the summer months;
- encourage business owners within the floodplain at Nundle and Woolomin to use the Business FloodSafe toolkit to assess and reduce their flood exposure.

7. DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

7.1 RECOMMENDATIONS

A draft Floodplain Risk Management Plan (FRMP) showing the preferred floodplain risk management measures for the Nundle and Woolomin study area is presented in this chapter. The recommended measures have been selected from the range of measures discussed in **Chapter 6**, after an assessment of each measure's impact on flood risk, as well as consideration of environmental, social, and economic factors. The recommended measures are presented in **Table 7.1**. The principal components of the Plan are presented below according to priority, which is assessed on the basis of how easily (quickly) each measure can be implemented and on value for money. The timing of the proposed works will depend on Council's overall budgetary commitments, and the availability of funds from other sources.

7.2 PRIORITISED MEASURES

High priority measures include:

- Council and State Water to consider Woolomin's flood mitigation requirements as part of the design of the Chaffey Dam augmentation (**Section 6.1.1.3**);
- Council to invite the owners of 5 properties exposed to intolerable flood risks at Nundle to participate in a voluntary house purchase scheme, as funds permit (**Section 6.2.1**);
- Council to investigate option for debris removal along Duncans Creek in order to mitigate flood risk;
- Council to consider the proposed revisions to the flood risk management controls in *TRDCP 2010*, as outlined in **Section 6.2.4.6**;
- Council to promote the reduction of flood risk to existing buildings as part of the redevelopment process (**Section 6.2.5.2**);
- Considering the pros and cons of further residential development on vacant lots, Council should not permit development on high hazard land in Nundle, but could permit the development of such land in Woolomin for a period of 2-5 years provided the risks to life and property can be adequately managed (**Section 6.2.5.3**);
- Council, SES and caravan park manager to improve the flood warning system in the manner described in **Section 6.3.1**;
- Council, SES and caravan park manager to improve emergency management capability and plans in the manner described in **Section 6.3.2**; and
- Council, SES and caravan park manager to improve the public's flood readiness in the manner described in **Section 6.3.3**.

Medium priority measures include:

- Council to review the flood study for Woolomin when ALS topography becomes available and/or if the Chaffey Dam stage-storage-discharge relationship changes (**Section 4.3**);
- Council to undertake preliminary design to assess the suite of levee and accompanying offset works which would be required to reduce damages and the frequency of outages at the Nundle water treatment plant, and then to implement the works if feasible (**Section 6.1.2.1**);
- Council to invite the owners of 1 property at Nundle and (at least) 7 properties at Woolomin to participate in a voluntary house raising/redevelopment scheme, with a

maximum $60K/house Government subsidy to raise the dwelling floors to above the 100 year (or higher) level (plus make other improvements to reduce the risk) (**Section 6.2.2**);

- Council to raise the water pumps in Hall Street and Oakenville Streets, Nundle (**Section 6.2.3**)

7.3 FUNDING AND IMPLEMENTATION

The total capital cost of implementing the draft Plan is estimated to be $2.5M, with maintenance costs of about $20K p.a. The timing of proposed works will depend on overall budgetary commitments of Council and the availability of funds from other sources. It is envisaged that the Plan would be implemented progressively over a 5 to 10 year time frame.

A variety of sources of funding may be drawn upon to implement the Nundle and Woolomin FRMP including:

- Council funds;
- State funding for flood mitigation measures through OEH;
- Commonwealth and State funding through the Natural Disaster Resilience Program;
- Funds from other organisations (e.g. SES) and private owners (e.g. Nundle Caravan Park);
- Volunteer labour from community groups.

Council can expect to receive the majority of financial assistance through OEH. These funds are available to implement measures that contribute to reducing existing flood problems. Funding assistance is usually provided on a 2:1 basis (State:Council) or a 1:1:1 basis (Commonwealth:State:Council).

Although much of the Plan may be eligible for Government assistance, funding cannot be guaranteed, since the limited Government funds are allocated on an annual basis to competing projects throughout the State. Options that receive Government funding must be of significant benefit to the community. Funding of investigation and design activities as well as any works is normally available. Maintenance, however, is usually the responsibility of Council.

7.4 ON-GOING REVIEW OF PLAN

The *Nundle and Woolomin FRMP* should be regarded as a dynamic instrument requiring review and modification over time. The catalyst for change could include flood events, revised flood modelling, better information about potential climate change flood impacts, legislative change, alterations in the availability of funding, or changes to the area's planning strategies. In any event, a thorough review every five years is recommended to ensure the ongoing relevance of the Plan.

TABLE 7.1 – Draft Nundle and Woolomin Floodplain Risk Management Plan

Measure No.*	Description	Capital Expenditure		Maintenance		Priority
		Est. Cost ($)	Funding Sources	Est. Cost ($ pa)	Funding Sources	
– (see Section 4.3)	Review flood study for Woolomin when ALS topography available and/or if Chaffey Dam stage-storage-discharge relationship changes (TRC)	$25K	OEH, Council	Nil	N/a	Medium
1.1.3	Consider Woolomin's flood mitigation requirements as part of Chaffey Dam augmentation design (TRC, State Water)	Nil	N/a	Nil	N/a	High
1.2.1	Levee around Nundle water treatment plant, with accompanying offset works (study first) (TRC)	$20K (study) $300K (works)	OEH, Council	Low	Council	Medium
1.4	Council to investigate options for debris removal along Duncans Creek in order to mitigate flood risk	Nil	N/a	Nil	N/a	High
2.1	Invite owners of 5 properties at Nundle to participate in a voluntary house purchase scheme (TRC)	$1.4M	OEH, Council	Nil	N/a	High
2.2	Invite owners of 1 property at Nundle and (at least) 7 properties at Woolomin to participate in a voluntary house raising/redevelopment scheme with $60K/house Government subsidy (TRC)	$480K	OEH, Council	Nil	N/a	Medium
2.3	Raise two water pumps at Nundle (TRC)	$50K	OEH, Council	Nil	N/a	Medium
2.4	*Existing planning controls:* ► Consider the proposed revisions to the flood risk management controls in *TRDCP 2010*, as outlined in Section 6.2.4.6 (TRC)	Low	Council	Nil	N/a	High
2.5	*Manage future development:* ► Use redevelopment to promote the reduction of flood risk to existing buildings (TRC) ► Considering the pros and cons of further residential development on vacant lots, do not permit development on high hazard land in Nundle, but permit the development of such land in Woolomin for a period of 2-5 years provided the risks to life and property can be adequately managed (TRC)	Low	Council	Nil	N/a	High
3.1	*Improve flood warning system:*					
	a. Alarm key rainfall and river level gauges above Nundle (TRC; Bureau)	Low	Bureau	Nil	N/a	High

Measure No.*	Description	Capital Expenditure		Maintenance		Priority
		Est. Cost ($)	Funding Sources	Est. Cost ($ pa)	Funding Sources	
	b. Analyse rain/river levels to inform selection of appropriate gauge triggers for alarming (SES)	Low	SES	Nil	N/a	High
	c. Install a telemetered river level gauge and rain gauge in Duncans Creek catchment (TRC; Bureau)	<$30K	Commonwealth, OEH, Council	$1K per rain gauge $5K per river gauge	Council	High
	d. Prepare a rainfall based flood intelligence tool for Nundle (SES) and install manual river gauge at accessible location in Nundle (TRC)	$10K	Council	Nil	N/a	High
	e. Pre-prepare a range of simple warning message templates for Nundle and Woolomin (SES)	Low	SES	Nil	N/a	High
	f. Establish automated telephone dial-out systems for Woolomin and Nundle (TRC)	$50K	Council	Low	Council	High
	g. Negotiate with State Water to retain the siren infrastructure at Woolomin and transfer to SES (TRC)	$20K	Council	Nil	N/a	High
	h. Install a public address system at Nundle Caravan Park (park manager)	$5K	Park manager	Nil	N/a	High
	i. Arrange to personally warn any campers below Nundle and at Woolomin (SES)	Nil	N/a	Nil	N/a	High
3.2	*Improve emergency management capability and plans:*					
	a. Update Local Flood Plan and other flood intelligence documents from this study (SES)	Low	SES	Low	SES	High
	b. Prepare flood emergency management plan for Nundle Caravan Park using template (park manager)	$5K (if consultant required)	Park manager	Low	Park manager	High
	c. Seal alternative evacuation route from Nundle Caravan Park to Jenkins Street (TRC)	$20K	OEH, Council	Nil	N/a	High
	d. Ensure any on-site vans on lower tier of Nundle Caravan Park remain mobile (park manager)	Nil	N/a	Nil	N/a	High
	e. Conduct audit of use of camping grounds down-stream of Nundle over summer; assess evacuation capability; prepare evacuation strategy (SES)	Low	SES	Nil	N/a	High
	f. Prepare evacuation strategy for Woolomin and resource the SES appropriately (SES)	Low	SES	Nil	N/a	High

Measure No.*	Description	Capital Expenditure		Maintenance		Priority
		Est. Cost ($)	Funding Sources	Est. Cost ($ pa)	Funding Sources	
3.3	*Improve public flood readiness:*					
	a. Prepare and distribute flood certificates to residents within the floodplain (TRC)	Nil	N/a	~$2K	Council	High
	b. Prepare and distribute a FloodSafe Guide for Woolomin (SES, TRC)	$10K	SES, Council	Nil	N/a	High
	c. Enhance the flood information available at Council's web-site (TRC)	$20K	Council	~$1K	Council	High
	d. Display flood marker and poster describing flood evacuation procedures at Nundle Caravan Park, and mark extent of flood-prone land on site maps (park manager)	$10K	Park manager	Nil	N/a	High
	e. Install additional signage at informal camping grounds downstream of Nundle (TRC)	$20K	OEH, Council	Nil	N/a	High
	f. Install flood marker at Riverside Park in Woolomin (TRC)	$10K	OEH, Council	Nil	N/a	High
	g. Establish an annual flood education "outreach" program across the Local Government Area (TRC, SES)	Nil	N/a	$10K	Council, SES	High
	h. Encourage business owners to use Business FloodSafe toolkit to assess and reduce their flood exposure (SES)	Nil	N/a	Nil	N/a	High
	TOTAL	**~$2.5M**		**~$20K**		

* To locate the report section in which the measure is described, for Measure No. 1.2.1 read Section 6.1.2.1, and so on.

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9. FREQUENTLY ASKED QUESTIONS

Why do flood levels change over time?

There is a chance that floods of various magnitudes will occur in the future. As the size of a flood increases, the chance that it will occur becomes rarer. Because some of these rare floods have never been experienced or accurately recorded since European settlement, the height of future floodwaters is normally predicted using computer models. These computer models simulate flood levels and velocities for a range of flood sizes and flood probabilities. Given the importance of estimating flood levels accurately, councils and the NSW Office of Environment and Heritage (OEH) engage experts to establish and operate the computer models.

From time to time the computer models are revised and predicted flood levels can change. The resultant change in flood levels however is normally very small. The reasons why the computer models are revised can include:

- new rainfall or ground topography information becomes available;
- new floods occur which provide additional data from which to fine-tune the models;
- better computer models become available as the science of flood modelling improves and computer capabilities increase; or
- flood mitigation works may have been carried out, or development within the catchment may have occurred, that was not previously simulated in the models.

How are these studies funded?

Flood studies and floodplain risk management studies are normally carried out under State Government guidelines and are often funded on a 1:1:1 basis among the Federal and State Governments, and councils. This funding arrangement is also available for the construction of flood mitigation works.

How have the flood risk maps been prepared?

Because some large and rare floods have often not been experienced or accurately recorded since European settlement commenced, computer models are used to simulate the depths and velocities of major floods. These computer models are normally established and operated by flooding experts employed by local and state government authorities. Because of the critical importance of the flood level estimates produced by the models, such modelling is subjected to very close scrutiny before flood information is formally adopted by a council. Maps of flood risks are prepared after consideration of such issues as:

- flood levels and velocities for a range of possible floods;
- ground levels;
- flood warning time and duration of flooding;
- suitability of evacuation and access routes; and
- emergency management during major floods.

What is the probable maximum flood (PMF)?

The PMF is the largest flood that could possibly occur. It is a very rare and improbable flood. Despite this, a number of historical floods in Australia have approached the magnitude of a PMF. Every property potentially inundated by a PMF will have some flood risk, even if it is very small. Under the State Government's Floodplain Development Manual (2005), councils must consider all flood risks, even these potentially small ones, when managing floodplains. As part of the State Government's Manual, the definitions of the terms 'flood liable', flood prone' and 'floodplain' refer to land inundated by the PMF.

What is the 100 year flood?

A 100 year flood is the flood that will occur or be exceeded on average once every 100 years. It has a probability of 1% of occurring in any given year. If your area has had a 100 year flood, it is a fallacy to think you will need to wait another 99 years before the next flood arrives. Floods do not happen like that. Some parts of Australia have received a couple of 100 year floods in one decade. On average, if you live to be 70 years old, you have a better than even chance of experiencing a 100 year flood.

Why do councils prepare floodplain management studies and plans?

Under NSW legislation, councils have the primary responsibility for management of development within floodplains. To appropriately manage development, councils need a strategic plan which considers the potential flood risks and balances these against the beneficial use of the floodplain by development. To do this, councils have to consider a range of environmental, social, economic, financial and engineering issues. This is what happens in a floodplain risk management study. The outcome of the study is the floodplain risk management plan, which details how best to manage flood risks in the floodplain for the foreseeable future.

Floodplain risk management plans normally comprise a range of works and measures such as:

- improvements to flood warning and emergency management;
- works (e.g. levees or detention basins) to protect existing development;
- voluntary purchase or house raising of severely flood-affected houses;
- planning and building controls to ensure future development is compatible with the flood risks; and
- measures to raise the community's awareness of flooding so that they are better able to deal with the flood risks they face.

Will the flood risk maps be changed?

Yes. All mapping undertaken by council is subjected to ongoing review. As these reviews take place, it is conceivable that changes to the mapping will occur, particularly if new flood level information or ground topography information becomes available. However, this is not expected to occur very often and the intervals between revisions to the maps would normally be many years. Many councils have a policy of reviewing and updating floodplain management studies and plans about every five to ten years. This is the likely frequency at which the maps may be amended.

10. GLOSSARY

Note that terms shown in bold are described elsewhere in this Glossary.

1% AEP flood	A **flood** that occurs (or is exceeded) on average once every 100 years. Also known as a 100 year flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
2% AEP flood	A **flood** that occurs (or is exceeded) on average once every 50 years. Also known as a 50 year flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
5% AEP flood	A **flood** that occurs (or is exceeded) on average once every 20 years. Also known as a 20 year flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
10% AEP flood	A **flood** that occurs (or is exceeded) on average once every 10 years. Also known as a 10 year flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
20% AEP flood	A **flood** that occurs (or is exceeded) on average once every 5 years. Also known as a 5 year flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
100 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 100 years. Also known as a 1% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
50 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 50 years. Also known as a 2% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
20 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 20 years. Also known as a 5% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
10 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 10 years. Also known as a 10% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
5 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 5 years. Also known as a 20% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
acid sulphate soils	Sediments which contain sulphidic mineral pyrite which may become extremely acid following disturbance or drainage as sulphur compounds react when exposed to oxygen to form sulphuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulphate Soil Manual published by the Acid Sulphate Soil Management Advisory Committee.
afflux	The increase in flood level upstream of a constriction of flood flows. A road culvert, a pipe or a narrowing of the stream channel could cause the constriction.

annual exceedance probability (AEP)	AEP (measured as a percentage) is a term used to describe the frequency or probability of floods occurring. Large floods occur rarely, whereas small floods occur more frequently. For example, a 1% AEP flood occurs (or is exceeded) on average once every 100 years. It is also referred to as the '100 year flood' or the '1 in 100 year flood'.
Australian Height Datum (AHD)	A common national plane of level approximately equivalent to the height above sea level. All flood levels, floor levels and ground levels are normally provided in metres AHD.
average annual damage (AAD)	Average annual damage is the average flood damage per year that would occur in an area over a long period of time.
average recurrence interval (ARI)	ARI (measured in years) is a term used to describe the frequency or probability of floods occurring. Large floods occur rarely, whereas small floods occur more frequently. For example, a 100 year ARI flood is a flood that occurs (or is exceeded) on average once every 100 years. See also **annual exceedance probability (AEP)**.
Bureau	The Australian Bureau of Meteorology.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site.
Development Control Plan (DCP)	A DCP is a plan prepared in accordance with Section 72 of the *Environmental Planning and Assessment Act, 1979* that provides detailed guidelines for the assessment of development applications.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (**m^3/s**). Discharge is different from the speed or **velocity** of flow, which is a measure of how fast the water is moving.
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the *Local Government Act 1993*.
effective warning time	The time available after receiving advice of an impending **flood** and before the floodwaters prevent appropriate flood response actions being undertaken. The **effective warning time** is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding. In NSW, the State Emergency Service (SES) is the principal agency involved in emergency management during floods.
flood	A relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam. It includes local overland flooding associated with major drainage before entering a watercourse. In addition, it includes coastal inundation resulting from raised sea levels, or waves overtopping the coastline.
flood awareness	An appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.

flood hazard	The potential for damage to property or risk to persons during a **flood**. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use.
flood liable land	Land susceptible to flooding up to the **probable maximum flood (PMF)**. Also called **flood prone land**. Note that the term 'flood liable land' now covers the whole of the **floodplain**, not just that part below the 100 year flood level.
flood planning levels (FPLs)	The combination of flood levels and **freeboards** selected for planning purposes, as determined in **floodplain risk management studies** and incorporated in **floodplain risk management plans**. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies.
flood prone land	Land susceptible to flooding up to the **probable maximum flood (PMF**). Also called **flood liable land**.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate damages during a **flood**.
flood risk precinct	An area of land with similar flood risks and where similar development controls may be applied by a council to manage the flood **risk**. (The flood risk is determined based on the existing development in the precinct or assuming the precinct is developed with normal residential uses). Usually the floodplain is categorised into three flood risk precincts — 'low', 'medium' and 'high' — although other classifications can sometimes be used. (See also **risk**).
Flood Study	A study that investigates flood behaviour, including identification of flood extents, flood levels and flood velocities for a range of flood sizes.
floodplain	The area of land that is subject to inundation by floods up to and including the **probable maximum flood** (PMF) event, that is, **flood prone land** or **flood liable land**.
Floodplain Risk Management Plan	The outcome of a **Floodplain Risk Management Study**. (Note that the term 'risk' is often dropped in common usage and 'Floodplain Risk Management Studies or Plans' are referred to as 'Floodplain Management Studies and Plans'.)
Floodplain Risk Management Study	These studies are carried out in accordance with the *Floodplain Development Manual* (NSW Government, 2005) and assess options for minimising the danger to life and property during **floods**. These options aim to achieve an equitable balance between environmental, social, economic, financial and engineering considerations. The outcome of a Floodplain Risk Management Study is a **Floodplain Risk Management Plan**.
floodway	Floodways are those parts of a floodplain where a significant discharge of water occurs during **floods**. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
flow	See **discharge**

freeboard	A factor of safety expressed as the height above the flood level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the **floodplain**, such and wave action, localised **hydraulic** behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as 'greenhouse' and climate change.
geographical information system (GIS)	A system of software designed to support the management, manipulation, analysis and display of spatially referenced data.
geomorphology	The study of landforms.
high flood hazard	For a particular size **flood**, there may be a possible danger to personal safety, able-bodied adults may have difficulty wading to safety, evacuation by trucks may be difficult and/or there may be a potential for significant structural damage to buildings.
hydraulics	Term given to the study of water flow; in particular, the assessment of flow parameters such as water level and **velocity**.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the estimation of **peak discharges**, flow volumes and the derivation of hydrographs (graphs that show how the discharge at any particular location varies with time during a flood).
Local Environmental Plan (LEP)	A Local Environmental Plan is a plan prepared in accordance with the *Environmental Planning and Assessment Act*, 1979, that defines zones, permissible uses within those zones and specifies development standards and other special matters for consideration with regard to the use or development of land.
low flood hazard	For a particular size flood, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.
m AHD	Metres **Australian Height Datum (AHD)**.
m/s	Metres per second. Unit used to describe the **velocity** of floodwaters. 10km/h $\approx$ 2.8m/s.
m^3/s	Cubic metres per second or 'cumecs'. A unit of measurement for flows or **discharges**. It is the rate of flow of water measured in terms of volume per unit time.
merit approach	The principles of the merit approach are embodied in the *Floodplain Development Manual* (NSW Government, 2005) and weigh up social, economic, ecological and cultural impacts of land use options for different **flood prone** areas together with flood damage, **hazard** and behaviour implications, and environmental protection and well being of the State's rivers and **floodplains**.
OEH	NSW Office of Environment and Heritage was formed in April 2011. Previously the State Government's Flooding Unit was part of the NSW Department of Environment, Climate Change and Water (DECCW). Prior to that it was part of the Department of Environment and Climate Change (DECC), the Department of Natural Resources (DNR), and the Department of Infrastructure, Planning and Natural Resources (DIPNR).

overland flow path	The path that floodwaters can follow when not confined within a flow channel. Overland flow paths can occur through private property or along roads.
peak discharge	The maximum **flow** or **discharge** during a flood.
present value	In relation to flood damage, is the sum of all future flood damages that can be expected over a fixed period (usually 20 years) expressed as a cost in today's value.
probable maximum flood (PMF)	The largest flood likely to ever occur. It has a very rare chance of occurring. The PMF defines the extent of **flood prone land** or **flood liable land**, that is, the **floodplain**.
reliable access	During a **flood**, reliable access means the ability for people to safely evacuate an area subject to imminent flooding within the **effective warning time**, having regard to the depth and **velocity** of floodwaters, the suitability of the evacuation route and other relevant factors.
risk	Risk is measured in terms of consequences and likelihood. In the context of floodplain management, it is the likelihood and consequences arising from the interaction of floods, communities and the environment. For example, the potential inundation of an aged person's facility presents a greater flood risk than the potential inundation of a sportsground amenities block (if both buildings were to experience the same type and probability of flooding). Reducing the probability of flooding reduces the risk, increasing the consequences increases risk. (See also **flood risk precinct**).
risk management	The process of identifying, analysing, evaluating, treating, monitoring and communicating risks. A generic framework for risk management in Australia is provided in the joint Australian and New Zealand Standard AS/NZS 4360;1999.
runoff	The amount of rainfall that ends up as flow in a stream, also known as rainfall excess.
SES	State Emergency Service of New South Wales.
Section 149 Certificates	In NSW, councils issue these certificates to potential property purchasers under Section 149 of the NSW Environmental Planning and Assessment Act. It is compulsory to attach S149(2) certificates to contracts for sale of land and these certificates generally identify policies affecting development of the land. Other information and risks concerning the property are generally provided on S149(5) certificates (which are not compulsory in contracts for sale of land).
stage–damage curve	A relationship between different water depths and the predicted flood damage at that depth.
velocity	The term used to describe the speed of floodwaters, usually in **m/s** (metres per second). 10km/h = 2.8m/s.

APPENDIX A

HISTORIC FLOODS

Feb 1955 flood
Extract from unknown newspaper 25 Feb 1955
Source: Gerard Ryan

Nundle Flood Worst In 45 Years

NUNDLE.—The worst flood for 45 years occurred last week when the water rose to the bottom of the bridge over the Peel River.

Five families were evacuated, they were the families of Messrs. M. Taylor, G. Phoo, H. Jackson, W. Mitchell and N. Fisher.

Although miles of fencing were washed away, little damage was done to stock or property.

At Bowling Alley Point the water entered the Public Hall, and one or two residences and fences were flattened.

At Woolomin the damage was severe. Nearly every home was affected by mud. Families were removed to the homes of relatives and friends. Linoleums and carpets were ruined. Refrigerators and furniture were badly damaged by the flood waters.

The bridge over the Peel is damaged beyond repair, and will have to be replaced.

The new Woolomin hall was washed off its blocks and carried several yards away.

At Dungowan, homes were isolated by the flood waters. One resident lost more than 1000 pullets and hens.

About 10 inches of rain fell at Nundle in four days, but it was the heavier rains at the head of the river that caused the river to flood twice in one week.

Nov 2000 flood

Extracts from *The Northern Daily Leader*

Tuesday 21 November 2000 p.3

Heartbreak for Nundle family

By Donna Hurley

NEVILLE and Leanne Hoad fought back tears yesterday as the devastating impact of a flash flood which roared through their Nundle home on Sunday night became apparent.

The SES rescued the family including their two children Courtney, 11, and Fabian, 7, using a tractor mounted with a dozer blade from their front step around 2 o'clock yesterday morning.

The terrified four scrambled into the blade and then onto the tractor as a wall of water described by local SES as like a "tidal surge" roared down the valley swamping the Hoads' weatherboard house and washing virtually everything away.

Washed away: Leanne, Neville and Courtney Hoad have been left devastated by the floodwaters which raged through their home on Nundle's Peel River flat on Sunday night. Photos: **Robert Chappel.**

Their six head of cattle, six hens including the chook house, a cockie in his cage, three cars, a ride-on mower and the entire garage and its contents were taken in the tide.

Neville said he found four head of cattle downstream yesterday morning but the other animals had simply disappeared.

"It was frightening, I tried to take the cat but she was clawing around my neck as I got onto the tractor so I threw her back inside and she was there this morning when we came back," Leanne said.

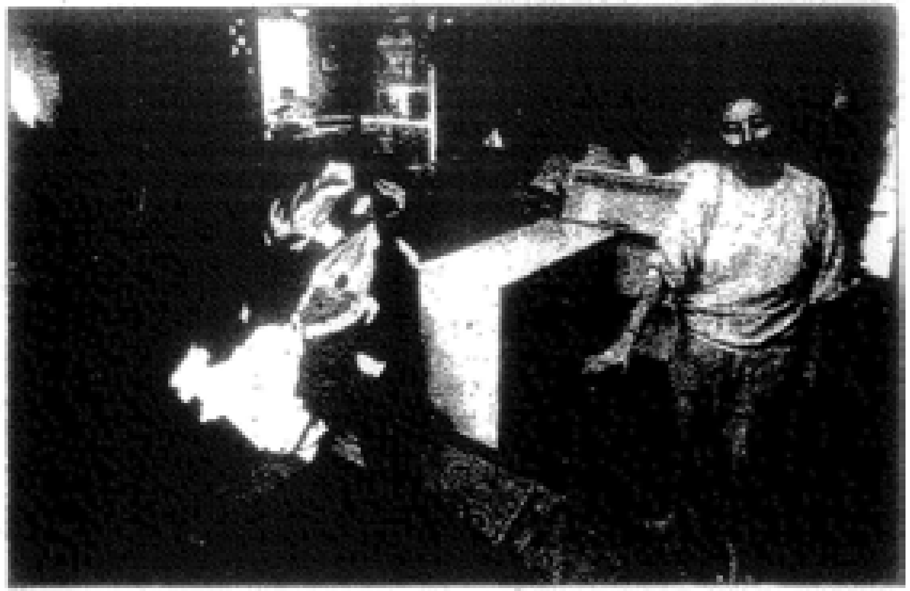
Neville said the family was sound asleep when a phone call from the SES around midnight alerted them to the Peel River's rising waters which had been boosted by a downpour of almost five inches in the head waters.

"I went to the back door and looked over to the river and could see the water coming up but I saw that two days ago, I wasn't worried, so I went and laid back down again.

"Leanne got up after a while to check and started yelling out at me that there was about two foot of water around the house," he said.

The Hoads spent the night at a local motel and yesterday with the help of volunteers sifting through the mud and wreckage.

"I don't know what we're going to do, we're here, that's about it," Neville said.



Leanne Hoad shows the height floodwaters reached in her Nundle home on Sunday night.

Tuesday 21 November 2000 p.6

Worst flood on record for Nundle

By Megan Dixon
News reporter

THE village of Nundle was in clean-up mode yesterday after the worst flood on record which saw three wooden bridges, including the one over the Peel at Bowling Alley Point, torn away.

The Peel River and Oakenville Creek broke their banks at midnight Sunday, flooding houses, shops and a caravan park.

The river was 250m wide in the village at the peak of the deluge, which dumped 115mm in the upper Peel valley between 8 o'clock Sunday night and 6am Monday.

After a week of solid rain, the storm was too much for the already saturated catchment, swollen creeks and rivers.

Nundle State Emergency Service controller Tony Taylor said the flood was more destructive than the worst flood on record in 1955.

"Houses in Woolomin are two to three feet under water and the village is isolated apart from a forestry road through Hanging Rock," Mr Taylor said.

"We're now cleaning up, feeding and accommodating people at Woolomin and Nundle whose houses were flooded.

"There is still a lot of water over the roads and some have been completely cut off because bridges have disappeared."

Several families were woken by the roar of the river and the heaviness of the rain at midnight and returned to bed, reassured that they were not in danger. Just 15 minutes later there was nearly a metre of water running through their houses.

Leanne and Neville Hoad's house was completely flooded and the force of the water lifted three cars – smashing two against a tree in their backyard and carrying another 200m.

Oakenville Creek was running through Nundle Garage and Nundle Country Cafe.

The creek pulled a metal door off its hinges at the garage and was nearly a metre high in the cafe and adjoining residence.

Markus Lang and Chelle Kuskoff at Nundle Country Cafe have furniture and belongings scattered throughout Nundle, lifted to higher ground by about 80 volunteers in the middle of the night.

Despite this, Nundle Country Cafe was open for business early yesterday morning.

The wooden fence around Nundle Recreation Ground was flattened and a brick toilet block damaged.

Kilometres of farm fencing were destroyed and many livestock lost.

Round plastic covered bales of silage belonging to Geoff Swain were lifted and deposited hundreds of metres downstream.

Nundle remains accessible from the New England Highway near Wallabadah and Garoo. The Peel River bridge at Nundle was open to light traffic only pending an engineer's inspection yesterday afternoon.

Couple loses everything

By Donna Hurley

NUNDLE couple Cal and Maree Bouveng thanked their lucky stars yesterday when they remembered they had insured their home and its contents for flood damage.

It will make the burden of mopping up from the 1m wall of water which flowed through their house on Sunday night so much easier but the scene remained heartbreaking.

Cal said they woke up around 1.45am yesterday to a phone call from the owner of the nearby caravan park who said the Peel River was at their door.

"I looked out the window and saw the water flowing through our front fence. I told my wife to get dressed and we jumped into the car parked in the garage and even then we had to back out in about a foot of water," he said.

The Bouvengs returned around 3am when the water had already dropped but not before it reached the window sills and completely surrounded the house.

"We've lost everything in the house, around $30,000 worth all up including the fence and gardens which we had just planted out," he said.

Insurance won't replace the photo albums but it will help Cal Bouveng and his wife Maree replace "everything" they lost during the Peel River flood in Nundle on Sunday night. Photo: Robert Chappel.

Thursday 23 November 2000 p.2

Woolomin problems compound

By Stephanie van Eyk
News reporter

THE tiny community of Woolomin is trying to cope with the devastation caused by flooding, but their lot has been made even worse with no drinking water or sewerage system.

They can't flush the toilet or turn on a tap to get a glass of water.

The floodwater didn't just wreck farmland, sheds, houses and possessions – it also made septic tanks overflow creating a serious health risk.

In Woolomin, much of the drinking water comes from wells or underground sources and could be easily contaminated by debris in the floodwater and raw sewage.

Septic tanks of up to 50 houses will have to be pumped out. Brian Howard and Ron Wells were manning the two trucks commissioned to pump out the tanks. Mr Howard said some were "mostly full of water and not much sewage".

Residents have been provided with portable toilets located in a central spot until all the septic tanks are given the all clear.

But the answer to the polluted drinking water problem is a little more complicated.

Any drinking water that has been touched by floodwater should not be consumed. Woolomin residents have been provided with bottled water to drink and a water tank on a truck for bathing and washing clothes.

Nundle SES-controller Tony Taylor said once the septic tanks were operational and NorthPower had finished checking the electrics of flood damaged houses the next step would be for residents to flush out their wells.

Mr Taylor said tank water should be safe to drink. And once wells have been flushed by pumping the water out until it's clear, Woolomin residents will be able to drink the water again.

If all goes as planned Mr Taylor said water and plumbing problems would be rectified by the weekend.

Village residents' household items now just soggy mess

IF YOU drive through Woolomin you will see mounds of soggy rubbish piled high in most people's front yards.

Closer inspection will reveal the "rubbish" is actually carpet and underlay, clothing, fridges, washing machines, freezers and other household items damaged beyond repair by floods.

One resident, Michael Claydon, said the house he was renting was extensively damaged. Before the floods hit he had moved or raised as many of his belongings as possible but he still lost $6000 or $7000 worth.

He was one of the luckier ones.

Christina Jack's house was one of the worst hit in the town. She's lost just about everything from the fridge to her couch and an old Bible given to her as a wedding present. The flood was so destructive she's decided to move.

Jan 2010 flood

Extracts from *The Northern Daily Leader*

Nundle campers move in nick of time as river rises

www.northerndailyleader.com.au/news/local/news/general/nundle-campers-move-in-nick-of-time-as-river-rises/1717198.aspx

03 Jan, 2010 09:37 PM

CAMPERS and caravanners were lucky to escape a quick-rising flood in Nundle on Saturday because the local SES couldn't get through to the Fossickers' Tourist Park manager's mobile phone.

Nundle SES controller Tony Taylor ended up driving down to the park's manager, Heath Atchison, to warn him he had about half an hour to move caravans and tents to higher ground before floodwaters arrived.

About eight caravans and two campervans were moved before the flood hit at 1.30pm.

"It would have been about 1pm we started to pull people out," Mr Atchison said.

"A few of them have left today.

"We were lucky — we had a lot of people leave on Saturday (morning), about 20."

Several houses in Nundle were also evacuated by the SES.

Mr Taylor said the flood happened "extremely fast".

A house in Hall St had to be evacuated, then two houses on the corner of Innes St and South Herring St.

"We start from the top of town because that's where the water comes from," he said.

Mr Taylor and five other SES volunteers also helped landowners move about 30 head of cattle and seven horses to higher ground, via the main street.

"Nundle Bridge was closed for approximately two hours," Mr Taylor said.

The Pearly Gates Bridge about 5km north of town "went under around 1pm — it was closed for a good hour or two".

He also said that the abutments were washed away on Barnard Bridge, 25km east of Nundle.

He said it wasn't as bad a flood as the 2000 flood.

"It would have been a metre-and-a-half less water," he said.

"The scary part about the 2000 floods was it was in the middle of the night.

"We're extremely lucky that the water that comes off Crawney Mountain wasn't as bad as the 2000 floods, so the majority of the water came out of the head of the Peel (River) and Nundle Creek."

He said Woolomin didn't flood this time, not like in the 2000 flood.

The big wet: Flash flood in Peel cuts water supply to Nundle

www.northerndailyleader.com.au/news/local/news/general/the-big-wet-flash-flood-in-peel-cuts-water-supply-to-nundle/1717205.aspx

SIMON CHAMBERLAIN

03 Jan, 2010 09:41 PM

NUNDLE residents are facing a domestic water crisis in the next couple of days and are being urged by the Tamworth Regional Council to restrict consumption to essential indoor use only.

The cause of the crisis was the flash flooding on the weekend when the water treatment plant was inundated, disrupting the town's supply.

The emergency has prompted a call from the council for a temporary and drastic cut in demand so the plant can continue to maintain enough supply for Nundle for the next few days.

The council's water spokesman Michael Bryant said the Peel River flooded Nundle's treatment plant settling ponds, and this brought a stop to all new production of treated water.

The council said the town was now relying on the reservoir stock and until staff can get in and clean out the settling ponds residents are being asked to conserve water.

Emergency water restrictions are now in force in Nundle until the problem is fixed.

Mr Bryant said residents are being asked to cut their town water supply use to a bare minimum – or essential indoor use only – to conserve supply.

It will take a couple of days to remove the sediment or silt dumped by floodwaters in the settling ponds and then resume normal water treatment production to supply village demand.

"We cannot produce any water at all at the moment until we clean out those ponds so we are asking people to limit their use of town water to essential internal needs only," Mr Bryant said.

