HENTY FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

GREATER HUME SHIRE COUNCIL

FINAL REPORT

APRIL 2017

Level 2, 160 Clarence Street
Sydney, NSW, 2000

Tel: 02 9299 2855
Fax: 02 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

HENTY – FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL REPORT

SEPTEMBER 2017

Project Henty – Floodplain Risk Management Study and Plan	**Project Number** 114040
Client Greater Hume Shire Council	**Client's Representative** Michael Oliver
Authors Zac Richards Beth Marson Stephen Yeo Neil Kennan	**Prepared by**  Zac Richards
Date 20 September 2017	**Verified by**  Steve Gray

Revision	Description	Date
3	Final	April 2017
2	Draft Final Report	January 2017
1	Draft Report	November 2015

HENTY – FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

TABLE OF CONTENTS

LIST OF APPENDICES

Appendix A: Glossary
Appendix B: Survey Brief
Appendix C: Community Consultation Newsletter and Questionnaire
Appendix D: Hydraulic Categorisation – Floodway Definition
Appendix E: Flood Damages Assessment
Appendix F: Draft Flood Management Development Control Plans & Policy
Appendix G: Management Options Mapping
Appendix H: Mitigation Option Details

LIST OF FIGURES

LIST OF TABLES

LIST OF DIAGRAMS

ACRONYMS

AAD	Annual Average Damages
ABCB	Australian Building Codes Board
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ALS	Airborne Laser Survey (also see LiDAR)
ARI	Average Recurrence Interval
ARTC	Australian Rail Track Corporation
AWE	Average Weekly Earnings
B/C	Benefit Cost Ratio
BCA	Building Codes Australia
BoM	Bureau of Meteorology
CFERP	Community Flood Emergency Response Plan
CMA	Catchment Management Authority
DA	Development Application
DCP	Development Control Plan
DEM	Digital Elevation Model (A grid of terrain elevations usually obtained from ALS)
DRM	Direct Rainfall Method
EP&A Act	Environmental Planning and Assessment Act
EPA	Environmental Protection Authority
ERP	Emergency Response Planning
FPA	Flood Planning Area
FPL	Flood Planning Level
FRMC	Flood Risk Management Committee
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
IPCC	Intergovernmental Panel for Climate Change
LEP	Local Environment Plan
LFP	Local Flood Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging (also see ALS)
mAHD	Meters above Australian High Datum
MHL	Manly Hydraulics Laboratory
NCC	National Construction Code
OEH	Office of Environment and Heritage
OSD	On Site Detention

PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PWD	Public Works Department
RMS	Roads and Maritime Services (formerly RTA)
SEPP	State Environmental Planning Policy
SES	State Emergency Services
TUFLOW	A one-dimensional (1D) and two-dimensional (2D) hydraulic computer model
WBNM	Watershed Bounded Network Model (hydrologic computer model)
WSUD	Water Sensitive Urban Design

In addition to the above listed Acronyms, a Glossary of terms is presented in Appendix A.

FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions 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.

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 in the execution of their floodplain management responsibilities. The Federal Government may also provide subsidies in some circumstances.

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

1. ***Flood Study***
   - Determine the nature and extent of the flood problem.
2. ***Floodplain Risk Management***
   - Evaluates management options for the floodplain in respect of both existing and proposed development.
3. ***Floodplain Risk Management Plan***
   - Involves formal adoption by Council of a plan of management for the floodplain.
4. ***Implementation of the Plan***
   - Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

This report relates to the Floodplain Risk Management Study and Floodplain Risk Management Plan phases of the process.

The Henty Floodplain Risk Management Study & Plan (FRMS&P) presented herein constitutes the second and third stages in the NSW Floodplain Risk Management Program for the township of Henty and follows on from the Flood Study prepared in September 2013. WMAwater have been engaged by Greater Hume Shire Council to prepare this FRMS&P under the guidance of Council's Floodplain Risk Management Committee (FRMC).

This report has been prepared with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

1. INTRODUCTION AND BACKGROUND

This Study has been prepared by WMAwater on behalf of Greater Hume Shire Council (Council). The Study is composed of two phases:

1. The Henty Floodplain Risk Management Study; and
2. The Henty Floodplain Risk Management Plan.

This document details; The Henty Floodplain Risk Management Study; and The Henty Floodplain Risk Management Plan (abbreviated to FRMS&P). This FRMS&P follows on from the Flood Study which defined the design flood behaviour in the township of Henty under existing conditions to determine the nature and extent of the existing flood problem.

1.1. Objectives

The main objective of this FRMS&P is to identify floodplain risk, test amelioration strategies for the management of risk and to put forward priorities and approximately costed recommendations in regards to flood risk mitigation at Henty.

Council requires consideration of a range of management options to effectively manage existing, future and continuing flood risks at Henty. The outcomes from the Floodplain Risk Management Study and Floodplain Risk Management Plan will also assist the SES in preparing a Local Flood Plan for Henty.

The Objectives are more specifically described in Section 1.1.1 and 1.1.2 below.

1.1.1. Floodplain Risk Management Study Objectives

The objective of the Floodplain Risk Management Study is to investigate a range of flood mitigation works and measures to address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Policy. This includes:

- Review of Council's existing environmental planning policies and instruments including Council's long term planning strategies for the Study Area;
- Obtain damage estimates under the range of design floods mentioned under existing conditions;
- Identification of works, measures and restrictions aimed to reduce the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events;
- To assess the effectiveness of the works and measures for reducing the effect of flooding on the community and development, both existing and future;
- To consider whether the proposed works and measures might produce adverse effects (environmental, social, economic, or flooding) in the floodplain and whether they can be minimised;
- Examination of the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's developments and disaster planning requirements;

- Examine ways in which the river and floodplain environment may be enhanced by preparing a strategy for vegetation planning that will create a valuable corridor of vegetation without having a detrimental effect on flooding; and
- Identification of modifications required to current policies in the light of investigations.

1.1.2. Floodplain Risk Management Plan Objectives

The Floodplain Risk Management Plan makes a range of recommendations relating to flood mitigation works and measures that address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Policy. The recommended works and measures presented in the Plan are aimed to:

- Reduce the flood hazard and risk to people and property in the community and to ensure future development is controlled in a manner consistent with the flood hazard and risk;
- Reduce private and public losses due to flooding;
- Protect and, where possible, enhance watercourses/creeks and floodplain environment;
- Be consistent with the objectives of relevant State policies, in particular, the Government's Flood Prone Lands and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act, 1979;
- Ensure that the 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 management plan are sustainable in social, environmental, ecological and economic terms;
- Ensure that the 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 a mechanism for the funding of the plan including priorities, staging, funding, responsibilities, constraints, and monitoring; and the
- Preparation of concept design for recommended works with sufficient detail to enable Council to apply for funding and progress to the investigation and design stage.

1.2. The Study Area

The township of Henty is located in the Greater Hume Shire Local Government Area (GHSC) situated in the Riverina region of southern New South Wales (NSW). GHSC is surrounded by the LGA's of Wagga Wagga, Urana, Tumut, Corowa, Tumbarumba, Albury and Indigo.

Henty has a population of 882 people (2011 census) and is located on the Olympic Highway, 17km north of Culcairn (see Figure 1 for Study Area layout).

The northern fringe of the town is crossed by Buckargingah Creek which originates 15 km east of Henty. It is an intermittent creek that drains to Doodle Comer Swamp in the south-west of town and at Henty has an approximately catchment area of 85 km². In the late 19th century, the Creek was diverted for safety reasons to its current course and as a result remnant levee banks exert some influence over flood behaviour (at Henty-Rand railway, the Main Southern Railway, Bartsch Avenue and Grubben Road). An additional flow path, the Northern Henty Flow Path, situated approximately 2 km to the north of town crosses the Olympic Highway between Kendalls and Grubben Roads. This flow path has an upstream catchment area of 22 km².

An additional study area outside of the main town limits exists east of Henty. The site (displayed on the insert of Figure 1) is known as the Henty Machinery Field Days site (HMFD) and is located on the corner of the Henty Cookardinia and Lubkes Roads. Flooding in this region is due to Buckargingah Creek.

1.3. Flood History of Henty

Buckargingah Creek is an ungauged stream, so only patchy anecdotal information on historical events exists. The flood of June 1931, like Holbrook and Culcairn is again prominent, however insufficient information is available to compare the June 1931 and October 2010 Henty floods with any confidence. It is possible that the damage to houses in the recent event was higher because of the increased level of development (Reference 3). It is noteworthy that the October 2010 event was a much rarer event at Henty than at either Culcairn or Holbrook and is estimated to have an exceedance probability between 0.5% and 0.2% AEP.

In recent times the October 2010 and March 2012 flood events are the largest with both events causing over floor inundation in a number of regions around Henty. Of these events the 2010 event is generally considered the larger of the two, however the variation in peak flood level fluctuates depending on location. This is likely due to a number of changes to structures and differences in bridge and culvert blockages between these two events. In addition, variance in the spatial distribution of rainfall may have also increased this effect, however a lack of gauges in the region make this hard to verify (see Reference 2 for further details).

Following the October 2010 event a number of lesser flood events have also occurred including those in December 2010 and January and February 2011.

1.4. Previous Reports

Previous reports have been reviewed and summarised in the Flood Study (Reference 2) including:

- Flood Intelligence Collection and Review for Towns and Villages in the Murray and Murrumbidgee Regions following the October 2010 Flood (Reference 3); and
- Flood Intelligence Collection and Review for Towns and Villages in the Murray and Murrumbidgee Regions following the March 2012 Flood (Reference 4).

1.5. Available Data for FRMS&P

1.5.1. Henty-Rand Rail Structure Survey

During the 2012 flood event in Henty, the Henty-Rand railway bridge south of Grubben Road was destroyed and has since been replaced. This has been recognised as a key hydraulic structure carrying floodwaters in the northern Henty Floodplain. Survey of this structure as part of the FRMS&P was undertaken and provided reduced levels and dimensions of the new structure. This structure was input into the revised hydraulic model as a bridge (see Section 3.2).

1.5.2. Floor Level Survey

Floor level survey was performed by Hydrographic & Cadastral Survey Pty. Ltd. for properties which were determined to experience 1% AEP peak flood level depths exceeding 300 mm adjacent to the building footprint. In total 12 properties (9 residential and 3 non-residential) were surveyed in Henty with the location of these properties displayed in Appendix B, Figure B2.

The floor levels of the remaining properties within the 1% AEP extent were estimated by use of ALS data in combination with visual inspection of properties floor level heights from ground by WMAwater engineers. For all other properties in the Study Area up to the PMF extent, floor levels were estimated using ALS data and the average floor height above ground of the surveyed and estimated floor levels.

1.6. Overview of Existing Catchment

1.6.1. Land Use and Demographic Overview

Understanding the social characteristics of the area can help in ensuring that the right risk management practices are adopted. The Census data can provide useful information on categories including dwelling and tenure type, languages spoken, age of population and movement of people into and from the area. Information has been extracted from the 2011 Census. The urban centre of the suburb of Henty has a population of 882 living in 460 private dwellings.

Of interest is the data on population movement in recent years. Generally residents who have lived in an area for a longer time will have a better understanding of local flooding issues than those who have recently moved to the area. Within the last five years of the 2011 census 30% of the population had moved to the Henty area and in the year prior to the 2011 census 10% of the population moved into the area. Based on this data, the majority of the current population would have experienced one or both of the recent flood events and therefore likely have good awareness of flood risk in the region.

It is useful to consider the tenure of housing. Those living in properties which they own are more likely to be aware of the flood risks and have measures in place to reduce them (where possible). Rental properties are likely to have a higher turnover of people living in them compared to privately owned properties and therefore those people in rental properties may be less aware of the flood risk. In Henty 20% of houses are rented.

The languages spoken by the population are also useful to consider as this can have implications in regard to the provision of flood information to the public. In Henty less than 1% of the population speak a language other than English at home.

Land use from the LEP 2011 is shown in Figure 2. The majority of Henty is comprised of lots zoned RU5 Rural Village areas. The RU5 classification not only allows for residential properties but also commercial/industrial of which there are approximately 40 in Henty. Land use outside of the township of Henty in the Buckargingah Creek catchment is generally zoned RU1 Primary Production with usage primarily devoted to grazing and cropping endeavours. Special Purpose zones (displayed as 'special' in Figure 2) are distributed throughout the town and allow for infrastructure uses, schools, churches and other community facilities.

Buckargingah Creek east of the Olympic Highway and Doodle Comer Swamp to the west of town are designated as W1 Natural Waterway which has limitations on permitted uses. Zone W1 predominantly aims to allow for boating uses, flood mitigation works, jetties, kiosks, recreation areas and facilities, roads and emergency services facilities. Commercial, industrial and residential land uses are prohibited (LEP 2011). Accordingly, the W1 Natural Waterway zoning is suitable for implementation with the floodway classification (see Section 4.4).

Outside the town boundaries, the only structures on the floodplain are roads and rail, individual farmhouses and other farm related infrastructure. Most roads are unsealed and creek and stream crossings are generally formed by low level causeways with the exception of bridges on Bartsch Avenue, the Olympic Highway and the Main Southern Line railroad.

1.6.2. Key Infrastructure on the Floodplain

Key infrastructure in the floodplain are those that impact on flood levels, for example upstream backwatering (and retention of floodwater) and lower levels in the downstream (relative to the case if the major structure was not there). Some of these may be deliberate flood management measures to control flooding. Table 1 below summarises each feature with the locations displayed on Figure 3.

Table 1: Key Infrastructure on the Floodplain

ID	Structure	Comment
1	Olympic Highway Culverts – Buckargingah Creek	The Olympic Highway crossing of Buckargingah Creek is composed of 4 x 2.4 m x 2.7 m box culverts. It was noted that in both of the 2010 and 2012 flood events these culverts were partially blocked significantly affecting flow conveyance (Reference 2).
2	Railway Bridge at Buckargingah Creek	Immediately downstream of the Structure #1 Olympic Highway Culverts also spanning Buckargingah Creek is the Main Southern Line railway bridge, which is approximately 14 m long with 3 spans. The bridge deck is 0.35 m thick. The cross sectional area of this structure is approximately 10% greater than the Olympic Highway Culverts (Structure #1) making the Highway the control for the region.
3	Olympic Box Highway Culverts – 200 m north of Creek	200 m north of Buckargingah Creek, 5 x 1.7 m x 2.4 m culverts cross the Olympic Highway connecting the northern floodplain from east to west. These culverts predominately take excess Buckargingah Creek flows that flow north due to backwatering caused by the Olympic Highway.
4	Box culverts under railway track – 200 m north of Creek	Immediately downstream of the Structure #3 culverts, an 18 m long bridge with five spans (4 x ⌀0.8 m columns) conveys flow through the Main Southern Line toward Structure #5. The bridge is on average 1.1 m high with a deck thickness of 0.75 m. Flow conveyance through the structure is greater than Structure #3, again making the Olympic Highway the control.
5	Box culverts under Henty-Rand railway track – 50 m downstream of railway	In the 2012 flood event, the Henty-Rand railway bridge was destroyed and has since been replaced with 4 x 2.7 m x 1.5 m box culverts (see Section 1.5.1).
6	Olympic Highway Box Culverts – 700 m north of Creek at Grubben Road	700 metres north of Buckargingah Creek, 2 x 1.5 m x 1.8 m box culverts cross the Olympic Highway. These culverts service overflow from the Northern Henty Flow Path (see Section 1.2) as well as Buckargingah Creek.
7	Box culverts under railway track – 700m north of Creek at Grubben Road	After flowing through the Structure #6 box culverts under the Olympic Highway, 4 x 1.2 m x 0.9 m box culverts convey flow beneath the railway.
8	Bartsch Avenue Bridge – Buckargingah Creek	Approximately 300 m downstream of the railway, Buckargingah Creek passes under Bartsch Avenue through 2 x 3 m x 3.2 m box culverts. The culvert capacity is significantly less than the upstream Buckargingah Creek crossings causing backwatering and structure overtopping.

2. COMMUNITY CONSULTATION

Community consultation is an important element of the floodplain risk management process, ultimately facilitating community engagement and acceptance of the overall project. During the Flood Study (Reference 2), community consultation was undertaken to assess the flood experience of the community and gather additional data. Further community consultation has also been undertaken as part of the FRMS&P. To date this has included a questionnaire, a community open day and a number of FRMC meetings. Goals of ongoing community consultation are to keep residents informed of progress and in the later stages gain their feedback on potential mitigation and management measures proposed. Final community consultation proposed is in the form of public exhibition of the Floodplain Risk Management Study and Floodplain Risk Management Plan.

It should also be noted that as part of the SES Data Collection Studies (Reference 3 and 4) following the 2010 and 2012 events, considerable consultation was performed including questionnaire distribution and interviews.

2.1. Questionnaire Distribution

A community newsletter and questionnaire (presented in Appendix C) was distributed to residents in Henty during September 2014. The newsletter aimed to inform the community of the Henty FRMS&P and the survey provided the community with an opportunity to highlight their flood affectation and to provide input into the current study. In particular, the questionnaire was intended to obtain ideas for mitigation works or management plans to reduce flood risk and, if applicable, to determine if the community is interested in Voluntary Purchase (VP) or Voluntary House Raising (VHR) schemes (see Sections 5.4.1 and 5.4.2).

A total of 11 replies (out of 816 distributed) resulted in a return rate of 1.3% which is low for this kind of study. It is normal that responses predominately come from residents that have been affected by flooding, however 11 is significantly less than the number of residents impacted by the recent events. The reduced return rate may have been due to the questionnaire being focused on obtaining flood risk solutions that many people are possibly not well placed to provide.

A summary of the questionnaire results is presented in Figure 4 with the questionnaire returnee locations displayed in Figure 5. Nine of the 11 questionnaire respondents mentioned that they thought flood risk at Henty should be ameliorated, particularly for flood risk due to Buckargingah Creek (9 responses). Five respondents thought that flooding at a frequency of 100 years or less is acceptable which is generally in line with the aims of the current study. However, five respondents mentioned that they thought any degree of flooding is never acceptable which would require the engineering of mitigation structures to the PMF. It was also found that the majority of people were interested in a VP (7 respondents interested) scheme and less than half were interested in the VHR (5 respondents interested) scheme.

Generally two topics were the focal point of all returned questionnaires. These were the impacts of creek clearing/maintenance and potential flood mitigation works. A summary of the key topics discussed in the returned questionnaires is presented below:

Creek Dredging, Clearing and Maintenance

- A number of questionnaires noted dredging and clearing debris from Buckargingah Creek to increase the channel conveyance and prevent the build-up of water through Henty (investigated in Section 5.3.4.4); and
- Clearing existing bridge and culverts structures under the railway and Olympic Highway at Buckargingah Creek and along the northern floodplain to aid in the drainage of flows from east to west (see Section 5.3.5).

Potential Flood Mitigation Works

- Increasing the conveyance capacity and number of culverts under the railway and Olympic Highway at Buckargingah Creek and along the northern floodplain to aid in the drainage of flows from east to west (see Section 5.3.5);
- Increasing the conveyance of drainage channels along either side of Pleasant Hills Road (see Section 5.3.4.2);
- Building an embankment on Grubben Road north of the Henty-Rand railway to stop flood water from flowing north from Buckargingah Creek (see Section 5.3.1.3);
- Removal of the grain silos and Canola Sheds levees to allow floodwaters to flow to the north-west (see Section 4.2); and
- Creating a drain to direct water from Grubben Road, south to Buckargingah Creek (see Section 5.3.3.2)

2.2. Community Consultation Open Day

A WMAwater engineer attended the township of Henty on the 14th of October 2014 with the purpose of interviewing residents to gain potential flood mitigation ideas to reduce flood affectation in Henty.

The meeting was attended by 8 people with many of these people also returning the questionnaire. Consequently, many of the concerns raised by the returned questionnaires were also discussed at the open day. A list of these topics is presented in Section 2.1, with again particular focus on the clearing and maintenance of existing culverts, table drains and Buckargingah Creek.

Two attendees commented that the construction of a levee to the east of the Grain site in the north of Henty had caused flooding to be exacerbated on properties south of the silo as flow paths have been diverted south (addressed in Section 4.2). Another attendee was concerned that the raised level of the Olympic Highway in recent years has had a damming affect for the eastern side of the highway. Other comments from attendees include using the playing fields on Pleasant Hills Road as storage to alleviate flood problems (see Section 5.3.8.1), creating an embankment along Grubben Road to stop flow traveling north in this areas (see Section 5.3.1.3), creating a drain from Grubben Road to allow water to drain quickly (see Section 5.3.3.2), straightening of Buckargingah Creek to increase conveyance (see Section 5.3.4.5) and clearing culverts to increase conveyance and reduce upstream flood levels.

2.3. Flood Risk Management Committee

The Henty Floodplain Risk Management Committee (FRMC) comprises a number of representatives from the local community, including residents, members of Council, the SES and OEH.

Regular meetings have been held (6 in total) in order to inform the FRMC of the study progress regarding data collection and community consultation as well as the modelling of flood mitigation measures. Following review and edits, the draft report requires recommendation to Council for endorsement in order to progress. At this stage exhibition of the draft document would be the normal course of action.

2.4. Public Exhibition of the Draft Final Henty FRMS&P

Public exhibition of the Draft Final Henty FRMS&P was undertaken to ensure community support of these documents. The Report was available to the public for scrutiny, for the period of one month. Digital copies of the reports were available on the Council website and a hard copy of the report was available at Council Offices and the local library. One submission was received in relation to the Henty FRMS&P. The submission related to Hotspot #4 and possible mitigation measures. Five mitigation measures were tested at the location of Hotspot #4, these were identified by the community and other key stakeholders and included channel and culvert modifications. None of the tested measures were shown to be viable for a reduction of property damage at Hotspot #4.

3. FLOOD STUDY SUMMARY AND FLOOD BEHAVIOUR

3.1. Aims and Objectives of the Flood Study

The information and results obtained from the Flood Study (Reference 2) defined existing flood behaviour and provided a firm basis for the development of the FRMS&P. Primarily, the study was developed in order to define the flood behaviour for the 5-year ARI, 10%, 5%, 2%, 1%, 0.5% AEP events and the PMF in Henty and to:

- Define flood behaviour in terms of flood levels, depths, velocities, flows and flood extents within the study area;
- Prepare flood extent mapping (for all design events modelled); and to
- Create a modelling system that might be used in the subsequent FRMS&P to test whatever flood mitigation works might be proposed by either the community, OEH, Council or the consultant.

In order to define flood behaviour, the Flood Study developed a hydrologic model, WBNM, in conjunction with a 1D/2D hydraulic model, TUFLOW. This methodology is presented in the Flood Study (Reference 2).

3.2. Flood Study Revisions/Updates

Since the Flood Study, one amendment to the hydraulic TUFLOW model has been made and incorporated into the design results. In the 2012 flood event in Henty, the Henty-Rand railway bridge south of Grubben Road was destroyed. This bridge has since been replaced and the dimensions of the new bridge have been incorporated into the model (see Section 1.5.1).

These changes had only minor localised effects on the Henty 1% AEP peak flood levels with differences less than 0.1m. The difference in peak flood level does not affect findings from the Flood Study (Reference 1).

3.3. Flood Mechanisms

Buckargingah Creek is the primary source of flooding in Henty, affecting northern Henty and in particular properties along Grubben Road and Pleasant Hills Road. An additional flow path, the Northern Henty Flow Path (NHFP), situated approximately 2 km to the north of town, crosses the Olympic Highway between Kendalls and Grubben Roads and compounds Buckargingah Creek flood issues.

Due to restricted culvert capacity, the Olympic Highway acts as a dam during flooding of both Buckargingah Creek and the NHFP. This causes flood waters to flow north and pond on the eastern side of the highway. This can lead to over floor flooding in Henty's north-east.

Residents on Grubben Road experience shallow flooding principally due to runoff that is conveyed through the culverts under the Olympic Highway and railway line at the culverts 700 m north of Buckargingah Creek (see Section 1.6.2). The culverts at Grubben Road convey floodwaters from Buckargingah creek towards the west, resulting in flood affected properties along this road. Flows from the Grubben Road region then flow in a westerly direction towards Doodle Comer Swamp, however a portion of this flow travels south across Angaston Street and Pleasant Hills Road and back into Buckargingah Creek. A number of properties in this region have been significantly flooded in recent flood events.

Overland flow at Pleasant Hills Road has caused properties along this road to be subject to flooding. Flood waters which have overtopped Buckargingah Creek, after passing through the railway culverts, flow down Pleasant Hills Road and inundate a number of properties along this road.

The township of Henty is situated on a hill, off the Buckargingah Creek floodplain, with the majority of the town unaffected by Buckargingah Creek flooding. However, minor overland flows can cause flooding in the town due to local rainfall. Buckargingah Creek and overland flow flooding are independent with the occurrence of one not necessarily coinciding with the other.

It is important to recognise that different types of flooding will need different management measures. Furthermore, different flooding mechanisms will require a different emergency response.

3.4. Design Events

The hydraulic model was run for the 5-year ARI, 10%, 5%, 2%, 1% and 0.5% AEP events as well as the PMF, for which a number of maps have been produced displaying the flood affected regions (see mapping included in the Flood Study – Reference 2). Please note that these maps have not been reproduced in the current study to account for the changes to the model, as the impact on peak flood levels and extents are insignificant (see Section 3.2). However, all modelling undertaken as part of the current study (mitigation runs, FPA and hydraulic categorisation) has been performed with the updated hydraulic model.

3.4.1. Critical Duration

The Buckargingah Creek critical duration at Henty is 18 hours for all design flood events excluding the PMF. Local flows generated from the local catchment model were determined to have a critical duration of 25 minutes.

The critical duration of the PMF at Henty was found to be 3 hours for both creek and overland flows.

3.4.2. Peak Flows

The peak flows for Buckargingah Creek upstream of Olympic Highway for the calibration/validation and design flood events are presented in Table 2.

Table 2: Buckargingah Creek upstream of Olympic Hwy - WBNM Model Peak Flows (m³/s)

	5Y	10%	5%	*2012 Event*	2%	1%	0.5%	*2010 Event*	PMF
Henty	28	38	61	79	80	97	116	160	1723

It should be noted that spatial variation in rainfall patterns and variations in structure blockage impacted on peak flood levels of the historic events (Reference 2). Accordingly, the above referenced flows of the historic events are potentially not a good indication of the magnitude of the peak flood levels for these events.

3.4.3. Flood Depths and Levels

Mapping of peak flood depths and level is included in the Flood Study (Reference 2). The map set includes the following;

- Peak flood depths and levels for the design flood events (PMF, 5-year ARI, 10%, 5%, 2%, 1% and 0.5% AEP) (all depths < 100 mm clipped, see paragraph below);
- Provisional Hazard and Hydraulic Category maps; and
- A summary of the performance of key hydraulic structures.

When establishing inundation patterns and/or peak flood levels, these are based on best available estimates of flood behaviour within the catchment. Inundation from creek and particularly local overland flow may vary depending on the actual rainfall event and local influences, for example; change in topography, blocked structures, road works etc. For the design events depths less than 100 mm have been considered ‘drainage’ rather than ‘flooding’ and accordingly, the design results figures only display flood depths in excess of 100 mm.

3.4.4. Flood Travel Time

Flood travel times between various locations along Buckargingah Creek are extracted from the Reference 2 hydrologic model and are presented in Table 3. This indicates flood peak travel times between Lubkes Road and the Olympic Highway in excess of 2 hours in the 1% AEP event, with generally longer times for more frequent floods, and shorter times for rarer floods. In the 1% AEP flood, negligible additional travel time is recorded for Henty-Pleasant Hills Road downstream of the Main Southern Railway.

For many inland creek and river systems, hydrologic modelling produces short response times due to the adopted Australian Rainfall and Runoff 1987 (ARR) temporal patterns. The times in Table 3 are therefore regarded as minimums. Insufficient information has been obtained from recent historical events to provide definitive observed flood peak travel times. Reports of the October 2010 flood threatening ‘Brookleigh’ homestead located about 5 km east of Henty and later flooding properties on the Olympic Highway suggest a travel time of about 1-1.5 hours (Reference 3), which is slightly longer than the modelled travel times for an event of that frequency (estimated 200 year to 500 year ARI – Reference 2).

Table 3: Flood Peak Travel Times – Buckargingah Creek

Event	Lubkes Rd (A) time of peak (h.mm)	Olympic Hwy (B) time of peak (h.mm)	Travel time A to B (h:mm)	Henty-Pleasant Hills Rd (C) time of peak (h.mm)	Travel time A to C (h:mm)
5Y ARI	8.06	12.04	**3:59**	13.79	**5:44**
10% AEP	8.05	12.71	**4:40**	13	**4:57**
5% AEP	8.02	10.55	**2:32**	10.75	**2:44**
2% AEP	7.97	10.44	**2:28**	10.6	**2:38**
1% AEP	7.85	10.15	**2:18**	10.29	**2:26**
0.5% AEP	7.77	8.52	**0:45**	8.76	**0:59**
PMF	3	3.5	**0:30**	3.51	**0:31**

3.5. Provisional Hydraulic Categories

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The *Floodplain Development Manual* (Reference 1) defines flood prone land to fall into one of the following three hydraulic categories (refer definition in Appendix A);

- Floodway;
- Flood Storage; and
- Flood Fringe.

Floodways are areas of the floodplain where a significant discharge of water occurs during floods and by definition if blocked would have a significant effect on flood flows, velocities or depths. Flood storage are areas of importance for the temporary storage of floodwaters and if filled would significantly increase flood levels due to the loss of flood attenuation. The remainder of the floodplain is defined as flood fringe. There is no technical definition of hydraulic categorisation and different approaches are used by different consultants and authorities.

Based on exploratory work carried out at Henty and reported upon in Appendix I of the Flood Study (Reference 2), provisional floodways were defined on the following basis:

*Floodway = Velocity * Depth > 0.25m^2/s AND Velocity > 0.25m/s OR Velocity > 1m/s*

The remainder of the floodplain outside the Floodway becomes either Flood Storage or Flood Fringe. In the Reference 2 study Flood Storage was defined as the land outside the Floodway if the depth is greater than 0.5 m and Flood Fringe if the depth is less than 0.5 m.

