# WE KNOW OUR FLOODS, OR DO WE?
# (OUTCOMES OF SOME RECENT FLOOD STUDIES)

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## Abstract

Tamworth Regional Council has recently completed a series of studies on its flood affected towns, as well as an investigation into potential flooding behind the city levee network. In many ways these were “just another study”, but some of the findings are worthy of discussion.

The Manilla study examined the impact of Split Rock Dam, which was built upstream in 1987. Although the modelling assumed that the dam was full at the start of the event, it showed that the spillway now delays the flood peak on the Manilla River and reduces the likelihood of a simultaneous peak with the Namoi River. This has significantly reduced the size of floods in Manilla, and has reduced the area of land that is now considered to be flood prone.

The town of Barraba also sits on the Manilla River upstream of Split Rock Dam. The study appeared to be straight forward, with the 1%AEP modelling able to predict the flood of record for the town. The map of the PMF, however, was surprising to many residents, with most of the town expected to be inundated in a very large event. At first this appeared to be an inaccuracy in the model, until it was shown that there is a “choke point” in the river valley just downstream. This could have very significant emergency management implications in larger events.

The “Behind the Levee Study” for Tamworth looked at the potential for damming of water during a large storm event. The existing stormwater system is typically 10%AEP capacity. Pipes are expected to surcharge during larger storms, and are closed during river floods. Modelling showed that in larger events, this could result in 300 properties being inundated on the “dry” side of the levee.

## Introduction

Tamworth Regional Council (TRC) is located in the New England Region of New South Wales, about 410 kilometres north-west of Sydney and 580 kilometres south of Brisbane. The TRC area is bounded by Gwydir Shire in the north, Uralla Shire and the Walcha Council area in the east, Upper Hunter Shire in the south, and Liverpool Plains, Gunnedah and Narrabri Shires in the west.

TRC was established in March 2004, amalgamating the northern NSW shires of Barraba, Manilla, Nundle and Parry and the city of Tamworth. It is one of the largest councils in inland NSW, with a population of over 56,000 spread over an area three times as large as the Sydney basin.

TRC is located within the Namoi River catchment, which itself covers about 4% of the wider Murray-Darling Basin catchment. The Namoi catchment area is about 42,000 square kilometres, borders the Gwydir and Castlereagh catchments and is bound by the Great Dividing Range in the east, the Liverpool Ranges and Warrumbungle Ranges in the south, and the Nandewar Ranges and Mount Kaputar to the north. Elevations range from over 1,500 metres to the south and east, to just 100 metres on the alluvial floodplain of the lower catchment west of Narrabri.

The TRC LGA covers about one-quarter of the upper reaches of the Namoi Catchment with an area of 9,600km.

The Namoi River rises in rugged ranges near Tamworth, forming a complex pattern of creeks and streams before joining the Barwon River at Walgett. Its main tributaries are the Manilla and Peel rivers, joining the Namoi upstream of Boggabri, and Coxs, Pian, Narrabri, Baradine and Bohena creeks joining below Boggabri. The river has developed an extensive floodplain, with around a quarter of the basin prone to flooding. Figure 1 details the area of the Namoi River Catchment.

Major tributaries of the Peel River are Goonoo Goonoo Creek, Cockburn River, and Dungowan Creek. The Peel River has a catchment area of around 4,700 square kilometres and contributes an average annual volume of approximately 280,000 megalitres to the Namoi River system.

The upper catchments of the Manilla River are located to the northwest of Tamworth. The river drains a large (771km$^2$) catchment before flowing through the town of Barraba. The river headwaters are located near Split Mountain Yard in the Nandewar Ranges and drains in a north-easterly direction to the Plumthorpe area, before turning south-east towards the town of Barraba. Approximately 20km south of Barraba the Manilla River discharges into Split Rock Dam. From here, the river drains southwards for a further 25km before it confluences with the Namoi River within the town of Manilla.

A number of significant tributaries discharge to the Manilla River, including the Barraba Creek, Millie Creek and Connor’s Creek, all with their confluences immediately north of Barraba. The catchments in the upstream reaches of these creeks are generally steep and heavily forested. Lower reaches are mostly rural in nature.

Keepit Dam, with a capacity of 426,000 megalitres, is the major irrigation storage for the Namoi catchment. Split Rock Dam, with a capacity of 397,000 megalitres augments the supply from Keepit Dam as well as supplying users along the Manilla River. Chaffey Dam, with a 62,000 megalitres capacity, regulates the flow of the Peel River and augments water supply to Tamworth.