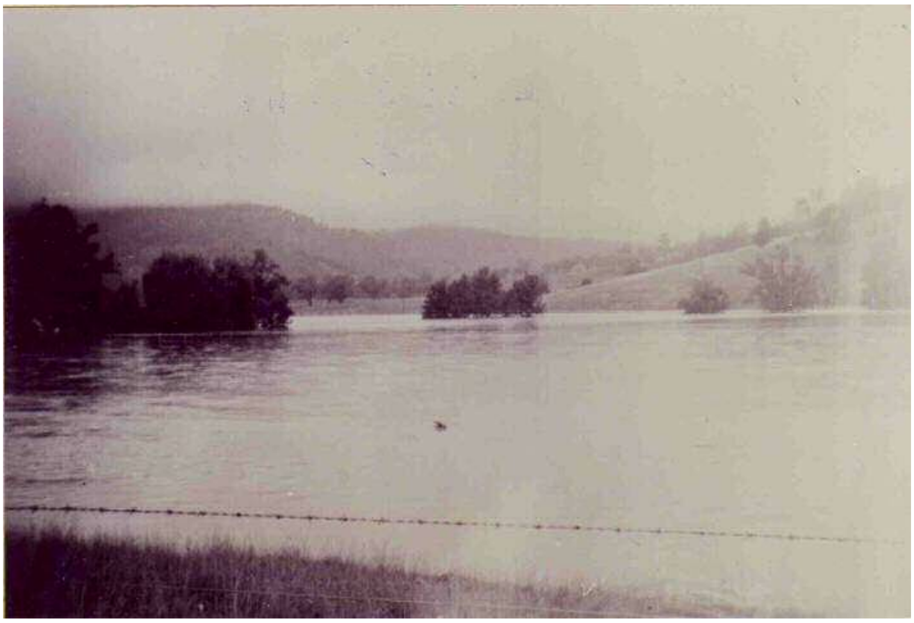
Photo archive

Woolomin floodplain, **1955** flood

Source: Gerard Ryan

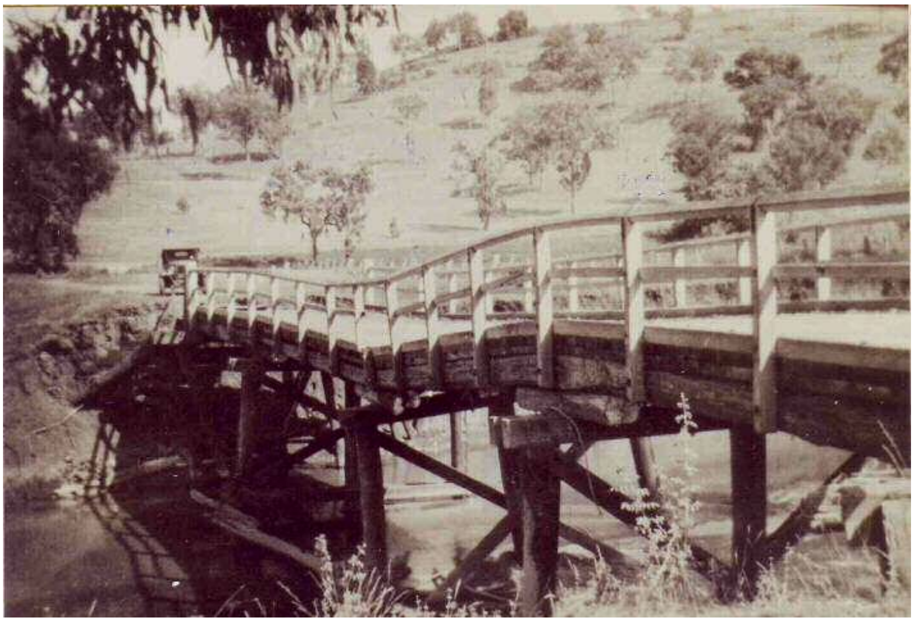
Woolomin floodplain, **1955** flood

Source: Gerard Ryan



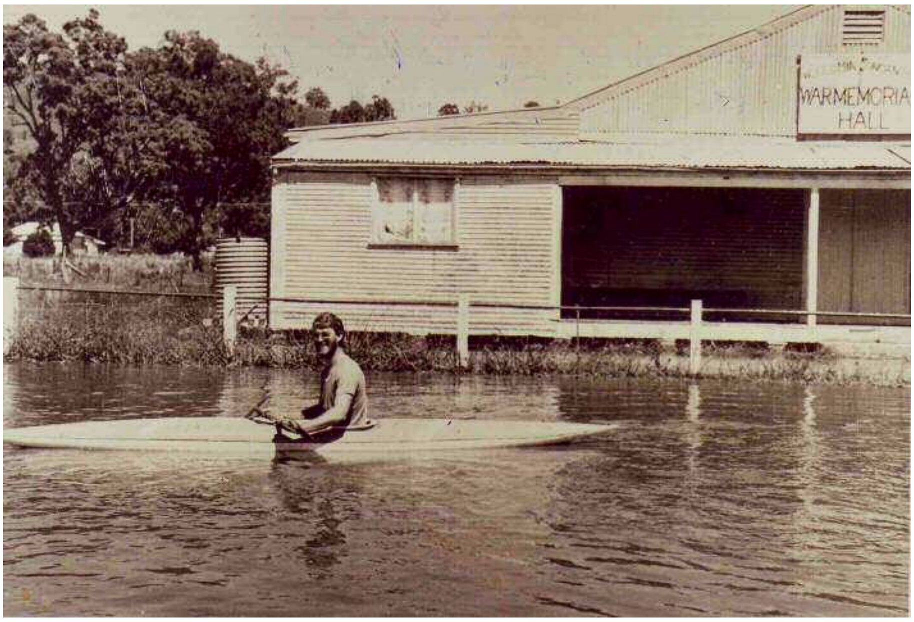
Looking up Duncans Creek, Woolomin, **1955** flood

Source: Gerard Ryan



Peel River bridge at Woolomin after **1955** flood

Source: Gerard Ryan



Woolomin hall, **1984** flood

Source: Gerard Ryan

Debris line at water treatment plant, Hall Street, Nundle, after **2000** flood

Source: OEH

Flood peak line at Jenkins Street house, Nundle, after **2000** flood

Source: OEH

Damaged floor coverings at Herring Street house, Nundle, after **2000** flood

Source: OEH

Destroyed caravan at Nundle Caravan Park after **2000** flood

Source: SES

Water stain at base of shop counter in Woolomin store, showing water level in **2000** flood

Source: Bewshers

Debris at Pearly Gates Bridge, Peel River upstream of Nundle, **2010** flood

Source: Kerrie Fearby

Nundle Bridge, **2010** flood

Source: Kerrie Fearby

Nundle Recreation Ground, **2010** flood

Source: Kerrie Fearby

Oakenville Creek through Nundle Caravan Park with causeway submerged, **2010** flood

Source: Kerrie Fearby

Damaged fencing at Nundle Recreation Ground after **2010** flood

Source: Kerrie Fearby

Damaged toilet block, Nundle Recreation Ground, after **2010** flood

Source: OEH

APPENDIX B

COMMUNITY CONSULTATION MATERIAL

- **Community Newsletter**
- **Community Questionnaire**
- **Agency Questionnaire**
- **Agency Response**

NUNDLE AND WOOLOMIN,
FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

COMMUNITY NEWSLETTER
NOVEMBER 2006

Introducing the study

Tamworth Regional Council has commissioned a study to identify and manage flood risks at Nundle and Woolomin. This study is called the **Nundle and Woolomin Floodplain Risk Management Study & Plan**.

Why do we need to consider flooding?

Nundle and Woolomin have a long history of flooding from the Peel River and local tributaries including Oakenville Creek and Duncans Creek. The villages were subject to flooding in 1955, 1984 and 1996. Flooding experienced on the night of **19/20 November 2000** is thought to be the flood of record. More than 110mm rain fell in 10 hours at Nundle. About 10 houses were flooded above floor level in Nundle, as well as several cabins and caravans. Two families had to be rescued under extremely dangerous conditions. The pump station and water treatment works were flooded and damaged. Three bridges were washed away. About 150 people at Woolomin had to be evacuated due to public health risks resulting from floodwaters causing septic tanks to overflow and foul the village groundwater supplies.

Destroyed caravan in Nundle Caravan Park after November 2000 flood *(Source: SES)*

Why do we need a study?

Under the NSW State Government's Flood Policy, the management of floodplains is the responsibility of local councils. Tamworth Regional Council is responsible for local planning, development controls and land management within floodplains at Nundle and Woolomin.

The Flood Policy states that councils need to prepare a Flood Study, a Floodplain Management Study and a Floodplain Management Plan to outline how they plan to manage floodplains now and in the future. By preparing these studies for Nundle and Woolomin, Council will meet its obligations and also open the way for Council to apply for State Government financial assistance to carry out works and other measures to reduce the risk.

Nundle Pump Station, showing the level of historical floods. The November 2000 flood reached to the middle railing.

Who is responsible for the study?

The study is being overseen by the Tamworth Regional Floodplain Management Committee. The Committee comprises representatives from the Council, the Department of Natural Resources, the State Emergency Service, and the local community. Current members are:

COUNCIL REPRESENTATIVES

- Cr Diane Carter (chairperson)
- Cr Phil Betts

COUNCIL OFFICERS

- Peter Resch
- Michael Bloem
- Alison McGaffin
- David Lewis
- Andrew Galvin

DEPARTMENT OF NATURAL RESOURCES

- Neal Albert

STATE EMERGENCY SERVICE

- Tony Taylor, Nundle Unit Controller

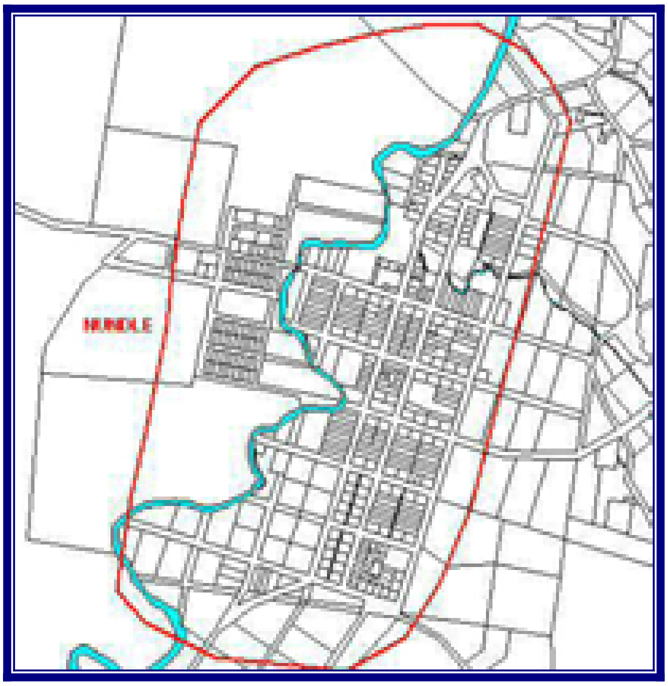
COMMUNITY REPRESENTATIVES

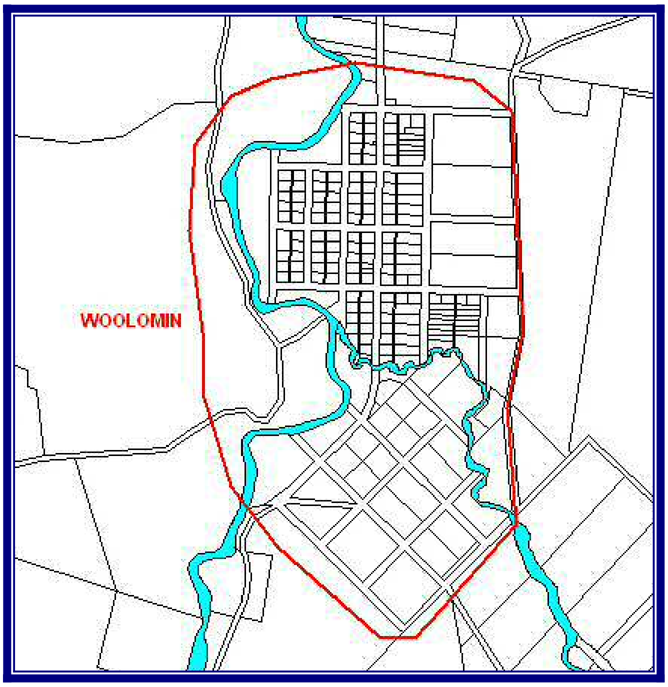
- Jackie Bromfield
- Robert Donoghoe
- Barry John
- Charles May

Council has commissioned Bewsher Consulting Pty Ltd to facilitate the Floodplain Management Study and Plan for Nundle and Woolomin. Bewsher Consulting is an independent company specialising in floodplain risk management.

Where is the study area?

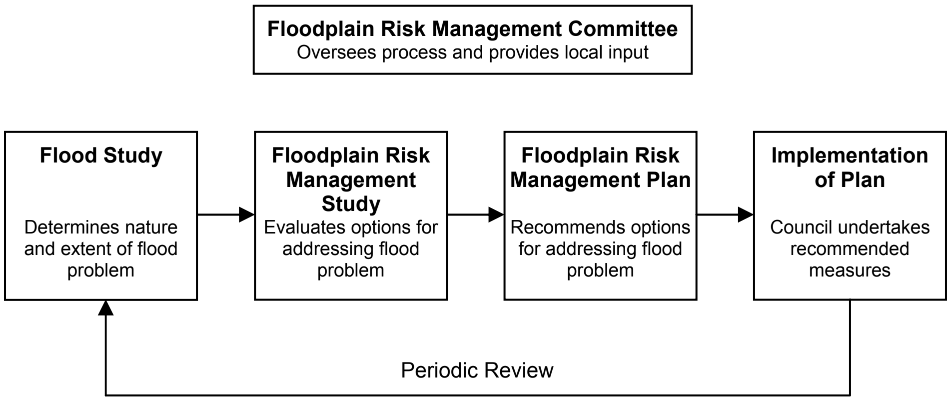
The extent of the study area is shown in the figures below:





What is the study about?

Floodplain risk management in NSW follows a process of defined steps. These are depicted in the diagram opposite.



The Floodplain Risk Management Process in NSW *(derived from the Floodplain Development Manual)*

The first step of the floodplain risk management process is the preparation of a **Flood Study**. This uses state-of-the-art computer modelling to simulate flood behaviour through the study area. A good deal of data is required to develop the model, including rainfall, topography, bridge and culvert capacity, and historic flood levels. The model will be fine-tuned to reproduce the flood behaviour experienced in the November 2000 event. From that base event, the model will be used to simulate flood behaviour in 'design' events, such as the 100 year flood.

The **Floodplain Risk Management Study** considers various options that may be able to reduce the damages caused by floods. This evaluation takes into account local residents' views, as well as environmental, social, economic and engineering factors. Among the options that could be considered are:

Measures that modify the way a flood behaves

a. Constructing detention basins
b. Constructing bypass channels or floodways
c. Enlarging bridges and culverts
d. Creek widening and/or dredging
e. Clearing creeks of debris
f. Removing floodplain obstructions
g. Constructing permanent levees
h. Filling low-lying land

Measures that modify property

i. Council purchasing the most severely flood affected properties
j. Raising houses above the 100 year flood level
k. 'Flood-proofing' properties (e.g. waterproofing walls, shutters)
l. Placing controls on new buildings (e.g. minimum floor levels)

Measures that modify people's response to flooding

m. Improving flood warning systems
n. Improving evacuation plans
o. Promoting community flood awareness
   - Installing flood markers (for example, on telegraph poles) to act as reminders of the heights of previous floods
   - Providing a certificate to all residents stating whether their property is flood-affected
p. Promoting community flood readiness
   - Assisting people to prepare Flood Action Plans.

This list is by no means exhaustive – we value your input and want to hear your ideas and opinions to make sure all options are considered.

The recommendations of the Study will include the best possible, most equitable, and locally supported measures to reduce flood problems. Recommendations will be brought together in the Nundle and Woolomin **Floodplain Risk Management Plan**, which will guide Council in managing the floodplain.

How can you be involved?

The success of the Nundle and Woolomin Floodplain Management Study & Plan hinges on your input and acceptance of the proposals. You can participate in the study in several ways:

1) A **community questionnaire** has been sent to households and businesses within the study area. This provides you with an opportunity to recall your experience of the November 2000 flood, to share your opinions about potential floodplain management measures, and to offer comment in relation to Council policy. If you have received a survey, please take a few minutes to complete it and return it in the reply paid envelope by 30th November. In due course we will summarise the main findings on the study web-site: www.bewsher.com.au/nundle.htm

2) If you know of a **mark** that records the level of the November 2000 flood, please indicate on the questionnaire. We would like to arrange for a surveyor to measure this.

3) As the study progresses, we will display posters that show the **flood model's depiction of the November 2000 flood**. We encourage you to inspect these posters, to ensure that the model accurately reflects this historical event. We will advise you of the display period during 2007.

4) Later in 2007 we will display posters showing the **recommended floodplain management measures**. We will again advise you of this display.

Frequently asked questions

What is a '100 year flood'?

A '100 year flood' means that in any one year there is a '1 in 100' or 1% chance that a flood of this size or larger will happen. Over many centuries, a '100 year flood' will happen on average once every 100 years.

What is a 'probable maximum flood'?

Floods bigger than a 1 in 100 year flood can occur with devastating effect: Nyngan (1990), Coffs Harbour (1996) and Katherine (1998).

The 'probable maximum flood' is the largest flood that could possibly happen. Under the NSW Government's Flood Policy, councils are now required to consider the risks of flooding up to this largest possible flood.

What is a floodplain?

With the release of new State Government guidelines in 2001, the words 'floodplain' and 'flood-prone land' now include all land that would be flooded by all floods up to the probable maximum flood.

Who can you contact for more information?

For more information about the Nundle and Woolomin Floodplain Management Study & Plan, please contact:

Tamworth Regional Council
Andrew Galvin
Phone: 6767-5532
E-mail: a.galvin@tamworth.nsw.gov.au

Bewsher Consulting Pty Ltd
Stephen Yeo
Phone: 9868-1966
E-mail: syeo@bewsher.com.au

Thank you for being part of this study

Tamworth Regional Council
NSW Government Department of Natural Resources
SES
Bewsher Consulting
Floodplain Management Consultants

Bewsher Consulting
Floodplain Management Consultants

Nundle and Woolomin Floodplain Risk Management Study

Community Survey, November 2006

SECTION A – YOUR CONTACT DETAILS

Name (optional): ____________________

Address within study area: ____________________

Postal address (if different): ____________________

Phone number: ____________________

Best time to call: ____________________

E-mail: ____________________

My property is a:

- ❑ House
- ❑ Business
- ❑ Farmland

Privacy note: Any personal details you give us are for use in this study only and will not be shared with other organisations. Sensitive information will only be reported in aggregate form.

SECTION B – YOUR FLOOD EXPERIENCE

1. How long have you lived/worked in Nundle or Woolomin? __________ years

2. Have you ever experienced a flood in Nundle or Woolomin?

- ❑ Yes
- ❑ No (If "no", go to Q6)

If yes, which floods?

- ❑ November 2000
- ❑ January 1996
- ❑ January 1984
- ❑ February 1955
- ❑ Other (please specify) __________

3. In the November 2000 flood, was the floor level of your house or business flooded?

- ❑ Yes
- ❑ No (If "no", go to Q4)

If yes, what was the maximum depth of water over the floor? __________

Do you have a mark that precisely shows the peak height of the November 2000 flood?
(It would help us if we could arrange for a surveyor to record the flood height, with your permission).

- ❑ Yes
- ❑ No

4. How much advance warning time did you receive prior to the November 2000 flood?

- ❑ Less than ½ an hour
- ❑ ½ an hour to 2 hours
- ❑ 2 hours to 6 hours
- ❑ More than 6 hours

5. Briefly describe any damages from the November 2000 flood.

____

____

____

____

SECTION C – FLOODPLAIN MANAGEMENT OPTIONS

6. What ONE or TWO solutions for dealing with the flood problem do you think deserve most consideration? Why?

____

____

____

____

____

____

please turn over ➔

7. **Please indicate your level of support for each of these potential floodplain management measures.** (Use ONE tick for each row).

Floodplain Management Measure	Support	Neutral	Against	Not sure
Measures that modify the way a flood behaves				
a. Constructing detention basins				
b. Constructing bypass channels or floodways				
c. Enlarging bridges and culverts				
d. Creek widening and/or dredging				
e. Clearing creeks of debris				
f. Removing floodplain obstructions				
g. Constructing permanent levees				
h. Filling low-lying land				
Measures that modify property				
i. Council purchasing the most severely flood affected properties				
j. Raising houses above the 100 year flood level				
k. 'Flood-proofing' properties (e.g. waterproofing walls, shutters)				
l. Placing controls on new buildings (e.g. minimum floor levels)				
Measures that modify people's response to flooding				
m. Improving flood warning systems				
n. Improving evacuation plans				
o. Promoting community flood awareness				
- Installing flood markers (e.g. on telegraph poles)				
- Providing a flood notification certificate to owners				
p. Promoting community flood readiness				

8. **Are there any particular locations that warrant attention?**

____

____

9. **Do you have any other suggestions about what the Study should address?**

____

____

SECTION D – COUNCIL POLICIES

10. **What level of control do you consider Council should place on new development to minimise flood-related risks?** (Tick one or more boxes)

- ❑ Prohibit all new development on land with any potential to flood.
- ❑ Prohibit all new development only in locations where it would be extremely hazardous.
- ❑ Prohibit subdivision of properties on land with any potential to flood.
- ❑ Prohibit subdivision only in locations where it would be extremely hazardous.
- ❑ Prohibit rezoning for new development on land with any potential to flood.
- ❑ Prohibit rezoning for new development only in locations where it would be extremely hazardous.
- ❑ Place restrictions on development such as minimum floor levels.

11. **How do you think information about the risks of flooding should be provided to the local community?** (Tick one or more boxes)

- ❑ Council should regularly send a certificate to residents stating their property's flood affectation.
- ❑ Council should advise only residents who ask them about their property's flood affectation.
- ❑ Council should issue flood certificates to inquiring prospective property purchasers.
- ❑ Council should have flood maps available at its office and on its web-site.
- ❑ Council should show the height of the November 2000 flood on telegraph poles.
- ❑ Council should provide no advice about flood affectation.

SECTION E – OTHER INFORMATION

12. What further involvement would you like to have in this Study? (Tick one or more boxes)

❑ Please include me on the mailing list
❑ I have photos of historic floods or flood damages that I am prepared to lend to the study team
❑ Please contact me for a phone interview
❑ No further involvement

PLEASE PROVIDE MORE INFORMATION OR COMMENTS HERE IF REQUIRED

Please return the completed questionnaire by 30th November to Bewsher Consulting:

1) using the attached reply-paid envelope (where provided), or

2) by posting your questionnaire (no stamp required) to: Bewsher Consulting
Reply Paid No. 352
EPPING NSW 1710

3) Fax: 9868-5759

4) Email: syeo@bewsher.com.au

Thank you for your assistance.

Bewsher Consulting
Floodplain Management Consultants

NUNDLE AND WOOLOMIN FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

STAKEHOLDER SURVEY

FOR AGENCIES, AUTHORITIES AND INTEREST GROUPS

FEBRUARY 2007

PART A: CONTACT DETAILS

Could you please complete the following table:

Name of Organisation:	
Contact Name:	
Position of Contact Person:	
Postal Address:	
Contact phone number:	
Contact fax number:	
Contact e-mail:	

PART B: POTENTIAL FLOOD DAMAGE TO PROPERTY, ASSETS OR SERVICES

We are interested in your views relating to the potential damage that COULD occur to your property, assets or services if they were inundated by floodwaters. Items that could be damaged by floodwaters through inundation or be damaged if undermined by erosion during a flood could include road surfaces, buildings, pumps, pumping stations, electricity substations, traffic signals, other electrical equipment, equipment and/or stock piles at depots, monitoring equipment as well as cables, conduits or pipes.

Please complete the following table using the examples as a guide. Please attach a separate sheet if required.

Please describe the property/ asset/service that could be damaged by floodwaters.	**Please provide the location of the property/ asset/service.**	**Please describe the type of damage that could be sustained if inundated by floodwaters.**	**Please estimate the approximate cost of damage that could be sustained.**	**Approximately, how long would it take to repair the damage.**	**How critical would the property/asset/service be to the community if it were damaged by floodwaters?**	**Could potential damage be reduced if flood mitigation works were constructed or if warnings were issued? Please give details.**
Sewer Pumping Station	Corner Smith and Jones Streets	Pumps would fail if inundated by more than 300 mm of water	$50,000	About 1 week	There would be no sewer to about 400 homes for up to 5 days	Pumps may be protected with at least 2 hours warning.
Road surface	Brown Street	Damage to road surface if inundated for > about 3–6 hrs	$100 per m^2 of affected pavement	About 2 weeks	About 5000 vehicles/day would have to find alternative routes for up to 2 weeks	Damage may be reduced if Brown Street bridge was enlarged.

PART C: POSSIBLE FUTURE WORKS CLOSE TO THE RIVER

Does your organisation have any planned future works close to the Peel River at Nundle or Woolomin that may have an impact on flood behaviour or have an impact on possible flood mitigation works such as bridge enlargements or channel widening?

Please complete the following table using the example as a guide. Please attach a separate sheet if required.

Proposed Work	Location (attach map if required)	Approximate Cost	Indicative Time Frame
600 mm dia sewer rising main	Crosses the river upstream of the William Long bridge	$10 million (2006 estimate)	Within next 5–10 years

PART D: RELEVANT REPORTS STUDIES AND DESIGNS

Are you aware of any reports, studies or design drawings that have been carried out within or including the study area?
These may or may not be related to flooding or the floodplain.

Please complete the following table.

Author	**Date**	**Title of report or drawing**	**Prepared for**	**Published by**	**Does your office have a copy we could borrow if required?**

PART E: COMMENTS AND MORE INFORMATION

Do you have any other comments about flood-related issues? Does your organisation have any specific issues that they think should be addressed by the Nundle and Woolomin Floodplain Risk Management Study? Please attach a separate sheet if required.

Please post your completed survey by **MONDAY 19TH MARCH** to:

Bewsher Consulting Pty Ltd
PO Box 352
EPPING NSW 1710

Attention: Stephen Yeo

Alternatively, email your comments to syeo@bewsher.com.au

For further information about the Nundle and Woolomin Floodplain Management Study, please contact:

- Andrew Galvin, Tamworth Regional Council, Ph: 6767 5532
- Stephen Yeo, Bewsher Consulting, Ph: 9868 1966

Thank you for your time and assistance

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Now incorporating NSW Fisheries
ABN 51 734 124 190-002

14th March 2007
Drew Bewsher
Bewsher Consulting Pty Ltd
PO Box 352
EPPING NSW 1710

RECEIVED
2 1 MAR 2007

Dear Drew

RE: Nundle & Woolomin Flood Study and Floodplain Risk Management Study & Plan

Thank you for giving NSW Department of Primary Industries Aquatic Habitat Protection Unit (AHPU) the opportunity to provide preliminary comments on the flood study & plan.

DPI AHPU is responsible for managing fish (including aquatic invertebrates), and fish habitat throughout NSW. The Department's goals encompass protecting the aquatic environment and promoting the rehabilitation of degraded aquatic environments. This includes protecting rare and threatened species and maintaining aquatic biodiversity.

This response reflects the policy and legislative role of NSW DPI Aquatic Habitat Protection Unit (AHPU) in relation to aquatic habitats and floodplains. Further policy information can be found in *NSW DPI Policy and Guidelines for Aquatic Habitat Management and Fish Conservation 1999* www.fisheries.nsw.gov.au/publications/aquahab.htm.

Floodplains, particularly when inundated, provide important resources for aquatic flora and fauna. Flooding releases nutrients and organic carbon from the floodplain stimulating the activity of aquatic invertebrates that are a major food source for adult and juvenile fish. The value of floodplain nursery habitat depends on the maintenance of connections between the river and the floodplain. A number of fish species such as Golden Perch and Silver Perch have a strong dependence on flooding and spawn in direct response to floods. These species have a migratory response to flooding and spawn their eggs on or near the floodplain and are reliant on adequate connectivity between the river and the floodplain for spawning success.

FISHERIES MANAGEMENT DIVISION
AQUATIC HABITAT PROTECTION UNIT
PO BOX 3047
TAMWORTH NSW 2340

www.dpi.nsw.gov.au

Tel: 02 6765 6046
Fax: 02 6762 1993

Legislation Section - Fisheries Management Act (1994)
Several divisions of the *Fisheries Management Act* 1994 are relevant to the Nundle and Woolomin Flood Study & Plan. Under Part 7 (s198-202) of the *Fisheries Management Act* 1994, *water land* (land that may be permanently or intermittently submerged by water) is protected. It is an offence to perform unauthorised *dredging and reclamation* works in *water land.* These works include construction of drains, roads, creek diversions, geotechnical investigations and excavating or reclaiming the bed or banks of any waterways.

Also contained within Part 7 (s218-220) of the Act, the passage of fish must not be blocked. A person who creates an obstruction without a permit, which could cause fish to be stranded or the destruction of immature fish or obstructs the free passage of fish, is guilty of an offence with heavy penalties.

Part 7A of the *Fisheries Management Act* 1994 also ensures that threatened species of fish are taken into consideration during the planning process and in decision-making by authorities.

Measure that Modify the way a Flood behaves
Attached are some specific comments that relate to page 3 of the community newsletter which our department believes should be taken on board as part of the planning process;

a. Constructing Detention Basins
DPI AHPU may support detention basins so long as these do not result in a blockage of fish passage or the stranding of fish or result in the net loss of fish habitat.

b. Constructing Bypass channels or Floodways
DPI AHPU believe that the flood study should aim to define a system of floodways that conforms to the natural drainage pattern and thereby ensures that fish passage and access to spawning and feeding locations is maintained by minimising significant alterations to the natural flow distribution and velocity.

c. Enlarging Bridges and Culverts
The department generally supports enlargement of bridges and culverts to enhance the hydraulic capacity of these structures. All such structures should be built in accordance to the Policy and Guideline document *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings.* The department has a legislative role issuing permits for the construction of bridges, culverts, causeways, etc.

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d. Creek Widening and or/dredging

DPI AHPU do not support creek widening/and or dredging. NSW DPI AHPU have a "No Net Habitat Loss" policy as outlined in the document *Policy and Guidelines for Aquatic Habitat Management and Fish Conservation 1999.* Incorporated into this policy to compensate for adverse environmental effects is DPI's policy of habitat compensation calculated on a 2:1 basis, whereby the creation of new (or remediating existing) habitat is calculated to "offset" the loss of existing habitat.

e. Clearing Creeks of Debris

DPI AHPU do not support clearing creeks of debris. Riparian vegetation and snags are critical to the health of streams. Riparian vegetation is a key component of fish habitat and directly interacts with the stream by providing nutrients, shading, temperature control, water quality control, and stream stability. Snags (large woody debris) consist of whole trees, limbs or root masses that have fallen or been washed into a waterway and have become partly or wholly submerged by water. Snags have a critical role to play in the ecological functioning of rivers by;

- providing cover for fish and aquatic invertebrates
- providing 'markers' to designate territorial boundaries for species that move or migrate within the river system such as Murray cod and golden perch,
- providing breeding sites for species such as river blackfish and Murray cod which lay adhesive eggs onto hard substrates,
- providing opportunities for algal, fungal, bacterial, benthic plants, macroinvertebrates and vertebrate communities to colonise,
- providing organic enrichment by capturing detritus and contributing to secondary production
- stabilisation and armouring of stream bed and banks, thereby preventing stream erosion, and
- increasing the physical habitat complexity of diversity of the stream.

The "removal of large woody debris" and the "degradation of riparian vegetation along NSW Watercourses" have been listed as Key Threatening Processes under Schedule 6 Of the *Fisheries Management Act* 1994 and the department has a responsibility to limit these impacts where possible.

f. Removing Floodplain Obstructions

DPI AHPU support the removal of artificial floodplain obstructions so that the natural drainage pattern is maintained, thereby ensuring that fish passage and flow paths are maintained through minimising barriers across permanent and intermittent watercourses and the floodplain.

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g. Constructing Permanent Levees

Flood mitigation structures such as permanent levees should only be constructed where there is a compelling need such as around a town or a dwelling.

h. Filling Low Lying Land

DPI AHPU do not support the filling of low lying land as these areas usually comprise of *water land* and can include important aquatic habitats such as permanent or ephemeral wetlands and floodrunners. The planning process should ensure that development of infrastructure does not occur in low lying flood prone land.

If you require any further information please contact me on (02) 6765 6046.
Yours sincerely,

D. Ward

DAVID WARD
FISHERIES CONSERVATION MANAGER (TAMWORTH)

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APPENDIX C

NUNDLE AND WOOLOMIN FLOOD STUDY REPORT

APPENDIX C

Nundle & Woolomin Flood Study

Draft Report

May 2012

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C.1 STUDY CATCHMENT

Both Nundle and Woolomin are located on the banks of the Peel River, as shown in **Figure C1**. Chaffey Dam, which is an important regional water supply reservoir, is located about seven kilometres downstream of Nundle. A significant tributary stream, Duncans Creek, joins the Peel River immediately upstream of Woolomin.

The total catchment areas at Nundle and Woolomin are approximately 234 and 539 square kilometres. The whole catchment is dominated by rural land uses.

C.2 MODEL ESTABLISHMENT

C.2.1 CHOICE OF MODELS

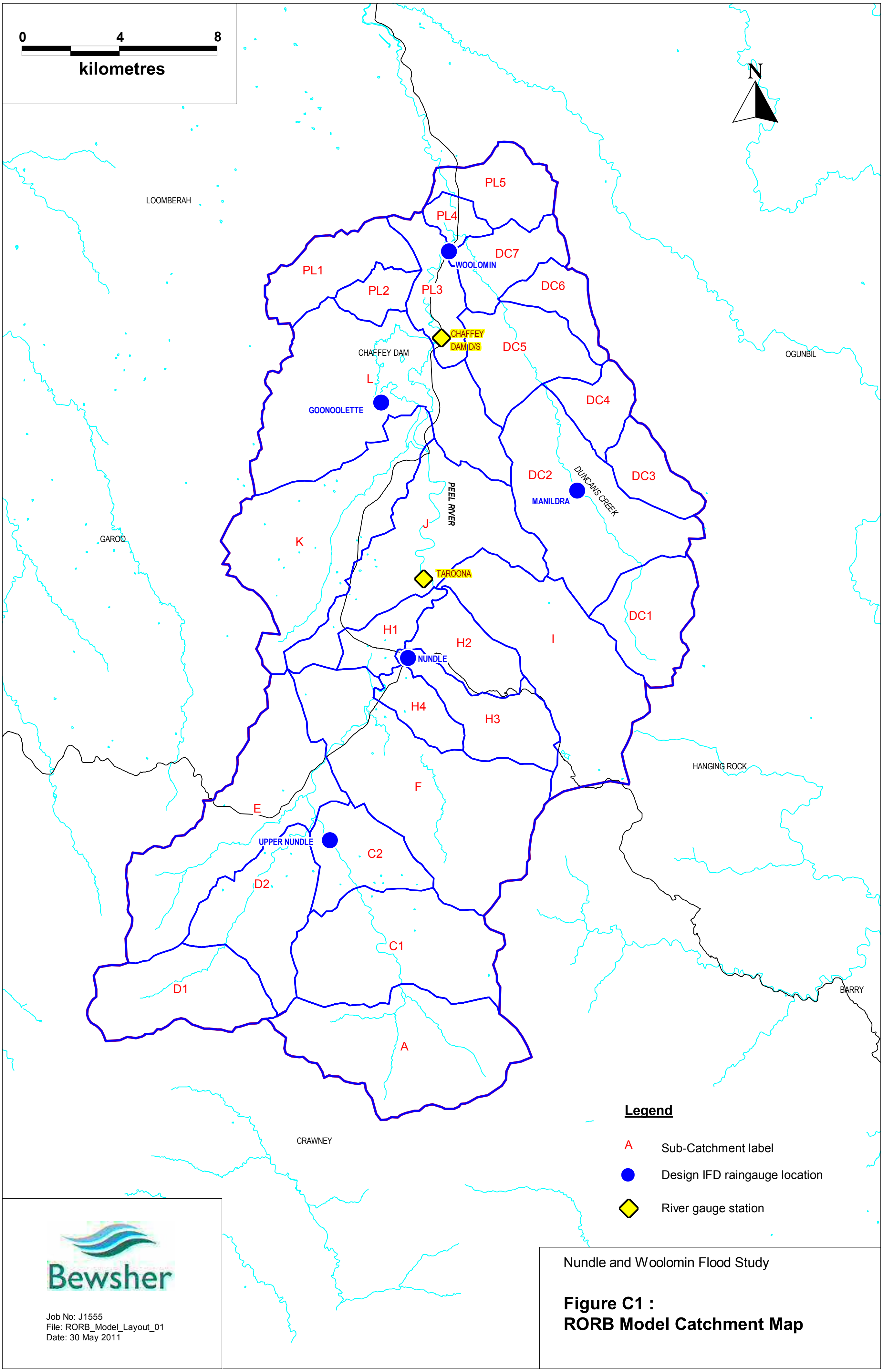
Since very significant effort had previously been expended by others in developing a RORB hydrologic model of the catchment draining to Chaffey Dam, it was determined that that model would form a suitable basis for the hydrologic model needed for this study.

