Dungog Floodplain Risk Management Study and Plan

Client: Dungog Shire Council

Reference: PA1316 Dungog FRMS&P

Revision: 01/Final

Date: 11 October 2017

Royal HaskoningDHV

HASKONING AUSTRALIA PTY LTD.

Level 3
2 Market Street
NSW 2300 Newcastle
Australia
Maritime & Aviation
Trade register number: ACN153656252

+61 2 4926 9500 **T**
Infosydney.mandw@rhdhv.com **E**
royalhaskoningdhv.com **W**

Document title:	Dungog Floodplain Risk Management Study and Plan
Document short title:	
Reference:	PA1316 Dungog FRMS&P
Revision:	01/Final
Date:	11 October 2017
Project name:	Dungog FRMS&P
Project number:	PA1316
Author(s):	Rohan Hudson and Ben Patterson

Drafted by:	Rohan Hudson
Checked by:	Ben Patterson
Date / initials:	
Approved by:	Ben Patterson
Date / initials:	

Classification
Final

EXECUTIVE SUMMARY

Introduction

Dungog is located in the Upper Hunter Region of New South Wales, approximately 60 km north of Newcastle and 70 km inland from the coastline at Seal Rocks. The township of Dungog is situated at the confluence of the Williams River and Myall Creek. Three smaller catchments including the township, Common Creek and Melbee Estate catchments also provide a source of flood risk to Dungog.

Dungog Shire Council (Council) is responsible for flood risk management and local land use planning within their Local Government Area (LGA). Council has commissioned Royal HaskoningDHV (RHDHV) to produce the Dungog Floodplain Risk Management Study and Plan (FRMS&P) on behalf of Council and the NSW Office of Environment and Heritage (OEH).

The present FRMS&P included developing a Flood Study that defined flood risk in Dungog from all sources (i.e. Williams River, Myall Creek and local township catchments. The Flood Study was completed in February 2017.

History of Flooding in Dungog

The extreme flooding that devastated Dungog on the 21st of April 2015 was caused by an East Coast Low that caused significant flooding and damage to a number of areas in the Hunter Region and Sydney and is often referred to as the April 2015 “super storm”. The storm produced catastrophic flooding in Dungog resulting in three fatalities, washing four houses away and flooded some 80 dwellings, many to ceiling level. The flood event is likely to have an approximate annual exceedance probability (AEP) of 0.1% or an approximate frequency of a 1 in 1000 year average recurrence interval (ARI).

Other significant floods include: The “Pasha Bulker storm of 8th June 2007 which flooded a number of low lying properties (on Hooke Street and Dowling Street) was approximately a 1 in 20 year ARI magnitude event. Three older significant events (with a 5yr - 10yr ARI magnitude) occurred in February 1990, October 1985 and April 1946. The recent January 2016 event was smaller than a 5yr ARI event.

Community Consultation

Community consultation was undertaken to inform the community about the development of the Floodplain Risk Management Study, its likely outcomes as well as improving the community’s awareness and readiness for flooding. The consultation process provided an opportunity to collect information on the community’s flood experience, their concerns on flooding issues and to collect feedback and ideas on potential floodplain management measures and other related issues. The key elements of the consultation program involved:

- Consultation with the Floodplain Management Committee through meetings, presentations and workshops;
- Development of a project study website (www.dungogfloodstudy.org) and Facebook page;
- Distribution of questionnaires and information brochures;
- Community information sessions; and
- Public exhibition of the Draft Floodplain Risk Management Study and Plan.

Flooding Behaviour

Flood behaviour in Dungog was quantified during the Dungog Flood Study (Royal HaskoningDHV, 2017) which investigated flooding from all flood mechanisms including: the Williams River, Myall Creek and the Local Township catchments. Flood extents from each individual flood mechanism were combined to produce a single envelope of design flood extents which represented the magnitude of flooding for a given frequency (i.e. annual exceedance probability (AEP) or average recurrence interval (ARI)) as discussed in **Section 4.1**.

The Dungog tailwater which is part of the Myall Creek flood mechanism is the main source of flood risk in Dungog accounting for 80-90% of above floor property inundation and flood damages. The Dungog tailwater is formed due to the floodplain constriction at Bennett Bridge, which is further influenced by the floodplain constriction at the Myall Creek Railway Bridge.

Only a few properties in Dungog are located on the Williams River floodplain. However, coincident flooding of the Williams River and Myall Creek can result in exacerbated flood levels in the Myall Creek catchment when small floods on Myall Creek occur at the same time as large floods on the Williams River.

The township of Dungog includes a small 1.6 km^2 catchment which drains into Myall Creek north of Hooke Street. Due to the small size of the catchment, this flood mechanism typically only produces “nuisance” type flash flooding which may be exacerbated by blocked or undersized drainage infrastructure. Low-lying areas to the south of Mackay Street may be influenced by backwater flowing from Myall Creek or the Williams River, which is the main source of flood risk and flood damage in Dungog.

Property Inundation Assessment

A summary of the location and frequency of above floor property inundation in Dungog is presented in **Section 4.2.2**. The assessment shows that:

- In an extreme flood (i.e. the PMF), 122 properties in Dungog are inundated above floor level. Of these properties, 89 are in the Myall Creek tailwater area, 12 are on the Williams River floodplain, 9 are adjacent to Common Creek and 12 are affected by overland flooding from the Dungog Township local catchment.
- In the rare, 0.2% AEP (500yr ARI) event, 46 properties in Dungog are inundated above floor level. Of these properties, 41 are in the Myall Creek tailwater area, 4 are on the Williams River floodplain and one property is flooded above floor level in the Dungog township local catchment.
- In the 1% AEP (100yr ARI) event, 22 properties in Dungog are inundated above floor level. Of these properties, 20 (91% of properties) are in the Myall Creek tailwater area, one is on the Williams River floodplain and one property is flooded above floor level in the Dungog township local catchment.
- In the 5% AEP (20yr ARI) event, 9 properties in Dungog are inundated above floor level. Of these properties, 8 (91% of properties) are in the Myall Creek tailwater area and one is on the Williams River floodplain and no properties are flooded above floor level in the Dungog township local catchment.

Flood Damages Assessment

The Average Annual Damage (AAD) is the main comparative factor that is derived from the flood damages assessment with which to evaluate the effectiveness of proposed mitigation options. The AAD represents the estimated tangible damages sustained every year on average over a given 'long' period of time and is determined using the full range of flood events previously considered in the FRMS. A summary of flood damages (AAD Contribution) and property inundation is presented in **Section 4.2.3** and shows:

- That the two "minor" 20% and 5% AEP (i.e. 5yr and 20yr ARI) events, which only flood up to 16 properties (and only 9 above floor level), floods contribute over 50% of the damages in the AAD value.
- While the PMF floods 122 properties above floor level, many to a significant depth, due to the low probability of such an event it only contributes 10% of damages to the AAD value.
- Using an AAD value and a 7% discount rate over 50 years the net present value of the existing condition flood damages in Dungog is **$3.4 Million**.
- With the exception of the PMF event, typically 90% of flood damages occur in the Dungog tailwater area which is due to the Myall Creek backwater flood mechanism.
- In the April 2015 superstorm, direct, tangible flood damages of $9.0 Million were calculated for properties in Dungog. This is approximately half the near $18 Million flood damages predicted to occur in the PMF.

Planning and Development Controls

Council's existing and proposed DCP provides general provisions relating to all the floodplains and specific provisions relating to individual floodplains which are subject to a Floodplain Management Plan. Some minor revisions to the proposed DCP are recommended based on the adopted FRMS&P for Dungog and the associated flood risk mapping derived in this study. In particular the DCP should be updated to be consistent with recent NSW DoP guidance as discussed in **Section 5.2**. .

Council will also need to update the LEP to ensure that future development where Council purchased the five properties (destroyed during the April 2015 superstorm) adjacent to Bennett Bridge, considers the high flood risk at these locations.

While the Department of Planning (DoP) Circular PS 07—03 means that the setting of a higher than standard (100yr +0.5m freeboard) FPL may be difficult, it is recommended that Council seek the adoption of a FPL based on the 500yr ARI level of 51.1 m AHD. A free-board of up to 0.5m (i.e. FPL of 51.6 m AHD) should be considered to further increase the survivability for mobility impaired (i.e. wheelchair bound or elderly) residents. It is recommended that Council adopts this higher FPL until the effectiveness of the proposed flood warning system (as presented in **Section 7**)) is fully assessed. If a future Council review finds that the flood warning system is able to effectively reduce the risk to life in severe events, the reduction of the FPL towards the more typical 1% AEP with 0.5m freeboard could be considered.

Floodplain Management Options Considered

Measures which can be employed to mitigate flooding and reduce flood damages can be separated into three broad categories including: **flood**, **property** and **response** modification measures. The following mitigation options (O1 – O11) were considered applicable/suitable for reducing flood risk in Dungog, and were therefore the subject of a detailed assessment (including flood damages and cost/benefit analysis) as part of this FRMS in **Section 6.4**.

<u>Flood modification measures</u>

O1) Major Myall Creek (Road and Rail) Bridge Modifications – Section 6.4.1

O2) Minor Myall Creek (Road and Rail) Bridge Modifications – Section 6.4.2

O3) Myall Creek Levee with Pumps – Section 6.4.3

O4) Myall Creek Levee with Diversion Culverts – Section 6.4.4

O5) Vegetation Removal with Scour Protection – Section 6.4.5

O6) Dungog Showground Detention Basin Augmentation – Section 6.4.6

O7) Dungog North-West Detention Basin – Section 6.4.7

Property modification measures

O8) Voluntary House Raising (VHR) – Section 6.4.8

O9) Voluntary House Purchase (VP) – Section 6.4.9

O10) Flood Resistant Surfacing for Bennett Park Tennis Courts – Section 6.4.10

Response modification measures

O11) Flood Warning System - The development of a flood warning system for Dungog is presented in detail in Section 7.

Recommended Floodplain Risk Management Options

An analysis of mitigation options O1-O5 shows that they result in a significant reduction in flood damages (between $1.3 and $2.4 Million). However, due to the high cost of implementing such measures, all benefit/cost (B/C) ratios are significantly below unity (one) and hence would not be considered for implementation on an a solely economic basis and have been given a low or very low priority in the floodplain risk management plan (FRMP).

For the O2 (Minor Bridge Upgrade) mitigation option, using the AAD approach, the calculated B/C ratio for this option is only 0.35 (due to the high cost of the scheme ($4.4 Million)). However, this mitigation measure is able to provide a 1.16 m reduction in peak flood levels for an extreme event such as the April 2015 superstorm. If future studies reveal that climate change has significantly altered the severity and intensity of storms in the Dungog region, such a scheme may be considered to reduce the impact of severe events.

Mitigation option O8 (VHR for 7 properties, demolition of 6 properties) produces the highest B/C ratio (2.2) but the lowest overall reduction in damages of just over $1.0 Million (a 30% reduction in flood damages). Given that the B/C ratio is considerably higher than one, this option would be recommended for implementation or further investigation and has been given a medium-high priority in the FRMP.

Mitigation option O9 (VP of 3 properties, VHR for 4 properties, demolition of 6 properties) produces a B/C ratio of 1.0 and hence this option could be recommended for implementation or further investigation on economic grounds. It should be noted that consideration for VP is not solely based on economic grounds and that VP schemes may be approved based on consideration of risk to life. Because VHR may increase the likelihood of residents sheltering in place during large events, there is the potential for increased risk to life during a severe event if residents can no longer be safely evacuated. **In order to reduce risk to life, option O9 should be considered in preference to option O8**. This option is considered a high priority in the FRMP.

Because none of the “flood modification measures” (O1-O7) are recommended for implementation, Dungog will still experience flood related risk to life and property issues during severe flood events. **In order to mitigate against this risk to life, a flood warning system (as presented in Section 7) is recommended**. This option is consider a very high priority in the FRMP.

Mitigation option O10 (Flood Resistant Surfacing for Bennett Park Tennis Courts) should only be considered if/when the existing court surface is next damaged.

Draft Dungog Floodplain Risk Management Plan

The following table forms an action list of the draft Dungog Floodplain Risk Management Plan (the Plan). The objective of the Plan is to recommend a range of property, response and flood modification measures to mitigate the existing and future flood affectation in the study area.

The Plan (as detailed in **Section 8**) should be regarded as a dynamic instrument requiring review and modification over time. The catalyst for change could include new flood events and experiences, 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 warranted to ensure the ongoing relevance of the Plan.

Mitigation Measures Recommended for Implementation

Measure*	Description	Estimated Capital Costs and (Ongoing Costs)	Responsibility and Funding	Priority / Time frame
O11	Flood Warning System	\$50,000 to \$100,000 (\$5,000 / yr)	Council and OEH	**Very High** 1-2 years[1]
P1	Adopt non-standard FPL for Dungog tailwater	Council staff time of ~\$5,000	Council	**Very High** <1 years
EM1	Emergency Management Planning (develop a Local Flood Plan)	SES and Council staff time of ~\$10,000	SES	**High** <1 years
P2	Update LEP for purchased properties near Bennett Bridge	Council staff time of ~\$5,000	Council	**High** <1 years
O9	VP for 3 properties, VHR for 4 properties demolition of 6 Alison Court properties.	VP = \$900,000 VHR = \$200,000 Demolition = \$120,000	VP – Council and OEH VHR - Property owner and OEH Demolition – Council[2]	**High** 1-5 years[2]
O10	Bennett Park Tennis Court Surface Protection	Synpave - \$100,000 Bonded grass - \$180,000.	Tennis Club and/or Council and/or Insurance Agency	**Medium** After flood damage
EM2	Community Flood Education	Council / SES staff time ~\$10,000	Council / SES	**Medium** 2-5 years
O2	Minor Bridge Upgrade	\$4.4 Million	Council and/or NSW RMS and OEH	**Low** 5-50 years[3]

Notes: * details of the mitigation measures are provided in **Table 6-10**, and **Section 6.4**

VP = Voluntary Purchase, VHR = Voluntary House Raising

1) a NSW Floodplain Management Application for the Flood Warning System was submitted in April 2017.

2) The demolition of 6 Alison Court properties was approved by Council in April 2017. VP and VHR options are subject to the availability of Council and OEH funding and negotiations with property owners. Funding for the demolition of the 6 properties through Federal Government Disaster Recovery Funds has been approved in principle but has not been forthcoming at this time.

3) This option should be considered if bridge upgrades are being considered due to maintenance or capacity requirements or if increases in storm intensity produce more regular flooding in Dungog.

Floodplain Risk Management Plan Actions

In September 2016, Dungog Shire Council (with 2:1 funding from NSW OEH) purchased the five properties on Dowling Street adjacent to Bennett Bridge that were washed away during the April 2015 super storm. The removal of these high risk lands from private ownership ensures that the overall level of flood risk in Dungog has been reduced. Council will need to update the LEP to ensure that future development in this location considers the high flood risk at these locations.

The demolition of 6 Council owned Alison Court properties was supported by Dungog Council in April 2017, as it was deemed that the independent senior living units should not be allowed in the newly designated FPA (flood planning area). The demolition of these units is likely to occur in 2018. The demolition of these 6 properties will reduce the risk to life and also future flood damages and was included in both the VHR and VP options assessed in mitigation options O8 and O9.

In April 2017, Dungog Council submitted a floodplain management grant application to obtain 2/3 funding from the NSW Government Office of Environment and Heritage (OEH) for the design, installation and operation of a flood warning system for Dungog. If the grant application is successful, then the flood warning system should be operational by 2019.

The voluntary purchase (VP) of 3 properties is recommended in the plan and is subject to Council's resolution to acquire the property and the property owners concurrence to participate. This measure can be the subject of an OEH grant application (due for lodgement in March each year) at Councils discretion and if successful Council would be required to fund 1/3 of the costs of purchase while OEH would fund 2/3 costs. Similarly, the Voluntary House Raising (VHR) of 4 properties is recommended in the plan and is subject to Council's resolution and the property owners concurrence to participate. Whilst Council may lodge a grant application for VHR at its discretion, if successful property owners would likely be required to pay 1/3 of the costs while OEH would fund 2/3 of the costs.

Emergency management in Dungog is also being improved with SES currently in the process of updating their Flood Plan using information produced during this FRMS&P study. The updated Flood Plan was released in July 2017 and will assist the SES improve the efficiency and effectiveness of evacuating properties at risk in Dungog.

Table of Contents

Table of Tables

Table of Figures

Appendices

Abbreviations and Glossary of Terms

Abbreviations	
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
AR&R	Australian Rainfall and Runoff (1987)
DEM	Digital Elevation Model (a technique to define ground surface elevation data on a grid)
DoP	NSW Department of Planning
FLC	Form Loss Co-efficient (i.e. structure hydraulic loss parameter)
IEAust	Institution of Engineers Australia
IFD	Intensity Frequency Distribution
FRMS&P	Floodplain Risk Management Study and Plan
LiDAR/ALS	Light Detection and Ranging (method used to collect ground surface elevation data using an aircraft)
MHL	Manly Hydraulic Laboratory
OEH	NSW Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
RHDHV	Royal HaskoningDHV
1D	One-dimensional (i.e. a flood model based on cross-section, pipe or structure information only)
2D	Two-dimensional (i.e. a flood model which is based on a full description of the ground terrain and is not restricted to cross-section data only)

Glossary of Terms	
Annual exceedance probability (AEP)	The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m3/s has an AEP of 5%, it means that there is a 5% chance (i.e. a 1 in 20 chance) of a peak discharge of 500 m3/s (or larger) occurring in any one year. (see also average recurrence interval)
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
Average recurrence interval (ARI)	The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. For example, floods with a discharge as great as (or greater than) the 20yr ARI design flood will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. (see also annual exceedance probability)
Catchment	The catchment at a particular point is the area of land that drains to that point.

Design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100yr ARI or 1% AEP flood).
Development	Existing or proposed works that may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.
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. For example meters per second (m/S)
Flood	Relatively high river or creek flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood Behaviour	The pattern / characteristics / nature of a flood.
Flood fringe	Land that may be affected by flooding but is not designated as floodway or flood storage
Flood hazard	The potential risk to life and limb and potential damage to property resulting from flooding. The degree of flood hazard varies with circumstances across the full range of floods.
Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum). Also referred to as “stage”.
Flood liable land	See flood prone land
Flood plain	Land adjacent to a river or creek that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood (PMF) event.
Flood plain management	The co-ordinated management of activities that occur on the floodplain
Flood plain risk management plan	A document outlining a range of actions aimed at improving floodplain management. The plan is the principal means of managing the risks associated with the use of the floodplain. A floodplain risk management plan needs to be developed in accordance with the principles and guidelines contained in the NSW Floodplain Management Manual. The plan usually contains both written and diagrammatic information describing how particular areas of the floodplain are to be used and managed to achieve defined objectives
Flood planning levels (FPL)	Flood planning levels selected for planning purposes are derived from a combination of the adopted flood level plus freeboard, as determined in floodplain management studies and incorporated in floodplain risk management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of landuse and for different flood plans. The concept of FPLs supersedes the “standard flood event”. As FPLs do not necessarily extend to the limits of flood prone land, floodplain risk management plans may apply to flood prone land beyond that defined by the FPLs.
Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event. Under the merit policy, the flood prone definition should not be seen as necessarily precluding development. Floodplain Risk Management Plans should encompass all flood prone land (i.e. the entire floodplain).
Flood source	The source of the floodwaters. In this study, Burrill Lake is the primary source of floodwaters.
Flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
Floodway	A flow path (sometimes artificial) that carries significant volumes of floodwaters during a flood.
Freeboard	A factor of safety usually expressed as a height above the adopted flood level thus determining the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.
Geomorphology	The study of the origin, characteristics and development of land forms
Gauging (tidal and flood)	Measurement of flows and water levels during tides or flood events.

Historical flood	A flood that has actually occurred
Hydraulic	The term given to the study of water flow in rivers, estuaries and coastal systems
Hydrodynamic	Pertaining to the movement of water
Hydrograph	A graph showing how a river or creek's discharge changes with time.
Hydrographic survey	Survey of the bed levels of a waterway.
Hydrologic	Pertaining to rainfall-runoff processes in catchments
Hydrology	The term given to the study of the rainfall-runoff process in catchments.
Isohyet	Equal rainfall contour
Morphological	Pertaining to geomorphology
Peak flood level, flow or velocity	The maximum flood level, flow or velocity that occurs during a flood event.
Pluviometer	A rainfall gauge capable of continuously measuring rainfall intensity
Probable maximum flood (PMF)	An extreme flood deemed to be the maximum flood likely to occur.
Probability	A statistical measure of the likely frequency or occurrence of flooding.
Riparian	The interface between land and waterway. Literally means "along the river margins"
Runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
Stage	See flood level
Stage hydrograph	A graph of water level over time
Sub-critical	Refers to flow in a channel that is relatively slow and deep
Topography	The shape of the surface features of land
TUFLOW	A hydraulic model that is used to simulate flood events.
Velocity	The speed at which the floodwaters are moving. A flood velocity predicted by a 2D computer flood model is quoted as the depth averaged velocity, i.e. the average velocity throughout the depth of the water column. A flood velocity predicted by a 1D or quasi- 2D computer flood model is quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section.
Water level	See flood level

PART A – FLOODPLAIN RISK MANAGEMENT STUDY

1 Introduction

Dungog Shire Council (Council) is responsible for flood risk management and local land use planning within the Local Government Area (LGA). Council has commissioned Royal HaskoningDHV (RHDHV) to produce the Dungog Floodplain Risk Management Study and Plan (FRMS&P) on behalf of Council and The NSW Office of Environment and Heritage (OEH). The project has been conducted under the state assisted Floodplain Management Program and received state financial support.