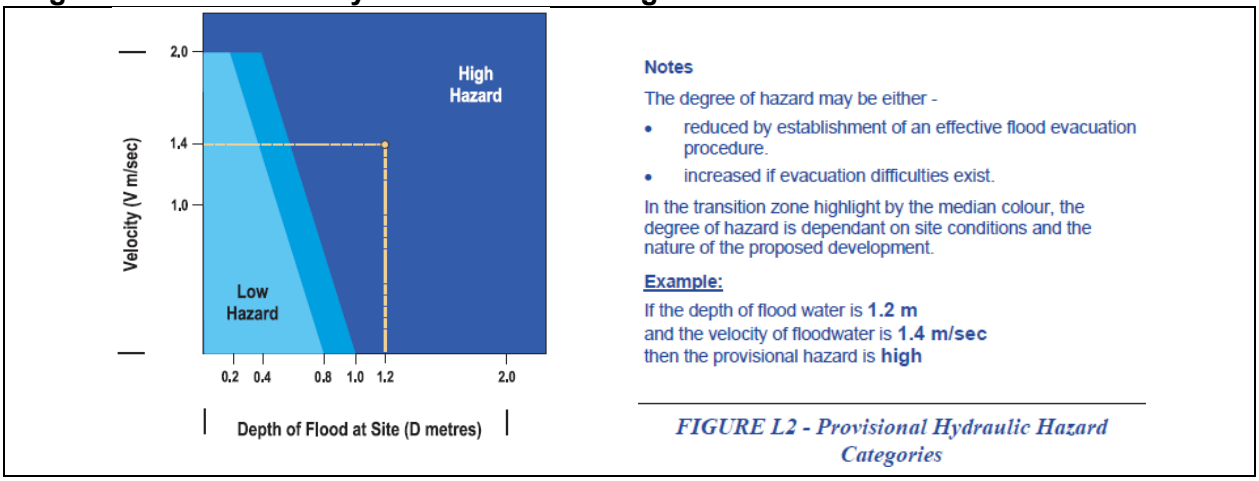
Using this classification system, limited extents in Henty are defined as floodway which seems appropriate given the distributed nature of flows in the overbank areas, away from defined watercourses. Nevertheless, there were some residential areas interacting with defined floodways, for example on Pleasant Hills Road.

A more detailed look at the floodway definition for Henty has been undertaken as part of the current study. The investigation takes into account Velocity x Depth criteria, encroachment analysis and percentage flow distribution. The true hydraulic categorisation is presented in Section 4.4.

3.6. Provisional Hydraulic Hazard Classification

The Flood Study (Reference 2) defined provisional flood hazard categories in accordance with the Floodplain Development Manual (Reference 1). Provisional hazard only takes account of the hydraulic aspects of flood hazard; depth and velocity (Diagram 1), while true hazard (see Section 4.5) takes into account additional factors such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows.

Diagram 1: Provisional Hydraulic Hazard Categories



Extracted from The Floodplain Development Manual (Reference 1)

The Flood Study (Reference 2) established high and low provisional hazard areas for the 5% AEP and 1% AEP events and the PMF. 1% AEP event high hazard areas tend to be limited to defined flow paths and the floodway and also those areas where water depth accumulates, such as upstream of farm dams.

3.7. Flood Liable Areas and Infrastructure

The October 2010 flood event provides an indication of flood liability and affected infrastructure as it is slightly larger than the 0.5% AEP flood.

Results of the Flood Study (Reference 2) indicate that numerous properties will suffer some degree of inundation during the 1% AEP event. Properties on the northern floodplain of Buckargingah Creek, particularly along Pleasant Hills Road and Grubben Road become inundated by events as small as the 5% AEP event. For the 1% AEP flood as many as 7 homes and 4 commercial lots are likely to become inundated above floor and many more will experience significant flooding of property lots (not necessarily over floor level inundation).

In terms of flood risk, Pleasant Hills Road and Grubben Road are particularly notable. At these locations, properties are subject to flood depths above floor level with a lack of egress, producing significant flood risk.

The following roads are also cut during the 1% AEP event by Buckargingah Creek flows:

- Olympic Highway;
- Bartsch Avenue;
- Cookardinia Road;
- Grubben Road;
- Angaston Road;
- Pleasant Hills Road; and
- Culcairn-Holbrook Road.

During such an event, modelling indicates that access to the township of Henty will be restricted from the north, east and west by flooding. The Olympic Highway to the south, whilst not in the study area, was cut off during the October 2010 event. Accordingly, Henty is potentially isolated by road for events from the 1% AEP and larger.

The PMF is found to inundate the northern floodplain with the majority of the town not flood affected from Buckargingah Creek flows. Generally peak flood levels will be 1 – 1.5 m higher than the 1% AEP event. This is indicative of a low-moderate flood risk situation.

3.7.1. Hotspots

The Flood Study identified a number of flooding “Hotspots” which are specific areas of interest from a flooding perspective. These include; locations where many residences are liable to flooding, where key drainage assets are not meeting design standards, or where key infrastructure, such as major roads, are flood affected. The hotspots, typically SES locations of interest, were identified and discussed in the Flood Study with respect to the behaviour of flooding at each location. The identified hotspots are summarised in Table 4 and displayed in Figure 3. For further information on the hotspots see the Culcairn, Henty and Holbrook Flood Studies (Reference 2).

Table 4: Hotspots

Hot Spot	Name	Comment
1	**Buckargingah Creek at Olympic Highway**	The Olympic Highway acts as an embankment during flooding of Buckargingah Creek. The culverts under the highway are insufficient for passing flood waters during a large flood event. Backed up floodwaters drain naturally towards the north, inundating properties in this area. Immediately downstream of the Olympic Highway and Railway bridges on Buckargingah Creek, the creek is forced through a 90 degree bend which during flood is over topped inundating areas downstream.
2	**Culverts 250m north of Buckargingah Creek at Olympic Highway**	This location experiences flooding from floodwaters overtopping Buckargingah Creek 200 m upstream (east of Hotspot 1) and also from the highway embankment/structure directing flows northwards. Runoff passing through the culverts drains towards the Government Dam. Upstream of the Henty-Rand Railway embankment a portion of the flood waters are directed towards the northwest and north due to the obstruction of the railway line.
3	**Buckargingah Creek at Bartsch Avenue**	Bartsch Avenue is a main road link for residents at Pleasant Hills Road with Henty. This road is flooded for all events exceeding the 5% AEP event. The creek banks are overtopped immediately downstream of the culverts under Bartsch Avenue and a portion of this flow is diverted over Pleasant Hills Road.
4	**Grubben Road**	Residents at Grubben Road experience shallow flooding principally due to runoff that is not conveyed through the culverts under the highway and railways south of this location. Floodwaters inundate residential lots as they drain to the west as shallow sheet flow at low velocity.
5	**Proposed Rezoning Area – Canola Sheds**	At this location, floodwaters arrive in large storm events from overland flows draining west at Grubben Road and runoff from upstream of Government Dam that cannot be conveyed though the culverts under the Henty-Rand Railway line. These floodwaters drain towards the northwest of this location on both sides of the old Henty-Rand railway line.

3.8. Future Development and Flooding

A current planning proposal seeks to amend the LEP 2012 land zoning at Henty with four areas proposed for rezoning in the study area (locations presented in Figure 1). These proposed rezoning regions have varying degrees of flood liability and an investigation into the suitability of these areas for rezoning has been undertaken in Section 4.3.

Future development within the FPA is not permitted with the NSW Environment Planning Assessment Act 1979 (EP&A Act) stating in Clause (5) of Direction 4.3:

> *(5) A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.*

Further details pertaining to Planning to the planning aspects of this study are presented in Sections 4.9 and 5.6.

4. FLOODPLAIN RISK MANAGEMENT STUDY

4.1. Objectives of the Floodplain Risk Management Study

The primary objective of the Floodplain Risk Management Study is to investigate a range of flood mitigation works and measures to address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Policy, as detailed in the Floodplain Development Manual (Reference 1). Other objectives include:

- Review Council's existing environmental planning policies and instruments including Council's long term planning strategies for the study area;
- Identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events;
- To assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future;
- To consider whether the proposed works and measures might produce adverse effects (environmental, social, economic, or flooding) on the floodplain and whether they can be minimised;
- Examination of the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's developments and disaster planning requirements.
- Examine ways in which the river and floodplain environment may be enhanced by preparing a strategy for vegetation planning that will create a valuable corridor of vegetation without having a detrimental effect on flooding;
- Identification of modifications required to current policies in the light of investigations; and
- Undertake effective community consultation and participation throughout the Study.

Further to this, this section considers the true hydraulic categorisation, true flood hazard classification, impacts of flooding to properties in Henty and key access issues. It also considers existing floodplain management at Henty in terms of both policy and planning as well as flood response. Structural flood management features are also considered. Potential options to reduce flood risks are discussed in Section 5.

Additionally, four rezoning regions are proposed throughout the study area. These proposed rezoning regions have varying degrees of flood liability and further details are presented in the Flood Study (Reference 2). Further comment/investigation has also been provided in Section 4.3.

4.2. Impact of the Grain Silos and Canola Shed levees on Flood Levels

A key concern of the community is the potential for the Grain Silos and Canola Sheds and their levees (situated to the north of town) to increase peak flood levels in residential areas. To investigate the impact of these structures, the 1% AEP event has been run with the Grain Silos, Canola Sheds and their levees removed.

Figure 6 displays the difference in peak flood levels relative to existing conditions for the 1% AEP event with removal of these structures. It can be seen that such works provide only localised impacts on flood level and that reductions in flood levels do not propagate into residential areas. However, reductions in peak flood levels may be more pronounced in larger events but are still unlikely to reduce flood affectation for residential properties.

4.3. Proposed Rezoning Regions Planning Measures

Henty is currently experiencing increased growth due to being situated approximately midway between the regional centres of both Wagga Wagga and Albury. Council is responding to this by considering rezoning a number of areas within the township. Predominantly rural land (RU1) is being reviewed and assessed to identify areas that can support future residential development.

Council is currently considering the rezoning of four sites as presented in Table 5 with the locations displayed in Figure 1 and Figure 2.

Table 5: Proposed Rezoning Areas

Zone Id	Current Zoning	Proposed Zoning	Area (ha)	Proposed Rezoning Suitability
1	RU1 Primary Production	R5 Large Lot Residential	47.5	No
2	RU1 Primary Production	R5 Large Lot Residential	57.7	Yes*
3	RU1 Primary Production	RU5 Village	10.6	Yes*
4	RU1 Primary Production	RU5 Village	32.4	Yes

* Not all areas of the proposed rezoning region are suitable for rezoning. Regions within the Henty FPA cannot be rezoned to a zone type that can lead to increased development (see Section 4.9.1, Clause (5) of Direction 4.3 of the EP&A act).

Each site has been analysed for its suitability for rezoning with details presented below. As part of this analysis, Figure 7 illustrates the rezoning areas currently under consideration with the Henty FPA (see Section 5.6.3) overlaid.

It is important to note that not all areas that are suitable for rezoning are flood free and accordingly it is recommended that the following is addressed before future development is undertaken:

- Consider ease/need for egress in relation to larger/rarer floods;
- Consider and apply appropriate flood proofing controls to industrial development within the FPA and more specifically the floodway; and
- Set minimum floor heights for dwellings in the Flood Planning Area (FPA).

Rezoning Area #1

Rezoning Area #1 is situated north of Angaston Road on the Buckargingah Creek floodplain and encompasses the Grain Silos and Canola Sheds mentioned in Section 4.2. The proposed Rezoning Area has an area of 47.5 ha. Examination of the Henty FPA indicates that the proposed rezoning area is contained within the FPA extent (see Figure 7). Therefore rezoning of this area is in disagreement with Clause (5) of Direction 4.3 of the EP&A Act (see Section 4.9.1), and from a flooding perspective this land is not suitable for rezoning to R5 Large Lot Residential.

Rezoning Area #2

Rezoning Area #2 is situated between Buckargingah Creek and Cookardinia Road to the east of Henty and has an area of 57.7 ha. Examination of the Henty FPA indicates that the majority of the proposed rezoning area is situated within the Henty FPA extent (see Figure 7) and is thus not suitable for rezoning as stipulated in Clause (5) of Direction 4.3 of the EP&A Act (see Section 4.9.1). However, regions outside of the Henty FPA extent, which are predominantly situated on higher ground proximate to Cookardinia Road are suitable for rezoning from a flooding perspective.

Rezoning Area #3

Rezoning Area #3 is situated to the east of Henty and to north of Yankee Crossing Road. The site has an area of 10.6 ha. Examination of the Henty FPA indicates that the majority of the proposed rezoning area is outside of the FPA extent (see Figure 7), with the exception of small area in the north-east of the site. Therefore rezoning of this area is not in disagreement with Clause (5) of Direction 4.3 of the EP&A Act (see Section 4.9.1), and from a flooding perspective this land is suitable for rezoning to RU5 Village.

Rezoning Area #4

Rezoning Area #4 is situated south-east of Henty and to the south of Yankee Crossing Road. The site has an area of 32.4 ha. Examination of the Henty FPA indicates that the proposed rezoning area is outside of the FPA extent (see Figure 7). Therefore rezoning of this area is not in disagreement with Clause (5) of Direction 4.3 of the EP&A Act (see Section 4.9.1), and from a flooding perspective this land is suitable for rezoning to RU5 Village.

4.4. True Hydraulic Categorisation

The Flood Study (Reference 2) defined the provisional hydraulic categorisation while the FRMS&P revised this to identify the true hydraulic categorisation.

Appendix D details the methods used to determine the floodway at Henty. Once the floodway was defined the remainder of the floodplain outside the floodway becomes either flood storage or flood fringe. In this study Flood Storage was defined as the land outside the Floodway if the depth is greater than 0.5 m and Flood Fringe if the depth is less than 0.5 m.

Hydraulic categorisation for the 5% and 1% AEP events and the PMF are presented in Figure 9 to Figure 11. The investigation into appropriate criteria for defining the Henty floodway is provided in Appendix D.

Using the methodology presented in Appendix D, the floodway is focused around Buckargingah Creek and the NHFP. A number of residential lots are defined within the Buckargingah Creek floodway in the study area. Henty overland flows were determined to not produce a significant floodway due to the relatively slow velocities and shallow depths in the region.

4.5. True Flood Hazard Classification

The Flood Study (Reference 2) defined the provisional hydraulic hazard while the FRMS&P is required to consider the true flood hazard. The Flood Study (Reference 2) found that high provisional hydraulic hazard tends to be limited to defined flow paths and also those areas where water depths accumulate, including an area where flows are trapped behind the Olympic Highway embankment. However, few provisional high hazard areas are in populated areas of Henty for the 1% AEP event.

To assess the true flood hazard all adverse effects of flooding have to be considered. As well as considering the provisional (hydraulic) hazard it also incorporates other criteria such as threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production and those detailed in Table 6.

Table 6: Hazard Classification

Criteria	Weight [1]	Comment
Size of the flood	Medium	The size or magnitude of the flood can affect depths and velocities. Relatively low flood hazard is associated with more frequent minor floods while less frequent major floods are more likely to present a high hazard situation. In the PMF, much of the floodplain on the northern side of Henty would experience depths and velocities that could pose a risk to the structural stability of buildings (after Reference 5).
Depth and velocity of floodwaters	Medium	The provisional hazard is the product of depths and velocity of flood waters. These can be influenced by the magnitude of the flood event. By and large at Henty, high velocities and depths during the 1% AEP event are confined to the creek channel, to dams and to the area immediately east of the Olympic Highway where deep flows can accumulate. In the PMF, a large area of floodplain on the northern side of Henty would experience high hydraulic hazard.
Rate of rise of floodwaters	Medium	Rate of rise of floodwaters is related to catchment size, soil type, slope and land use cover. It is also influenced by the spatial and temporal pattern of rainfall during events. The rate of rise can be quite rapid at Henty due to the relatively small catchment size.
Duration of flooding	Low	The greater the duration of flooding the more disruption to the community and potential flood damages. A short period of inundation may allow some materials to dry and recover whereas a long duration may increase damages to roads or cause damages beyond repair. The flood duration at Henty is relatively short.
Effective warning and evacuation time	High	This is dependent on the rate at which waters rise, an effective flood warning system and the awareness and readiness of the community to act. No BoM flood warnings are issued for the streams and creeks in the Greater Hume LGA; therefore specific warning is limited.

Criteria	Weight [1]	Comment
Flood awareness and readiness of the community	Medium	The community of Henty has a degree of flood awareness but it is likely to be limited to those people aware of the recent events. Recent flooding events and community consultation undertaken as part of the current flood risk management process (of which this report forms part) has raised awareness of the flood problem. The awareness of the community has a medium weight in considering flood hazard as a more aware community may be able to better prepare and therefore potentially evacuate before hazards become high. General community awareness tends to reduce as the time between flood events lengthens and people become less prepared for the next flood event. Even a flood-aware community is unlikely to be wise to the impacts of a larger, less frequent event. Because flood warning is limited at Henty, it is particularly important for floodplain residents to be flood-ready so that they can detect the signs of the onset of flooding and evacuate.
Effective flood access	Medium	Access is affected by the depths and velocities of flood waters, the distance to higher ground, the number of people using and the capacity of evacuation routes, and good communication. A number of roads in Henty could become hazardous and even impassable during flooding, particularly in larger events. Bartsch Avenue could be cut in relatively frequent events. Although an evacuation route via Henty-Pleasant Hills Road, Grubben Road and the Olympic Highway appears to be trafficable in events up to 0.5% AEP (after Reference 6), some residents' driveways might not be safely navigated in such an event.
Evacuation problems	Medium	Evacuation problems could also be exacerbated by the time of day during which flooding occurs. A flood at night would be more difficult to detect and flooded roads would be more difficult to navigate. The number of people to be evacuated and the limited resources of the SES and other rescue services can make evacuation difficult. Mobility of people, such as the elderly, children or disabled, who are less likely to be able to move through floodwaters is also challenging.
Type of development	Low	The type of flood prone development will influence the ease of evacuation. Longer term home owners would likely have a better understanding of flood risk than a guest at a hotel while residents from a residential care home are likely to be less mobile than average.
Additional Concerns	Low/ medium	The Flood Study showed that floating debris can block structures such as at the Olympic Highway crossing of Buckargingah Creek, forcing additional floodwater to the north. Debris can also cause injury to wading pedestrians or structural damages to property.

[1] Relative weighting in assessing the hazard for Henty determined by interrogation of Reference 2 results and discussion with the Henty FRMC

The flood hazard for the study area varies by location based on the relative depths, velocities and effective flood access. Flood hazard will vary depending on the magnitude of the event, and therefore its AEP.

Consideration was given to upgrading the low provisional hydraulic hazard mapped for the Buckargingah Creek floodplain in the vicinity of Henty-Pleasant Hills Road to high true hazard, given the limited warning time, potential difficulty of access to the main town of Henty, and the potential for highly hazardous conditions during extreme flooding. But the depths and velocities are modest in events up to and including the 0.5% AEP flood, making it difficult to justify upgrading the hazard on the basis of flooding as improbable as a PMF. Nevertheless, consideration will need to be given to means of reducing risk to life in rarer events.

Consideration was also given to upgrading the hazard at houses along Olympic Highway that are bounded on three sides by high hydraulic hazard conditions in the 1% AEP flood. Even though the elevated Olympic Highway is only about 15 metres from the houses, and if safely reached provides a flood-free route to Henty town (in events up to and including the 0.5% AEP flood), based on Reference 6 the maximum depths and velocities from the houses to the road in the 1% AEP event are marginal for pedestrian evacuation (depth about 0.9 m, velocity about 1.4 m/s, depth-velocity product about 0.7 m^2/s). Given the limited flood warning and evacuation difficulties at this site, the true hazard here is considered high.

Elsewhere, only minor amendments (increased hazard classification of low hazard areas totally surrounded by high hazard areas) to the provisional flood hazard have been made with the true flood hazard for the 1% AEP event displayed in Figure 12. This includes the area behind the remnant levee near the Government dam.

There may be some localised areas subject to higher hazard where flood velocities are high, such as near obstructions to flow or culverts and drains that would not be identified at the current scale of the result mapping.

4.6. Impacts of Flooding

4.6.1. Residential Properties

Residential properties suffer damages from flooding in a number of ways. Direct damages include loss of property contents and/or damage to the structure of the property. Indirect damage costs can be incurred when property occupiers live elsewhere while repairs are being made. A flood damages assessment was undertaken for 175 residential properties. Surveyed floor level data was not available for all properties. Therefore in some cases floor level estimates were made by site visit and ALS data (see Section 1.5.2). A summary of the flood damages assessment is provided in the following sections with full details included in Appendix E.

4.6.1.1. Number of Inundated Residential Properties

The floor level survey and design results (Reference 2) were used to identify over floor flood affectation for residential properties and to determine what AEP is responsible for over floor flooding in the first instance. Figure 15 presents the design event during which residential properties are first inundated above floor level while Table 7 below details the total number of properties flooded in each design event.

Table 7: Number of Flood Prone Residential Properties

Event	No. Properties Affected	No. Flooded Above Floor Level
5-year ARI	8	0
10% AEP	11	0
5% AEP	24	3
2% AEP	27	6
March 2012	28	7
1% AEP	29	7
0.5% AEP	31	9
October 2010	28	10
PMF	121	42

NOTE: Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded or that the entire lot is inundated.

At Henty, the majority of residential floor levels are not inundated over floor even in the PMF due to Henty being located on a small hill off the Buckargingah floodplain. However, there are a number of properties situated on the Buckargingah Creek floodplain that are inundated above floor in smaller, more frequent events. Three properties upstream of the Olympic Highway are inundated in events as small as the 5% AEP, and immediately downstream on Grubben Road a further two properties are also inundated by similar sized events. The region between Angaston Road and Pleasant Hills Road also contains a property that is flooded in the 5% AEP event.

The Flood Study (Reference 2) determined the probability of the October 2010 flood event to be 0.5% - 0.2% AEP, which is reflected in the number of properties flooded above floor.

4.6.1.2. Residential Flood Damages Assessment

In assessing various mitigation measures it is important to compare them using a suitable metric. By applying a monetary value to property damages and then comparing damage estimates for the existing situation with assumed mitigation work (approximately costed) a benefit/cost (B/C) ratio can be calculated which is readily comparable. A flood damages assessment was undertaken for 128 residential properties likely to be affected in the PMF event in order to identify potential flood damages for a range of design events. A summary of the assessment is provided in the following sections with full details included in Appendix E.

Table 8 shows the potential damages for a range of design events and the Annual Average Damage (AAD). This forms the base case scenario against which damages from a number of mitigation measures can be assessed. Investigation into variation of damage values and B/C ratios for various flood mitigation management options are presented in Section 5.3 for preferred management options.

Table 8: Potential Residential Damages for Henty

Event	No. Flooded Above Floor Level	Total Damages for Event	Event Contribution to AAD (%)
5-year ARI	0	$ 42,000	14
10% AEP	0	$ 53,000	10
5% AEP	3	$ 214,000	15
2% AEP	6	$ 464,000	22
1% AEP	7	$ 522,000	11
0.5% AEP	9	$ 623,000	6
PMF	42	$ 3,521,000	22
Average Annual Damages (AAD)		**$ 46,000**	

The event damages due to residential property flooding for the October 2010 and March 2012 flood events are estimated to be $810,000 and $400,000 respectively.

4.6.2. Non-Residential - Commercial, Industrial and Agricultural Activities

There is little specifically zoned commercial land in Henty (Figure 2), rather the main developed area is zoned RU5 Rural Village. This allows for a range of land uses, services and facilities that are associated with a rural village and includes some small commercial properties. The majority of non-residential properties are situated off the Buckargingah Creek floodplain, with only a small number situated in flood affected areas. Commercial damages would also be sustained in agricultural areas zoned as RU1 Primary Production. These areas are predominantly used for grazing and cropping.

Non-residential properties are affected either directly by flood damage or indirectly by loss of business due to restricted customer and/or employee access. Costs vary significantly dependent on the type of activity;

- Type of business – stock based or not, costs of damages to goods;
- Duration of flooding – affects how long a business may be closed for not just whether the business itself if closed, but when access to it is restored;
- Ability to move stock or assets before onset of flooding - some large machinery will not be able to moved and in other instances there may be no sufficient warning time to move stock to dry locations; and
- Ability to transfer business to a temporary location.

The magnitude of flood damages to agricultural activities can be largely dependent on the depth and duration of flooding. Longer duration flooding can damage crops and ground leading to loss of harvest or suitable grazing lands. Although grazing animals such as sheep and cattle, may be able to be moved, this would often be to less suitable grazing land.

An explanation of the methods used to assess commercial damages is provided in Appendix E.

4.6.2.1. Number of Inundated Non-Residential Properties

The floor level survey and design results (Reference 2) were used to identify over floor flood liability and first event to cause the same for non-residential properties in Henty. Figure 15 show the design event during which non-residential properties are first inundated above floor level while Table 9 below details the total number of non-residential properties flooded in each design event.

Table 9: Number of Flood Prone Non-Residential Properties

Event	No. Properties Affected	No. Flooded Above Floor Level
5-year ARI	3	1
10% AEP	3	1
5% AEP	5	2
2% AEP	5	2
March 2012	5	2
1% AEP	5	2
0.5% AEP	5	2
October 2010	5	2
PMF	9	7

NOTE: Properties affected are those where there is flooding above ground level within the property boundary (ie the lot). This does not necessarily mean that any buildings on the property are flooded or that the entire lot is inundated.

4.6.2.2. Non-Residential Flood Damages Assessment

A flood damages assessment was undertaken for 20 PMF flood liable non-residential properties to calculate flood damages for a range of design events. A summary of the assessment is provided in the following sections with full details included in Appendix E.

Table 10 shows the potential damages for a range of design events and the Annual Average Damage (AAD). This forms the base case scenario against which damages from a number of mitigation measures can be assessed. Changes to damages values through various flood management options and the B/C analysis have been discussed in Section 5.3 for the preferred management options.

Table 10: Potential Non-Residential Damages for Henty

Event	No. Flooded Above Floor Level	Total Damages for Event	Event Contribution to AAD (%)
5-year ARI	1	$ 132,000	36
10% AEP	1	$ 132,000	24
5% AEP	2	$ 171,000	14
2% AEP	2	$ 266,000	12
1% AEP	2	$ 275,000	5
0.5% AEP	2	$ 283,000	3
PMF	7	$ 989,000	6
Average Annual Damages (AAD)		**$ 54,000**	

The event damages due to non-residential property flooding for the October 2010 and March 2012 flood events are estimated to be $520,000 and $160,000 respectively.

4.6.3. Public Infrastructure and Other Land Uses

Public sector (non-building) damages include; recreational/tourist facilities, water and sewerage supply, gas supply, telephone supply, electricity supply including transmission poles/lines, sub-stations and underground cables, rail, roads and bridges including traffic lights/signs, and costs to employ emergency services and assist in cleaning up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

Costs to Councils from flooding typically comprise:

- Clean-up costs;
- Erosion and siltation;
- Drain cleanout and maintenance;
- Removing fallen trees;
- Inundation of Council buildings;
- Direct damage to roads, bridges and culverts;
- Removing vehicles washed away;
- Assistance to ratepayers;
- Increases in insurance premiums;
- Closures of streets;
- Loss of working life of road pavements; and
- Operational costs in the lead up to and during flood events.

4.6.3.1. Electricity

The Henty electrical zone sub-station is situated on the Olympic Highway approximately 3.5 km north of town. This region is outside of the study area but well above the level of the Buckargingah Creek PMF level.

Liaison with Essential Energy has revealed that the site does experience local run off from nearby minor catchments, however flooding was not an issue in the 2010 flood which had an estimated ARI ranging between 200 to 500 years. The site is protected by a brick retaining wall to the east and a minor drainage channel to divert flows. Accordingly, flooding due to local run off is unlikely.

However, in the event of a flood Essential Energy should be notified so that an emergency response team can be assembled to perform a risk assessment of the infrastructure.

4.6.3.2. Sewerage

The Henty sewerage treatment plant is situated in Doodle Comer Swamp south-west of the corner of Comer Street and Rosler Parade. The main pond and associated infrastructure is leveed with a minimum freeboard of 1 m above the level of the PMF. The Henty sewerage treatment plant is therefore not flood liable.

4.6.3.3. Schools

Henty has two schools, Henty Public School at 43 Sladen Street and St Paul's Lutheran Primary School at 34 Lyne Street. There is also a pre-school at 23 Lyne Street.

Overland flow modelling suggests that inundation of the primary school building floors is not expected even in the local storm PMF, but playgrounds could be flooded and access along Sladen Street, Lyne Street and Comer Street could be disrupted in this extreme event. The pre-school could possibly be flooded to very shallow depths in the PMF, and water could reach depths of about 0.3m in Lyne Street adjacent to the facility.

Overland flow inundation to the schools would have different impacts depending on the time of day. The most serious scenario is probably if a heavy local storm occurs as the school day is ending, and parents and children should be educated about the danger of entering floodwaters. Although flooding at the schools is very unlikely, it is important that the schools have effective emergency plans that consider flooding.

4.6.3.4. Hospital

Henty Hospital is located at 7 Keighran Street.

Available data suggests that it is unlikely to be flooded above floor even in the PMF, but there could be shallow, low-hazard inundation in the surrounding streets due to extreme local rainfall (non-creek flooding).

4.6.3.5. Henty Machinery Field Days Site

Henty Machinery Field Days is an agribusiness supermarket attracting more than 60,000 visitors each year (about September). It is regarded as southern Australia's single biggest agricultural event, showcasing the latest in machinery and farm equipment, outdoors and camping products, farm produce, agronomy, country lifestyle, government and health services, agribusiness and finance services. It is located on the corner of the Henty-Cookardinia and Lubkes Roads about 7km east of Henty, next to Buckargingah Creek (see www.hmfd.com.au for additional information).

The site is located on the floodplain of Buckargingah Creek with the sites layout displayed in Figure 13 along with the various design flood extents. The fringe of the site could be flooded in events as frequent as the 10% AEP flood, but even up to the 0.5% AEP flood, the area inundated is relatively modest and the hydraulic hazard would still be low. In the PMF, about half the site would be flooded to depths and velocities constituting a high hydraulic hazard, but the southern half of the site is free of flooding even in the PMF.

