Report

Wee Waa Levee Flood Investigation

JUNE 2015

Prepared for

Narrabri Shire Council

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Abbreviations

Abbreviation	Description
1D	One Dimensional
2D	Two Dimensional
AAD	Average Annual Damage
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AHIMS	Aboriginal Heritage Information Management System
ARI	Annual Recurrence Interval
AR&R	Australian Rainfall and Runoff
CMA	Catchment Management Authority
OEH	Office of Environment and Heritage (formally DECCW)
DIPNR	Department of Infrastructure, Planning and Natural Resources
DoP	Department of Planning and Infrastructure (formally DIPNR)
DWE	Department of Water and Energy
EPA	Environment Protection Agency
EP&A Act	Environmental Planning and Assessment Act
EPBC	Environment Protection and Biodiversity Conservation
FMC	Floodplain Risk Management Committee
FMM	Floodplain Management Manual
FPL	Flood Planning Level
FRMS	Floodplain Risk Management Study
FRMP	Floodplain Risk Management Plan
FRMS&P	Floodplain Risk Management Study and Plan
LEP	Local Environmental Plan
LGA	Local Government Area
NOW	New South Wales Office of Water (part of Department of Primary Industries)
PMF	Probably Maximum Flood
PMP	Probable Maximum Precipitation
SEPP	State Environmental Planning Policy
SES	State Emergency Services
SLWCA	Strategic Land and Water Quality Analysis

Executive Summary

Wee Waa is situated on the Namoi River floodplain near the confluence of the Namoi River and the Wee Waa Lagoon. The majority of Wee Waa's residential, commercial and industrial properties are protected by an existing earthen levee that surrounds the town. The levee surrounding Wee Waa is the only defence against flood inundation and therefore Narrabri Shire Council would like to better understand the structure.

This study investigates the hydraulic effectiveness of the current levee, assess the need for future improvements and also attempt to establish the flood overtopping levels of the levee, for the benefit of emergency services.

The 2D TUFLOW model developed for the project gave a good representation of the flooding along the Namoi River in the vicinity of Wee Waa. The 2D TUFLOW model was found to compare well with both the Mike 11 results and the data record at the Gunidgera gauge.

The model analysis suggested that the current levee (surveyed 2010) is adequate to protect the town of Wee Waa from a flood equivalent in size to that of the 1971 event. It is also suggested that the design levels recommended by the Department of Water Resources in 1993 may not meet the requirements of the 1971 flood + 1m.

The levee does not protect the town from a 1% AEP flood with sections of it being overtopped. This results in ponded water up to 1.0m deep occurring in some areas within the levee. If the levee were to be improved to meet the criteria of the 1% AEP event + 1m, it would result in the raising a 6,500m length by between 0.5m and 1.2m.

Correlations were developed between a number of locations around the levee and the Glencoe and Gunidgera gauges. The SES have derived an informal correlation for when the levee is likely to be overtopped. It was found that the model matched the SES information, supporting the accuracy of the derived correlations. These correlations should aid the SES in determining when flood defence actions are required in Wee Waa.

Introduction

1.1 Background

Wee Waa is situated on the Namoi River floodplain near the confluence of the Namoi River and the Wee Waa Lagoon. The town has a population of approximately 1,700 and is situated in the middle of the Namoi River floodplain. During large flood events, floodwaters spread out over the floodplain, reaching significant depths and affecting large areas of agricultural land. The majority of Wee Waa's residential, commercial and industrial properties are protected by an existing earthen levee that surrounds the town. Narrabri Shire Council is responsible for local planning and land management in the town of Wee Waa.

The levee surrounding Wee Waa is the only defence against flood inundation and therefore Narrabri Shire Council would like to better understand the structure. This study aims to investigate the hydraulic effectiveness of the current levee, assess the need for future improvements and also attempt to establish the flood overtopping levels of the levee, for the benefit of emergency services.

1.2 Objectives

The objectives of the study were as follows:

a) Models were developed for the 1% AEP flood events, together with the 1971 flood, the "Levee Failure" flood and the "Extreme Flood" (3 x 1% AEP storm) under existing catchment and floodplain conditions. The "Levee Failure" flood was a storm of sufficient size to overtop the existing levee and was produced by scaling the 1% AEP design inflow hydrograph. These modelling scenarios are discussed in detail in Section 2.
b) A profile of the flood height for the events listed in a) was plotted on a long section of the existing levee,
c) The performance of the levee during the events detailed in a) was assessed. The required design criteria (that is, the definition of whether the levee is adequate as a flood control measure) was assumed to be sufficient to prevent the larger of; a repeat of the 1971 flood; or the 1% AEP design storm. The requirements to defend against the "Extreme Flood" were also included for information.
d) Hazard maps will be produced for the events listed in a).
e) The following specific requirements from the SES were addressed:

  - The level at the Wee Waa flood warning gauge that will result in the Wee Waa levee being overtopped was calculated, however there was no investigation into the accuracy of the correlation. This means that more sophisticated flood warning analyses are required to make an accurate correlation, however this is outside the scope of this investigation.
  - Levee overtopping locations were identified along with a broad scale sequence of flooding.
  - An estimate of the depth of ponding within the Wee Waa levee was given for the events listed in a).
  - A level on the flood warning gauge was supplied so that sections of the levee can be closed prior to the flood peak arriving, but no investigation into the accuracy of the correlation was carried out.

1.3 Study area

Wee Waa is situated on the Namoi River floodplain at the confluence of the Namoi River and the Wee Waa Lagoon. The Namoi River's catchment to a point just downstream of Wee Waa totals 30,000 km^2. The study area is shown in Figure 1-1 and the model boundary is highlighted. The model's representation of the Namoi River extends from a point just downstream of the Collins Bridge (approximately 8 km upstream of Wee Waa), to a point approximately 2km downstream of the town.