1.1 Study Objectives

The primary purpose of the FRMS&P is to reduce risk to life and property by identifying, assessing and comparing various risk management options whilst considering opportunities for environmental enhancement as part of the mitigation works (NSW State Government, 2005). This study assessed a suite of flood risk management measures and their associated tangible and intangible costs and determined a range of options for inclusion in the Floodplain Risk Management Plan and potential future implementation.

1.1.1 Dungog Flood Study Objectives

The FRMS&P included provision of a Flood Study that defined flood risk in Dungog from all sources (i.e. Williams River, Myall Creek and local township catchments). The flood study required the development of flood models that could define the existing flood risk in Dungog and evaluate potential mitigation options assessed as part of the Floodplain Risk Management Study. A draft Dungog Flood Study was delivered to Council in February 2017.

1.1.2 Floodplain Risk Management Study Objectives

The aim of a Floodplain Risk Management Study is to assess a range of flood mitigation strategies to alleviate flood risk in an LGA, in accordance with the NSW Government's Flood Prone Land Policy. The objectives of this study include:

- Reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk (taking into account the potential impacts of climate change).
- Reduce private and public losses due to flooding.
- Protect and where possible enhance the floodplain environment.
- Be consistent with the objectives of relevant State guidelines and policies, in particular, the Government's Flood Prone Land and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning Assessment Act, 1979.

1.1.3 Floodplain Risk Management Draft Plan Objectives

The Floodplain Risk Management Draft Plan presents a range of flood mitigation recommendations to address the existing flood liability of an LGA. The objectives of the plan are outlined below:

- Ensure that the draft floodplain risk management plan is fully integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council's obligations under the Local Government Act, 1993 and has the support of the local community.

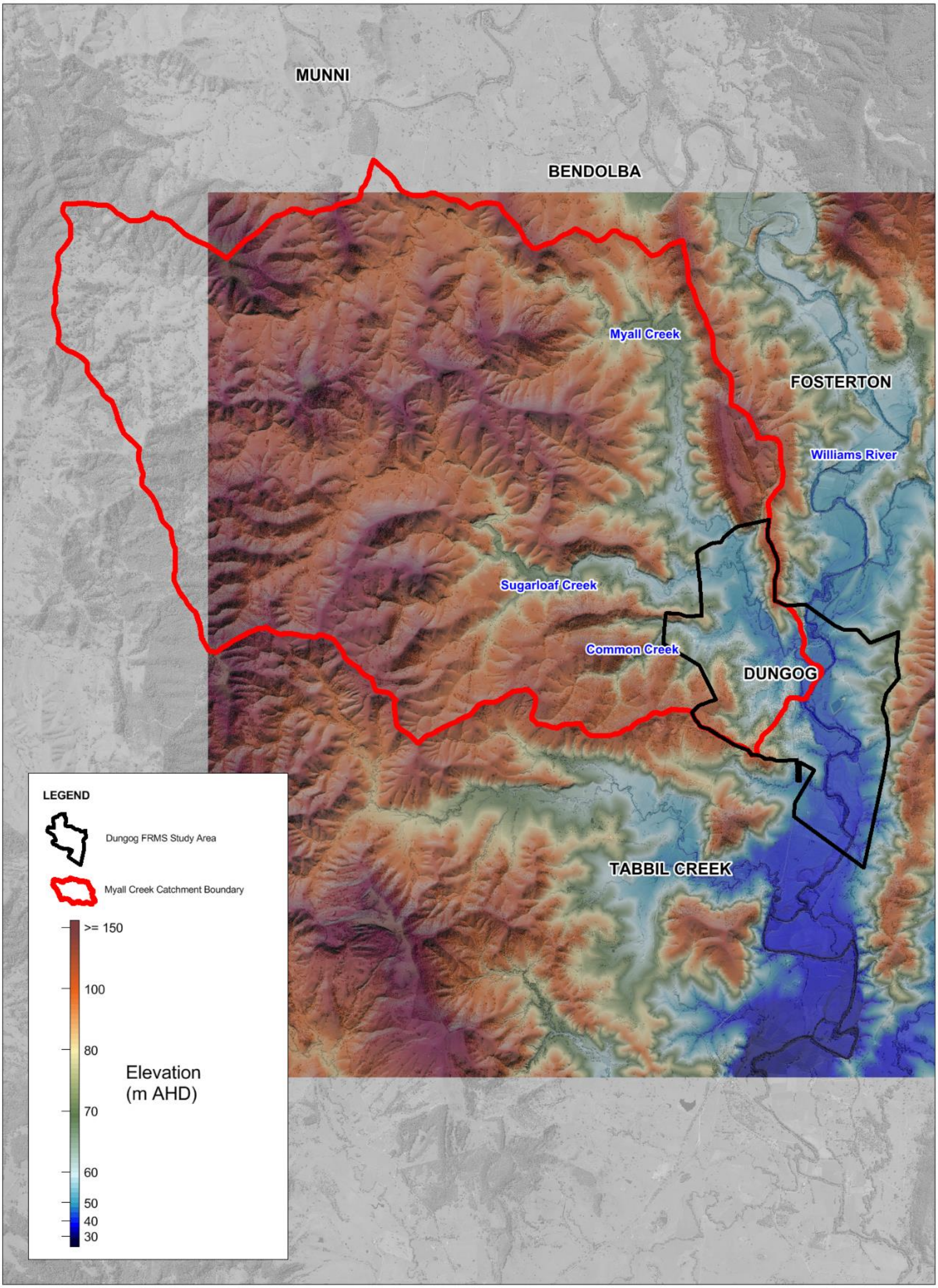
- Ensure actions arising out of the draft plan are sustainable in social, environmental, ecological and economic terms.

- Ensure that the draft floodplain risk management plan is fully integrated with the local Emergency Management Plan (Flood Plan) and other relevant catchment management plans.

- Establish a program for implementation and suggest a mechanism for the funding of the plan, which should include priorities, staging, funding, responsibilities, constraints and monitoring.

1.2 The Study Area

The town of Dungog is located in Upper Hunter Region of New South Wales approximately 60 km north of Newcastle and 70 km west of the coastline at Seal Rocks. The township of Dungog is situated at the confluence of the Williams River and Myall Creek as presented in **Figure 1-1**. Three smaller catchments also provide a source of flood risk to Dungog as detailed in **Section 2.1.** The Dungog township has a population of approximately 2200. The study area is limited to the Dungog township and includes approximately 4 km of the Williams River floodplain, approximately 3 km of the Myall Creek floodplain (including Common Creek) and the local township catchment.



Royal HaskoningDHV
Enhancing Society Together

FIGURE 1-1

STUDY AREA, LIDAR ELEVATION DATA AND MYALL CREEK CATCHMENT BOUNDARY

NORTH

0 0.75 1.5km
Approx. Scale

SCALE 1:80,000 PAGE SIZE A4

FILEPATH I:\Projects\PA1316_Dungog FPRMS&P\GIS\Workspaces\ReportFigs\FRMS\Figure_StudyArea&Elevs_v1a.WOR

1.3 The Need for Floodplain Management in Dungog

Flooding in Dungog can occur from a range of flood mechanisms including the:

- Williams River;
- Myall Creek;
- Common Creek;
- The local township catchment;
- Melbee Estate catchment.

Details of these flood mechanisms are provided in **Section 2.1**. The local catchment provides a source of regular "nuisance type" flooding due to the low channel capacity and number of properties the channels run through. In terms of over floor flooding, Myall Creek provides the greatest source of flood damage in Dungog (refer **Section 4.2**) due to the tailwater formed by the floodplain constrictions at Bennett Bridge and the Railway Bridge.

The potential magnitude of flood risk that could occur in Dungog was realised during the April 2015 "superstorm" which caused three fatalities, washed away 4 houses and flooded a further 80 dwellings, many to ceiling level. While the storm was estimated to have a frequency (i.e. magnitude) of a 0.1% AEP (or 1 in 1000 year average return period) event (Royal HaskoningDHV, 2017a), the development of mitigation measures aimed at preventing future tragedy and reducing the costs of flood damages to the Dungog community is important.

Effective floodplain risk management identifies which properties or areas in Dungog are at highest risk and will determine and prioritise appropriate mitigation measures to reduce the risk. Flooding considerations are also an important constraint to the location and nature of future development in the study area. By determining the detailed flooding characteristics of the study area including the full extent of floodplain inundation for a range of design event magnitudes, the flood study outcomes provided further detail for future development planning in the catchment.

Council has commissioned this study with the desire to approach local floodplain management in a considered and systematic manner. This study comprises the final stages of that systematic approach, as outlined in the Floodplain Development Manual (NSW Government, 2005). The approach will allow for more informed planning decisions within the floodplains of Dungog.

1.4 The Floodplain Management Process

The NSW State Government's Flood Policy provides a framework to support the sustainable use of floodplains. The Policy is specifically structured to support development of mitigation measures to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Policy and practice are defined in the Government's Floodplain Development Manual (2005).

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils with their floodplain management responsibilities.

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

1. Establish Floodplain Risk Management Committee (or Working Group) - Conducts a vital oversight role for the floodplain risk management process, acting as a focus and forum for discussion of key issues in formulating the management plan.

2. Flood Study - Determines the nature and extent of the flood problem.

3. Floodplain Risk Management Study - Evaluates management options for the floodplain in respect of both existing and proposed development.

4. Floodplain Risk Management Plan - Involves formal adoption by Council of a plan of management for the floodplain.

5. Implementation of the Plan - Construction of flood mitigation works to protect existing development, and use of flood risk management measures (such as development controls) to ensure new development is compatible with the flood hazard.

The Dungog Flood Study (Royal HaskoningDHV, 2017a) defines the existing flood behaviour and establishes the basis for future floodplain management activities.

The Dungog Floodplain Risk Management Study and Plan (this document) constitutes the third and fourth stages of the management process. It has been prepared for Dungog Shire Council to provide the basis for future management of flood liable land within the catchment.

1.5 About This Report

This report documents the Study's objectives, results and recommendations.

Section 1 introduces the study.

Section 2 provides background information including a catchment description, history of flooding and previous investigations.

Section 3 outlines the community consultation program undertaken.

Section 4 describes the flooding behaviour in the study area including a property inundation and damages assessment.

Section 5 presents a review of existing planning provisions.

Section 6 provides an assessment of relevant floodplain management measures.

Section 7 considers the requirement of a flood warning system for Dungog.

Section 8 presents the recommended measures and an implementation plan.

1.6 Design Event Terminology (AEP & ARI Explanation)

Design flood events are hypothetical floods used for floodplain risk management. They are based on having a probability of occurrence specified either as:

- Annual Exceedance Probability (AEP) expressed as a percentage; or
- Average Recurrence Interval (ARI) expressed in years.

The relationship between AEP and ARI is presented in **Table 1-1** with further descriptions of typical design event terminology provided in **Figure 1-2**.

Table 1-1: Design Event Terminology (AEP & ARI Explanation)

Annual Exceedance Probability AEP (%)	Average Recurrence Interval (ARI, 1 in X years)	Comment
Probable Maximum Flood (PMF)		A hypothetical flood or combination of floods which represent an extreme scenario.
0.2%	**500 yr**	A hypothetical flood or combination of floods likely to occur on average once every 500 years or with a 0.2% probability of occurring in any given year
0.5%	**200 yr**	As for the 0.2% AEP flood but with a 0.5% probability or 200 year return period.
1%	**100 yr**	As for the 0.2% AEP flood but with a 1% probability or 100 year return period.
2%	**50 yr**	As for the 0.2% AEP flood but with a 2% probability or 50 year return period.
5%	**20 yr**	As for the 0.2% AEP flood but with a 5% probability or 20 year return period.
20%	**5 yr**	As for the 0.2% AEP flood but with a 20% probability or approximately a 5 year return period.

Although the probability of a flood of a given size occurring remains the same from year to year (unless the flood regime is altered or new data lead to a revision of statistical estimates), the chance of such a flood occurring at least once in any continuous period increases as the length of time increases. **Table 1-2** shows the probability of experiencing various-sized floods at least once or twice in a lifetime. Over an 80 year timeframe/lifetime there is a 7.7% change of experiencing a 1 in 1000 ARI (0.1% AEP) such as the April 2015 Dungog superstorm. This puts the likelihood of such a severe and very rare event into some perspective, though thankfully for the residents of Dungog, the probability of experiencing a second 1 in 1000 ARI (0.1% AEP) magnitude event in an 80 year period is only 0.3%.

Table 1-2: Probability of experiencing a given-sized flood one or more times in 80 years

Source: Managing the floodplain: a guide to best practice in flood risk management in Australia (AEMI (2013))

Annual exceedance probability (%)	Approximate Average recurrence interval (years)	Probability of experiencing a given-sized flood in an 80-year period	
		At least once (%)	At least twice (%)
20	5	100	100
10	10	99.9	99.8
5	20	98.4	91.4
2	50	80.1	47.7
1	100	55.3	19.1
0.5	200	33.0	6.11
0.2	500	14.8	1.14
0.1	1,000	7.69	0.30
0.01	10,000	0.80	0.003

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			↓	
			PMP/ PMPDF	

Figure 1-2: Australian Rainfall and Runoff (2016) Preferred Terminology

2 Background Information

2.1 Catchment Description and Flood Mechanisms

Dungog is located in the Upper Hunter Region of New South Wales approximately 60 km north of Newcastle and 70 km west of the coastline at Seal Rocks. The township of Dungog is situated at the confluence of the Williams River and Myall Creek as presented in **Figure 1-1**. Three smaller catchments also provide a source of flood risk to Dungog as detailed in **Table 2-1** and **Figure 2-1** and described below.

Table 2-1: Details of Dugong's Catchments

Source	Catchment Size
Williams River	670 km^2
Myall Creek	74.5 km^2
Township Catchment	1.6 km^2
Common Creek	5.0 km^2
Melbee Estate	0.25 km^2

2.1.1 Williams River Flood Mechanism

The Williams River drains some 670 km^2 of catchment upstream of Dungog and when in flood can inundate a number of low lying properties east of the railway line. The catchment is largely forested though includes some cleared rural lands. Chichester Dam is located upstream of Dungog, however, the dam is operated for water storage, not flood mitigation purposes. Large floods also result in backwater flooding of Myall Creek which can flood low lying properties in Dungog. Due to the size of the catchment, longer 12-48 hour rainfall events are required to cause significant flooding in Dungog from the Williams River catchment.

2.1.2 Myall Creek Flood Mechanism

Myall Creek drains 74.5 km^2 of catchment upstream of Dungog. Myall Creek flows to the north of Dungog before passing under Bennett Bridge and the Rail Bridge (Main Northern Railway) before discharging into the Williams River immediately east of the township. The catchment is largely cleared rural lands though includes forested areas in the upper catchment. During the April 2015 flood event, extreme rainfall in this catchment produced catastrophic flooding in Dungog resulting in three fatalities, washing four houses away and flooding some 80 dwellings, many to ceiling level. Myall Creek flooding is exacerbated by afflux (i.e. increased water levels upstream of the structure due to floodplain constriction) at the bridge structures and tailwater flooding from the Williams River, which causes flooding of low lying land to the south of Hooke Street. The critical duration of the catchment is 9 hours.

2.1.3 Town Catchment Flood Mechanism

The township of Dungog includes a small 1.6 km^2 catchment which drains into Myall Creek north of Hooke Street. There are two main (un-named) drainage lines, the larger of the two drains land between Dowling and Abelard Street and includes the catchment around the showground. The smaller catchment is to the west of Abelard Street and north of Mackay Street. The catchment is mostly low-density urban with some semi-urban areas. Detention basins are present at the showground and sportsground. Due to the small size of the catchment, this flood mechanism typically only produces “nuisance” type flash flooding which may be exacerbated by blocked or undersized drainage infrastructure. Low-lying areas to the south of Mackay Street may be influenced by backwater flowing from Myall Creek or the Williams River.

2.1.4 Common Creek Flood Mechanism

The Common Creek is located to the north-west of Dungog and flows into Myall Creek after passing under Chichester Dam Road. Afflux due to the bridge restricting the floodplain discharge can result in flooding of a number of properties on Hillview Avenue. During high creek flows, flooding of properties on the floodplain fringe at the industrial estate located on Common Creek road can also occur.

2.1.5 Melbee Estate Flood Mechanism

A small 0.25 km^2 catchment drains the Melbee Estate through a culvert under the railway line which then drains into the Williams River. During extreme flood events, the railway embankment can be overtopped in very large events (such as the April 2015 superstorm) and cause minor flooding of three properties on Gladstone Street.

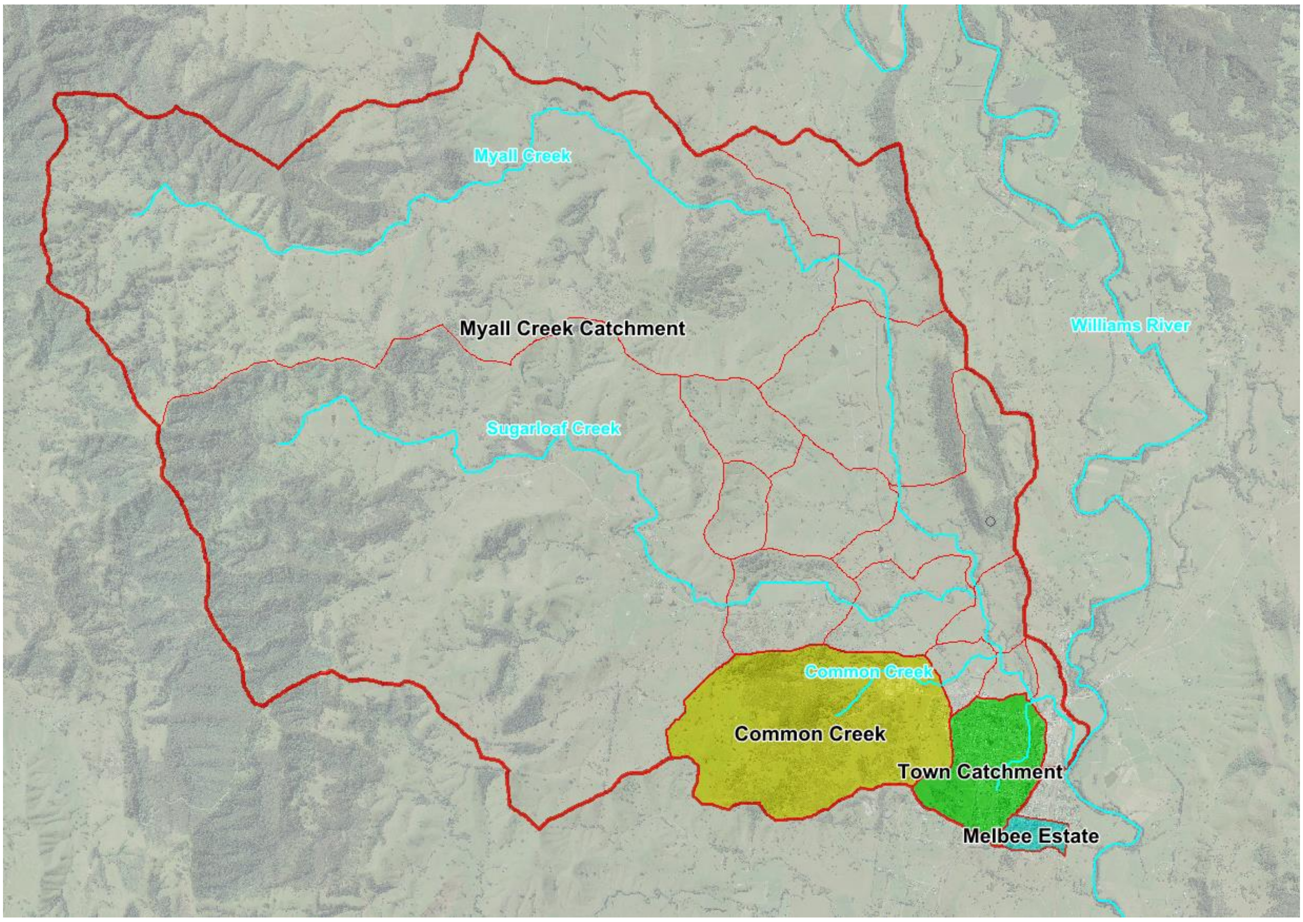


Figure 2-1: Locations of Key Catchments in Dungog

2.2 History of Flooding

The extreme flooding that devastated Dungog on the 21st of April 2015 was caused by an East Coast Low (ECL) that caused significant flooding and damage to a number of areas in the Hunter Region and Sydney and is often referred to as the April 2015 “super storm”. The storm produced catastrophic flooding in Dungog resulting in three fatalities, washing four houses away and flooded some 80 dwellings, many to ceiling level.