Historically, flooding of Buckargingah Creek has been infrequent and the probability of serious flooding occurring at the same time as the three or so days of the annual agribusiness supermarket is very low. Nevertheless, the consequences could be serious and require consideration in a flood emergency plan for the site (see Section 5.5.2).

4.6.3.6. Operations Centres

In the October 2010 flood, the flood operation was managed from the Rural Fire Service station at the corner of Olympic Highway and Fox Street.

This site is modelled as not flooded in the PMF, from either Buckargingah Creek flooding or from local overland flows.

4.6.3.7. Evacuation Centres

The Greater Hume Local Flood Plan (Volume 1, Section 3.18.42) lists the Henty Community Club in South Street as the preferred evacuation centre.

This site is unlikely to be flooded above floor even in the PMF, but could be surrounded by shallow, low hazard inundation in the street from an extreme local storm (non-creek flooding).

4.7. Road Inundation and Access

Understanding flood access issues is critical to effective evacuation and flood response planning.

During the October 2010 flood, Henty was cut off from the north and south by flooding of the Olympic Highway and from the west by flooding of Henty-Pleasant Hills Road (Reference 3). It is likely that Henty-Cookardinia Road to the east of the town was also affected. Mullers Road would have been flooded.

The Flood Study (Reference 2) modelled peak flows, flood levels and velocities within Henty. A selection of flood depths at road low-points is presented in Table 11. The Olympic Highway could be cut 2.4 km north of Buckargingah Creek in relatively frequent flood events. Interestingly, photography shows water was over the Olympic Highway adjacent to No. 5538 Olympic Way in the October 2010 flood (Reference 3), at an area modelled as not flooded in the 0.5% AEP (200 year ARI) event. (That flood is estimated as a 200-500 year ARI event, and flooding may also have been exacerbated by culvert blockage to the south). Probably the key road of interest is Bartsch Avenue which is flooded even in the 5 year ARI event. The Flood Study (Reference 2) reports that this road is expected to be inundated for about 14 hours in the 1% AEP event, and this could be even longer when measured at the low-point (see Chart 1).

Table 11: Flood Depths at Road Crossings

Event	Henty-Cookardinia Road 320m east of Third Ave	Olympic Hwy 2.4km north of Buckargingah Creek	Bartsch Ave 50m east of Buckargingah Creek	Grubben Road just u/s Henty-Rand railway
5-year ARI	0.19	n/a	0.22	n/a
10% AEP	0.21	n/a	0.35	0.04
5% AEP	0.25	0.16	0.44	0.07
2% AEP	0.27	0.23	0.47	0.09
1% AEP	0.29	0.37	0.49	0.10
0.5% AEP	0.31	0.46	0.51	0.12
PMF	1.31	1.67	1.20	0.88

Research undertaken for the revision of ARR shows that vehicles can become unstable in shallow depths (~0.1m) where velocities approach 3 m/s. Small cars can float in still water depths of only 0.3 m (Reference 6). In addition, once flooding has subsided, structural damage could make access over a bridge unsafe.

Information about the depths and velocities of road inundation and likely timing of road closures can aid flood response planning, and ensure that evacuation occurs in a timely fashion before conditions deteriorate and hinder the evacuation process, requiring rescue boats and helicopters.

Council manages all roads within the Shire other than the Hume Highway and Olympic Way, which are managed by the Roads and Maritime Services (RMS). Both Council and the RMS have primary responsibility for closing and reopening flooded roads, though the NSW Police Force also has this authority. NSW SES may assist these organisations where resources allow.

4.8. Evacuation Constraints

In order to assist in the planning and implementation of response strategies, the NSW SES in conjunction with OEH has developed guidelines to classify communities according to the ease of evacuation (Reference 7). These flood Emergency Response Planning (ERP) classifications are mapped for various design floods by considering the inundation of land, roads and overland evacuation routes. Based on the guidelines, communities are classified as either: Flood Islands; Rising Road Access; Overland Escape Route; Trapped Perimeter or Indirectly Affected areas. The classification relates directly to the operational questions of evacuation, rescue and resupply (Table 12).

Table 12: Emergency Response Planning Classification of Communities

	EMERGENCY RESPONSE		
Classification	**Resupply**	**Rescue/Medivac**	**Evacuation**
High flood island	Yes	Possibly	Possibly
Low flood island	No	Yes	Yes
Area with rising road access	No	Possibly	Yes
Area with overland escape routes	No	Possibly	Yes
Low trapped perimeter	No	Yes	Yes
High trapped perimeter	Yes	Possibly	Possibly
Indirectly affected areas	Possibly	Possibly	Possibly

Provisional ERP classification was undertaken for the 5% AEP, 1% AEP and PMF events with the classified regions presented in the Flood Study (Reference 2). The NSW SES also gave consideration to these classifications as part of the drafting of Volume 2 of the Local Flood Plan undertaken as part of the post-March 2012 flood intelligence review (Reference 4).

Most of the residential and developed area of Henty is unaffected by creek flooding. Properties on the southern side of Buckargingah Creek that could be flooded (e.g. in Fox Street) generally have Rising Road Access to higher ground. One homestead located in Zone B on Figure 79 of the Flood Study (Reference 2) is potentially cut off from Henty by flooding from a drain that crosses a low-point along Henty-Cookardinia Road (see Table 11). This property is a High Trapped Perimeter in the 1% AEP flood but a Low Trapped Perimeter in the PMF.

Houses along the Olympic Highway north of Buckargingah Creek generally have Rising Road Access along the Highway to Henty in events up to and including the 0.5% AEP flood, though at a finer scale it is apparent that the houses are first surrounded then inundated by floodwater in the 5% or 2% AEP floods (Low Flood Islands). The Olympic Highway would be flooded in a PMF.

Residents along Grubben Road would probably not be cut off by floodwater in events up to and including the 0.5% AEP flood, being able to reach Henty via the railway crossing near Lot 15 and the Olympic Highway.

Houses towards the western end of Angaston Road and along Henty-Pleasant Hills Road could be isolated by flooding of driveways in relatively frequent events and could subsequently be flooded above floor (mostly only for floods of 0.5% AEP or rarer) (Low Flood Island).

A key issue with the Low Flood Island areas upstream and downstream of the Olympic Highway is achieving a reasonable effective warning time. Given Low Flood Island status the NSW SES's preference must be to evacuate these people prior to the flood event occurring.

4.9. Legislative and Planning Management

4.9.1. State Legislative and Planning Context

It is important to understand the state legislation that overarches all local legislation to enable appropriate floodplain risk management measures to be proposed that are in keeping with both state and local statutory requirements. This section discusses the state legislation that influences planning in relation to flood risk at the local government level.

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling development.

Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. Specifically, Direction 4.3 states:

Objectives

(1) The objectives of this direction are:

(a) to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and

(b) to ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

Clause (3) of Direction 4.3 states:

(3) This direction applies when a relevant planning authority prepares a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.

Clauses (4)-(9) of Direction 4.3 state:

(4) A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).

(5) A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.

(6) A planning proposal must not contain provisions that apply to the flood planning areas which:

(a) permit development in floodway areas,

(b) permit development that will result in significant flood impacts to other properties,

(c) permit a significant increase in the development of that land,

(d) are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or

(e) permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.

(7) A planning proposal must not impose flood related development controls above the residential flood planning level for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

(8) For the purposes of a planning proposal, a relevant planning authority must not determine a flood planning level that is inconsistent with the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas) unless a relevant planning authority provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

(9) A planning proposal may be inconsistent with this direction only if the relevant planning authority can satisfy the Director-General (or an officer of the Department nominated by the Director-General) that:

(a) the planning proposal is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or

(b) the provisions of the planning proposal that are inconsistent are of minor significance.

4.9.1.1. NSW Flood Prone Land Policy

The primary objectives of the NSW Government's Flood Prone Land Policy are:

- to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and

- to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Floodplain Development Manual 2005 (the Manual), relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy.

The Manual outlines a merits approach based on floodplain management. At the strategic level, this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk.

The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both, it recognises that a different emphasis is required to address issues particular to a rural floodplain. These issues include:

- The large area of land under investigation;
- The complexity of flood behaviour;
- The impacts of protection works for valuable crops on flood behaviour;
- The period of inundation;
- The uncertainties associated with flood related data, and
- The environmental values associated with flood dependent ecosystems on a rural floodplain.

4.9.1.2. Section 149 Planning Certificates

Section 149 of the EP&A Act states:

(1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a planning certificate) with respect to any land within the area of the council.

(2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected with this or any other Act or otherwise).

(3) (Repealed)

(4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.

The Environmental Planning and Assessment Regulation 2000 prescribes the matters which must be included in a s.149 Planning Certificate, including whether a parcel of land is subject to controls relating to flooding.

4.9.1.3. State Environmental Planning Policy (Exempt and Complying Development Codes (2008))

The aims of State Environmental Planning Policy (Exempt and Complying Development) 2008 are:

This Policy aims to provide streamlined assessment processes for development that complies with specified development standards by:

(a) providing exempt and complying development codes that have State-wide application, and

(b) identifying, in the exempt development codes, types of development that are of minimal environmental impact that may be carried out without the need for development consent, and

(c) identifying, in the complying development codes, types of complying development that may be carried out in accordance with a complying development certificate as defined in the Act, and

(d) enabling the progressive extension of the types of development in this Policy, and

(e) providing transitional arrangements for the introduction of the State-wide codes, including the amendment of other environmental planning instruments.

4.9.1.4. General Housing Code

Part 3 of the SEPP relates to the *"General Housing Code"*.

Division 1 of Part 3 of the SEPP, which comprises clauses 3.1-3.6 of the SEPP, relates to:

Development that is complying development under this code

Clause 3.1 states:

> ***3.1 Land to which code applies***
>
> *This code applies to development that is specified in clauses 3.2-3.5 on any lot in Zone R1, R2, R3, R4 or RU5 that:*
>
> *(a) has an area of at least 200 m^2, and*
>
> *(b) has a width, measured at the building line fronting a primary road, of at least 6m.*

Clause 3.2 of the SEPP states:

> ***3.2 New single storey and two storey dwelling houses***
>
> *The erection of a new single storey or two storey dwelling house is development specified for this code.*

Clauses 3.3-3.5 generally relate to single and two storey dwelling houses and ancillary development.

Division 2 of Part 3 of the SEPP contains:

> ***Development standards for this code***

Subdivision 9 contains:

> ***Development standards for particular land***

Subdivision 9 contains Clause 3.36C of the SEPP which relates to development standards for the General Housing Code on *"flood control lots"*. A *"flood control lot"* is defined in the SEPP as:

> ***flood control lot*** *means a lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing).*
>
> ***Note.*** *This information is a prescribed matter for the purpose of a certificate under section 149 (2) of the Act.*

As such, a *"flood control lot"* is a lot where the Council has provided for flood related development controls, which are all lots with notation on a s.149 Planning Certificate that flood related development controls apply. This is generally land which falls within the *"Flood Planning Area"*.

Clause 3.36C states:

3.36C Development standards for flood control lots

(1) This clause applies:

(a) to all development specified for this code that is to be carried out on a flood control lot, and

(b) in addition to all other development standards specified for this code.

(2) The development must not be on any part of a flood control lot unless that part of the lot has been certified, for the purposes of the issue of the relevant complying development certificate, by the council or a professional engineer who specialises in hydraulic engineering as not being any of the following:

(a) a flood storage area,

(b) a floodway area,

(c) a flow path,

(d) a high hazard area,

(e) a high risk area.

(3) The development must, to the extent it is within a flood planning area:

(a) have all habitable rooms no lower than the floor levels set by the council for that lot, and

(b) have the part of the development at or below the flood planning level constructed of flood compatible material, and

(c) be able to withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), and

(d) not increase flood affectation elsewhere in the floodplain, and

(e) have reliable access for pedestrians and vehicles from the development, at a minimum level equal to the lowest habitable floor level of the development, to a safe refuge, and

(f) have open car parking spaces or carports that are no lower than the 20-year flood level, and

(g) have driveways between car parking spaces and the connecting public roadway that will not be inundated by a depth of water greater than 0.3m during a 1:100 ARI (average recurrent interval) flood event.

(4) A standard specified in subclause (3) (c) or (d) is satisfied if a joint report by a professional engineer who specialises in hydraulic engineering and a professional engineer who specialises in civil engineering confirms that the development:

(a) can withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), or

(b) will not increase flood affectation elsewhere in the floodplain.

(5) If a word or expression used in this clause is defined in the Floodplain Development Manual, the word or expression has the same meaning as it has in that Manual unless it is otherwise defined in this clause.

(6) In this clause:

***flood compatible material** means building materials and surface finishes capable of withstanding prolonged immersion in water.*

***Floodplain Development Manual** means the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005.*

***flow path** means a flow path identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

***high hazard area** means a high hazard area identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

***high risk area** means a high risk area identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

4.9.1.5. Rural Housing Code

Part 3A of the SEPP contains the *"Rural Housing Code"*.

Division 1 of Part 3A of the SEPP defines:

> ***Development that is complying development under this code***

Clauses 3A.1 and 3A.2 state:

> ***3A.1 Land to which code applies***
>
> *This code applies to development that is specified in clauses 3A.2-3A.5 on lots in Zones RU1, RU2, RU3, RU4, RU6 and R5.*
>
> ***3A.2 New single storey and two storey dwelling houses***
>
> *(1) The erection of a new single storey or two storey dwelling house is development specified for this code if the development is erected on a lot:*
>
> *(a) in Zone RU1, RU2, RU4 or RU6 that has an area of at least 4,000m^2, or*
>
> *(b) in Zone R5.*
>
> *(2) This clause does not apply if the size of the lot is less than the minimum lot size for the erection of a dwelling house under the environmental planning instrument applying to the lot.*

Clause 3A.38 contains:

> ***Development standards for flood control lots***

The development standards contained in clause 3A.38 are the same as those contained in clause 3.36 as detailed above.

4.9.1.6. Summary of State Legislative and Planning Polices

From the above discussion of both the General Housing Code and the Rural Housing Code, it is clear that, unless a lot affected by flooding is included as a *"flood control lot"*, a s.149 notification is not required and, as a result, planning controls relating to flooding do not apply and a Complying Certificate can be granted without having regard to any Council flood controls. This scenario has considerable implications with regard to Council deciding whether a lot which is flood affected is included in the Floor Planning Area.

4.9.2. Local Council Policy

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding. Plans and Polices have been discussed below and have been reviewed in regards to flood risk management to identify where improvements might be made (see Section 5.6).

A LEP guides land use and development by zoning all land, identifying appropriate land uses that are allowed in each zone, and controlling development through other planning standards and Development Planning Controls (DCPs). LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to. Greater Hume Shire Council's LEP was adopted in 2012 and was prepared under the Standard Instrument LEP program.

4.9.2.1. Greater Hume Local Environment Plan 2012 (LEP 2012)

Clause 6.1A of LEP 2012 relates to flood planning and states:

> ***6.1A Flood planning***
>
> *(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 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.

4.9.2.2. Greater Hume Development Control Plan 2013

Chapter 8 of the Greater Hume DCP 2013 deals with flood liable land.

Chapter 8 contains a number of objectives for development, some of which relate to outdated definitions or documents which has been repealed, for example, objective (l) is:

(l) deal consistently with applications for development on flood affected land, generally in accordance with the Floodplain Management Manual: The Management of Flood Liable Land issued by the New South Wales Government 2005;

A number of recommended amendments to Chapter 8 of the DCP, including use of the 1% AEP design flood level plus freeboard are given in Section 5.6 and a draft policy is presented in Appendix F.

5. FLOODPLAIN RISK MANAGEMENT MEASURES

5.1. Identifying Floodplain Risk Management Measures

This FRMS aims to identify and assess risk management measures which could be put in place to mitigate flooding risk and reduce flood damages. This section sets out a number of measures which could be of benefit to Henty. As well as the hydraulic impacts, flood risk management measures are assessed against the legal, structural, environmental, social and economic conditions or constraints of the local area. In the following sections a range of management options have been considered to effectively manage existing and future flood risks at Henty.

5.2. Risk Management Measures Categories

The 2005 NSW Government's Floodplain Development Manual (Reference 1) separates risk management measures into three broad categories.

Flood modification measures modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvements, levees or defined floodways. Pit and pipe improvement and even pumps may also be considered where practical.

Property modification measures modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase/voluntary house raising.

Response modification measures modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

Table 13 provides a summary of typical floodplain risk management measures that have been assessed for the current study. It should be noted that many of these management measures are not appropriate for Henty and have not been recommended.

Table 13: Flood Risk Management Measures

Flood Modification	Property Modification	Response Modification
Levees (Lv)	Land zoning	Community awareness
Temporary Defences (TD)	Voluntary purchase	Flood warning
Channel Construction (CC)	Building & development controls	Evacuation planning
Channel Modification (CM)	Flood proofing	Evacuation access
Major Structure Modification (MSM)	House raising	Flood plan / recovery plan
Drainage Network Modification (DNM)	Flood access	
Drainage Maintenance (DM)		
Retarding Basins (RB)		

5.3. Flood Modification Measures

The purpose of flood modification measures is to modify the behaviour of the flood itself by reducing flood levels or velocities by excluding water from areas under threat. These measures usually involve structural works, most often permanent but temporary structures can be deployed where sufficient flood warning is available. This section considers management measures which modify flood behaviour on a wider scale. Flood modification measures at the individual property scale are discussed in Section 5.4.4.

Table 14 lists the modelled modification options and Figure G 1 (Appendix G) displays spatial locations of the modelled options.

Table 14: Flood Modification Measures Tested

Option	Description	Type*	Report Section
L1	West Showground Road Levee	(Lv)	5.3.1.1
L2	East Showgrounds Levee	(Lv)	5.3.1.2
L3	Grubben Road Levee	(Lv)	5.3.1.3
L4	Angaston Road Levee	(Lv)	5.3.1.4
L5	East Henty Levee	(Lv)	5.3.1.5
L1, L3 L5	Combined Levee System	(Lv)	5.3.1.6
L1, L4, S1, C3	Combined Levee and Drainage System	(Lv, CC & CM)	5.3.1.7
C1	Channel between Olympic Highway and Railway embankment	(CC)	5.3.3.1
C2	Channel to carry flow between Grubben Road and Angaston Road	(CC)	5.3.3.2
C3	Grain Silos and Canola Sheds Channel	(CC)	5.3.3.3
C4	Channel across Grubben Road to meet existing drainage channel	(CC)	5.3.3.4
L3, C2, C4	Grubben Road Combined Mitigation Option	(Lv & CC)	5.3.3.5
S1	Increasing capacity of table drains along of Pleasant Hills Road	(CM)	5.3.4.2
S2	Buckargingah Creek, Henty Government Dam Bypass	(CM)	5.3.4.3
S3	Buckargingah Creek channel clearing	(CM)	5.3.4.4
S4	Straightening Buckargingah Creek	(CM)	5.3.4.5
A1	Increasing Buckargingah Creek bridge crossing conveyance	(MSM)	5.3.5.1
A2	Increasing culvert conveyance 200 m north of Buckargingah Creek	(MSM)	5.3.5.2
A3	Increasing culvert conveyance 700 m north of Buckargingah Creek	(MSM)	5.3.5.3
A4	Increases structure conveyance - Options A1, A2 and A3 Combined	(MSM)	5.3.5.4

* See Table 13 for Type classification description

Flood impact maps have been produced to display the effect that the various mitigation structures have on flood behaviour. These maps display the difference in peak flood level between the 1% AEP design event and the same event with the mitigation structure implemented. Impact maps have only been presented where significant impacts have been produced.

Mitigation options that were determined to provide significant benefits in terms of reduction in private property inundation have had damages assessments undertaken such that a Cost/Benefit ratio could be produced.

5.3.1. Levees and Bunds

DESCRIPTION

Levees involve the construction of raised embankments between the watercourse and flood affected areas so as to prevent the ingress of floodwater up to a design height. Levees usually take the form of earth embankments but can also be constructed of concrete walls or similar where there is limited space or other constraints. They are more commonly used on large river systems, for example on the Murrumbidgee at Wagga Wagga, but can also be found on small creeks in urban areas and in overland flow situations where they usually take the form of smaller bunds.

Flood gates, flap valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee.

Localised levees or bunding can be applied around individual properties. Such measures are considered minor property adjustments and are discussed in Section 5.4.4.

DISCUSSION

Once constructed, levee systems generally have a low maintenance cost although the levee system needs to be inspected on a regular basis for erosion or failure. Although a levee can keep out flood waters, flooding can occur within the levee due to local runoff being unable to drain. In addition, as the levee causes a displacement of water from one area of the floodplain to another they should be carefully designed using hydraulic modelling techniques so as to ensure the levee does not increase flood risk to an adjacent area.

The design height of the levee is the event for which it prevents flooding and usually also includes a freeboard to allow for settlement of the structure overtime or variations in flood levels due to the behaviour of the flood event, wave action from passing vehicles or watercraft and effects of wind.

Various levee alignments have been considered for Henty to mitigate flooding from Buckargingah Creek. These include:

1. Option L1 – West Showground Road Levee (see Section 5.3.1.1);
2. Option L2 – East Showground Levee (see Section 5.3.1.2);
3. Option L3 – Grubben Road Levee (see Section 5.3.1.3);
4. Option L4 – Angaston Road Levee (see Section 5.3.1.4); and
5. Option L5 – East Henty Levee (see Section 5.3.1.5).

In addition to the above listed Options, the following combined levee systems have also been analysed:

6. Options L1, L3 and L5 – Combined Levee System (see Section 5.3.1.6).
7. Options L1, L4, S1 and C3 – Combined Levee and Drainage System (see Section 5.3.1.7).

Further details of these structures are presented in the following sections and their locations displayed in Figure G 1.

5.3.1.1. Option L1 – West Showground Road Levee

Mitigation Option L1 involves the implementation of a levee along West Showground Road and Pleasant Hills Road. This levee was designed to prevent flood waters from inundating properties to the west of the levee by confining flood waters to the showground. The tested levee alignment is approximately 560 m long with a maximum crest height of 2.05 m (average of approximately 1.45 m) above surrounding ground level (determined using the 1% AEP flood event and assuming 0.75 m freeboard, see Appendix H for freeboard selection details).

The Option L2 impact map for the 1% AEP event is presented in Figure G 2. It shows that a large area of land inside of the levee experiences reduced peak flood levels, particularly properties that have previously experienced flooding along Pleasant Hills Road. Reductions in peak flood level of up to 0.6 m were present, leaving some areas no longer flood affected in the 1% AEP event. However the Option L1 Levee alignment does not totally exclude flood waters from inside of the levee due to the Angaston Street flow path that conveys flood water from the north (see Section 3.3). This issue can be address by construction of the Angaston Road Levee (see Section 5.3.1.4). Outside the levee, increases in flood level of up to 0.7 m were experienced at the showground. Increases in peak flood levels outside of the levee are less than 0.1 m in the vicinity of residential properties and are unlikely to adversely affect homes in this region.

Option L1 has been considered for further investigation and damages assessment was undertaken to determine the B/C ratio for implementation. The estimated residential and non-residential damages are displayed in Table 15 and Table 16 respectively.

Table 15: Option L1 – Estimated Residential Damages for Henty

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Long Flooded Over Floor
5-year ARI	0	$ 42,000	0
10% AEP	0	$ 57,000	0
5% AEP	2	$ 180,000	1
2% AEP	5	$ 399,000	1
1% AEP	6	$ 443,000	1
0.5% AEP	7	$ 526,000	2
PMF	42	$ 3,403,000	0
Average Annual Damages (AAD)		**$ 43,000**	

Table 16: Option L1 – Estimated Non-Residential Damages for Henty

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Long Flooded Over Floor
5-year ARI	0	$ 17,000	0
10% AEP	0	$ 17,000	0
5% AEP	0	$ 22,000	1
2% AEP	0	$ 23,000	1
1% AEP	0	$ 24,000	1
0.5% AEP	0	$ 25,000	1
PMF	7	$ 893,000	0
Average Annual Damages (AAD)		**$ 9,000**	

The estimated cost of construction for Options L1 is $526,000. The combined AAD (residential and non-residential) is $52,000 which is a $48,000 reduction in AAD with implementations of Option L1. By estimating the expected damages for the next 50 years assuming implementation of the above mentioned options a B/C ratio of 1.4 has been calculated.

Information on the preliminary costing and design of Option L1 is contained in Appendix H.

Option L1, whilst having a high B/C ratio, only offers protection to a limited number of properties and is thus not recommended for further investigation in isolation. However, Option L1 was also considered in combination with Options L3 and L5 to provide flood mitigation to a wider area. Further details presented in Section 5.3.1.6. Furthermore, Option L1 was also investigated with Options L4, S1 and C3, with details presented in Section 5.3.1.7.

5.3.1.2. Option L2 – East Showgrounds Levee

Option L2 investigated the construction of a levee parallel to Grubben Road (see Figure G 3) between Pleasant Hills Road and Angaston Road, designed to prevent the flood waters from flowing through the Showground and flooding properties north of Pleasant Hills Road. The levee alignment has a design length of 320 m and a maximum height of approximately 1.25 m (average of 0.85 m) relative to surrounding ground level (determined using the 1% AEP flood event and assuming 0.75 m freeboard, see Appendix H for freeboard selection details).

In the 1% AEP flood event the levee reduces flood impacts at the showground with minor (less than 0.05m) reductions in impacts to nearby by properties as shown in Figure G 3. This option is not recommended for further investigation as it does not significantly mitigate flooding for residential properties in its vicinity.

5.3.1.3. Option L3 – Grubben Road Levee

Option L3 involved the construction of a road-side levee along Grubben Road between Angaston Road and the railway as recommended by the community consultation process (see Section 2). The levee has a length of 180 m and maximum height of 0.95 m (average of 0.55 m) and was designed to prevent flood waters from flowing north along Grubben Road.

A flood impact map for the 1% AEP event is presented in Figure G 4. It was found that Option L3 reduced flood levels by 0.15 m in areas north of the levee with minor areas no longer affected by the 1% AEP event. However, reduced flood levels for private dwellings are negligible. Upstream of the levee, flood levels are increased by up to 0.1 m however this does not affect private land, with impacts confined to the showground and common areas.

Due to the insignificant decreases in peak flood level and flood affectation, Option L3 is not recommended for further investigation by itself however, this option has been recommended together with Options C2 and C4 in Section 5.3.3.5. Option L3 has also been examined in combination with Options L1 and L5 (see Section 5.3.1.6) and with Options L1, L5, S1 and C3 in Section 5.3.1.7.

5.3.1.4. Option L4 – Angaston Road Levee

The construction of a levee along the northern side of Angaston Road was considered as a mitigation measure to prevent flood waters from inundating properties along Pleasant Hills Road from the north. This levee measures 600 m in length with a maximum height of 1.15 m (average height of 0.85 m) above surrounding ground level (determined using the 1% AEP flood event and assuming 0.75 m freeboard, see Appendix H for freeboard selection details).

In the 1% AEP Event, there were minor reductions in peak flood levels with the area immediately downstream of the levee no longer flood affected in the 1% AEP Event. Outside the levee, peak flood levels were slightly increased by up to 0.15 m with neighbouring properties experiencing increased levels by approximately 0.02 m. However, Option L4 does not affect over floor flood liability outside of the levee.

Option L4 has not been recommended as an individual mitigation strategy however it has been considered in combination with Options L1, S1 and C3 as a potential mitigation measure for Henty (see Section 5.3.1.7).

5.3.1.5. Option L5 – East Henty Levee

Option L5 investigated the construction of a levee perpendicular to the eastern side of the Olympic Highway, to prevent flood waters inundating properties to the north of the levee. The levee was designed to be 600 m long with a maximum height of 1.45 m (average height of 0.95 m, determined using the 1% AEP flood event and assuming 0.75 m freeboard, see Appendix H for freeboard selection details).

Figure G 5 shows the flood impacts resulting from this mitigation in the 1% AEP event. Peak flood levels to the north of the levee were significantly reduced (by up to 1.4 m) and large areas are no longer flood affected around residential properties. Flood impacts were also reduced by up to 0.2 m at properties along Grubben Road on the western side of the railway. Upstream of the highway, outside of the levee, peak flood levels increase by up to 0.3 m and the Olympic Highway is overtopped. Further downstream, near the Henty Government Dams and Pleasant Hills Road, flood levels increase by up to 0.1 m in the 1% AEP event.

Option L5 has been considered for further investigation and has been modelled with Options L1 and L3 to further improve flood protection (see Section 5.3.1.6).

5.3.1.6. Option L1, L3 and L5 – Combined Levee System

Options L1, L3 and L5 were investigated as a combined levee system (see Sections 5.3.1.1, 5.3.1.3 and 5.3.1.5 respectively). These levees are intended to prevent floodwaters from Buckargingah Creek flowing toward the northern floodplain and flooding residential properties in the area.

The flood impacts in the 1% AEP event for this mitigation measure are shown in Figure G 6. Peak flood levels to the north of the levees were significantly reduced with large areas no longer affected by flooding. Flood affectation upstream of the Olympic Highway is significantly reduced as per Section 5.3.1.5. Along Grubben Road, properties which previously experienced yard and over floor flooding are no longer flooded in the 1% AEP event. Similarly, previously flood affected properties on Angaston Street and Pleasant Hills Road are no longer flood affected.

Outside of the levees, marked increases in peak flood levels are present. Properties along Fox Street do experience increased flood levels, however increases in peak flood levels do not affect over floor flood liability with the majority of properties floor levels above the level of the PMF. In addition to the properties along Fox Street, a property situated between Pleasant Hills Road and Buckargingah Creek also experiences increased flood levels (0.1 m proximate to the property), however again over floor flood liability is not impacted on as the property's floor level is well above the 0.5% AEP flood level.

A damages assessment was undertaken to determine the B/C ratio for the implementation of the combined scenarios. The estimated residential and non-residential damages are displayed in the following tables.