The study area is characterised by very flat terrain with elevations dropping approximately 1 metre per 1500 metres (0.067%) generally in an east to west direction. Small variations in contours are associated with drainage lines, alluvial depositions along stream courses and earth levees surrounding the township of Wee Waa and some agricultural properties.

Google Maps - ©2012 Google

Figure 1-1 Study Area with the green line representing the model boundary

1.4 Data collection

A combination of data sources was obtained and used during the flood study to achieve a detailed understanding of the study area and develop the required hydraulic model. These sources include aerial photography and satellite imagery from historical flood events, reports, plans and survey information.

The following sections outline these data sources and Appendix A contains a data inventory.

1 Introduction

1.4.1 Aerial photography

Aerial photography of the Wee Waa study area is available for many of the historical flood events. Table 1-1 lists the available imagery.

Table 1-1 Available aerial photography

Historical Flood	Available imagery
January/February 1971	Aerial flood mosaic
January/February 1984	Aerial flood mosaic
July 1998	Vertical aerial photography and aerial flood mosaic

The aerial photography was used to compare historical flood extents to the modelled inundation areas.

A Google Earth aerial photo was used as a background for the TUFLOW model to provide context and locations within the study area.

1.4.2 Reports and plans

Several reports and plans were used as a source of data including

- *Narrabri Shire Local Displan* by Narrabri Shire Local Emergency Management Committee.
- *Economic Risk Analysis of Wee Waa Levee Upgrading* by Water Resources Consulting Service 1993
- *Audit of Flood Levees for New South Wales – Summary Report* by NSW Public Works Department – Dams and Civil Section 1992
- *Narrabri – Wee Waa Flood Study* Department of Infrastructure, Planning and Natural Resources 2003
- *Narrabri – Wee Waa Flood Management Plan* by NSW Department of Natural Resources 2005.

As part of the development of the *Narrabri – Wee Waa Floodplain Management Study* and *Plan* a Mike 11 model of the Namoi River from Mollee Weir (near Narrabri) to Merah North (west of Wee Waa) was constructed. The construction methodology, calibration and verification of this Mike 11 model is detailed in the *Narrabri – Wee Waa Flood Study* report. This model was supplied to URS and was assumed to be correct. URS did not undertake any independent verification or review of this model. This Mike 11 model provided input and information for the formation of the 2D TUFLOW model (Sections 2 & 3) used in this investigation.

1.4.3 Survey information

In order to undertake a detailed hydraulic assessment of the study area, detailed survey information was required. The modelling approach chosen used a two dimensional (2D) TUFLOW hydraulic model which is described further in Section 3.

TUFLOW requires detailed terrain data to create the basic model structure. URS commissioned AAMHatch to undertake a LiDAR survey of Wee Waa and the surrounding area. The survey covered an area of approximately 110km^2, which includes a 25km reach of the Namoi River, its tributaries, the surrounding floodplains/farm area and the town of Wee Waa. The survey information was provided to

1 Introduction

URS as 1m grid points which were then used to produce a Digital Terrain Model (DTM) in the MapInfo GIS package.

One limitation problem with the supplied LiDAR survey data is that LiDAR cannot penetrate water. As a result the Namoi River "bed level", as picked up by the LiDAR, was the water surface at that time and is higher than the actual river bed level. The raised level was particularly pronounced immediately upstream of the Gunidgera weir where the water level was found to be approximately 5m deep. The weir creates a backwater effect that stretches through the majority of the model and further upstream. During a flood event, this water can be considered as stationary and not contributing to the available area of flow. Therefore the model response should not be affected by this limitation to the LiDAR data.

Current and historical levee height data was also provided so that the height of the Wee Waa levee could be more accurately represented for all study events.

Observed flood levels at various locations throughout the study area were also supplied for the 1984 and 1971 floods.

1.4.4 Gauging stations

Flood height records were sourced from the gauging stations shown in Table 1-2 from the Department of Primary Industries NSW Office of Water (NOW) website.

Table 1-2 Gauging Station Data

Gauge Name	Gauge Number	Years of Record	Gauge Zero (mAHD)	Approximate Location
Namoi at Glencoe	419900	1995 – date	188.5	Downstream of Collins Bridge
Namoi at Gunidgera Weir	419060	2007-2007	185.065	3km north of Wee Waa
Namoi River At D/S Gunidgera Weir	419059	1975 – date	182.73	Downstream of the Gunidgera Weir

It should be noted, that the continuity and reliability of the gauge records can vary depending on changes in; the physical location of the gauging site, river geometry, the gauge zero level and associated rating curve over the record period.

The Gunidgera weir is located approximately 3km north of Wee Waa it is one of several weirs on the Namoi River that stores water for local irrigation purposes. The weir is "approximately 5 metres in height and approximately 50 metres across the length of the crest. The weir is a regulating structure which can be electronically operated and monitored remotely. The gates currently remain closed throughout the year during all but flooding conditions, when they are gradually opened to prevent overtopping and potential structural failure of the weir." (NSW Department of Primary Industries, 2006)

This weir has not been included in the TUFLOW model which may influence model results at the Gunidgera gauging station (419059) directly downstream of the weir. This gauging location is being used for verification of the model; however there are no records for how the weir gates have been operated, if at all, during past events. Therefore it was decided to artificially smooth out the change in water level caused by the weir by linearly interpolating between the upstream and downstream water levels.

Hydrology

2.1 Review of flood frequency

2.1.1 Background

A review of the existing flood frequency analysis was undertaken, based on the procedures outlined in the Australian Rainfall and Runoff guidance. Correlations were established between the Mollee, Glencoe and Gunidgera Gauging Stations. The comparisons and correlations utilised water level data from the gauge records.