Given that the major flood regimes at both Nundle and Woolomin would see substantial — and potentially complex — overbank and tributary flow regimes, it was determined that two dimensional (2D) modelling software should be utilised. The widely used and Australian-written TUFLOW software was chosen.

C.2.2 RORB MODEL

In 1998 the then Department of Land and Water Conservation (DLWC) established a RORB model for the Chaffey Dam catchment as part of a spillway adequacy assessment of the dam (**Reference C1**). The model, which was made up of twelve sub-catchments, was calibrated to seven historical events which were recorded between February 1971 and August 1990. For all the calibration events, RORB parameter m was set at 0.8 as recommended in the RORB manual. A range of k_c values (4-34), initial loss values (0-36mm) and continuing loss values (0-4.7mm/h) were used to achieve fits to observed flow hydrographs. Of the seven modelled events, a multiple storm burst event in February 1971 had a recorded peak flow which was much larger than any of the other events. Based on a weighting of the calibration events, a design event k_c value of 9 was subsequently adopted. Losses of 15.0mm and 2.5mm/h were adopted for the 100 year ARI event modelling and 0mm and 1.0mm/h adopted for the PMF modelling.

Subsequently, in 2005 the then Department of Infrastructure Planning and Natural Resources (DIPNR) was commissioned by State Water (**Reference C2**) to review the spillway adequacy of Chaffey Dam in the light of the revision of probable maximum precipitation (PMP) estimates by the Bureau of Meteorology. The 1998 DLWC RORB model was adopted for that review.



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Date: 30 May 2011

Nundle and Woolomin Flood Study

Figure C1 :
RORB Model Catchment Map

Since that RORB model's outlet corresponded to the dam, it has been expanded for this study. That is, it includes the additional catchment areas above the township of Woolomin which is located approximately 7 kilometres downstream of the dam. The expanded model (as shown in **Figure C1**) includes the Duncans Creek catchment of 101 km^2 and the total catchment area to just below Woolomin is about 540 km$^{2.}$

The expanded model included sub-division of the 2005 model's 'H sub-catchment' since that model had treated the sub-catchment areas lying east of Nundle as part of a lumped catchment. This included separate definition of the Oakenville Creek catchment whose channel flows through the middle of the Nundle township area (and corresponds to sub-catchment H3 in **Figure C1**).

The 2005 definition of the stage-storage relationship above the Chaffey Dam Full Supply Level (FSL) was initially preserved for this study.

C.2.3 NUNDLE TUFLOW MODEL

C.2.3.1 Topographic Data

Tamworth Regional Council undertook survey of Peel River channel cross sections, eastern tributary cross sections and spot heights in private properties. This information was supplemented with photogrammetry coverage. Some concerns arose following a review of the initial processed survey output and this led to some changes being made by Council's contractor. These changes saw the mean elevation difference for the data set dropping from 0.21m to 0.06m.

The Nundle floodplain is relatively narrow since it is also bounded by steep slopes on both sides, especially on the eastern side. In those edge-of-floodplain areas, the DEM was extended as-necessary using 10 metre contour interval mapping.

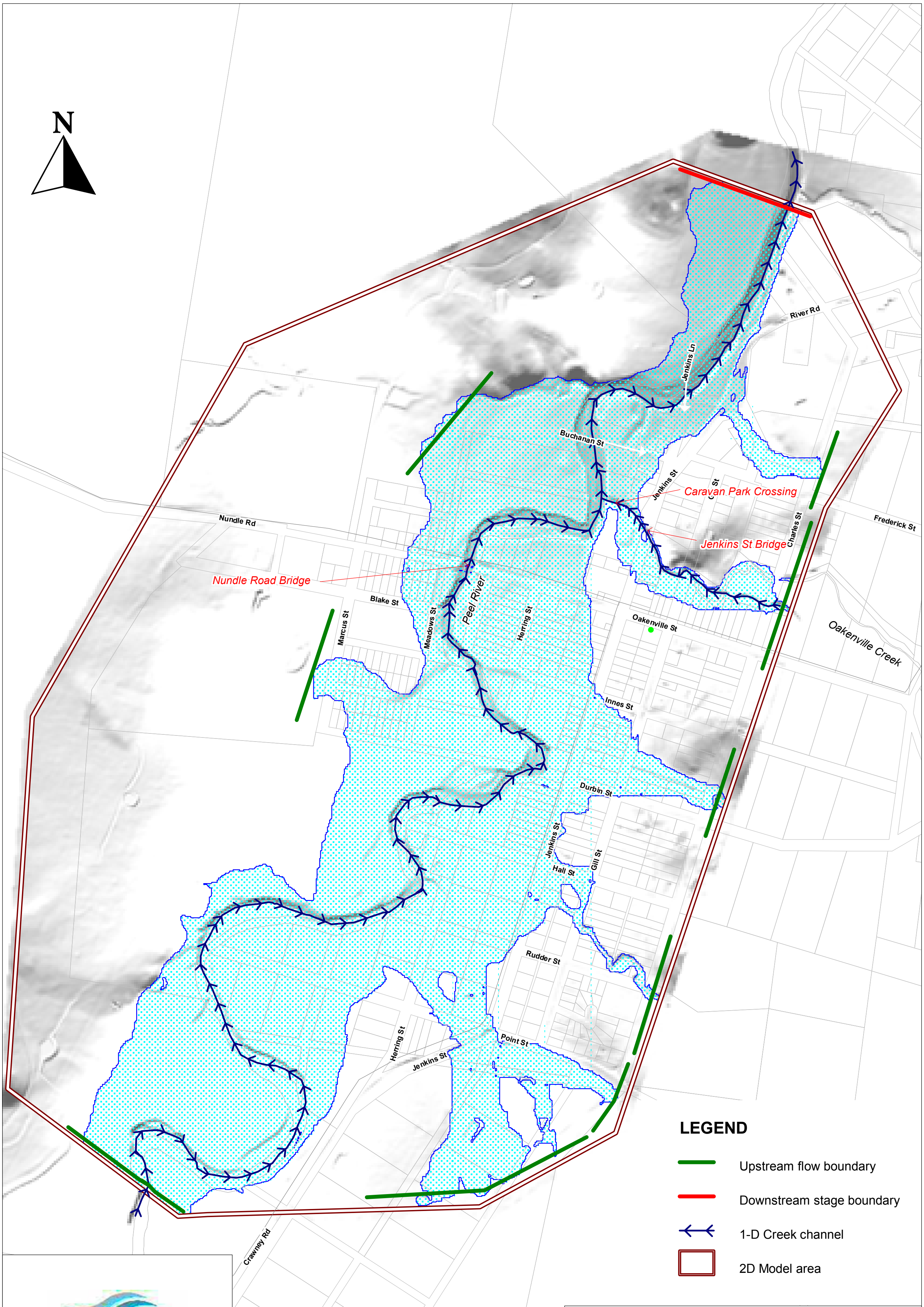
C.2.3.2 Model Structure

Both the Peel River channel and the Oakenville Creek channel are modelled as 1D channels 'nested' within the 2D domain. The 2D grid size is three metres.

Peel River and Oakenville Creek flows are imported as flow hydrographs at the most upstream 1D channel nodes while the remaining minor eastern tributary flows are added directly at the edge of the 2D domain.

Figure C2 shows the model structure and boundary condition locations in the model.

Table C1 lists the structures which are included in the Nundle model.



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Date: 30 May 2011

Nundle and Woolomin Flood Study

Figure C2 :
Nundle TUFLOW Model Structure

TABLE C1: NUNDLE FLOODPLAIN STRUCTURES

Structure	Details	Information Source
Nundle Bridge over Peel River	Bridge was replaced in 2008. <u>Pre-2008 structure</u> Timber Frame / concrete deck Deck level: 591mAHD. <u>Post-2008 structure</u> Concrete Deck level: 591m AHD	Photo Surveyor & photo
Jenkins Street Bridge over Oakenville Creek	Concrete bridge structure Deck level: 594.4m AHD (est.)	Photo and sketch
Caravan Park Crossing over Oakenville Creek	5 x 0.65m dia pipes	Photos
Oakenville Street (300m east of Peel River)	Single 0.6m dia pipe	Council Survey 2011
Hall Street (330m East of Peel River)	Single 0.45m dia pipe	Council Survey 2011
Gill Street (Between Hall Street and Rudder Street)	Twin 0.9m dia pipes	Council Survey 2011
Jenkins Street (Point Street intersection)	Triple 2.4x1.2m dia pipes	Council Survey 2011

Hydraulic roughness parameter values were assigned on the basis of aerial photography, first hand floodplain observations and land use types. They are listed in **Table C2**.

TABLE C2: TUFLOW MODEL 'MANNINGS N' ROUGHNESS VALUES

Surface Condition	Mannings n Value
Road reserve	0.025
Short grass / bare earth	0.030
Farm land	0.050
Cleared floodplain	0.060
Dense vegetated floodplain	0.08
Forest	0.1
Building footprint	1.0
Natural channel	0.06 – 0.078
Concrete Channel	0.02 – 0.025

C.2.4 WOOLOMIN TUFLOW MODEL

C.2.4.1 Topographic Data

Through a contracted surveyor, Tamworth Regional Council undertook survey of Peel River cross sections, Duncans Creek channel cross sections plus spot levels along both the river and creek top of banks, roadway spot levels and additional spot levels in a number of private properties. Unlike Nundle, there was no photogrammetry data for Woolomin.

Similar to the situation at Nundle, the Woolomin floodplain is relatively narrow since it is also bounded by steep hill slopes on both sides. In those edge-of-floodplain areas, the DEM was extended as-necessary using 10 metre contour interval mapping.

Due to the somewhat limited base data set, the quality of the resulting DEM is considered to be relatively coarse.

C.2.4.2 Model Structure

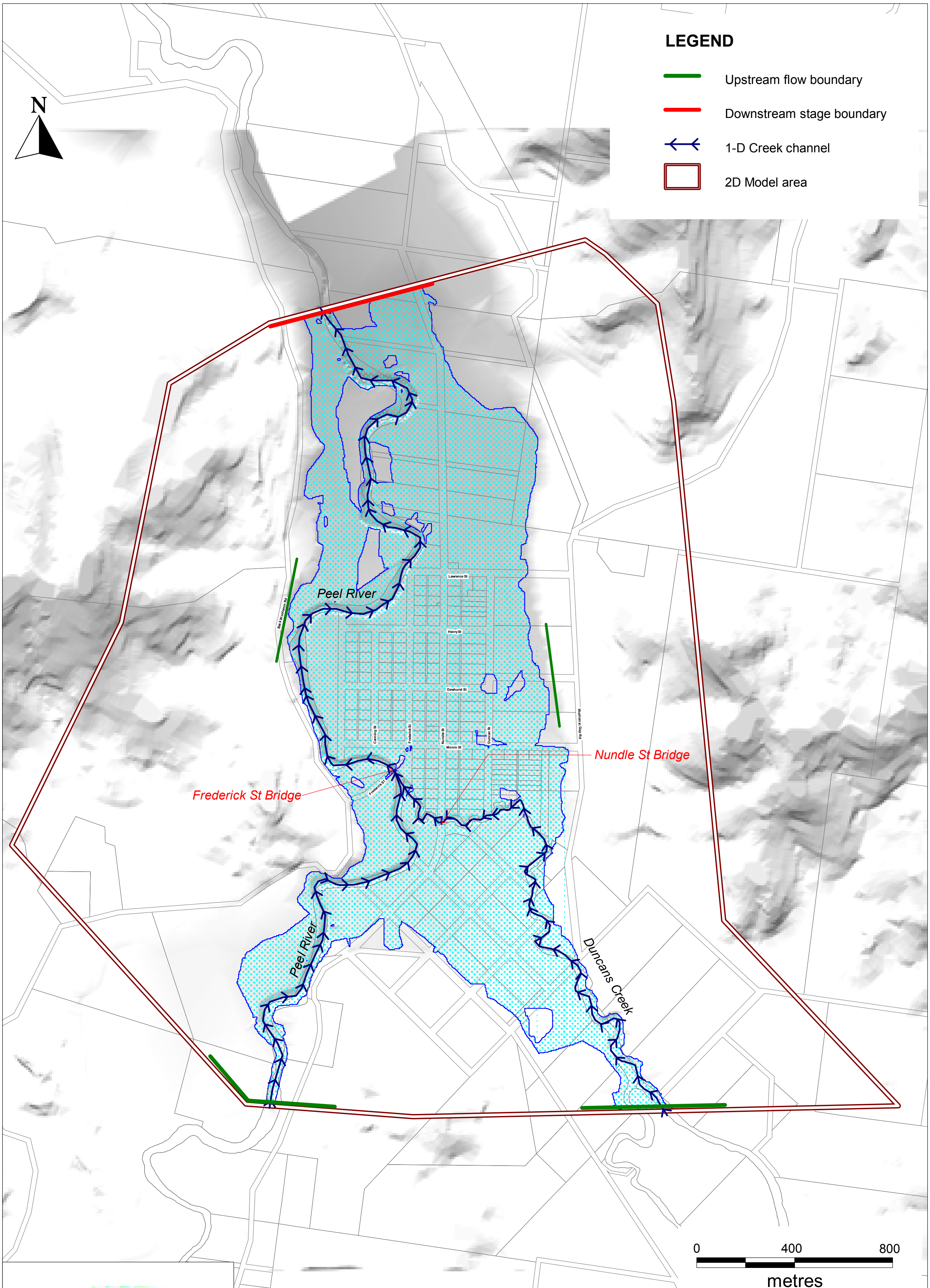
Both the Peel River and Duncans Creek are modelled as 1D channels embedded in 2D model domain. As for Nundle, the 2D grid size is three metres.

The Peel River and Duncans Creek flows are imported as flow hydrographs at the most upstream 1D channel nodes. **Figure C3** shows the model structure and boundary condition locations in the model.

Table C3 lists the structures which are included in the Woolomin model.

TABLE C3: WOOLOMIN FLOODPLAIN STRUCTURES

Structure	Details	Information Source
Frederick Street bridge over Peel River	Timber Frame / concrete deck Deck level: 475.6mAHD. Deck depth: 500mm (est.)	Surveyor & sketch provided by Council
Nundle St Bridge over Duncans Creek	<u>Pre-2010 Structure</u> Concrete bridge structure Deck level: 474.9m AHD <u>Post-2010 Structure</u> Concrete bridge structure Deck Level: 474.9m AHD	Surveyor & sketch provided by Council 'Civil Build' drawings provided by Council. (Datum estimated)



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Date: 30 May 2011

Nundle and Woolomin Flood Study

Figure C3 :
Woolomin TUFLOW Model Structure

TABLE C4: SUMMARY OF RAINFALL DATA FOR NOVEMBER 2000 EVENT

Station_Name	Rain Gauge ID	Data	Daily Rainfall (mm) 18-Nov-2000	19-Nov-2000	20-Nov-2000	3 Day Total
NUNDLE POST OFFICE	55041	Daily	NA	NA	NA	175.6
NUNDLE (BENONI)	55078	Daily	10.0	53.0	72.0	135.0
LOOMBERAH (PENDENE)	55176	Daily	9.6	37.4	44.6	91.6
DUNGOWAN (RAVENCROFT)	55181	Daily	10.2	37.6	48.8	96.6
WOOLOMIN (CULWULLA)	55189	Daily	5.6	46.4	61.6	113.6
OGUNBIL (WATERFALL)	55193	Daily	4.5	52.0	64.0	120.5
HANGING ROCK (ANDEVA)	55200	Daily	5.0	68.0	104.0	177.0
NUNDLE (KEEVA)	55245	Daily	10.0	62.0	97.0	169.0
OGUNBIL (AMAROO)	55262	Daily	4.0	52.0	57.0	113.0
BOWLING ALLEY POINT (WEONA)	55298	Daily	5.1	47.0	58.0	110.1
NUNDLE (CHAFFEY DAM)	55302	Continuous rainfall data	8.2	45.8	95.0	149.0
NUNDLE (OLSLAND)	60127	Daily	10.0	69.8	51.8	131.6
NUNDLE (BARRY)	60128	Continuous rainfall data	2.6	71.4	15.8	89.8
MURRURUNDI (TIMOR)	61195	Daily	2.6	80.8	121.0	204.4
ELLERSTON (POITREL)	61196	Daily	7.2	64.4	41.2	112.8
PEEL RIVER (TAROONA)	55298	Continuous rainfall data	5.5	51.5	68.5	125.5

Using the same approach as for the Nundle model, the hydraulic roughness parameter values have been determined to be the same as those adopted for the Nundle model (reference **Table C2**).

C.3 MODEL CALIBRATION AND VERIFICATION

Floods experienced in November 2000 and January 2010 represented substantial events at Nundle and since significant numbers of flood marks had been surveyed both have been used for model calibration and verification purposes.

Whilst the same November 2000 flood event was also significant at Woolomin the same was not the case for the January 2010 storm. Consequently only the November 2000 event was used for model calibration at Woolomin.

C.3.1 NOVEMBER 2000 EVENT

C.3.1.1 Rainfall

Widespread rainfalls were experienced over the period of 18th to 20th November with the heaviest falls experienced on the 20th.

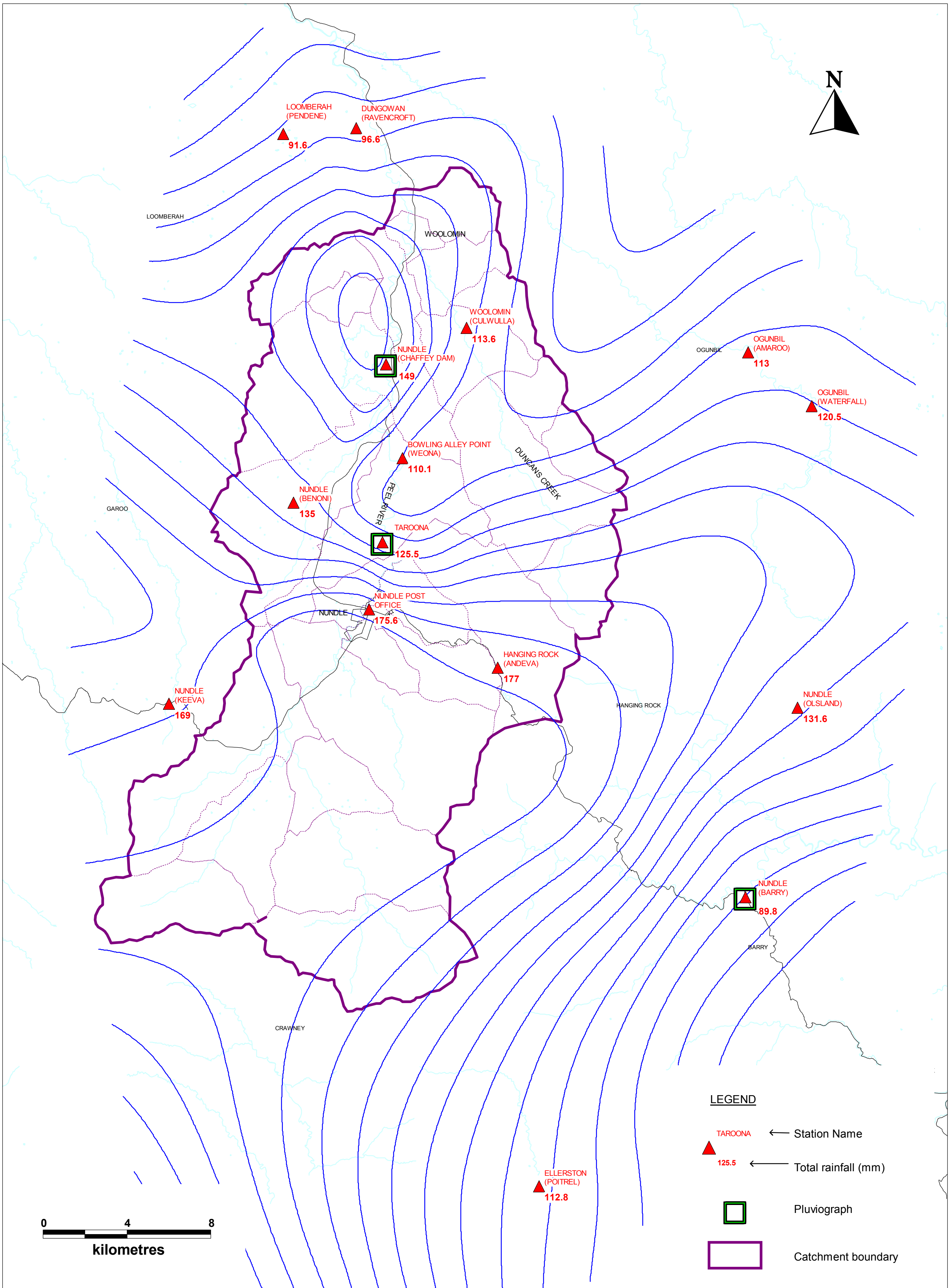
Daily rainfall data in and adjacent to the Peel River catchment was collected. That data set is presented in **Table C4** and the corresponding 3 day totals and derived isohyetal contours are also shown in **Figure C4**.

Continuous rainfall records were available for the pluviograph stations listed in **Table C5.**

TABLE C5: PLUVIOGRAPH DATA FOR NOVEMBER 2000 EVENT

Station Name	Station ID	Type	Relative Location (see Figure C4)
Nundle (Chaffey Dam)	055302	Rainfall depth recorded at 6 minute intervals	Within study catchment
Taroona	055298	0.5mm tipping bucket record	Within study catchment
Nundle (Barry)	060128	0.5mm tipping bucket record	Outside study catchment

Figure C5 presents the Chaffey Dam rainfall pattern for the 18-20 November and the two main rainfall periods can be clearly seen. **Figure C6** presents the accumulative rainfall depths recorded at Chaffey Dam, Taroona and Barry over the three day period. All three stations show that the first storm period happened at about the same time, but in the second storm the Taroona and Barry pluviographs recorded the rainfall one to two hours earlier. Hence the second burst time sequences indicate that the storm mechanism is moving in a northerly direction.



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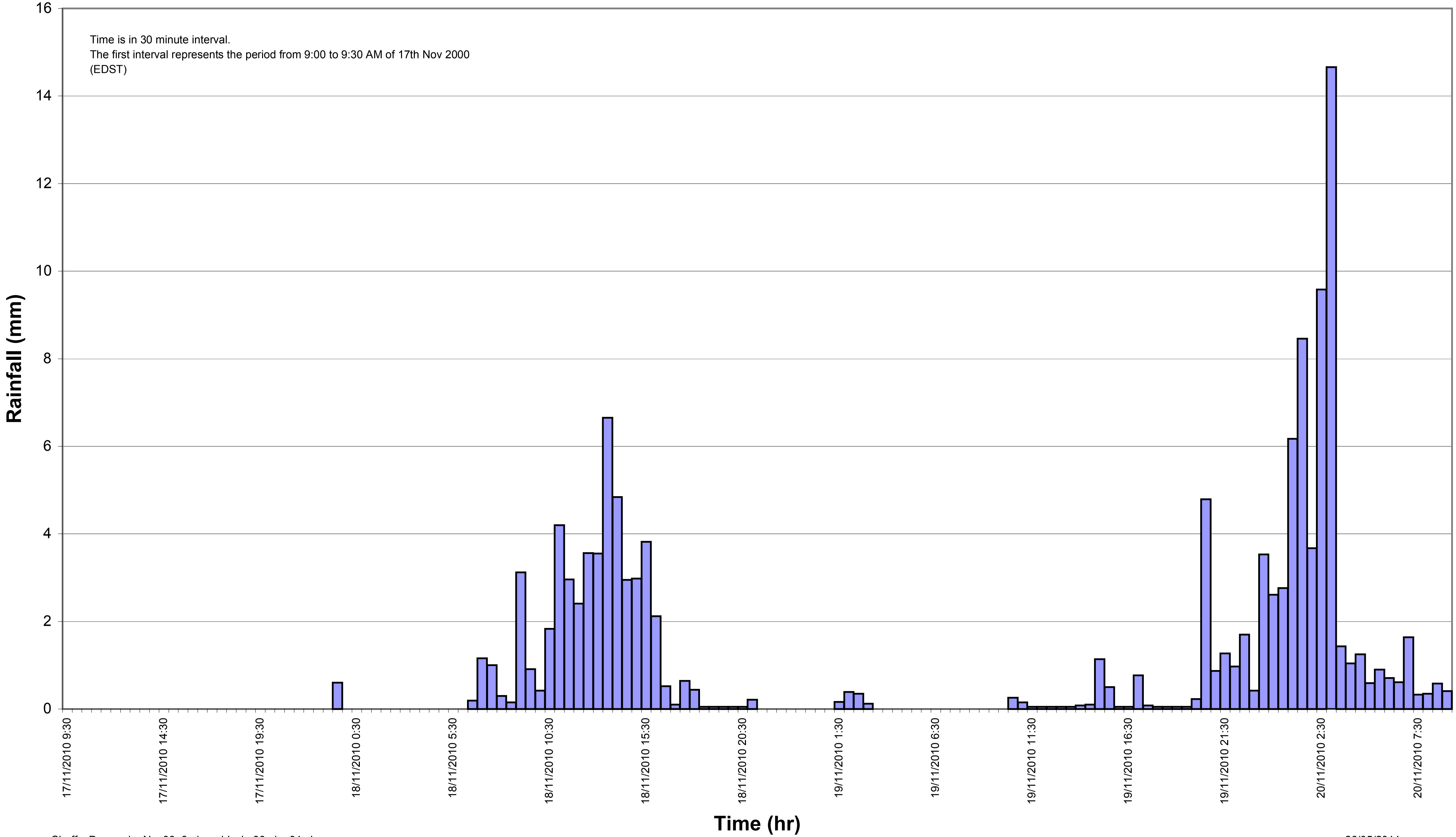
File: Nov2000Rain_01
Date: 30 May 2011

Nundle and Woolomin Flood Study

Figure C4 :
Spatial Distribution of November 2000 Rainfall (3 Day Rainfall Totals)

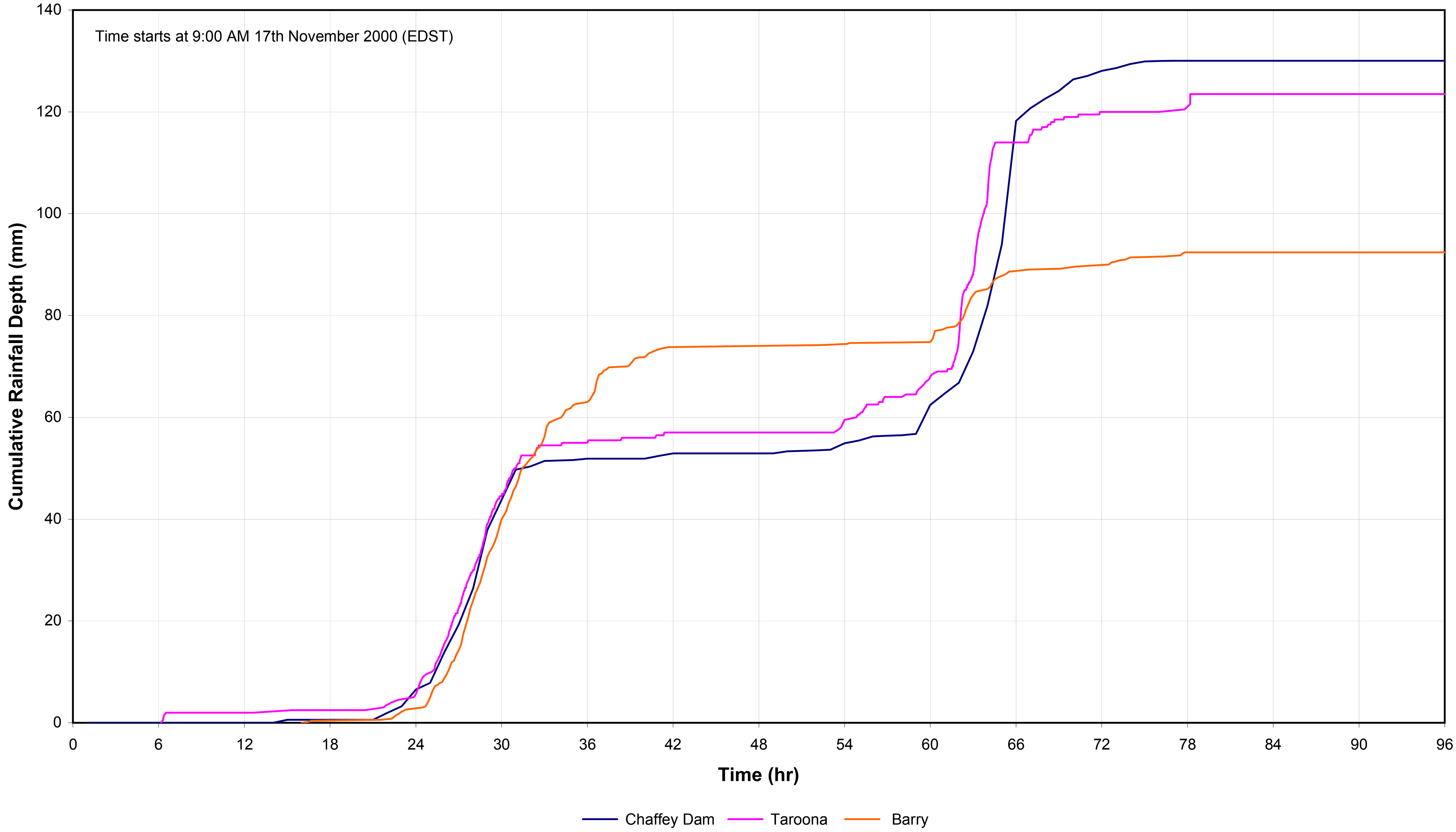
Figure C5: Rainfall Pattern at Chaffey Dam for 18-20 Nov 2000 Storm



ChaffeyDam_rain_Nov00_6min_reblock_30min_01.xls

26/05/2011

Figure C6: Comparison of Nov 2000 Cumulative Rainfall Temporal Patterns



C.3.1.2 RORB Calibration

Since the Nundle (Barry) station is located some distance from the study catchment, its temporal pattern has not been used in the RORB model of the storm.

The extended RORB model was run using the 3-day rainfall spatial distribution shown in **Figure C4**. For sub-catchments located south of Taroona, the timing of the second burst has been shifted to reflect an extrapolation of the time difference between the Taroona and Chaffey Dam patterns. The previous RORB catchment model k_c value of 9 was initially adopted and together with losses of 50 mm and 1.8 mm/hr, a satisfactory fit was achieved for peak flow and a good fit obtained for the time of the hydrograph peak.

However when the design event models were subsequently run for Nundle and Woolomin, the relationships between the November 2000 flood and 100 year design flood regimes appeared to be inconsistent. Additional research was undertaken – including flood frequency analysis using data collected at Bowling Alley Point (1915-1970) and Taroona (1993-2010) and also potential temporal pattern differences across the whole catchment – and it was concluded that the use of a k_c value of 14 for the extended model would be more appropriate (**Reference C11**). Together with adoption of the earlier losses (of 50 mm and 1.8 mm/h), the k_c value of 14 produced a very good fit to both peak flow and time of the hydrograph peak at Taroona (see **Figure C7**) and this was superior to that which was achieved using a k_c value of 9.

Peak RORB model flows throughout the catchment for the November 2000 event are listed in **Table C6.**

C.3.1.3 Nundle TUFLOW Calibration

Surveyed flood levels were available from two sources; marks surveyed by DECC (now known as the Office of Environment and Heritage, or OEH, with the Department of Premier and Cabinet) not long after the 2000 flood and marks surveyed by Council's surveyor in 2010 (while undertaking the complimentary survey of building floor levels, etc.). It follows that since the Council survey was undertaken about ten years after the event, any differences between the two sets of data might be resolved by giving more weighting to the DECC values.

The RORB-based flow hydrographs (reference **Table C6** for RORB model peak flow values) were imported into the TUFLOW model.

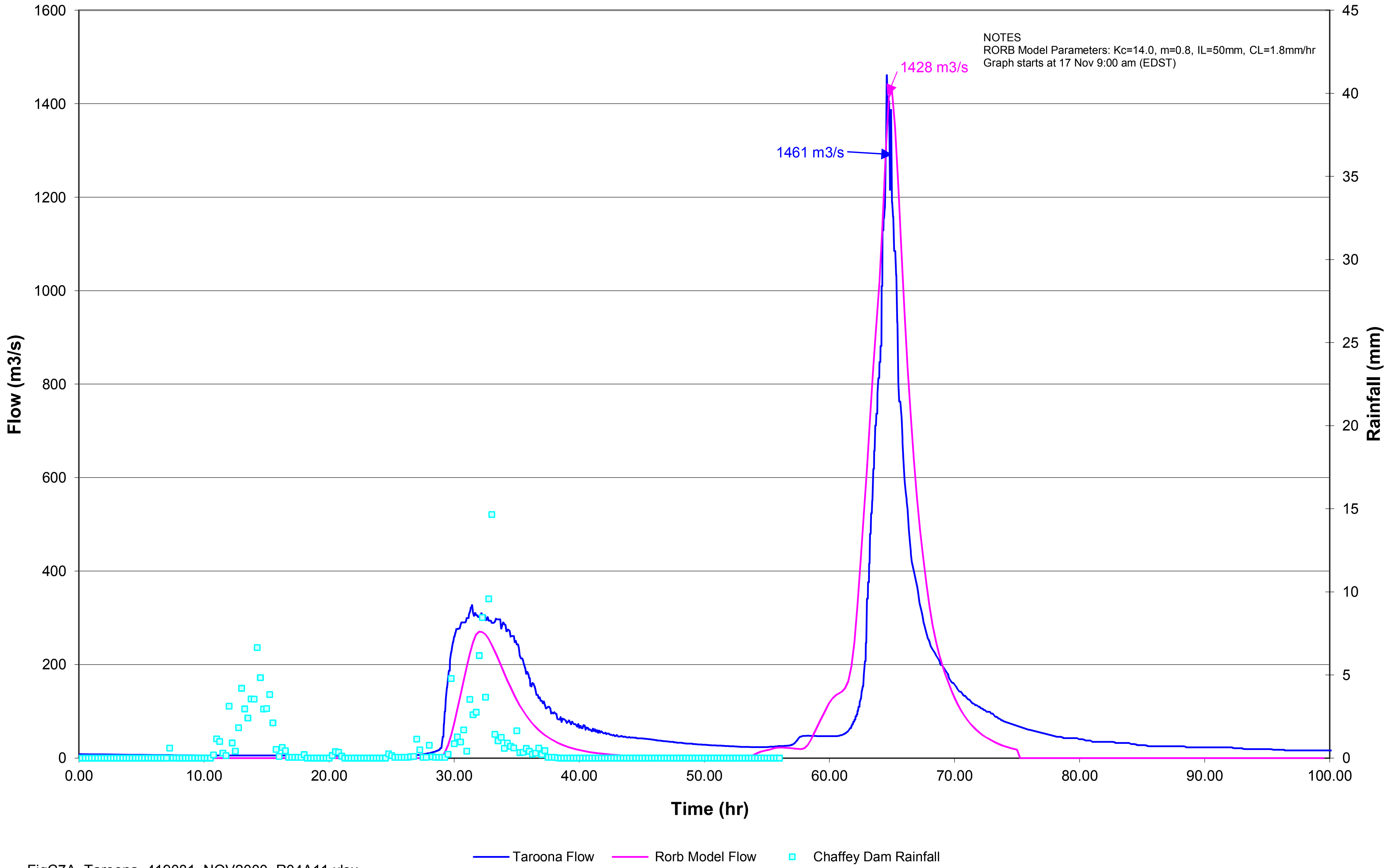
Table C7 tabulates the calibration results and it can be seen that overall a good fit has been obtained. The modelled flood inundation map is presented in **Figure C8**.