While it is difficult to define the probability of such an extreme event it can be characterised as having:

- Delivered a two hour burst of rainfall that was nearly twice the 1 in 100 year ARI (i.e. 1% AEP) design IFD estimate and 30 mm more than the 500yr ARI design estimate.
- Produced Myall Creek discharge that was 1.9 times the 100yr ARI discharge;
- Produced flooding in Dungog that was 1 m higher that the 1 in 500 ARI design event;
- Based on the above, the flood event is likely to have an approximate annual exceedance probability (AEP) of 0.1% or an approximate frequency of a 1 in 1000 year average recurrence interval (ARI).

Other significant floods include:

- The “Pasha Bulker storm of 8th June 2007 which flooded a number of low lying properties (on Hooke Street and Dowling Street) and had a peak flood level of 49.4 m AHD (i.e. ~ 1 in 20 year ARI).
- 6th January 2016 – flooded the former bus depot but did not inundate any houses. (< 1 in 5 yr ARI).
- Yeo (2015b) provides a summary of flood events in Dungog obtained by an archive search of the Dungog Chronicle and Maitland Mercury. Three significant events include:
    - 2-3 February, 1990 – Indicates local catchment flooding and Myall Creek flooded Reliance motors to a depth of 1m. It reached the back steps of a property near Bennett Bridge (Dowling Street), so was smaller than the 2007 flood event.
    - 13 October, 1985 – Indicates local catchment flooding (including damage to the Bennett Park Tennis Courts) and Myall Creek flooded Reliance motors to a depth of 0.6m (i.e. was smaller than the 1990 flood) and reached the verandah at 38 Brown Street.
    - 19 April, 1946 – Reportedly the largest flood in Dungog observed at the time, water reached the verandah at 38 Brown Street so is likely to be of similar magnitude to the 1985 flood. However, given that the current Bennett Bridge was constructed in the late 1960’s, the correlation between Myall Creek flow and flood level could be different for earlier flood events. Yeo (2015b) indicates that in 1979 (when Alison Court was approved), the highest observed flood level was 48.8 m AHD which is likely to be from this 1946 event. A comparison to current design flood levels (see **Table 4-2**) indicates the 1946 event was approximately a 5yr ARI (20% AEP) event.
- A number of other (predominantly Williams River) flood events are listed in **Table 2-2.** These include events in 1963, 1978, and 1990. While some information regarding the severity of these events was revealed during the community consultation process, no firm flood marks in the Dungog township could be obtained.

Table 2-2: Recorded Williams River Flow (Upstream Dungog)

Date	Gauge Level (mAHD)	DNR Stage (m)	Flow (m^3/s) (TUFLOW Rating)
18/3/1963	50.17	n/a	2250
19/3/1978	50.22	9.0	1722
4/2/1990	50.20	8.98	1705
8/6/2007	-	7.5	~730[1]
21/4/2015	-	8.7	~1450[2]
6/1/2016	-	8.0	~1000[1]

Notes: (1) flow based on comparison of levels and discharge with other similar events
(2) flow based on TUFLOW model output from calibration event
Data for events prior to 2010 sourced from Table 5-4 of BMT WBM (2009)
Flow data (DPI Rating) from http://www.bom.gov.au/waterdata/ (Williams River at Dungog (Factory Mill Race)

An analysis of the flood history of Dungog shows that in the 150 years of settlement prior to the April 2015 superstorm event, the largest recorded flood was the June 2007 "Pasha Bulker" event which produced a flood level of similar magnitude to the 5% AEP (20yr ARI). Other significant events prior to this occurred in 1990, 1985 and 1946, however, it appears that these events were likely to be 20% AEP (5yr ARI) – 10% AEP (10yr ARI) magnitude events.

2.3 Previous Studies

2.3.1 Dungog Flood Study (Royal HaskoningDHV, 2017)

The present FRMS&P included developing a Flood Study that defined flood risk in Dungog from all sources (i.e. Williams River, Myall Creek and local township catchments). A draft Dungog Flood Study report was delivered to Council in February 2017. The report detailed the results and findings of the Flood Study investigations including:

- a description of the study area;
- a summary of available historical flood related data;
- establishment and calibration of hydrologic and hydraulic models;
- the estimation of design flood behaviour for existing catchment conditions;
- sensitivity analysis of the model results to variation of input parameters; and
- providing the required mapping for future floodplain management activities.

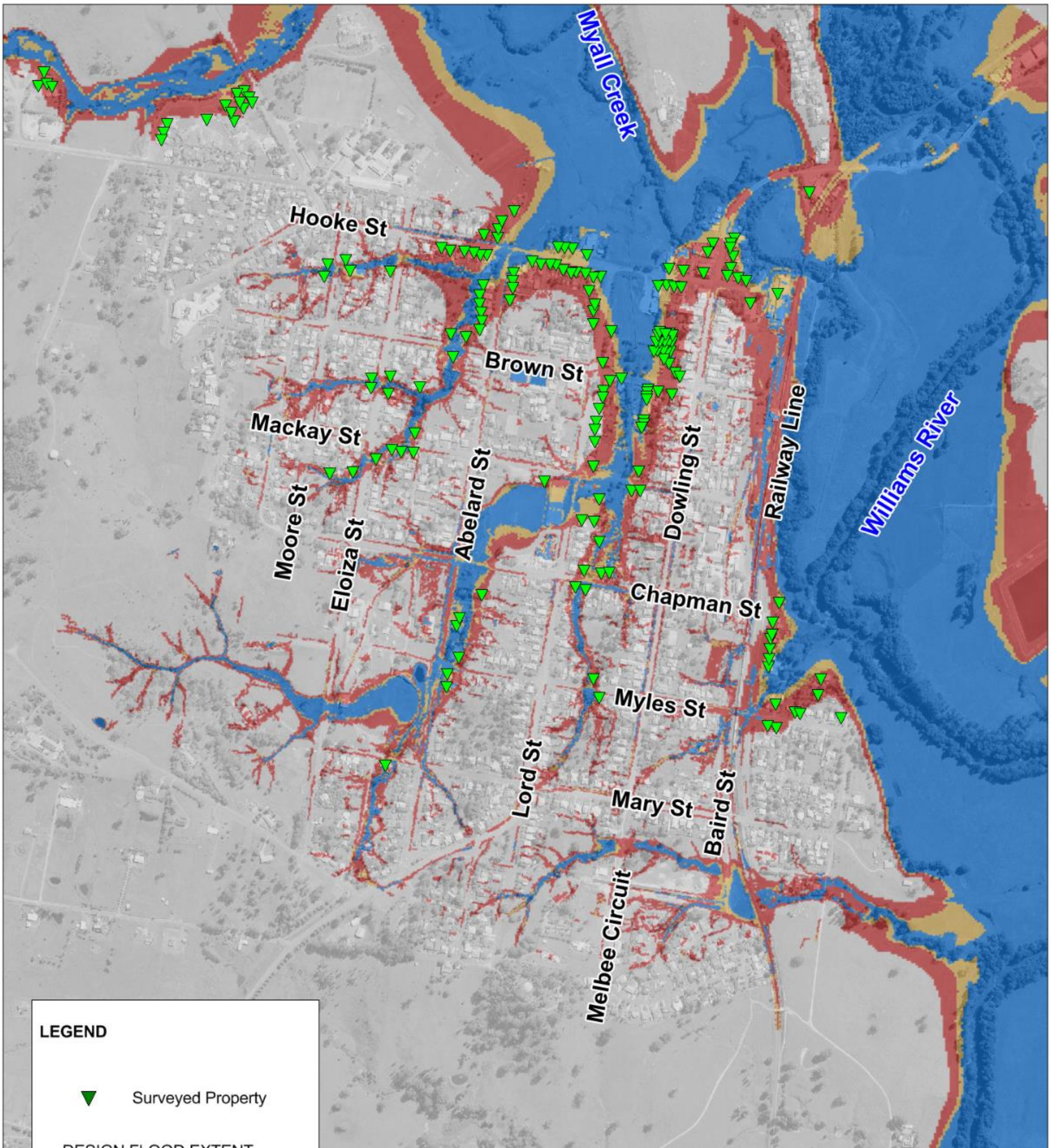
A range of study outputs from the Dungog Flood Study are presented in **Section 4.1** including flood extents and peak flood levels. The flood models developed during the Flood Study were used to evaluate potential mitigation options assessed as part of the Floodplain Risk Management Study as described in **Section 6.4**.

2.3.2 Other Studies

A number of previous studies have been undertaken to investigate flooding in Dungog. The two most recent and useful studies are the *"Williams River Flood Study" (*BMT WBM, 2009) and the *"Post Event Flood Behaviour Analysis and Review of Flood Intelligence – Dungog Township – Myall Creek Catchment and Tributaries"* (BMT WBM, 2015). Survey information and drawings from an unpublished hydraulic analysis (undertaken in 1996) of stormwater drainage infrastructure (immediately upstream and downstream of the Dungog Showground) were also made available for this study. Information regarding culverts, and pipes and floor levels were extracted from this data set and used in the current study. A summary of these studies is presented in the Dungog Flood Study Report (Royal HaskoningDHV, 2017).

2.4 Floor Level Survey

Floor level survey was performed by Marshall Scott surveyors for all properties that may be flooded in July 2016 for this study. Existing data for six properties was derived from the 1996 hydraulic analysis of the Dungog Showground. A total of 176 properties were surveyed in these key areas for the purpose of undertaking an inundation and damages assessment (as presented in **Section 4.2**). The location of surveyed floor levels are shown in **Figure 2-2**.



Royal HaskoningDHV
Enhancing Society Together

FIGURE 2-2

FLOOD EXTENTS AND LOCATION OF PROPERTIES IN FLOOD DAMAGES DATABASE

NORTH

0 125 250m
Approx. Scale

SCALE 1:12,500

PAGE SIZE A4

FILEPATH I:\Projects\PA1316_Dungog FPRMS&P\GIS\Workspaces\ReportFigs\FRMS\Figure_PropertyDatabase_v1a.wor

3 Community Consultation

Community consultation is a fundamental element of the floodplain risk management process as it facilitates community engagement and ultimately aids the endorsement of the overall project.

A range of consultation and communication methods have been utilised including:

- A media release in the Dungog Chronicle at the start of the project (http://www.dungogchronicle.com.au/story/4022751/flood-plan-coming/):
- Development of a project study website providing information on the study (www.dungogfloodstudy.org);
- Development of a project study Facebook page providing information and an opportunity for feedback and engagement (www.facebook.com/DungogFloodStudy);
- An information brochure and questionnaire was delivered to all residents and businesses in Dungog informing them of the study and requesting any information on previous flood events. The survey was available online at www.surveymonkey.com/r/DungogFloodStudy.
- Discussion with individual home owners during site visits;
- A community information evening held on the 7th December 2016 at the Doug Walters (Sports Ground) Pavilion (Mackay St, Dungog), presenting the results of the Dungog Flood Study and providing an initial assessment of potential mitigation options.
- A final community consultation session was held on the 5th July 2017 at the Doug Walters (Sports Ground) Pavilion (Mackay St, Dungog), presenting the findings of the floodplain risk management study and the draft floodplain risk management plan.

3.1 Summary of Questionnaire Responses

As part of the community consultation undertaken during the FRMS&P process a study brochure and questionnaire was sent to approximately 2200 Dungog residents. 32 responses were received including 8 using the online form. 11 of the respondents reported above floor flooding in the April 2015 flood events while 9 properties experienced yard flooding and a total of 16 reported some form of flood related damage. One of the respondents also reported above floor flooding in the 8th June 2007 (Pasha Bulker) storm event. 16 respondents reported having flood insurance for their properties. 22 respondents provided suggestions for flood mitigation options which have been summarised in **Table 3-1**.

Table 3-1: Summary of Suggested Mitigation Options from Community Questionnaire Responses

Suggested Mitigation Option	No. Responses
Clean Stormwater Drains	14
Improved Drainage Network/System	7
Clean / remove vegetation from Myall Creek	6
Flood Warning System	4
Levee or Detention basin(s)	3
Education Programme	2
Government declaration of storm or flood event (for insurance reasons)	1
Increased SES presence	1
Raise or relocate homes	1

Suggested Mitigation Option	No. Responses
Improve Bridge Design	1

3.2 Community Information Session

A community information session was held on 7th December 2016 at the Doug Walters (Sports Ground) Pavilion (Mackay St, Dungog).

The primary objective of this community engagement was to inform the community of the progress of the study. Posters and a power point presentation were used to present study outputs to the community.

Overall, there was good attendance at this session in comparison to the catchment size. Feedback from the session included:

- There was general consensus that the models were able to reproduce the observed flood behaviour of the April 2015 storm event.
- A flood warning system was necessary in Dungog to reduce the potential for further tragedy and to reduce the fear and anxiety of future flood events that were a result of experiencing the severe April 2015 storm event.
- Residents who had been flooded more than once were in favour of Council purchasing their properties if no other mitigation options would be effective.

3.3 Public Exhibition of the Draft Dungog FRMS&P and Community Presentation

Public exhibition of the Draft Dungog FRMS&P was undertaken to gain the support of the local community. The report was made available digitally on the study website with links from Councils website. A hard copy was also displayed at the Council Offices for a period of one month for the public's comments. The public exhibition period was from 21 June to 21 July 2017. On the 5th July, 2017 a community presentation outlining the process and findings of the Dungog FRMS&P was held at the Doug Walters (Sports Ground) Pavilion (Mackay St, Dungog).

Only a single formal response was received during the community consultation period. Due to the nature of the response no formal reply was deemed necessary.

4 Existing Flood Behaviour, Property Inundation and Damages

4.1 Existing Flood Behaviour

Flood behaviour in Dungog was quantified during the Dungog Flood Study (Royal HaskoningDHV, 2017) which investigated flooding from all flood mechanisms including: the Williams River, Myall Creek and the Local Township catchments. Flood extents from each individual flood mechanism were combined to produce a single design flood extent which represents the magnitude of flooding for a given frequency (i.e. annual exceedance probability (AEP) or average recurrence interval (ARI)).

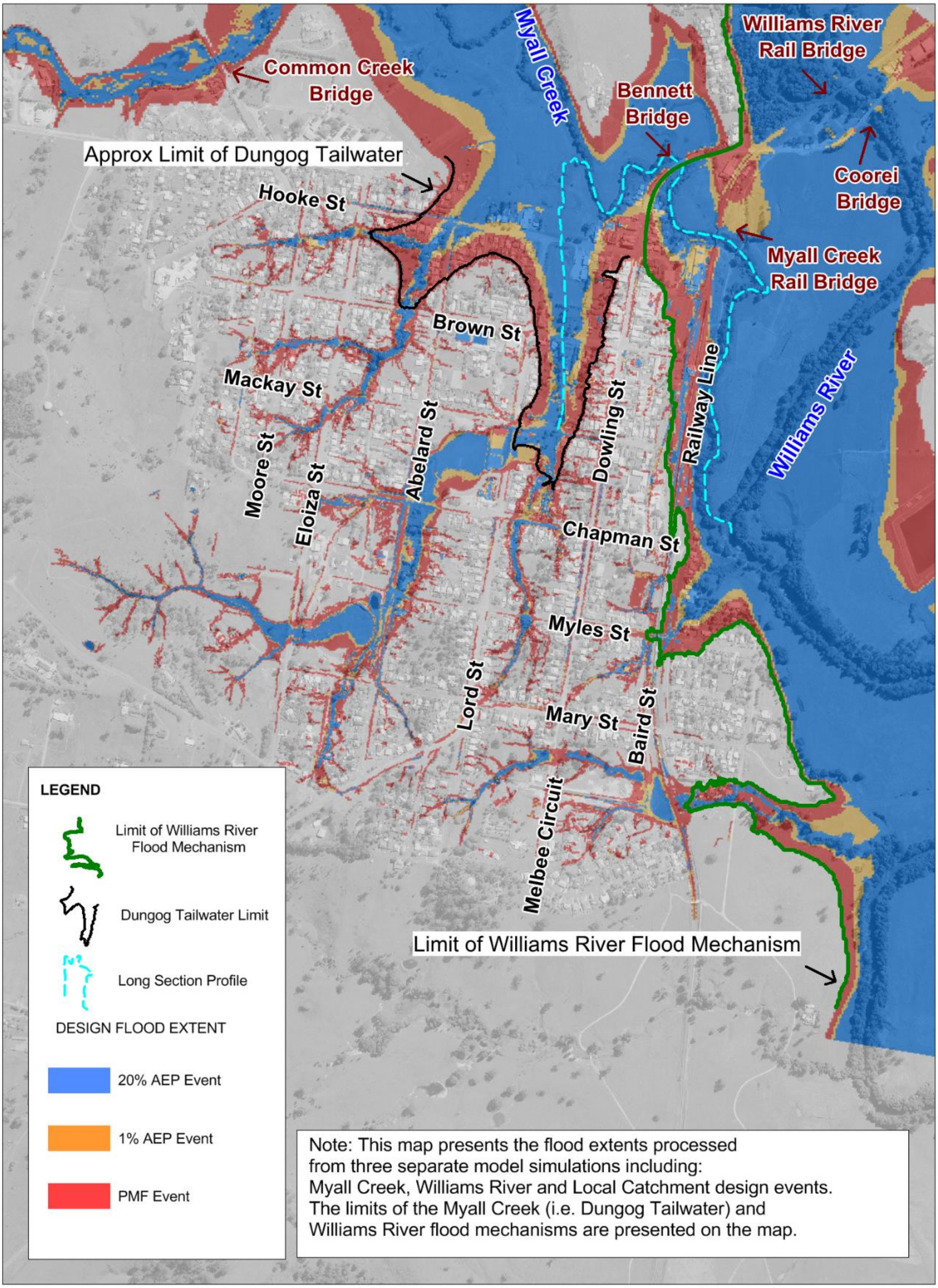
Design flood extents for three events including the: 20% AEP (5yr ARI), 1% AEP (100yr ARI) and Probable Maximum Flood (PMF) are presented in **Figure 4-1**. Included in **Figure 4-1** is a line indicating the limit of Dungog tailwater flooding from Myall Creek. Upstream of this line, peak flood levels are due to the local catchment flood mechanism, while downstream of the line, peak flood levels are due to Myall Creek floodwaters. The long-section flood profiles presented in **Figure 4-3** show the Dungog tailwater is formed due to the floodplain constriction at Bennett Bridge, which is further influenced by the floodplain constriction at the Myall Creek Railway Bridge. The influence of these constrictions on peak flood level during the April 2015 flood event is presented in **Figure 4-4.**

The Dungog tailwater which is part of the Myall Creek flood mechanism is the main source of flood risk in Dungog accounting for 80-90% of above floor property inundation and flood damages (refer **Section 4.2**).

Also included in the **Figure 4-1** is a line indicating the limit of flooding from the Williams River whose floodplain lies to the east of Dungog. Only a few properties in Dungog are located on the Williams River floodplain. However, coincident flooding of the Williams River and Myall Creek can result in exacerbated flood levels in the Myall Creek when small floods on the Myall Creek occur at the same time as large floods on the Williams River as presented in **Figure 4-3**.

The extent of flooding from the Common Creek catchment is also presented in **Figure 4-1**. Flooding from both the local township catchment (and Melbee Estate) is also presented in **Figure 4-1.**

Results of the Local Catchment flood mechanism without a coincident Myall Creek or Williams River flood are presented in **Figure 4-2.** The Figure shows a line indicating the flood extent due to the Myall Creek alone and shows that peak flood levels in the Dungog tailwater are due to the Myall Creek and not the local catchment.



Royal HaskoningDHV
Enhancing Society Together

FIGURE 4-1

COMBINED DESIGN FLOOD EXTENTS (5YR (20% AEP), 100YR (1% AEP) & PMF EVENTS)

NORTH

0 125 250m
Approx. Scale

SCALE 1:12,500

PAGE SIZE A4

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.