Table 17: Combined Options L1, L3 and L5 – Residential Damages for Henty

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	0	$ 42,000	0
10% AEP	0	$ 53,000	0
5% AEP	0	$ 72,000	3
2% AEP	0	$ 79,000	6
1% AEP	0	$ 88,000	7
0.5% AEP	1	$ 137,000	8
PMF	42	$ 3,367,000	42
Average Annual Damages (AAD)		**$ 27,000**	

Table 18: Combined Options L1, L3 and L5 – Non - Residential Damages for Henty

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	0	$ 17,000	0
10% AEP	0	$ 17,000	0
5% AEP	0	$ 22,000	1
2% AEP	0	$ 23,000	1
1% AEP	0	$ 24,000	1
0.5% AEP	0	$ 25,000	1
PMF	7	$ 871,000	0
Average Annual Damages (AAD)		**$ 9,000**	

The estimated cost of implementation for the combined Options L1, L3 and L5 is estimated to be $1,110,000. The combined AAD (residential and non-residential) is $36,000 which is a $64,000 reduction in AAD with implementations of the combined Options L1, L3 and L5. By estimating the expected damages for the next 50 years assuming implementation of the above mentioned options a B/C ratio of 0.9 has been calculated.

Information on the preliminary costing and design of the combined options L1, L3 and L5 are contained in Appendix H.

SUMMARY

Implementation of the proposed mitigation measures provides a B/C ratio close to one and effectively removes flood affectation for all properties up to the 1% AEP at Henty.

RECOMMENDATIONS

The following measures are recommended:

► Recommended that detailed costing and design be undertaken for the combined **OPTIONS L1, L3 and L5.**

5.3.1.7. Option L1, L4, S1 and C3 – Combined Levee and Drainage System

Options L1, L4, S1 and C3 (see Sections 5.3.1.1, 5.3.1.4, 5.3.4.2 and 5.3.3.1 respectively) were combined and modelled as a potential mitigation measure to alleviate flooding for properties situated along Angaston and Pleasant Hills Road. This series of levees and channels aimed to prevent floodwaters from entering properties prone to flooding and redirect the floodwaters into drainage channels.

Figure G 7 shows the flood impacts in the 1% AEP event for these combined options. A large area of no longer flood affected land is shown for properties north of Pleasant Hills Road with peak flood levels reduced by up to 0.6 m. Increases to flood levels are present outside of the levee however do not affect residential areas.

A damages assessment was undertaken to determine the B/C ratio for implementation of the combined scenarios. The estimated residential and non-residential damages are shown in Table 19 and Table 20.

Table 19: Combined Options L1, L4, S1 and C3 – Residential Damages for Henty

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	0	$ 42,000	0
10% AEP	0	$ 57,000	0
5% AEP	2	$ 180,000	1
2% AEP	5	$ 390,000	1
1% AEP	5	$ 415,000	2
0.5% AEP	5	$ 472,000	4
PMF	42	$ 3,359,000	0
Average Annual Damages (AAD)		**$ 42,000**	

Table 20: Combined Options L1, L4, S1 and C3 – Non - Residential Damages for Henty

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	0	$ 17,000	0
10% AEP	0	$ 17,000	0
5% AEP	0	$ 22,000	1
2% AEP	0	$ 23,000	1
1% AEP	0	$ 24,000	1
0.5% AEP	0	$ 25,000	1
PMF	7	$ 871,000	0
Average Annual Damages (AAD)		**$ 9,000**	

The estimated cost of implementation for the combined Options L1, L4, S1 and C3 is estimated to be $1,374,000. The combined AAD (residential and non-residential) is $51,000 which is a reduction of $49,000. By estimating the expected damages for the next 50 years assuming implementation of the above mentioned options a B/C ratio of 0.5 has been calculated.

SUMMARY

The combined Options L1, L4, S1 and C3 is not recommended for further investigation due to the low B/C ratio. In addition to this the combined Options L1, L3 and L5 provides significant flood mitigation and has a B/C ratio greater than one and is recommended for implementation.

5.3.2. Temporary Flood Barriers

DESCRIPTION

Temporary flood barriers include demountable defences, wall systems and sandbagging which are deployed before the onset of flooding.

DISCUSSION

Demountable defences can be used to protect large areas and are often used as a means to assist in current mitigation measures rather than as sole protection measures. For example they are best used to fill in gaps in levees or raising them as the risk of levee overtopping develops. The effectiveness of these measures relies on sufficient warning time and the ability of a workforce to install. They are more likely to be used for mainstream fluvial flooding from rivers which have sufficient warning time and are not a suitable technique for overland flooding.

The use of temporary measures in protecting individual properties, such as sandbagging, is discussed in Section 5.4.3.

SUMMARY

In Henty, demountable defences are unlikely to be able to be used to reduce flood risk and inundation due to the lack of suitable locations for their placement and insufficient warning time.

5.3.3. Channel Construction

DESCRIPTION

Channels can be an effective way to transfer and confine flow in a flooding situation and can aid in reducing peak flood levels, extents and duration.

DISCUSSION

An investigation into mitigation strategies for Buckargingah Creek flow breakouts lead to the modelling of various channels to assist in the removal of flood waters and reduction of peak flood levels. The scenarios described below were aimed at removing flood waters on the Buckargingah Creek northern floodplain. Details of these Options are investigated in the following sections.

5.3.3.1. Option C1 – Channel between Olympic Highway and Railway embankment

Option C1 was modelled by constructing a 0.5 m deep by 6 m wide channel situated between the Main Southern Railway and the Olympic Highway. This measure aimed to redirect flood waters from the culverts under the Main Southern Railway and Olympic Highway 700 m north of Buckargingah Creek (see Table 1, Section 1.6.2) to the south back toward Buckargingah Creek and reduce peak flood levels to properties along Grubben Road.

Mitigation Option C1 was modelled for the 1% AEP event and was shown to be ineffective with no significant change in peak flood levels.

Due to the lack of significant impacts provided by Option C1, further investigation of this scenario is not warranted.

5.3.3.2. Option C2 – Channel to carry flow between Grubben Road and Angaston Road

Option C2 involved modelling of a 12 m wide, 1 m deep channel to carry flow between Grubben and Angaston Roads. This measure was intended to prevent floodwaters from dispersing at Grubben Road and inundating nearby properties and was recommended by Henty residents as part of the Community Consultation process (see Section 2).

Option C2 was tested for the 1% AEP event. Peak flood levels were reduced by up to 0.1 m in the immediate vicinity of the drain, however nearby properties did not benefit from any significant reduction to peak flood levels. Accordingly Option C2 is not recommended for further investigation.

Option C2 has also been tested in combination with Options L3 and C4 to reduce flood affectation along Grubben Road (see Section 5.3.3.5).

5.3.3.3. Option C3 – Grain Silos and Canola Sheds Channel

Option C3 involved modelling of a channel parallel and to the south of the Henty-Rand railway and around the Grain Silos. This channel aimed to convey flood waters away from Angaston Road properties in the north-westerly direction and was recommended by Henty community members as part of the Community Consultation program (see Section 5.3.3.3).

Option C3 was modelled for the 1% AEP event and reduced flood levels by up to 0.2 m in the vicinity of the channel, however provided minimal benefits to residential properties along Angaston Street.

Accordingly, further investigation into Option C3 is not warranted however this measure has been considered in combination with Options L1, L4 and S1, see Section 5.3.1.7.

5.3.3.4. Option C4 – Channel across Grubben Road to meet existing drainage channel

Option C4 investigates the construction of a 12 metre wide, 1.2 metre deep drainage channel from the Main Southern Railway culverts 700 m north of Buckargingah Creek (see Table 1, Section 1.6.2) across Grubben Road and into the existing drainage channel. At present, water from the railway culverts is dispersed as shallow sheet flow through the region after backing up along Grubben Road. Option C4 intends to prevent this dispersion by providing a defined channel across Grubben Road into the existing drainage channel.

Option C4 was examined for the 1% AEP event but was shown to provide little benefit to residential properties as the region still experiences flow along Grubben Road from Buckargingah Creek to the south.

The implementation of Option C4 would be ineffective as an individual mitigation strategy though it has been tested in conjunction with Options L3 and C2 as a measure to alleviate flooding in the Grubben Road region, see Section 5.3.3.5.

5.3.3.5. Options L3, C2 and C4 – Grubben Road Combined Mitigation Option

Options L3, C2 and C4 (see Sections 5.3.1.3, 5.3.3.2 and 5.3.3.4 respectively) were modelled together to alleviate the flood issue in the Grubben Road region.

This combination of Options was tested for the 1% AEP event and the flood impacts are presented in Figure G 8. It was found that there were large areas and properties along Grubben Road that were no longer affected by flooding. Areas surrounding the drain toward Angaston Road experienced reduced flood levels of up to 0.2 m in some areas. South of the Option L3 (see Section 5.3.1.3) levee, increases to peak flood level were experienced which did have some impact on residential and non-residential properties.

A damages assessment was undertaken to determine the B/C ratio for implementation of the combined scenarios. The estimated residential and non-residential damages are shown in Table 21 and Table 20.

Table 21: Combined Options L3, C2 and C4 – Estimated Residential Damages for Henty

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	0	$ 42,000	0
10% AEP	0	$ 50,000	0
5% AEP	2	$ 178,000	1
2% AEP	4	$ 363,000	2
1% AEP	6	$ 432,000	1
0.5% AEP	7	$ 511,000	2
PMF	42	$ 3,491,000	0
Average Annual Damages (AAD)		**$ 41,000**	

Table 22: Combined Options L3, C2 and C4 – Non - Residential Damages for Henty

Event	No. Flooded Above Floor Level	Total Damages for Event	No. of Properties No Longer Flooded Over Floor
5-year ARI	1	$ 132,000	0
10% AEP	1	$ 132,000	0
5% AEP	2	$ 266,000	0
2% AEP	2	$ 266,000	0
1% AEP	2	$ 282,000	0
0.5% AEP	2	$ 283,000	0
PMF	7	$ 981,000	0
Average Annual Damages (AAD)		**$ 58,000**	

The cost of implementation for the combined Options L3, C3 and C4 is estimated to be $421,000. The combined AAD (residential and non-residential) is $99,000 which is a $1,000 reduction in AAD. By estimating the expected damages for the next 50 years assuming implementation of the above mentioned options a B/C ratio of 0.1 has been calculated.

It should be noted that these works do produce an increase in peak flood levels and associated damages to properties along Pleasant Hills Road, particularly for non-residential properties which experienced an increase in AAD of $2,000.

Due to increases in peak flood levels and flood damages, these combined Options are not recommended for further investigation.

Information on the preliminary costing and design of the combined options L3, C3 and C4 are contained in Appendix H.

SUMMARY

The construction of additional channels in Henty to confine floodwaters from Buckargingah Creek breakouts were found to be ineffective in regards to reducing over floor inundation. Modifications to existing channels prove more slightly more effective and this is investigated in the following section (see Section 5.3.4).

5.3.4. Channel Modifications

DESCRIPTION

Channel modification includes a range of measures from increasing the size of a channel, straightening, concrete lining, removal of obstructing structures, dredging and vegetation clearing. In some instances 'naturalising' the channel upstream can reduce peak levels downstream by slowing flows and making better use of flood storage. On the other hand, straightening and channelling the flow can improve flooding by removing flood waters from an area more efficiently. However, such measures may also increase flood levels in adjacent or downstream locations.

DISCUSSION

A number of issues relating to existing flow channels have been discussed as part of the community consultation program (see Section 2). Residents have raised concerns with the amount of debris in Buckargingah Creek and also the possibility of dredging the Creek. These have been investigated in the following sections.

5.3.4.1. Strategy for Vegetation Planting

Vegetation management planning should be investigated from a Buckargingah Creek catchment-wide perspective in the first instance and then in a more localised manner for Henty. A catchment wide investigation is beyond the scope of the current study, however should be considered by Council in conjunction with Local Land Services (LLS) for the future.

The Murray region Local Land Services (LLS) are responsible for Buckargingah Creek at Henty. Council should liaise with LLS to determine to what degree Buckargingah Creek can be cleared of vegetation, however there is generally no problem with removal of exotic trees and vegetation such as willows. Clearing or dredging on a broad scale would also require approval of various other state government organisations such as Fisheries and the Office of Water. The Roads and Maritime Service (RMS) have authority from the Environmental Protection Authority (EPA) to remove debris built up against structures.

Council should request a strategy for vegetation planting of Buckargingah Creek to examine ways in which the river and floodplain environment may be enhanced to create a valuable corridor of vegetation without having a detrimental effect on flooding. As noted above, clearing of vegetation can be beneficial to reduce flood levels and reduce the risk of blockage of downstream structures. A suitable strategy for vegetation planting would need to balance the need for native vegetation and a thriving riparian corridor whilst managing the build-up of or clearance of vegetation to avoid unwanted effects on flood behaviour.

Management of vegetation can reduce flood levels by increasing the flow area within the channel by reducing potential for obstruction and blockage. Vegetation thinning on a regular basis to prevent build up is recommended. However, the impact of such works is generally minimal as shown in Section 5.3.4.4.

5.3.4.2. Option S1 – Increasing capacity of table drains along of Pleasant Hills Road

It was suggested in the Henty Community Consultation (Section 2) that the conveyance of the existing table drains along Pleasant Hills Road be increased to accommodate overflow of flood water from Buckargingah Creek to reduce flood levels along Pleasant Hills Road. The capacity of the existing drains on either side of Pleasant Hills Road were increased such that the new drains have a width of 12 m and depth of 1 m.

Option S1 was investigated for the 1% AEP event and the impact map is presented in Figure G 9. Reductions to peak flood levels of up to 0.15 m were experienced near residential properties on Pleasant Hills Road, however reduced flood levels were generally less than 0.05 m.

The size of the investigated table drains (two 12 m wide x 1 m deep) are much larger (and much more expensive) than what would generally be considered for this type of mitigation work. However, even with the exaggerated conveyance of these drains, Option S1 does not significantly ameliorate the flood problem along Pleasant Hills Road.

This measure has not been recommended for further investigation, however it has been investigated in combination with Options L1, L4 and C3 (see Section 5.3.1.7).

5.3.4.3. Option S2 – Buckargingah Creek, Henty Government Dam Bypass

Modelling of Option S2 involved straightening Buckargingah Creek to bypass the Henty Government Dam to assist in flow conveyance downstream of the Olympic Highway and Main Southern Railway line. A channel was added at the downstream side of the railway at Buckargingah Creek to bypass the Henty Government Dam.

This option was tested for the 1% AEP Event and showed reductions in peak flood levels of up to 0.1 m in the vicinity of the bypass channel and minor reductions (less than 0.05 m) to peak flood levels in residential areas upstream of the Olympic Highway.

Option S2 is not recommended for further investigation due to the relatively small impact on flood levels in the 1% AEP event and the substantial environmental and monetary costs of redirecting the existing creek.

5.3.4.4. Option S3 – Buckargingah Creek channel clearing

Option S3 was modelled by reducing the Buckargingah Creek channel roughness from a Mannings 'n' of 0.08 to 0.04 to simulate clearing of the channel from its current state to well-kept grass channel (an exaggeration of what is actually possible). This measure, as suggested in the Community Consultation (see Section 2), was used to show the impact that channel clearing and the associated increased channel efficiency has on peak flood levels.

It was found that clearing of the channel led to no significant reduction in peak flood levels for the township of Henty or the Buckargingah Creek floodplain.

Option S3 shows that even if the creek were to be cleared of vegetation and replaced with well-kept grass the impact on peak flood levels is relatively minor for populated regions. However, it is recommended that the strategies mentioned in Section 5.3.4.1 be pursued by Council so that further increases to vegetation density do not occur.

5.3.4.5. Option S4 – Straightening Buckargingah Creek

The sinuous nature of Buckargingah Creek was considered by members of the community as a possible cause of exacerbation of flooding along Pleasant Hills Road (see Section 2). Option S4 investigated the straightening of Buckargingah Creek at its downstream end (as shown in Figure G 10) to assist in the draining of flows into Doodle Comer Swamp.

In the 1% AEP event, Option S4 made only minor reductions to peak flood levels in residential areas. Properties along Pleasant Hills Road experience a maximum reduction in peak flood levels of 0.1 m. Figure G 10 shows the flood impacts for this mitigation measure.

Option S4 is not recommended for further investigation due to the associated minor reduction in flood levels. Further, the monetary and environmental cost associated with straightening Buckarginigah Creek and creating a new drainage channel would be great compared to the insignificant reduction in peak flood levels.

Due to the minor benefit associated with implementation of this option as well as the significant monetary and environmental costs, this scenario has not been considered further.

SUMMARY

Management of vegetation in Buckargingah Creek will have some benefits in reducing flood levels and preventing further build-up of debris and siltation of the Creek however should be considered carefully with the implications of environment effects.

Increasing existing major drainage infrastructure was generally shown to be ineffective. Options S1 and S4 did show some reduction in peak flood levels however will not be considered further due to an expected low B/C ratio.

RECOMMENDATIONS

The following measures are recommended:

► Management of vegetation in Buckargingah Creek to prevent blockage impacts on flood behaviour.

5.3.5. Major Structure Modification

DESCRIPTION

Hydraulic controls such as bridges or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. By increasing hydraulic conveyance, flood levels upstream of a structure can be decreased. Generally the most effective way of increasing hydraulic conveyance is by increasing a structure's cross sectional area (normal to the flow direction). This is often done by lengthening a bridge or raising the deck level.

DISCUSSION

A number of significant hydraulic structures that affect flood behaviour are situated in the study area. As part of the Community Consultation (see Section 2.1) and at the request of Council, a number of scenarios of increased conveyance capacity of the Olympic Highway and Main Southern Railway bridges and culverts have been modelled. These include:

1. Option A1 – Widening bridges over Buckargingah Creek (see Table 1, ID #1 & #2, Section 1.6.2) presented in Section 5.3.5.1;
2. Option A2 – Widening Olympic Highway and Railway bridges 200 m north of Buckargingah Creek (see Table 1, ID #3 & #4, Section 1.6.2) presented in Section 5.3.5.2);
3. Option A3 – Widening Olympic Highway and Railway bridges 700 m north of Buckargingah Creek (see Table 1, ID #6 & #7, Section 1.6.2) presented in Section 5.3.5.3); and
4. Option A4 – Simultaneous widening of bridges in Options A1, A2 and A3 (see Section 5.3.5.4).

5.3.5.1. Option A1 – Increasing Buckargingah Creek bridge crossing conveyance

Option A1 assesses the impact of increasing the length of the Main Southern Railway and Olympic Highway bridges over Buckargingah creek to increase flow conveyance. It was expected that increasing the conveyance of these structures may reduce flood levels upstream of the Olympic Highway.

In the 1% AEP event, the impacts for Option A1 were widespread as shown on Figure G 11. On the eastern side of the highway, flood levels typically decreased by less than 0.2 m and decreases in flood levels for residential properties are less than 0.1 m. Downstream of the Railway peak flood levels are increased by less than 0.1 m, however some minor increases to flood levels are experienced at residential properties (less than 0.05 m).

Option A1 is not recommended for further investigation due to the minor decreases in peak flood levels at residential properties within the study area. Further, the costs of construction associated with implementing this scenario would be much greater than the benefits to the AAD.

5.3.5.2. Option A2 – Increasing culvert conveyance 200 m north of Buckargingah Creek

Similar to Option A1, Option A2 investigates the impact of increasing the conveyance capacity of the Railway and Olympic Highway structure crossing 200 m north of Buckargingah Creek (see Table 1, ID #3 & #4, Section 1.6.2).

Figure G 12 presents the impact on peak flood levels that implementation of Option A2 produces during the 1% AEP event. It can be seen that upstream of Olympic Highway decreases in peak flood level up to and exceeding 0.3 m are present with some severely flood affected residences experiencing reductions in flood level of up to 0.6 m. Downstream of the Railway, flood levels are typically increased by up to 0.1 m with this increase affecting properties on Pleasant Hills Road.

Option A2 is not recommended for further investigation due to the significant cost of construction and the impacts to properties downstream of the bridge upgrades. In addition to this, better flood mitigation can be provided by the combined Options L1, L3 and L5 (see Section 5.3.1.6).

5.3.5.3. Option A3 – Increasing culvert conveyance 700 m north of Buckargingah Creek

Option A3 investigates the viability of increasing the conveyance capacity of the Olympic Highway and Railway culverts situated 700 m north of Buckargingah Creek (see Table 1, ID #6 & #7, Section 1.6.2).

Figure G 13 shows the flood impacts of Option A3 in the 1% AEP event. Peak flood levels are reduced by up to 0.2 m on the upstream side of the Olympic Highway. Increases in peak flood levels of up to 0.1 m are experienced at residential properties on Grubben Road.

Option A3 is not recommended for further investigation due to the minor decrease in peak flood levels for properties upstream of the Olympic Highway, increases to flood levels along Grubben Road and the likely high cost of construction.

5.3.5.4. Option A4 – Increases structure conveyance - Options A1, A2 and A3 Combined

Option A4 was used to simulate the widening of all Olympic Highway and Railway bridges and culverts described in Options A1 (Section 5.3.5.1), A2 (Section 5.3.5.2) and A3 (Section 5.3.5.3).

The combined scenario was tested for the 1% AEP event (see Figure G 14) and produced significant reductions in peak flood levels (up to 1.15 m) on the eastern side of the Olympic Highway. On the downstream side of the railway, flood levels increased by up to 0.2 m which does affect residential properties.

Option A4 is not recommended for further investigation due to the impact on downstream properties and the high cost of construction that would produce a B/C ratio much lower than one. In addition to this, better flood mitigation can be provided by the combined Options L1, L3 and L5 (see Section 5.3.1.6).

SUMMARY

Major flow obstructions, such as inadequately designed roads and bridges, restrict flow conveyance capacity and cause increased peak flood levels. However, an investigation into increasing the conveyance capacity of the Main Southern Railway and Olympic Highway bridges over Buckargingah creek and the floodplain showed only limited mitigation is possible through modifications of these structures with a large capital outlay.

5.3.6. Combined Mitigation Options

DISCUSSION

To optimise investigated flood mitigation Options in Henty many of the measures discussed thus far in Section 5 have also been considered in combination with each other. Table 23 outlines the various combinations of mitigation Options investigated and discusses their impact.

Table 23: Investigated Combined Options

Options	Sections	Impact
L1, L3, C3, S1, A4	5.3.1.1, 5.3.1.3, 5.3.3.3, 5.3.4.2 & 5.3.5.4	No significant impact beyond Options L1, L3 and L5 (see Section 5.3.1.6). Large capital outlay.
L1, S1	5.3.1.1 & 5.3.4.2	No significant impact beyond individual options.
L1, C3, S1	5.3.1.1, 5.3.3.3 & 5.3.4.2	No significant impact beyond individual options.
L1, C3, S1, A4	5.3.1.1, 5.3.3.3, 5.3.4.2 & 5.3.5.4	No significant impact beyond Options L1, L3 and L5 (see Section 5.3.1.6). Large capital outlay.
L1, L4, S1	5.3.1.1, 5.3.1.4 & 5.3.4.2	No significant impact beyond Options L1, L3 and L5 (see Section 5.3.1.6).
S1, A1	5.3.4.2 & 5.3.5.1	No significant impact beyond individual options.
C2, C3	5.3.3.2 & 5.3.3.3	No significant impact beyond individual options.
C2, C4	5.3.3.2 & 5.3.3.4	No significant impact beyond individual options.

SUMMARY

Examination of various combinations of mitigation Options were shown to not significantly improve positive flood impacts. Due to the often high cost of construction of many of these options, implementation of these combination is not advised.

5.3.7. Drainage Maintenance

DESCRIPTION

Maintenance of the drainage network is important to ensure that it is operating with maximum efficiency and to reduce risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network. Vegetation maintenance within the Buckargingah Creek channel is discussed in Section 5.3.4.1.

DISCUSSION

The Community Consultation process (see Section 2.1) highlighted the community's concerns about creek and channel maintenance. In particular, culverts under the Olympic Highway and Main Southern Railway are known to have been partially blocked during recent flood events. The introduction of maintenance protocols or policies would ensure that drainage assets are effectively managed and regularly maintained such that they will perform as required particularly on those rare occasions when they are needed. This is complicated for the Olympic Highway and Main Southern Railway crossings as these are owned by RMS and the Australian Rail Track Corporation (ARTC). RMS and ARTC are responsible for these drainage structures and Council should liaise with these authorities in regards to drainage maintenance.

SUMMARY

Regular maintenance can reduce risk of blockage of structures during flood events and ensure that flood waters are drained efficiently. It would be beneficial for Council to maintain a record of drainage infrastructure within the LGA and of the authority, organisation or body responsible for its maintenance.

RECOMMENDATIONS

The following measures are recommended:

► Identify policies for general maintenance of drains and channels and determination of protocols for ownership maintenance and development / upgrade of infrastructure.

► Develop a database of all drainage infrastructure and its owner and authority, organisation or body responsible for its maintenance.

5.3.8. Retarding Basins

DESCRIPTION

Retarding basins work by storing runoff and releasing it after the event peak. These measures are appropriate for use in controlling flooding by mitigating the effects of increased runoff caused by development and can be either installed as part of a new development to prevent increases in runoff rates, or retrofitted into existing catchment drainage systems to alleviate existing flood problems.

DISCUSSION

These systems are easy to implement when new development is proposed, as Council can place the responsibility on the developer to provide appropriate drainage systems. This is usually implemented through development controls requiring that runoff rates from new developments are not greater than existing rates. Often the 1% AEP event is used as the design event, but flows also need to be restricted back to the pre-development rates for smaller events. Hydraulic structures can be used to restrict the discharges rates from site to a variable rate, dependent on rainfall volumes and the hydraulic head in the retarding basin.

Retarding basins can also have benefits for the community other than flood control. For example, some basins when dry are used as sports fields and recreation grounds, others can be designed to be permanently wet creating scenic wildlife areas. There are also pollution control benefits associated with retention basins allowing settlement of particulates and sediments.

Large retarding basins can be a safety hazard. Appropriate safety controls such as fencing and signage should be included as part of the overall asset. In NSW, particularly large basins may be prescribed by the Dam Safety Committee (DSC) which means that the DSC will maintain a continuing oversight of their safety. This is applicable to basins identified as a possible threat to communities downstream in case of failure. Like the rest of the drainage system, retarding basins have maintenance requirements. Regular checks and maintenance will be required by Council or agreements put in place with the developer and land holder. This is particularly applicable to basins identified as being a threat to communities downstream in case of failure.

5.3.8.1. Option B1 – Pleasant Hills Road playing fields basin

It was suggested in the community consultation (see Section 2.2) that the playing fields along Pleasant Hills Road could be used as storage basins to alleviate the flood problem for properties along this road.

This scenario was modelled for the 1% AEP event and the impacts of this measure are shown in Figure G 15. The basin provides no real protection to property or decreases in flood level and actually exacerbates flood depths and extents in the region surrounding the basin. Inside the basin, peak flood depths over 2 m are expected which could potentially pose a risk to life.

Option B1 has not been considered for further investigation since the basin did not reduce peak flood levels for nearby flood affected residential properties.

5.3.8.2. Option B2 – Henty Government Dams basin

Option B2 investigated the creation of a large basin at the location of the existing Government Dams as recommended in Community Consultation (see Section 2). The basin was recommended by Henty residents to reduce peak flood levels to affected properties along Pleasant Hills Road.

Figure G 16 shows the 1% AEP flood impacts of Option B2. The basin provided no reduction in peak flood levels or mitigation of flood liability to flood prone properties. Accordingly, Option B2 has not been recommended for further investigation.

SUMMARY

Detention basins mitigate flow by storing water for a limited period of time. Retarding basins as a flood mitigation option are ineffective for Buckargingah Creek flows due to the large upstream catchment. The storage volume of the tested basins are insignificant compared to the total volume of the flood event which leads to the basins filling before the arrival of the flood peak. This then leads to the flood event passing through the basin unattenuated.

5.4. Property Modification Measures

Property modification measures refer to the modifications to existing development and/or development controls on property and community infrastructure for future development. Flood modification measures which apply at the individual property scale have also been included in this section.

New performance requirements for buildings in flood hazard areas were introduced in the National Construction Code (NCC) in 2013 with The Australian Building Codes Board (ABCB)'s 'Construction of Buildings in Flood Hazard Areas' and the accompanying Handbook (References 15 and 16). This Standard contains requirements to ensure new buildings and structures located in flood hazard areas do not collapse during a flood when subjected to flood actions, and includes consideration of appropriate construction, use of appropriate materials, electrical, plumbing and drainage installation as well as setting floor levels. It applies to residential buildings (Classes 1, 2, 3 and 4) and health care buildings (Classes 9a and 9c). The Standard is not intended to override any land use planning controls imposed by Council or the appropriate authority.

5.4.1. House Raising

DESCRIPTION

House raising has been widely used throughout NSW to eliminate or significantly reduce flooding of habitable floors particularly in lower hazard areas of the floodplain, albeit in limited overall numbers. However it has limited application as it is not suitable for all building types being more suitable for non-brick single storey buildings. House raising is unlikely to be approved in high hazard areas.

DISCUSSION

The benefit of house raising is that it eliminates above floor flooding and consequently reduces flood damages. House raising also provides a safe refuge during a flood, assuming that the building is suitably designed for the water and debris loading. However the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during a medical emergency, or floods larger than the design flood occur, particularly in high hazard areas.

The type of construction of a house can make raising an unfeasible option as raising a brick property can be structurally difficult and also incur significantly higher costs than a timber property. Many of the residences in Henty are brick construction or slab and floor and therefore house raising is unlikely.

For new development, floor level requirements will negate the need for future raising of properties.

SUMMARY

House raising is not considered to be the most cost effective option for the type of flooding in Henty with the combined Option L1, L3 and L5 (see Section 5.3.1.6) preferred for flood mitigation on the Buckargingah Creek floodplain. Accordingly, no specific houses have been identified for raising. Flood proofing is more appropriate and cost effective for use in shallow flood depths, especially those affected by overland flows rather than mainstream flooding. Houses in high hazard areas are better dealt with through voluntary purchase.

5.4.2. Voluntary Purchase

DESCRIPTION

Voluntary Purchase (VP) involves the acquisition of flood affected properties, in particular those frequently inundated in high hazard areas, and demolition of the residence to remove it from the floodplain. Removal of properties can help to restore the natural hydraulic capacity of the floodplain; the storage volume and waterway area. Voluntary purchase is mainly used in more hazardous areas over the long term as a means of removing isolated or remaining buildings to free both residents and potential rescuers from the danger and cost of future floods.