2.1.2 Previous Analysis

In 1992, the NSW Public Works Department (PWD) as part of the 'Audit of Flood Levees for NSW Town of Wee Waa' conducted a flood frequency analysis based on the flood levels observed at Gauging Station 419019 Namoi River at Wee Waa between 1956 and 1976. Due to the short record, this site was not included in the analysis for this study, but serves as a demonstration of previous hydrology work carried out in the area.

The annual maximum flood levels for a 20 year period of record (1956-1975) at this gauging station were extracted. A smooth curve of flood level against Annual Exceedance Probability (AEP) was drawn on semi-logarithmic paper and is shown in Figure 2-1. The flood frequency curve was not extrapolated beyond an AEP of 3.3%. This AEP was assigned to the 1971 flood level, even though the 1955 flood reached a level at Wee Waa slightly higher than that of the 1971 flood.

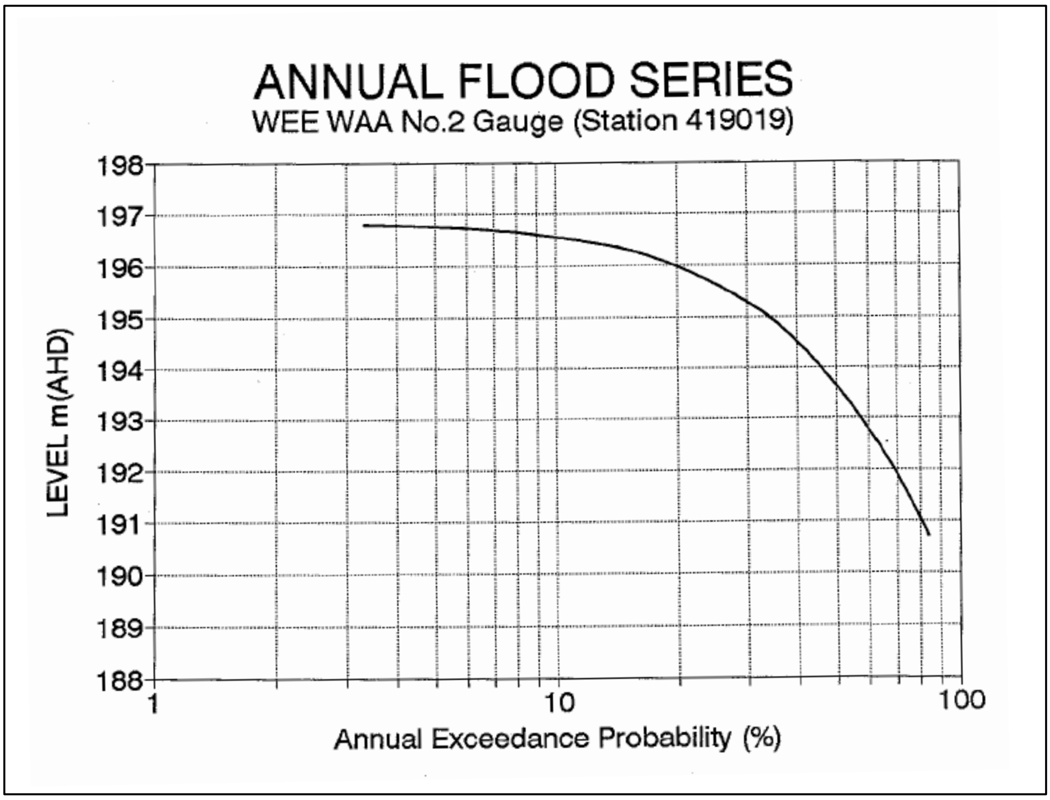

Figure 2-1 Flood frequency analysis for Wee Waa No.2 Gauge from the NSW Public Works Department (1992)

2.1.3 URS methodology

To establish a better understanding of the hydrological characteristics of the Namoi River as it passes through the Wee Waa study area river water levels were taken from gauging stations on the Namoi River to determine if a correlation could be established.

The gauging stations used were the Mollee (419039), Glencoe (419059, also known as the Wee Waa flood gauge) and Gunidgera (419900) flood gauges. Table 1-2 summarises the data from the gauging stations considered. All streamflow data from these gauging stations were considered. However, missing and/or erroneous data along with various periods of record meant that the only large flood event that was recorded at all three gauges was the 1998 flood. The recorded river water levels had the gauge datum height added so that the water elevation could be determined. The recorded water elevation at Mollee was then plotted against the recorded water elevation at Glencoe.