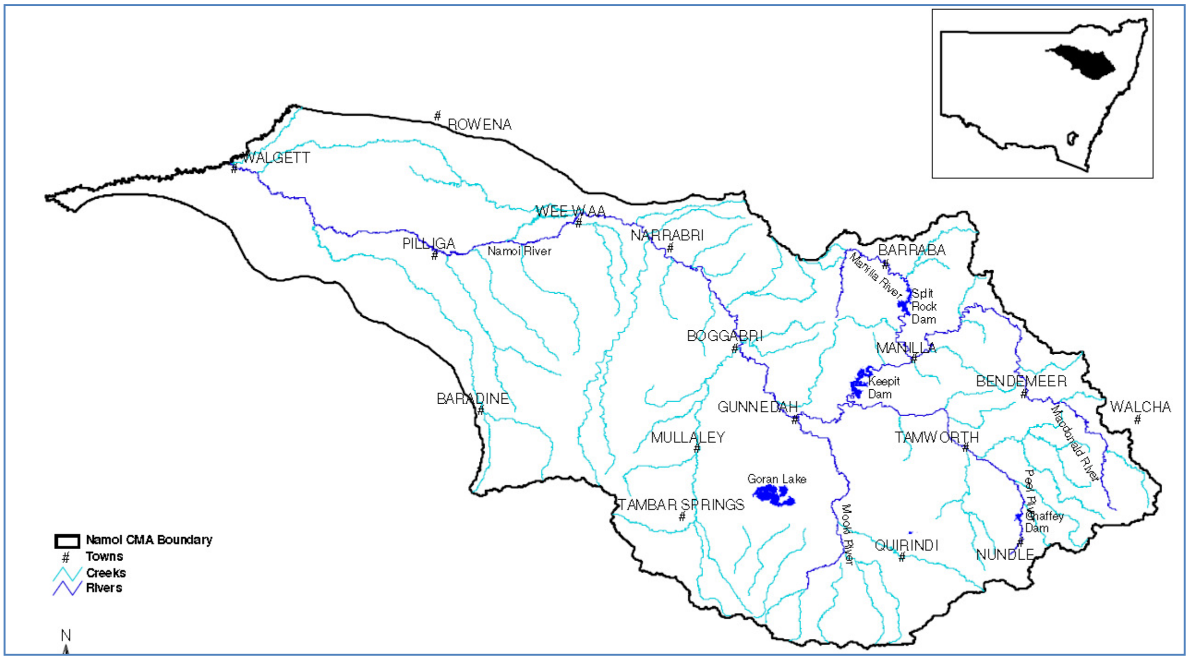


**Figure 1 – Namoi River Catchment**

***Tamworth City Catchment, Drainage and Flooding***

Tamworth City is located on the Peel River just downstream of its confluence with the Cockburn River. The CBD and much of the industrial area of the city are constructed on the Peel River floodplain. To protect the city, a network of flood mitigation levees has been constructed in different stages over the past 80 years;

- The CBD levee was originally constructed in the 1930's to protect existing commercial development located along the northern overbank of the Peel River. The levee was raised on several occasions in the period 1976-1978 in response to perceived flood threats, and again in 1996-1997 to provide a one metre level of protection to the 100 year ARI Design Flood.
- The Western Levee was built in 2002-03 and protects existing residential and commercial development.
- The Taminda Levee was originally constructed as a private levee around the Tamworth Racecourse, and was upgraded in 2008-09 to form a 2.7km long levee which protects commercial and industrial property located in the Taminda area.

Stormwater discharging to the Peel River from the local catchments is controlled by twenty-three individual drainage lines, including the following;

- Ungated pressure lines that have a single inlet upstream of the CBD and above the 100 year ARI event level. These lines are designed to capture flows from the extensive undeveloped catchment upstream of the CBD and discharge them directly to the Peel River.
- Gravity drainage lines equipped with manually operated penstock type flood gates along the levees to provide backwater flooding protection. When the Peel River is in flood, the gates are closed and any stormwater captured on the "dry-side" of the levees is stored within the drainage network and surcharge storage areas until such time that the river recedes and the gates can be re-opened.

Flooding in the Tamworth Urban Area is typically characterized as short-term rises in the Peel River as a result of rainfall in the Peel and Cockburn River catchments. Goonoo Goonoo Creek and Timbumburi Creek are tributaries of the Peel with catchments to the south-west and west of the city respectively and discharge to the river in the urban area of the city, contributing to flooding of the CBD.

Five major floods have occurred in the Peel River in the Tamworth urban area since records commenced, with the 1910 and 1955 floods generally being regarded as the largest and most damaging, and the 2008 flood being the most recent. Moderate flood levels have been reached on over 60 occasions in the last 90 years.

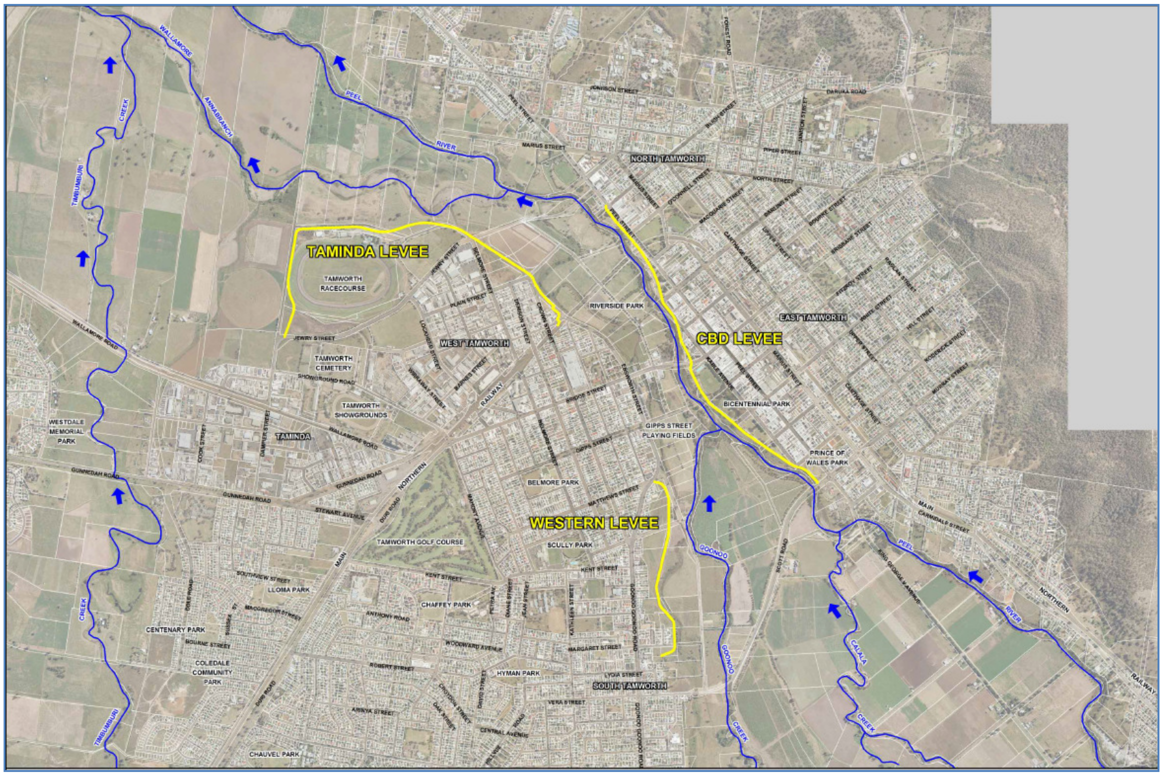


**Figure 2 – Tamworth City Rivers and Levees**

### ***Barraba Township Catchment, Drainage and Flooding***

The township of Barraba is located on the southern bank of the Manilla River, approximately 100km north-west of Tamworth. Upstream of Barraba the river drains a catchment of steep and heavily forested land, sloping to rural entitlements in the lower reaches. In many areas, particularly towards Barraba, the river generally has a deep, well defined channel with a wide floodplain.