Although measures such as flood proofing or raising could reduce flood damages for properties in high risk areas during smaller events, the high hazard means that conditions are unsafe for people and they would still need to be evacuated before the onset of flooding. Voluntary purchase of the properties would allow the areas to be given over to public open space and would remove the high hazard risk to residents here. Voluntary purchase would be the only way of reducing flood risk and hazard for those residents by encouraging them to move to a less flood hazardous area. The purchased properties should be demolished and the land rezoned as appropriate use such as E2 Environmental Conservation or similar in the LEP so that no development may take place. The land can also be defined as floodway in Council's DCP.

DISCUSSION

Voluntary purchase is an effective strategy where it is impractical or uneconomic to mitigate high flood hazard to an existing property and it is more appropriate to cease occupation to meet the above objectives. Voluntary Purchase is often a measure that is used as part of a wider management strategy rather than on its own. Government funding for voluntary purchase schemes can be made available through the Floodplain Management Program as long as a number of complying criteria are met. Voluntary purchase areas are not classified under any specific land use in the Standard Instrument LEP. However, Council can consider creating Voluntary Purchase zones through their DCP or requiring that voluntary purchase zones apply to all flood prone areas also identified as being high hazard floodway.

Typically flood risk at Henty is low due to relatively shallow flood depths and velocities. The criteria for a VP scheme is that properties must be situated in a high hazard floodway. A number of properties situated on the Buckargingah Creek floodplain may be eligible for VP, however funding from the State Government for VP is limited with priority placed on properties with higher risk potential. In addition, with the construction of the combined Option L1, L3 and L5 (see Section 5.3.1.6) levee system, flood affection of these properties (for events up the 1% AEP) would no longer be an issue. Accordingly VP is typically not suitable for Henty, conditional to the combined Option L1, L3 and L5 levee system and associated infrastructure being designed constructed and maintained to current standards.

CONCLUSION

VP schemes generally have low B/C ratios and are only likely to obtain funding in high risk flooding situations. Additionally, such schemes often take many years to obtain sufficient funding to purchase all properties eligible for the scheme. It is recommended that the combined Option L1, L3 and L5 (see Section 5.3.1.6) be implemented as this will reduce flood risk and negate the need for a VP scheme at Henty.

RECOMMENDATIONS

The following measures are recommended:

► Define a floodway in Council's DCP where no future residential development should be permissible.

5.4.3. Flood Proofing

DESCRIPTION

Flood proofing is often divided into two categories; wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damages and/or reduce recovery times by choice of materials which are resistant to flood waters and facilitates drainage and ventilation after flooding. Dry proofing aims to totally exclude flood waters from entering a building and is best incorporated into a structure at the construction phase.

As an alternative to retrofitting permanent flood proofing measures to existing properties, temporary flood barrier methods can also be achieved by the use of sandbags in conjunction with plastic sheeting or private flood barriers which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding.

DISCUSSION

Retro fitting permanent flood proofing measures can be difficult and permanent flood proofing is best achieved during construction. Temporary flood proofing can be achieved during flooding although relies on someone to put up flood gates or similar and therefore effective flood warning times and the time of flooding can affect their efficiency.

Whilst it is a requirement of the Floodplain Development Manual (Reference 1) that new residential properties have their floor levels above the 1% AEP event plus a freeboard, commercial properties are not subject to such requirements unless stipulated by Councils. New commercial buildings can be required to be flood proofed to the Flood Planning Level (FPL) when constructed which would include consideration of suitable materials, electrical and other services installation and efficient sealing of any possible entrances for water. Council would make these requirements through the DCP and planning controls. It is recommended that planning controls allow some flexibility for either dry or wet flood proofing to be used, and for temporary flood gate options to also be included in building design for low risk non-habitable development.

Temporary flood barrier measures such as sandbagging and flood barriers can be a cheaper option than retrofitting to existing properties and can be useful in areas where there is frequent shallow flooding. Sandbagging, often used in conjunction with plastic sheeting, can provide a solution for dealing with flooding in smaller areas and at individual properties. Henty does not have a SES unit, however the Culcairn SES headquarters maintains a small supply of sandbags; back-up supplies are available through the Murrumbidgee SES Region Headquarters in Wagga. A motorised sandbag-filling machine is available from Wagga Wagga SES Unit and Murrumbidgee Region Headquarters (Reference 7). Whilst sandbags and plastic sheeting seldom prevent the ingress of floodwaters entirely, they can substantially decrease the depth of over floor flooding and decrease foulness of floodwaters, thus aiding the clean-up process. There is little warning time in Henty and although the use of temporary measures should not be discouraged they should not be relied on as a solution to flood problems at individual properties.

SUMMARY

Flood proofing is a good solution to reducing flood risk to commercial and industrial properties and should be encouraged for all new development of this type, particularly where floor levels may be low. Consideration of appropriate construction materials is still needed for those residential developments where floor levels will be raised above the 1% AEP flood level but structures can still become inundated below the floor level.

Temporary flood proofing techniques may be deployed although lack of warning time may limit their efficiency and they should be considered as a secondary option to more permanent measures being implemented.

RECOMMENDATIONS

The following measures are recommended:

► Include requirements for flood proofing for new development, wet or dry as appropriate, in development controls. In particular this approach should be the minimal requirement for non-habitable buildings such as commercial or industrial developments where floor levels are not always required above the FPL.

5.4.4. Minor Property Adjustments

DESCRIPTION

In overland flow areas, minor property adjustments can be used to manage overland flows through private property and minimise impacts on dwellings by helping to divert local overland flows away from dwellings and access points. Such adjustments can include low level bunding (small levees) around individual properties, amendments to fences or construction of fences which act as deflector levees, modifying gardens and ground levels etc. all of which can affect the local continuity of overland flow paths.

DISCUSSION

It is difficult for Council to enforce property adjustments and furthermore the issue can be complicated by requirements of s149 certificates. In addition, adjustments on one property may have knock on effects on adjoining properties, or require modifications on neighbouring properties to be effective. Some residents have commented that they believe small features on neighbourhood properties have increased flooding on their own property. Therefore any works in flood prone areas which could modify the localised flood behaviour should be shown to have no significant impact on adjoining properties and be subject to approval from Council.

SUMMARY

Minor property adjustments can have localised benefits, however they should be assessed for their impact on neighbouring properties. There are no specific recommendations regarding minor property adjustments for Henty, however Council may want to consider some controls on these due to impacts on neighbouring properties.

5.5. Response Modification Measures

Response modification measures aim to reduce risks to life and property in the event of flooding through improvements to flood prediction and warning, improvements to emergency management capabilities and planning, and through better flood-educated communities.

5.5.1. Flood Warning

DESCRIPTION

The purpose of a flood warning is to provide advice on impending flooding so people can take action to minimise its negative impacts. An effective flood warning system requires integration of a number of components (Reference 8):

- monitoring of rainfall and river flows that may lead to flooding;
- prediction of flood severity and the time of onset of particular levels of flooding;
- interpretation of the prediction to determine the likely flood impacts on the community;
- construction of warning messages describing what is happening and will happen, the expected impact and what actions should be taken;
- dissemination of warning messages;
- response to the warnings by the agencies involved and community members; and
- review of the warning system after flood events.

Where effective flood warnings are provided, risk to life and property can be significantly reduced. Studies have shown that flood warning systems generally have high B/C ratios if sufficient warning time is provided and if the population at risk is aware of the threat and prepared to respond appropriately.

The Buckargingah Creek catchment is relatively small (113 km^2 at Henty) so floods tend to rise quickly following the onset of flood-producing rainfall. The critical duration – the duration of the storm that produces the largest flows and highest flood levels in the hydraulic model – is 6 hours (and 18 hours – the two storm durations yielded similar flows) for most design events and 3 hours for the PMF. The critical duration for local overland flooding at Henty is only 25 minutes for most design events (Reference 2).

Warning times would be even shorter, and this locates the catchment within a 'flash flood' setting where the provision of an effective flood warning service is problematic. Several challenges to an effective flood warning service have been identified for flash flood catchments (References 9 and 10):

- Flash floods are less predictable than larger scale flooding. Rainfall over small catchments is usually not well predicted by numerical weather prediction models;
- For flash floods, there is little time to develop reliable flood warnings and for effective dissemination and response to the flood warnings. More rapid user response is required, which necessitates specialised communication systems and a high level of public flood awareness and readiness;
- A reliance on rainfall triggers increases the frequency of false alarms; and
- The use of water level triggers may not allow sufficient time for response.

For these reasons, the Bureau of Meteorology traditionally has not issued specific flood predictions for flash flood catchments. But it does provide more general services that may be of some benefit in alerting the emergency services and community to the threat of flooding:

- General Weather forecast. This may indicate the likelihood of heavy rain from synoptic scale events, typically with more than 24 hours' notice;
- Flood Watch. This is issued by the NSW Flood Warning Centre, typically providing 24 to 48 hours' notice that flooding is possible based upon current catchment conditions and future rainfall, which is predicted by computer models of the atmosphere;
- Severe Weather Warning. This is issued for synoptic scale events when torrential rain and/or flash flooding (or other hazardous phenomena) are forecast; and
- Severe Thunderstorm Warning. This is issued by the Severe Weather Team, typically providing 0.5 to 2 hours' notice of impending severe storms. These forecasts are based upon radar and, if available, data from field stations, reports from storm spotters, as well as an analysis of the synoptic situation.

The severe floods of October 2010 and March 2012 were preceded by Severe Weather Warnings for flash flooding, and a Flood Watch for the Murrumbidgee catchment was also issued in advance of the March 2012 event. However, there were no formal, specific warnings of flooding for Henty.

NSW SES may issue Local Flood Advices for locations like Henty not covered by Bureau Flood Warnings, but there is no indication that these were issued prior to the October 2010 and March 2012 floods. NSW SES may also issue Evacuation Warnings, advising that people should prepare to evacuate an area. These may be followed by Evacuation Orders, requiring the evacuation of all persons from an area, issued through door knock, radio, automated telephone, SMS and/or other forms of media. Once the risk has subsided an All Clear is issued.

DISCUSSION

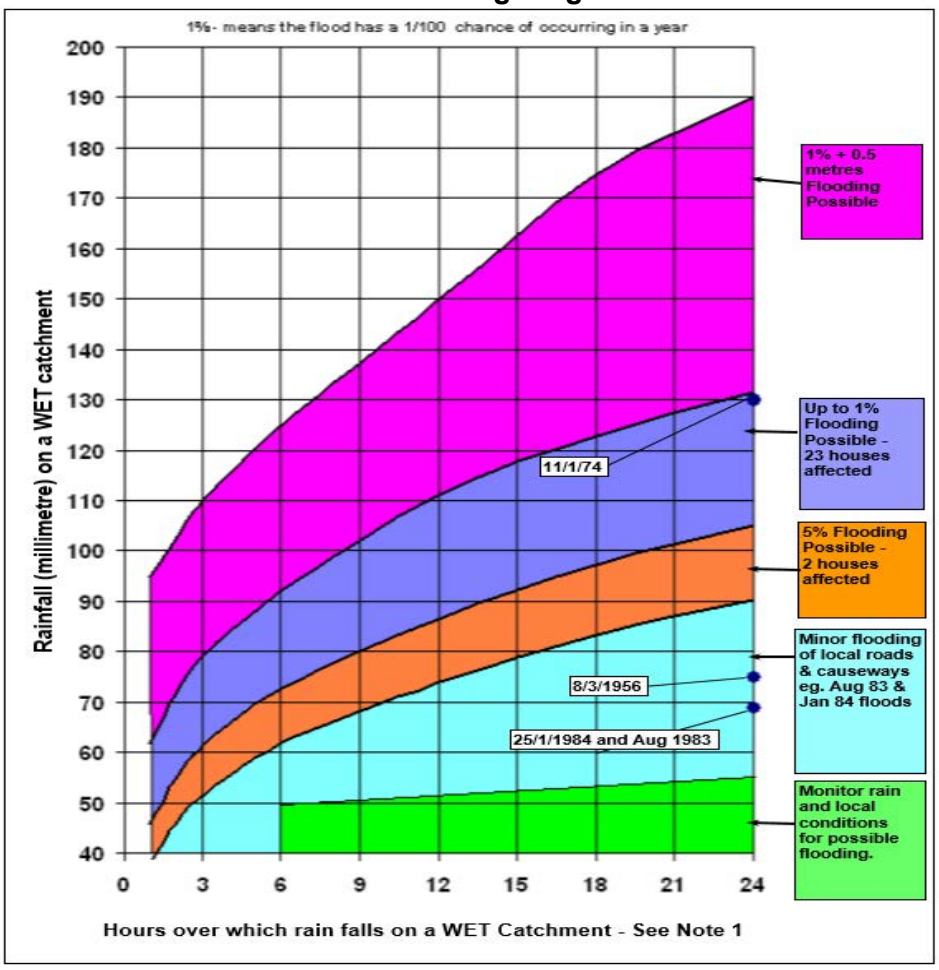
Consideration has been given to the need and opportunity for providing earlier and more specific warnings for Henty.

The need may be assessed primarily by considering the risk to life when residents do not evacuate. The October 2010 flood was a relatively rare event (> 200 year ARI, Reference 2), and while about 11 houses were inundated over floor from Buckargingah Creek flooding, the depths were relatively shallow (generally less than 0.4 m, Reference 3) and should not pose much risk to life. Of the design events, it is only in the PMF where the depths and velocities are of a magnitude that would threaten the structural stability of the 17 dwellings and 4 non-residential buildings. Several of these properties would initially be isolated by flooding of their driveways, prior to inundation of floods (i.e. a dangerous Low Flood Island setting).

Management of the residual risk to life in very rare events requires consideration. One option is to ensure that any new houses in the floodplain are designed so as to structurally withstand the forces of floodwater, debris and buoyancy in a PMF, and to provide a refuge area above the PMF level (see Section 5.5.2). This would lessen the need for improvements to flood warning, evacuation and rescue capability, because emergency managers could have confidence that even in the worst scenario, people should be able to survive a flood in their houses.

Another option is to install automatic rainfall and water level recorders to better assess the threat of flooding. For the October 2010 and March 2012 floods, some daily rainfalls were recorded by residents in the Buckargingah catchment (References 3 and 4), but these are of limited value for real-time flood warning for a catchment where the critical duration is less than 24 hours. A pluviometer could be installed in the catchment at a cost of about $10K plus $2K per annum for maintenance. The data could be listed near real-time on a website that could be monitored by NSW SES when a Flood Watch or Severe Weather Warning was issued or heavy local rain was being observed. Potential consequences of rainfall intensities could be described using a flood forecasting tool, similar to what the Bureau of Meteorology prepared for Cootamundra (see Image 1). The Flood Study could provide inputs for the Buckargingah Creek catchment. However, installing just one pluviometer for the catchment might not provide adequate spatial coverage to define the pattern of rainfall in a particular storm event.

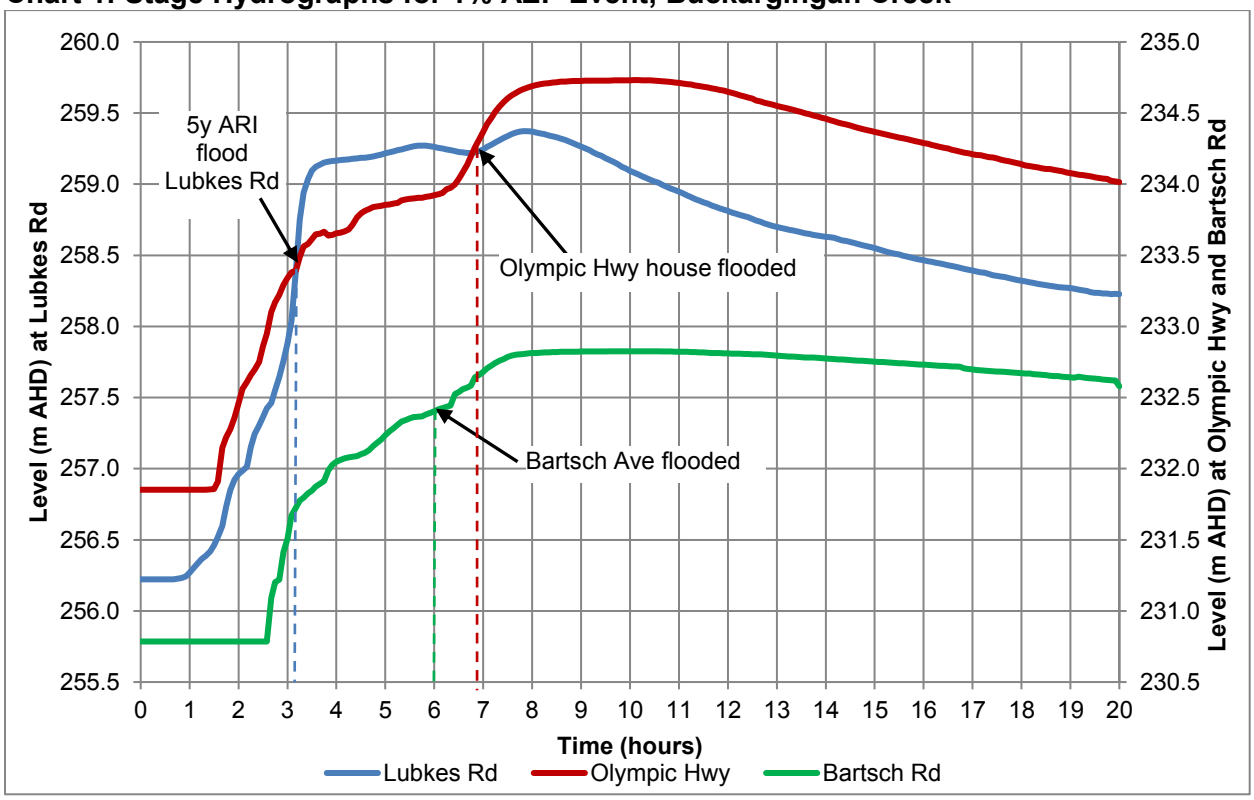
Image 1: Cootamundra Flash Flood Forecasting Diagram



An automatic water level recorder could be installed at Lubkes Road about 10 km upstream of the Olympic Highway. The modelled flood peak travel time between this site and the Olympic Highway is about 2½ hours in the 1% AEP event, though this could be shorter in rarer events (Table 3)[1]. It is possible to pre-configure a water level recorder such that it issues an SMS to the emergency services when a pre-determined threshold is reached. One scenario is pictured in Chart 1, with the trigger level at Lubkes Road set at the 5 year ARI flood level. Based on the design 1% AEP flood hydrograph, this is expected to allow more than 2 hours advance notice of flooding of Bartsch Avenue and more than 3 hours notice of flooding of Olympic Way houses. The Lubkes Road site is adjacent to the Henty Machinery Field Days site and – in the unlikely event of a flood emergency coinciding with the hosting of the annual agribusiness supermarket – would also have the advantage of directly monitoring water levels for that highly patronised event. A water level recorder could cost about $20 K to install plus $5 K p.a. maintenance.

[1] As noted in Section 3.4.4 the hydrologic model could be biased towards shorter flood travel times due to the adopted temporal patterns.

Chart 1: Stage Hydrographs for 1% AEP Event, Buckargingah Creek



The historical infrequency of flooding at Henty, with a dry creek much of the time, the rarity of floods posing significant risk to life, the relatively low number of houses on the floodplain, and competing demands for Council's annual asset management budget, suggest that a flood prediction system relying on automatic recorders may be difficult to maintain.

For Henty, it is considered that an appropriate scale of investment for the improvement of flood predictions is for the establishment and maintenance of a network of hydrological observers in the Buckargingah Creek catchment, providing intelligence during severe weather. This would benefit from installing manually read rain gauges and a water level gauge at Lubkes Road to enable quantitative descriptions of rainfall intensities and flood magnitude. It is understood that there is already a manual gauge at the Mullers Road causeway upstream of Henty and that monitoring of this gauge provided some forewarning of the March 2012 flood, until the flood rose higher than the gauge plates (Reference 4). Its location is closer to Henty than Lubkes Road so would provide less time for responses. But in a system based on manual monitoring of rainfalls or water levels, built-in redundancies are advisable. The Mullers Road site is located close to the 'Dosyvale' homestead that lies on higher ground, so could conceivably be monitored (perhaps with realignment to be read from the direction of the homestead) by the owners.

A local flood warning system could be developed along the lines suggested in Table 24, though precise triggers would need to be chosen after closer analysis and local input.

Table 24: Concept for Henty Flood Warning System

Stage	Trigger	NSW SES (or other official) Action
Ready	Flood Watch or Severe Weather Warning for torrential rain or flash flooding issued; or wet catchment primed for flooding	• Contact farmers to ask them to monitor rain/water levels every 6-8 hours and report to SES Region • Contact floodplain residents to ensure they are aware of the possibility of flooding and are prepared to evacuate • Evacuate any more dependent floodplain residents • Prepare personnel/resources for possible flood rescues • Prepare personnel/resources to close roads
Set	Heavy rain that exceeds pre-determined threshold	• Contact floodplain residents to ensure they are ready for evacuation at short notice
Go	Water level at Lubkes Road that exceeds pre-determined threshold	• Contact floodplain residents to urge immediate evacuation (if still safe to do so) • Close roads as required

A manual water level gauge and a flood warden system was an effective structure for alerting the residents of Ganmain to a rising flood in February-March 2012 (Reference 4). While the catchment to Ganmain is a slightly larger catchment than Buckargingah Creek, it is considered that a well-maintained system at Henty could prove equally effective.

SUMMARY

As a flash flood catchment, the provision of an effective flood warning service for the Buckargingah Creek catchment to Henty is difficult. Various options have been considered to improve flood prediction times, with the establishment of a network of farmers monitoring rainfall and water levels considered most realistic. Manual gauge plates should be installed at Lubkes Road crossing, and a flood intelligence card for this gauge should be populated over time. Further analysis of design rainfalls is required to draft a flood forecasting diagram. Rainfall and water level triggers need to be selected for the development of a Henty flood warning system. Ongoing education of floodplain residents is vital to ensure they understand how to respond.

RECOMMENDATIONS

The following measures are recommended:

► Install flood gauge plates at Lubkes Road crossing of Buckargingah Creek and additional flood gauge plates at Mullers Road (Council);

► Develop and maintain a rainfall/flood observer network in the Buckargingah Creek catchment (Council and NSW SES);

► Develop a flash flood forecasting diagram relating rainfall intensities and durations to approximate consequences (NSW SES);

► Develop a flood intelligence card for the proposed Lubkes Road gauge, relating flood heights to consequences (NSW SES);

► Investigate and select rainfall and water level triggers for proposed Henty flood warning system (NSW SES).

5.5.2. Flood Emergency Management Planning

DESCRIPTION

Effective planning for emergency response is a vital way of reducing risk to life and property, particularly for infrequent floods that are not managed through flood or property modification.

The NSW State Emergency Service (SES) is the legislated combat agency for floods in NSW and is responsible for the control of flood operations. This role is undergirded by detailed flood planning. NSW SES maintains the Greater Hume Local Flood Plan (Reference 7) and flood intelligence cards for key stream gauges.

Residents living in and proprietors working in the floodplain can also prepare individual plans tailored to their situation.

DISCUSSION

The Greater Hume Local Flood Plan (LFP) (Reference 7) is a sub-plan of the Greater Hume Shire Council Local Emergency Management Plan. Volume 1 of the LFP was endorsed in March 2013 and outlines responsibilities and procedures for preparing for, responding to and recovering from floods within the Shire.

Clause 3.5 of Volume 1 of the LFP describes the location of operations centres. The NSW SES does not have a Unit at Henty (the nearest is Culcairn). It is understood that the RFS performs some of the NSW SES functions. The local RFS headquarters could be listed in Clause 3.5.

Clause 3.18.42 of Volume 1 of the LFP lists the Henty Community Club in South Street, Henty, as suitable for use as a flood evacuation centre. Section 4.6.3.7 outlined the flood risk at this location. It is not expected to be inundated above floor in a local overland flow PMF.

Clause 3.9 of Volume 1 of the LFP deals with the provision of flood information and warnings. If a system similar to that described in Section 5.5.1 is implemented, it is recommended that the LFP be updated to describe this.

Clause 3.14 of Volume 1 of the LFP deals with road and traffic control. Considering the depth of floodwater across the road and the reckless behaviour of many drivers (see Image 2), the RFS expressed surprised that people were not drowned on the Olympic Highway during the October 2010 flood. RFS personnel request that this risk be much better managed by either 1) a rapid deployment of RMS staff and/or NSW Police to close the Highway promptly, or 2) authorising the RFS to close the Highway with the assistance of local wardens (Reference 4). The NSW SES could liaise with RMS and NSW Police to progress this issue.

Image 2: Rescue on Olympic Highway, October 2010

Olympic Highway near Yerong Creek, Source: *Eastern Riverina Chronicle*

Clause 3.17 of Volume 1 of the LFP addresses the management of flood rescue operations, recognising that there may be a residual population which does not evacuate during the early stages of flooding and which subsequently requires rescue. While there are opportunities for improving flood warning systems, levels of community awareness and readiness to promote timely evacuation, the reality is that some people may not evacuate in a timely fashion and in an extreme flood could be trapped in houses with water rising. Henty is not well prepared for flood rescue operations. Liaison with NSW SES suggests that the use of high clearance vehicles is not favoured. A flood boat is not considered suitable due to the terrain, vegetation and fences. Helicopters may not be able to gain access to a site due to overhead hazards and the remote location, particularly at night where night-rated aircraft are required. It is recommended that NSW SES give further consideration to developing and maintaining a flood rescue capability for Henty, without having to draw on resources from Culcairn which might be inaccessible during a regional flood.

Because NSW SES relies on the RFS for assistance at Henty, the functioning of a local flood warning system and the provision of flood rescue capability would require significant involvement from the RFS, who will need to be consulted about proposed arrangements, and potentially trained in managing local flood operations including rescues.

In some jurisdictions in NSW, particularly for flash flood situations where safe evacuation is difficult to guarantee and where flood durations are typically short, the planning authority requires for new or redeveloped houses in the floodplain that either:

1. Evacuation to high land can be assured; or
2. a structurally sound building contains a PMF refuge so that trapped residents can temporarily evacuate upstairs in a severe flood.

This approach should be considered for Henty, because its implementation would gradually reduce risk to life. For existing houses, there may be scope for funding construction of small, strong, elevated single-roomed buildings that could function as emergency refuges. Under current conditions, timely evacuation is imperative because several dwelling structures would be subject to an extreme hazard in the PMF, and if residents wait to see the magnitude of a flood, it might be too late to evacuate.

Other recommended minor amendments to Volume 1 of the LFP are as follows:

- Clause 1.3.3: Buckargingah Creek should also be listed, draining to Doodle Comer Swamp;
- Attachment 3 needs to show all relevant watercourses (and ideally, water level recorders) in the LGA, including Buckargingah Creek.

Volume 2 of the LFP has yet to be finalised and includes Annexes describing the flood threat, effects on the community and response arrangements for each sector such as property protection, evacuation, rescue and resupply. Volume 2 of the post-March 2012 flood intelligence review (Reference 4) included draft updates to Volume 2 of the LFP template to incorporate findings from the flood intelligence review and preliminary results of the Flood Study. As part of this FRMS&P, further amendments to the draft LFP have been made (to the same scope as for Reference 4), drawing on the results of the finalised Flood Study and the assessment of flood problems undertaken as part of this FRMS&P. It is recommended that NSW SES review the proposed changes and complete Volume 2 of the LFP. If any flood mitigation works as implemented as a result of this FRMS&P, the LFP will require additional updates.

Findings of the Flood Study and FRMS&P that need to be incorporated into the LFP include:

- Design flood extents, depths, velocities, hazard and travel times;
- Predicted building inundation in design floods up to PMF;
- Predicted road inundation in design floods up to PMF; and
- Evacuation constraints in design floods up to PMF.

In addition to updating the LFP, it is recommended that NSW SES prepare a flood emergency management plan for the Henty Machinery Field Days event, held annually in September. Whilst the likelihood of a serious flood coinciding with this event is low, the consequences of flooding in a very large flood could be serious (see Section 4.6.3.5), commending preparation of a plan.

There would be benefit in NSW SES and Council encouraging and helping flood-prone residents to prepare and update their own flood emergency response plans.

SUMMARY

Planning for flooding is a vital way of reducing flood risks to life and property. Plans need to be reviewed after flooding and after new information is made available from flood investigations. NSW SES has the lead role in planning for and responding to floods, but the RFS has a significant role at Henty. There is a need to update the Greater Hume Local Flood Plan. However best practice teaches that people will respond more effectively when households are also engaged in planning to respond to floods.

RECOMMENDATIONS

The following measures are recommended:

► Liaise with RMS, NSW Police and RFS to develop protocols facilitating the early closure of the Olympic Highway during floods, reducing the number of rescues (NSW SES);

► Give further consideration to developing and maintaining a flood rescue capability for Henty (NSW SES);

► Liaise with RFS for the consolidation of arrangements to manage a local flood warning system and to develop a flood rescue capability (NSW SES);

► For new dwellings in Buckargingah Creek floodplain, consider requiring provision of 'shelter-in-place'; for existing dwellings, consider sponsoring shelters (Council);

► Review draft updates and complete Greater Hume Local Flood Plan, drawing on flood intelligence from the Flood Study (Reference 2) and this FRMS&P (NSW SES);

► Prepare a flood emergency management plan for the Henty Machinery Field Days event (NSW SES);

► Assist floodplain residents to prepare tailored individual flood emergency plans (NSW SES and Council).

5.5.3. Community Flood Education

DESCRIPTION

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

> *'People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension… Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the combat agency, with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced.'* (Reference 12)

Based on learnings from recent disasters, the focus of community disaster education has now turned from a concentration on raising awareness and preparedness to building community resilience through learning. Simply disseminating information to the community does not necessarily trigger changed attitudes and behaviours. Flood education programs are most effective when they:

- Are participatory i.e. not consisting only of top-down provision of information but where the community has input to the development, implementation and evaluation of education activities;
- Involve a range of learning styles including experiential learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, DVDs, the media), collaborative group learning (e.g. scenario role plays with community groups) and community discourse (e.g. forums, post-event de-briefs);
- Are aligned with structural and other non-structural methods used in floodplain risk management and with emergency management measures such as operations and planning; and
- Are ongoing programs rather than one-off, unintegrated 'campaigns', with activities varied for the learner.

It is difficult to accurately assess the benefits of a community flood education program but the consensus is that the benefits far outweigh the costs. Nevertheless, sponsors must appreciate that ongoing funding is required to sustain gains that have been made.