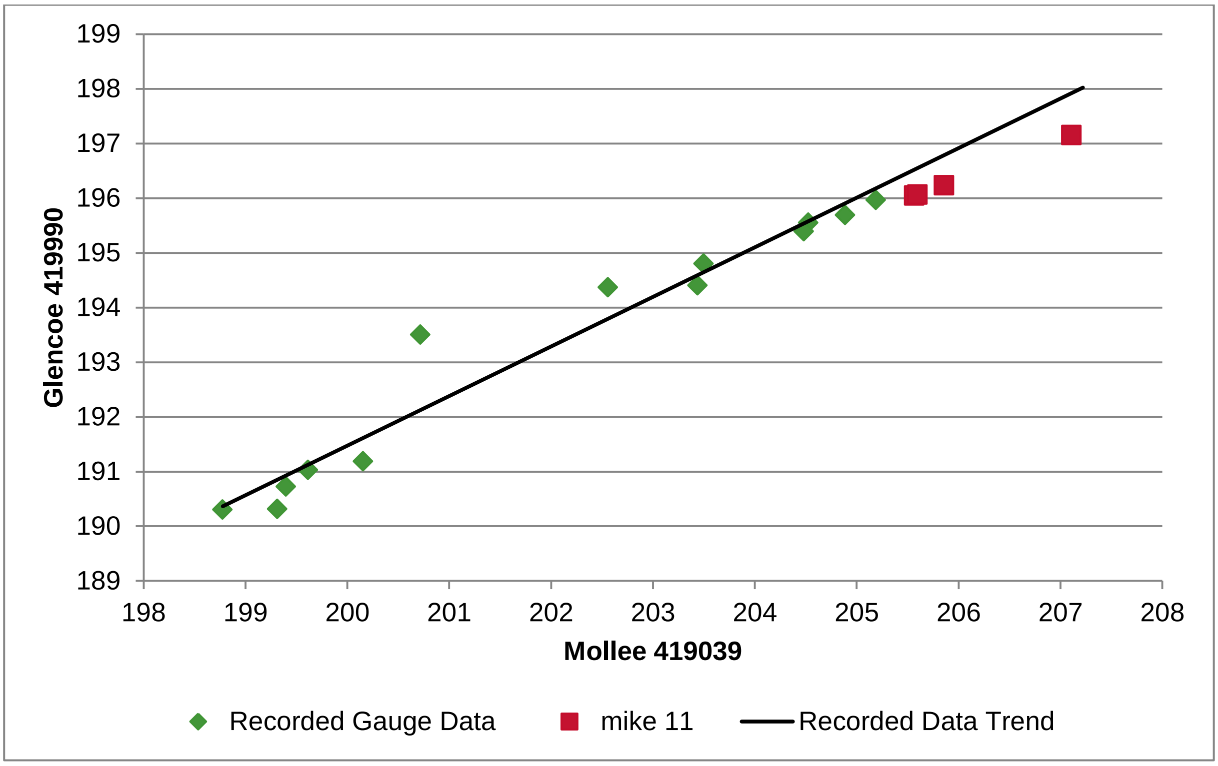

Figure 2-2 Recorded gauge data correlation and Mike 11 modelled correlation

As shown in Figure 2-2 there is roughly a linear correlation between the water elevations recorded at the Mollee and Glencoe gauges. The water elevation results from the floods modelled in Mike 11 from Mollee (Mike 11 chainage 0) and Glencoe (Mike 11 model Chainage 22986) show a similar linear correlation. This suggests that the Mike 11 model realistically represents flow behaviour at the two sites.

A similar exercise was undertaken to correlate recorded water elevations at the Glencoe and Gunidgera gauges. The results are shown in Figure 2-3.

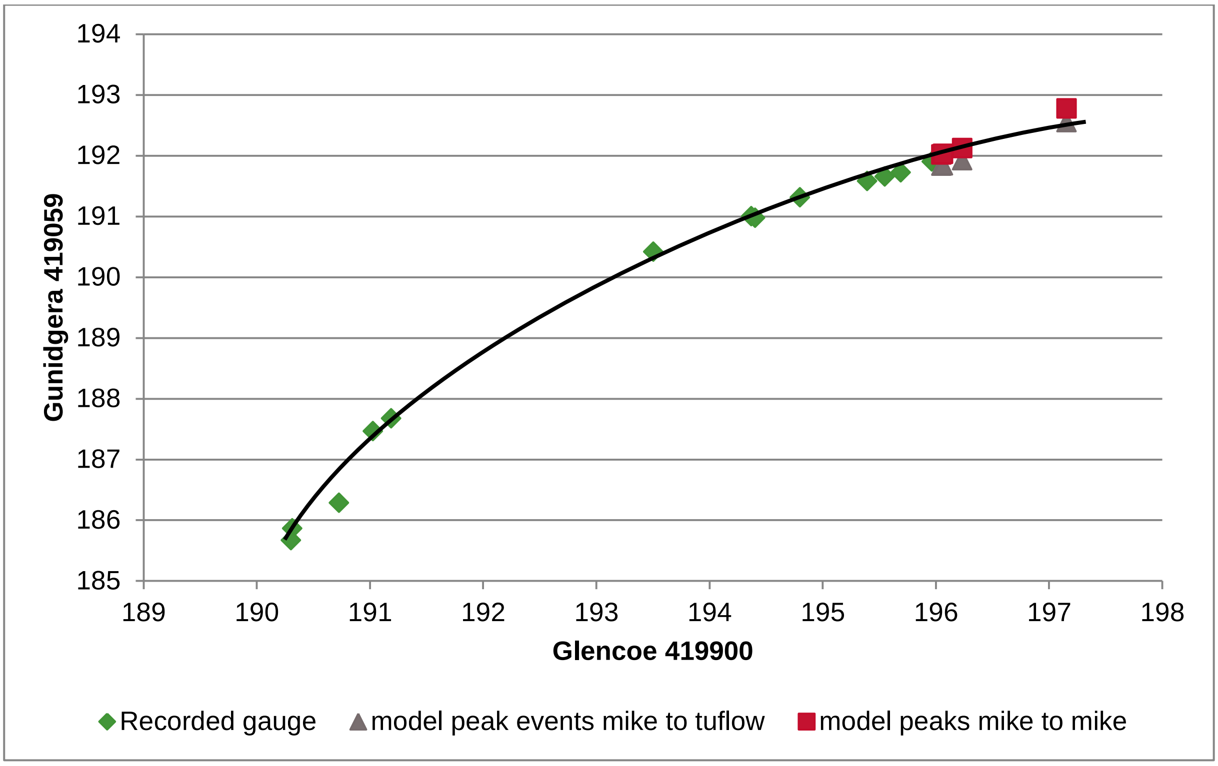

Figure 2-3 Recorded gauging's at Glencoe and Gunidgera with model data

As shown in Figure 2-3 there is a correlation between the water elevation results recorded at the Glencoe and Gunidgera gauges.

There are two sets of model results represented on the figure. One set compares the existing Mike 11 model results for both sites and the other compares the TUFLOW results for Gunidgera against the Mike 11 results for Glencoe. The Mike 11 results for both gauges matched the correlation shown by the recorded values, again suggesting that the Mike 11 model realistically represents flow behaviour at the two sites. The TUFLOW model results at Gunidgera are consistently lower than the Mike 11 results; however the correlation line sits between both the MIKE 11 results and the TUFLOW results. The TUFLOW results appear to be marginally underestimating the flood level at Gunidgera this is further discussed in Section 3.5 where the Gunidgera observed flood level is compared to the modelled Gunidgera flood level. This slight discrepancy in levels is discussed in Appendix C. This shows that both models are appropriately representing flood conditions in the Namoi River. A verification of the TUFLOW model was undertaken to further test the model results and is discussed in Section 3.5.