TABLE C6: SUMMARY OF RORB MODEL FLOWS FOR NOV 2000 AND JAN 2010 FLOODS

Location	Nov-2000	Jan-2010
Peel River U/S of Nundle	1377	867
Tributary H4	49	55
Tributary H3	87	96
Tributary H1	48	38
Tributary H2	70	55
Peel River D/S of Nundle	1443	1007
Peel River Taroona	1429	953
Chaffey Dam Outflow	627	217
Peel River US of Woolomin	638	225
Duncans Creek US of Woolomin	423	39
Peel River DS of Woolomin (see note)	996	238

Note: The flows in the Peel River DS of Woolomin include inflows from Duncans Creek. As discussed in Section C.3.1.4, during the calibration to the November 2000 flood, Duncans Creek flows were brought forward two hours in order to obtain a better fit to the oberved behaviour. The flow of 996 cumecs reported in this table represents the raw RORB results without this timing adjustment. With the timing adjustment, the RORB peak flow would be approximately 700 cumecs.

Figure C7: Calibration to Nov 2000 Flood Flow Hydrograph at Taroona



FigC7A_Taroona_419081_NOV2000_R04A11.xlsx

TABLE C7: SUMMARY OF CALIBRATION FOR NOVEMBER 2000 FLOOD AT NUNDLE

BC_ID	Source	Location	Flood Marker Number	Observed Flood Level (mAHD)	DEM Ground Level (mAHD)	Modelled Flood Level (mAHD)	Difference Modelled Minus Observed Flood Level (m)	Comments
N1	DECCW		FL01A	598.27	597.85	598.26	-0.01	Good fit
N2	DECCW		FL01	596.91	596.60	596.85	-0.06	Good fit
N3	DECCW		FL02	596.24	595.35	596.52	0.27	Good fit
N4	DECCW		FL03	595.18	594.51	595.62	0.44	
N5	DECCW		FL05	594.60	594.23	594.39	-0.21	Good fit
N6	DECCW		FL04	594.47	593.30	594.46	-0.01	Good fit
N7	Council Surveyor	Pump Station	6017	595.06	592.18	594.57	-0.49	
N8	DECCW	Pump Station	FL06	594.84	592.30	594.59	-0.25	Modelled flood level range : 594.44 - 594.75 across structure.
N9	DECCW		FL07	594.11	593.11	593.70	-0.41	
N10	Council Surveyor		6033	593.25	593.33	593.61	0.35	Dem level higher than obs flood level.
N11	Council Surveyor		6049	592.91	592.00	592.98	0.07	Good fit
N12	DECCW		FL08	592.70	592.27	592.88	0.18	Good fit
N13	Council Surveyor		6052	592.69	592.18	592.88	0.19	Good fit
N14	DECCW		FL09	592.72	591.40	592.76	0.04	Good fit
N15	DECCW		FL10	592.03	591.15	592.63	0.60	
N16	DECCW		FL12	591.21	590.89	591.26	0.05	Good fit
N17	DECCW		FL11	591.31	589.70	591.28	-0.03	Good fit
N18	DECCW		FL13	590.05	589.99	590.89	0.84	Very steep flood gradient at this location.
N19	DECCW		FL13A	589.96	589.13	590.16	0.20	Good fit
N20	DECCW		FL14	589.96	589.10	589.79	-0.17	Good fit
N21	DECCW		FL18	591.49	592.74	592.97	1.48	Dem level higher than obs flood level.
N22	DECCW		FL17	589.16	587.90	589.60	0.44	
N23	DECCW		FL15A	589.17	588.00	589.37	0.20	Good fit †
N24	Council Surveyor		6116	588.58	588.29	589.30	0.72	Obs flood level inconsistent with adjacent N23 & N25.
N25	DECCW		FL15B	589.11	588.55	589.30	0.18	Good fit †
N26	Council Surveyor		6128	588.75	588.38	588.69	-0.07	Good fit
N27	DECCW		FL16B	588.21	587.39	588.51	0.30	Good fit
N28	DECCW		FL16A	588.28	587.35	588.52	0.24	Good fit
N29	Council Surveyor		6137	588.25	587.78	588.47	0.22	Good fit
N30	Council Surveyor		6150	586.87	586.41	587.16	0.28	Good fit
N31	DECCW		FL21B	587.40	586.33	587.70	0.30	Good fit
N32	DECCW		FL21A	585.37	584.92	586.31	0.94	

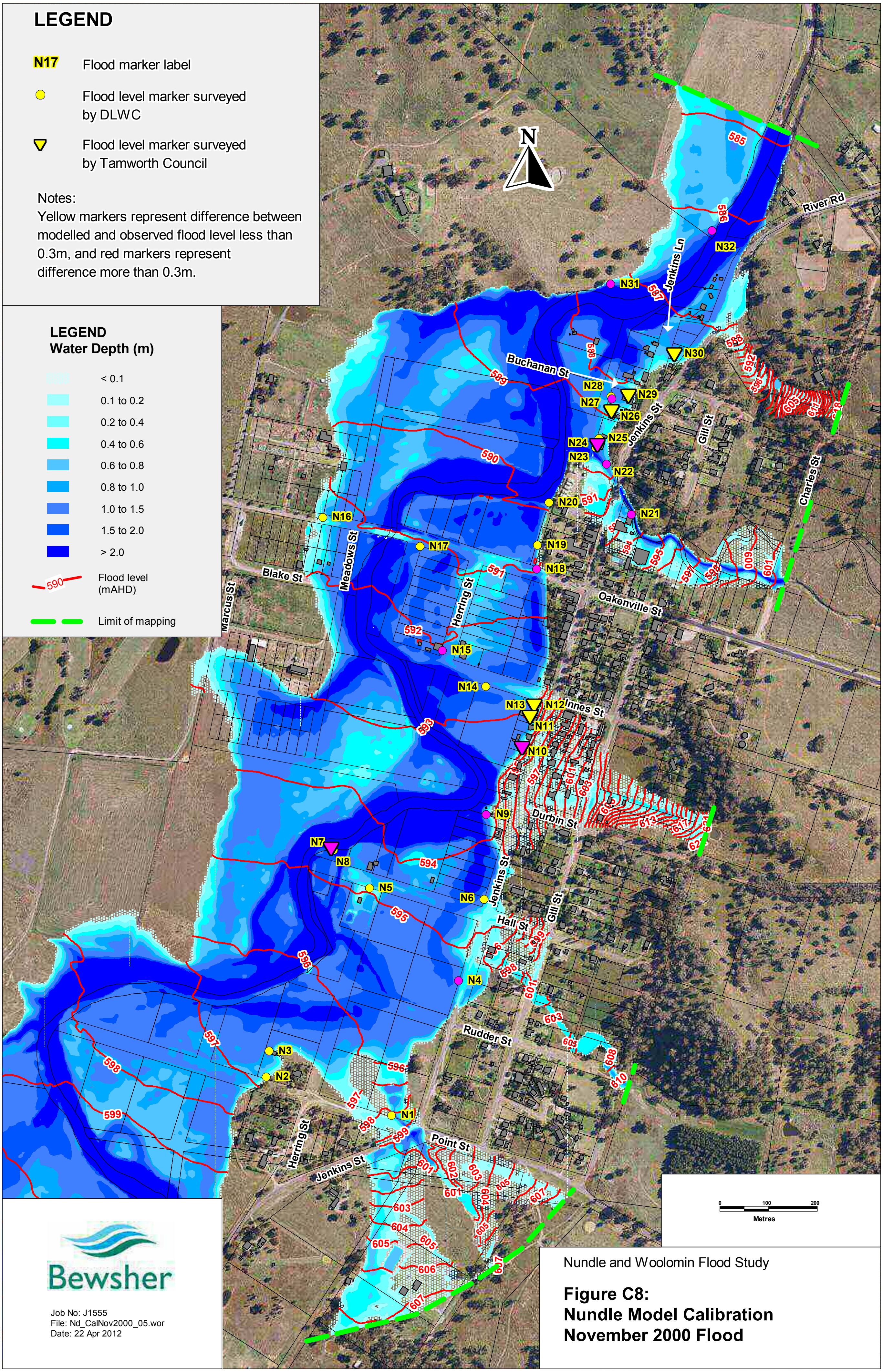
Notes

For location of calibration points, refer to Figure C8.

"Good fit" refers to modelled flood level being within 0.3m of the surveyed level.

"DEM level higher than obs flood level" means impossible for modelled level to match the observed level.

† Referenceto 7th April 2011 DECC email.



Nundle and Woolomin Flood Study

Figure C8:
Nundle Model Calibration
November 2000 Flood

C.3.1.4 Woolomin TUFLOW Calibration

The RORB model hydrographs generated using the k_c value of 14 (see **Table C6)** were imported into the Woolomin TUFLOW model. The resultant flood contours were found to be consistently 'high' relative to the overall picture of flood levels obtained from the survey of historic data. That is, whereas the modelled flood levels were found to be similar to the highest of the surveyed flood levels, they were found to be much higher than most of the levels. Consequently all the various model inputs, including inflow hydrographs, were reviewed. It was noticeable that both the Peel River and Duncans Creek hydrographs had nearly the same time-to-peak values at Woolomin yet this was not consistent with the historic observations of Duncans Creek peaking earlier.

Therefore a trial, based on bringing forward the Duncans Creek hydrograph peak by two hours, was undertaken. The resultant TUFLOW map presented a flood regime through Woolomin which approximated a 'line of best fit' picture through the population of surveyed flood marks.

Given:
(a) the historic picture of Duncans Creek peaking earlier; and
(b) that there were no storm temporal patterns recorded in the Duncans Creek catchment (and hence the storm pattern is uncertain across the catchment),

it was considered that the trial run represented a reasonable approximation of the most likely historic scenario. It was therefore adopted and **Figure C9** presents the corresponding extent of inundation and associated flood contours.

Table C8 tabulates the comparison of TUFLOW model results and survey marks and it can be seen that overall a good fit has been obtained.

C.3.2 JANUARY 2010 EVENT

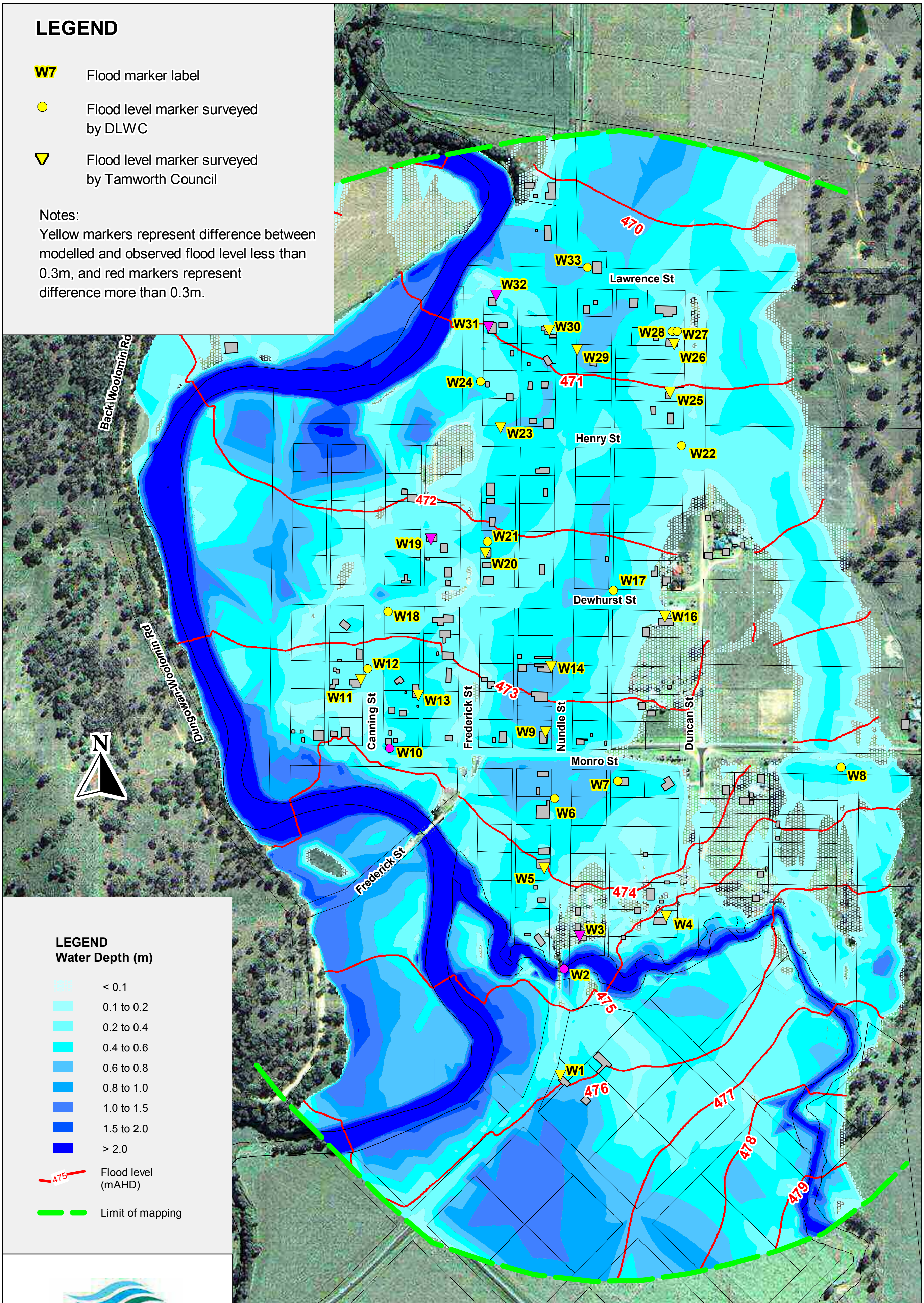
C.3.2.1 Rainfall

The rainfall was concentrated over approximately thirty hours spanning the 1st and 2nd of January.

Daily rainfall data for the event is presented in **Table C9** while the 2-day totals and corresponding derived isohyetal contours are presented in **Figure C10**. It can be seen that the spatial distribution various significantly over the catchment with recorded rainfall depths at Nundle and further south — e.g. Nundle (Hanging Rock), Nundle (Malonga) and Nundle (Keeva) all recording totals in excess of 100mm — being significantly higher than the northern records; e.g. Nundle (Chaffey Dam) recorded only 45mm for the same period.

Records from four pluviograph stations were available for the event. Their temporal patterns are presented in **Figure C11a** and **Figure C11b** while their cumulative rainfall totals are presented in **Figure C12**. It can be seen from **Figure C12** that the four patterns are all quite similar.

Since all four stations are located within the study catchment, all the temporal patterns were subsequently used in the RORB model.



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File: WM_CalNov2000_06
Date: 22 Apr 2012

Notes:
Flood depths shown are approximate due to underlying topographic base.

Nundle and Woolomin Flood Study

Figure C9: Woolomin Model Calibration November 2000 Flood

TABLE C8 : SUMMARY OF CALIBRATION FOR NOVEMBER 2000 EVENT AT WOOLOMIN

BC_ID	Source	Location	Observed Flood Level (mAHD)	DEM Ground Level (mAHD)	Modelled Flood Level (mAHD)	Difference Modelled Minus Surveyed Flood Level (m)	Comments
W1	Council Surveyor		475.60	475.43	475.72	0.12	Good fit
W2	DECCW		475.05	472.50	474.70	-0.36	
W3	Council Surveyor	86-88 MIDDLE ST	475.11	474.77	474.75	-0.36	
W4	Council Surveyor	81-83 DUNCAN	475.23	474.98	475.20	-0.02	Good fit
W5	Council Surveyor	73-75 MIDDLE ST	474.20	473.46	474.06	-0.14	Good fit
W6	DECCW		473.49	473.01	473.54	0.05	Good fit
W7	DECCW		473.44	473.01	473.52	0.08	Good fit
W8	DECCW		474.57	474.10	474.57	0.00	Good fit
W9	Council Surveyor	57-59 MIDDLE ST	473.04	472.45	473.14	0.10	Good fit
W10	DECCW		473.63	473.46	473.96	0.33	
W11	Council Surveyor	29-31 CANNING	473.26	472.91	473.21	-0.05	Good fit
W12	DECCW		472.99	472.86	473.20	0.21	Good fit
W13	Council Surveyor	34-36 CANNING	473.23	472.81	473.35	0.12	Good fit
W14	Council Surveyor	41-51 MIDDLE ST	472.62	472.14	472.75	0.13	Good fit
W16	Council Surveyor	41-47 DUNCAN	472.57	472.23	472.37	-0.20	Good fit
W17	DECCW		472.34	471.80	472.36	0.02	Good fit
W18	DECCW		472.61	472.49	472.71	0.10	Good fit
W19	Council Surveyor	13-15 FREDERICK	472.59	472.08	472.26	-0.33	
W20	Council Surveyor	34-36 FREDERICK	472.36	471.64	472.08	-0.29	Good fit
W21	DECCW		471.88	471.50	472.07	0.19	Good fit
W22	DECCW		471.46	470.94	471.26	-0.20	Good fit
W23	Council Surveyor	18-20 FREDERICK	471.47	470.88	471.46	-0.01	Good fit
W24	DECCW		471.32	470.84	471.25	-0.07	Good fit
W25	Council Surveyor	13-15 DUNCAN	471.19	470.83	471.04	-0.15	Good fit
W26	Council Surveyor	7 DUNCAN	471.01	470.59	470.79	-0.22	Good fit
W27	DECCW		470.52	470.43	470.67	0.14	Good fit
W28	DECCW		470.61	470.43	470.67	0.05	Good fit
W29	Council Surveyor	6-12 MIDDLE ST	470.89	470.29	470.89	0.00	Good fit
W30	Council Surveyor	1/7 MIDDLE ST	470.89	470.34	470.76	-0.13	Good fit
W31	Council Surveyor	6-8 FREDERICK	471.42	470.59	470.99	-0.43	
W32	Council Surveyor	2/4 FREDERICK	471.61	470.32	470.70	-0.91	Obs flood level is higher than u/s mark W31.
W33	DECCW		470.56	469.82	470.43	-0.13	Good fit

Notes

For location of calibration points, refer to Figure C9.

"Good fit" refers to modelled flood level being within 0.3m of the observed level.

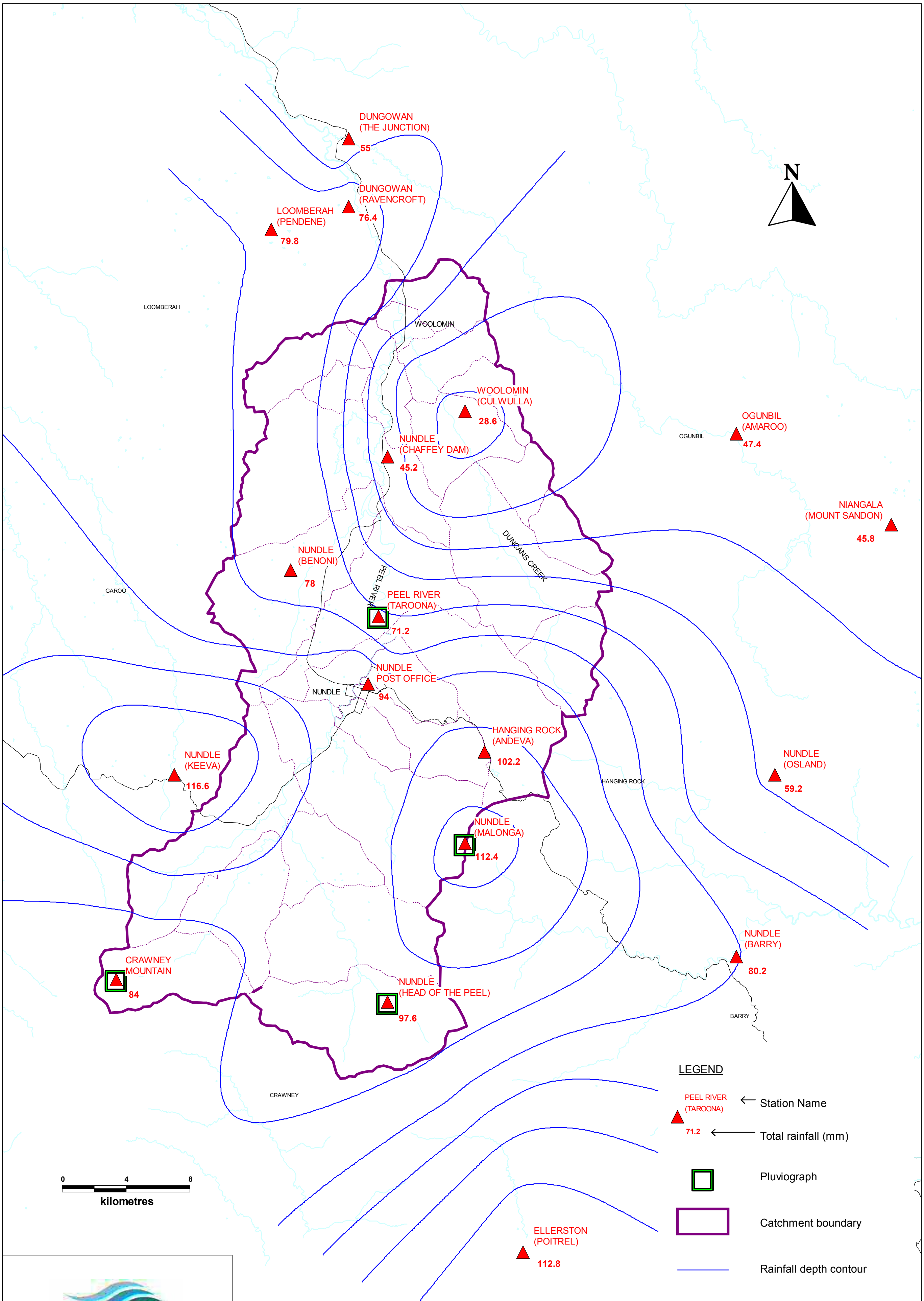
TABLE C9: SUMMARY OF RAINFALL DATA FOR JANUARY 2010 EVENT

Station Name	Rain Gauge ID	Data	Daily Rainfall (mm)		2 Day Total
			2-Jan-10	3-Jan-10	
NUNDLE POST OFFICE #	55041	Daily	49.4	44.6	94.0
HANGING ROCK (ANDEVA)	55200	Daily	52.0	50.2	102.2
NUNDLE (BENONI)	55078	Daily	41.0	37.0	78.0
NUNDLE (MALONGA)	55335	Continuous rainfall data	46.8	65.6	112.4
NUNDLE (KEEVA)	55245	Daily	58.2	58.4	116.6
NUNDLE (CHAFFEY DAM)	55302	Daily	25.4	19.8	45.2
NUNDLE (HEAD OF THE PEEL)	55336	Continuous rainfall data	40.0	57.6	97.6
WOOLOMIN (CULWULLA)	55189	Daily	1.6	27.0	28.6
CRAWNEY MOUNTAIN	55337	Continuous rainfall data	37.0	47.0	84.0
NUNDLE (OSLAND)	60127	Daily	4.8	54.4	59.2
NUNDLE (BARRY)	60128	Daily	20.4	59.8	80.2
OGUNBIL (AMAROO)	55262	Daily	27.6	19.8	47.4
GOWRIE (LALLYBROCH)	55195	Daily	60.0	35.6	95.6
DUNGOWAN (RAVENCROFT)	55181	Daily	25.6	50.8	76.4
LOOMBERAH (PENDENE)	55176	Daily	28.2	51.6	79.8
NIANGALA (MOUNT SANDON)	55322	Daily	26.8	19.0	45.8
ELLERSTON (POITREL)	61196	Daily	19.2	26.0	45.2
DUNGOWAN (THE JUNCTION)	55170	Daily	23.6	31.4	55.0
PEEL RIVER (TAROONA)	419081	Continuous rainfall data	37.4	33.8	71.2

Notes

Nundle Post Office rainfall from 1 Jan 2010 to 4 Jan 2010 is given as total of the four days. Rainfall for each day shown in the table is interplotated from pattern of Taroona daily rainfall.

Daily rain 2010.xls



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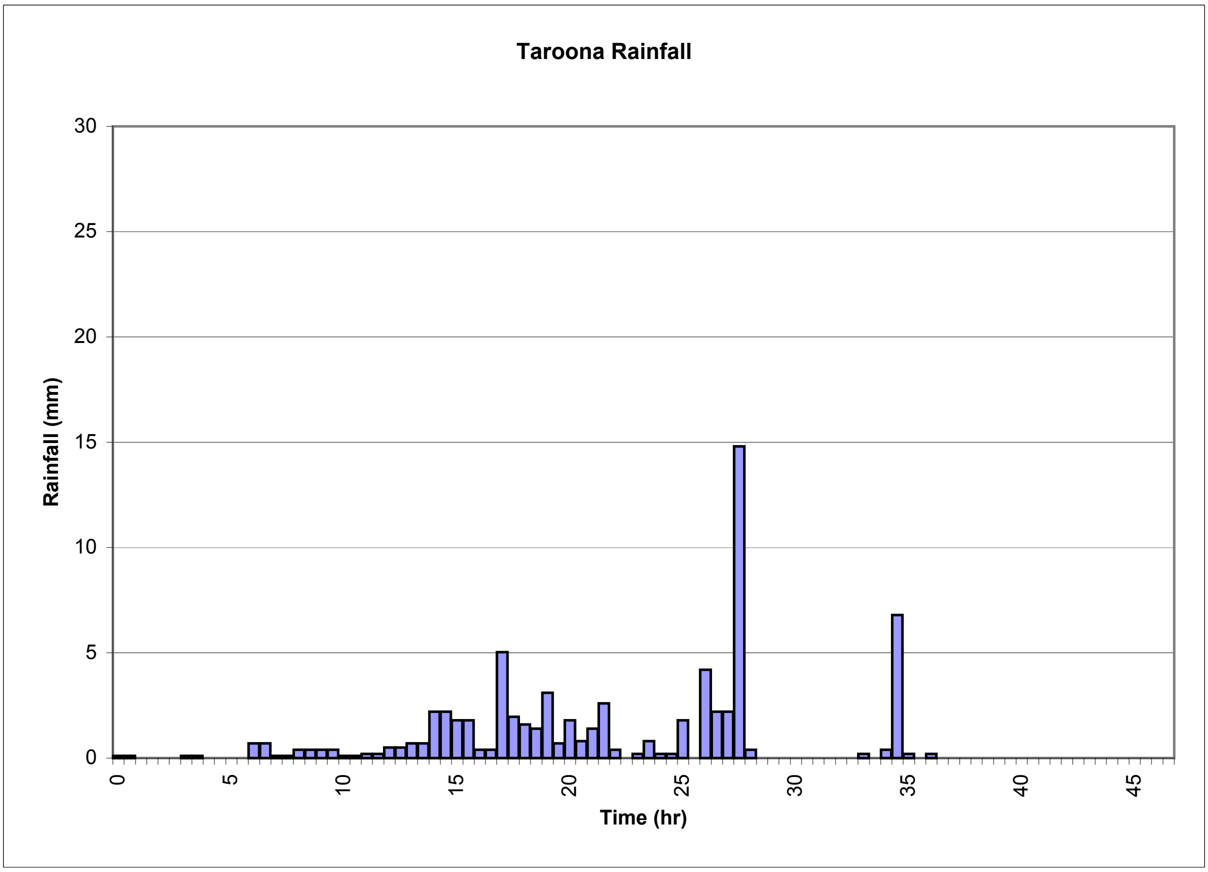
Job No: J1555
File: Jan2010Rain_01
Date: 30 May 2011

Nundle and Woolomin Flood Study

Figure C10 :
Spatial Distribution of January 2010 Rainfall (2 Day Rainfall Totals)

Figure C11a: Temporal Pattern at Taroona and Head of Peel for 1-2 January 2010

(Graph starts at 9:00 am 1st January 2010 am EDST)



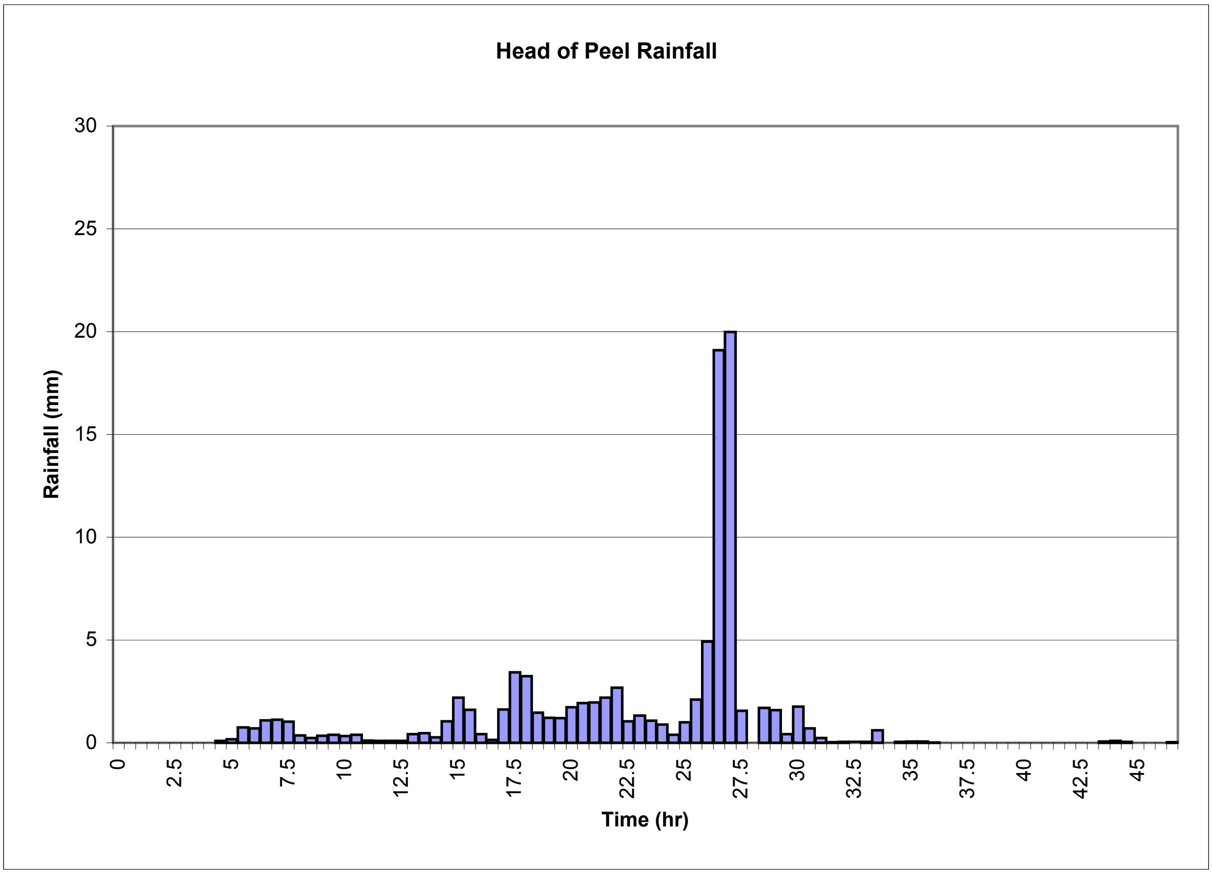
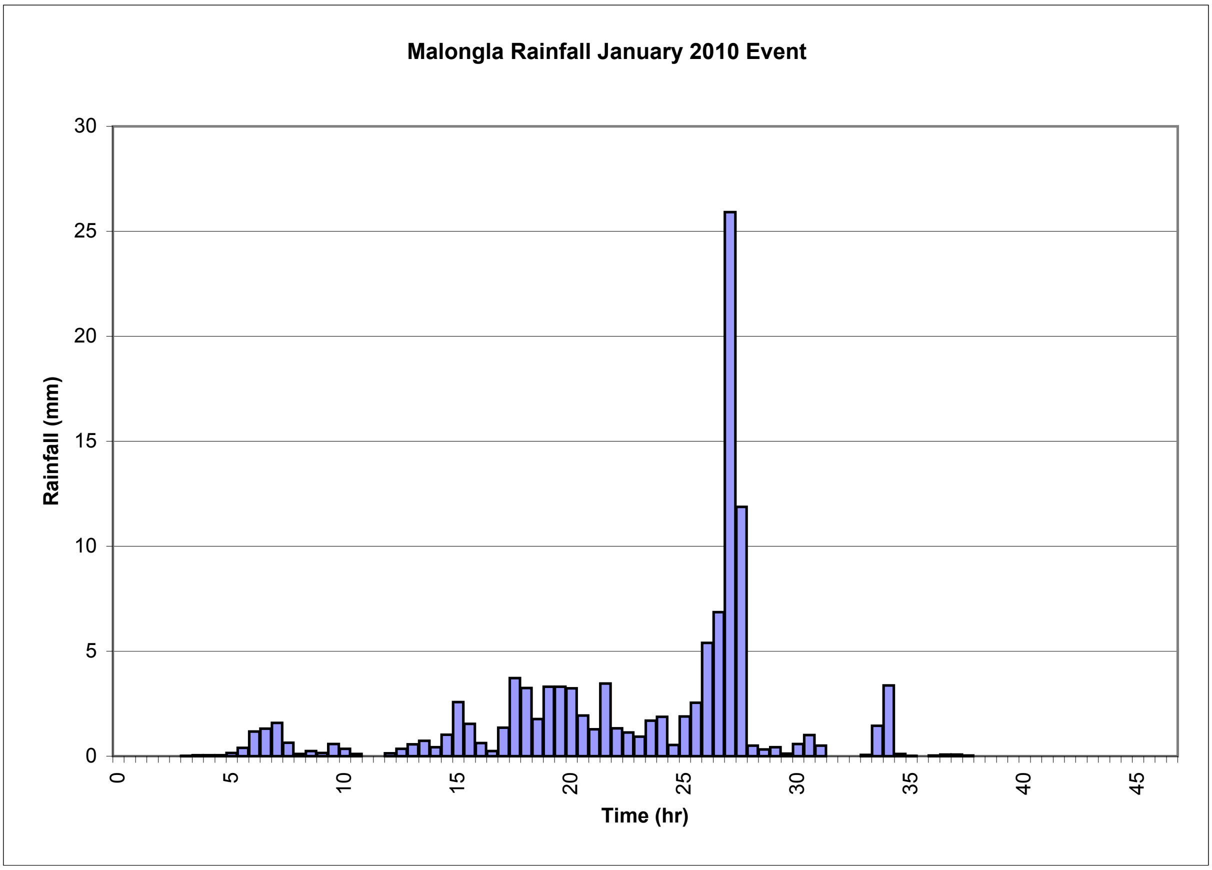


Figure C11b: Temporal Pattern at Malongla and Crawney Mountain for 1-2 January 2010

(Graph starts at 9:00 am 1st January 2010 am EDST)