FILEPATH I:\Projects\PA1316_Dungog FPRMS&P\GIS\Workspaces\ReportFigs\FRMS\Figure_FloodExtents_v1b.wor

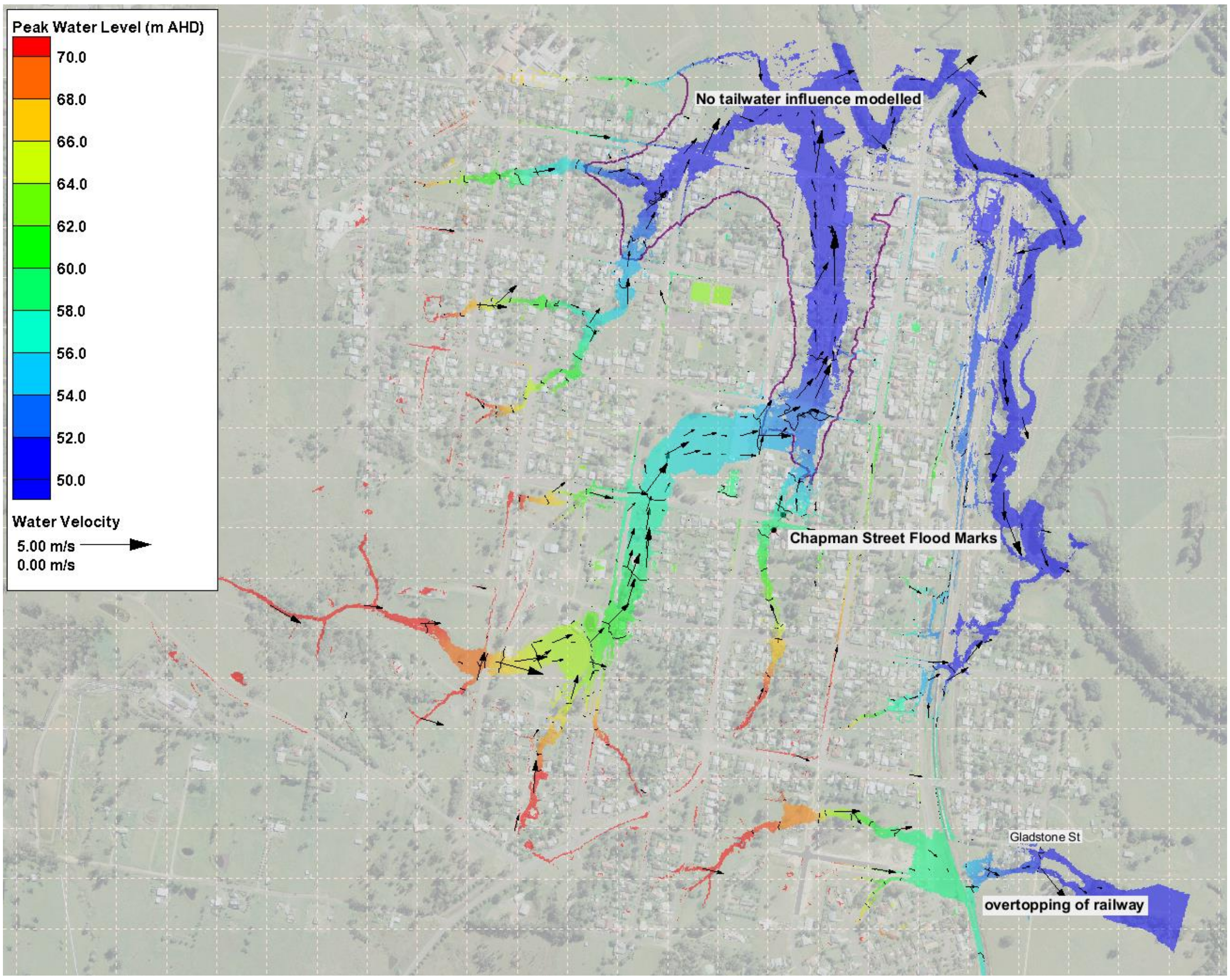


Figure 4-2: Local Catchment Peak Water Level April 2015

4.1.1 Coincident Conditions and Combined Flood Mechanism Results

A summary of the adopted coincident conditions for all three sources of flooding in Dungog is presented in **Table 4-1**. Flood profiles for the 5yr, 20yr, 100yr, 500yr and PMF from Myall Creek or Williams River sources are presented in **Figure 4-3**. With the exception of the PMF, all adopted Myall Creek design events produce the highest flood levels upstream of Bennett Bridge. The influence of the floodplain constrictions at Bennett Bridge and the Railway Bridge are clearly evident in the Myall Creek dominated design events.

Table 4-1: Adopted Design Conditions for Three Sources of Flood Mechanisms

Event	Myall Creek Event Myall Discharge / Williams Discharge)	Williams River Event (Myall Discharge / Williams Discharge)	Local Catchment
5yr	5yr / 5yr	5yr / 5yr	5yr
20yr	20yr / 5yr	5yr / 20yr	10yr
50yr	50yr / 5yr	5yr / 50yr	50yr
100yr	100yr / 10yr	20yr / 100 yr	100yr
200yr	200yr / 20yr	20yr / 200yr	200yr
500yr	500yr / 20yr	20yr / 500yr	500yr
PMF	3 x 100yr / 100yr	500yr / PMF (GTSM)	PMF (GSDM)

GSDM = Generalised short duration method, **GTSM =** Generalised tropical storm method

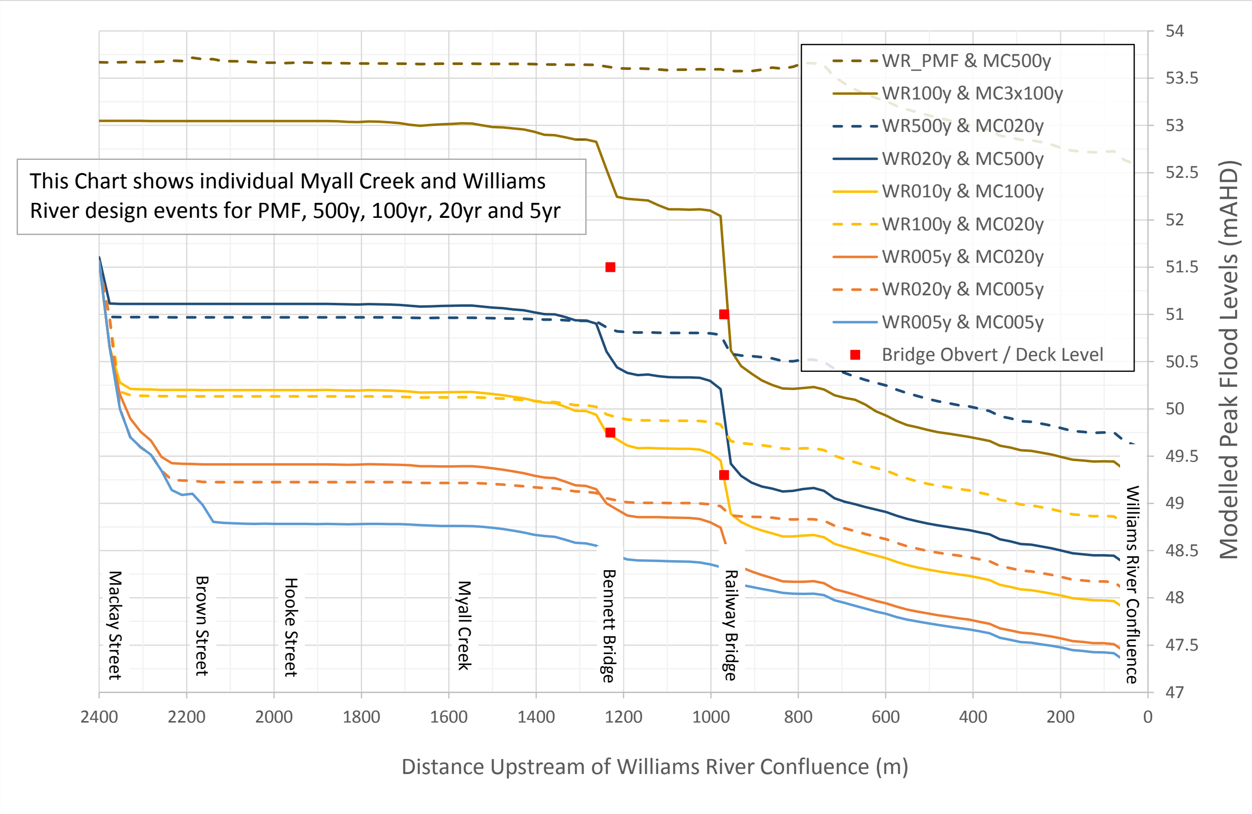


Figure 4-3: Longitudinal Profiles for a Range of Coincident Myall Creek and Williams River Design Events

Note: the location of the longitudinal section is presented in **Figure 4-1**

4.1.2 Peak Flood Levels

A summary of peak flood levels in the Dungog tailwater is presented in **Table 4-2** while flood profiles for seven design events and the April 2015 event are presented in **Figure 4-4**.

Table 4-2: Design Peak Water Levels in Dungog Tailwater (from RHDHV, 2017)

Design Conditions AEP / ARI	Hooke St Peak Flood Level (m AHD)
20% / 5yr	48.78
5% / 20yr	49.41
2% / 50yr	49.82
1% / 100yr	**50.2**
0.5% / 200yr	50.64
0.2% / 500yr	51.11
PMF	53.65
April 2015	51.98

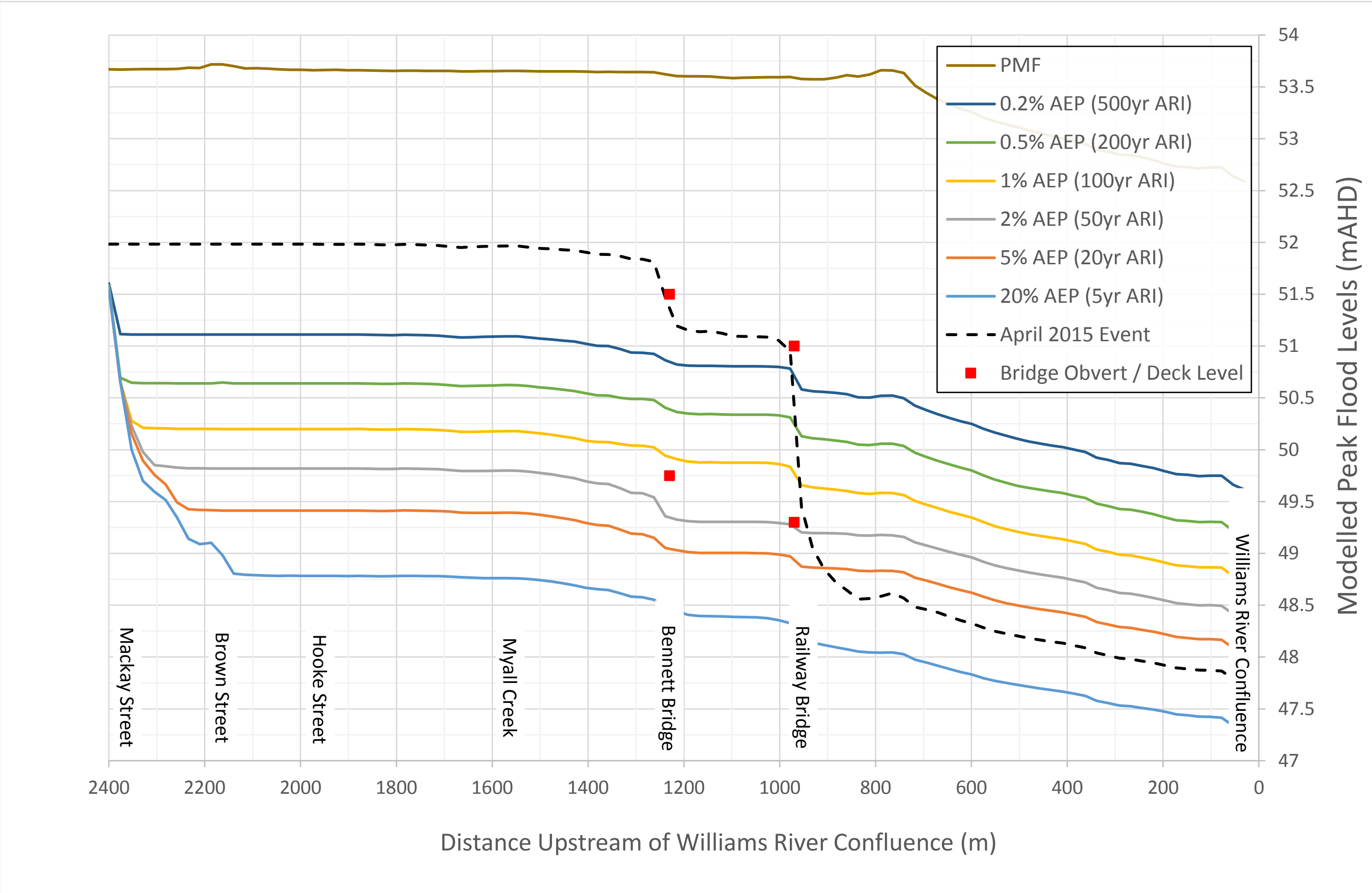


Figure 4-4: Town Drain and Myall Creek Long Section (Peak Flood Level for 7 Design Events)

4.2 Property Inundation and Flood Damages Assessment

A flood damage assessment has been undertaken to identify flood affected property, to quantify the extent of damages in economic terms for existing flood conditions (see below) and to enable the assessment of the relative merit of potential flood mitigation options by means of benefit-cost analysis (as detailed in **Section 6.4**). The general process for undertaking a flood damages assessment incorporates:

- Identifying properties subject to flooding;
- Determining depth of inundation above floor level for a range of design event magnitudes;
- Defining appropriate stage-damage relationships for various property types/uses;
- Estimating potential flood damage for each property; and
- Calculating the total flood damage for a range of design events.

4.2.1 Property Database

A property database was established containing information regarding flood liable properties. The database contains the required information to carry out the flood damages assessment including:

Location Data: The locations of flood affected properties were determined by examining Council cadastre information and detailed aerial photography. Using a GIS system property data could be efficiently extracted into the property database. A total of 172 properties were identified as falling within the PMF. However, it should be noted that a small number of these properties did not experience under or above floor flooding. It should be noted that the database represents the catchment as at July 2016 when the survey was undertaken. As such it excludes any properties that were destroyed during the April 2015 event, but does include the six Alison Court properties that Council (in early 2017) agreed to demolish.

Land Use: For the purposes of the flood damage assessment, property was considered as either residential or non-residential (i.e. commercial or government). Commercial and Government (i.e. Libraries, Community Halls, etc.) properties have been identified from the property survey. Public infrastructure and utility assets (i.e. pumping stations, electricity sub-stations, etc.) have been excluded from the damages assessment.

Ground and Floor Level Data: A floor level survey of identified property within the PMF flood extent was undertaken by Marshall Scott Surveyors. The survey provided: building floor level, geographic coordinates, building classification (i.e. residential, commercial or Government), year constructed, number of stories, construction type (i.e. brick or weatherboard), foundation type (slab on ground or piers) and photographic record to identify property type. Ground level data was based on the DEM.

The distribution of surveyed properties within the study area with reference to the PMF flood extent is shown in **Figure 2-2**.

Flood Level Data: The design flood levels across the catchment were adopted from the Dungog Flood Study (Royal HaskoningDHV, 2017). The flood modelling results were used to generate a continuous flood profile across the floodplain. Flood levels calculated from the TUFLOW model were queried from TUFLOW's GIS output at each property reference point, creating a property specific flood level. The resulting flood level is then used to determine a depth of flooding above the floor level or ground level. This depth of flooding is then used to calculate a property specific flood damage estimate using the adopted damage curve.

4.2.2 Property Inundation Assessment

A summary of the location and frequency of above floor property inundation in Dungog is presented in **Figure 4-6** and **Table 4-3**. The assessment shows that:

- in an extreme flood (i.e. the PMF), 122 properties in Dungog are inundated above floor level. Of these properties, 89 (~70% of properties) are in the Myall Creek tailwater area, 12 ((~10% of properties) are on the Williams River floodplain, 9 are adjacent to Common Creek and 12 are affected by overland flooding from the Dungog Township local catchment.
- In the rare, 0.2% AEP (500yr ARI) event, 46 properties in Dungog are inundated above floor level. Of these properties, 41 (89% of properties) are in the Myall Creek tailwater area, 4 (9% of properties) are on the Williams River floodplain and 1 property is flooded above floor level in the Dungog Township local catchment.
- In the 1% AEP (100yr ARI) event, 22 properties in Dungog are inundated above floor level. Of these properties, 20 (91% of properties) are in the Myall Creek tailwater area, 1 is on the Williams River floodplain and 1 property is flooded above floor level in the Dungog Township local catchment.
- In the 5% AEP (20yr ARI) event, 9 properties in Dungog are inundated above floor level. Of these properties, 8 (91% of properties) are in the Myall Creek tailwater area and 1 is on the Williams River floodplain and no properties are flooded above floor level in the Dungog Township local catchment.
- With the exception of the 20% AEP (5yr ARI), in which 2 out of the 3 inundated properties are classified non-residential (i.e. commercial), in all other design events, residential properties make up 80-90% of the above floor inundated properties.
- The analysis shows that in the April 2015 event, 69 properties in Dungog were inundated above floor level. Of these properties, 59 were in the Myall Creek tailwater area, 9 are adjacent to Common Creek and 1 property experienced above floor flooding in the Dungog Township local catchment. It should be noted that this analysis does not include the 5 properties near Bennett Bridge that were destroyed during the event. It also excludes one severely flooded property on Hooke Street that was demolished shortly after the flood event.

Table 4-3: Summary of Above Floor Property Inundation by Flood Mechanism and Property Type

AEP / ARI	Study Area (i.e. Total)	Myall Creek Tailwater	Williams River	Common Creek	Dungog Township	Residential	Non-Residential
PMF	122	89	12	9	12	102	20
0.2% / 500yr	46	41	4	0	1	42	4
0.5% / 200yr	32	30	1	0	1	28	4
1% / 100yr	**22**	**20**	**1**	**0**	**1**	**18**	**4**
2% / 50yr	14	12	1	0	1	12	2
5% / 20yr	9	8	1	0	0	7	2
20% / 5yr	3	3	0	0	0	1	2
April 2015	69	59	0	9	1	60	9

For events above the 2% AEP (50yr ARI), typically a further 14-19 properties may experience below floor flooding. A summary of the number of properties that experience underfloor (or near house) flooding is presented in **Table 4-7**.