A number of significant floods have occurred in Barraba, including;

- A significant event in February 1864;
- A major flood event that affected much of regional NSW in February 1955;
- A flood in January 1964, that is generally considered to be the largest flood since European settlement;
- Moderate flood events in 1971, 1974, 1984, 1998, 2003 and 2004.

Floodwaters in the catchment tend to rise quickly and isolate communities and properties for several days. Many houses can be inundated in flood events necessitating evacuations. The nature of flooding varies considerably from in-stream flood ways to areas where the floodwaters inundate floodplains at bends in the river and where floodwaters backup into the lower reaches of tributary creeks. There are a number of rainfall and river gauging data in the catchment, with records dating back as far as 1971.

### *Manilla Township Catchment, Drainage and Flooding*

The upper catchments of the Manilla and Namoi Rivers drain large areas (2075km$^2$ and 3075km$^2$ respectively) before they confluence at Manilla, approximately 25km upstream of Keepit Dam on the Namoi River.

The Namoi River has it's confluences near its headwaters with the McDonald River, which itself drains a 3075km$^2$ catchment. The McDonald River headwaters are located in the Dividing Range approximately 70km west of Tamworth. It discharges through the towns of Woolbrook and Bendemeer upstream of the confluence with the Namoi River.

A number of significant tributaries discharge to the Manilla, Namoi and McDonald Rivers as follows;

- Barraba Creek at Barraba;
- Bohra Creek at Upper Manilla;
- Yarramanbully and Halls Creek near Manilla, and
- A number of tributaries along the length of the McDonald River

A number of significant floods have occurred in Manilla, including;

- A significant event in 1840;
- A significant event in February 1864 in which 4 of the 12 total residents were drowned;
- A significant event in 1910;
- Since 1941 when gauging started there have been 16 minor, 3 moderate and 2 major floods;
- The February 1955 flood was a major event and is enshrined in many residents' memories. It was noted as the worst in 100 years, and;
- More recent flood events have occurred in 1971, 1984, 1998 and 2004.

As with Barraba, floodwaters in both catchments tend to rise quickly and isolate communities and properties for several days. There are a number of rainfall and river gauging data in the catchment, with records dating back as far as 1916.

Split Rock Dam, constructed upstream of Manilla on the Manilla River, was completed in 1979. The purpose of the dam is principally for irrigation, not for flood mitigation, and the effect of the dam storage on flood planning levels in Manilla is a focus of this paper.

## History of Flood Studies in Tamworth, Manilla and Barraba

### *Tamworth City*

Several studies have been commissioned to model the flood behaviour of the Peel River in Tamworth over the years, and a major outcome of these studies has been the construction of a sophisticated network of flood mitigation levees, ungated pressure drainage lines and detention and retention storages to protect residential and commercial property from flooding in the river. However, since the construction of these drainage systems little research has been undertaken to ascertain flood behaviour behind the levees, particularly when the river is in flood. It was generally considered that such an event was unlikely, however the major flood event of 2008, which created this exact situation when a localized 1 in 200 year flood event occurred in West Tamworth at the same time that the Peel River was in flood, identified a gap in the city's extensive flood data knowledge.

### *Manilla and Barraba*

Following the amalgamation of the five former Councils in 2004, it was realized that whilst there was good data for river levels available at most towns and villages, very little was known about flood behaviour and flood depths outside Tamworth City. Flood Planning Levels were typically derived from anecdotal evidence and media reporting to substantiate historical flood behaviour in the towns and villages throughout the region.

In 2006 Council commissioned Bewsher Consulting Pty Ltd to conduct a preliminary assessment of the flood problem at 11 towns and villages throughout the Tamworth LGA. The principle aim of the assessments was to identify flood problems, prioritise the towns and villages according to the general scope of the problem, and to develop a strategic plan for the preparation of detailed flood studies and floodplain management studies and plans, as stipulated in the New South Wales Government's Floodplain Development Manual (April 2005).

A prioritised plan for future flood studies and floodplain management studies and plans within the Tamworth LGA was prepared. The principal factor for allocating priorities was the number of buildings located within the historical flood extent. The typical flood velocities and available warning times were also considered, as was the frequency of the historical event under consideration.

### *Commissioning of Recent Studies*

In accordance with the prioritised plan, both Barraba and Manilla were given high priorities for future studies, as was a Behind The Levees study for Tamworth City.

Council commissioned Lyall and Associates to model the behaviour of catchments behind the Tamworth levees determine the extent of risk to properties from ponding behind the levees themselves. GHD were commissioned to model the flood behaviour in Manilla and Barraba and to determine the risk of flooding of existing properties within the floodplain.

## Study Methodology

### *General*

The methodology for each study followed the same basic structure;

1. Identify the catchment, including survey information to identify the shape of the ground in the vicinity of the study area;

2. Hydraulic modelling to assess the rainfall and resulting runoff;
3. Hydraulic modelling to assess the likely channel flow generated by a particular storm;
4. Calibration of the models to ensure they accurately depict known flood events
5. Validation of the models to confirm that they are able to reproduce other known flood events;
6. Design flood modelling to model and map the likely flood heights in various events;
7. Damage assessment to estimate the likely damage caused by different sized flood events; and
8. Community consultation both during and upon completion of the studies.

***Tamworth City***

The Tamworth Behind the Levees Study had the additional consideration of the likelihood of coincidental events. This is due to the fact that there are two possible modes of flooding behind a levee. The first mode would occur if the pipes through the levee were too small to carry the storm flow, causing water to back up behind the levee wall.

The second mode of flooding could occur if there was a flood occurring on the river side of the levee, which would see the pipe outlets closed to prevent flood water flowing back through the levee. If a storm event the occurred on the “dry side” of the levee, the levee would effectively be a sealed bucket that could fill up and cause properties to flood. This would only occur if the two events were to occur at the same time. The likelihood of this coincident event occurring was reviewed as part of the Tamworth Behind the Levee Study.