DISCUSSION

Current levels of flood awareness in Henty are relatively high, being within five years of the severe flood of October 2010 when about 15 houses and 3 non-residential buildings were flooded over floor (Reference 3). Lesser floods in 2011 and March 2012 would have taught the community that the October 2010 flood was not a 'one-off'. Nevertheless, Census data indicate that 35% of Henty residents lived in a different address 5 years prior to the 2011 Census. Population turnover and the progress of time mean that over time the community's remembrance of the floods of 2010-12 will gradually decline and their readiness to respond appropriately to future flood emergencies will wane. This means that there is a need to build flood readiness for people unfamiliar with flooding and to maintain flood readiness through ongoing flood education. If a local flood warning system is developed for Henty (Section 5.5.1), it will be vital that the community understands how it operates and what the trigger levels signify for their response.

Table 25 provides a list of methods to build and sustain flood readiness, which may be developed and supported by NSW SES and Council. These include methods both to inform and to prepare the community, with the objective of building resilience.

Table 25: Methods to Increase Flood Awareness and Preparedness

Method	Comment
S149 certificate notifications	Section 149 planning certificates should record whether the land is subject to any planning and development controls due to its flood affectation. Council also has opportunity to provide more detailed information about the land's flood affectation under S149(5) of the EP&A Act 1979. This information may be particularly valued by prospective purchasers but has a limited reach and is typically issued only upon request and payment of a fee.
Letter/certificate/ pamphlet from Council	These may be sent annually with a rates notice or separately. A Council database of flood liable properties makes this a relatively inexpensive and effective measure. The intention of flood certificates is to inform individual property owners of the flood situation (flood levels, ground levels) at their particular property. It is the site-specific nature of this advice that offers a chance of overcoming the scepticism typical of a community that has not experienced serious flooding for some years. Only after floodplain occupants accept that they could have a problem are they ready to take on board ideas about addressing that problem. A pamphlet can inform residents of the on-going implementation of the Floodplain Risk Management Plan and provide tips to respond appropriately to flooding (e.g. evacuate early; never drive, ride or walk through floodwater). Proactive and regular issuance is desirable.
Council website	Council already provides an 'emergency information' portal on its website. An additional flood management portal would be of value to describe the floodplain management process and include Flood Studies and Floodplain Risk Management Studies, a history of flooding in Greater Hume LGA, procedures for how to obtain flood information, answers to frequently asked questions (FAQs), and advice on becoming flood prepared. The portal could also provide links to Bureau of Meteorology warnings and NSW Office of Water gauge heights.
Community Working Group	Council could initiate a Community Working Group framework to provide a valuable two way conduit between the local residents and Council.
School project	School students can learn about historical floods by interviewing older residents and documenting what happened. A project could also involve talks from various authorities (e.g. NSW SES) and can be combined with topics relating to water quality, drainage management, etc.
Articles in local newspapers	Ongoing articles in the newspapers will ensure that the flood issues are not forgotten. Historical features and remembrance of past events are interesting for local residents and can provoke preparedness for future events.
Library display	The library could collect historical flood photos and stories to prepare a display, which could be accompanied by appropriate flood safety messages. The Greens Gunyah Museum in Lockhart has an impressive collection of historical flood photos.
Mobile display	Such a display as described above could also be used at local festivals and for school visitations, accompanied by NSW SES staff, who should be trained to encourage and equip households to prepare flood emergency plans.

Method	Comment
NSW SES FloodSafe Guide	Now that a Flood Study has been prepared, and given the experiences of major floods in the recent past, once the Local Flood Plan is finalised, it would be timely to prepare a FloodSafe guide for Henty describing flood behaviours in historical and design floods, describing the local flood warning system (if implemented) and particularly highlighting the priority of early evacuation and the danger of late evacuation. If major flood mitigation works will be implemented following this FRMS&P, it would be advisable to wait until these are done.
NSW SES Business FloodSafe Breakfast	The NSW SES has prepared a FloodSafe Business template, which businesses can use to plan for flooding. A breakfast barbeque could be convened at an appropriate location to promote completion of plans and to provide site-specific flood information.
'Meet the street' events	'Meet-the-street' events involve NSW SES and Council setting up a stall at an appropriate location (e.g. Henty showground) at a time that people will be at home. An event would be promoted via personal invitation. The stall could consist of flood maps on boards, NSW SES banners and NSW SES materials to hand out (e.g. Henty FloodSafe guide when available). The materials are used to engage with people and make them aware of flood risk, encourage preparedness behaviours (e.g. develop emergency plans) and help them understand what to do during and after a flood. There is also value in encouraging property owners to develop self-help networks and particularly to check on neighbours if a flood is imminent.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or similar to indicate the level reached in historical and design floods. Depth indicators advise of potential hazards, particularly to drivers. These are inexpensive and effective but in some flood communities are not well accepted as it is perceived that they affect property values. Flood depth indicators with historical markers could be installed adjacent to the Bartsch Avenue low-point (away from private property) to show the height flood waters reached in the 2010 and 2012 events as well as in selected design flood events up to the PMF.

SUMMARY

Although recent flood events and the flood risk management process have raised community flood awareness, this is expected to wane over time. For Henty, flooding of a similar magnitude to the October 2010 flood had probably not occurred since 1931. If there are long periods without damaging flooding, it is difficult to maintain the community's interest and preparedness. Ongoing flood education will be required to build and maintain flood resilience and to prepare the community for larger and faster-rising floods than it has previously experienced. If a local flood warning system is developed for Henty, education is vital to ensure people understand the triggers and how they should respond. Particular attention may be required to persuade people to evacuate early from the Henty-Pleasant Hills Road area, since delaying evacuation until the magnitude of floods becomes visible means that they may be trapped. Also, given regular loss of life in Australia from people attempting to cross floodwater or play in floodwater, messages to discourage people from engaging in these unsafe behaviours are desirable.

Council will need to develop a program from the above measures after taking into account the views of the local community, funding considerations and other education programs within the LGA. However, for the purposes of this FRMS&P, we recommend that the following measures be given a high priority:

- Regular issuance of flood certificates and pamphlets to landowners within the floodplain;
- Preparation of a library flood photo and story display;
- Commemoration of the 10th anniversary of the October 2010 flood;
- Preparation of a Henty FloodSafe guide;
- A meet-the-street meeting for Grubben Road, Angaston Road and Henty-Pleasant Hills Road (possibly at the showground);
- Installation of flood depth indicators adjacent to the Bartsch Avenue low-point together with signage along the lines of: 'If it's flooded, forget it' (see Image 3).

Image 3: Risky Driving Behaviours at the Bartsch Avenue low-point

October 2010 flood, Source: Ken Dale

March 2012 flood, Source: Border Mail

RECOMMENDATIONS

The following measures are recommended:

► Engage with community to prepare an ongoing flood education program, with appropriate methods for program evaluation (NSW SES and Council);

► Regularly issue flood certificates and pamphlets to landowners within the floodplain (Council);

► Prepare a library photo and story display (Council and NSW SES);

► Commemorate the 10th anniversary of the 2010 flood (NSW SES and Council);

► Prepare a Henty FloodSafe guide (NSW SES and Council);

► Arrange a meet-the-street meeting for Grubben Road/Angaston Road/Henty-Pleasant Hills Road (NSW SES and Council);

► Install flood depth indicators and signage to dissuade motorists from entering floodwater at the Bartsch Avenue low-point (Council).

5.6. Planning and Future Development Control Measures

5.6.1. Land Use Zoning

DESCRIPTION

Appropriate land use planning can assist in reducing future flood risk and ensure development on flood affected areas is flood compatible. Appropriate land use controls in flood affected areas can prevent inappropriate development from occurring and thus reduce flood risk. Land use zones are generally governed by a Local Environmental Plan (LEP). To make any significant changes to the provisions of an LEP, a planning proposal must be prepared. Residential uses and sensitive land uses such as seniors living facilities, hospitals and child care centres etc. should not be permitted in the floodway or high hazard areas.

Council should consider appropriate controls, including floor levels and/or flood proofing, for commercial and industrial development if permitted on the floodway and ensure that development does not cause flood issues to be offset elsewhere. Ratified flood data and mapping should be utilised to inform the Flood Planning Area and levels set for all residential development on land which is located within the FPA (see Section 5.6.3).

DISCUSSION

The current land use zones for Henty are presented in Figure 2. Ratified data and modelling now provide a best estimate of the FPA (see Section 5.6.3).

Flood Hazard categories have been further considered in relation to contextual issues (i.e. high depths and short warning time frames) which can cause potential problems in terms of evacuation.

Figure 80 of the Flood Study, reproduced herein as Figure 14 shows the flood Emergency Response Classifications (ERC) which designate areas for which evacuation may be constrained during a flood event. These "constrained evacuation" areas need careful consideration in terms of existing undeveloped lands and lands subject to planning proposals for rezoning.

Some ways of dealing with "constrained evacuation" areas should include:

1. Rezoning existing undeveloped land to better reflect flood characteristics.
2. Placing a moratorium on any further planning proposals in flood affected areas.
3. Requiring new dwellings to include refuge structures which will be accessible in a PMF event.
4. Include a community refuge as part of any future community building in precincts with "constrained evacuation".

Council should review existing zones against flood information and maps to ensure that current permissible uses are still appropriate or apply flood controls including floor levels or flood proofing where required.

Council should, having regard to Direction 4.3 from the Minister, review any existing planning proposals to account for updated flood planning information and mapping (see Section 4.3).

Flood controls and floor levels should be introduced into the Council's DCP to ensure appropriate management of flood affected land in accordance with existing State policies.

SUMMARY

Appropriate land use planning can assist in reducing future flood risk and ensure development in flooded areas is flood compatible. Residential uses and sensitive land uses such as aged care facilities, hospitals and child care centres etc. should not be permitted in the floodway or high hazard areas. Council should consider appropriate controls including floor levels and or flood proofing for commercial or industrial development if permitted on the flood way and ensure that such development does not cause flood issues to be offset elsewhere. Ratified flood data and mapping should be utilised to inform the FPA and levels set for all residential development on land that exists in the FPA.

Flood data and mapping should be used strategically in the planning process to inform existing zoned areas and proposed rezoning areas in Henty.

RECOMMENDATIONS

The following measures are recommended:

►Reconsider existing zones against current flood data and mapping, introduce flood controls or floor levels where appropriate or back zone if land is identified in the flood way.

►Council consider either restricting future development or requiring refuge provision in precincts with known "constrained evacuation" areas.

5.6.2. Flood Planning Levels

DESCRIPTION

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (the Manual) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control measure for managing future flood risk and is derived from a combination of a flood event and a freeboard.

The Manual states that, in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard which is typically 500 mm.

According to the Manual, the purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of a FPL, is actually provided given the following factors:

- Uncertainty in estimating flood levels;
- Differences in water level because of local factors;
- Increases due to wave action; and
- The cumulative effect of subsequent infill development on existing zoned land.

Typically, the FPL is used to define the minimum level at which habitable floor levels should be constructed.

DISCUSSION

The Floodplain Development Manual states that the FPL for standard residential development is the 1% AEP flood event plus a freeboard which is typically 500 mm. Depending on the nature of the development and the level of flood risk, individual FPLs can be adopted for a local area within a greater floodplain area. For example in areas prone only to shallow overland flooding, application of the 500 mm freeboard can be excessive. Selecting the appropriate FPL for a particular floodplain involves trading off the social and economic benefits of a reduction in the frequency, inconvenience, damage and risk to life caused by flooding against the social, economic and environmental costs of restricting land use in flood prone areas and of implementing management measures.

The FPL can be varied depending on the use, and the vulnerability of the building/development to flooding. For example, residential development could be considered more vulnerable due to people being present, whilst commercial development could be considered less vulnerable, or it could be accepted that commercial property owners are willing to take a higher risk. For developments more vulnerable to flooding (hospitals, schools, electricity sub-stations, seniors housing and the like) consideration should be given to events rarer than the 1% AEP when determining their FPL and either consider the PMF or situating those developments outside the floodplain where possible.

For the less vulnerable commercial and industrial developments, flood proofing (see Section 5.4.3) a building can be considered where raising floor levels is not an option or not feasible, but should not be allowed for residential developments or more vulnerable uses. For example, it could be a requirement that residential dwellings are to have floor levels above the FPL, whilst commercial properties could have lower floor levels but be subject to other controls such as flood proofing to the level of the FPL.

At Henty, overland flow flooding is a non-issue and mainstream flooding due to Buckargingah Creek is responsible for flood liability. Accordingly, the 1% AEP flood level plus 500 mm freeboard is recommended for use as the FPL. For industrial and commercial areas, the Council can either set their own floor height or require flood proofing where the FPA applies to industrial or commercial land.

More sensitive land uses such as nursing homes, hospitals and child care centres and the like should ideally be located outside of the FPA.

SUMMARY

The FPL should be used to set finished floor level requirements for residential development. Less vulnerable uses such as commercial developments could be subject to lower floor level requirements but it is recommended that they should be subject to flood proofing to the FPL where floor levels are lower. More vulnerable developments and critical infrastructure should be subject to more stringent requirements if possible. A FPL of 1% AEP plus 0.5 m is considered appropriate for Henty.

The benefits and consequences of different criteria for setting both the FPA and FPL should be considered together as it is important both are compatible.

RECOMMENDATIONS

The following measures are recommended:

► The FPL should be set as the 1% AEP event plus 0.5 m for residential areas within Henty and subject to the FPA.

► Council can decide on floor level requirements for non-residential developments at their discretion but should take into account proximity to major overland flow routes, flood hazard at the subject site and surrounding area etc.

► For commercial or industrial developments where finished floor levels are not set at the FPL, flood proofing measures will be required to the FPL.

► More vulnerable developments within Henty such as hospitals, schools, services including power should at the very least have floor levels and access at the FPL or PMF level, whichever is higher.

5.6.3. Flood Planning Area

DESCRIPTION

The Flood Planning Area (FPA) is an area to which flood planning controls are applied. An FPA map is a required outcome of the FRMS&P.

It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. Typically, and as per the Floodplain Development Manual, the FPA will be based on the flood extent formed by the 1% AEP mainstream flooding event plus freeboard (typically 500 mm) and, therefore, extended further than the extent of the 1% AEP event. Planning controls may, therefore, be applied to development which is not necessarily within the 1% AEP flood extent but is in the FPA. The purpose of extending the FPA past the 1% AEP flood extent is to allow for any future increases in flood extent due to climate change, as well as an allowance for differences between flood behaviour during events, however, where flooding is from overland flows, this criteria may not be appropriate and an alternative, more appropriate, criteria needs to be defined.

The NSW Standard Instrument LEP does not include a specific land use zone classification for flood prone land, rather it permits a Flood Planning Area map to be included as a layer imposed across all land use zones.

DISCUSSION

The FPA as defined by the Floodplain Development Manual (1% AEP + freeboard) is suitable for areas of mainstream flooding such as those affected by Buckargingah Creek. Typically areas experiencing overland flow flooding require other methods for definition of the FPA due to shallow flood depths that do not tend to increase significantly for rarer events. However, at Henty overland flow flooding is a non-issue and mainstream flooding due to Buckargingah Creek is responsible for flood liability.

SUMMARY

Defining the FPA is crucial as the FPA is a key concept referred to in the LEP. The Buckargingah Creek FPA is defined on the basis of the Floodplain Development Manual. Flood liability is solely due to Buckargingah and overland flow flooding is a non-issue with run-off in Henty being classified as drainage issues.

The Henty FPA map is presented in Figure 16.

RECOMMENDATIONS

The following measures are recommended:

► Include the FPA as defined in this study in the DCP (as per Figure 16).

5.6.4. Update Flood Related Planning Policies and Development Controls

DESCRIPTION

Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to:

- Guide new development away from high flood risk locations.
- Ensure that new development does not increase flood risk elsewhere.
- Develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

DISCUSSION

Following a review of the LEP 2012 and Council's current policy regarding flooding the following measures are recommended.

Greater Hume Local Environmental Plan 2012

Council may wish to review land zoning within areas defined as floodway (see Section 4.4) to prevent inappropriate development in these areas.

Flood Policy/DCP

A DCP should be created and it should include the FPA map (Figure 16). In addition to the objectives already stated and considerations included within Chapter 8 of the Greater Hume DCP 2013, it is recommended the Policy should consider:

- Controls on development in flood prone land;
- Controls on development outside the FPA but where development could exacerbate flood risk elsewhere; and
- Controls on drainage easements.

Key considerations for the Flood Policy are listed below. Many of these have been discussed within this report.

<u>For developments with the FPA</u>

- Building floor levels - consideration for different development types;
- Flood Proofing;
- Impact of development on adjacent or surrounding properties; and
- Consideration of hazard at the site and development type.

For all developments within the catchment regardless of flood affectation (could be in a separate OSD or drainage policy)

- Development drainage - limit discharge to that of pre-development site.
- Water quality.
- Responsibility for maintenance and compliance.

Specific text inclusions suggested for a flood management DCP are presented in Appendix G. The DCP should be prepared to be applicable to all flood prone land within the LGA, rather than only specific to Henty to provide a consistent approach for development with the LGA. Any recommendations or suggestions in the FRMS&P with regard to planning and policy should be revised and approved by Council planners.

SUMMARY

Up to date planning controls are vital in managing flood risk and Council should update the DCP by introducing a Flood Policy comprising controls on development in flood prone land as well as controls to ensure development, whether or not in flood prone land, will impact on flood behaviour elsewhere. Crucial is inclusion of the FPA in the DCP as a means of determining to which property flood related development controls will apply.

RECOMMENDATIONS

The following measures are recommended:

► Introduce a Flood Policy comprising controls on development in flood prone land, drainage requirements from all new developments (a draft policy is included in Appendix F). Include the FPA in the flooding DCP.

5.6.5. Modification to the S149 Certificates

DESCRIPTION

The Environmental Planning and Assessment Regulation 2000 (the Regulation), at Clause 279 and Schedule 4, prescribes that Councils must provide a disclosure document whereby any interested party can learn the zone and any other planning controls that may apply to a parcel of land.

Schedule 4 of the Regulation prescribes the format of the Planning Certificate. Part 7A of Schedule 4 states:

> ***7A Flood related development controls information***
>
> *(1) Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.*
>
> *(2) Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.*
>
> *(3) Words and expressions in this clause have the same meanings as in the standard instrument set out in the Standard Instrument (Local Environmental Plans) Order 2006.*

Legal reviews of the effectiveness of s.149 Planning Certificates have suggested it would be appropriate to also provide information as to the scale of the risk (low, moderate or high) and also whether flooding applies generally to the area or more specifically to the land the subject of the certificate.

DISCUSSION

Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on:

- The type of flooding;
- Whether flooding is from major rivers or local overland flooding; and
- The extent of flooding (whether widespread or relatively confined).

It should be noted that the s.149 Planning Certificate only relates to the subject land and not any specific building on the property.

While the legislation currently does not mandate revealing the extent of flood inundation in an s.149(2) Planning Certificate, there is scope within an s.149(5) Planning Certificate for providing this additional type of information.

There can be a general perception from the public that insurance companies, lending authorities or other organisations may disadvantage flood liable properties that have only a very small part of their property inundated by floodwaters. Some Councils have addressed this concern by adding information in s.149(5) Planning Certificates to show the percentage of the property inundated as well as floor levels and other flood related information. In addition, the hazard category could be provided, and also advice regarding climate change increases in flood level.

The compulsory s.149(2) Planning Certificate should include, in terms of flood risk:

- Whether or not the property is in the FPA;
- Any development controls due to the property being within the FPA;
- Responsibility for maintenance and compliance for OSD features; and
- Highlight any drainage easements through the property and controls that apply.

Some Councils include detailed flooding information in s.149(5) Planning Certificates as standard practice. This ensures that residents are made fully aware of flood risks before purchasing a property. However, people who are current property owners often feel that this information devalues their properties and would rather not know. Flood related information in s.149(5) Planning Certificates should include:

- Flood levels / depths over the property;
- Percentage of property which is flood affected;
- The likelihood of flooding;
- Floor levels (from Council's floor level survey if available); and
- Potential flood hazard.

SUMMARY

As Council information for s.149 Planning Certificates and Development Restriction Certificates is obtained mainly from computerised databases and maps, Council should investigate ways to make property-based flooding information more accessible via its web-site.

Data from the hydraulic modelling used in this FRMS&P should be incorporated into Council's s.149 Planning Certificate database. All residents should be advised by personalised mail from Council if their land is affected. Council should determine the appropriate event for advising residents that the same criteria is used as in establishing the FPA.

RECOMMENDATIONS

The following measures are recommended:

► Update and re-issue s149 certificates based on this FRMS. It is encouraged that full details are provided in Part(5) as standard practice when a Part(2) is requested.

► Provide flooding information on Councils website.

6. FLOODPLAIN RISK MANAGEMENT PLAN

This section comprises the Floodplain Management Plan and forms a framework identifying aims, objectives and a guide to the list of strategies by which the plan will be implemented. Any recommendations in terms of policy should be reviewed and approved by Council's planners.

6.1. Aims and Objectives

The primary objective of the Floodplain Management Plan is to recommend a range of property, response and flood modifications that address the existing and future flood problems, in accordance with the Floodplain Development Manual (Reference 1). The recommended works and measures presented in the Plan will:

- 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;
- Reduce private and public losses due to flooding;
- Protect and, where possible, enhance the river and floodplain environment;
- Be consistent with the objectives of relevant State policies, in particular, the Government's Flood Prone Lands and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act, 1979;
- Ensure that the 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 management plan are sustainable in social, environmental, ecological and economic terms;
- Ensure that the floodplain risk management plan is fully integrated with the local emergency management plan (Local Flood Plan) and other relevant catchment management plans; and
- Establish a program for implementation and a mechanism for the funding of the plan and should include priorities, staging, funding, responsibilities, constraints, and monitoring.

6.2. Identification of Actions Suitable For Implementation

The following matrix (Table 26) identifies the practical options which have been identified to the Henty Floodplain Risk Management Committee for further approval. Those options or strategies approved by the Committee will be further investigated.

Table 26: Measures Recommended for Implementation – Risk Management Options Matrix

Measure	Description	Priority	Benefits	Concerns	Implementation, Costs and Funding
FLOOD MODIFICATION MEASURES					
Option L1, L3 and L5 - Combined Levee System (Section 5.3.1.6)	This combined levee option is designed to prevent floodwaters from Buckargingah Creek flowing north and flooding residential properties in areas: • upstream of the Olympic Highway; and on • Grubben Road; • Pleasant Hills Road; and • Angaston Street.	High Consider for detailed design and costing	B/C = 0.9 Implementation of combined Option L1, L3 and L5 levee system provides a B/C ratio close to one and effectively removes flood affectation for all properties up to and including the 1% AEP at Henty.	None.	Council would be responsible for costs and implementation. Some funding may be available through the Floodplain Risk Management Program.
Strategy for Buckargingah Creek vegetation management (Section 5.3.4.5)	Clearing of debris and overgrown vegetation from the Creek.	Medium	Can minimise build-up of debris and hence channel blockage.	Environmental concerns over loss of riparian corridor, habitats and native vegetation.	Council would be responsible for costs and implementation. The Murray LLS would also need involvement. Approval from the relevant government bodies is necessary in some cases and clearance will be limited by legislation.
Drainage maintenance (section 5.3.7)	Council should regularly address drainage maintenance including unblocking and repairing where necessary.	High	Will maintain drainage efficiency in Henty and prevent additional flooding caused by blockage of channels or structures.	Structures not under the jurisdiction of Council, including those maintained by RMS and ARTC may not be efficiently maintained.	Council will be responsible for costs and regular maintenance apart from those structures under the jurisdiction of RMS and ARTC.
Drainage Assets Database (Section 5.3.7)	Develop database of all drainage assets and notify body responsible for their maintenance.	Low	Would allow Council to better maintain the drainage in the area and reduce responsibility issues.	Needs to be maintained.	Council would be responsible for costs and implementation of the database as well as RMS and ARTC to establish details of their infrastructure. The Murray LLS would also need involvement.
PROPERTY MODIFICATION MEASURES					
Flood proofing (section 5.4.3)	Permanent or temporary measures can be used. Possible to retrofit to existing buildings but can be a requirement for new development.	Low	Can reduce damages to properties in flood prone areas.	Can be difficult and costly to retrofit. Temporary measures require time for installation and warning is limited in Henty.	Requirements for new development to be flood proofed can be included in the Flood Management DCP.

Measure	Description	Priority	Benefits	Concerns	Implementation, Costs and Funding
RESPONSE MODIFICATION MEASURES					
Install flood gauge plates at Lubkes Road crossing of Buckargingah Creek and additional flood gauge plates at Mullers Road (Section 5.5.1)	Manual read gauges at Lubkes and Mullers Road crossings of Buckargingah Creek could be used to provide warning of an impending flood. The current gauge at Lubkes Road were overtopped during the March 2012 flood and were thus not able to be used once the flood level exceeded the gauge height.	Medium	Installation of manual depth indicators would reduce risk to motorists driving during periods of heavy rainfall. Additionally, following issuance of a Flood Watch or Severe Weather Warning, or during heavy rain, the NSW SES could periodically monitor these depth indicators and over time develop coarse intelligence to better inform flood predictions for Henty.	None.	Council will be responsible for costs and regular maintenance of the manual gauges. The NSW SES in conjunction with would be responsible monitoring these gauges in times of heavy flow.
Develop a rainfall/flood observer network on Buckargingah Creek (Section 5.5.1)	A flood observation network provides intelligence as a flood is rising which can be useful for the NSW SES. It should be ensured that all emergency operations agencies, such as NSW SES and police etc. and the local community, liaise and coordinate effectively during a flood event.	Medium	Potential for faster and more accurate information on impending floods. Better coordinated emergency response with more personnel available to assist.	None.	NSW SES are the responsible for organisation.
Prepare a Flood Intelligence Card for the proposed Lubkes Road gauge (Section 5.5.1)	FIC's provide usable flood intelligence that can be used to inform emergency procedure.	High	Emergency procedure is supplied for flooding at Henty which would lead to increased efficiency and reduced flood risk.	Need for strong communication with communities of concern.	SES are responsible for maintaining the FIC.
Preparation for potential future floods to increase flood warning by: • Developing rainfall/consequence diagram; and • Investigating rainfall and water level triggers for Henty. See Section 5.5.1 for more information.	Various measures can be undertaken to increase flood warning time. This includes: • Potential consequences of rainfall intensities could be described using a flood forecasting tool; and • Progressively develop relationships between flood depth indicators / observer stations and downstream water level recorders.	Medium	Preparation for future flood events will greatly increase flood warning time and risk of error by reducing decision making requirements during an event.	None.	NSW SES are the responsible for implementation and funding.
Facilitate early closure of the Olympic Highway during flood (Section 5.5.2)	Liaise with RMS, NSW Police and RFS to develop protocols facilitating the early closure of the Olympic Highway during floods.	Medium	Reduce the number of flood rescues required on the Olympic Highway during flood, thus reducing NSW SES requirements.	None.	RMS are responsible for closure of the Olympic Highway during flood, however assistance provided by Council, NSW Police and RFS could assist in reducing the required closure timeframe.

Measure	Description	Priority	Benefits	Concerns	Implementation, Costs and Funding
Consideration of Henty NSW SES Unit for flood rescue function (Section 5.5.2)	Due to the rapid rate of rise of Buckargingah Creek and the potential for residents on the Henty Floodplain to become isolated during larger flood events, Henty NSW SES Unit could have the capability to undertake flood rescue at short notice.	Low	People at risk during flooding of the Henty Floodplain will have timely assistance when considering the fast flood response time of the Buckargingah Creek catchment.	None.	NSW SES are the responsible for implementation and funding.
NSW SES liaison with RFS for management of Henty flood assistance (Section 5.5.2)	The NSW SES should liaise with RFS for the consolidation of arrangements to manage a local flood warning system and for RFS to develop a flood rescue capability	Medium	If the NSW SES is unable to provide a SES unit at Henty, the RFS can provide assistance in terms of flood warning and rescue.	None.	NSW SES in conjunction with RFS would be responsible for organisation and funding.
Consider provisions for 'shelter-in-place' (Section 5.5.2)	Construction of residential building such that they function as an emergency evacuation shelter for residents during the PMF should be considered. Residences must maintain structural integrity in an extreme flood and have reliable access during flood.	Low	Under current conditions, timely evacuation from houses on the floodplain at Henty is imperative because in the PMF the combination of depths and velocities there presents an 'extreme' hazard to structures, and if residents wait to see the magnitude of a flood, it might be too late to evacuate. If all homes have shelter-in-place capability then this would provide residents that cannot evacuate in time, safety during extreme flood events.	Provisions for shelter-in-place would likely increase the cost of new home significantly.	The home owner would be responsible for additional construction and maintenance costs.
Review and update the Greater Hume Local Flood Plan and Flood Intelligence Cards (Section 5.5.2).	Local Flood Plan sets out measures to take before and during flooding. FIC's provide usable flood intelligence that can be used to inform emergency procedure.	High	Provide more information such that informed decision can be made during a flood and allow flood preparedness. Latest information from the Flood Study and the FRMS&P can be included. FICs for the proposed Lubkes Road gauge provide emergency procedure leading to increased efficiency and reduced flood risk.	Need for strong communication with communities of concern.	NSW SES are responsible for maintaining the Local Flood Plan the FICs.
Henty Machinery Field Days (HMFD) to develop flood emergency plan (Section 5.5.2)	HMFD event is at risk of flooding due to Buckargingah Creek and should prepare for potential flooding by preparing flood emergency plans.	Medium	Reduce flood risk for participants of the HMFD event.	None.	Council and the NSW SES have shared responsibility.
Encourage floodplain exposures to develop flood emergency plans (Section 5.5.2)	Key floodplain exposures that are at risk of flooding should prepare for potential flooding by preparing flood emergency plans.	Medium	Reduce flood risk for locations situated in the highest risk areas.	None.	Council and the NSW SES have shared responsibility.