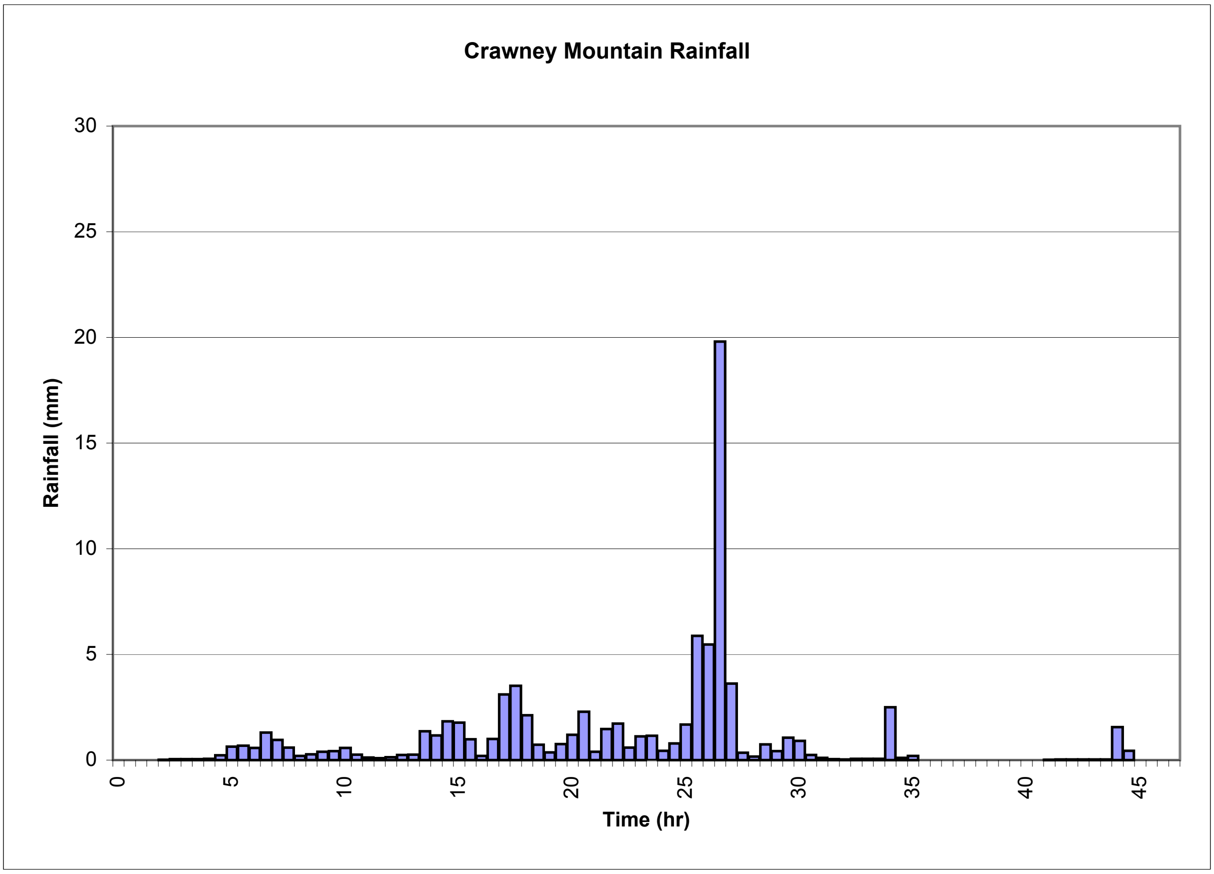
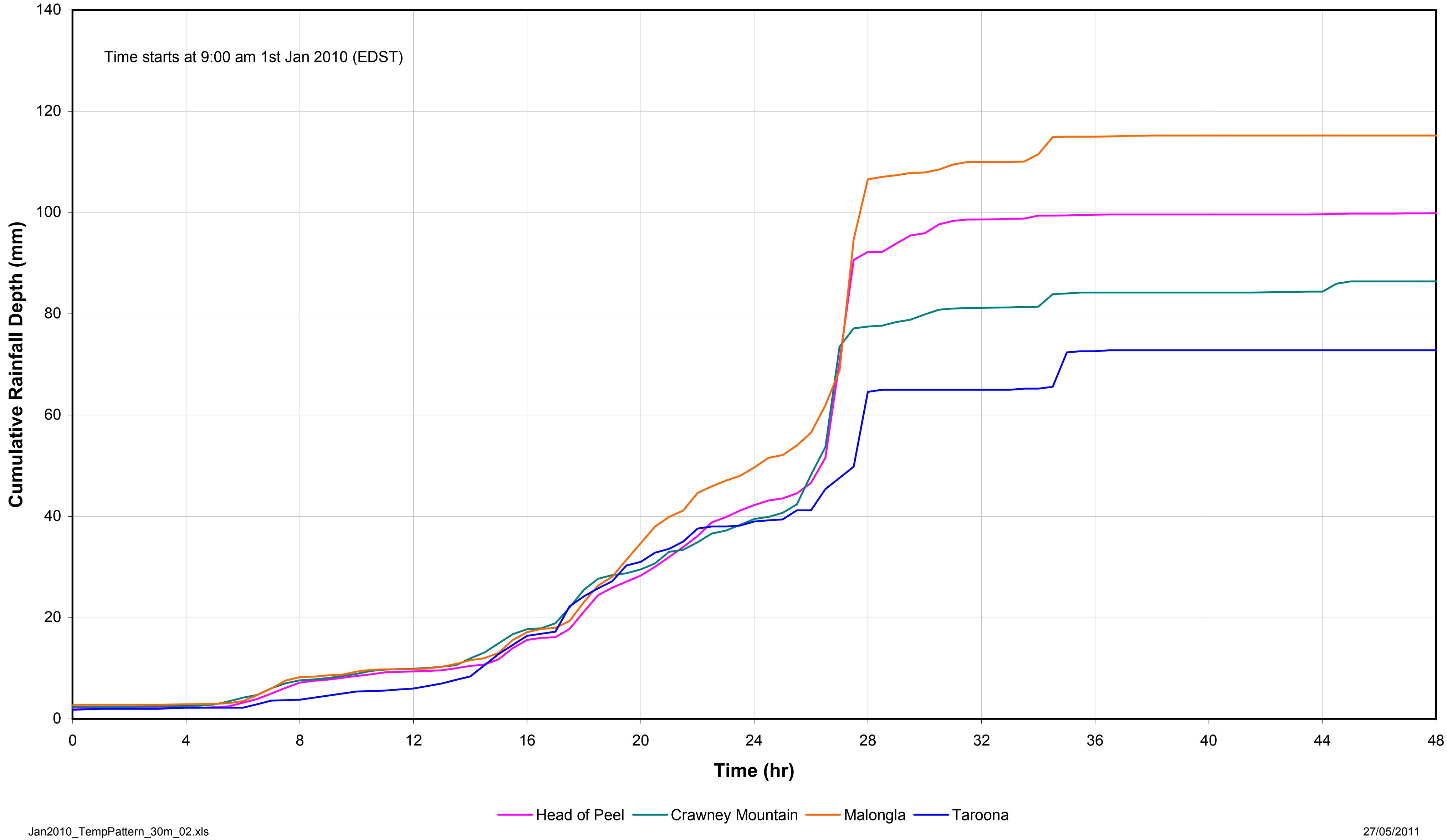


Figure C12: Comparison of January 2010 Cumulative Rainfall Temporal Patterns



Jan2010_TempPattern_30m_02.xls

27/05/2011

C.3.2.2 RORB Modelling

The spatial pattern shown in **Figure C10** and the four temporal patterns were used to develop the rainfall pattern used in the RORB model. Each sub-catchment was assigned the temporal pattern of the closest pluviograph.

The calibration k_c and m values of 14.0 and 0.8 respectively were preserved. Based on losses of 45 mm and 2.0 mm/h – that is, similar to those used in the calibration modelling - the RORB model was run using the spatial and temporal patterns detailed above. **Figure C14** allows the comparison of the RORB flow hydrograph with the recorded hydrograph at Taroona.

C.3.2.3 TUFLOW Modelling

The RORB flow hydrographs were imported into the TUFLOW model. **Table C10** tabulates the flood level results against the surveyed marks while **Figure C13** presents the modelled extent of inundation and associated flood contours.

Overall a reasonable fit has been obtained and therefore it is considered that the TUFLOW model had been satisfactorily verified.

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TABLE C10: SUMMARY OF VERIFICATION FOR JANUARY 2010 FLOOD AT NUNDLE

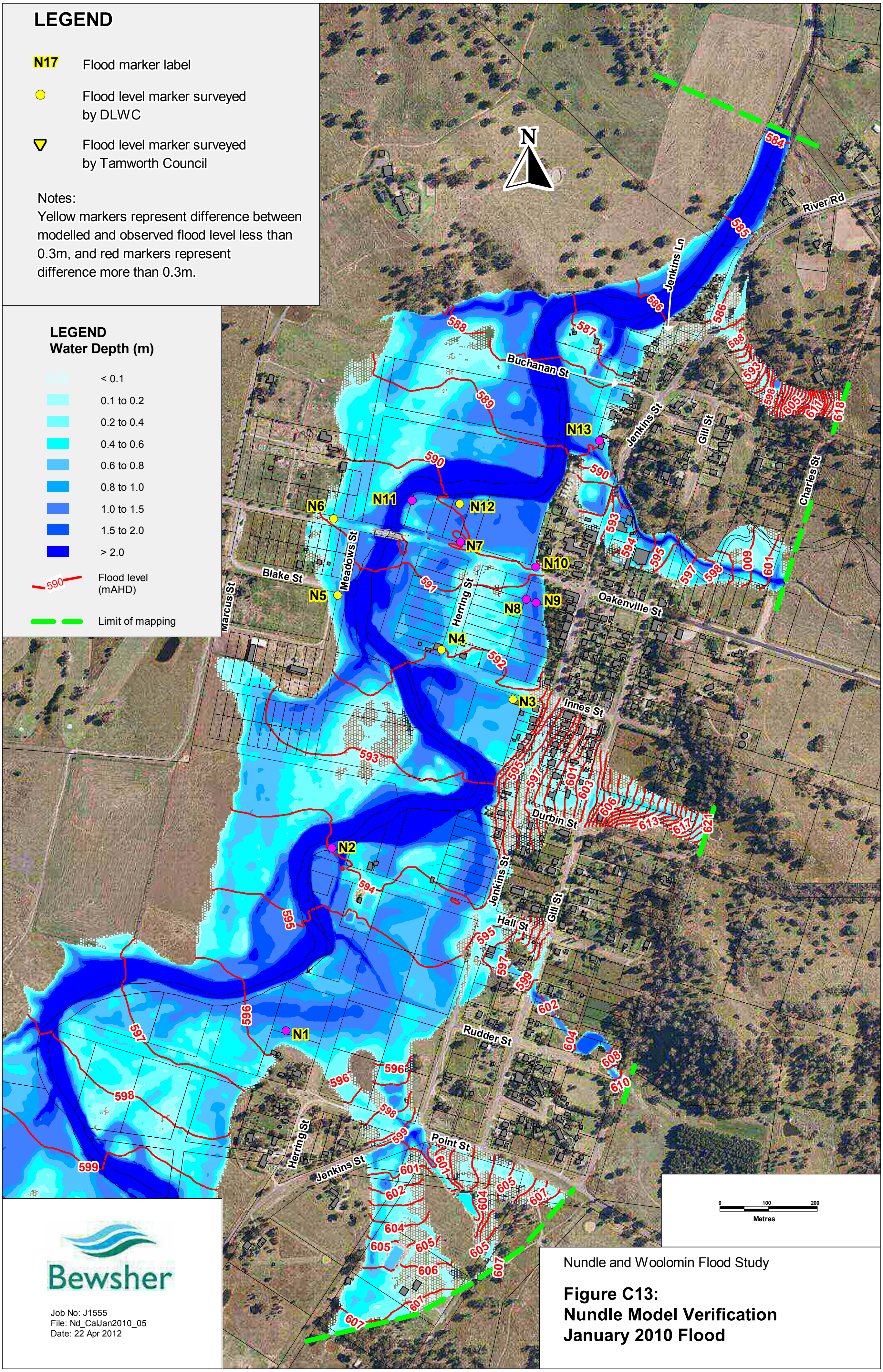
BC_ID	Location	Flood Mark Number	Observed Flood Level (mAHD)	DEM Ground Level (mAHD)	Modelled Flood Level (mAHD)	Difference Modelled Minus Observed Flood Level (m)	Comments
N1	Private pump shed crn of (approx 0.69m above ns)	12	595.34	594.99	595.73	0.39	
N2	Top of deck of pump station	11	594.50	592.18	594.15	-0.34	Modelled flood range 593.7-594.1 across structure.
N3	Crn of shed 0.18 m above first nail line.	10	592.22	591.59	592.26	0.04	Good fit
N4	House - top of first board or top of landing.	9	592.05	591.13	592.06	0.01	Good fit
N5	Gate Post (rough)	8	591.22	590.53	591.50	0.28	Good fit
N6	Fence Post	7	590.70	590.39	590.82	0.12	Good fit
N7	Toilet Block	5	589.58	589.11	589.96	0.38	
N8	Crn Fence	3	590.85	590.08	591.26	0.41	
N9	Gate Post	4	590.57	589.65	591.27	0.69	
N10	Nundle Rd	2	589.48	589.62	590.01	0.52	DEM level higher than observed level.
N11	Pump St	13	589.77	588.76	590.20	0.43	
N12	Tree	6	589.83	588.96	589.94	0.11	Good fit
N13	Caravan park showers	1	588.55	588.52	588.91	0.37	

Notes

For location of calibration points, refer to Figure C13.

Good fit refers to modelled flood level being within 0.3m of the observed level.

DEM level higher than obs flood level means impossible for modelled level to match the observed.



LEGEND

N17	Flood marker label
○	Flood level marker surveyed by DLWC
▽	Flood level marker surveyed by Tamworth Council

Notes:
Yellow markers represent difference between modelled and observed flood level less than 0.3m, and red markers represent difference more than 0.3m.

LEGEND
Water Depth (m)

- < 0.1
- 0.1 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- 590 Flood level (mAHD)
- Limit of mapping

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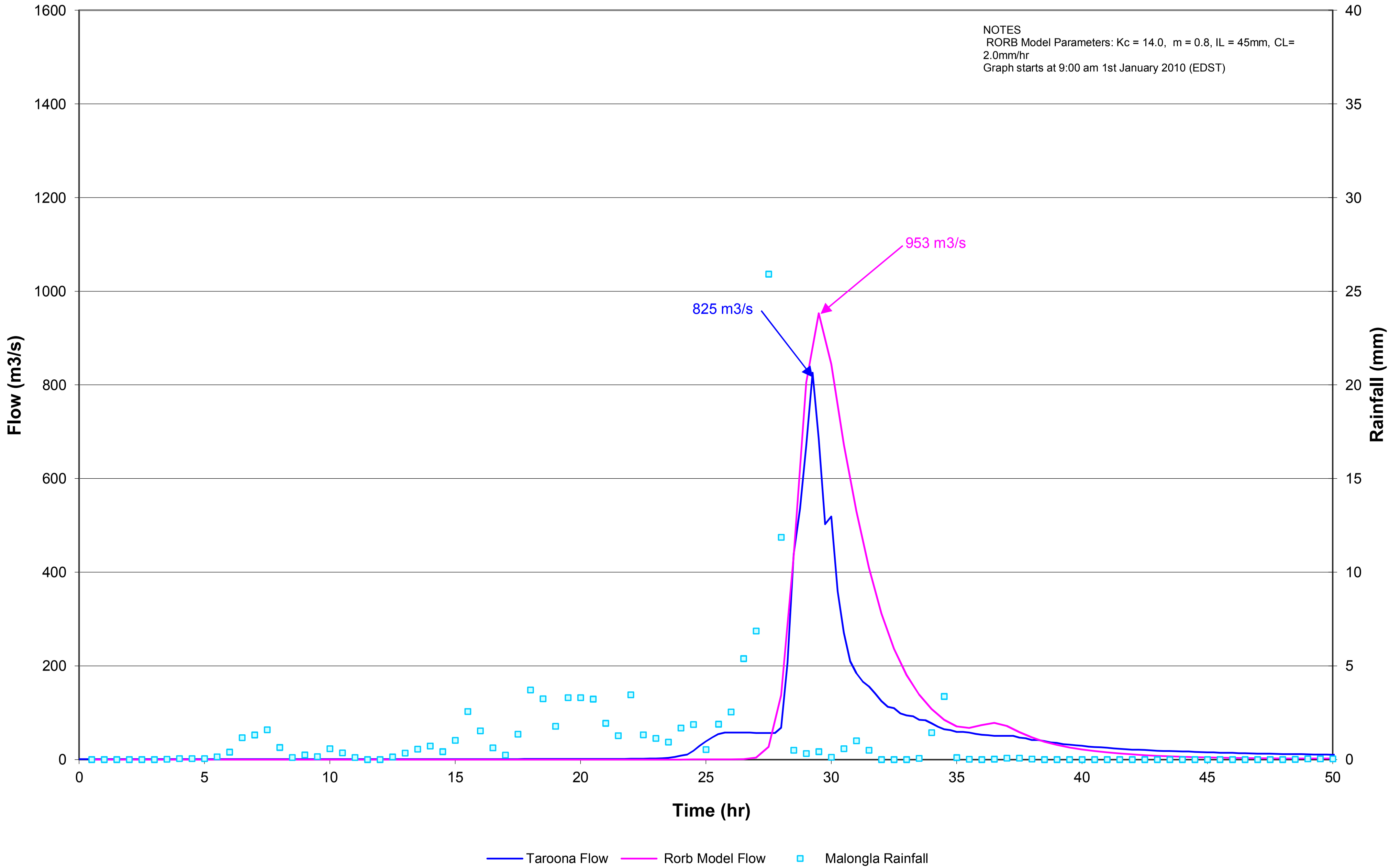
Job No: J1555
File: Nd_CalJan2010_05
Date: 22 Apr 2012

Nundle and Woolomin Flood Study

Figure C13:
Nundle Model Verification
January 2010 Flood

Figure C14: Calibration to Jan 2010 Flood Flow Hydrograph at Taroona



C.4 DESIGN EVENT MODELLING

C.4.1 RORB MODEL PARAMETERS, RAINFALLS & LOSSES

Following the successful replication of the 2000 and 2010 flood regimes, RORB model parameter values of 14.0 for k_c and 0.8 for m were adopted for all the Peel River design event modelling.

Five rainfall station locations were selected to represent the rainfall intensities across the catchment (see **Figure C1**) and their respective intensity-frequency-duration (IFD) information was obtained via the BoM on-line system. There were only small differences in the five sets of data and individual RORB sub-catchment rainfall intensities were based on the nearest station.

The design storm temporal patterns are as per AR&R 'Zone 2' (defined by Figure 3.2 in AR&R 1987 Vol 2, **Reference C4**).

Table C11 lists the loss values adopted for the various design events.

TABLE C11: DESIGN EVENT RAINFALL LOSSES

Design Event	Initial Loss (mm)	Continuing Loss (mm/h)
20 year	15.0	2.5
50 year	15.0	2.5
100 year	15.0	2.5
PMF	0.0	1.0

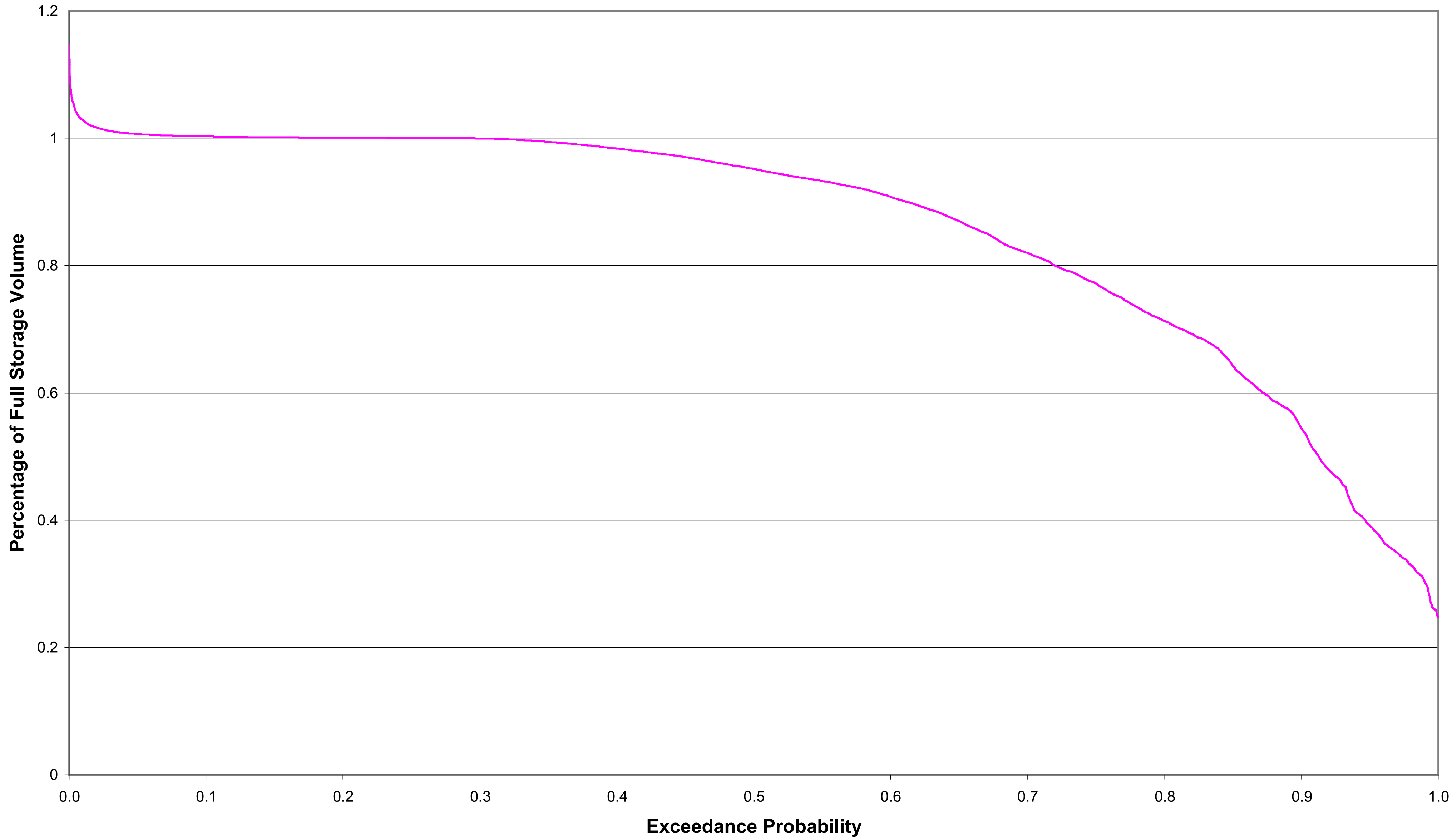
C.4.2 CHAFFEY DAM DESIGN WATER LEVELS

Since Chaffey Dam is located just upstream of Woolomin, its impact on the passage of a flood event is very relevant to assessing the flood regime at Woolomin. In this regard it is important to recognise that not only is the dam a dedicated water supply storage but it also has no operational capability for either controlling its flood-time water levels or the time at which spill would commence. It therefore follows that it is important to establish if the dam volume at the start of a major flood event has a significant impact on the passage of the flood through the dam. This has been achieved by examining the results of:

(a) long term simulations of daily water levels in the dam; and
(b) the RORB model for a range of initial volume conditions.

The NSW Office of Water (NOW) has an IQQM model of the Namoi Valley. Using the model, NOW provided time series data for Chaffey Dam daily storage levels based on 117 years of simulation (for 'current conditions') and the resultant dam storage-frequency plot is presented in **Figure C15**. From the plot, it can be seen that the dam is full only about 30% of the time. However it is 90% full about 60% of the time and 80% full about 82% of the time.

Figure C15: Chaffey Dam Storage Frequency Plot



To test the sensitivity of initial storage volume to the outflow flood peak, the RORB model was run with a range of starting volumes for different 100 year ARI storm durations. **Table C12** summarises the results as percentage amounts of flow attenuation with each initial starting volume scenario. (While these runs were undertaken at the stage of the project when the modelling was being undertaken using a k_c value of 9.0, the attenuation results directly reflect the routing of total event runoff volumes which do not change regardless of changes in k_c and hence the earlier results were retained.) The information contained in **Table C12** shows that: [1]

- the percentage of attenuation increases with each lowering of the initial storage volume;
- for the same initial storage volume, the attenuation impact is larger for shorter duration storms;
- when the dam is 100% full at the start of the event, the peak inflow is attenuated between 65% and 75%. When the dam is 80% full at the start of the flood, the attenuation increases to 76%−94%;
- however when the dam is more than 80% full, most of the attenuation results from the spillway routing rather than the airspace at the start of an event.

As a result of the assessments, it is concluded that most of the time the dam will be close to full at the start of a major flood event. Significant attenuation of inflows will occur in all events. Whilst the amount of attention increases as the assumed initial storage volume is lowered, nevertheless the vast majority of the attention results from the spillway routing (except when the dam is less than 50% full which occurs only about 10% of the time). Consequently for all design event simulations, the dam has been modelled as being full at the start of the simulation.

C.4.3 20 YEAR TO 100 YEAR ARI DESIGN EVENTS

C.4.3.1 Peel River Flows

Following an allowance for areal reduction factors based on the Peel River catchment area at Nundle, the RORB design model was run for a range of 20 year ARI, 50 year ARI and 100 year ARI storm durations using the temporal patterns provided in *Australian Rainfall & Runoff* (**Reference C4**). The resultant flows are presented in **Table C13**. It can be seen from the table that the critical duration Peel River events are 48 hours at Nundle and 72 hours at Woolomin.

C.4.3.2 Nundle Eastern Tributary Flows

Since the various Nundle eastern tributary catchments are very small relative to the Peel River catchment it follows that the **Table C13** RORB-based flows do not represent appropriate design flows for the tributaries. Therefore their design flows have been calculated on the basis of adjusting their RORB model one hour storm duration flows to match peak flows as calculated using the AR&R Probabilistic Rational Method or PRM (**Reference C5**). Those PRM flows are also tabulated in **Table C13.**

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[1] There are two other effects that support adoption of full storage conditions at the start of the design flood events. Firstly, design rainfalls are rainfall 'bursts' which ignore any antecedent rainfall prior to the bursts. If this antecedent rainfall was considered, higher initial storage levels should be used. Secondly, the frequency analysis presented in **Figure C15** assumes that major flood producing rainfall and generally wetter conditions (producing higher storage volumes) are statistically independent. Whilst no statistical assessments have been undertaken for this catchment as part of this Study, it is quite likely that such rainfall does occur as part of wetter rather than drier hydrologic sequences.

TABLE C12: ATTENUATION AFFECT OF CHAFFEY DAM

a) Q_{IN} : Peak Inflow at Chaffey Dam (m3/s)

Event	100 Year ARI 2hr	100 Year ARI 6hr	100 Year ARI 24hr	100 Year ARI 48hr
Inflow	1589	1948	2289	2490

b) Q_{OUT} : Peak Outflow at Chaffey Dam (m3/s)

	Event			
Initial Volume	100 Year ARI 2hr	100 Year ARI 6hr	100 Year ARI 24hr	100 Year ARI 48hr
100%	399	679	742	749
90%	225	518	683	720
80%	91	347	553	557
70%	0	189	425	403
60%	0	74	297	270
50%	0	0	199	202

c) Peak Outflow Percentage Attenuation $(Q_{IN} - Q_{OUT}) \div Q_{IN}$

	Event			
Initial Volume	100 Year ARI 2hr	100 Year ARI 6hr	100 Year ARI 24hr	100 Year ARI 48hr
100%	75%	65%	68%	70%
90%	86%	73%	70%	71%
80%	94%	82%	76%	78%
70%	100%	90%	81%	84%
60%	100%	96%	87%	89%
50%	100%	100%	91%	92%

d) Proportion of Attention due to Initial Storage $(Q_{OUT\,(100\%)} - Q_{OUT}) \div (Q_{IN} - Q_{OUT})$

	Event			
Initial Volume	100 Year ARI 2hr	100 Year ARI 6hr	100 Year ARI 24hr	100 Year ARI 48hr
100%	0%	0%	0%	0%
90%	13%	11%	4%	2%
80%	21%	21%	11%	10%
70%	25%	28%	17%	17%
60%	25%	32%	22%	22%
50%	25%	35%	26%	24%

e) Proportion of Attention due to Spillway Routing $(Q_{IN} - Q_{OUT\,(100\%)}) \div (Q_{IN} - Q_{OUT})$

	Event			
Initial Volume	100 Year ARI 2hr	100 Year ARI 6hr	100 Year ARI 24hr	100 Year ARI 48hr
100%	100%	100%	100%	100%
90%	87%	89%	96%	98%
80%	79%	79%	89%	90%
70%	75%	72%	83%	83%
60%	75%	68%	78%	78%
50%	75%	65%	74%	76%

TABLE C13: SUMMARY OF RORB MODEL 20 YEAR -100 YEAR RESULTS

RORB Parameters: kc = 14 m = 0.8

100 Year ARI

Location	Duration (hours)														Max	PRM	Catchment
	0.75h	1h	1hh	2h	3h	4hh	6h	9h	12h	18h	24h	36h	48h	72h			Area (km2)
Peel River U/S of Nundle	482	587	665	804	928	980	1003	882	933	932	1189	1220	**1259**	1074	**1259**		213
Tributary H4	55	67	64	69	**83**	74	60	61	64	65	64	49	50	33	**83**	92	6.7
Tributary H3	71	87	90	95	**110**	99	91	89	109	103	103	97	100	69	**110**	190	13.8
Tributary H1	68	85	76	88	**99**	89	69	70	68	72	74	52	53	35	**99**	96	7
Tributary H2	95	117	110	121	**143**	127	103	103	107	109	109	80	83	55	**143**	151	11
Peel River D/S of Nundle	487	666	801	922	1039	1107	1119	1040	1127	1115	1323	1431	**1478**	1246	**1478**		251
Chaffey Dam Outflow	121	181	260	331	446	539	605	663	668	739	738	739	740	**750**	**750**		409
Peel River US of Woolomin	143	180	258	329	444	537	604	666	690	769	**777**	767	764	773	**777**		
Duncans Creek US of Woolomin	281	389	490	549	591	595	586	549	588	586	673	652	**680**	501	**680**		101
Peel River DS of Woolomin	365	505	644	730	789	798	779	860	831	1044	968	946	988	**1078**	**1078**		542

50 Year ARI

Location	Duration (hours)														Max	PRM	Catchment
	45m	1h	1hh	2h	3h	4hh	6h	9h	12h	18h	24h	36h	48h	72h			Area (km2)
Peel River U/S of Nundle	388	474	535	658	772	824	845	733	789	772	1018	1040	**1070**	925	**1070**		213
Tributary H4	45	55	53	57	**71**	62	50	51	57	57	56	43	44	29	**71**	92	6.7
Tributary H3	57	70	74	80	91	84	78	77	**93**	88	91	85	87	59	**93**	190	13.8
Tributary H1	56	69	64	73	**86**	77	58	59	61	64	65	45	47	30	**86**	96	7
Tributary H2	78	96	92	98	**123**	108	86	86	95	96	95	71	73	47	**123**	151	11
Peel River D/S of Nundle	379	528	655	761	866	930	945	868	938	935	1131	1223	**1258**	1070	**1258**		251
Chaffey Dam Outflow	96	138	202	262	357	438	496	548	555	660	654	657	661	**715**	**715**		409
Peel River US of Woolomin	112	145	201	260	354	436	495	550	570	665	669	664	674	**729**	**729**		
Duncans Creek US of Woolomin	218	308	401	457	492	505	497	466	494	489	583	565	**586**	432	**586**		101
Peel River DS of Woolomin	285	402	527	609	661	679	671	708	683	**868**	818	814	844	859	**868**		542

20 Year ARI

Location	Duration (hours)														Max	PRM	Catchment
	45m	1h	1hh	2h	3h	4hh	6h	9h	12h	18h	24h	36h	48h	72h			Area (km2)
Peel River U/S of Nundle	268	350	379	478	588	657	684	598	661	643	865	903	**929**	817	**929**		213
Tributary H4	31	41	42	45	**61**	53	42	43	52	52	47	39	40	26	**61**	92	6.7
Tributary H3	39	51	56	62	75	71	67	67	**83**	77	80	76	78	53	**83**	190	13.8
Tributary H1	39	52	51	57	**75**	66	49	50	56	59	56	41	42	27	**75**	96	7
Tributary H2	55	72	72	78	**106**	92	72	74	87	88	81	64	66	42	**106**	151	11
Peel River D/S of Nundle	244	371	475	565	661	741	769	725	796	791	963	1054	**1084**	942	**1084**		251
Chaffey Dam Outflow	68	96	138	183	251	317	363	408	422	509	520	533	537	**583**	**583**		409
Peel River US of Woolomin	75	103	137	182	249	315	362	408	430	512	529	535	544	**591**	**591**		
Duncans Creek US of Woolomin	140	214	290	344	395	416	416	396	424	416	503	500	**516**	381	**516**		101
Peel River DS of Woolomin	185	281	382	458	525	560	565	526	569	670	694	717	**739**	700	**739**		542

TABLE C14: SUMMARY OF RORB MODEL RESULTS FOR DUNCANS CREEK

RORB Parameters: kc = 10.2, m = 0.8

100 Year ARI

	Duration (hours)													
Location	1h	1hh	2h	3h	4hh	6h	9h	12h	18h	24h	36h	48h	72h	Max
Duncuns Creek US of Woolomin	143	190	227	273	302	317	274	275	298	346	364	380	**395**	**395**

50 Year ARI

	Duration (hours)													
Location	1h	1hh	2h	3h	4hh	6h	9h	12h	18h	24h	36h	48h	72h	Max
Duncuns Creek US of Woolomin	114	154	187	226	253	269	189	231	253	297	310	321	**331**	**331**

20 Year ARI

	Duration (hours)													
Location	1h	1hh	2h	3h	4hh	6h	9h	12h	18h	24h	36h	48h	72h	Max
Duncuns Creek US of Woolomin	81	112	139	170	199	214	189	190	207	249	265	274	**281**	**281**

C.4.3.3 Duncans Creek Flows

Since the Duncans Creek catchment is also significantly smaller than the overall Peel River catchment, it also follows that the **Table C13** flows do not represent appropriate design flows for that catchment. To calculate the design flows, a stand-alone RORB model was created by separating the Duncans Creek catchment model from the overall RORB catchment. All sub-catchments were preserved, except for DC2 which was split into two smaller sub-catchments in accordance with guidelines in the RORB model manual.

This stand-alone model's design flows were then generated using the regional RORB k_c value of 10.2 (based on the Kleemola regional relationship presented in *Australian Rainfall & Runoff,* **Reference C5**). The resultant flows are presented in **Table C14**.

C.4.3.4 Allowances for Blockage

The following allowances have been made for blockage of bridge and conduit waterways:

(a) for bridge structures − 25% blockage; and
(b) for conduits (i.e. pipes and rectangular culverts) − 50% blockage.

C.4.3.5 Nundle and Woolomin Design Flood Scenarios

Since both Nundle and Woolomin have Peel River tributary catchments whose response to rainfall is much shorter than for the river itself, it was recognised that several different design event scenarios would need to be considered when undertaking the hydraulic modelling. This is detailed in **Sections C.4.3.6** and **C.4.3.7**.

C.4.3.6 Nundle Design Flood Mapping

For the design runs, the calibrated TUFLOW model was run for a number of different scenarios and then the various sets of results were enveloped to produce the 20 year ARI, 50 year ARI and 100 year ARI flood inundation maps, see **Figures C16, C17** and **C18.**

The various scenarios for each design event were:

- 48 hour storm RORB-based hydrographs (both blocked and unblocked) to reflect the worst case scenario for the Peel River floodplain,

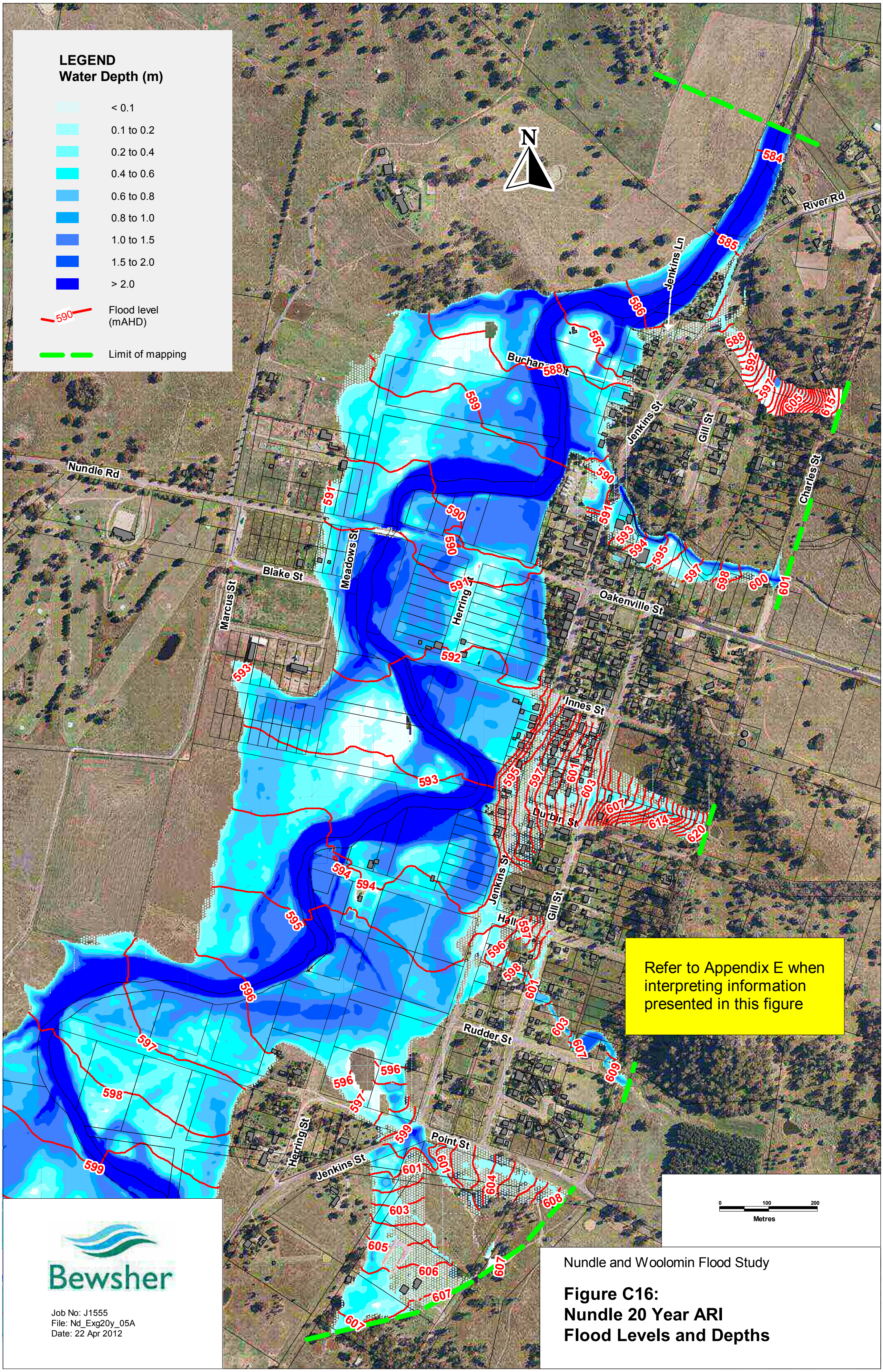
- 1 hour storm PRM-adjusted RORB hydrographs (both blocked and unblocked) to reflect the worst case scenario for the eastern tributaries.