The study of flood behaviour behind the levees involved the development of a hydrologic model of the local catchments which drain behind the town levees, and a hydraulic model which extended a sufficient distance behind the town levees to adequately define local drainage patterns. The hydrologic model was a runoff-routing model based on the DRAINS software, with the inbuilt RAFTS and DRAINS modelling approaches used for generating discharge hydrographs from the rural and urbanized parts of the study area, respectively. A depth averaged, one and two-dimensional free surface flow hydraulic modelling approach was chosen as it allowed for the interaction of flow in the stormwater drainage lines which discharge directly to the Peel River floodplain and the various overland flow paths which lie directly behind the town levees. The time varying effects of elevated water levels in the Peel River were also taken in account. The TUFLOW hydraulic modelling program was adopted for this purpose.

Local catchment flood behaviour behind the town levees was defined in terms of flows, levels and velocities for floods ranging between 2 and 200 years ARI, as well as for the Probable Maximum Flood (PMF). In order to understand the full range of potential flooding behind the town levels the hydraulic model was run for the cases where the manually operated flood gates are in either their fully open or fully closed position.

***Barraba and Manilla***

The hydrology for the Manilla and Barraba flood studies was developed using the RORB hydrological model. The model was setup as an end of catchment model, producing flood hydrographs for the Namoi and Manilla Rivers upstream of the Manilla town.

*RORB is a general runoff and stream flow routing program used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to produce rainfall-excess and routes this through catchment storage to produce runoff hydrographs at any location. It can also be used to design retarding basins and to route floods through channel networks.*
*(RORB 6 User Manual).*

The flood conveyance through the townships of Manilla and Barraba was completed using the TUFLOW hydraulic model.

## Results of the Studies

### *Manilla*

The results of the Manilla study were heavily influenced by the impact of Split Rock Dam on the catchment. With several large floods on record from the period before the dam's construction, the mitigating impact of the dam was considered in detail.

The study found that Split Rock Dam had a significant impact on the downstream flood heights, even if the storage was full at the start of the storm event. This is due to the impact of the spillway, and the storage capacity above the outlet level, restricting flow from the dam throughout the flood.

The figures below demonstrate the flow attenuation in the Manilla River upstream of Manilla due to Split Rock Dam. The peak flow in the Manilla River upstream of the Manilla township is reduced by 37%. The attenuation of this peak results in a reduction in the peak flow downstream of the Namoi-Manilla confluence of 60%.

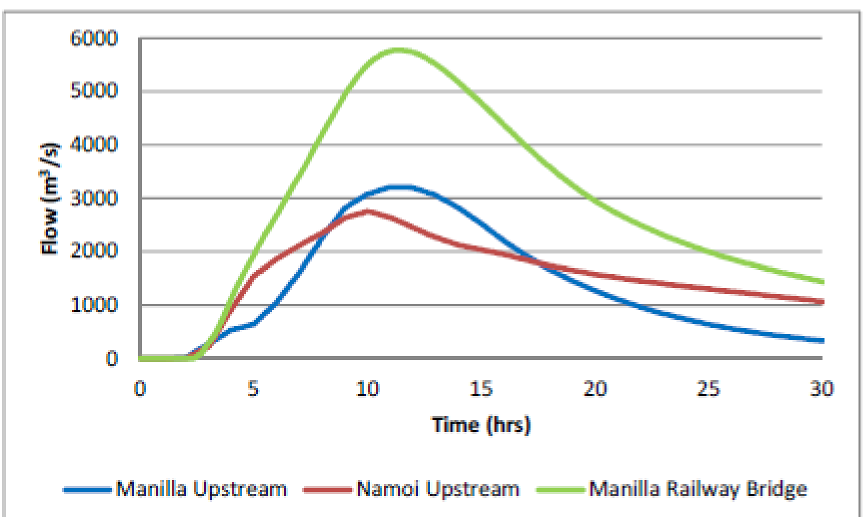


**Figure 3 - 1% AEP Hydrographs Before Construction of Split Rock Dam**

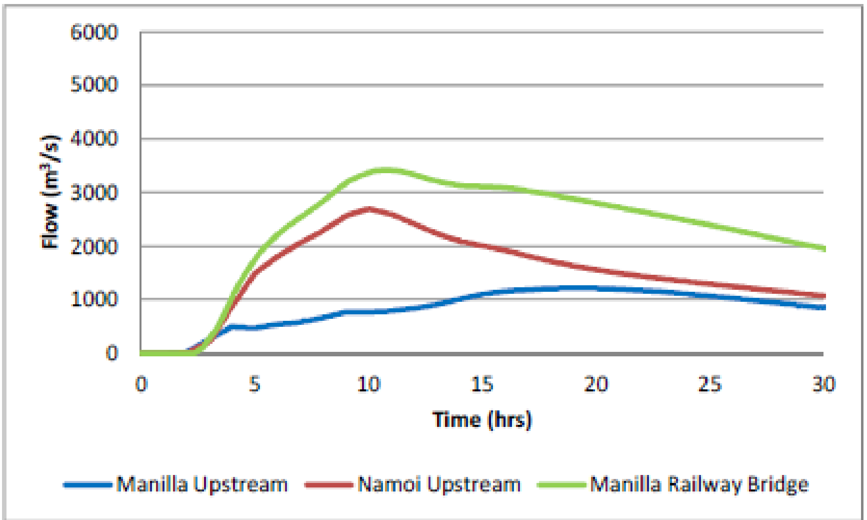


**Figure 4 - 1% AEP Hydrographs After Construction of Split Rock Dam**

In events up to the 5% AEP event floor levels of properties are not expected to be inundated across the floodplain. In a 1 % AEP event only 9 properties are expected to be inundated. Beyond the 1% event, the numbers of floor levels inundated increases rapidly with 130 floor levels inundated in a 0.5% event and 545 floor levels expected to be inundated in a PMF.

The relatively low levels of inundation noted for events below the 1% AEP event are attributed to the influences of Split Rock dam, and its impact on attenuation of flood peaks in the Manilla River. The following flood maps show the depth of flooding for the 1% AEP pre-dam and post-dam events.