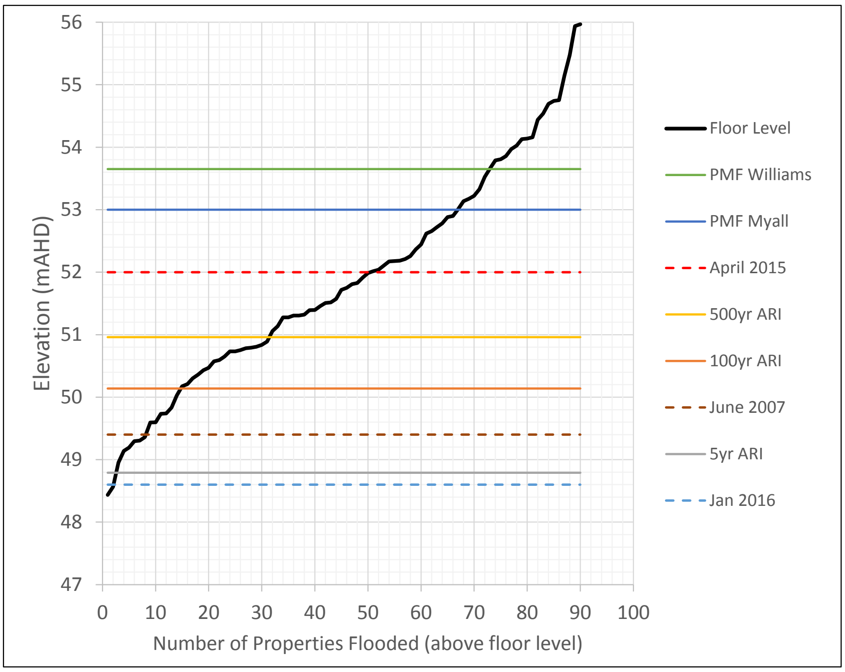
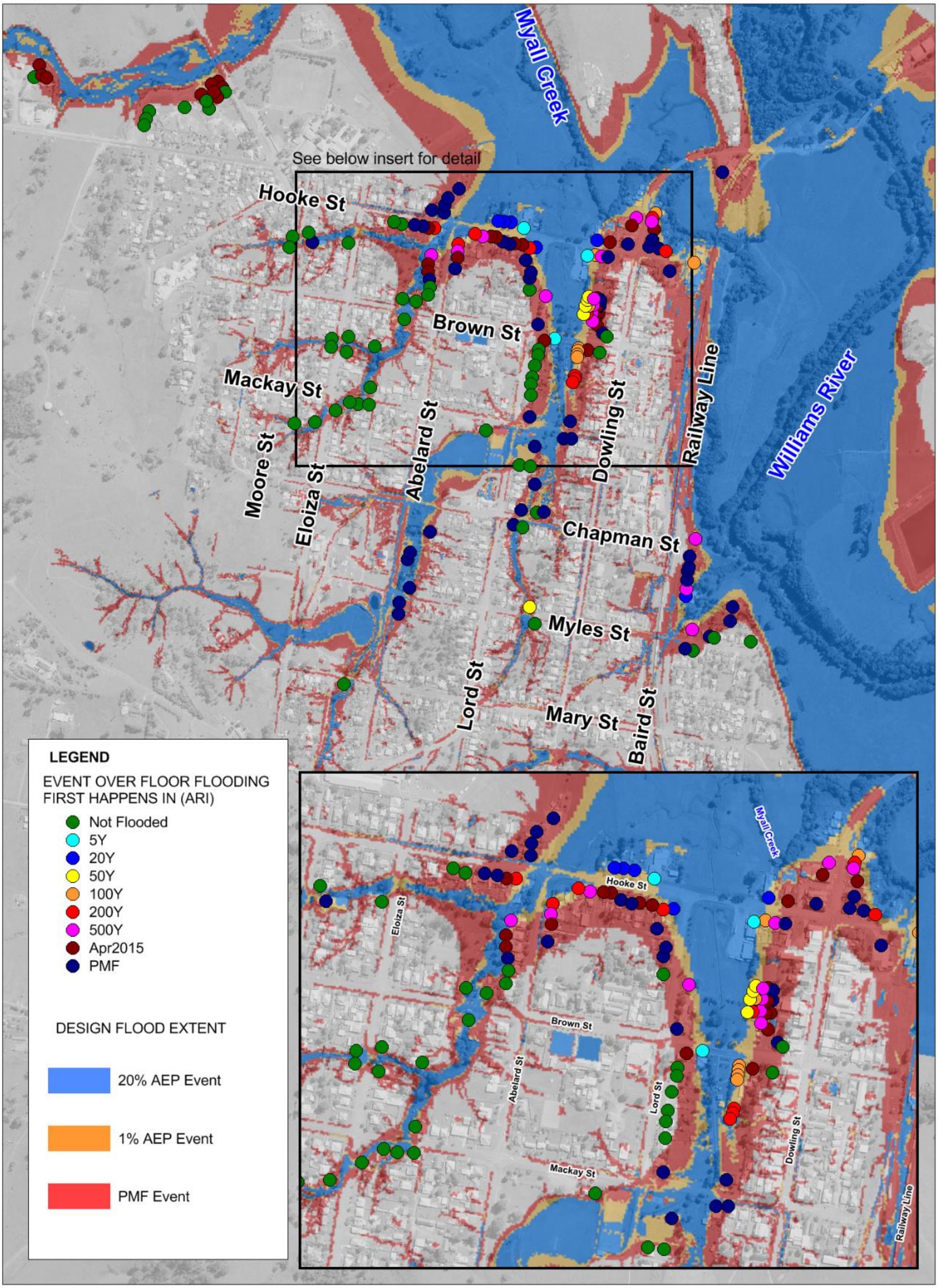


Figure 4-5: Flood Stage vs Property Floor Levels (Dungog Tailwater)



Royal HaskoningDHV
Enhancing Society Together

FIGURE 4-6

LOCATION AND FREQUENCY OF ABOVE FLOOR FLOODING IN DUNGOG

NORTH

0 125 250m
Approx. Scale

SCALE 1:12,500

PAGE SIZE A4

FILEPATH I:\Projects\PA1316_Dungog FPRMS&P\GIS\Workspaces\ReportFigs\FRMS\Figure_AboveFloorFloodingFrequency_v1a.wor

4.2.3 *Flood Damages Assessment*

Background

Flood damages are typically divided at the primary level, into tangible and intangible damages and at a secondary level, as direct and indirect damages. Tangible damages are those for which a monetary value can easily be assigned, while intangible damages are those to which a monetary value cannot easily be attributed and arise from social and environmental effects caused by flooding including factors such as: loss of life and injury, inconvenience, disruption of family and social activities, stress, anxiety and physical and psychological ill-health.

Tangible damages may be direct or indirect flood damages. Direct damages are directly attributed from the actions of flooding (inundation and flow, on property and structures), while indirect damages arise from the disruptions to physical and economic activities caused by flooding. Examples of indirect damages include: losses due to the disruption of business, expenses of alternative accommodation, disruption of public services, emergency relief aid and clean-up costs. This study only attempts to calculate tangible, direct damages which is appropriate for the comparison of mitigation options.

Given the variability of property and contents values, the total likely damages figure in any given flood event is approximate only and while useful to gauge the magnitude of the flood problem, it is of little value for absolute economic evaluation. Given that the primary purpose of the flood damages estimates are to evaluate the economic effectiveness of proposed mitigation options, the methods used are considered appropriate.

The Average Annual Damage (AAD) is the main comparative factor that is derived from this flood damages assessment with which to evaluate the effective of proposed mitigation options. The AAD represents the estimated tangible damages sustained every year on average over a given 'long' period of time and is determined using the full range of flood events previously considered in the FRMS. The AAD damage calculation considers that in many years there may be no flood damage, in some years there will be minor damage (caused by small, relatively frequent floods) and, in a few years, there will major flood damage (caused by large, rare flood events). Estimation of the AAD provides a basis for comparing the effectiveness of different floodplain management measure (i.e. the reduction in the AAD) as presented in **Section 6**.

Damages Methodology

The estimates of flood damages for Dungog were prepared following the guidelines detailed in: 'Floodplain Risk Management Guideline: Residential Flood Damages' (DECCW, 2007).

The DECCW method utilises separate stage-discharge curves for different residential building types. In the flood damages assessment all residential properties were categorised as either slab on ground, single story high set, or two storey as per DECCW recommendations. The relevant building type was determined using the property database developed for the study.

The DECCW residential curves are based on various input data including CPI, regional cost factor, flood awareness, flood warning time, typical cost of contents, typical building footprint and insurance. For high-set houses, there is some accommodation for damages associated with flooding beneath the floor level, as this space is often used for storage. The DECCW method accounts for a combination of direct and indirect damages including allowances for clean-up costs and alternative accommodation. For this assessment, the parameters as presented in **Table 4-4** were used:

Table 4-4: Damages Assessment Parameters

Parameter	Value Adopted
Post November 2001 adjustment factor	**1.70** (average weekly earnings at February 2017)
Regional Cost Variation factor	**1.25** (Rawlinsons 2016)
Post Flood Inflation Factor	**1.50**
Flood Level Awareness	**Low**
Effective Warning Time	**0 hours** (There is no warning system on Myall Creek)

Results of Damages Assessment

The results of the damages assessment is presented in:

- **Table 4-5**, which presents a summary of flood damages ($) by flood mechanism and property type;
- **Table 4-6**, which presents the above data showing the percentage flood damages by flood mechanism and property type; and
- **Table 4-7,** which summarises the flood damages in terms of each events contribution to the annual average damage (AAD) quantity (as previously described) and also defines how many properties are inundated in a given event.
- **Table 4-8**, provides a summary of net present value (NPV) calculations which uses the AAD value to calculate the total damages over a 50 year forward timeframe in term of today's costs for a range of discount factors

A number of key points regarding flood damages for the existing conditions include:

- In the 1% AEP (100yr ARI) event, it is estimated that $2.4 Million of tangible flood damages would occur in Dungog. The majority (i.e. 90%, $2.2 Million) of these damages are attributed to the Myall Creek (i.e. tailwater) flood mechanism. In the 1% AEP event, flood damages from the Williams River are estimated to be $112,000 while the local township catchment is estimated to cause $123,000 of flood damage. In the Common Creek catchment no damages are calculated to occur as all properties were built above the 1% AEP flood level.
- In the 1% AEP (100yr ARI) event, residential properties make up 80% (i.e. $1.8 Million) with non-residential (i.e. either: Commercial, Industrial or Government) properties estimated to incur an estimated $486,300 worth of flood damages.
- With the exception of the PMF event, typically 90% of flood damages occur in the Dungog tailwater area which is due to the Myall Creek backwater flood mechanism.
- In the April 2015 superstorm, flood damages of $9.0 Million were calculated for Dungog. This is approximately half the near $18 Million flood damages predicted to occur in the PMF.
- With the exception of the 20% AEP (5yr ARI), residential properties make up 74% or more of the flood damage costs.

A summary of flood damages (AAD Contribution) and property inundation is presented in **Table 4-7** and shows:

- That the two "minor" 20% and 5% AEP (i.e. 5yr and 20yr ARI) events, which only flood up to 16 properties (and only 9 above floor level), contribute over 50% of the damages in the AAD value.
- While the PMF floods 122 properties above floor level, many to a significant depth, due to the low probability of such an event, it only contributes 10% of damages to the AAD value.

A calculation of the average annual damages (AAD) costs for Dungog shows that over a sufficiently long period of time (in which the full range of design floods occurs) flood damages average out to $230,000 per year. If there was no inflation, then at the end of a 50 year timeframe it is estimated that there would be a total of $11.5 Million damages in Dungog. As economic theory shows that todays $11.5 Million dollars, will not buy $11.5 Million dollars of goods in 50 years' time, it is important to carry out a net present values (NPV) calculation to understand the cost of covering future damages in terms of dollars now. Adopting a 7% discount rate (which is typical for this type of study and the likely future economic conditions) shows that over a 50 year time frame, the damages in today's dollars is reduced to $3.4 Million. **Table 4-8** shows the impact on the NPV calculation of adopting a higher or lower discount rate. This 7% discount rate was adopted for the assessment of mitigation option presented in **Section 6**.

Table 4-5: Summary of Flood Damages by Flood Mechanism and Property Type

AEP / ARI	Study Area (i.e. Total)	Myall Creek Tailwater	Williams River	Common Creek	Dungog Township	Residential	Non-Residential
PMF	$17,807,232	$13,925,732	$1,793,611	$962,095	$1,125,794	$15,241,416	$2,565,816
0.2% / 500yr	$5,465,815	$4,966,171	$367,540	$0	$132,104	$4,777,701	$688,114
0.5% / 200yr	$3,699,482	$3,362,719	$213,861	$0	$122,902	$3,142,883	$556,599
1% / 100yr	**$2,413,193**	**$2,174,372**	**$111,817**	**$0**	**$127,004**	**$1,926,893**	**$486,300**
2% / 50yr	$1,520,873	$1,353,904	$94,410	$0	$72,559	$1,207,045	$313,827
5% / 20yr	$872,226	$757,708	$47,059	$0	$67,459	$642,381	$229,845
20% / 5yr	$253,173	$232,773	$0	$0	$20,400	$72,559	$180,614
AAD	**$230,134**	**$203,651**	**$10,519**	**$957**	**$15,006**	**$152,390**	**$77,744**
April 2015	$9,065,789	$7,962,386	$5,100	$966,198	$132,104	$7,814,539	$1,251,250

Table 4-6: Summary of Percentage Flood Damage by Flood Mechanism and Property Type

AEP / ARI	Study Area (i.e. Total)	Myall Creek Tailwater	Williams River	Common Creek	Dungog Township	Residential	Non-Residential
PMF	$17,807,232	78%	10%	5%	6%	86%	14%
0.2% / 500yr	$5,465,815	91%	7%	0%	2%	87%	13%
0.5% / 200yr	$3,699,482	91%	6%	0%	3%	85%	15%
1% / 100yr	**$2,413,193**	90%	5%	0%	5%	80%	20%

AEP / ARI	Study Area (i.e. Total)	Myall Creek Tailwater	Williams River	Common Creek	Dungog Township	Residential	Non-Residential
2% / 50yr	$1,520,873	89%	6%	0%	5%	79%	21%
5% / 20yr	$872,226	87%	5%	0%	8%	74%	26%
20% / 5yr	$253,173	92%	0%	0%	8%	29%	71%
AAD	**$230,134**	88%	5%	0%	7%	66%	34%
April 2015	$9,065,789	88%	0%	11%	1%	86%	14%

Table 4-7: Summary of Flood Damages (AAD Contribution) and Property Inundation

AEP / ARI	Total Damages	Contribution to AAD ($)	Contribution to AAD (%)	Cumulative Contribution to AAD (%)	Properties Above Floor	Properties (Underfloor / Grounds)
PMF	$17,807,232	$23,335	10%	100%	122	138
0.2% / 500yr	$5,465,815	$13,748	6%	90%	46	65
0.5% / 200yr	$3,699,482	$15,282	7%	84%	32	50
1% / 100yr	**$2,413,193**	$19,670	9%	77%	22	41
2% / 50yr	$1,520,873	$35,896	16%	69%	14	28
5% / 20yr	$872,226	$84,405	37%	53%	9	16
20% / 5yr	$253,173	$37,976	16%	16%	3	8
AAD	-	**$230,134**	100%		-	-
April 2015	$9,065,789	-	-		69	94

Table 4-8: Summary of NPV of Damages over 50 Years for a Range of Discount Factors

Discount Factor	NPV of Damages over 50 Years
0%	$ 11,506,700
4%	$ 5,173,917
7%	$ 3,406,156
11%	$ 2,310,927

4.3 Road & Rail Inundation Assessment

An assessment of potential road and rail inundation during flood events has been undertaken to assist in the formulation of effective evacuation strategies.

Chichester Road – access for Chichester Dam and a number of small localities such as Bendolba, and Bandon Grove. The two low flooded locations on Hooke Street can be avoided by alternate routes along the higher western side of Dungog. The bridge over Common Creek has a deck level of approximately 54.5mAHD and is only flooded in the PMF. However, the bridge crossings at Sugarloaf Creek and Myall Creek are outside the model domain so could not be assessed in this study.

Bennett Bridge Approach (Myall Creek) – low point is 49.4m AHD. In the 50yr ARI the road is just overtopped (< 100mm) and likely to be for less than 1 hour. In the 100yr ARI, the road is inundated to a depth of 0.6 m (WL = 50.0mAHD) at high velocity for 2-6 hours.

Coorei Bridge Approach (Williams River) – low point is 48.5m AHD. Inundation occurs in the 5yr ARI with the road overtopped by ~0.3-0.5m and inundation could be for 2-24 hours.

Railway (Williams River) – low point is 50.8m AHD. Inundation occurs in the 50yr ARI with the western bank overtopped by ~0.2-0.3m and inundation could be for 2-24 hours.

Railway (Myall Creek) – low point is 50.8m AHD. Inundation would only occur for events greater than the 500yr ARI Myall Creek design event, however, the Williams River crossing is more easily inundated from Williams River events.

Hooke Street (Dungog tailwater) – The lowest point on Hooke Street (between Lord and Dowling Streets) is just 46.5 m AHD and is inundated by over 2 m of water in the 5yr ARI event. There is another low area on Hooke Street at the Abelard Street intersection where the road level is 49.0mAHD and could be inundated by ~0.1m in the 5yr ARI event. As the key flood mechanism at this location is tailwater flooding from Myall Creek road closures of up to 24 hours could occur. However, the gridded road layout in Dungog, means that alternate (generally) flood free routes are available.

Brown Street (Dungog tailwater) – The lowest point on Brown Street (between Lord and Dowling Streets) is 49.0 m AHD and would just be overtopped by local catchment runoff in the 5yr ARI event. In the 100yr event this location would be inundated by over 1m of water. Again a road closure of up to 24 hours could occur, however, alternate routes are available.

Mackay Street (edge of Dungog tailwater) – The lowest point on Mackay Street (between Lord and Dowling Streets) is 51.2 m AHD so would only affected by tailwater flooding for events greater than the 500yr ARI. However, the road is inundated by 0.1-0.4m of fast moving, shallow flows from the local catchment in events which exceed the under road culvert capacity.

Local Catchment Road Closures – Other road closures in the Dungog Township catchment are possible. However, closures are likely to be limited to 1-2 hours and flow depths would generally be less than 0.5m (mostly 0.1-0.2m) though high velocity flood flows would make road crossing hazardous to all but large tractors, trucks and 4WDs. Roads higher up in the local catchment such as Mary Street and Eloiza Street would be generally less flood affected.

4.4 Hydraulic Categorisation

The Floodplain Development Manual (NSW State Government, 2005) defines three hydraulic categories; the floodway, flood storage and flood fringe. The floodway describes areas where a significant volume of water flows during floods and if only partially blocked would cause a significant increase in flood levels and/or a significant redistribution of flood flow. Floodway's are often areas with deep flows with high velocities. Flood storage describes areas on floodplains that are important for temporary storage of floodwaters during a flood. If the capacity of the flood storage area is substantially reduced by factors, such as development, flood levels in nearby areas may rise and increase the peak discharge downstream. The flood fringe is the remaining area of flood affected land.

The Dungog Flood Study (Royal HaskoningDHV, 2017) determined the hydraulic categories for the 5% AEP, 1% AEP and PMF as presented in the Map Compendium (Appendix A).

4.5 True Flood Hazard Classification

The Draft Dungog Flood Study (Royal HaskoningDHV, 2017) defined the provisional hydraulic hazard based on the methodology outlined in Appendix L of the NSW Floodplain Development Manual (NSW State Government, 2005). This approach used a depth-velocity relationship to define areas as high and low hazard.

The current FRMS&P proposes to use the flood hazard curves proposed by Smith et al. (2014) and recommended by the Australian Emergency Management Institute (AEMI). This approach provides a range of hazard classifications which increase in severity based on the safety threat posed to vehicles, people and buildings. These classifications and the corresponding flood hazard curves are shown in **Table 4-9** and **Figure 4-7** respectively.

Table 4-9: Hazard Classifications

Hazard Classification	Description
H1	*No vulnerability constraints*
H2	Unsafe for small vehicles
H3	Unsafe for all vehicles, children and the elderly
H4	Unsafe for all people and all vehicles
H5	Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure.

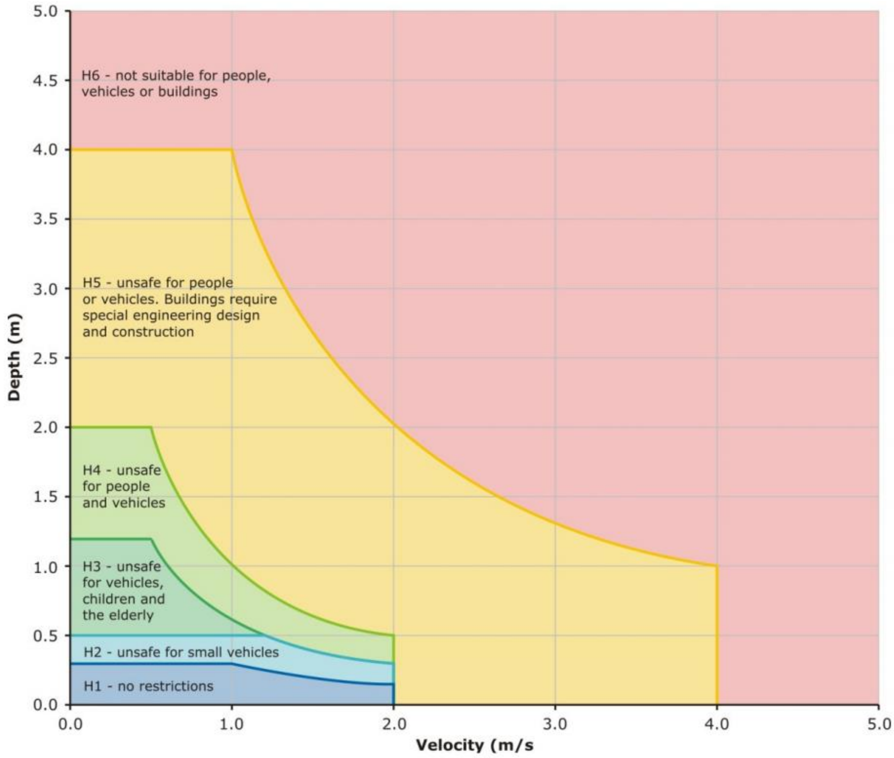


Figure 4-7: Combined Flood Hazard Curves (Smith et. al. 2014)

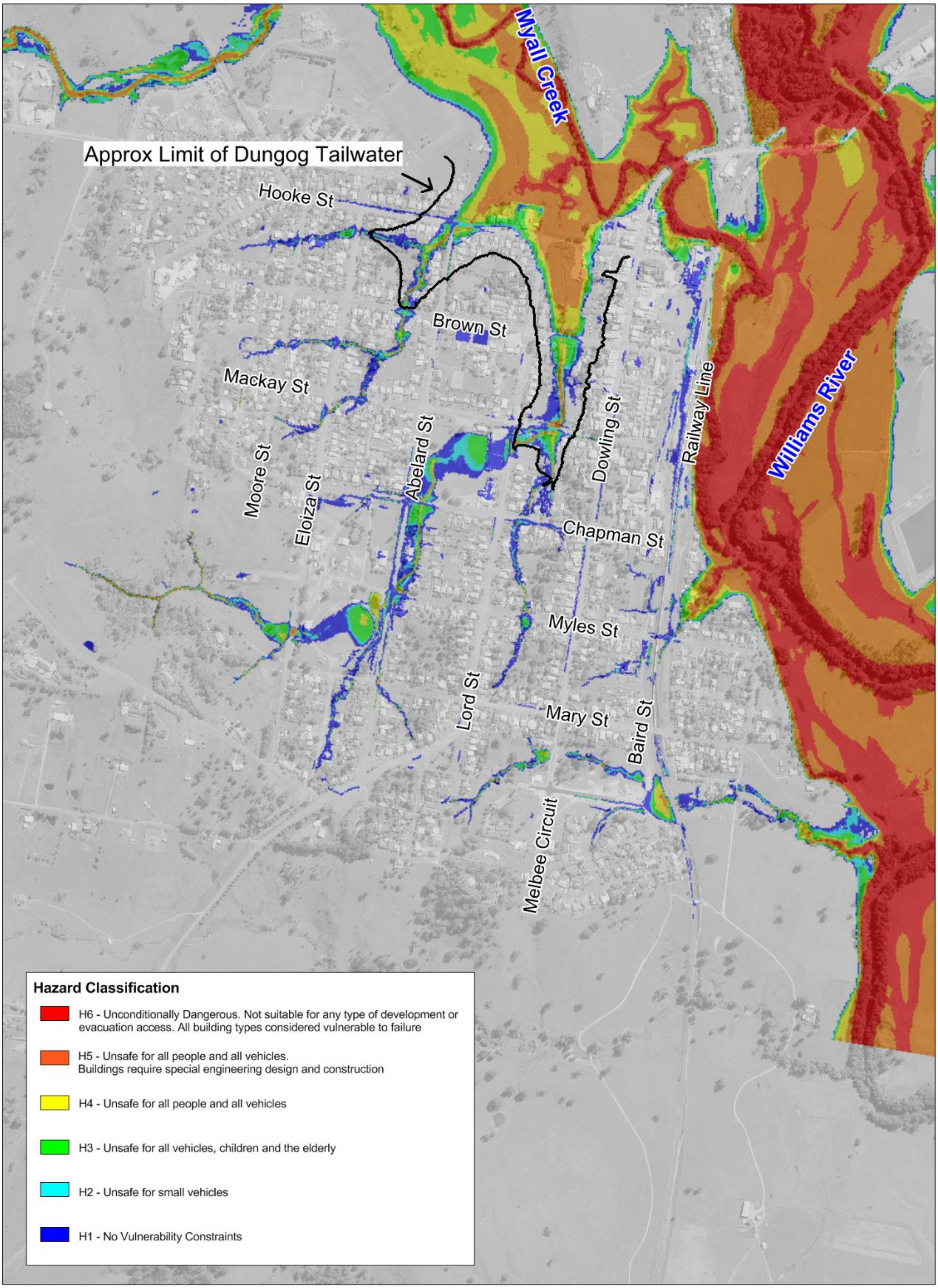
In conjunction with considering the hydraulic hazard using the flood depths and velocities from the hydraulic model, it is important to consider other criteria such as: size of the flood, effective warning time, flood readiness, rate of rise of floodwaters, depth and velocity of floodwaters, duration of flooding, evacuation problems, effective flood access and type of land use. These factors are assessed in **Table 4-10**.