By checking the correlation between recorded gauges, it was then possible to extend the correlation to other areas of the modelling. One such correlation considered water levels at Glencoe and the predicted corresponding water levels that could be expected at various locations around the Wee Waa levee. These are discussed in Section 4.2.

2.1.4 TUFLOW model boundaries

The TUFLOW model requires all boundaries of the hydraulic model to be specified in terms of water level over time, discharge over time or a discharge/height relationship (Q/h relationship). The existing

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Mike 11 model was used to establish boundary conditions and determine inflow hydrographs for the TUFLOW model. Hydrographs that were provided with the Mike 11 model were the 1971, 1984 and 1998 floods as well as the 1% AEP flood. The 1%AEP flood was scaled up to produce a 3 x 1%AEP flood. The Mike 11 model has inflow hydrographs which are then routed through the model to the various downstream boundaries. The area represented by the TUFLOW model is located within the Mike 11 model and therefore the results from a suitable location within the Mike 11 model have been used to create the inflows for the TUFLOW model. The extraction of inflows for the TUFLOW model is described below.

Table 2-1 Peak inflows used in both the Mike11 and TUFLOW models

	Inflow to Mike11 Model		Inflow to TUFLOW Model	
Event	Peak Flow (m^3/s)	Peak Flow (ML/d)	Peak Flow (m^3/s)	Peak Flow (ML/d)
1971	2,847	245,981	2,002	172,982
1984	2,234	193,018	1,655	142,953
1998	2,280	196,992	1,681	145,219
1% AEP	6,672	576,461	4,302	371,715
3x1% AEP	20,016	1,729,382	12,907	1,115,144

The boundary conditions used in the TUFLOW modelling of the Wee Waa study area consisted of:

- Upstream boundaries – flood hydrographs were used at the upstream boundary of the TUFLOW model. These hydrographs were extracted from the Mike 11 model at locations that represent the inflow boundaries of the TUFLOW model. Figure 2-4 shows the locations of the Mike 11 model that were used to extract the hydrographs. Both inflows required the combination of hydrographs from two branches of the Mike 11 model. The Namoi River inflow hydrograph was a combination of flow within the Namoi River and the Myal Vale_FW branch in the Mike 11 model. The Mollee Creek hydrograph was taken as being a combination of Mollee Creek and Bundock Creek. In the Mike 11 model a nominal steady state inflow flow of $85m^3/s$ was used to represent the combined contribution of Mollee and Bundock Creek inflows. Although Mike 11 then routes this flow through the river network this steady state inflow may result in an over estimation of flows and flood heights to the south of the Wee Waa Levee. This routing of flow in the Mike 11 model also results in cross flow escaping the Namoi River and contributing to the TUFLOW Mollee inflow.
  This combination approach was necessary because the Mike 11 model (*Narrabri – Wee Waa Flood Study* DIPNR, 2003) attempts to represent the open floodplain through a large number of interconnected flow paths. To ensure all of the flow is included in the TUFLOW model, all of the branches crossing the inflow boundaries were combined into two hydrographs. Combining the flow in the creeks ensured that flood water was not “lost”, causing a reduction in the flood levels around Wee Waa.
- Downstream boundaries – discharge rating curves (Q/h relations) were used as the downstream boundary conditions. TUFLOW automatically generates these discharge rating curves based on the slope of the flood wave. In this case it was taken as being 0.007, the same gradient as the topography.

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It should be noted that water has not been allowed to leave the model to the north. Tests were carried out allowing water to leave the model via a boundary at this location; however this resulted in a loss of volume that had a negative effect on water levels throughout the model. A decision was therefore made to allow the glass walling effect to the north in order to improve the model results around Wee Waa which is the main focus of the study.