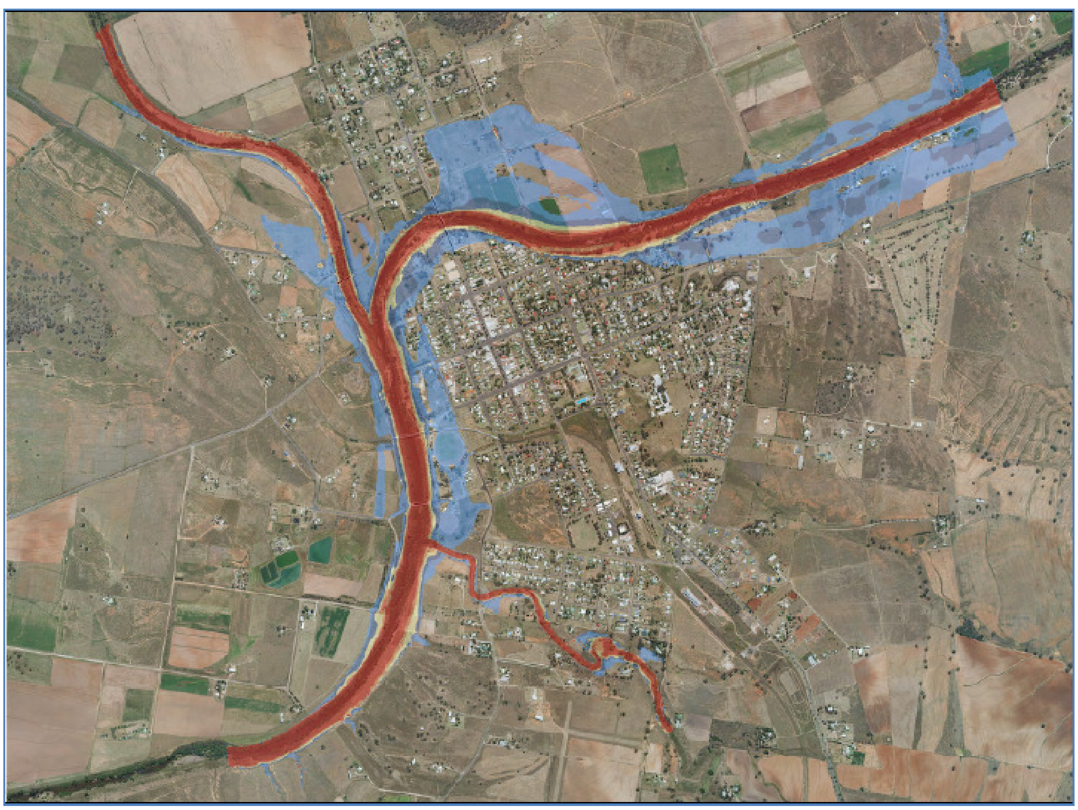

**Figure 5 - 1% AEP Flood Event - Manilla**

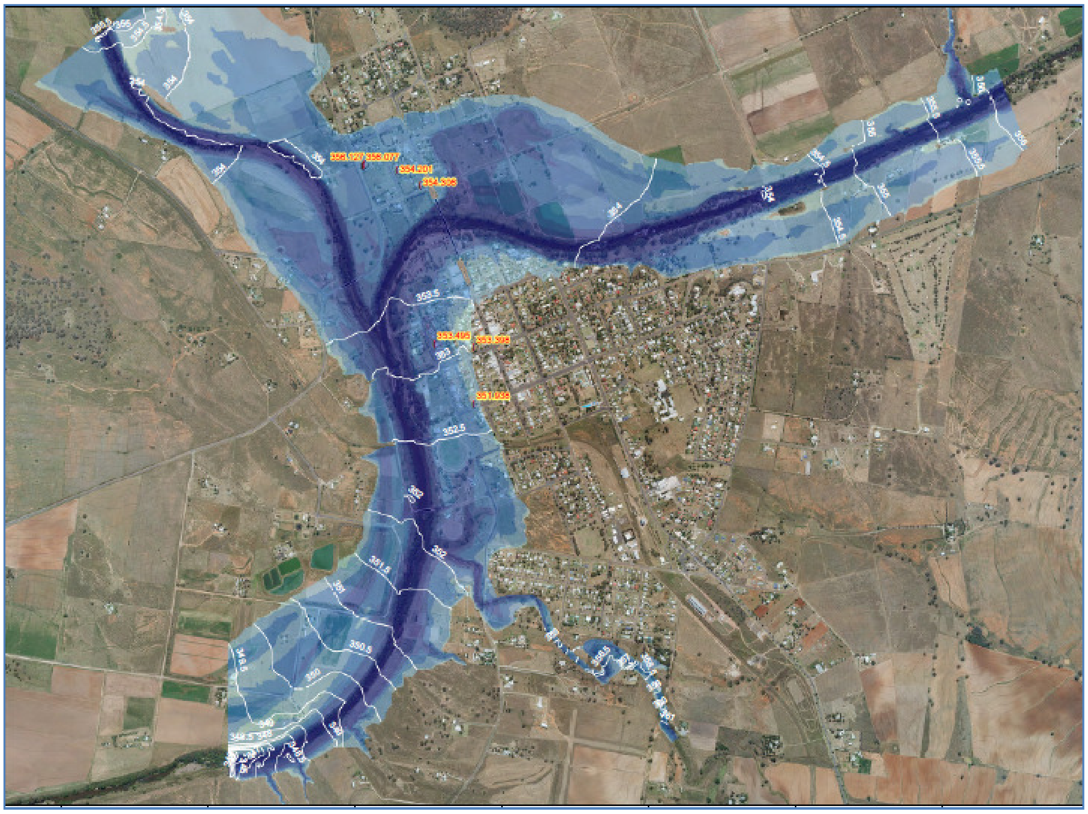

**Figure 6 - 1% AEP Pre-Dam Event - Manilla**

### *Barraba*

The results of the Barraba study were influenced by the significant tributaries discharging into the Manilla River immediately upstream of Barraba. Whilst only a small number of existing properties are affected by the 1% AEP event, the floodplain is designated as “high hazard”, carrying either deep or high velocity flows. This is particularly the case on the northern and eastern floodplains.