Table 4-10: Hazard Assessment of Variables

Criteria	Weight	Comment
Size of the flood	Medium	The magnitude of a flood affects the depths and velocities produced in an event. Low flood hazard typically is associated with more frequent flood events while high hazard flows usually occur during rare (major) flood events. Typically, flood affectation in Dungog tailwater increases significantly for rare events.
Depth and velocity of floodwaters	High	The flood hazard is related to the product of depths and velocity of flood waters which are influenced by the size of the flood. In Dungog tailwater velocity is low while depths are very high. Overtopping of Dowling Street adjacent to Bennett Bridge can result in very high velocity flood flows.
Rate of rise of floodwaters	Medium	The rate of rise of floodwaters is influenced by the catchment size, soil type, slope and land use. The spatial and temporal pattern of the rainfall is also related to the rate of rise. The rate of rise in the study area for the local and Myall Creek catchments can be quite rapid due to the relatively small catchment size and shape of these catchments. The Williams River

Criteria	Weight	Comment
		catchment carries flow from a much larger upstream catchment and as such the rate of rise is considerably slower.
Duration of flooding	Low	Typically, the longer the duration of flooding, the more disruption caused to the community and greater the potential flood damages. The duration of flooding from the Williams River can be long, 12-48 hours, while flooding from the Myall Creek is shorter 6-24 hours, and local catchment flooding is likely to be 1-5 hours.
Effective warning and evacuation time	Medium	Flood warning and evacuation is subject to the rate of rise, the flood awareness of the community and availably of a flood warning system. While there is a flood warning system for the Williams River, there is currently no warning system for the Myall Creek or local catchment. While a flood warning system for the Myall Creek should be developed within 1-2 years, the local catchment is too small for a warning system to be of use.
Flood awareness and readiness of the community	Low	Flood awareness in the community is likely to be quite high due to the recent April 2015 flood event. However, ongoing community education will be required to ensure awareness and readiness are maintained in the future.
Effective flood access	Medium	Effective flood access is affected by depths and velocities of floodwaters, evacuation distance, the number of people using the evacuation route and effective communication. In the study area a number of streets could be inundated by floodwaters in larger events and consideration of evacuation timing is important. Flood access and evacuation issues are further discussed in Section 7.
Evacuation problems	Medium	Some flood prone areas are likely to experience evacuation problems in the catchments due to the rapid rate of rise of a flood event, the limited flood warning time and the demographics of the community. These problems could be further exacerbated by the time of day during which flooding occurs. However, in general most flood affected properties have relatively short evacuation distances. Evacuation is further discussed in Section 7.
Type of development	Medium	The type of development will influence factors such as the level of flood awareness, the mobility of occupants and population density. Long term residents are likely to have a higher level of flood awareness than those visiting the area. Further, mobility and evacuation is more difficult for a school, child care facility or aged care home.

An assessment of the variables presented in **Table 4-10** did not significantly change the flood hazard classifications using the AEMI classifications which are less influenced by these factors than the hazard classifications outlined in Appendix L of the NSW Floodplain Development Manual (NSW State Government, 2005). True flood hazard maps for the 5% AEP, 1% AEP and PMF events are presented in **Figure 4-8**, **Figure 4-9** and **Figure 4-10** respectively.



Royal HaskoningDHV
Enhancing Society Together

FIGURE 4-8

COMBINED TRUE FLOOD HAZARD
5% AEP (20yr ARI)

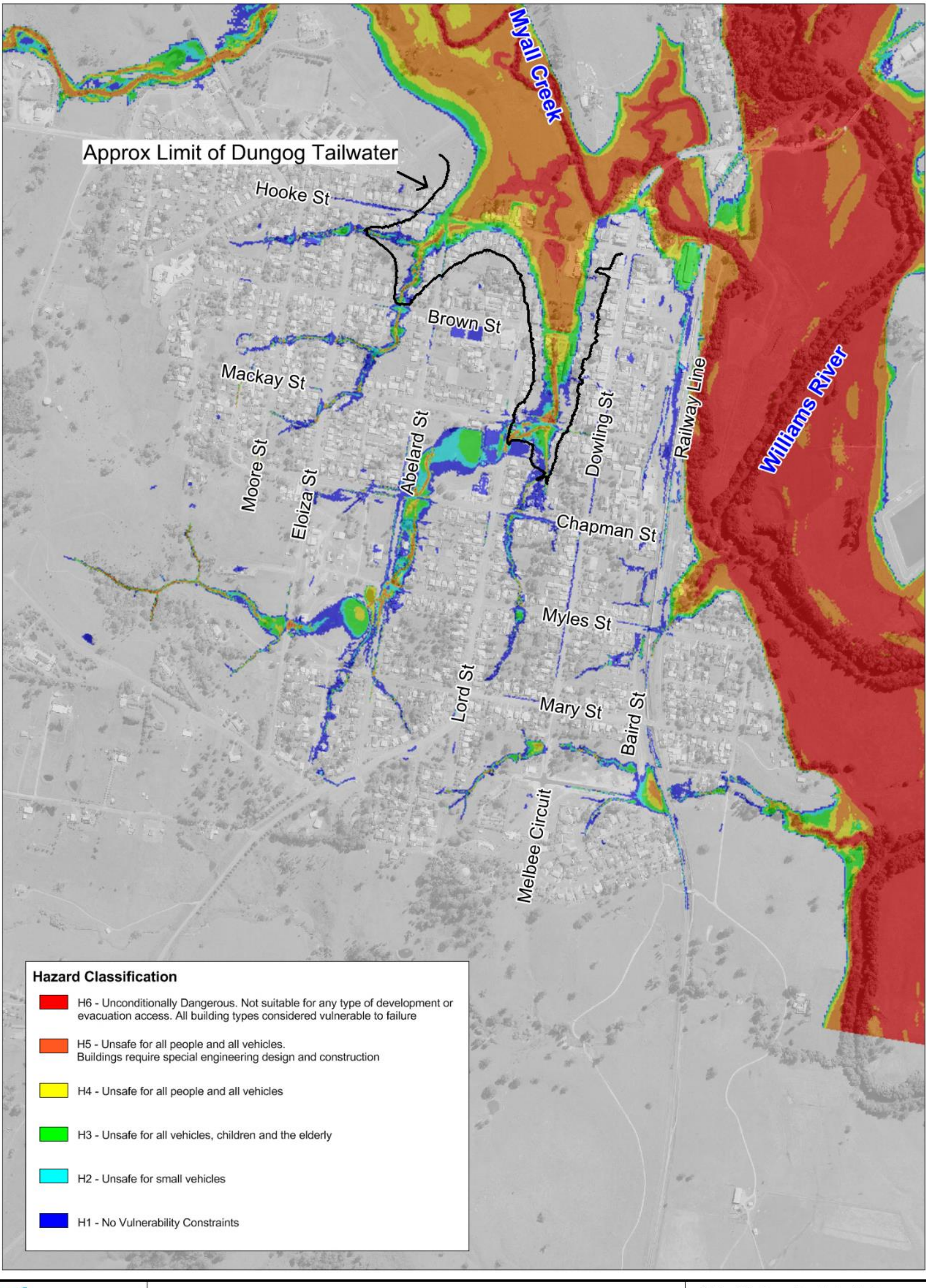
NORTH

0 125 250m
Approx. Scale

SCALE 1:12,500

PAGE SIZE A4

FILEPATH I:\Projects\PA1316_Dungog FPRMS&P\GIS\Workspaces\ReportFigs\FRMS\Figure_FloodHazard_AEM_020yr_v1a_A4.wor



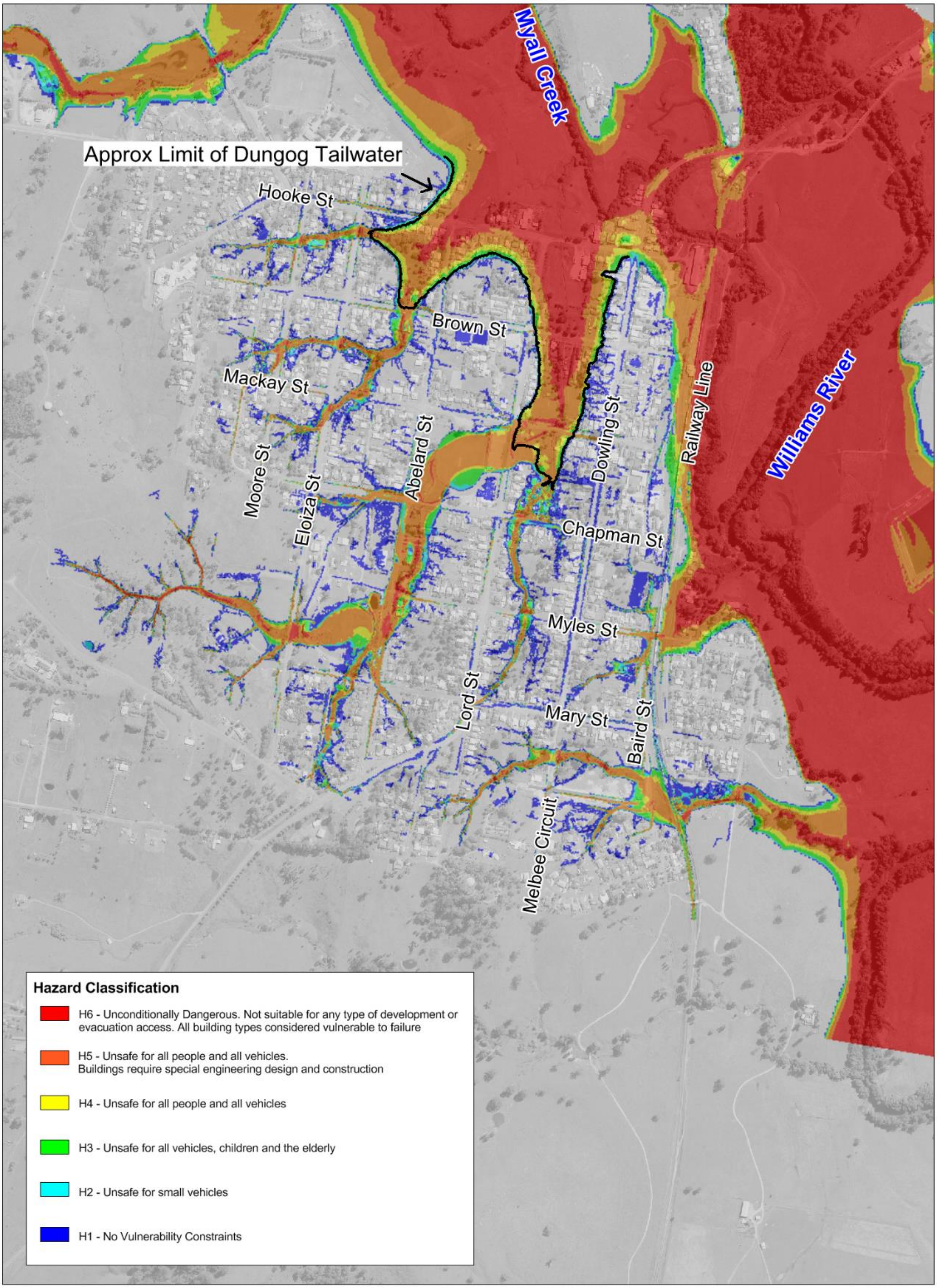
Royal HaskoningDHV
Enhancing Society Together

FIGURE 4-9

COMBINED TRUE FLOOD HAZARD
1% AEP (100yr ARI)

SCALE 1:12,500 PAGE SIZE A4

FILEPATH I:\Projects\PA1316_Dungog FPRMS&P\GIS\Workspaces\ReportFigs\FRMS\Figure_FloodHazard_AEM_100yr_v1a_A4.wor



Royal HaskoningDHV
Enhancing Society Together

FIGURE 4-10

COMBINED TRUE FLOOD HAZARD
PMF (EXTREME EVENT)

NORTH

0 125 250m
Approx. Scale

SCALE 1:12,500

PAGE SIZE A4

FILEPATH I:\Projects\PA1316_Dungog FPRMS&P\GIS\Workspaces\ReportFigs\FRMS\Figure_FloodHazard_AEM_PMF_v1a_A4.wor

4.6 Access and Evacuation Constraints (ERP Classification)

A key part of emergency planning and effective evacuation is identifying the barriers to flood access and implementing plans to overcome this. The majority of the study area has ease of egress to higher flood free areas, however the access routes to a number of key locations are likely to become inundated rapidly by floodwaters and as such encounter some evacuation difficulties. These key locations are listed below:

- ***Area 1:*** Properties between 44 and 62 Hooke Street may need to evacuate up the driveway of 60 Hooke Street (towards the grounds of the St Joseph Catholic School) due to road inundation.
- ***Area 2:*** the units at 30 Brown Street (Johnsons Flats) are raised above the floodplain, which means these units should be evacuated early to avoid the residents becoming trapped while "sheltering in place".

The NSW SES in collaboration with OEH developed the Flood Emergency Response Planning (ERP) classifications (NSW State Government, 2007) to categorize communities according to the ease of evacuation. These guidelines assist the planning and implementation of response strategies. These classifications are determined by analysis of inundation of land, road and overland evacuation routes. Communities are classified as Flood Islands, Rising Road Access, Overland Escape Route, Trapped Perimeter Areas or Indirectly Affected areas.

The Flood ERP Guidelines present these classifications in relation to operational functions such as resupply, rescue and evacuation shown in **Table 4-11**.

Table 4-11: Response Required for Difference Flood ERP Classifications

Classification	Response Required		
	Resupply	Rescue / Medivac	Evacuation
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Area with Rising Road Access	No	Possibly	Yes
Areas with Overland Escape Routes	No	Possibly	Yes
Low Trapped Perimeter	No	Yes	Yes
High Trapper Perimeter	Yes	Possibly	Possibly
Indirectly Affected Areas	Possibly	Possibly	Possibly

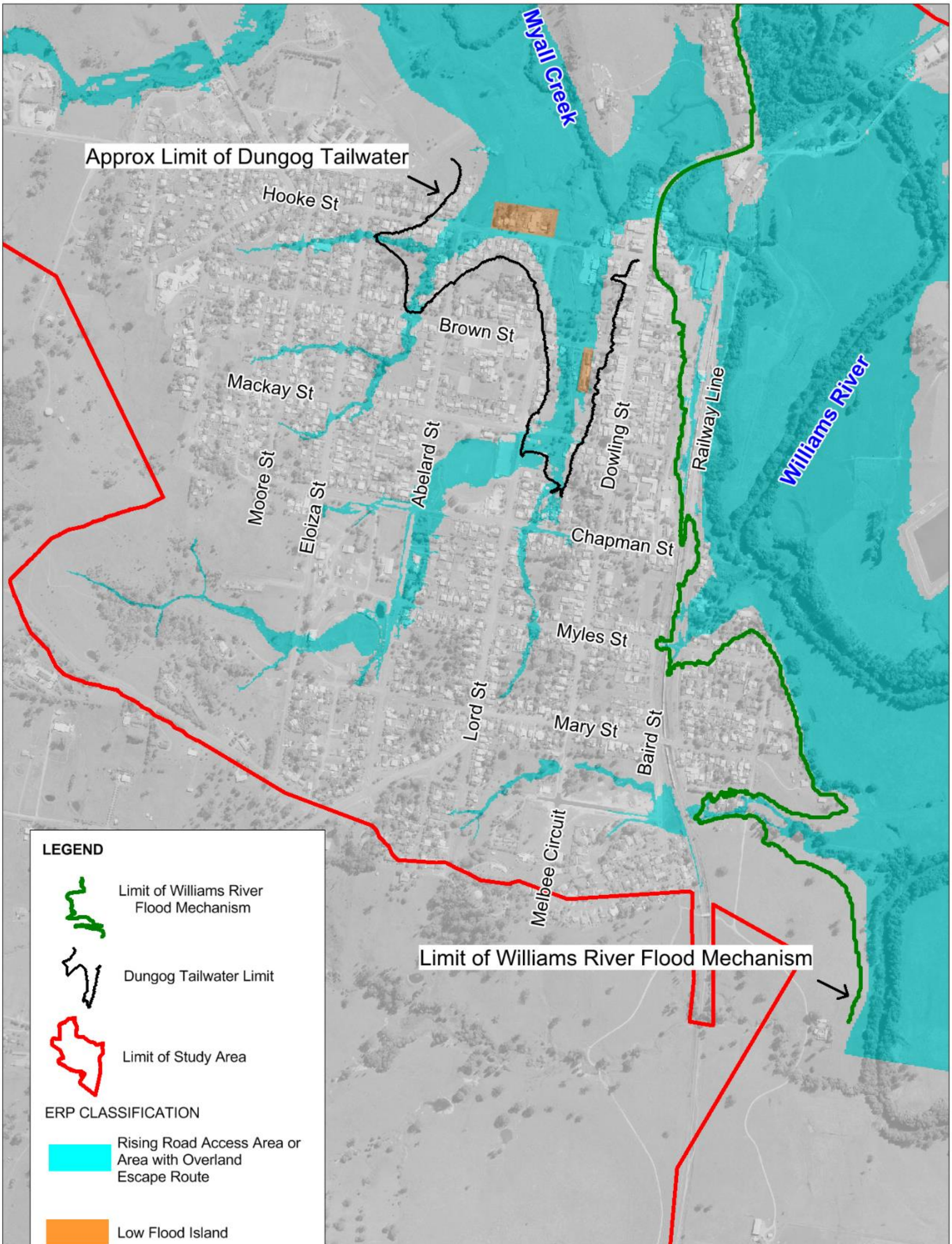
ERP classifications were determined for areas within the 1% AEP and PMF extents in the Study Area. These classifications are shown in **Figure 4-11** for the 1% AEP and **Figure 4-12** for the PMF event.