The modelling of the design event floods provided the opportunity to assess the relative size of the Nundle November 2000 flood. Reviews of:

(a) the RORB model peak flows at Nundle, Taroona and the inflow to Chaffey Dam; and
(b) the TUFLOW 2000 and 100 year ARI flood maps,

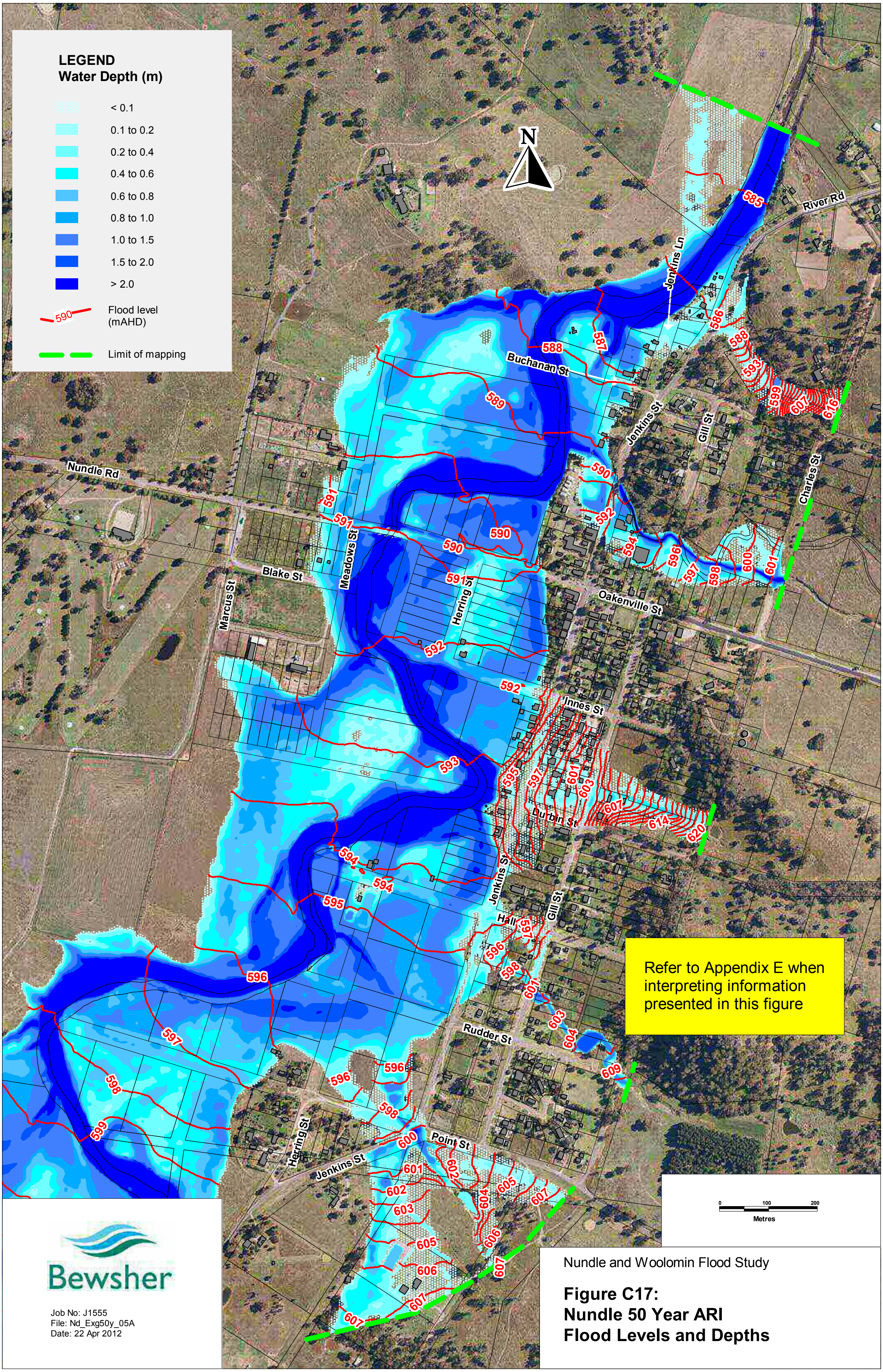
revealed that the 2000 event was similar to the 100 year ARI flood.

Figure C19 defines the hydraulic hazard zones in the Nundle 100 year ARI floodplain where the zones are based on the criteria presented in Figure L2 of the 2005 Floodplain Development Manual (**Reference C10**).



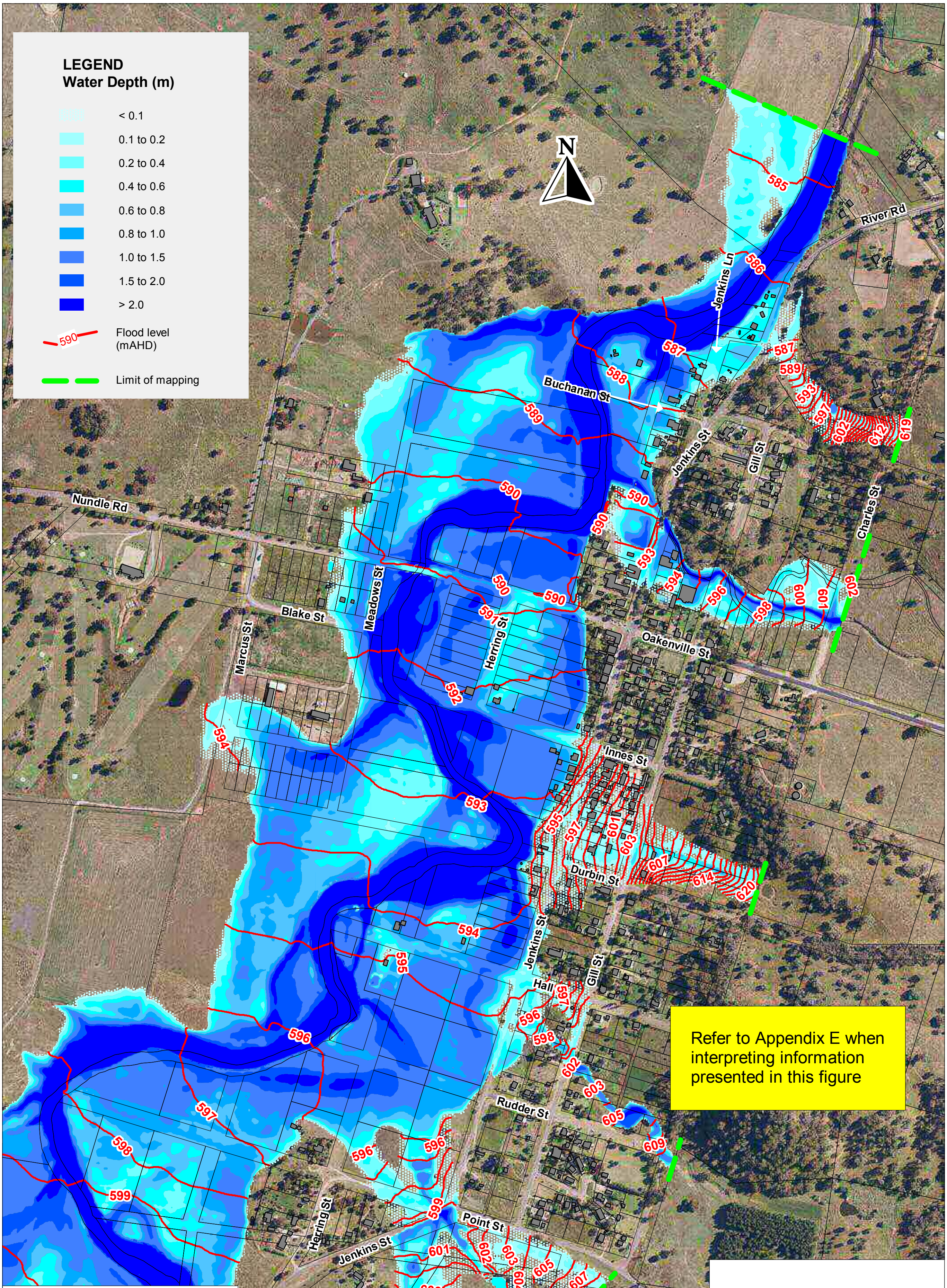
Nundle and Woolomin Flood Study

Figure C16:
Nundle 20 Year ARI
Flood Levels and Depths



Nundle and Woolomin Flood Study

Figure C17: Nundle 50 Year ARI Flood Levels and Depths



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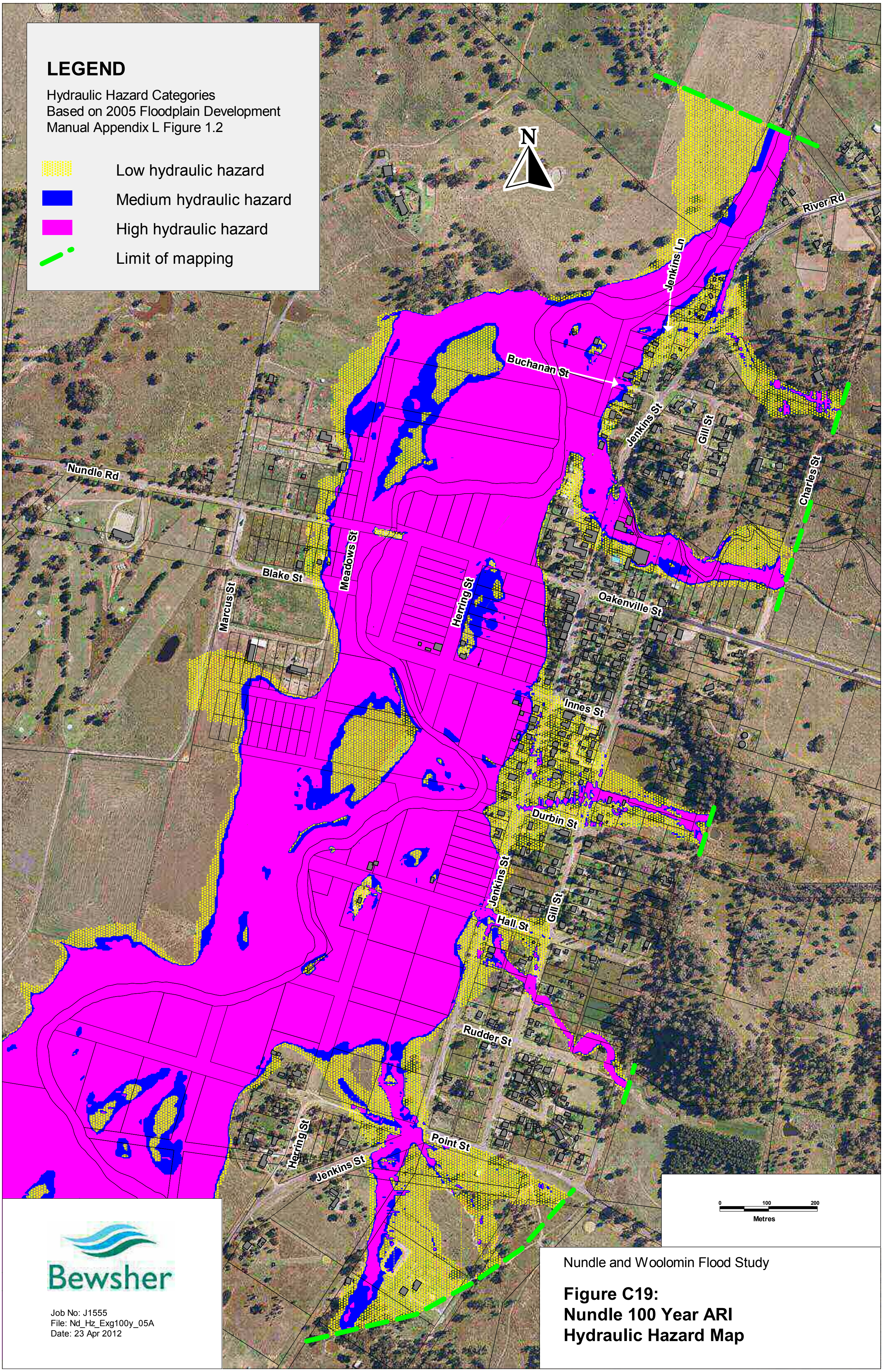
Job No: J1555
File: Nd_Exg100y_05A
Date: 22 Apr 2012

Nundle and Woolomin Flood Study

Figure C18:
Nundle 100 Year ARI
Flood Levels and Depths



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Job No: J1555
File: Nd_Hz_Exg100y_05A
Date: 23 Apr 2012

Nundle and Woolomin Flood Study

Figure C19:
Nundle 100 Year ARI
Hydraulic Hazard Map

Figure C20 defines the impact of potential climate change throughout the Nundle 100 year ARI floodplain based on a 15% increase in design rainfall intensities. The map, which has been prepared on the basis of enveloping the same series of 'blocked' and 'unblocked' runs which were done to generate the 100 year ARI flood map, shows that the flood levels would typically increase by between 0.2 and 0.3 metres. (While the figure was produced at a stage of the project when the RORB modelling was based on a k_c value of 9.0, it was determined that the overall trend in increasing flood levels would not change with the final adopted k_c value and therefore the earlier results remained valid.)

C.4.3.7 Woolomin Design Flood Mapping

For the design runs, the calibrated TUFLOW model was run for a number of different scenarios and then the various sets of results were enveloped to produce the 20 year ARI, 50 year ARI and 100 year ARI flood inundation maps, see Figures **C21, C22** and **C23**.
The various scenarios for each design event were:

- 72 hour storm duration Peel River catchment RORB-based hydrographs (both blocked and unblocked) to reflect the worst case scenario for the Peel River floodplain;
- 72 hour storm duration Duncans Creek RORB hydrographs (both blocked and unblocked) to reflect the worst case scenario for Duncans Creek.

The modelling of the design event floods provided the opportunity to assess the relative size of the 2000 Woolomin flood. Review of the RORB model peak flows along the Peel River showed that upstream of Chaffey Dam (that is, at Nundle, Taroona and the dam itself) the historic event was similar to the 100 year ARI event. However due to the routing of different total flood volumes through the dam, the historic event was less than a 100 year ARI flood downstream of the dam. Review of flows for Duncans Creek at Woolomin showed that the historic event was similar to the 100 year ARI event.

Figure C24 defines hydraulic hazard zones in the Woolomin 100 year ARI floodplain where the zones are based on the criteria presented in Figure L2 of the 2005 Floodplain Development Manual (**Reference C10**).

Figure C25 defines the impact of potential climate change throughout the Woolomin 100 year ARI floodplain based on a 15% increase in design rainfall intensities (and the map has been prepared on the basis of enveloping the same series of 'blocked' and 'unblocked' runs which were done to generate the 100 year ARI flood map). The figure shows that the flood levels would typically increase by between 0.1 and 0.2 metres. (As was the case for the Nundle climate change modelling, **Figure C25** was produced at a stage of the project when the RORB modelling was based on a k_c value of 9.0 and just as for Nundle those earlier results remained valid.)

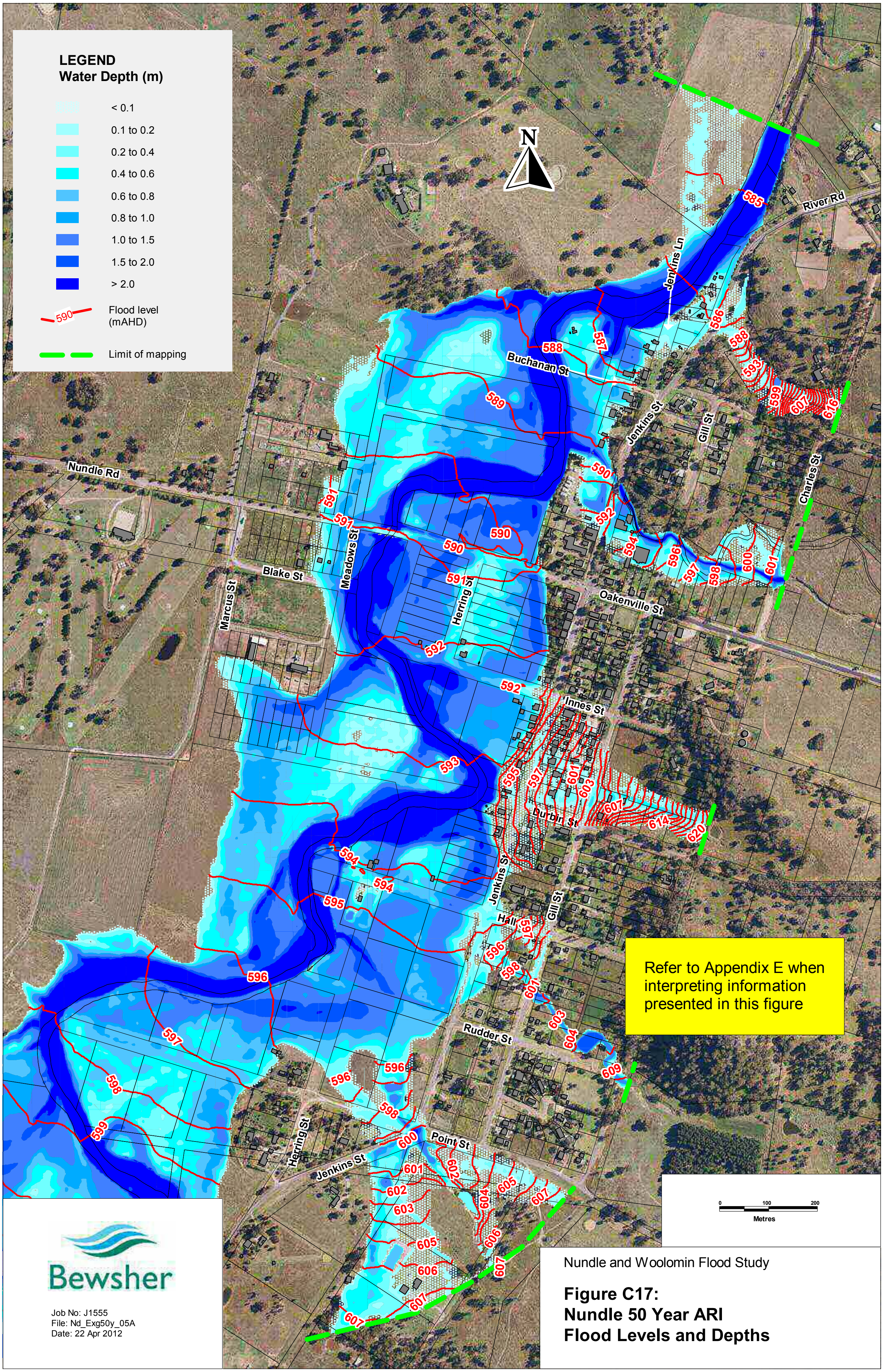
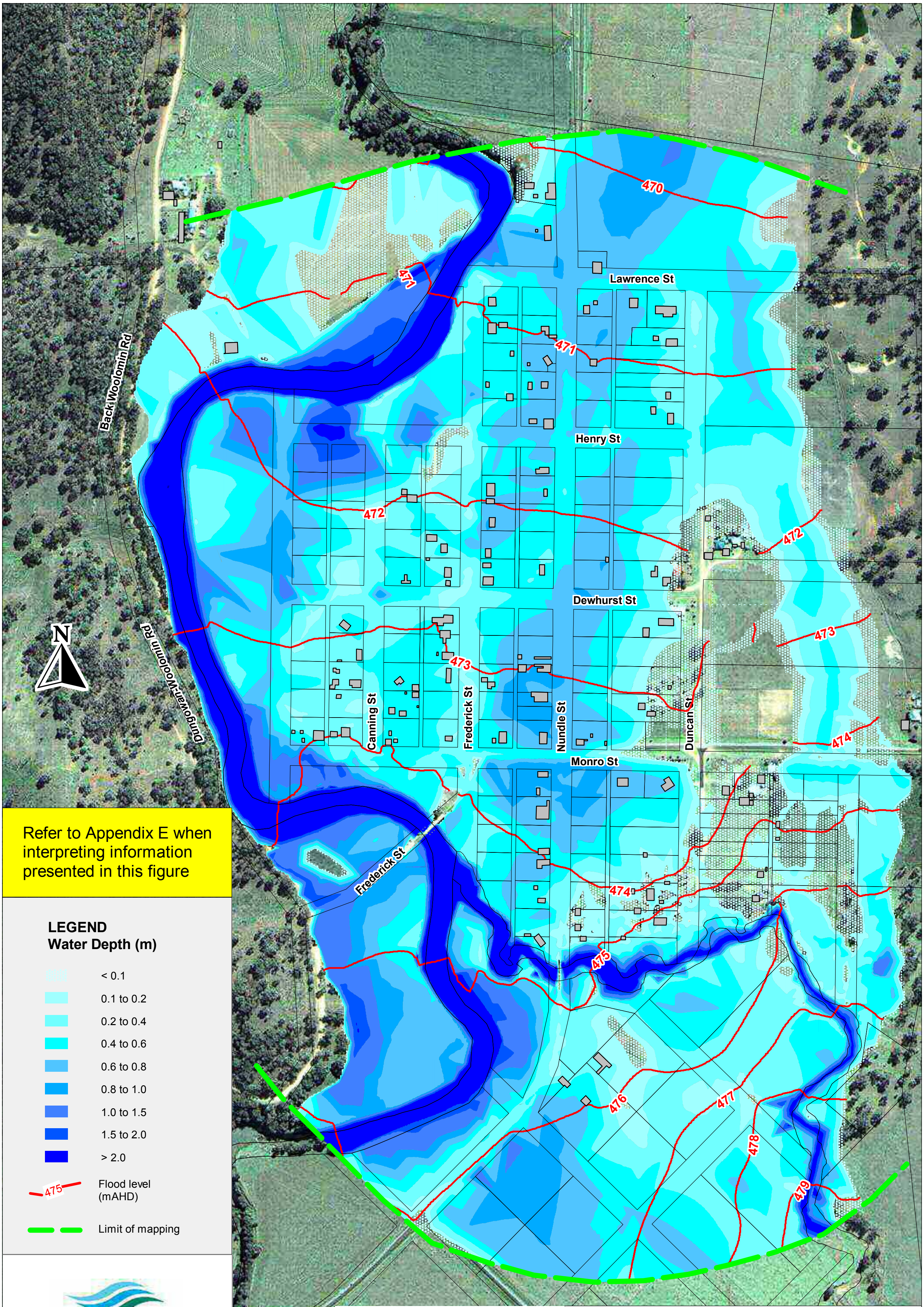


Figure C17: Nundle 50 Year ARI Flood Levels and Depths



Refer to Appendix E when interpreting information presented in this figure

LEGEND
Water Depth (m)

- < 0.1
- 0.1 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- 475 Flood level (mAHD)
- Limit of mapping

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Job No: J1555
File: WM_Exg20y_05
Date: 22 Apr 2012

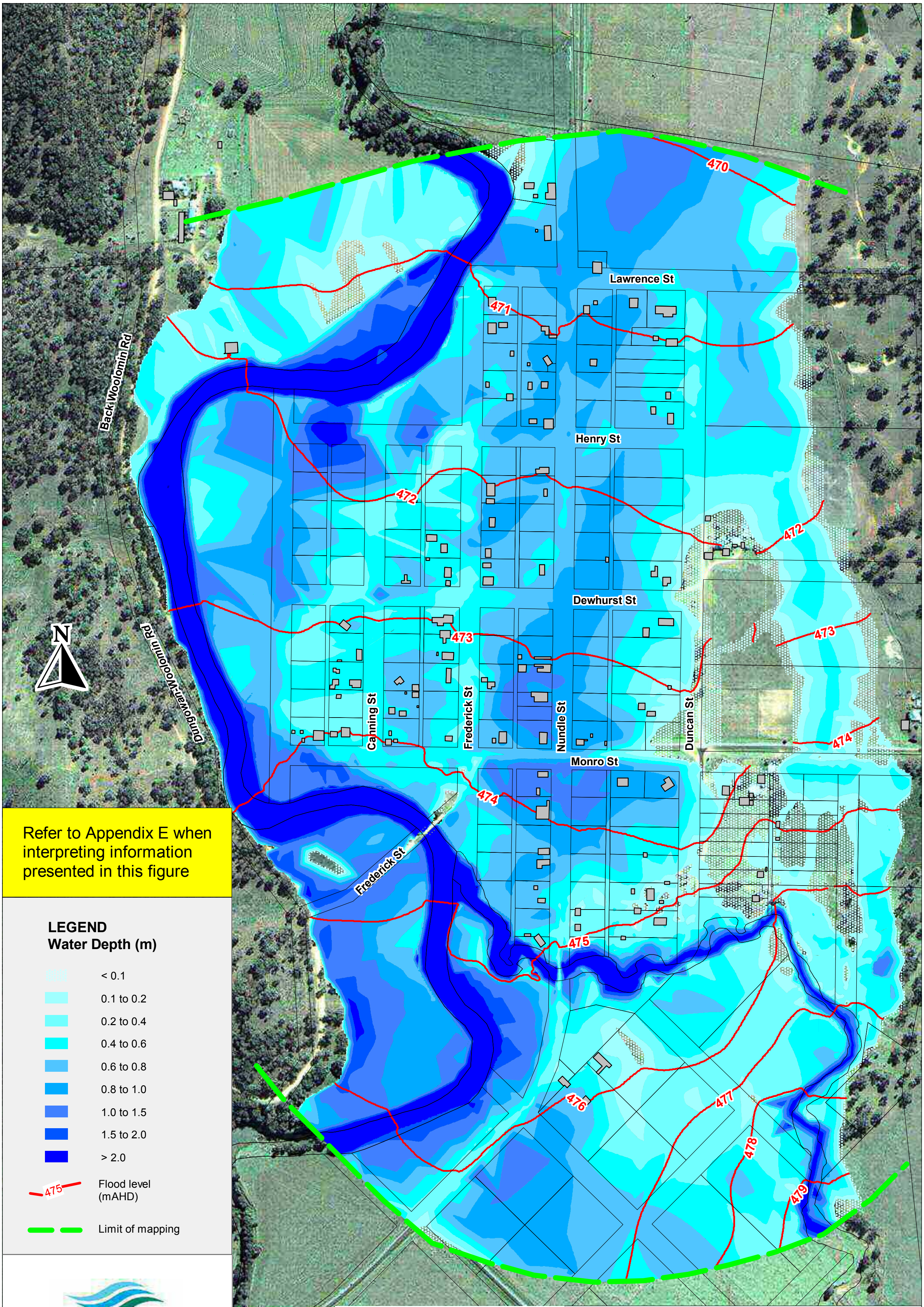
Notes:
Flood depths shown are approximate due to underlying topographic base.

0 100 200
metres

Nundle and Woolomin Flood Study

Figure C21:
Woolomin 20 Year ARI
Flood Levels and Depths

Refer to Appendix E when interpreting information presented in this figure



LEGEND
Water Depth (m)

- < 0.1
- 0.1 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- Flood level (mAHD)
- Limit of mapping

Bewsher

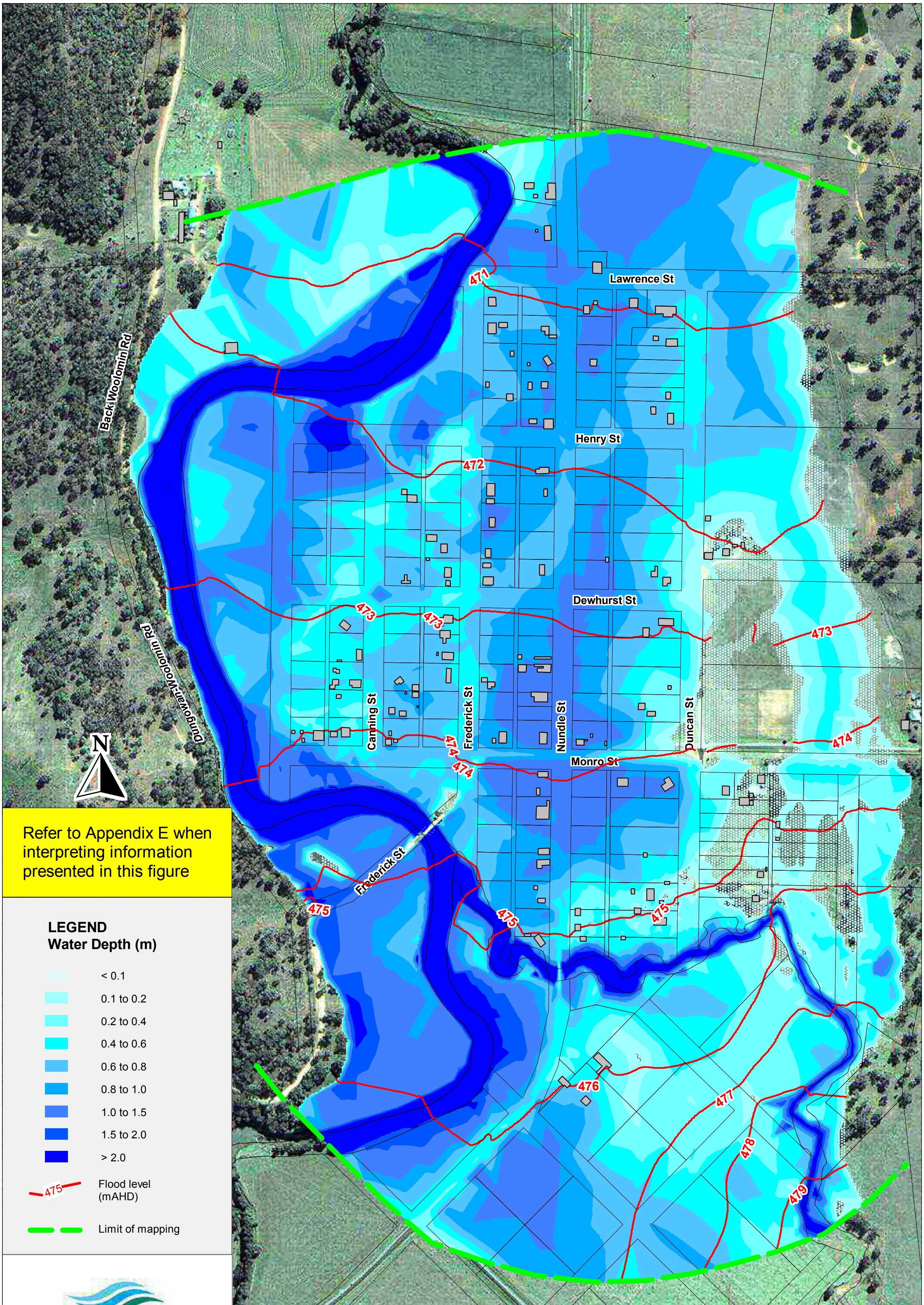
Job No: J1555
File: Wm_Exg50y_05
Date: 22 Apr 2012

Notes:
Flood depths shown are approximate due to underlying topographic base.

0 100 200
metres

Nundle and Woolomin Flood Study

Figure C22:
Woolomin 50 Year ARI
Flood Levels and Depths



Refer to Appendix E when interpreting information presented in this figure

LEGEND
Water Depth (m)

- < 0.1
- 0.1 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- 475 Flood level (mAHD)
- Limit of mapping

Bewsher

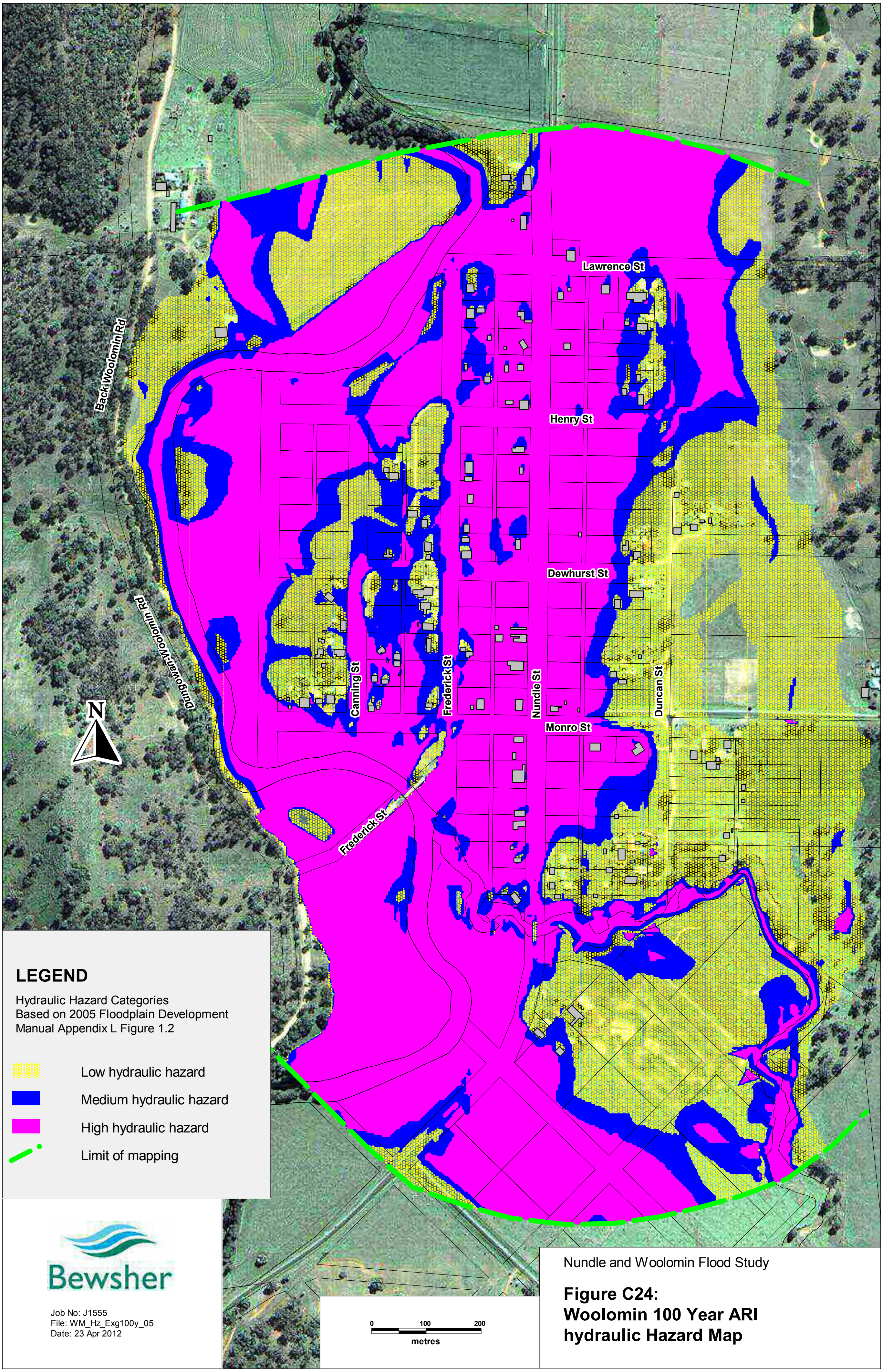
Job No: J1555
File: Wm_Exg100y_05
Date: 22 Apr 2012

Notes:
Flood depths shown are approximate due to underlying topographic base.