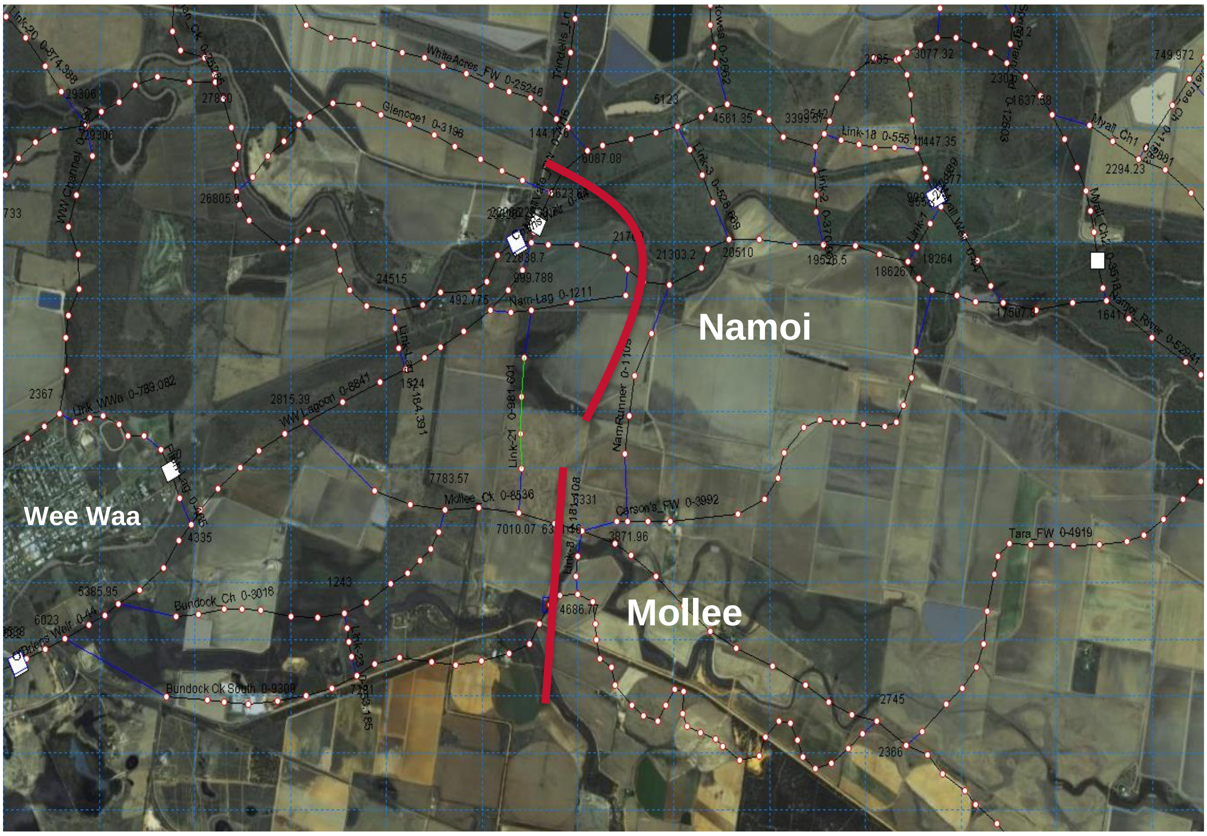

Figure 2-4 Mike 11 cut points for hydrograph extraction

Hydraulic modelling

Investigation of flooding and floodplain management issues requires a detailed understanding and knowledge of flooding behaviour within the study area. To supplement available information on historical flood events and to satisfy the overall objectives of the Wee Waa Levee Flood Study, computer based hydraulic models have been used to simulate flooding behaviour. In this instance the two dimensional hydraulic modelling package TUFLOW was used.

3.1 TUFLOW model

TUFLOW is a computer program for simulating depth-averaged, two and one-dimensional free-surface flows such as those that occur from floods and tides. TUFLOW was originally developed for modelling two-dimensional (2D) flows; its name is derived from Two-dimensional Unsteady FLOW. However, it also incorporates the full functionality of the ESTRY 1D network or quasi-2D modelling system. In order to do this it needs detailed topography data of the study area.

The TUFLOW model is built up of a grid of cells which take a level from the DTM, built using the LiDAR survey data. Water is then allowed to pass freely between the cells, following known hydraulic principles. The cell size therefore controls the resolution of the model, with smaller cell sizes allowing for more topographic detail in the model (consequently leading to larger models which take longer to simulate flood events).

To reduce the size and run time of the Wee Waa TUFLOW model the 1m grid points were used to create cross sections for a 1D Namoi River channel. This was embedded into a 2D matrix that represented the surrounding floodplains. The result was a model that allowed the detailed topography of the Namoi River channel to be defined whilst the relatively flat floodplain was based on a 20m cell size. The model achieved an accurate representation of the study area while reducing the size and run time of the TUFLOW model.

As the Namoi River floodplains were modelled at a “course” 20m cell spacing additional “thin” features (those features where height difference may occur at less than 20m spacing) such as bridges, levees and roads were added to the TUFLOW model.

3.2 Representation of the Wee Waa Levee

Several variations of the Wee Waa levee were developed to represent the alterations that have been made over time. Figure 3-2 shows survey of the levee taken after improvement works in 1984. To gain a consistent reference point all levee chainages start at the same place as the 2010 survey zero chainage. This allows easy correlation between the different levee heights and flood events. A plan showing the location of chainage zero for the 1992 and 2010 survey is shown in Figure 3-1 and the detailed survey plan can be found in Appendix B.

3 Hydraulic modelling

Figure 3-1 Wee Waa levee chainages

The 1971 design levee is the levee height that was proposed after the 1971 flood. It was designed to be "equal to the 1955 and 1971 flood plus 900mm" (NSW Public Works Department – Dams and Civil Section. (1992).