In the 1% AEP event, egress to flood free land is available for most of the study area. These areas will have flood free access to emergency services and other vital facilities. Of note are the two isolated areas classified as Low Flood Islands, previously described. Emergency Services (such as the SES) should be aware of the risk of isolation of these areas and the necessary actions (such as evacuation and/or shelter-in-place) outlined in their Local Flood Plan.

In the PMF event, the same two areas of the study area are classified as Low Flood Islands. These locations are subject to isolation and, subsequently, inundation from flood waters. The rapid rise of very rare to extreme events means that if these areas are not evacuated early, residents who opt to shelter in place may not survive as above ceiling flooding could occur for a number of properties.

Because the final magnitude of an flood event cannot be known until after the event, and the rate of rise is the Dungog tailwater is very high, the evacuation of areas identified in the PMF ERP Classification should occur in all significant flood events (where water levels in the Dungog tailwater are likely to exceed 48.0 m AHD (see **Table 7-2**)).

While the emergency response planning classifications detail broad areas requiring evacuation, this information should be used along with the property inundation assessment provided in **Section 4.2.2**. **Figure 4-6** shows the design flood event a property is first inundated in so provides very useful information to prioritise and schedule property evacuations.



Royal HaskoningDHV
Enhancing Society Together

© Haskoning Australia Pty Ltd

FIGURE 4-11

ERP CLASSIFICATION
1% AEP (100yr ARI) EVENT

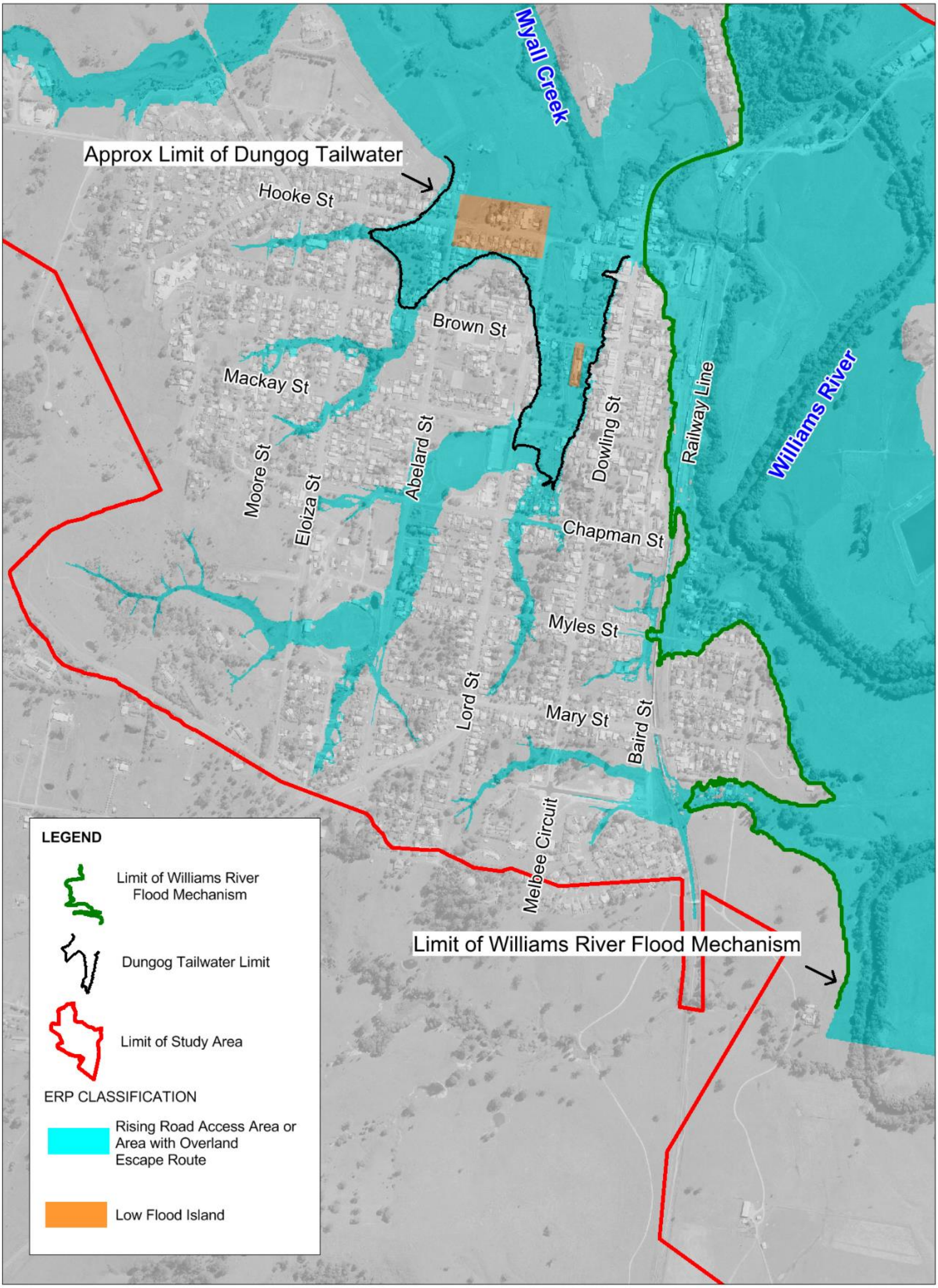
NORTH

0 125 250m
Approx. Scale

SCALE 1:12,500

PAGE SIZE A4

FILEPATH I:\Projects\PA1316_Dungog FPRMS&P\GIS\Workspaces\ReportFigs\FRMS\Figure_ERP_Classification_100yr_v1a_A4.wor



Royal HaskoningDHV
Enhancing Society Together

FIGURE 4-12

ERP CLASSIFICATION
PMF (EXTREME EVENT)

NORTH

0 125 250m
Approx. Scale

SCALE 1:12,500

PAGE SIZE A4

FILEPATH I:\Projects\PA1316_Dungog FPRMS&P\GIS\Workspaces\ReportFigs\FRMS\Figure_ERP_Classification_PMF_v1a_A4.wor

5 Review of Existing Planning Provisions

Within New South Wales, land use planning and development follows the following hierarchy, in decreasing order of seniority:

- Environmental Planning and Assessment Act (EPA Act)
- State Environmental Planning Policies (SEPP)
- Local Environmental Plans (LEPs)
- Development Control Plans (DCPs)

Land use planning and development controls are key mechanisms by which Council can manage some of the flood related risks within flood-affected areas of Dungog (as well as across the wider LGA).

In the Dungog LGA, development is controlled through the Dungog Local Environment Plan (LEP) and various Development Control Plans (DCPs). The LEP is a planning instrument which designates land use and development in the LGA, while DCPs regulate development with specific guidelines and parameters.

A review of existing planning controls has been undertaken with the objective to:

- review the existing planning and development control framework relevant to the formulation of planning instruments and the assessment of development applications in flood affected areas, and
- make specific planning recommendations in regards to flood risk management, including an outline of suggested planning controls (refer **Section 5.4**).

5.1 Local Environment Plan

A Local Environmental Plan (LEP) is prepared in accordance with Part 3 Division 4 of the EP&A Act 1979 and operates as a local planning instrument that establishes the framework for the planning and control of land uses. The LEP defines zones, permissible land uses within those zones, and specific development standards and special considerations with regard to the use or development of land.

The Dungog Local Environment Plan 2014 (LEP 2014) (Dungog Shire Council, 2014) has been prepared in accordance with the NSW State Government's Standard Instrument (Local Environmental Plans) Order 2006, which requires local Council's to implement a Standard Instrument LEP. The State Government has created the Standard Instrument LEP to assist in streamlining the NSW Planning system.

5.1.1 Flood Planning (Clause 6.3)

Clause 6.3 of the Dungog Local Environment Plan 2014 relates to development on flood liable land. The LEP provisions incorporate general considerations in regard to development of flood liable land. These provisions require the approval process to consider the impact of proposed development on local flood behaviour, the impact of flooding on the development and the requirements of adopted Floodplain Risk Management Plans that are applicable. Specifically Clause 6.3 states:

1) The objectives of this clause are as follows:

(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,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to:

(a) land identified as "Flood planning area" on the Flood Planning Map, and

(b) other land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) will not 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) will not 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.

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.

(5) In this clause, **flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.

5.1.2 Stormwater management (Clause 6.4)

Clause 6.4 of the Dungog Local Environment Plan 2014 relates to stormwater management. The LEP provisions incorporate general considerations in regard to stormwater impacts. These provisions require the approval process to consider the impact of stormwater on the environment or adjacent properties. Specifically Clause 6.3 states:

(1) The objective of this clause is to minimise the impacts of urban stormwater on land to which this clause applies and on adjoining properties, native bushland and receiving waters.

(2) This clause applies to all land in residential, business and industrial zones.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is designed to maximise the use of water permeable surfaces on the land having regard to the soil characteristics affecting on-site infiltration of water, and

(b) includes, if practicable, on-site stormwater retention for use as an alternative supply to mains water, groundwater or river water, and

(c) avoids any significant adverse impacts of stormwater runoff on adjoining properties, native bushland and receiving waters, or if that impact cannot be reasonably avoided, minimises and mitigates the impact.

5.1.3 Land Use

The Dungog LEP 2014 identifies a number of land use zones including existing and future development areas, based on stated objectives for each zoning and provisions made for each zoning. The land use zones under the Dungog LEP 2014 are as follows:

- Rural Zones: RU1 Primary Production, RU3 Forestry and RU5 Village;
- Residential Zones: R1 General Residential and R5 Large Lot Residential;
- Business Zones: B2 Local Centre and B4 Mixed Use;
- Industrial Zones: IN1 General Industrial;
- Special Purpose Zones: SP2 Infrastructure;
- Recreation Zones: RE1 Public Recreation and RE2 Private Recreation;
- Environment Protection Zones: E1 National Parks and Nature Reserves, E3 Environmental Management and E4 Environmental Living; and
- Waterway Zones: W1 Natural Waterways.

Within the Study area there are four main land use zones as described below and shown in **Figure 5-1**.

R1 – General Residential - This zone is generally intended to provide for the housing needs of the community and to enable other land uses that provide facilities or services to meet the day to day needs of residents.
B2 – Local Centre – This zone is generally intended to provide a range of retail, business, entertainment and community uses that serve the need of people who live in, work in and visit the local area. The catchment area located within this zone also contains some residential development.
RE1 – Public Recreation – This zone is generally intended to be used for public open space or recreational purposes and provide a range of recreational settings and activities and compatible land uses.
E3 – Environmental Management – This zone is generally intended to: protect, manage and restore areas with special ecological, scientific, cultural or aesthetic values; provide for a limited range of development that does not have an adverse effect on those values; and promote the rural amenity and scenic landscape values of the area and prevent the silhouetting of unsympathetic development on ridgelines.

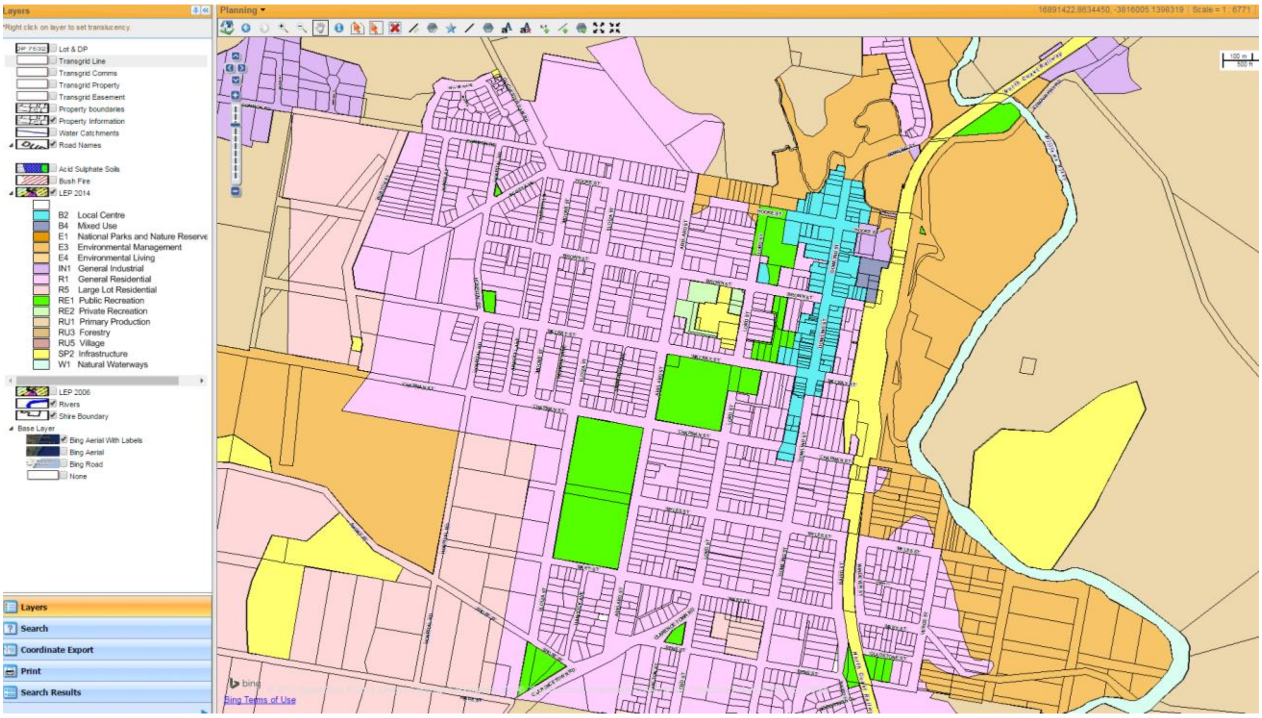


Figure 5-1: Dungog Land Use Zones (LEP 2014)

A review of the LEP 2014 land use zones in relation to flooding indicates that the LEP is yet to be updated to consider the properties (to the south of Bennett Bridge) that were washed away during the April 2015 major flood event, that have subsequently been purchased by Council. It is recommended that these areas are rezoned with a land use compatible with the high flood risk experience in this location.

5.1.4 Flood Planning Maps

The existing LEP 2014 Flood Planning Map is presented in **Figure 5-2**. It appears that the currently adopted flood planning area is based on the Williams River Flood Study (BMT WBM, 2009). The flood planning area should be updated based on the current Dungog Flood Study when the LEP is next revised. It is recommended that the flood maps are moved from the LEP to a location (i.e. document or online map server) that can be more easily updated.

Figure 5-2: Dungog Flood Planning Area Map (LEP 2014 – FLD_009AC)

5.2 Development Control Plan

A draft of the proposed update to the “Managing our Floodplains” section (currently Section 8 of Part C of the Dungog Development Control Plan No 1 (Dungog Shire Council (2004)), was provided to RHDHV by Dungog Council for review. The draft is expected to replace the existing plan which was adopted in May 2004.

The DCP floodplain management policy is used to assess development proposals to determine if they are permissible and the required controls.

The policy looks at:

- The land use category of the proposed development,
- The part/type of the floodplain the development is proposed,
- The required controls (i.e. minimum building levels and building materials) to make the development permissible.

The policy also specifies the required information used to assess a development application. The policy provides details on permissible fencing requirements and guidance on the required documentation for house raising applications.

The adopted land use categories are defined in Schedule 1 and include:

1. Essential community facilities
2. Critical utilities
3. Subdivision and filling
4. Residential
5. Commercial or Industrial
6. Recreation or agriculture
7. Minor development

The adopted floodplain management zones used in the floodplain management matrix (Schedule 2) are defined in the below table.

FLOODPLAIN MANAGEMENT ZONES	CRITERIA
1. Floodway and Excessive Depth Zone	Floodway or depth > 4m in 1% AEP event
2. High Risk (Velocity and Depth) Zone	Remaining area where provisional hazard is high in 1% AEP event
3. Isolated Islands Zone	Remaining area where evacuation is possible only through Zones 1 or 2
4. Low Risk Zone	Remaining area below extreme flood level

The definition of these zones are presented in the Paterson River Floodplain Management Study Report (Bewsher Consulting, 2001). While the DCP notes that,

"the name of the floodplain management zone may vary between flood studies, however the zone shall be taken to mean the equivalent zone which meets the Criteria listed in column 2."

An examination of the Clarence Town FRMS (BMT WBM, 2014) indicates that in some instances there is no directly comparable zone. Also these floodplain management zones do not appear to be in agreement with those specified in the Department of Planning Circular PS 07—03 (see Section 5.3.1). It is recommended that floodplain management zones presented in SCHEDULE 4 - OTHER FLOODPLAIN AREAS PLANNING MATRIX CONTROLS of the current DCP be adopted.

The adopted flood planning level definitions are presented in Schedule 3 as defined in the below table. It should be noted that the adoption of the 0.5% AEP FPL for the Paterson River floodplain do not appear to be in agreement with the guidance provided in Department of Planning Circular PS 07—03 (see Section 5.3.1) which states that unless there are exceptional circumstances, the FPL should be defined as the 1% AEP (with appropriate freeboard).

Location	Flood Planning Level
Paterson River Floodplain	0.5% AEP level
All other Floodplains	1% AEP level plus 500mm freeboard

The adopted planning matrix is defined in Schedule 2 of the draft DCP, and provides information regarding suitable land uses and the required development control considerations. Considering that both the adopted floodplain management zones and FPL are not in agreement with the guidance provided in Department of Planning Circular PS 07—03 (see Section 5.3.1) it is likely that this schedule will need to be updated to be more in line with Schedule 4 of the existing DCP which is presented in **Figure 5-3**.

This matrix of planning controls is used to define development controls within the floodplain (as defined in Councils DCP 1 – Managing Our Floodplains) and define suitable provisions for the following (assuming the recommended 1% AEP flood level plus 0.5m freeboard provision is incorporated into the DCP):

- Restricting development in high hazard areas of the floodplain;
- Specifying minimum floor levels;
- the use of flood compatible building components below a certain level;
- that structures located in high flood risk areas are structurally sound;
- that development does not increase flood behaviour elsewhere;
- maximising opportunities for people to safely evacuate;
- maximising opportunities for flood awareness; and
- other specific considerations regarding the management and design of the property.

There are however, some recommendations for additions to the development control matrix including:

- Lowest habitable floor levels should be elevated above finished ground level.
- Proponents encouraged to construct at higher levels with available flood level information across a range of design flood magnitudes (up to Extreme Flood Level (i.e. PMF)).

SCHEDULE 4 - OTHER FLOODPLAIN AREAS PLANNING MATRIX CONTROLS

Development Control Consideration	FLOODPLAIN MANAGEMENT BAND: OUTER FLOODPLAIN ABOVE 1% AEP FLOOD (PLUS 0.5 FREEBOARD) TO EF							FLOOD FRINGE BETWEEN HIGHHAZARD AREA TO 1% AEP FLOOD (PLUS 0.5m FREEBOARD)							FLOODWAY HIGH HAZARD AREA						
	Essential Comm. Facilities	Critical Utilities	Subdivision and Filling	Residential	Commercial or Industrial	Recreation or Agriculture	Minor Development	Essential Comm. Facilities	Critical Utilities	Subdivision and Filling	Residential	Commercial or Industrial	Recreation or Agriculture	Minor Development	Essential Comm Facilities	Critical Utilities	Subdivision & Filling	Residential	Commercial or Industrial	Recreation or Agric	Minor Development
Floor Level	3	3									2	2 or 5	1	4						1	4
Building Components	2	2									1	1	1	1						1	1
Structural Soundness	2	2								1	1	1	1	1						1	1
Flood Affection	2	2	2		2					1	2	2	2	2						1	1
Evacuation/ Access	2	2	3		3					1,3	3	3	3							1,3	3
Flood awareness	2	2	2	2	2	2	2			1,2	2	2	2	2						2	2
Management and Design	1	1	4							4	1,2,3	1,2,3	1,2,3	1,3						1,2,3	1,2,3

Unsuitable land use

Not relevant

EF REFERS TO THE PROBABLE MAXIMUM OR EXTREME FLOOD

FLOOR LEVEL

1	All Floor levels to be equal to or greater than the 5% AEP Flood level plus 0.5m (Freeboard) unless determined by a risk assessment
2	Floor levels (excluding non-habitable residential floorspace) to be equal to or greater than the 1% AEP flood plus 0.5m (freeboard) and other floor levels equal to or greater than the 1% AEP flood (no freeboard).
3	All floor levels to be equal to or greater than the EF level.
4	Floor levels to be as close to the design floor level as practical and no lower than the existing floor level when an addition to an existing building.
5	Floor levels of shops and offices to be as close to the 1% AEP flood level plus 0.5 m (freeboard) as practical or more than 30% of floor area or equivalent storage space to be above the 1% AEP flood level plus 0.5 m (freeboard), or premises to be flood proofed (eg. Flood shutters for the shops) below the design floor level.

FLOOD COMPATIBLE BUILDING COMPONENTS

1	All structures to have flood compatible building components below or at the 1%AEP Flood Level plus 0.5m (freeboard)
2	All structures to have flood compatible building components below or at the EF Level

STRUCTURAL SOUNDNESS

1	Engineers certificate to confirm any structure subject to a flood up to and including the 1% AEP flood level can withstand the force of flood water, debris and buoyancy.
2	Engineers certificate to confirm any structure subject to a flood up to and including the EF level can withstand the force of flood water, debris and buoyancy.