0 100 200
metres

Nundle and Woolomin Flood Study

Figure C23:
Woolomin 100 Year ARI
Flood Levels and Depths



LEGEND

Hydraulic Hazard Categories
Based on 2005 Floodplain Development
Manual Appendix L Figure 1.2

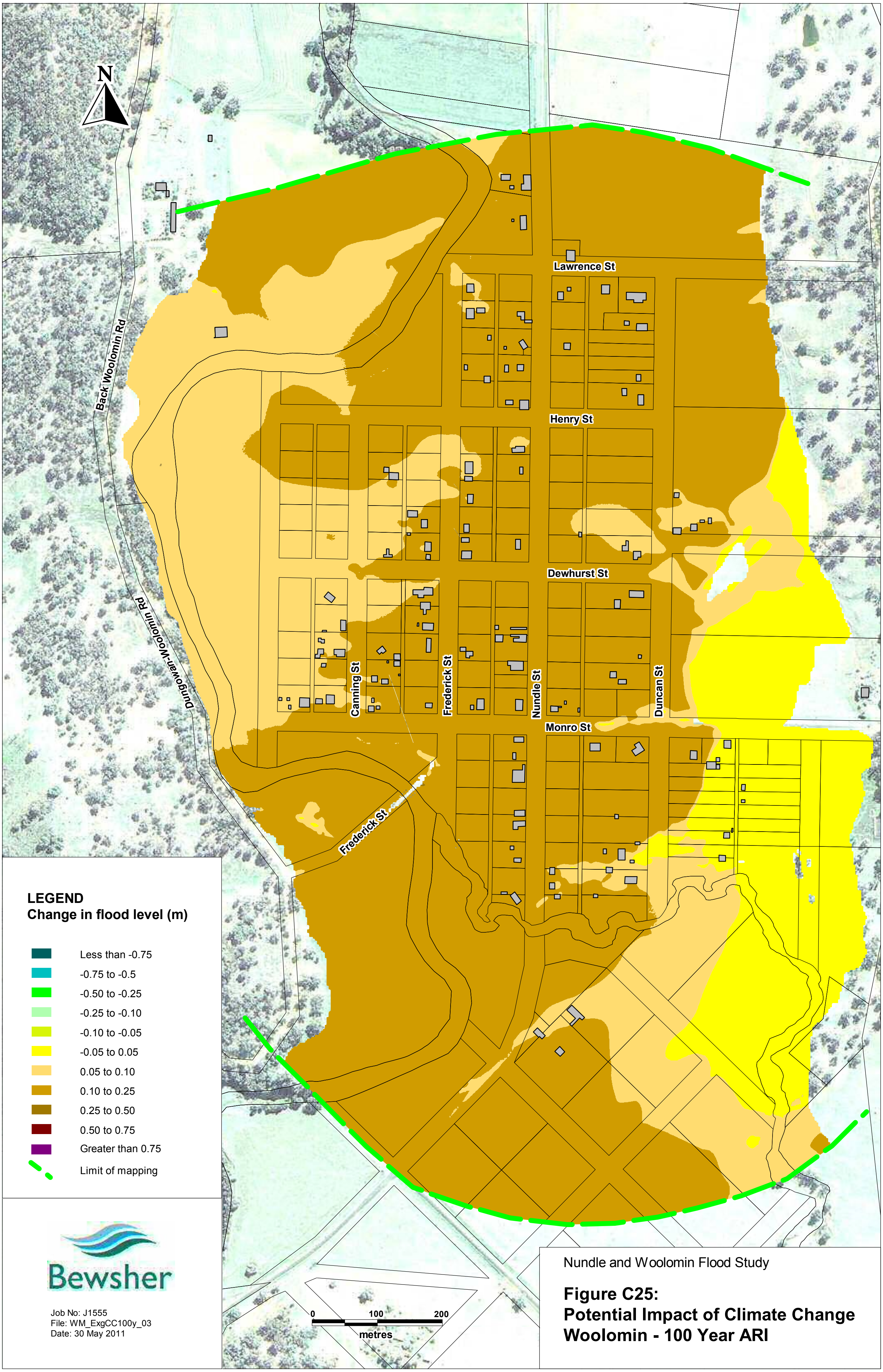
- Low hydraulic hazard
- Medium hydraulic hazard
- High hydraulic hazard
- Limit of mapping

Bewsher

Job No: J1555
File: WM_Hz_Exg100y_05
Date: 23 Apr 2012

Nundle and Woolomin Flood Study

Figure C24:
Woolomin 100 Year ARI
hydraulic Hazard Map



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Job No: J1555
File: WM_ExgCC100y_03
Date: 30 May 2011

Nundle and Woolomin Flood Study

Figure C25:
Potential Impact of Climate Change
Woolomin - 100 Year ARI

C.4.4 PROBABLE MAXIMUM FLOOD MODELLING

C.4.4.1 Probable Maximum Precipitation

Following its 2003 revision of both the Generalised Short Duration Method (GSDM) (**Reference C7)** and the Generalised Tropical Storm Method (GTSMR) (**Reference C8**), BoM also prepared a PMP report specifically for Chaffey (**Reference C9**). The data provided in that latter report was then used in the DIPNR 2005 Chaffey Dam report (**Reference C2**). The DIPNR study found that the revised PMP values represented significant increases in rainfall and consequently higher PMF flows were generated.

For this study, the 2005 PMP values were preserved and the rainfall totals for the extended RORB model were generated in accordance with the principles provided in the GSDM and GTSMR methods.

C.4.4.2 Assessment of Chaffey Dam Outflows

Recently a fuse plug spillway was constructed at Chaffey Dam. Given this situation, the RORB model's stage-discharge relationship was updated with information provided by State Water (which included the rating information for both the fuse plug and the morning glory spillways). The resultant stage-discharge relationship together with the dam's overall stage-storage relationship is defined in **Figure C26**.

C.4.4.3 PMF Flows

As part of the process of finalising the calculation of Peel River PMF flows at both Nundle and Woolomin, this study's RORB (k_c=9.0) model was initially tested against the 2005 RORB (k_c=9.0) model results to ensure that the extension of the model (with the associated RORB software in-built adjustment of catchment-wide storage terms) would not significantly change those earlier PMF flow values. This involved this study's model initially preserving the 2005 study's RORB spillway configuration. Model parameters, rainfall depths and losses parameters were also preserved from the 2005 model such that the only difference was the fact that this study's RORB included the catchment extension to Woolomin. **Part A** of **Table C15** summarises the resultant catchment-wide PMF flows for this model (which is designated as Model ID 2011a).

Part B of **Table C15** then provides a comparison of Model 2011a dam inflows and outflows with those generated by the 2005 dam model and it can be seen that there are only relatively small changes in inflows and outflows. While the maximum difference is a 4.5% increase in dam inflow (in the 3 hour storm duration event), the flow differences in the longer duration events is less than 1%.

The RORB (k_c=9.0) model 2011a was then revised to incorporate the stage-discharge and stage-storage relationships shown in **Figure C26** and the same series of storm events was then tested. The resultant peak flows are presented in **Part C** of **Table C15**.

Part C of the table shows that the 1.5 hour storm duration flow is the most critical event for the Peel River at Nundle. At Woolomin, the 1.5 hour storm duration event is found to be critical for Duncans Creek while the 6 hour storm duration is critical for the Peel River.

As discussed in **Section C.3.1.2** the model parameter k_c=9.0 utilised in the 2005 RORB model (and the models investigated by the current study in 2011) was recalibrated and k_c=14 was adopted for the 20 year, 50 year and 100 year ARI design runs presented in the current study.

Nevertheless for PMF design flows k_c=9.0 was retained as the additional effort in updating the model was not considered to be justified and noting that retention of k_c=9.0 maintained consistency with the model used for the Chaffey Dam spillway upgrades undertaken by State Water.

C.4.4.4 Nundle PMF Flood Mapping

For the PMF mapping, the TUFLOW model was run for the 1.5 hour storm duration event (with blocked conditions) and the resultant PMF inundation map was produced, see **Figure C27**.

The PMF levels are very significantly higher than the 100 year ARI levels with differences varying between approximately eight metres near Buchanan Street and about five metres near Point Street. That the level difference is greater near Buchanan Street is due to the downstream convergence of flow that occurs where the river valley narrows.

C.4.4.5 Woolomin PMF Flood Mapping

For the PMF mapping, the calibrated TUFLOW model was run for several different scenarios and then the various sets of results were enveloped to produce the resultant PMF flood inundation map, see **Figure C28**.

The various scenarios were:

- 6 hour storm RORB-based hydrographs (blocked conditions) to reflect the worst case scenario for the Peel River floodplain;

- 1.5 hour storm Duncans Creek RORB hydrographs (blocked conditions) to reflect the worst case scenario for Duncans Creek.

The resultant PMF levels are between about two and three metres higher than the 100 year ARI levels. It is noted that the differences are smaller than for Nundle due principally to the attenuation of Peel River flows through Chaffey Dam but also the narrow valley situation at Nundle.

TABLE C15: SUMMARY OF RORB PMF DISCHARGES

A) Morning Glory Spillway + Spill over Dam Crest (Assumptions adopted in 2005 Study) - Model ID 2011a

Location	Duration (hr) 1h	1hh	2h	2hh	3h	6h	12h	18h	24h	36h	48h	Max
Peel River U/S of Nundle	12594	14514	12879	12540	12205	9347	5560	4360	3643	3773	3848	**14514**
Tributary H4	834	773	623	570	468	320	208	156	127	131	134	**834**
Tributary H3	1193	1175	985	938	894	630	402	309	253	261	267	**1193**
Tributary H1	864	785	619	566	500	338	220	165	133	138	141	**864**
Tributary H2	1245	1156	920	848	771	527	343	258	208	216	221	**1245**
Peel River D/S of Nundle	14695	16824	14906	14609	14179	10980	6252	4945	4159	4310	4387	**16824**
Chaffey Dam Inflow	14866	19179	18782	19733	19489	15568	9933	7791	6505	6778	6885	**19733**
Chaffey Dam Outflow	907	1382	1777	3158	4123	6929	5455	4666	4295	5410	5678	**6929**
Chaffey Dam Peak Elevation	531.12	534.11	534.39	535.37	536.04	537.32	536.65	536.28	536.11	536.63	536.75	**537**
Peel River US of Woolomin	1930	2096	1924	3125	4080	7061	5623	5194	4284	5465	6033	**7061**
Duncans Creek US of Woolomin	5811	6203	5315	5061	4788	3404	2641	2089	1741	1787	1831	**6203**
Peel River DS of Woolomin	7596	8351	7316	7041	6728	7915	6695	5837	5109	6674	7337	**8351**

B) Comparison of 2005 and 2011 Chaffey Dam Inflow and Outflow

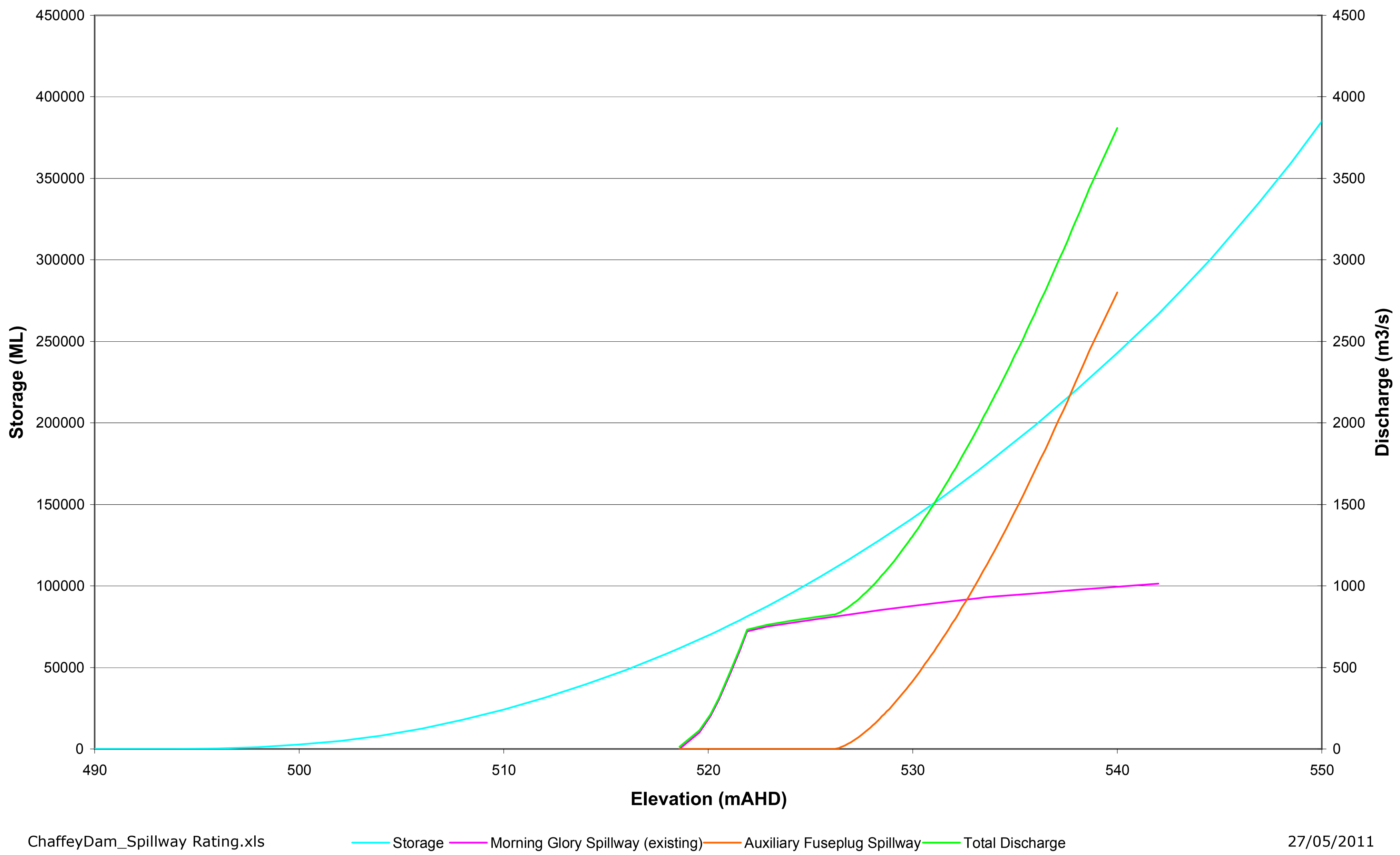
Location	Duration (hr) 1h	1hh	2h	2hh	3h	6h	12h	18h	24h	36h	48h
Chaffey Dam Inflow (2005)†	NA	NA	NA	NA	18644	15197	9988	7844	6533	6800	6912
Chaffey Dam Inflow (2011a)	14866	19179	18782	19733	19489	15568	9933	7791	6505	6778	6885
Percentage Change from (2005)	NA	NA	NA	NA	4.5	2.4	-0.6	-0.7	-0.4	-0.3	-0.4
Chaffey Dam Outflow (2005)†	NA	NA	NA	NA	4092	6961	5463	4630	4341	5455	5720
Chaffey Dam Outflow (2011a)	907	1382	1777	3158	4123	6929	5455	4666	4295	5410	5678
Percentage Change from (2005)	NA	NA	NA	NA	0.8	-0.5	-0.2	0.8	-1.1	-0.8	-0.7

† Discharges reproduced from Table 10 of 2005 study report

C) Morning Glory Spillway + Auxiliary Fuse Plug Spillway (2011 Conditions) - Model ID 2011b

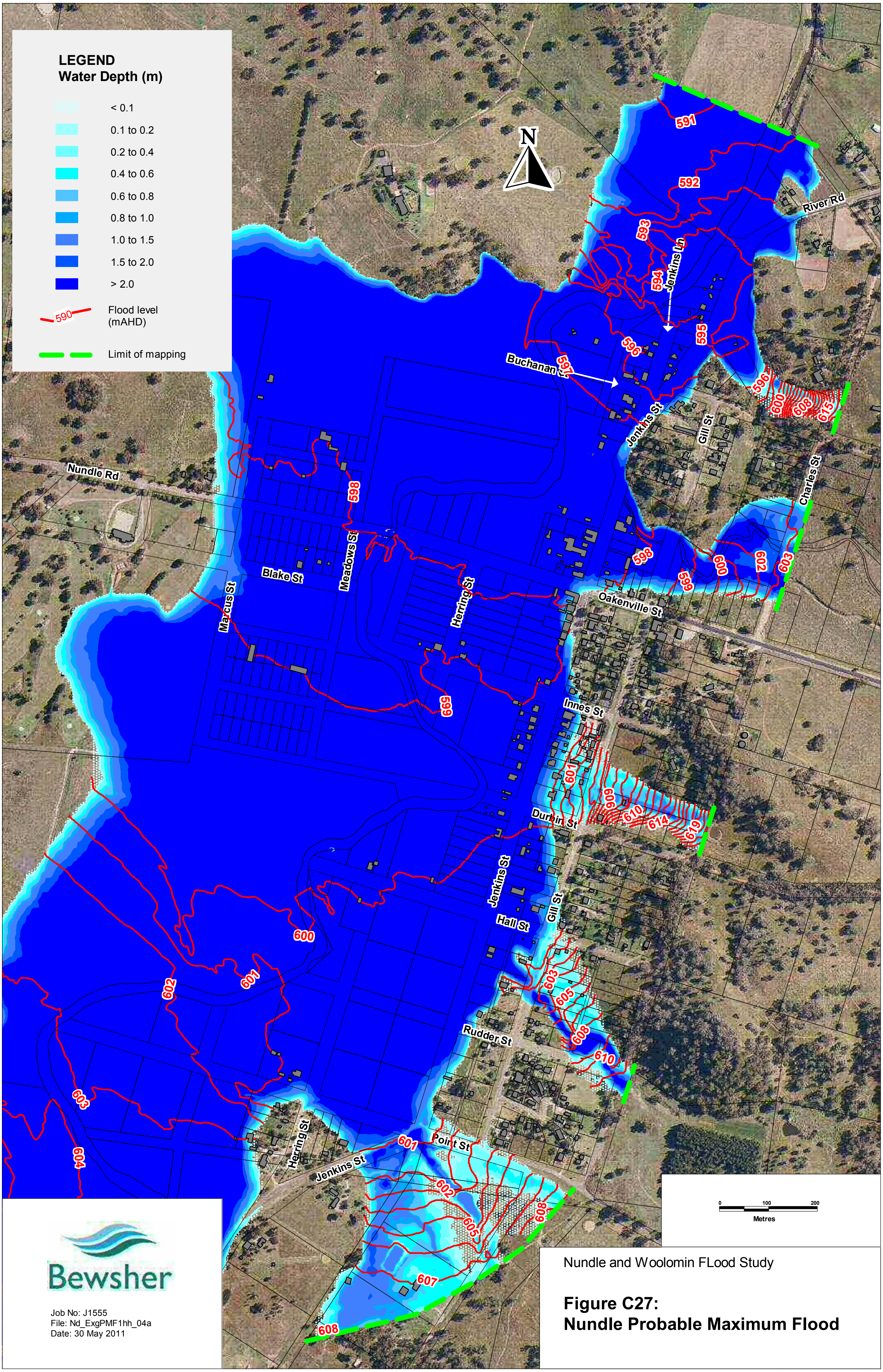
Location	Duration (hr) 1h	1hh	2h	2hh	3h	6h	12h	18h	24h	36h	48h	Max
Peel River U/S of Nundle	12594	14514	12879	12540	12205	9347	5560	4360	3643	3773	3848	**14514**
Tributary H4	834	773	623	570	468	320	208	156	127	131	134	**834**
Tributary H3	1193	1175	985	938	894	630	402	309	253	261	267	**1193**
Tributary H1	864	785	619	566	500	338	220	165	133	138	141	**864**
Tributary H2	1245	1156	920	848	771	527	343	258	208	216	221	**1245**
Peel River D/S of Nundle	14695	16824	14906	14609	14179	10980	6252	4945	4159	4310	4387	**16824**
Chaffey Dam Inflow	14866	19179	18782	19733	19489	15568	9933	7791	6505	6778	6885	**19733**
Chaffey Dam Outflow	1449	2050	2136	2482	2738	3489	3240	3114	2999	3334	3461	**3489**
Chaffey Dam Peak Elevation	530.76	533.52	533.88	535.26	536.22	538.82	537.98	537.55	537.15	538.29	538.72	**539**
Peel River US of Woolomin	1930	2096	2134	2480	2738	3551	3476	3328	3118	3497	3608	**3608**
Duncans Creek US of Woolomin	5811	6203	5315	5061	4788	3404	2641	2089	1741	1787	1831	**6203**
Peel River DS of Woolomin	7596	8351	7316	7041	6727	5230	5004	4547	4193	4621	4826	**8351**

Figure C26: Chaffey Dam Stage-Storage-Discharge Relationship



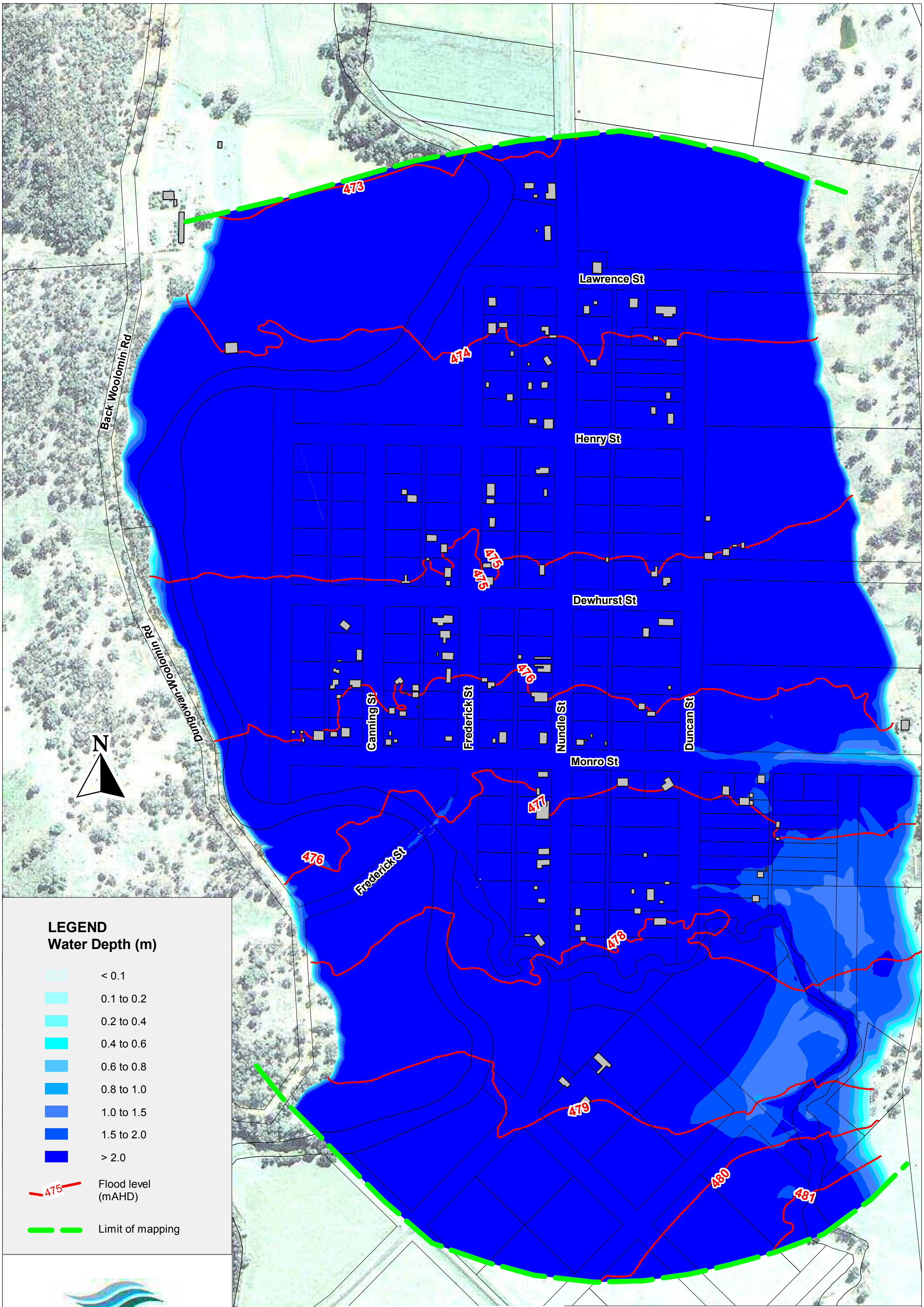
ChaffeyDam_Spillway Rating.xls

27/05/2011



Nundle and Woolomin FLood Study

Figure C27:
Nundle Probable Maximum Flood



LEGEND
Water Depth (m)

- < 0.1
- 0.1 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- 475 Flood level (mAHD)
- Limit of mapping

Bewsher

Job No: J1555
File: Wm_ExgPMF_03
Date: 30 May 2011

Notes:
Flood depths shown are approximate due to underlying topographic base.

0 100 200
metres

Nundle and Woolomin Flood Study

Figure C28:
Woolomin Probable Maximum Flood

C.5 REFERENCES

C1. DLWC (1998) *Chaffey Dam Review of Probable Maximum Flood and Spillway Adequacy Assessment.*

C2. DIPNR (2005) *Chaffey Dam Assessment of Spillway Adequacy using GTSMR PMP Estimates*. Edited Version of March report.

C3. River station data obtained from the NSW Government Water Information website.

C4. Institution of Engineers, Australia (1987) *Australian Rainfall & Runoff*. Volume 2.

C5. Institution of Engineers, Australia (2001) *Australian Rainfall & Runoff*. Book VI.

C6. Monash University (2010). *RORB, Version 6 Runoff Routing Program User Manual*. January 2010.

C7. Bureau of Meteorology (2003a) The *Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method*. June.

C8. Bureau of Meteorology (2003b) The *Estimation of Probable Maximum Precipitation in Australia: Generalised Tropical Storm Method*. November.

C9. Bureau of Meteorology (2003c) *Generalised Probable Maximum Precipitation Estimates for the Chaffey Dam Catchment.* Hydrometeorology Advisory Service. HAS Report No: GTSMR/13R.

C10. NSW Government (2005) *Floodplain Development Manual.* April. ISBN 0 7347 5476 0.

C11. Bewsher Consulting (2011) Letter to Tamworth Regional Council dated 15 December 2011. Ref J1555L_7.

APPENDIX D

FLOOD DAMAGES MATERIAL

- – Inputs for Deriving Residential Sector Stage-Damage data
- – Outputs of Residential Sector Stage-Damage data

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT

Version 3.00 October 2007 — Queries to duncan.mcluckie@dnr.nsw.gov.au

PROJECT	DETAILS	DATE	JOB No.
Nundle and Woolomin FRMS&P	**Damages Assessment**	**May-11**	**J1555**

BUILDINGS

Regional Cost Variation Factor	1.00	*From Rawlinsons*			
Post late 2001 adjustments	1.47	*Changes in AWE see AWE Stats Worksheet*			
Post Flood Inflation Factor	1.00	*1.0*	*to*	*1.5*	
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*			

	Regional City			Regional Town		
	Houses Affected		Factor	Houses Affected		Factor
Small scale impact	<	50	1.00	<	10	1.00
Medium scale impacts in Regional City		100	1.20		30	1.30
Large scale impacts in Regional City	>	150	1.40	>	50	1.50

Typical Duration of Immersion	1	hours			
Building Damage Repair Limitation Factor	0.85	*due to no insurance*	*short duration*		*long duration*
		Suggested range	*0.85*	*to*	*1.00*
Typical House Size	220	m^2	*240 m^2 is Base*		
Building Size Adjustment	0.9				
Total Building Adjustment Factor	**1.15**				

CONTENTS

Average Contents Relevant to Site	$ 55,000		*Base for 240 m^2 house*	*$ 60,000*	
Post late 2001 adjustments	1.47	*From above*			
Contents Damage Repair Limitation Factor	0.75	*due to no insurance*	*short duration*		*long duration*
Sub-Total Adjustment Factor	1.10	*Suggested range*	*0.75*	*to*	*0.90*
Level of Flood Awareness	low	*low or high only. Low default unless otherwise justifiable.*			
Effective Warning Time	0	hour			
Interpolated DRF adjustment (Awareness/Time)	1.00	IDRF = Interpolated Damage Reduction Factor			
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*			
Total Contents Adjustment Factor AFD <= TTBH	**1.10**	AFD = Above Floor Depth			
Total Contents Adjustment Factor AFD > TTBH	**1.10**				

Most recent advice from Victorian Rapid Assessment Method

Low level of awareness is expected norm (long term average) any deviation needs to be justified.

Basic contents damages are based upon a DRF of	*0.9*				
Effective Warning time (hours)	***0***	***3***	***6***	***12***	***24***
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
Effective Warning time (hours)	*0*	*3*	*0*		
Site Specific iterations	*1.00*	*0.89*	*1.00*		

ADDITIONAL FACTORS

Post late 2001 adjustments	1.47	*From above*
External Damage	$ 6,700	*$6,700 recommended without justification*
Clean Up Costs	$ 4,000	*$4,000 recommended without justification*
Likely Time in Alternate Accommodation	3	weeks
Additional accommodation costs /Loss of Rent	$ 220	*$220 per week recommended without justification*

TWO STOREY HOUSE BUILDING & CONTENTS FACTORS

Up to Second Floor Level, less than	2.6	m	70%	Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	110%	Single Storey Slab on Ground

Base Curves

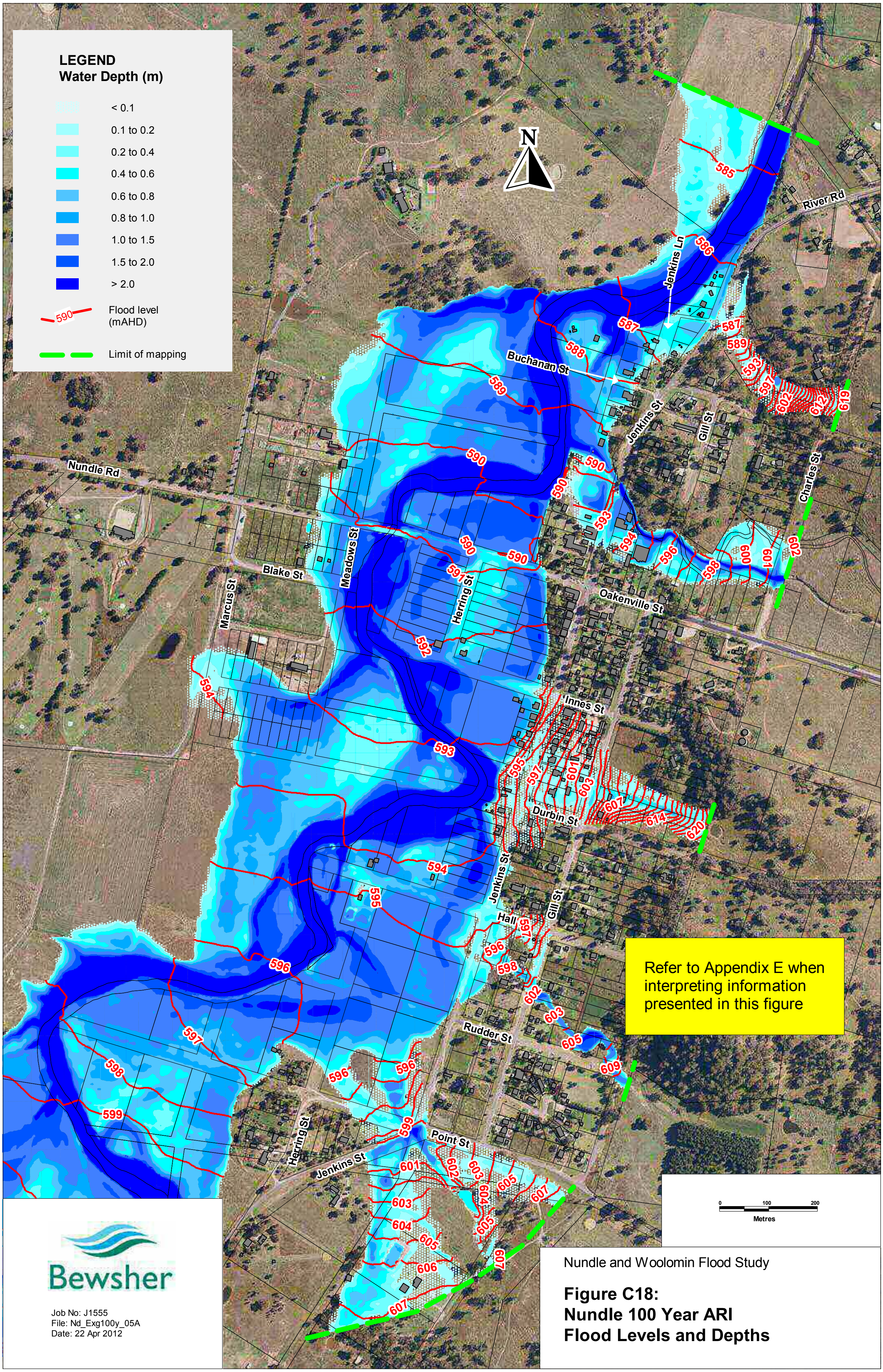
AFD = Above Floor Depth

Single Storey Slab/Low Set	13164	+	4871		x	AFD in metres	
Structure with GST	AFD	greater than	0.0	m			
Validity Limits	AFD	less than or equal to			6	m	
Single Storey High Set	16586	+	7454		x	AFD	
Structure with GST	AFD	greater than	-1.50	m			
Validity Limits	AFD	less than or equal to			6	m	
Contents	20000	+	20000		x	AFD	
Contents with GST	AFD	greater than			0		
Validity Limits	AFD	less than or equal to			2		

Floodplain Specific Damage Curves for Individual Residences

Steps in Curve 0.1 m

	Single Storey High Set	Single Storey Slab/Low Set	2 Storey Houses
Type	**1**	**2**	**3**
AFD from Modelling	**Damage**	**Damage**	**Damage**
-5.00	$0	$0	$0
-1.50	$9,849	$0	$0
-1.40	$16,894	$0	$0
-1.30	$17,748	$0	$0
-1.20	$18,601	$0	$0
-1.10	$19,455	$0	$0
-1.00	$20,309	$0	$0
-0.90	$21,163	$0	$0
-0.80	$22,016	$0	$0
-0.70	$22,870	$0	$0
-0.60	$23,724	$0	$0
-0.50	$24,577	$9,849	$9,849
-0.40	$25,431	$9,849	$9,849
-0.30	$26,285	$9,849	$9,849
-0.20	$27,139	$9,849	$9,849
-0.10	$27,992	$9,849	$9,849
0.00	$55,909	$24,926	$20,403
0.10	$58,784	$54,568	$41,152
0.20	$61,659	$57,147	$42,958
0.30	$64,534	$59,726	$44,763
0.40	$67,409	$62,306	$46,569
0.50	$70,283	$64,885	$48,374
0.60	$73,158	$67,464	$50,179
0.70	$76,033	$70,043	$51,985
0.80	$78,908	$72,622	$53,790
0.90	$81,783	$75,201	$55,596
1.00	$84,658	$77,780	$57,401
1.10	$87,533	$80,360	$59,206
1.20	$90,408	$82,939	$61,012
1.30	$93,283	$85,518	$62,817
1.40	$96,158	$88,097	$64,623
1.50	$99,033	$90,676	$66,428
1.60	$101,908	$93,255	$68,233
1.70	$104,783	$95,834	$70,039
1.80	$107,658	$98,414	$71,844
1.90	$110,533	$100,993	$73,650
2.00	$113,408	$103,572	$75,455
2.10	$114,262	$104,130	$75,846
2.20	$115,115	$104,688	$76,236
2.30	$115,969	$105,246	$76,627
2.40	$116,823	$105,803	$77,017
2.50	$117,677	$106,361	$77,408
2.60	$118,530	$106,919	$77,798
2.70	$119,384	$107,477	$117,240
2.80	$120,238	$108,035	$117,854
2.90	$121,091	$108,593	$118,467
3.00	$121,945	$109,151	$119,081
3.50	$126,214	$111,940	$122,149
4.00	$130,482	$114,730	$125,218
4.50	$134,751	$117,519	$128,286
5.00	$139,019	$120,309	$131,354