Measure	Description	Priority	Benefits	Concerns	Implementation, Costs and Funding
Undertake a community flood education program (Section 5.5.3).	A community flood education program with the following components should be undertaken: • Engage with the community to prepare an ongoing flood education program. • Regularly issue flood certificates and pamphlets to residents on the floodplain. • Prepare a library photo and story display about the 2010 flood. • Commemorate the 10th anniversary of the 2010 flood. • Prepare a Henty FloodSafe guide. • Host a Business FloodSafe breakfast. • Organise community days for the NSW SES and residents of Grubben, Angaston and Pleasant Hills Roads. • Install flood depth indicators and signage to dissuade motorists from entering floodwater at Bartsch Avenue.	On going	Continuing awareness of the community leads to better preparedness and therefore fewer damages during a flood event.	People begin to ignore advice and information if too much is given, particularly if they believe there is little risk of flooding.	Council and NSW SES. Can be variable depending on the methods used. Can be incorporated with other Council information provision to reduce costs.
PLANNING AND FUTURE DEVELOPMENT					
Define a floodway in Council's DCP (Section 4.4 and 5.6.1)	Define a floodway in Council's DCP where no future residential development is permissible. Reconsider existing zones against current flood data and mapping, introduce flood controls or floor levels where appropriate or back zone if land is identified in the flood way.	Medium	Reduced flood risk and development impacts is possible by ensuring that development does not occur in the floodway.	None.	Council are responsible for amending the DCP.
Consider precincts with known 'constrained evacuation' (Section 5.6.1)	Council consider either restricting future development or requiring refuge provision in precincts with known "constrained evacuation" areas	Medium	Reduced risk to life during extreme flood events and reduced requirement on the NSW SES.	None.	Council are responsible for amending the DCP.
Define the Flood Planning Level (Section 5.6.2)	A requirement of the Floodplain Development Manual. Used to set requirements for floor levels and flood proofing in development controls.	High	For residential properties it ensures habitable floor levels are above the 1% AEP flood level (plus 0.5 m freeboard) and therefore reduced flood damages. For commercial, and other less vulnerable land uses, the FPL can be used to set requirements for minimum floor level or elevation to which flood proofing must be provided.	Can have implications with requirements for maximum building heights and access to buildings for the less able.	Will be implemented through amendments to the DCP through a Flood Policy. Council to make decision on FPL for uses other than residential although recommendations have been given in this report.

Measure	Description	Priority	Benefits	Concerns	Implementation, Costs and Funding
Redefine the Flood Planning Area and incorporate into Council's DCP (Section 5.6.3)	A requirement of the Floodplain Development Manual. The FPA is required to identify all properties to which flood related development controls will apply. More vulnerable developments within Henty such as hospitals, schools, services including power should be preferably situated outside the PMF flood extent or at the very least have floor levels and access at the FPL or PMF level, whichever is higher.	High	Provides a clear method of identifying properties subject to flood related development controls.	There is a need to include properties impacted by both mainstream and overland flow. Also good communication with residents about process is key.	The revised FPA map should be included in Councils DCP.
Update and Re-issue S149 certificates (section 5.6.5)	Issued to residents to identify any hazards at their property and development controls that apply.	Medium	Can inform residents of the flood risk at each property and if Part 5 is also included supply additional information such as the type of flooding affecting the property or whether the property is in a high hazard area or floodway. Ensures residents aware of development controls, such as minimum floor levels, at their property. Can also inform residents of drainage easements through properties and their responsibilities.	Part 2 is compulsory. Some residents do not like the additional information provided under Part 5 and believe it can affect insurance premiums and value of land.	To be implemented by Council. Would follow on from adoption of a revised DCP for flooding.
Provide flood information on Council's website (Section 5.6.5)	Provide flood information on Council's website.	Low	Easily accessible information for the community which will typically reduce Council's workload to produce such information on demand.	None.	To be implemented by Council.

7. ACKNOWLEDGEMENTS

WMAwater wish to acknowledge the assistance of the Greater Hume Shire Council staff and the FRMC in carrying out this study as well as the residents of Henty. We would also like to acknowledge the excellent work carried out by Stephen Yeo as part of The Flood Intelligence collection (References 3 and 4) as well as OEH and SES for managing and financing the work.

Greater Hume Shire Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

8. REFERENCES

NSW Government

1. **Floodplain Development Manual**
   2005

Greater Hume Shire Council

2. **Culcairn, Henty, Holbrook Flood Studies**
   WMAwater, September 2013

Bewsher Consulting Pty Ltd

3. **Flood Intelligence Collection and Review for Towns and Villages in the Murray and Murrumbidgee Regions following the October 2010 Flood – Final Draft Report**
   Prepared for NSW SES, December 2011

Dr Stephen Yeo

4. **Flood Intelligence Collection and Review for Towns and Villages in the Murray and Murrumbidgee Regions following the March 2012 Flood – Final Draft Report**
   Prepared for NSW SES, January 2013

McLuckie, D., Babister, M., Smith, G. and R. Thomson

5. **'Updating National Guidance on Best Practice Flood Risk Management', 54th Annual FMA conference, Deniliquin**
   Floodplain Management Association, May 2014

Smith, G. and R. Cox

6. **'Safety Design Criteria', Book 9 Chapter 6 (Draft), Australian Rainfall and Runoff Revision**
   IE (Aust), 2009

NSW SES

7. **Greater Hume Shire Local Flood Plan, Volume 1**
   February 2013

Attorney General's Department

8. **Flood Warning – Australian Emergency Manuals Series, Manual 21**
   Commonwealth of Australia, 2009

McKay, G.

9. **'Flash flood warning systems – Are they a waste of time?', 44th Annual FMA Conference, Coffs Harbour, pp.1-7**
   Floodplain Management Association, May 2004

McKay, G.
10. **'Guidelines for local flash flood warning system proposals', 48th Annual FMA Conference, Wollongong**
Floodplain Management Association, February 2008

AFAC
11. **Guideline on Emergency Planning and Response to Protect Life in Flash Flood Events**
Australasian Fire and Emergency Service Authorities Council, April 2013

Keys, C.
12. **'A combat agency and its hazard: a New South Wales State Emergency Service perspective on the management of flooding',** ***Australian Journal of Emergency Management*****, 17(2), 14-18, 50-55**
2002

Department of Environment and Climate Change
13. **Flood Emergency Response Classification of Communities**
NSW State Government, October 2010

Office of Environment and Heritage
14. **Floodplain Management Program – Guidelines for Voluntary Purchase Schemes**
NSW State Government, February 2013

15. **Construction of Buildings In Flood Hazard Areas – ABCB Standard**
Australian Building Codes Board, Version 2012.2

16. **Construction of Buildings In Flood Hazard Areas – Information Handbook**
Australian Building Codes Board, Version 2012.3

Department of Environment and Climate Change
17. **Floodplain Risk Management Guidelines**
NSW State Government, October 2007

WMAwater
18. **Lockhart and The Rock Flood Studies**
Prepared for Lockhart Shire Council, July 2014

NSW Government Public Works
19. **Wagga Wagga Levee Upgrade - Flood Freeboard**
November 2010

Figures

FIGURE 1
HENTY STUDY AREA

Grubben Road
Kendalls Road
Lubkes Road
Mullers Road
Angaston Road
Henty Cookardinia Road
Woods Road
Ivor Street
Yankee Crossing Road
Henty Swamp Road
Olympic Highway
Brackley Road
Olympic Highway
Angaston Road
West Showground Road
Buckargingah Creek
Elm Street
Smart Street
Sladen Street
Lyne Street
Keightley Street
Smith Street
Comer Street
Alan Street
Ivor Street
Railway Parade
Fox Street
Sladen Street East
First Street
Second Avenue
Third Avenue
Fourth Street
Rosler Parade
Henty Swamp Road
Henry Walla Road
Yankee Crossing Road
Henty Cookardinia Road
1
2
3
4

N

Land Proposed for Rezoning
Study Area
Roads
Creek
Cadastre

0 0.25 0.5 1 1.5 km

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure01_Henty_Study_Area.mxd

FIGURE 2
HENTY LEP 2011
LAND USE

Grubben Road
Olympic Highway
Mullers Road
Angaston Road
West Showground Road
Henty Pleasant Hills Road
Bartsch Avenue
Elm Street
Smart Street
Fox Street
Sladen Street
Sladen Street East
Henty Cookardinia Road
Lyne Street
Keightley Street
First Street
Smith Street
Comer Street
Allan Street
Ivor Street
Second Avenue
Third Avenue
Railway Parade
Fourth Street
Rosler Parade
Henty Swamp Road
Henty Walla Road
Yankee Crossing Road
1
2
3
4

N

Land Proposed for Rezoning
Roads
Study Area

LEP Zones

E2
R5
RE2
RU1
RU4
RU5
SP2
Special
Wetlands/Creeks

0 0.25 0.5 1 1.5 2 km

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure02_Henty_LEP.mxd

FIGURE 3
HENTY
KEY LOCATIONS AND FLOOD HOTSPOTS

Grubben Road
Orange Flat Lane
Olympic Highway
Kendalls Road
Angaston Road
West Showground Road
Henty Pleasant Hills Road
Bartsch Avenue
Comer Street
Alan Street
Railway Parade
Fox Street
Smart Street
Lyne Street
Sladen Street East
Henty Cockardinia Road
Mullers Road

N

Hotspots
Key Hydraulic Structures

1% AEP Event Depth (m)
- 0.1 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- > 2

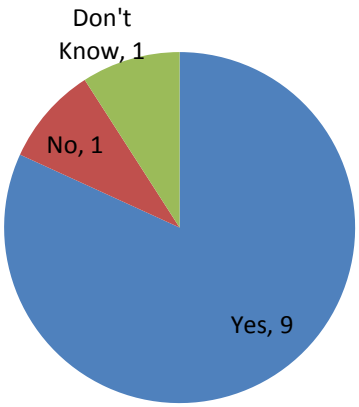
0 0.25 0.5 1 1.5 km

NOTE: Displayed inundation patterns and extents pertain to the 1% AEP event and are based on best available estimates of flood behaviour. Acutal inundation patterns may vary slightly during an event. All depths less than 100 mm have been trimmed from this figure.

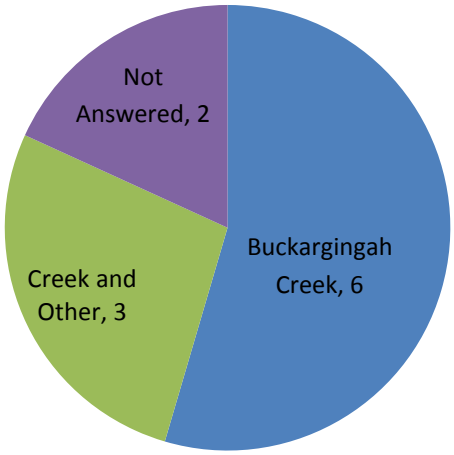
J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure03_Key_Locations_and_Flood_HotSpots.mxd

FIGURE 4
COMMUNITY SURVEY RESPONSE SUMMARY
HENTY

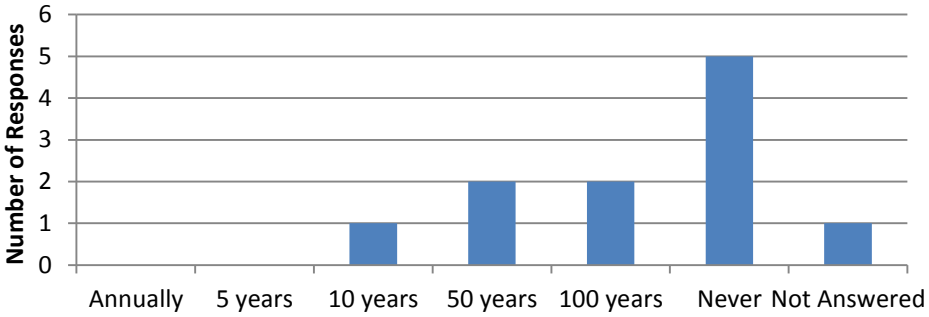
Do you think something should be done to reduce flood risk in Henty?



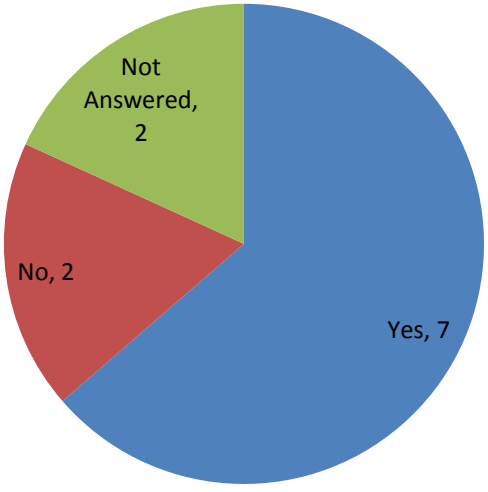
Is the flood risk you are referring to due to: Buckargingah Creek, Other



At what frequency would you consider flooding to be "acceptable"?



If eligible, would you be interested in a Voluntary Purchase scheme?



If eligible, would you be interested in a Voluntary House Raising scheme?

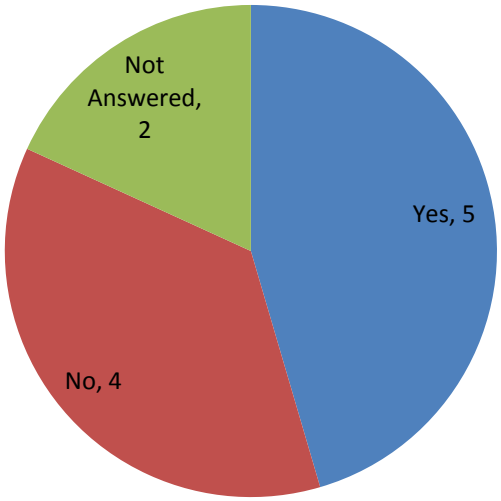


FIGURE 5
COMMUNITY CONSULTATION RESPONDENTS
HENTY

Henty Pleasant Hills Road
West Showground Road
Olympic Highway
Corner Street
Keighran Street
Smart Street
Fox Street
Graham Street
Sladen Street East
Lyne Street
Keightley Street
Hayes Street
Day Street
Smith Street
Allan Street
Kierath Street
Spence Street
Nor Street
Rosler Parade
Henty Swamp
Henty Walla Road
First Avenue
Second Avenue
Third Avenue
First Street
Second Street
Third Street
Fourth Street
Yankee Crossing Road
Angaston Road
Millers Road
Railway Parade
Ashcrofts Road
Merri Merio Road
Back Henty Road

N

Questionnaire Response Locations
Roads

0 0.125 0.25 0.5 0.75 1 km

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure05_Questionnaire_Response_Locations.mxd

FIGURE 6

IMPACT OF GRAIN SILOS AND CANOLA SHED LEVEES
1% AEP PEAK FLOOD LEVELS

Grubben Road

Orange Flat Lane

Olympic Highway

N

Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with removal of the Grain Silos and Canola Sheds. The warmer colours (yellow to red) indicate an increase in peak flood level with removal of Silos and Sheds and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded with removal of the Silos and Sheds.

0 250 500 1,000 1,500 Meters

0 0.5 1 2 3 4 Km

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure06_100Y_Impact_Silos_and_Shed_Levees.mxd

FIGURE 7
PROPOSED DEVELOPMENT AREAS
HENTY FLOOD PLANNING AREA

Grubben Road
Orange Flat Lane
Olympic Highway
Muller's Road
Angaston Road
West Showground Road
Henty Pleasant Hills Road
Bartsch Avenue
Elm Street
Smart Street
Sladen Street
Lyne Street
Keightley Street
Fox Street
Sladen Street East
First Street
Second Avenue
Third Avenue
Fourth Street
Railway Parade
Smith Street
Comer Street
Allan Street
Mor Street
Rosler Parade
Henty Swamp Road
Henty Walla Road
Henty Cookardinia Road
Yankee Crossing Road

1
2
3
4

N

Study Area
Land Proposed for Rezoning
Henty FPA

0 0.25 0.5 1 1.5
km

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure07_Proposed_Upzoning_Regions_with_Recommended_FPA.mxd

FIGURE 8
PROPOSED DEVELOPMENT AREAS
HENTY 1% AEP HYDRAULIC HAZARD

Grubben Road
Orange Flat Lane
Olympic Highway
Mullers Road
Angaston Road
West Showground Road
Henty Pleasant Hills Road
Bartsch Avenue
Elm Street
Smart Street
Fox Street
Sladen Street
Sladen Street East
Lyne Street
Keightley Street
First Street
Smith Street
Corner Street
Allan Street
Ivor Street
Second Avenue
Third Avenue
Fourth Street
Railway Parade
Rosler Parade
Henty Cookardinia Road
Henty Swamp Road
Henty Walla Road
Yankee Crossing Road
1
2
3
4
N
Land Proposed for Rezoning
Study Area
True Hydraulic Hazard
Low Hazard
High Hazard
0 0.25 0.5 1 1.5
km

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure08_True_Hydraulic_Hazard_Henty_100y.mxd

FIGURE 9
HYDRAULIC CATEGORISATION
5% AEP EVENT

Kendalls Road
Kendalls Road
Shippards Road
Orange Flat Lane
Orange Flat Lane
Olympic Highway
Olympic Highway
Grubben Road
Grubben Road
Angaston Road
Angaston Road
West Showground Road
Henty Pleasant Hills Road
Bartsch Avenue
Elm Street
Smart Street
Sladen Street
Lyne Street
Smith Street
Smith Street
Corner Street
Allan Street
Ivor Street
Ivor Street
Railway Parade
Railway Parade
Sladen Street East
First Street
Third Avenue
Henty Cookardinia Road
Henty Cookardinia Road
Mullers Road

N

Roads
Cadastre
Hydraulic Categorisation
Flood Fringe
Flood Storage
Floodway

0 250 500 1,000 1,500
Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure09_5%AEP_HydCat_Henty.mxd

FIGURE 10
HYDRAULIC CATEGORISATION
1% AEP EVENT

Kendalls Road
Orange Flat Lane
Olympic Highway
Grubben Road
Angaston Road
West Showground Road
Henty Pleasant Hills Road
Bartsch Avenue
Elm Street
Smart Street
Sladen Street
Lyne Street
Smith Street
Comer Street
Allan Street
Ivor Street
Railway Parade
Sladen Street East
First Street
Third Avenue
Henty Cookardinia Road
Mullers Road

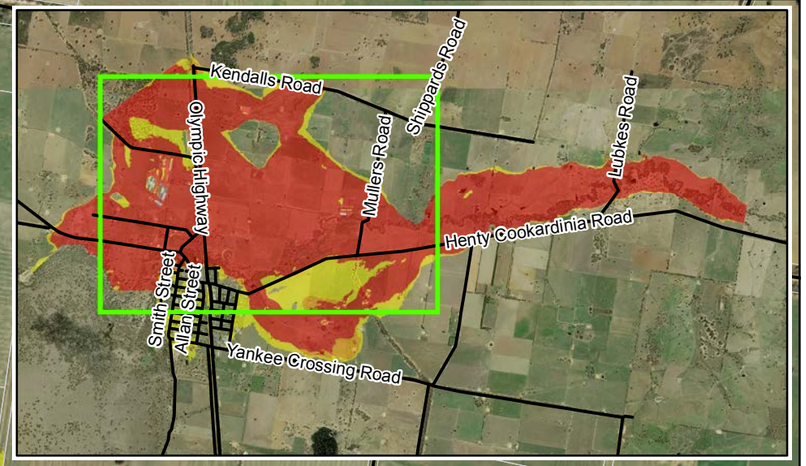
N

Roads
Cadastre
Hydraulic Categorisation
Flood Fringe
Flood Storage
Floodway

0 250 500 1,000 1,500
Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure10_1%AEP_HydCat_Henty.mxd

FIGURE 11
HYDRAULIC CATEGORISATION
PMF EVENT



Kendalls Road
Orange Flat Lane
Olympic Highway
Grubben Road
Mullers Road
Angaston Road
West Showground Road
Henty Pleasant Hills Road
Bartsch Avenue
Elm Street
Smart Street
Railway Parade
Sladen Street
Lyne Street
Sladen Street East
Henty Cookardinia Road
Smith Street
Comer Street
Allan Street
Ivor Street
First Street
Third Avenue

N

Cadastre
Hydraulic Categorisation
Flood Fringe
Flood Storage
Floodway

0 250 500 1,000 1,500
Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure11_PMF_HydCat_Henty.mxd

FIGURE 12
TRUE HYDRAULIC HAZARD
HENTY
1% AEP

Grubben Road
Orange Flat Lane
Olympic Highway
Angaston Road
Henty Pleasant Hills Road
West Showground Road
Bartsch Avenue
Elm Street
Smart Street
Sladen Street
Lyne Street
Keightley Street
Smith Street
Comer Street
Day Street
Allan Street
Ivor Street
Rosler Parade
Railway Parade
Fox Street
Sladen Street East
First Avenue
First Street
Second Avenue
Third Avenue
Fourth Street
Henty Cookardinia Road
Mullers Road

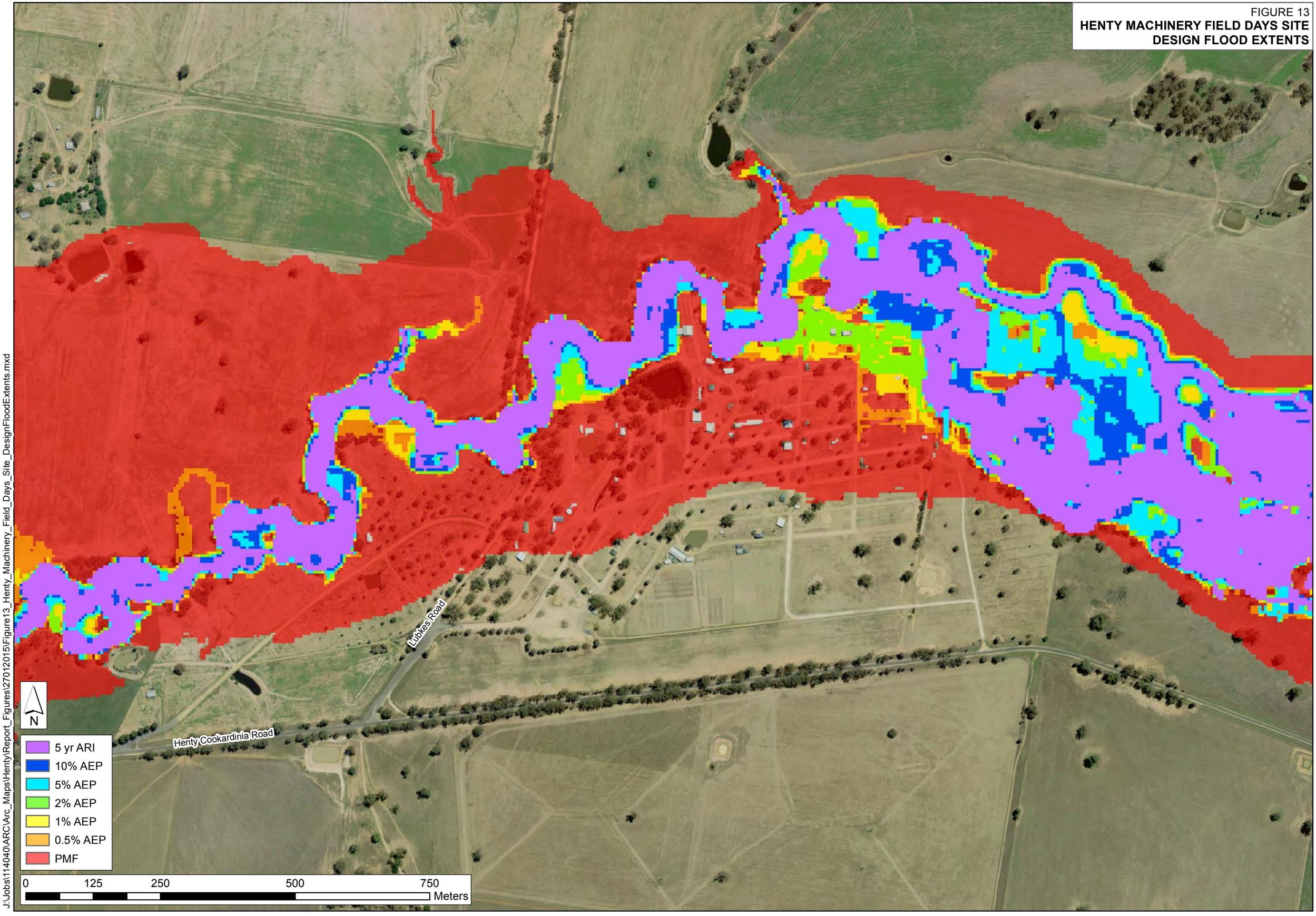
N

Cadastre
Reporting Area
True Hydraulic Hazard
Low Hazard
High Hazard

0 250 500 1,000 1,500
Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure12_True_Hydraulic_Hazard_Henty_100y.mxd

FIGURE 13
HENTY MACHINERY FIELD DAYS SITE
DESIGN FLOOD EXTENTS



J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure13_Henty_Machinery_Field_Days_Site_DesignFloodExtents.mxd

FIGURE 14
FLOOD ERP CLASSIFICATIONS
HENTY

ZONE: A
20YR: Rising Road Access Area
100YR: Rising Road Access Area
PMP :Low Flood Island

ZONE: E
20YR: Low Flood Island
100YR: Low Flood Island
PMP :Low Flood Island

ZONE: A
20YR: Rising Road Access Area
100YR: Rising Road Access Area
PMP :Low Flood Island

ZONE: B
20YR: High Trapped Perimeter Area
100YR: High Trapped Perimeter Area
PMP :Low Flood Island

ZONE: E
20YR: Low Flood Island
100YR: Low Flood Island
PMP :Low Flood Island

ZONE: C
20YR: Not Flood Affected
100YR: Not Flood Affected
PMP :Indirectly Affected Area

ZONE: D
20YR: Not Flood Affected
100YR: Not Flood Affected
PMP :Indirectly Affected Area

ZONE: F
20YR: Indirectly Affected Area
100YR: Indirectly Affected Area
PMP :Rising Road Access Area

ZONE: C
20YR: Not Flood Affected
100YR: Not Flood Affected
PMP :Indirectly Affected Area

ZONE: E
20YR: Low Flood Island
100YR: Low Flood Island
PMP :Low Flood Island

N

ERP ZONE
- A
- B
- C
- D
- E
- F
- 5% Flood Extent
- PMF Flood Extent

1% AEP Flood Depth (m)
- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- > 2

0 0.25 0.5 1 1.5 km

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure14_Flood_Emergency_Response_Classifications.mxd

FIGURE 15
EVENT PROPERTIES FIRST FLOODED ABOVE FLOOR LEVEL

Angaston Road
Henty Pleasant Hills Road
West Showground Road
Grubben Road
Olympic Highway
Railway Parade
Comer Street
Bartsch Avenue
Keighran Street
Smart Street
Sladen Street
Lyne Street
Keightley Street
Hayes Street
Day Street
Smith Street
Allan Street
Kierath Street
Ivor Street
Fox Street
Graham Street
Sladen Street East
Henty Cookardinia Road
First Avenue
Second Avenue
Third Avenue
First Street
Second Street
Third Street
Fourth Street

N

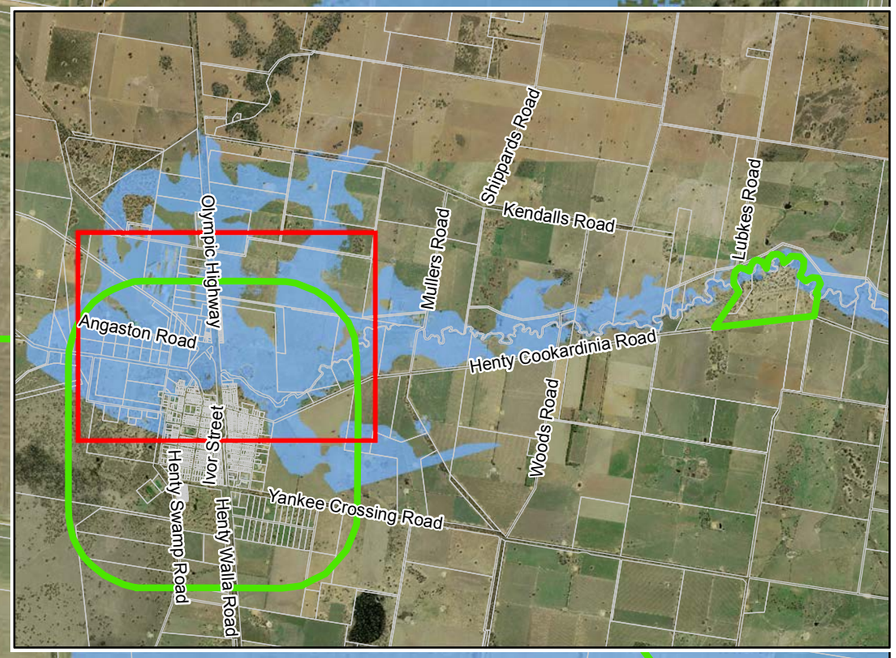
Flooding above floor level
- 5yr ARI
- 10% AEP
- 5% AEP
- 2% AEP
- 1% AEP
- 0.5% AEP
- >0.5% AEP

Flooding above floor level
- Residential
- Commercial

0 0.25 0.5 1 1.5 km

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure15_Event_Properties_First_Flooded_Above_Floor_Level.mxd

FIGURE 16
HENTY FLOOD PLANNING AREA



Orange Flat Lane
Grubbenden Road
Olympic Highway
Angaston Road
West Showground Road
Henty Pleasant Hills Road
Comer Street
Barisch Avenue
Smart Street
Railway Parade
Fox Street
Graham Street
Sladen Street
Allan Street
Sladen Street East
Lyne Street
Comer Street
Keightley Street
First Avenue
Second Avenue
Third Avenue
First Street
Ivor Street
Henty Cookardinia Road

N

Study Area
Henty FPA

0 0.25 0.5 1 1.5 km

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\27012015\Figure16_Henty_FPA.mxd

Appendix A

A. Appendix A: Glossary

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
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 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

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, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.

flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the flood liable land concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the standard flood event in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or major overland flow paths through developed areas outside of defined drainage reserves; and/or the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding.
peak discharge	The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to water level. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

FLOOR LEVEL SURVEY FOR CULCAIRN, HENTY AND HOLBROOK FLOODPLAIN RISK MANAGEMENT STUDIES

1. Background

WMAwater are preparing the Culcairn, Henty and Holbrook Floodplain Risk Management Studies on behalf of Greater Hume Shire Council. Part of this work involves obtaining floor levels of all potential flood liable buildings (habitable and commercial buildings but not sheds or garages) within the study area (attached plans). To undertake the survey WMAwater seeks to appoint a suitably qualified and experienced surveyor to obtain building information for the properties as shown on the attached figures and tables.