FLOOD EFFECT ON OTHERS

1	Engineers report required to prove that the development of an existing allotment will not increase flood affection elsewhere.
2	The impact of the development on flood affection elsewhere to be considered.

EVACUATION ACCESS

1	Reliable access for pedestrians required during a 1% AEP flood.
2	Reliable access for pedestrians and vehicles required at or above the EF level.
3	Consideration required regarding an appropriate flood evacuation strategy & pedestrian / vehicular access route for both before and during a flood.

FLOOD AWARENESS

1	Restrictions to be placed on title advising of minimum floor levels required relative to the flood level.
2	S149(2) certificates to notify of applicability of this DCP

MANAGEMENT AND DESIGN

1	Flood plan required where floor levels are below the design floor level.
2	Applicant to Demonstrate that there is an area where goods may be stored above the 1% AEP flood level plus 0.5m (freeboard) during floods.
3	Applicant to provide controls where necessary to prevent the discharge of pollution during floods, including compliance with the 'Environmental and Health Protection Guidelines – On-site Sewage Management for Single Households' dated February 1998 and published by the State Government.
4	Applicant to demonstrate that potential development as a consequence of a subdivision proposal can be undertaken without any significant flood effect elsewhere and can access an appropriate pedestrian / vehicular route as part of a flood evacuation strategy if required.

Figure 5-3: Planning Matrix Controls in Current Dungog DCP

5.3 Flood Planning Level Considerations

Department of Planning Circular PS 07—03 (see Section 5.3.1) and associated guideline on development controls on low risk flood areas states:

"unless there are exceptional circumstances, councils should adopt the 100-year flood as the FPL for residential development. In proposing a case for exceptional circumstances, a council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood."

If Dungog Council was to adopt a different FPL to the above, approval would have to be sought from the Department of Natural Resources (DoNR) and the Department of Planning (DoP). Given the severity and impact of the flooding that occurred during the April 2015 event, it is anticipated that the DoNR and DoP would accept this as an "exceptional circumstance" and consider a higher than normal FPL. However, it could be argued that, provided that a suitable flood warning system can be developed and safe evacuation paths established, it is possible that the 1% AEP, with 0.5m freeboard may be sufficient for Dungog.

A summary of relevant and historic FPL and flood levels is provided in **Table 5-1.** It shows that a "standard" FPL of 50.7 m AHD is applicable for the Hooke Street (backwater area). If a flood of similar magnitude to the April 2015 "superstorm" occurred again, this would result in water depths of 1.3m occurring in habitable areas of new developments. This is considered a "survivable depth" for most people. However, this 1.3m depth is not considered a "survivable depth" for mobility impaired (i.e. wheelchair bound) or elderly residents. Therefore, given the high portion of older residents in Dungog, it is strongly recommended that a higher FPL than the "standard" 100yr ARI with 0.5m freeboard is adopted in the Dungog tailwater.

Table 5-1: Summary of Historic Flood Planning Levels (FPL) in Dungog

Year	Hooke St FPL (m AHD)	Comments
1979	49.8	Minimum Floor Level of Alison Court (Approved in 1979 and constructed in 1980's. Based on the observed "Top Flood Level" of 48.8mAHD (Yeo, 2015a)
1989/2004	52.0	An FPL for Dungog of 52.0mAHD is presented in the "Managing our Floodplains" Chapter (Adopted May 2004) of the Dungog Shire Wide DCP No 1. See below note (a) for details regarding this level.
2009	50.10	Williams River Flood Study (BMT WBM, 2009), 1% AEP Williams River and Tributaries + 0.5m
November 2015	50.90	Dungog Post Event Flood Behaviour Analysis (BMT WBM, 2015), 1% AEP Myall Creek with 5% AEP Williams River + 0.5m
2017	50.70	Dungog Flood Study (RHDHV, 2017), 1% AEP Myall Creek with 10% AEP Williams River + 0.5m
Observed April 2015 Flood Level	**52.0 (FL not FPL)**	**This event was extreme and is estimated be approximately a 0.1% AEP/ 1000yr ARI.**

Note (a): The level at Dungog is depicted on the map at around the 52m AHD level but there is no textural annotation attached to the map give an exact recorded level. The recurrence interval is not known for this flood and it is assumed to be a 'highest observed' flood. The map is dated 11th July 1989.

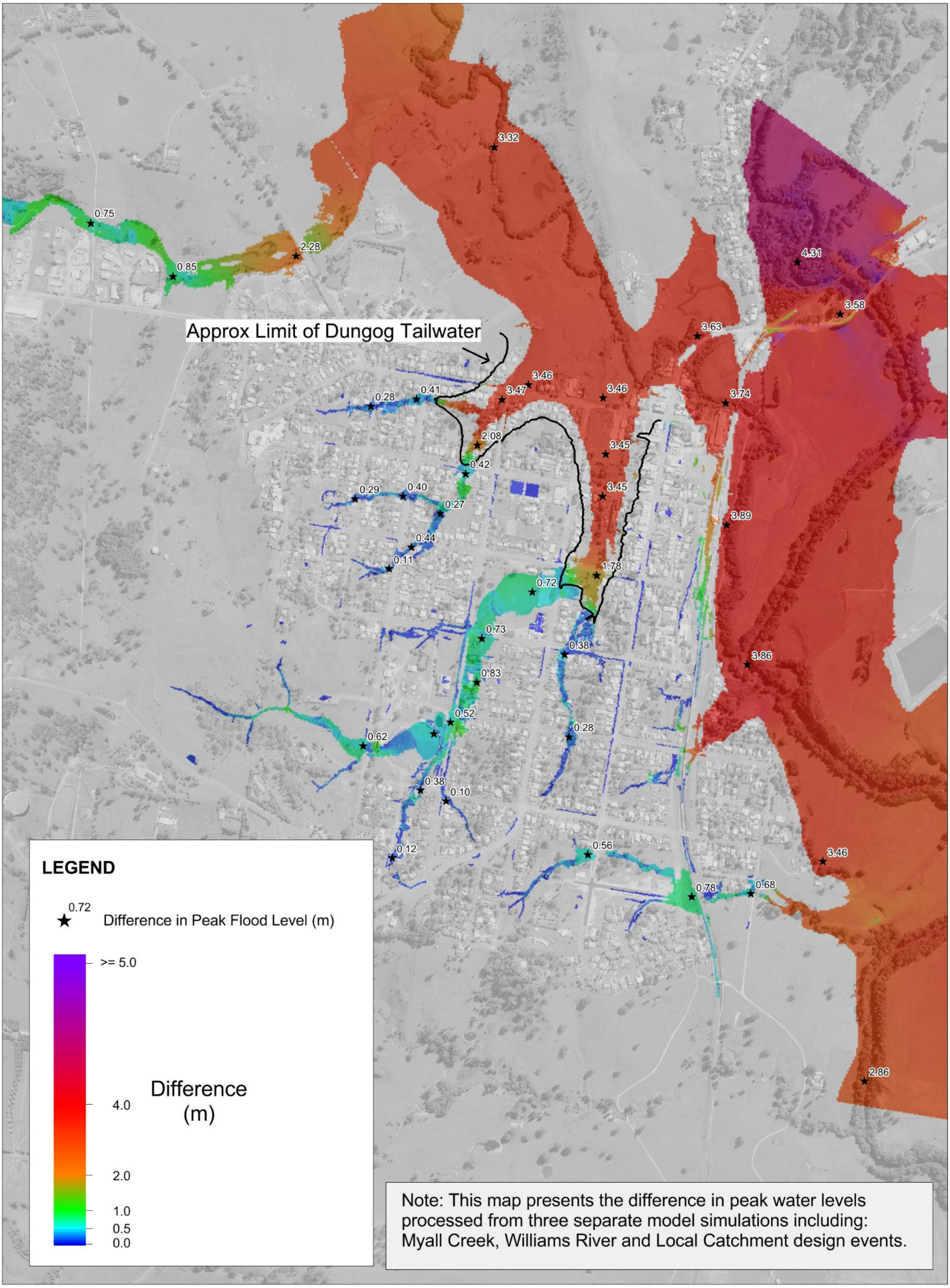
A summary of peak design flood levels from Royal HaskoningDHV (2017) for the Hooke Street tailwater for a number of design flood events is shown in **Table 5-2**.

Table 5-2: Design Peak Water Levels in Dungog Tailwater (Hooke Street)

Design Conditions AEP / ARI	Peak Flood Level (m AHD)
1% / 100yr	**50.2 (FPL = 50.7 (i.e. with 0.5 freeboard))**
0.5% / 200yr	50.64
0.2% / 500yr	51.11
PMF	53.65
April 2015	51.98

While the Department of Planning Circular PS 07—03 means that the setting of a higher FPL may be difficult, it is recommended that Council seek the adoption of a FPL based on the 500yr ARI level of 51.1 m AHD. A free-board of up to 0.5m (i.e. FPL of 51.6 m AHD) should be considered to further increase the survivability for mobility impaired (i.e. wheelchair bound or elderly) residents. It is recommended that Council adopts this higher FPL until the effectiveness of the proposed flood warning system (as presented in **Section 7**)) is fully assessed. If a future Council review finds that the flood warning system is able to effectively reduce the risk to life in severe events, the reduction of the FPL towards the more typical 1% AEP with 0.5m freeboard could be considered.

Further justification of the benefit of applying for a higher than standard FPL in the Dungog tailwater is due to the specific flood behaviour in this area, due to the floodplain constrictions at Bennett Bridge and the Myall Creek Rail Bridge. The difference in peak flood levels in the PMF (i.e. extreme flood) and the 1% AEP (100yr ARI) flood are presented in **Figure 5-4**. The figures shows that in the Dungog tailwater the PMF is nearly 3.5 m higher than the 100yr ARI flood levels, while in the local catchment flood areas, the PMF levels are only 0.1 to 0.8 m higher than the 100yr ARI flood levels. A further example of how rare (i.e. > 100yr ARI magnitude) floods in the Dungog tailwater area could result in risk to life is presented in **Figure 5-5** which maps the difference in peak flood levels in the 0.2% AEP (500yr ARI) and the 1% AEP (100yr ARI). The figure shows that in the Dungog tailwater, the 500yr event is nearly 0.9 m higher than the 100yr ARI flood levels, while in the local catchment flood areas, the 500yr levels are only 0.01 to 0.2 m higher than the 100yr ARI flood levels. These two figures highlight the difference in flood behaviour in extreme events on the local catchment and the Dungog tailwater area.



Royal HaskoningDHV
Enhancing Society Together

FIGURE 5-4

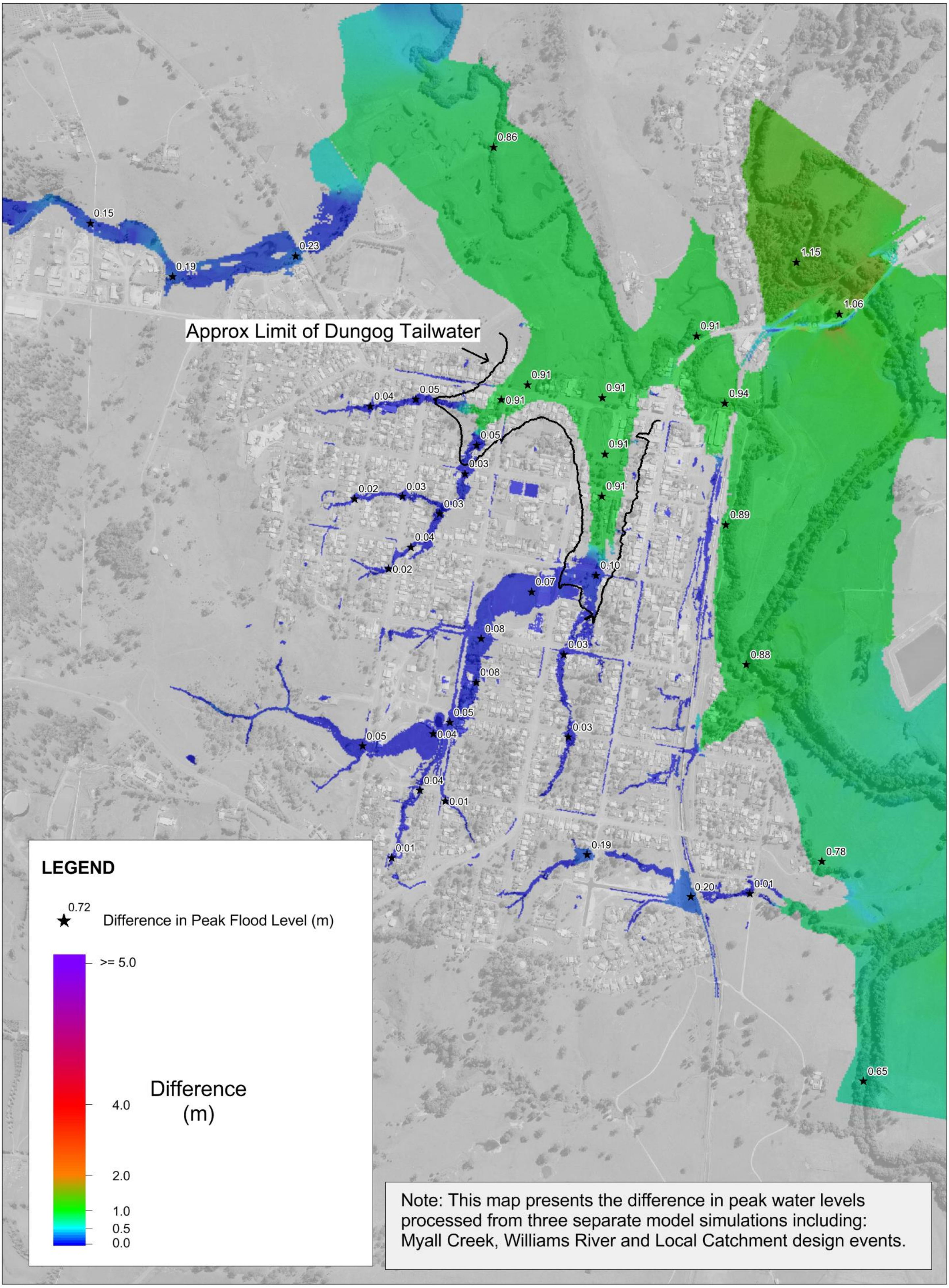
DIFFERENCE BETWEEN PEAK FLOOD LEVELS (PMF AND 100YR ARI (1% AEP) EVENT)

NORTH

0 125 250m
Approx. Scale

SCALE 1:20,000 PAGE SIZE A4

FILEPATH I:\Projects\PA1316_Dungog FPRMS&P\GIS\Workspaces\ReportFigs\FRMS\Figure_Diff_PMF-100yr_v1b_A4rs.WOR



Note: This map presents the difference in peak water levels processed from three separate model simulations including: Myall Creek, Williams River and Local Catchment design events.

Royal HaskoningDHV
Enhancing Society Together

FIGURE 5-5

DIFFERENCE BETWEEN PEAK FLOOD LEVELS (500yr (0.2%AEP) AND 100YR ARI (1% AEP) EVENT)

NORTH

0 125 250m
Approx. Scale

SCALE 1:20,000 PAGE SIZE A4

FILEPATH I:\Projects\PA1316_Dungog FPRMS&P\GIS\Workspaces\ReportFigs\FRMS\Figure_Diff_500yr-100yr_v1b_A4rs.WOR

5.3.1 Department of Planning Circular PS 07—03 (2007)

The circular and (NSW Government Department of Planning, 2007) provides an overview of a new guideline (on development controls on low risk flood areas) to the Floodplain Development Manual and changes to the Environmental Planning and Assessment Regulation 2000 and section 117 Direction on flood prone land.

Relevant sections from the Guideline are shown below.

Categories of Flood Prone Land

To balance protection of existing and future inhabitants from flood hazard and the potential danger and damage associated with use of the flood prone land, the Manual promotes the appropriate use of flood prone land by breaking it down into areas dependent upon frequency of inundation, their hydraulic function (floodways in which floodwaters are conveyed, flood storage areas where flood waters are temporarily stored during flood events, and flood fringe areas) and flood hazard (a minimum of two categories, high and low). These categories assist councils in determining appropriate development limits and controls to reflect the variation in flood risk across flood prone land and the associated consequences on residents and their property. Key categories are:

1. Floodways: Floodways are the areas of the floodplain which are essential to convey flood waters. Development of these areas would have significant adverse impacts upon flood behaviour which in turn may result in adverse effects on other development and the community. Development of floodways would also expose occupants and their property to significant levels of flood danger and damage.

2. Below the residential FPL: The area of the floodplain where residential development is subject to flood related development controls, i.e. below the residential FPL (as determined in accordance with the Floodplain Development Manual). These are the areas of the floodplain where development limits and controls are used to reduce the frequency of exposure of people and property to flood risk and the associated danger and damage. Development controls in this area need may limit the area that can be developed and may include minimum fill levels, minimum floor levels, the requirement to use flood compatible building materials and need to address emergency management issues as outlined in (3) below.

3. Above the residential FPL: The area of flood prone land above the residential FPL and therefore these are areas where residential development is not subject to flood related development controls. These areas generally have a low risk of flooding and are sometimes known as low flood risk areas. As such, they are areas where no development controls should apply for residential development but the safety of people and associated emergency response management needs to be considered and may result in:

- *Restrictions on types of development which are particularly vulnerable to emergency response, for example developments for aged care.*
- *Restrictions on critical emergency response and recovery facilities and infrastructure. These aim to ensure that these facilities and the infrastructure can fulfil their emergency response and recovery functions during and after a flood event. Examples include evacuation centres and routes, hospitals and major utility facilities.*

Standards for Flood Controls for Residential Development

Councils are responsible for determining the appropriate flood planning levels for land within their local government area. Whilst the flood used to determine the residential FPL is a decision of the local council, the Manual highlights that FPLs for typical residential development would generally be based around the 100 year flood plus an appropriate freeboard (typically 0.5m).

This Guideline confirms that, unless there are exceptional circumstances, councils should adopt the 100 year flood as the FPL for residential development. In proposing a case for exceptional circumstances, a Council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood.

Unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land with a low probability of flooding, that is, land above the residential FPL (low flood risk areas).

Justification for variations to the above should be provided in writing to, and agreed by, the Department of Natural Resources and the Department of Planning prior to exhibition of a draft local environmental plan or a draft development control plan that proposes to introduce flood related development controls on residential development.

5.4 Review of Floodplain Management Aspects of Dungog Planning Policy's

A review of the floodplain management aspects of current or proposed Dungog Planning Policy (i.e. LEP 2014 and the DCP) indicates that the LEP appears to be in line with regulatory requirements, however, it could be improved by considering the following points:

- The LEP is yet to be updated to consider the properties (to the south of Bennett Bridge) washed away during the April 2015 storm that have subsequently been purchased by Council. It is recommended that these areas are rezoned with a land use compatible with the high flood risk experienced at this location.
- Mapping is currently based on the Williams River Flood Study (BMT WBM, 2009) and should be updated to use output from the current Dungog Flood Study (Royal HaskoningDHV, 2017).
- While the stormwater management policy in Clause 6.4 of the Dungog LEP 2014, reduces the likelihood of future developments generating additional runoff, the policy could be strengthened by requiring new developments to introduce stormwater controls that result in no increase in peak offsite discharge.

A review of the floodplain management aspects of the current or proposed Dungog DCP indicates the DCP is not in line with regulatory requirements (i.e. the Department of Planning Circular PS 07—03). It should be improved by considering the following points:

- Adoption of the floodplain planning control matrix provided in Schedule 4 of the current DCP (**Figure 5-3**).
- Adoption of the 1% AEP (+ 0.5m freeboard) FPL for all floodplains excluding the Dungog tailwater (where the April 2015 event provides sufficient evidence for the adoption of a higher FPL of up to 51.6 m AHD) which would provide for reduced risk to life in Dungog during extreme events.

- Adoption of the "Child care centres and Housing for Aged and Disabled persons" in the "Essential Community Facilities or Sensitive Land User" as per the proposed, not the current DCP. This is required due to the difficulties posed by evacuation of these facilities during flood events.

In addition to the above points the following should be considered:

- Lowest habitable floor levels should be elevated 0.2 m above finished ground level.
- Proponents encouraged to construct at higher levels with available flood level information across range of design flood magnitudes (up to Extreme Flood Level).
- Quantifying a practical/sensible limit on increases in flood affection. i.e. minor increases in local flooding of up to 0.1 m within 10 m of a development that do not impact on an existing or planned building will be considered. Outside of this immediate area, changes of up to 2 cm will be considered on a merits based approach.
- It is recommended that the flood maps are moved from the LEP to a location (i.e. document or online map server) that can be more easily updated.