In events up to the 5% AEP event floor levels of properties are not expected to be inundated across the floodplain. In a 1% AEP event the number of properties expected to experience floor level inundation is 30. Beyond the 1% event, the numbers of floor levels inundated increases rapidly with 110 floor levels inundated in a 0.5% event and 475 floor levels expected to be inundated in a PMF.

In larger events inundation across the study area is extensive and in a PMF wide spread flooding would be expected. In a PMF it would appear that a floodplain breakout may occur. Flood depths would be in excess of 10m, immediately adjacent to the creeks and for large areas of the floodplain. This may be due to a topographical constriction in the floodplain immediately downstream of Barraba where the floodplain either side of the Manilla River narrows to 185m wide. This causes a damming effect in the township and very high velocity flows of greater than 2m/s around the constriction.

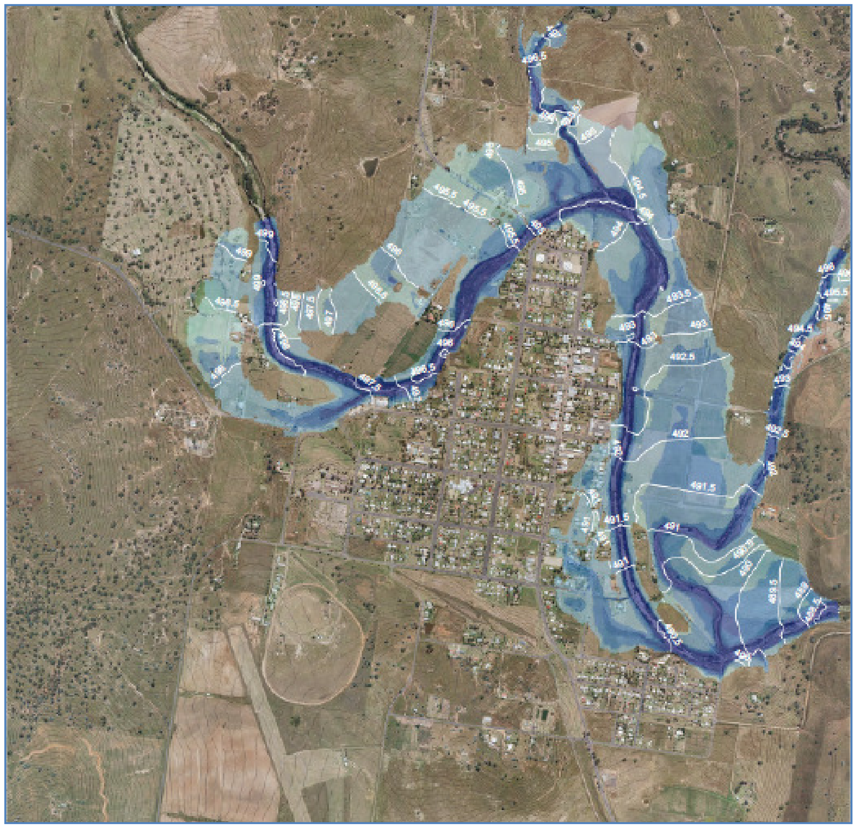

Figure 7 - 1% AEP Flood Event - Barraba

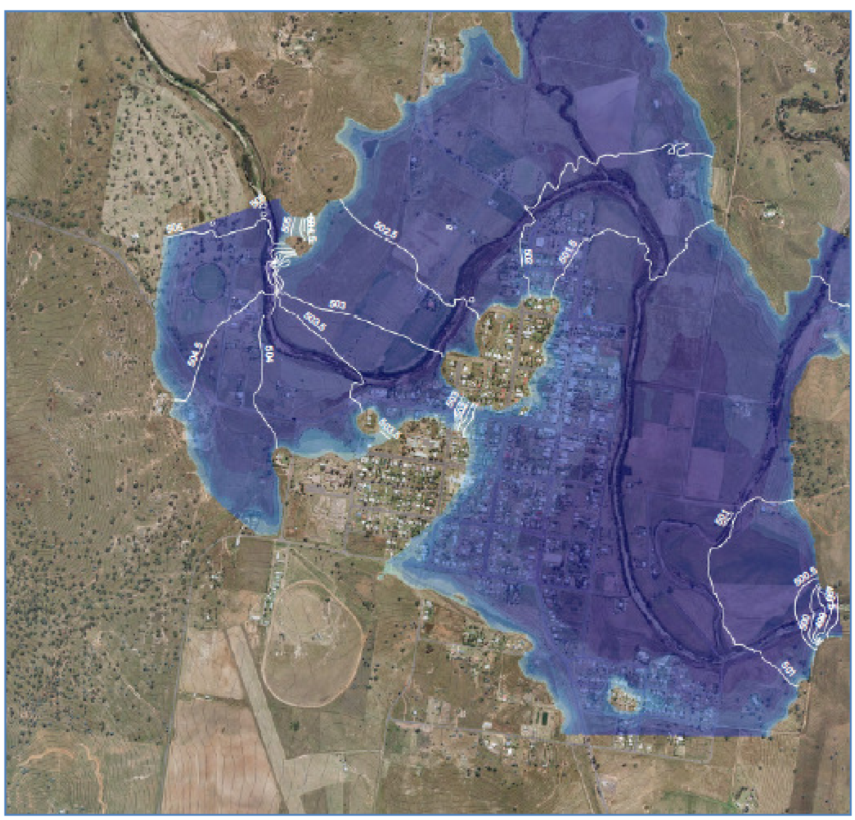

Figure 8 - PMF Flood Event - Barraba

***Tamworth City***

Each of the relevant catchments was modelled over numerous storm events to assess the worst case. For small sub-catchments, with the stormwater gates fully open, a relatively short duration intense storm would overload the pipes ability to carry the peak flow. For the case of the stormwater gates fully closed, a relatively long and steady storm event was required to produce the largest volume of water banking up behind the levee. Analysis of flooding in the Peel River noted that the river can be above the critical 4m height requiring closure of the flood gates for up to 40 hours, and so a 36 hour storm duration was used for the gates closure case.