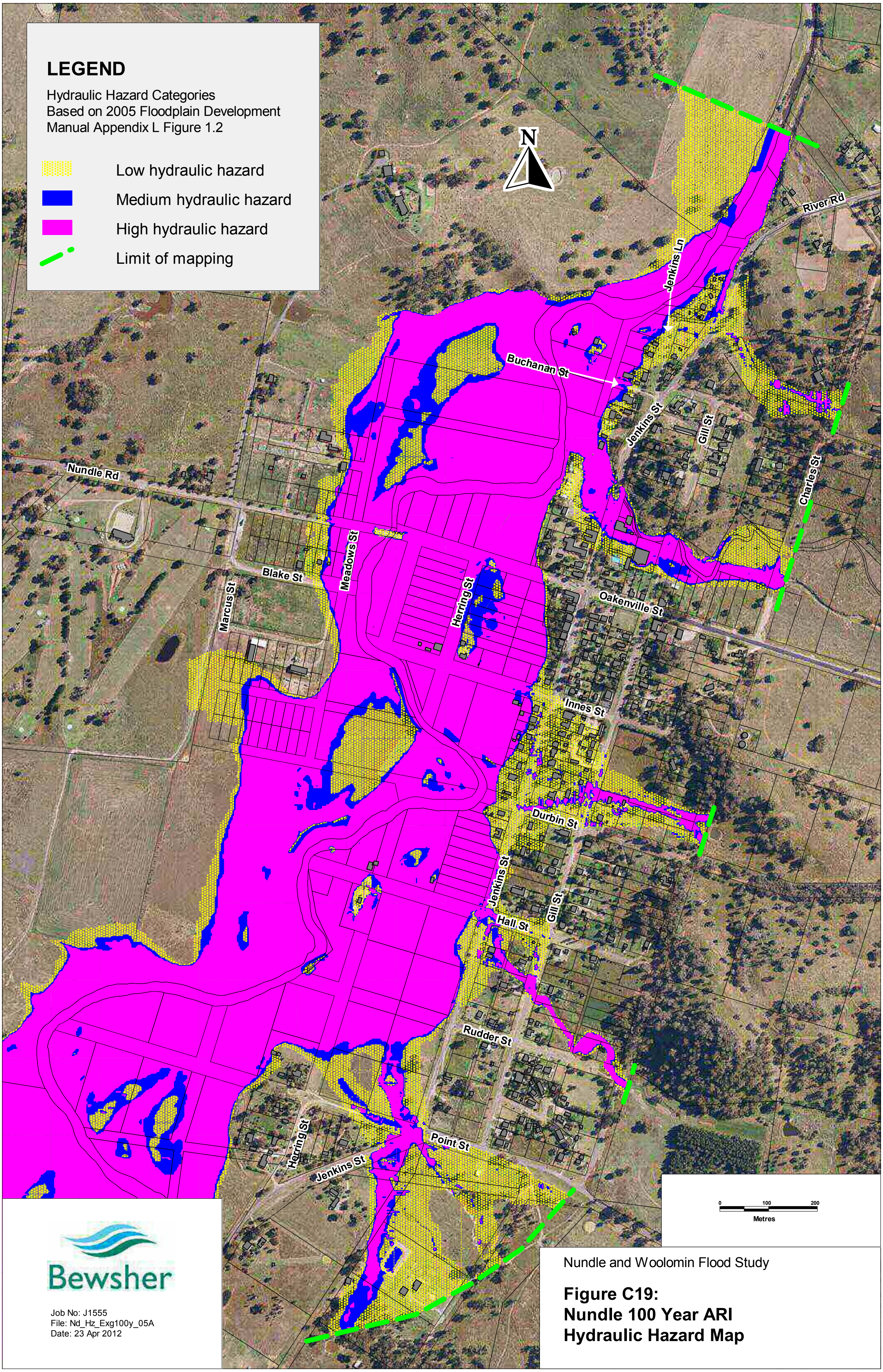
Refer to Appendix E when interpreting information presented in this figure

Bewsher

Job No: J1555
File: Nd_Exg100y_05A
Date: 22 Apr 2012

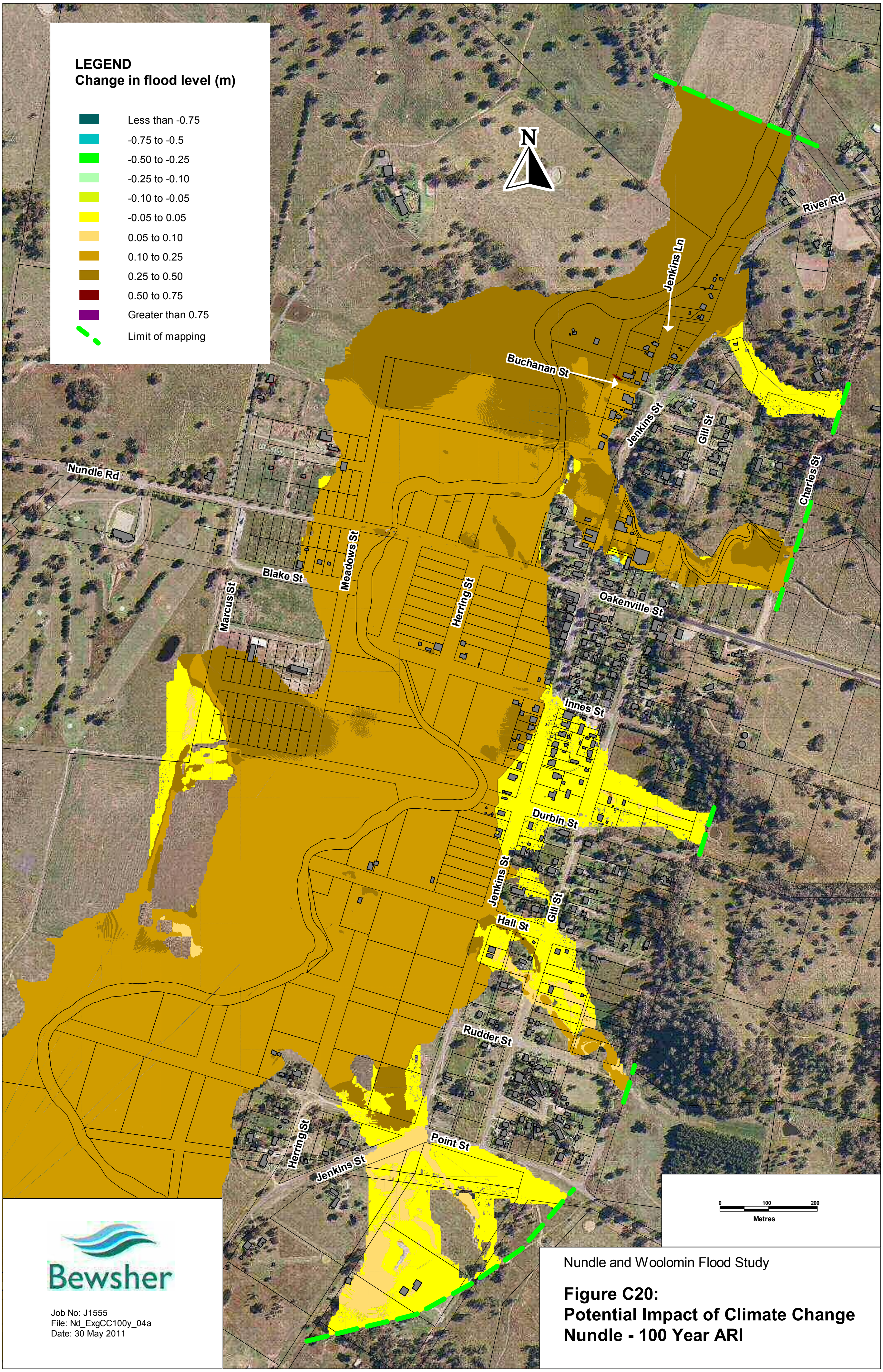
Nundle and Woolomin Flood Study

Figure C18:
Nundle 100 Year ARI
Flood Levels and Depths



Nundle and Woolomin Flood Study

Figure C19:
Nundle 100 Year ARI
Hydraulic Hazard Map

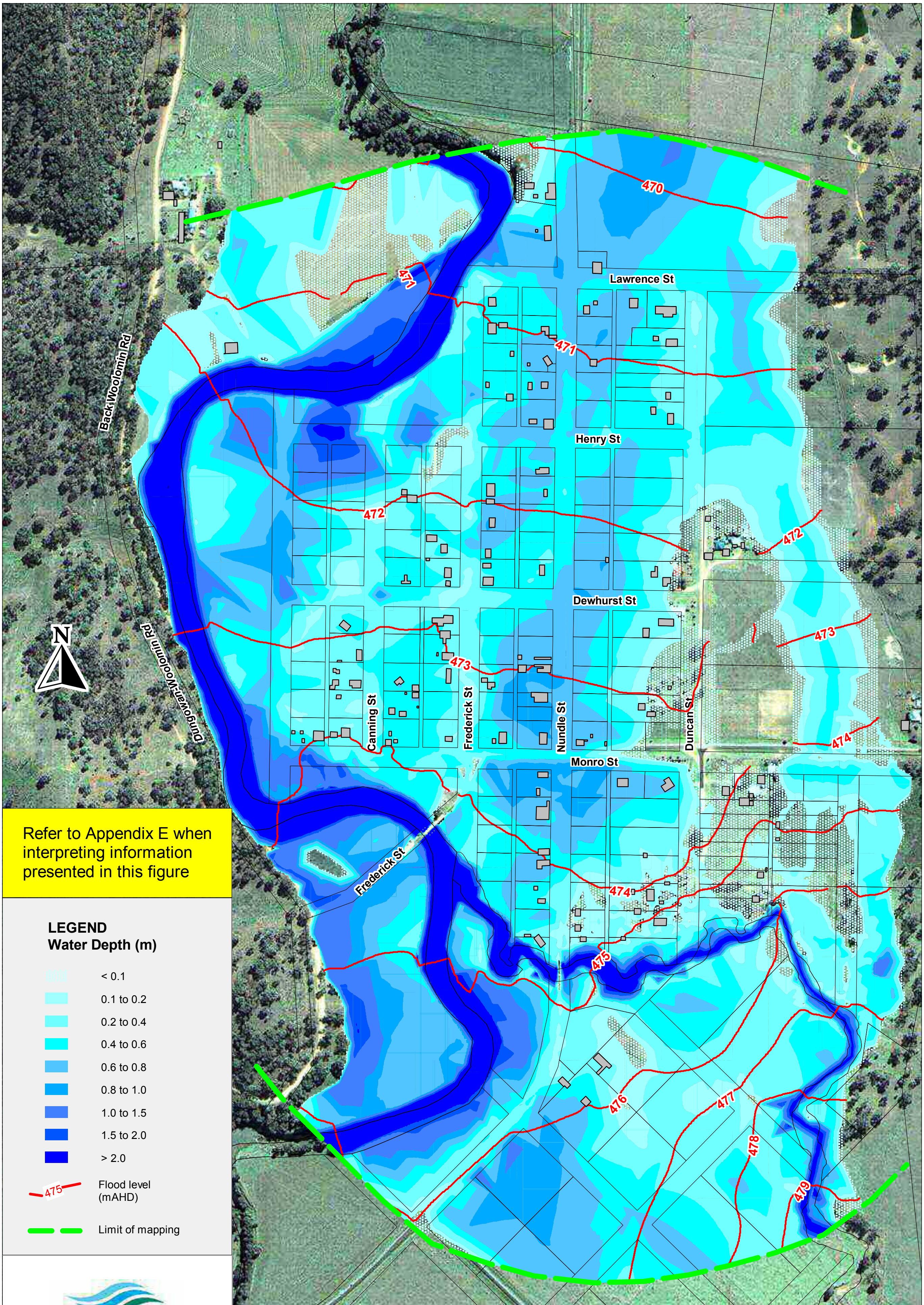


Bewsher

Job No: J1555
File: Nd_ExgCC100y_04a
Date: 30 May 2011

Nundle and Woolomin Flood Study

Figure C20:
Potential Impact of Climate Change
Nundle - 100 Year ARI



Refer to Appendix E when interpreting information presented in this figure

LEGEND
Water Depth (m)

- < 0.1
- 0.1 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- Flood level (mAHD)
- Limit of mapping

Bewsher

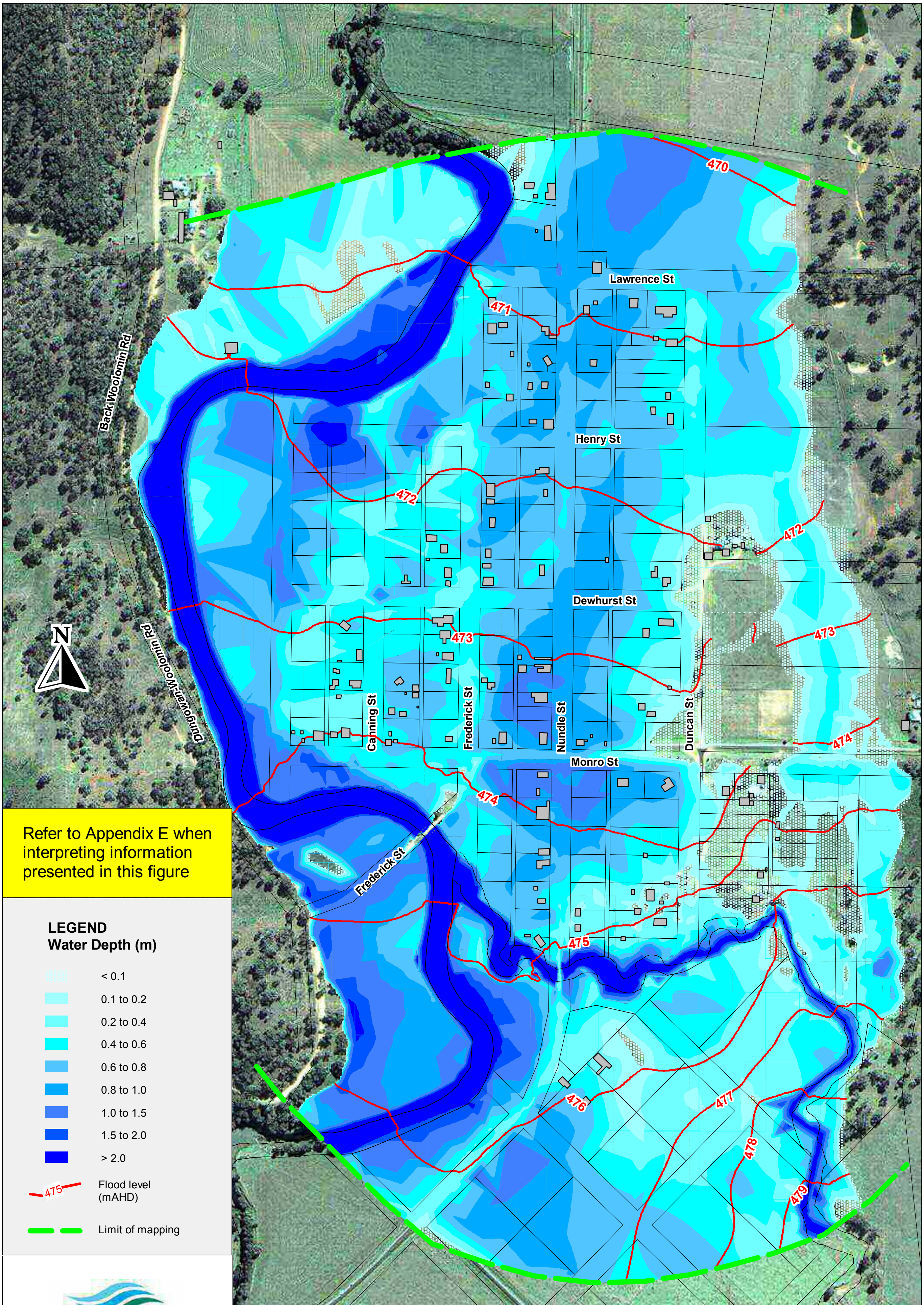
Job No: J1555
File: WM_Exg20y_05
Date: 22 Apr 2012

Notes:
Flood depths shown are approximate due to underlying topographic base.

0 100 200
metres

Nundle and Woolomin Flood Study

Figure C21:
Woolomin 20 Year ARI
Flood Levels and Depths



Refer to Appendix E when interpreting information presented in this figure

LEGEND
Water Depth (m)

- < 0.1
- 0.1 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- 475 Flood level (mAHD)
- Limit of mapping

Bewsher

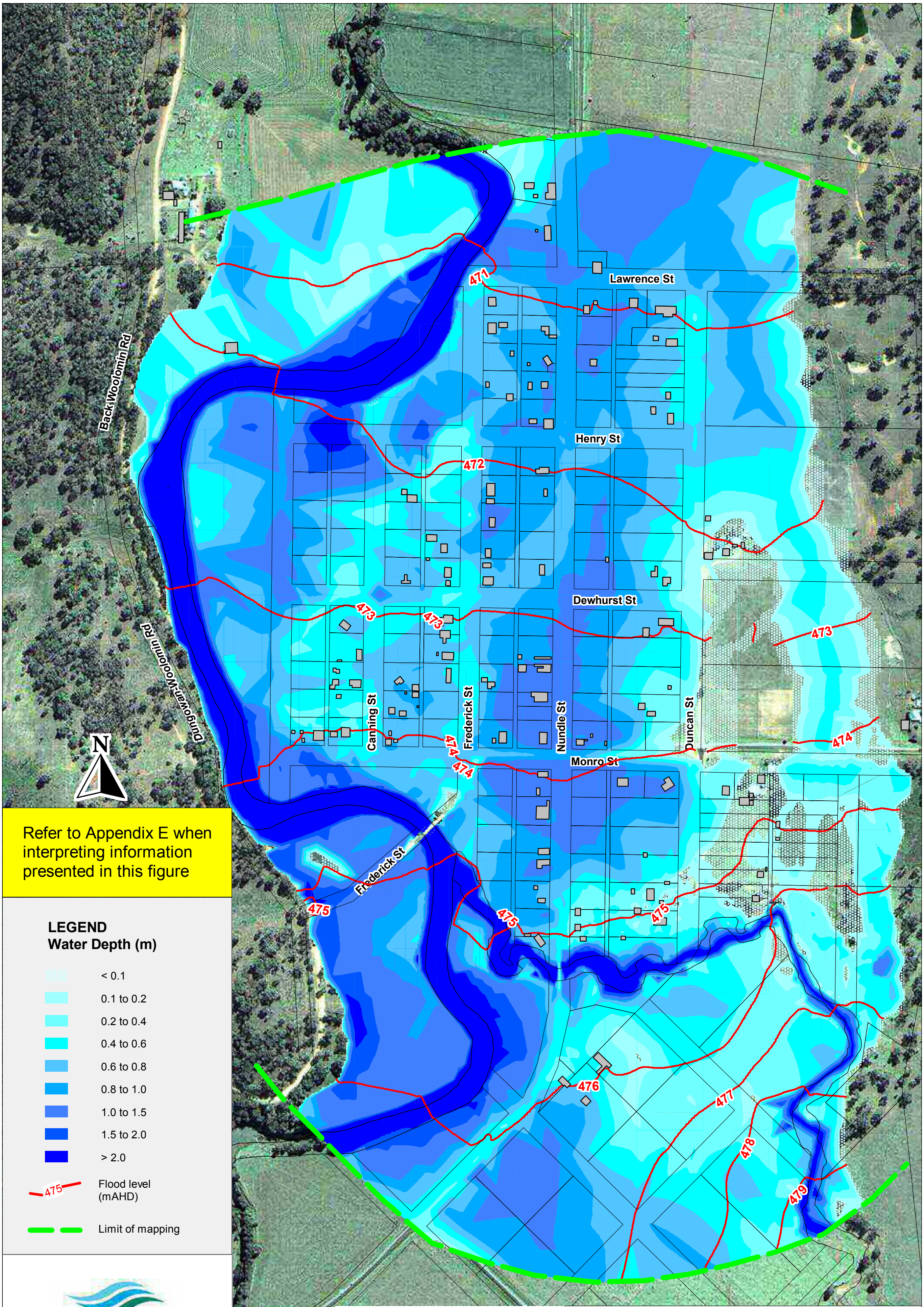
Job No: J1555
File: Wm_Exg50y_05
Date: 22 Apr 2012

Notes:
Flood depths shown are approximate due to underlying topographic base.

0 100 200
metres

Nundle and Woolomin Flood Study

Figure C22:
Woolomin 50 Year ARI Flood Levels and Depths



Refer to Appendix E when interpreting information presented in this figure

LEGEND
Water Depth (m)

- < 0.1
- 0.1 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

475 Flood level (mAHD)

Limit of mapping

Bewsher

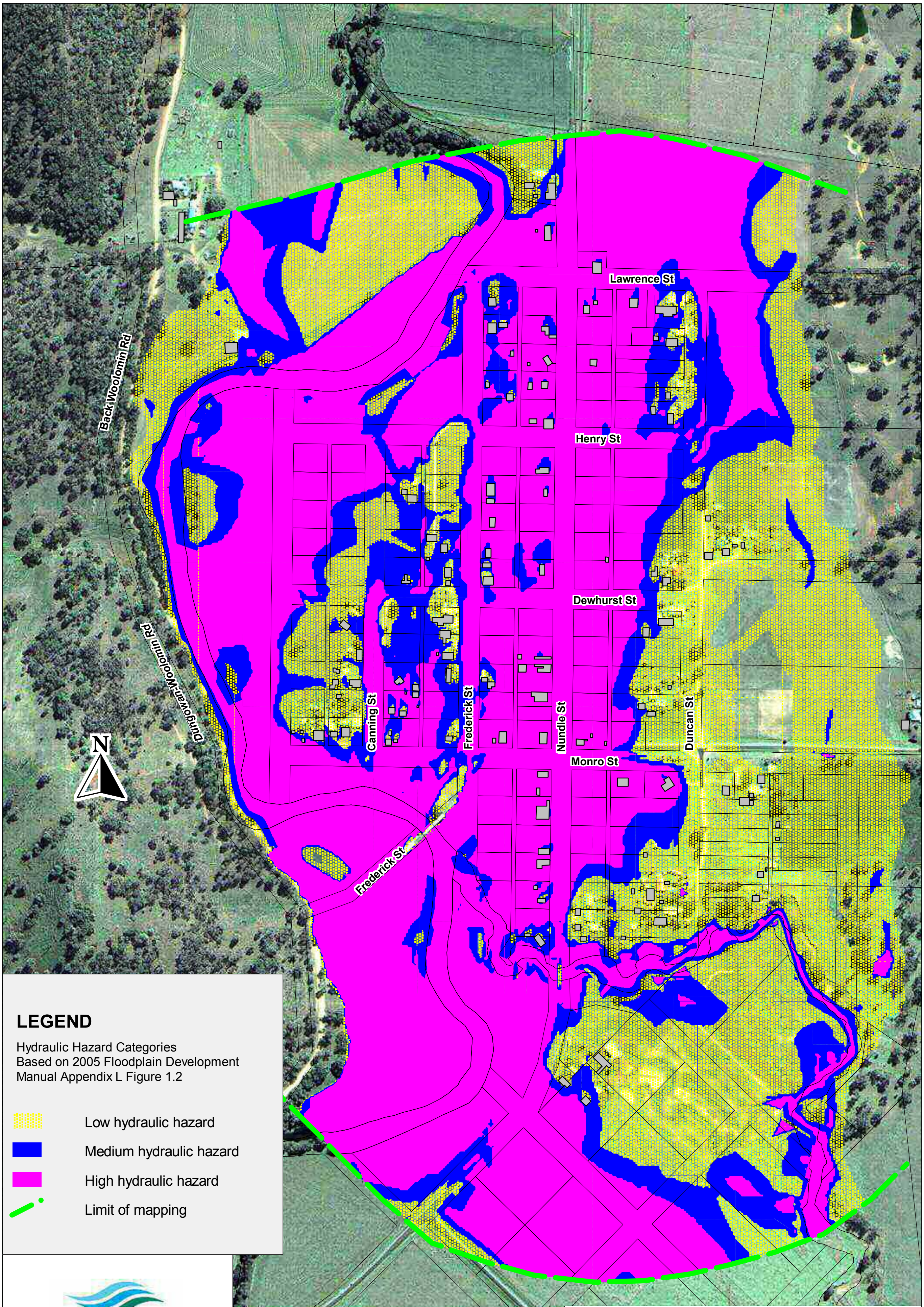
Job No: J1555
File: Wm_Exg100y_05
Date: 22 Apr 2012

Notes:
Flood depths shown are approximate due to underlying topographic base.

0 100 200
metres

Nundle and Woolomin Flood Study

Figure C23:
Woolomin 100 Year ARI
Flood Levels and Depths

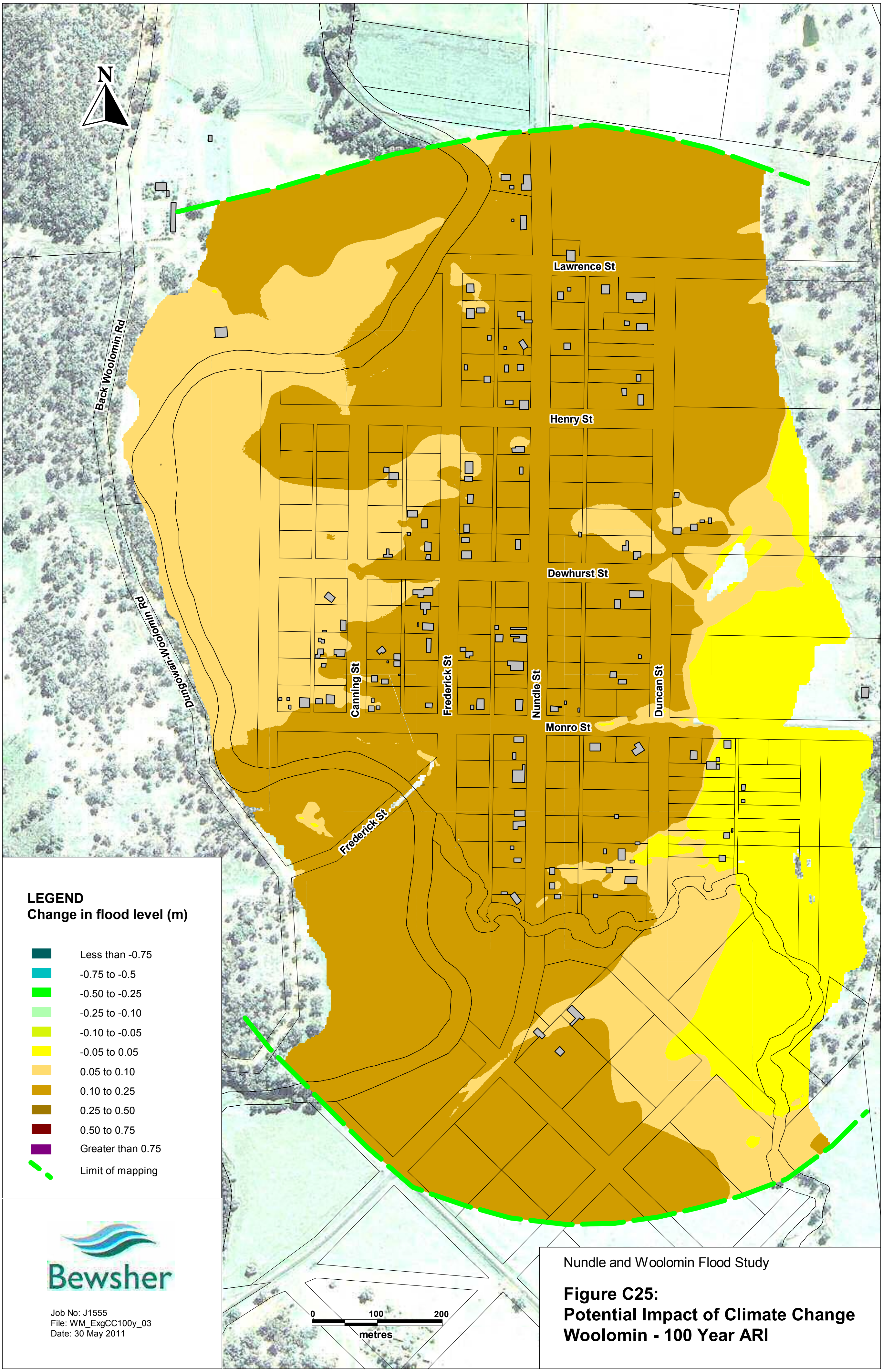


Bewsher

Job No: J1555
File: WM_Hz_Exg100y_05
Date: 23 Apr 2012

Nundle and Woolomin Flood Study

Figure C24:
Woolomin 100 Year ARI
hydraulic Hazard Map



Nundle and Woolomin Flood Study

Figure C25:
Potential Impact of Climate Change
Woolomin - 100 Year ARI

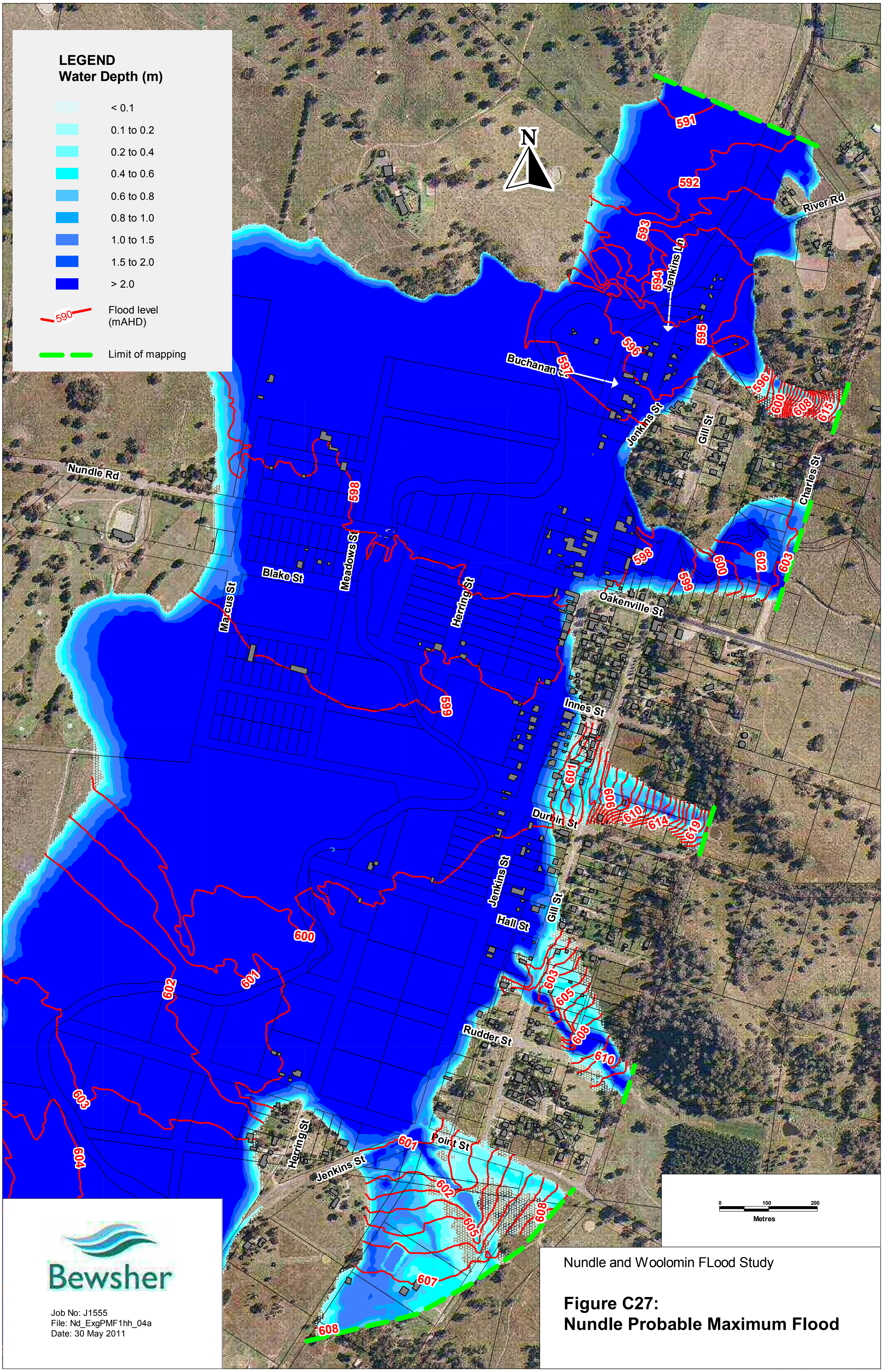
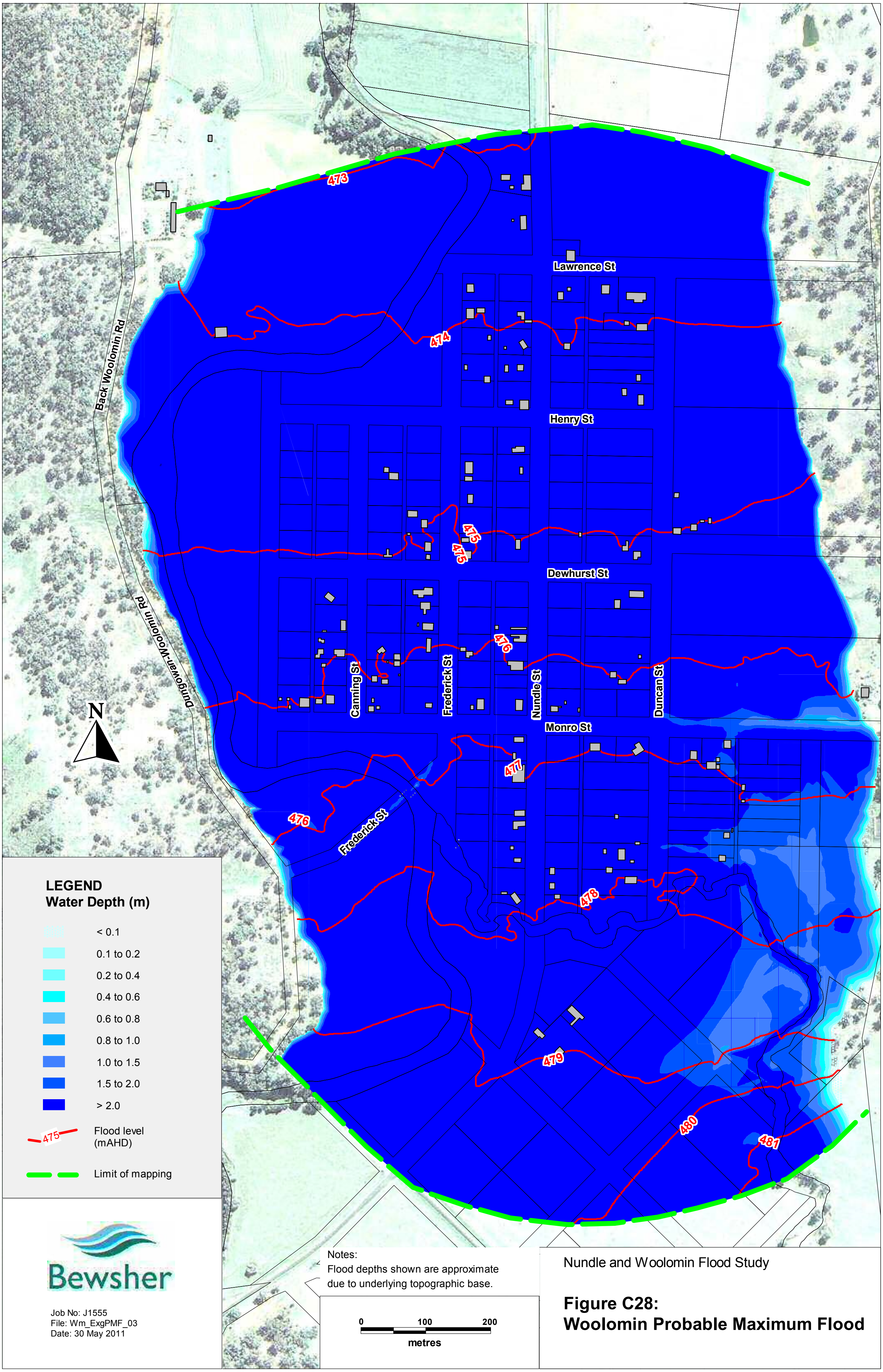


Figure C27: Nundle Probable Maximum Flood



Bewsher

Job No: J1555
File: Wm_ExgPMF_03
Date: 30 May 2011

Notes:
Flood depths shown are approximate due to underlying topographic base.

Nundle and Woolomin Flood Study

Figure C28:
Woolomin Probable Maximum Flood