3 Hydraulic modelling

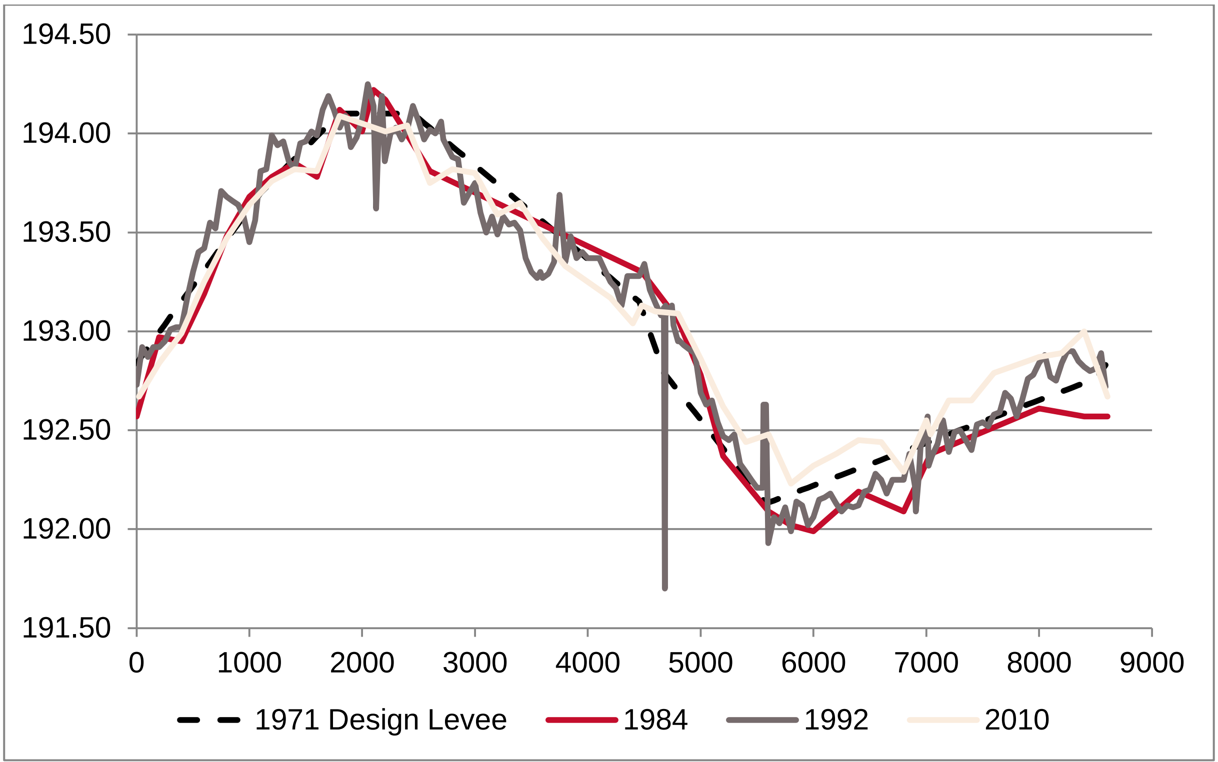

Figure 3-2 Wee Waa levee levels since 1984

The flood year and the survey used to determine the height of the levee at the time of the flood is shown in Table 3-1. The 1971 event prompted the design and construction of the levee, so no structure existed at the time of the flood.

Table 3-1 Levee height survey data and corresponding flood

Levee Height survey	Flood
No levee present	1971
Early 1984	1984
1992	1998
2010	1% AEP
2010	3x1% AEP

Following the initial construction of the levee in the early ‘80s, improvement works have been carried out in an ad hoc process that was not recorded. The supplied surveyed levels were therefore used as an accurate record of any works or changes in height that may have occurred.

Other levees in the floodplain were given a RL of 200m (AHD) under the direction of OEH with the exception of the 2 shown on the map in Appendix B. This was done to ensure they were not overtopped and the 2 levees that were not raised in height used the height identified by the LiDAR survey.

3.3 Channel roughness

One of the primary factors that govern flooding behaviour is the resistance to flow or hydraulic roughness. The TUFLOW model uses Manning's 'n' values to represent the hydraulic roughness of the floodplain. Table 3-2 shows the material type and the assigned roughness value with Figure 3-3 showing where they were applied within the model. The default roughness for all areas of the model was a value of 0.065 unless otherwise covered by the polygons shown in Figure 3-3. These roughness values were based on the values used in the MIKE 11 model and also standard values as shown in Open Channel Hydraulics (Chow, 1959).

Table 3-2 Materials for manning's n

Material Number	Material Type	Manning's n
1	Rural Properties	0.065
2	Short Grass	0.045
3	Bushes	0.15
4	Concrete	0.015
5	Floodplain	0.075
6	Namoi River & Water Courses	0.05
7	Wetland & Lagoon	0.045