The Taminda and Western levees were found to generally have adequate storage behind them to store the 1% AEP storm without significantly impacting on private properties. There was the possibility, however, that localized property damage may occur from overland flows on the approach to each levee.

On the other hand, there were a number of deficiencies identified in the stormwater management for the CBD, the most intensely developed area of the region. During the 36 hour storm duration with the flood gates closed, it was found that many commercial properties within the CBD, that were previously thought to be protected from flooding by the levees, could by inundated with as much as 1m of floodwater.

There are three principle reasons for the large amount of ponding behind the levees;

1. The large catchment upstream of the pressure lines generates enough runoff in a 20 year ARI event to surcharge these at their upstream inlets, which not only eliminates the potential runoff storage within the lines themselves, but also creates additional runoff downstream which is required to be stored on the surface behind the levees.
2. The runoff generated by the large catchment downstream of the pressure lines is all required to be temporarily stored when the gates are fully closed. Whilst there is some capacity within the drainage lines themselves, the majority of the flows are required to be stored on the surface.
3. The relatively high density of commercial development in the CBD limits the amount of safe temporary storage area available during the period that the gates are fully closed.

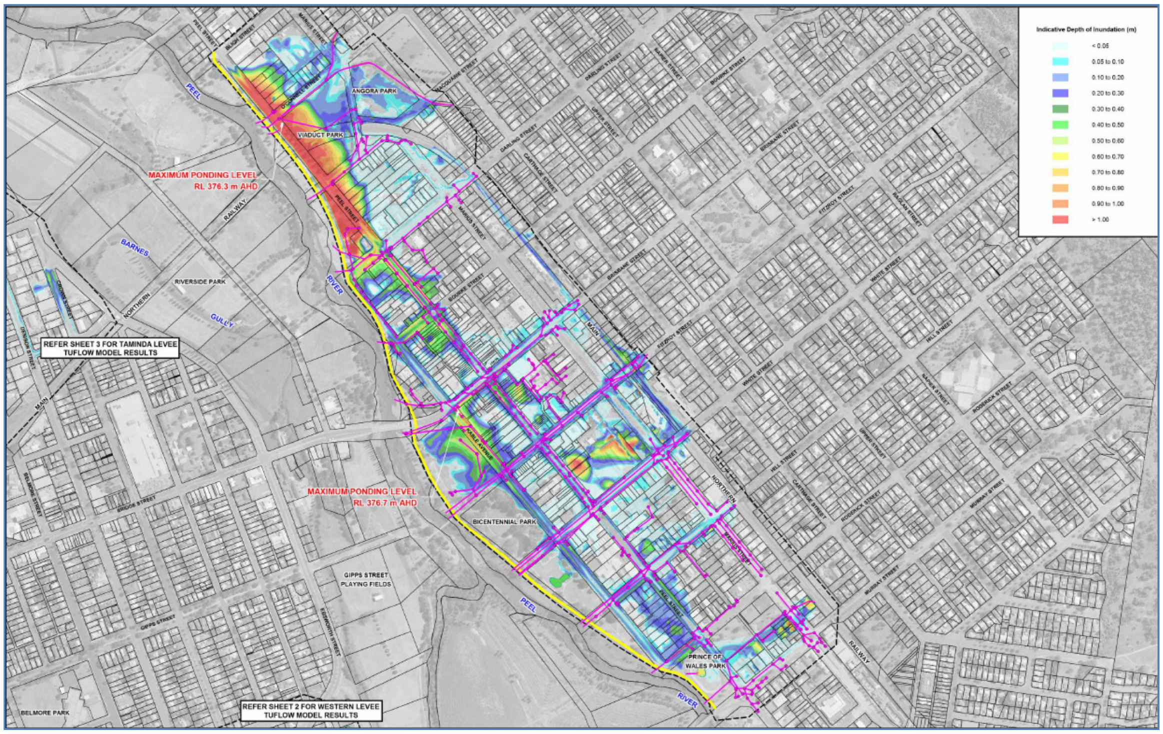


**Figure 9 - 1% AEP with Gates Open - Tamworth City**

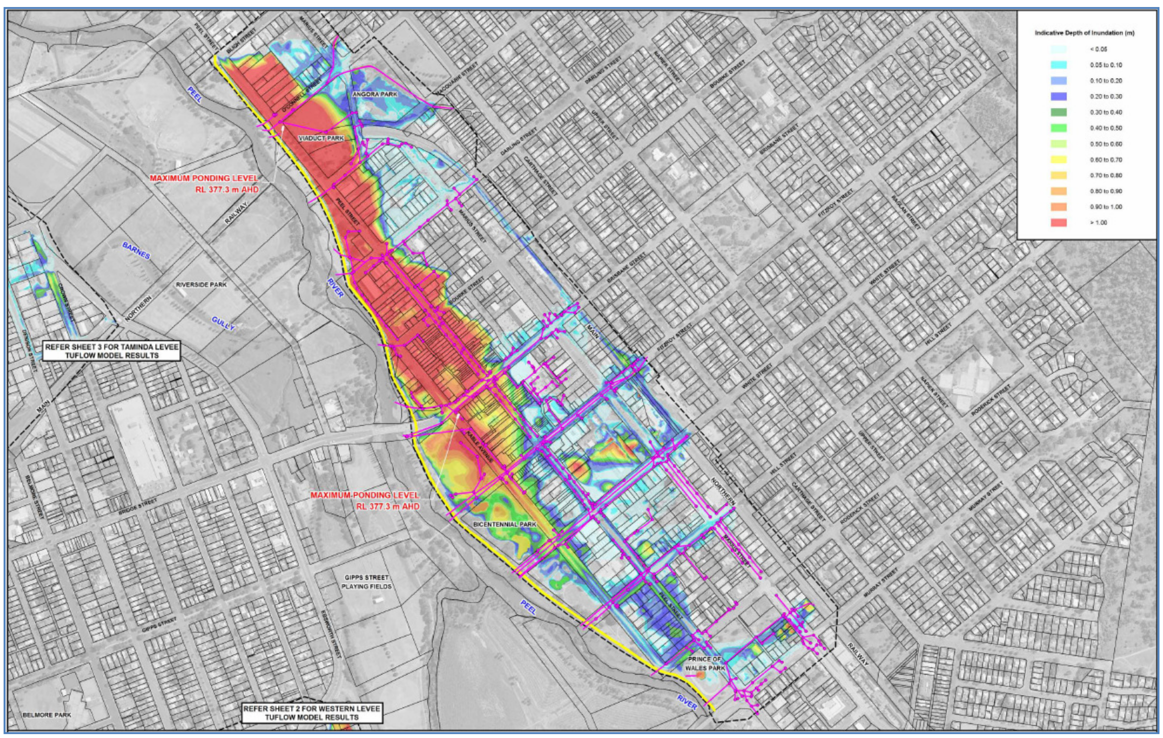


**Figure 10 - 1% AEP with Gates Closed - Tamworth City**

## Flood Damage Estimates

An estimate of the costs of flood damages was prepared to enable benefit-cost analysis of any proposed mitigation measures to be completed. Flood damages are determined by assessing the numbers of flood affected properties and then estimating a direct damage cost for a range of flooding events (in terms of flood depth).

For most residential dwellings, flood damage increases with the depth of flooding. The Floodplain Management (FDM) and Coastal Support Section of the Department of Natural Resources (DNR, now Office of Environment and Heritage) has developed relationship between flood depth and damage based on various parameters for house and contents value, and flooding characteristics.

The resulting depth-damage curves are used as a basis for estimating other direct and indirect costs from flooding.

The Average Annual Damage (AAD) is calculated based on an estimate of the property damage caused to each property that is flooded above its floor level. It takes into account the chance of this event happening, and the depth of inundation. It allows for the estimated value of house contents, as well as the additional cost of alternative accommodation during the cleanup. This estimate is totalled for each of the properties affected by each event to provide a total estimate cost of damage each year.

The Net Present Value (NPV) is generally the total AAD over a period of time, typically 20 years, using a discounted cash flow to allow for the time value of money. The NPV of Damage would give an indication of the possible savings that would result from any investment in flood mitigation infrastructure.

The following methodology was used to estimate the AAD and the NPV of the AAD over a 20-year period:

- The floor levels of properties affected by flooding for a range of flood events were estimated from the flood simulations and floor level survey;
- The cost of damage for the flooding was estimated for each flood event and depth range, using typical house and contents damage cost and the percentage of damage for the particular depth;
- A direct damage bill for each storm event was calculated;
- Flood recurrence interval was plotted against total damage and integrated to find the area under the graph, which provides the AAD; and
- A present value for the AAD was estimated based on a 7% discount rate over a 20-year period.

For Manilla the Annual Average Damage is estimated at $300k. Over a 20-year period, this has a Net Present Value of $3.28 million. For the assessment of flood damages, it was assumed Split Rock Dam was at Full Supply Capacity.

In Barraba the Annual Average Damage is estimated at $308k. Over a 20-year period, this has a Net Present Value of $3.26 million.

For Tamworth City the estimation of urban flood damages was carried out for property located behind the CBD and Western Levees. Urban flood damages for property located behind the Taminda Levee were not estimated because existing development in this area is not impacted by local catchment runoff which ponds directly behind the levee (i.e. the subject of this present investigation); rather it is impacted by overland flow which approaches the levee from the surrounding local catchment. Damages from floods ranging between the 2 year ARI and PMF events were assessed for both the gates open and gates closed cases.

The Present Worth Value of damages behind the CBD Levee for all flood events up to the 100 year ARI increases from $3.58 Million assuming the flood gates are always open, to $42.45 Million assuming the flood gates are always closed. Therefore schemes costing up to $42.45 Million could be economically justified if they eliminated damages for all flood events up to the 100 year ARI event (i.e. if it is assumed that the flood gates are always closed during flood producing rain).

## Planning and Future Development

The Flood Planning Level is a term defined in Councils LEP. This is set at a level that is 0.5m higher than the 1% AEP flood. Properties that have land below the Flood Planning Level would typically require special consideration before any development would be approved.

The Flood Planning Levels proposed for Manilla and Barraba in the studies were adopted by Council in 2012. The levels in Barraba closely resembled those adopted in most recent LEP, albeit with the addition of the 0.5m freeboard. In Manilla, significant amounts of land have had the flood restriction removed, principally due to the effect of Split Rock Dam. This potentially enables further development of previously undevelopable land.

In Tamworth City, Council is still considering the impacts of the report before adopting revised Flood Planning Levels for the CBD. The study concluded that;

> *"...there is a reasonable chance in any one year that the penstock type flood gates will be closed at the time flood producing rainfall is experienced over the catchments which drain behind the town levees. That said, the severity of flooding experienced behind the town levees will be a function of the duration over which water levels remain above the critical trigger level of 4 m on the town gauge combined with the duration intense rainfall is experienced over the associated local catchment."*

Council will need to further consider the implications and the probability of the coincidence events that cause the most severe flooding behind the levees as well as the gates open / gates closed cases before determining a Flood Planning Level.

## Conclusions

The three flood studies commissioned by Tamworth Regional Council have produced unexpected and unique results. In Manilla, the influence of Split Rock Dam as a flood mitigation device has previously been discounted, but the studies show that peak flow rates are reduced by up to 60%, even if the dam is full at the time of the event. In Barraba, the narrowing of the floodplain downstream of the township results in a dramatic increase in the flood footprint for any event greater than the 100 year ARI. Finally, in Tamworth the effect of flooding behind the flood mitigation levees during coincidence events has identified a significant risk to property in a major flood event, so much so that Council has been forced to re-consider its position with regard to Flood Planning Levels and strategic development planning of the Tamworth CBD.

The studies in Barraba and Tamworth may have significant impacts on Emergency Management, as the previous assumptions about flood behaviour, particularly in large events, may be incorrect.

Further work to development Flood Risk Management Plans will study these issues further, with the ultimate aim to have a robust and accurate policy regarding development and floodplain management in the Tamworth Region.

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