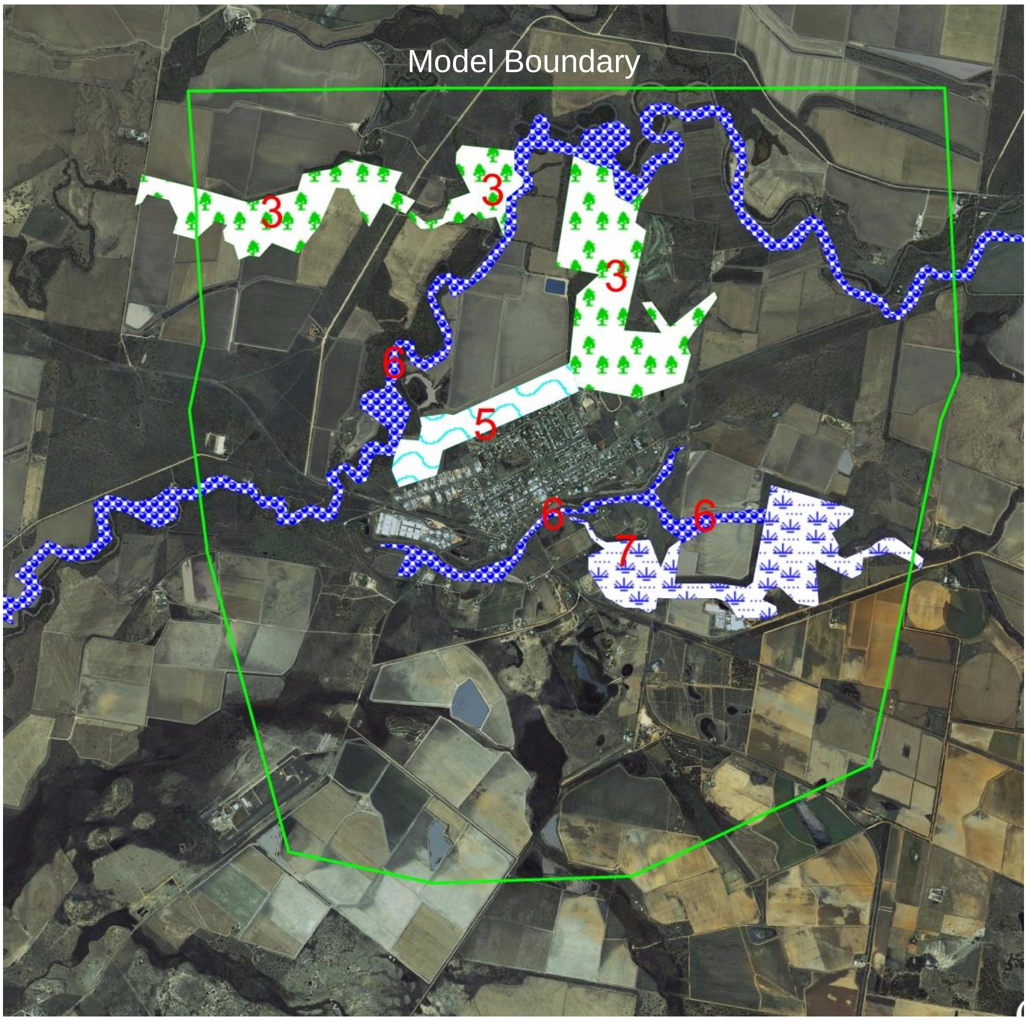

Figure 3-3 Manning's n material polygons

3.4 Boundaries

The TUFLOW model requires all boundaries of the hydraulic model to be specified in terms of water level, discharge or a discharge/height relationship (Q/h relationship). The existing Mike 11 model was used to establish boundary conditions and determine inflow hydrographs for the TUFLOW model. Hydrographs that were provided with the Mike 11 model were the 1971, 1984 and 1998 floods as well as the 1% AEP flood. The 1% AEP flood was scaled up to produce a 3 x 1%AEP flood. As discussed in section 2.1.4, the boundary conditions used in the modelling of the Wee Waa study area consisted of:

1. Upstream boundaries – flood hydrographs of the Namoi River and Mollee Creek, taken from Mike 11, were used at the upstream boundary of the TUFLOW model.
2. Downstream boundaries – discharge rating curves (Q/h relations) were used as the downstream boundary conditions for flows leaving the model.

As stated earlier, model performance was tested with boundaries at the northern edge of the model, intended to allow flow to leave the model. During this testing, it was found that the volume of water in the model was not sufficient to achieve the recorded peak flood levels at the Gunidgera gauge. A better fit to the recorded data was achieved by allowing the flow to “glass wall” against the model boundary at the northern end of the model. This means the flow would build up against the model boundary rather than being contained by the topography of the model. It was also found that the flood levels around Wee Waa were also improved, so the boundaries were removed permanently

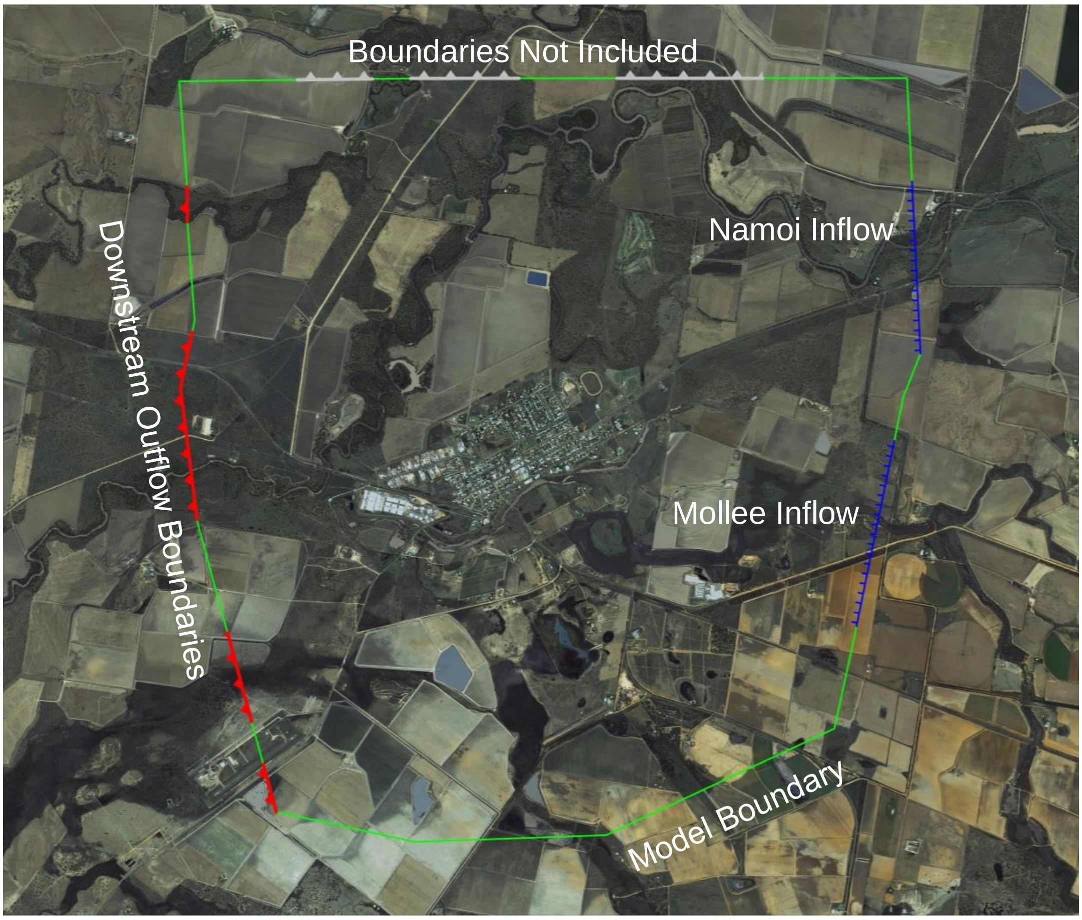

Figure 3-4 Location of TUFLOW boundaries

3.5 Model verification

The Gunidgera gauge (419059) just downstream of the Gunidgera weir was used to compare observed and modelled flood levels. However it was only possible to compare observed and modelled flood levels for the 1998 flood as there was no gauging information available for any of the other floods included in the Mike 11 Modelling. This limits the extent to which the model can be calibrated, limiting this to a verification exercise.

Further validation for other historic floods was undertaken by comparing observed peak flood levels with modelled peak flood levels. The observed data took the form of recorded spot water levels around the Wee Waa levee and other structures.