You are invited to provide a quotation by **Friday 29th August**, detailing your fixed price proposal and timeframe for completion to undertake the works as described below.

2. Floor Level Survey

Complete the attached example Table 1 for each of the properties/buildings.

The following number of properties will be surveyed:

- Culcairn – 117 buildings
- Henty – 12 buildings
- Holbrook – 108 buildings

In addition to the above listed properties an estimated 10 not yet identified utilities situated within these towns will also require survey. This should be factored into your quote and the locations of these will be provided at a later date. Including these 10 utilities there are total of 247 properties that require survey.

The requested properties with buildings that need to be surveyed are identified on the attached figures and tabulated address lists. These can also be provided in the form of GIS layers (Mapinfo and ArcGIS format) if required. The number of properties does not necessarily indicate the exact number of buildings to be surveyed; this is particularly important for commercial areas. In some instances several properties may span one building or there may be several buildings on each property. Please ensure that where there is more than one building on a property, all commercial, industrial and residential buildings are surveyed (and identified as residential, commercial/industrial or other). Any small sheds or garages do not need to be included. This is not expected to significantly affect the number of properties to be surveyed as the majority of buildings in these towns are stand alone homes.

We have provided the following information to assist you with your quotation:

- Figures showing the properties to be surveyed in each town (this can be provided in GIS format if required - MapInfo or ArcGIS);
- Address lists for each town of the properties that require survey; and
- Example table for format of floor level information.

It is not expected that private property will need to be accessed to complete the proposed works. However please note that the surveyor is to follow all OEH/Council protocols for entering private property and the relevant Occupational Health and Safety requirements for working in traffic. In addition to this, all properties not surveyed will need to detail the reason why survey has not been performed. If a level is taken at a location other than the floor level this must also be noted with details provided.

3. Deliverables

The following deliverables are required for each survey.

- Completed Table 1 in a spreadsheet to include;
    - WMA property ID;
    - Number of buildings on property (small sheds / garages do not need to be included);
    - Property name, number and street address;
    - XY co-ordinate of survey point in MGA56;
    - Indicative ground level of property (taken at the same location as floor level survey mark or as close as possible) in mAHD;
    - Lowest floor level (lowest habitable level if residential) in mAHD;
    - If residential;
        - Habitable floor level;
        - Number of storeys;
        - Comment if habitable uses on ground floor;
        - House size (observational estimate);
        - Floor and Wall construction.
    - If non-residential;
        - Type of use, Commercial, Industrial, Public etc;
        - Name / nature of business or use;
        - Lowest floor level;
        - Approximate floor area;
        - Floor and Wall construction.

For residential blocks where one floor level applied to the block, the number of ground floor properties needs to be noted. Likewise for commercial office blocks, the number of ground floor companies needs to be noted.

4. Projection and Datum

All data is required in the Map Grid of Australia (MGA) Zone 55 projected Cartesian coordinate system, based on the Geocentric Datum of Australia (GDA) 1994 geocentric coordinate system. An easting and northing is required for each survey point. All survey levels will be in metres reduced to Australian Height Datum (m AHD).

5. Tender Requirements

Please provide a fixed price quotation to undertake the above work together with a timetable for completion via email to **richards@wmawater.com.au by Friday 29th August**. Please contact the undersigned if you require any further clarification.

Zac Richards – Project Engineer
WMAwater, Level 2, 160 Clarence Street, SYDNEY, NSW 2000
Telephone: (02) 9299 2855
Email: richards@wmawater.com.au

ATTACHMENTS:

- Figure 1 – Culcairn properties map
- Figure 2 – Henty properties map
- Figure 3 – Holbrook properties map
- Table 1 – Example of data format for completion
- Table 2 – Culcairn properties list
- Table 3 – Henty properties list
- Table 4 – Holbrook properties list

FIGURE 01
CULCAIRN
FLOOR LEVEL SURVEY

Hamilton Street
Lions Place
Thomas Place
Railway Parade
Melville Street
Olympic Highway
Hopetoun Street
Gordon Street
Munro Street
Hoy Street
Melrose Street
Princes Street
Fifield Close
Elizabeth Street
Queen Street
Douglas Street
Douglas Street
Victoria Street
Victoria Street
Black Street
Henty Street
Henty Street
Federal Street
Albert Street
Balfour Street
Balfour St (Service Rd)
Stock Route
Kimdeen Street
McBean Street
Henty Street
Federal Street
Balfour Street
Edward Street
Gordon Street
Gamble Street
Donald Street
Fraser Street
Blair Street
Railway Parade
Munro Street
King Street
King Street
King Street
Wattle Street
Walbundrie Road
South Street
Jubilee Park Road
Waterworks Road

N

Properties
Roads
Cadastre

0 0.25 0.5 1 1.5
km

J:\Jobs\114040\Admin\Survey_Brief\Culcairn_FL_survey.mxd

FIGURE 02
HENTY
SURVEY PROPERTIES

Angaston Road
Grubben Road
West Showground Road
Henty Pleasant Hills Road
Buckargingah Creek
Olympic Highway
Comer Street
Barisch Avenue
Elm Street
Comer Street
Railway Parade
Fox Street
Graham Street
Keighran Street
Smart Street

N

Properties
Roads
Creek
Cadastre

0 0.05 0.1 0.2 0.3 km

J:\Jobs\114040\Admin\Survey_Brief\Henty_FL_survey.mxd

FIGURE 03
HOLBROOK
SURVEY PROPERTIES

Mountain Creek Road
Culcairn Holbrook Road
Tip Road
Diggers Lane
Millswood Road
Bond Street
Spring Street
Fleet Street
Steel Street
Bath Street
Rankin Street
Ford Street
Racecourse Road
Bruce Street
Morgans Ridge Creek
Raymond Street
Wallace Street
Murdoch Place
Spurr Street
Railway Parade
Webb Street
Stirbeck Street
Croft Street
Welton Street
Frampton Street
Thorpe Street
Swift Street
Peel Street
Vine Street
Ross Street
Young Street
King Street
Wilson Street
Hume Highway
Hume Street
Bowler Street
Halford Drive
Gundagai Street
Hay Street
Young Street
Murray Street
Ten Mile Creek
Nyhan Street
Byng Street
Bardwell Street
Macinnes Street
William Street
Hume Freeway
Malabar Road
Jingellic Road

N

Properties
Roads
Creeks

0 0.25 0.5 1 1.5 2 km

J:\Jobs\114040\Admin\Survey_Brief\Holbrook_FL_survey.mxd

Table 1 - Format for Provision of Floor Level Data

									RESIDENTIAL BUILDINGS						NON RESIDENTIAL BUILDINGS						
WMA ID	Total number of buildings	Comment	Street Number	Street Name	Sub-Area	Easting	Northing	Indicative Ground Level (m AHD)	Lowest Habitable Floor Level (m AHD)	Number of Storeys	Do people live on the Ground Floor (Y or N)	**House Size** - Small (S), Medium (M), Large (L)	**Floor Construction** Pier (P) or Slab (S) Other - describe	**Wall Construction** Brick stone or rendered (B), Clad (C) , Mixed (M)	Type (commercial = C, industrial = I, public = P)	Name and Nature of Use/Business eg. Bob's Nursery, toilet block	Lowest Floor Level (m AHD)	Approximate Floor Area (m^2)	**Floor Construction** Pier (P) or Slab (S) Other - describe	**Wall Construction** Brick stone or rendered (B), Clad (C) , Mixed (M)	
HOL1	1		31	Smith Street	Holbrook	349719.030	6298859.741	152.53	152.81	1	Y	L	S	B							
HOL2	1		36	Smith Street	Holbrook	349719.030	6298859.741	156.35	154.19	1	Y	L	S	B							
HOL3	2	building 1	38a	Smith Street	Holbrook	349719.030	6298859.741	152.86	153.25	2	Y	L	S	M							
		building 2	38b	Smith Street		349719.030	6298859.741	152.83	153.45	2	Y	L	S	M							
HOL5	2		67	Jones Road	Holbrook	349719.030	6298859.741	152.50							C	BOB'S ELECTRICAL	154.47	225	S	M	second building is shed
HOL6	1		11	Jones Road	Holbrook	349719.030	6298859.741	152.50							C	CENTRAL COAST STAIRS	152.84	1000	S	M	
HOL7	1		15	Jones Road	Holbrook	349719.030	6298859.741	152.08							I	CUSTOM STAINLESS DESIGN	152.30	800	S	B	
HOL8	1		2A	Newcastle Street	Holbrook	349719.030	6298859.741	162.40	162.91	1	Y	L	P	C							
HOL10	1		31	Newcastle Street	Holbrook	349719.030	6298859.741	152.19	152.79	2	Y	S	P	B							
HOL11	1	flats - 5 units on ground floor	1	Bob Street	Holbrook	349719.030	6298859.741	153.26	153.98	56	Y	S	S	C							All units on ground floor have same floor level

Table 2

Culcairn Property Addresses

ID	X	Y	Address	ID	X	Y	Address
CUL1	503992	6052908	16 MUNRO STREET	**CUL73**	503671	6053597	11 MELROSE STREET
CUL2	503888	6052920	VACANT LAND' 22 EDWARD STREET	**CUL74**	503705	6053598	12 MELROSE STREET
CUL3	503655	6053122	24 HENTY STREET	**CUL75**	503768	6053607	14 MELROSE STREET
CUL4	503807	6052940	CULCAIRN HOSPITAL' 53 BALFOUR STREET	**CUL76**	503752	6053645	15 HOPETOUN STREET
CUL5	503997	6052932	18 MUNRO STREET	**CUL77**	503670	6053658	7 HOPETOUN STREET
CUL6	504034	6052925	5 FAHEY CRESCENT	**CUL78**	503610	6053635	1 HOPETOUN STREET
CUL7	504032	6052954	7 FAHEY CRESCENT	**CUL79**	503763	6053735	8 HOPETOUN STREET
CUL8	504145	6053018	81 BALFOUR STREET	**CUL80**	504085	6053466	46 MUNRO STREET
CUL9	504120	6053017	79 BALFOUR STREET	**CUL81**	504141	6053849	84 MUNRO STREET
CUL10	504098	6053014	77 BALFOUR STREET	**CUL82**	504162	6053930	88 MUNRO STREET
CUL11	504137	6052983	17 FEDERAL STREET	**CUL83**	504168	6053950	90 MUNRO STREET
CUL12	504131	6052958	15 FEDERAL STREET	**CUL84**	504170	6053974	90A MUNRO STREET
CUL13	504127	6052935	13 FEDERAL STREET	**CUL85**	504186	6053963	90A MUNRO STREET
CUL14	504119	6052895	9 FEDERAL STREET	**CUL86**	504171	6054016	92 MUNRO STREET
CUL15	504068	6052908	8 FAHEY CRESCENT	**CUL87**	504370	6052288	NILLIMBEK' 165 TAYLORS ROAD
CUL16	504177	6052991	CULCAIRN SWIMMING POOL' FEDERAL STREET	**CUL88**	504398	6052369	NILLIMBEK' 165 TAYLORS ROAD
CUL17	504218	6053183	24 FEDERAL STREET	**CUL89**	504052	6052324	WATTLE STREET
CUL18	504157	6053098	108 BALFOUR STREET	**CUL90**	503662	6052542	1 MELVILLE STREET
CUL19	504034	6053180	30 MUNRO STREET	**CUL91**	503943	6052908	26 EDWARD STREET
CUL20	504147	6053165	19 FEDERAL STREET	**CUL92**	503997	6052965	20 MUNRO STREET
CUL21	503912	6053047	90 BALFOUR STREET	**CUL93**	503525	6052869	6 MELVILLE STREET
CUL22	503869	6053038	86 BALFOUR STREET	**CUL94**	503550	6052897	41 BALFOUR STREET
CUL23	503849	6053035	84 BALFOUR STREET	**CUL95**	503526	6052902	CORNER OF BALFOUR AND MELVILLE STREETS
CUL24	503829	6053035	82 BALFOUR STREET	**CUL96**	503660	6052927	45 BALFOUR STREET
CUL25	503804	6053105	18 GORDON STREET	**CUL97**	503614	6052912	CULCAIRN PUBLIC SCHOOL' BALFOUR STREET
CUL26	503802	6053079	16 GORDON STREET	**CUL100**	503467	6052877	RAILWAY PARADE
CUL27	503836	6053108	29 HENTY STREET	**CUL101**	503280	6052593	CULCAIRN CARAVAN PARK' OLYMPIC HIGHWAY
CUL28	503856	6053112	31 HENTY STREET	**CUL102**	502928	6052585	5 SOUTH STREET
CUL29	503878	6053114	33 HENTY STREET	**CUL103**	503056	6052564	7 SOUTH STREET
CUL30	503897	6053122	35 HENTY STREET	**CUL104**	502417	6052594	WILLESDENE' 101 WALBUNDRIE ROAD
CUL31	503914	6053120	37 HENTY STREET	**CUL105**	502373	6052614	WILLESDENE' 101 WALBUNDRIE ROAD
CUL32	503811	6053151	20 GORDON STREET	**CUL106**	502773	6052349	MALABAR' 2901 OLYMPIC HIGHWAY
CUL33	503835	6053156	20 GORDON STREET	**CUL107**	503108	6052912	18 BALFOUR STREET
CUL34	503831	6053179	20 GORDON STREET	**CUL108**	502919	6052860	2 BALFOUR STREET
CUL35	503860	6053167	38 HENTY STREET EAST	**CUL109**	502949	6052855	8 BALFOUR STREET
CUL36	503631	6052983	66 BALFOUR STREET	**CUL110**	502969	6052909	1 KIRNDEEN STREET
CUL37	503615	6053070	17 HENTY STREET	**CUL111**	503063	6053577	51 MCBEAN STREET
CUL38	503635	6053071	19 HENTY STREET	**CUL112**	503247	6053743	24 HAMILTON STREET
CUL39	503652	6053072	21 HENTY STREET EAST	**CUL113**	503811	6053745	10 HOPETOUN STREET
CUL40	503674	6053077	23 HENTY STREET EAST	**CUL114**	503824	6052575	9 WATTLE STREET
CUL41	503692	6053078	25 HENTY STREET	**CUL115**	503846	6052584	9 WATTLE STREET
CUL42	503738	6053092	23 GORDON STREET	**CUL116**	503881	6052591	11A WATTLE STREET
CUL43	503727	6053061	21 GORDON STREET	**CUL117**	503895	6052594	11A WATTLE STREET
CUL44	503561	6053098	22 MELVILLE STREET	**CUL118**	503925	6052583	13 WATTLE STREET
CUL45	503565	6053123	24 MELVILLE STREET	**CUL119**	503512	6053141	25 MELVILLE STREET
CUL46	503584	6053108	22 MELVILLE STREET				
CUL47	503595	6053112	1 VICTORIA STREET				
CUL48	503592	6053130	1 VICTORIA STREET				
CUL49	503619	6053115	20 HENTY STREET EAST				
CUL50	503635	6053121	22 HENTY STREET				
CUL51	503689	6053128	28 HENTY STREET EAST				
CUL52	503685	6053149	28 HENTY STREET EAST				
CUL53	503672	6053126	26 HENTY STREET EAST				
CUL54	503752	6053208	12 VICTORIA STREET				
CUL55	503701	6053200	8 VICTORIA STREET				
CUL56	503673	6053193	6 VICTORIA STREET				
CUL57	503772	6053218	14 VICTORIA STREET				
CUL58	503574	6053170	26 MELVILLE STREET				
CUL59	503575	6053191	28 MELVILLE STREET				
CUL60	503604	6053265	34 MELVILLE STREET				
CUL61	503631	6053182	2 VICTORIA STREET				
CUL62	503598	6053337	36 MELVILLE STREET				
CUL63	503627	6053375	40 MELVILLE STREET				
CUL64	503635	6053445	2 PRINCES STREET				
CUL65	503595	6053435	44 MELVILLE STREET				
CUL66	503582	6053460	46 MELVILLE STREET				
CUL67	503629	6053524	5 MELROSE STREET				
CUL68	503699	6053529	9 MELROSE STREET				
CUL69	503747	6053537	13 MELROSE STREET				
CUL70	503772	6053551	15 MELROSE STREET				
CUL71	503598	6053564	CULCAIRN MOTOR INN' 2 MELROSE STREET				
CUL72	503591	6053591	CULCAIRN MOTOR INN' 2 MELROSE STREET				

Table 3

Henty Property Addresses

ID	X	Y	Address
HEN1	502338	6070215	'EDEN PARK' 2350 HENTY PLEASANT HILLS ROAD
HEN2	502446	6070178	2363 HENTY PLEASANT HILLS ROAD
HEN3	502647	6070341	'HENTY SHOWGROUND' HENTY PLEASANT HILLS ROAD
HEN4	502341	6070324	2341 HENTY PLEASANT HILLS ROAD
HEN5	502314	6070341	'BUNDERRY' 73 ANGASTON ROAD
HEN6	502527	6070173	2363 HENTY PLEASANT HILLS ROAD
HEN7	503177	6070758	'LOW PLAINS' 5570 OLYMPIC HIGHWAY
HEN8	503199	6070442	5540 OLYMPIC HIGHWAY
HEN9	503205	6070422	5538 OLYMPIC HIGHWAY
HEN10	502730	6069942	ELM STREET
HEN11	503061	6070464	2 ANGASTON ROAD
HEN12	503062	6070532	GRUBBEN ROAD

Table 4

Holbrook Property Addresses

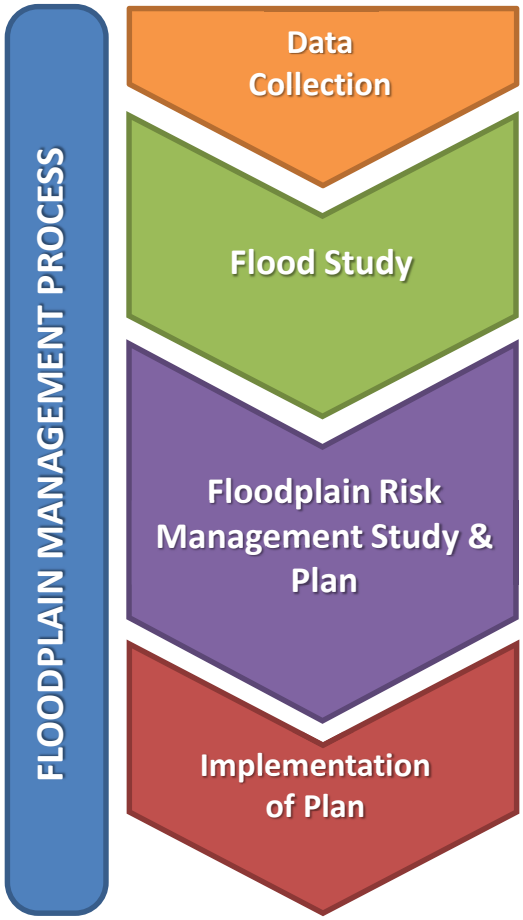
ID	X	Y	Address	ID	X	Y	Address
HOL1	528102	6046836	31 BOWLER STREET	HOL73	528079	6045975	2 BARDWELL STREET
HOL2	528289	6046550	97 ALBURY STREET	HOL74	528102	6045967	2 BARDWELL STREET
HOL3	528286	6046530	89 ALBURY STREET	HOL75	528123	6045974	8 BARDWELL STREET
HOL4	528264	6046479	'HOLBROOK HALL & OLD OFFICES' 40 YOUNG STREET	HOL76	528136	6046019	1 BYNG STREET
HOL5	528344	6046499	78-80 ALBURY STREET	HOL77	528096	6046049	JOLLY SWAGMAN MOTEL' 46 ALBURY STREET
HOL6	528402	6046464	1 SWIFT STREET	HOL78	528121	6046076	JOLLY SWAGMAN MOTEL' 46 ALBURY STREET
HOL7	528602	6046787	53 SWIFT STREET	HOL79	528168	6046080	3 BYNG STREET
HOL8	528594	6046772	51 SWIFT STREET	HOL80	528126	6046151	50 ALBURY STREET
HOL9	528584	6046754	49 SWIFT STREET	HOL81	528109	6046123	48 ALBURY STREET
HOL10	528520	6046400	51 YOUNG STREET	HOL82	528159	6046196	52 ALBURY STREET
HOL11	528496	6046410	49 YOUNG STREET	HOL83	528249	6046210	17 BYNG STREET
HOL12	528477	6046422	47 YOUNG STREET	HOL84	528179	6046237	56 ALBURY STREET
HOL13	528466	6046433	45 YOUNG STREET	HOL85	528182	6046254	60 ALBURY STREET
HOL14	528456	6046445	43 YOUNG STREET	HOL86	528229	6046317	68 ALBURY STREET
HOL15	528475	6046471	10 SWIFT STREET	HOL87	528236	6046336	72 ALBURY STREET
HOL16	528484	6046484	10 SWIFT STREET	HOL88	528252	6046352	76 ALBURY STREET
HOL17	528567	6046485	17 GUNDAGAI STREET	HOL89	528298	6046320	4 HAY STREET
HOL18	528579	6046502	19-21 GUNDAGAI STREET	HOL90	528286	6046331	2 HAY STREET
HOL19	528537	6046572	20 SWIFT STREET	HOL91	527919	6045972	MORRISONS' ALBURY STREET
HOL20	528581	6046559	10 HUME STREET	HOL92	528011	6046071	GLENNDALE PARK MOTEL' 59-65 ALBURY ST
HOL21	528572	6046573	22 SWIFT STREET	HOL93	527938	6046063	2-4 NYHAN STREET
HOL22	528610	6046547	12 HUME STREET	HOL94	527964	6046133	10-12 NYHAN STREET
HOL23	528491	6046504	12 SWIFT STREET	HOL95	527999	6046172	14 NYHAN STREET
HOL24	528650	6046634	11 HUME STREET	HOL96	528036	6046209	10 MURRAY STREET
HOL25	528634	6046633	9 HUME STREET	HOL97	528015	6046220	8 MURRAY STREET
HOL26	528654	6046598	13 HUME STREET	HOL98	527935	6046202	17 NYHAN STREET
HOL27	528635	6046601	11 HUME STREET	HOL99	528369	6045854	31 MCINNES STREET
HOL28	528623	6046613	9 HUME STREET	HOL100	528341	6045943	28 BARDWELL STREET
HOL29	528676	6046773	38 SWIFT STREET	HOL101	528044	6046266	7A MURRAY STREET
HOL30	528731	6046736	65 BOWLER STREET	HOL102	528089	6046238	77 ALBURY STREET
HOL31	528767	6046739	BRIGADOON' 65 BOWLER STREET	HOL103	528107	6046225	77 ALBURY STREET
HOL32	528794	6046730	BOWLER STREET	HOL104	528120	6046241	79 ALBURY STREET
HOL33	528816	6046730	67 BOWLER STREET	HOL105	528130	6046273	HOLBROOK TYRE SERVICE' 81 ALBURY STREET
HOL34	528863	6046750	67A BOWLER STREET	HOL109	528174	6046323	WOOLPACK INN MUSEUM' 83 ALBURY ST
HOL35	527909	6046779	9 PURTELL STREET	HOL111	528317	6046311	6 HAY STREET
HOL36	527745	6046892	1 BOWLER STREET	HOL112	528510	6045862	45 MCINNES STREET
HOL37	527762	6046969	26-28 RAILWAY PARADE				
HOL38	527821	6046907	7-9 BOWLER STREET				
HOL39	528970	6047031	38 PEEL STREET				
HOL40	528987	6047053	40 PEEL STREET				
HOL41	528995	6047072	42 PEEL STREET				
HOL42	529200	6047146	2-8 VINE STREET				
HOL43	529432	6047320	RANKIN STREET				
HOL44	529102	6047110	1 VINE STREET				
HOL45	527594	6047492	PEARDONS MILL' TIP ROAD				
HOL46	527664	6047521	PEARDONS MILL' TIP ROAD				
HOL47	527623	6047529	PEARDONS MILL' TIP ROAD				
HOL48	529896	6044370	WATER PARK' 224 JINGELLIC ROAD				
HOL49	529999	6044248	WATER PARK' 224 JINGELLIC ROAD				
HOL50	528863	6045696	96 JINGELLIC ROAD				
HOL51	528843	6045660	96 JINGELLIC ROAD				
HOL52	528682	6045686	THE OASIS' MCINNES STREET				
HOL53	528695	6045746	THE OASIS' MCINNES STREET				
HOL54	528692	6045730	THE OASIS' MCINNES STREET				
HOL55	528833	6045938	THE OLD PARSONAGE' 78 JINGELLIC ROAD				
HOL56	528508	6045831	45 MCINNES STREET				
HOL57	528486	6045834	43 MCINNES STREET				
HOL58	528469	6045835	41 MCINNES STREET				
HOL59	528451	6045843	39 MCINNES STREET				
HOL60	528428	6045843	37 MCINNES STREET				
HOL61	528404	6045933	32 BARDWELL STREET				
HOL62	528323	6045942	26 BARDWELL STREET				
HOL63	528283	6045944	22 BARDWELL STREET				
HOL64	528262	6045954	18-20 BARDWELL STREET				
HOL65	528267	6046001	21 BARDWELL STREET				
HOL66	528288	6046028	3 NOLAN STREET				
HOL67	528217	6046031	4-6 BYNG STREET				
HOL68	528345	6046268	18 BYNG STREET				
HOL69	528221	6045957	16 BARDWELL STREET				
HOL70	528206	6045963	14 BARDWELL STREET				
HOL71	528183	6045962	10-12 BARDWELL STREET				
HOL72	528152	6045896	11 MCINNES STREET				

Appendix C

Henty

Floodplain Risk Management Study & Plan

A Floodplain Risk Management Study and Plan (the Study) is currently being prepared for Henty. This is the next phase of the Floodplain Management Process after completion of the Culcairn, Henty and Holbrook Flood Studies (the Flood Study) last year. Greater Hume Shire Council (Council) has appointed WMAwater to undertake this Study.



The Floodplain Management Process

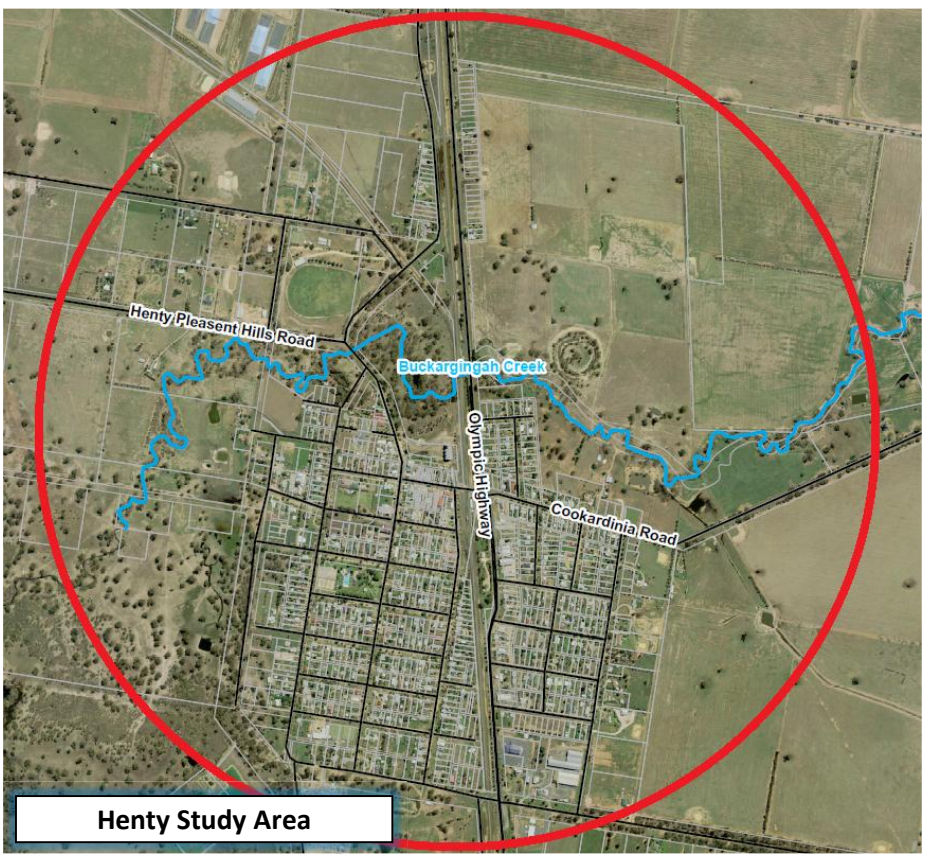
The State Government's Flood Policy aims to reduce the impacts of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding. Under the Policy, local government is responsible for managing flood liable land.

The Policy encourages the development of:

- solutions to existing flood problems in developed areas and
- strategies for ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in existing developed areas.

The State Government's Flood Policy provides for technical and financial support for a number of floodplain management activities. Funding for this study was provided from the State Government's Flood Risk Management Program and Greater Hume Shire Council.

Henty Study Area and Flood History



Flooding in Henty is primarily due to Buckargingah Creek (the Creek) which at Henty has a catchment area of 85 km². An additional flow path to the north of the Creek is also responsible for some flooding. Various manmade structures such as the Olympic Highway, Main Southern Railway and Henty-Pleasant Hills Road lead to backwatering and flow diversion which in some instances has exacerbated the flood problem.

During October 2010 and again in March 2012 record flooding occurred in Henty due to Buckargingah Creek and the northern flow path mentioned above. The October 2010 flood is generally considered to be the larger of the two with the event inundating approximately 20 homes and businesses over floor level and causing significant damage throughout the town. The Flood Study estimated that this event had an Average Recurrence Interval (ARI) between 200 and 500 years.

Henty

Floodplain Risk Management Study & Plan

An important aspect of this Study is devising various flood mitigation options that will reduce flood risk, liability and damage. WMAwater engineers have come up with various mitigation measures, however often flood affected communities also will have various ideas of how flood affectation can be reduced. This is where we need your help. Please complete the attached questionnaire and come to our community workshop day at Henty.

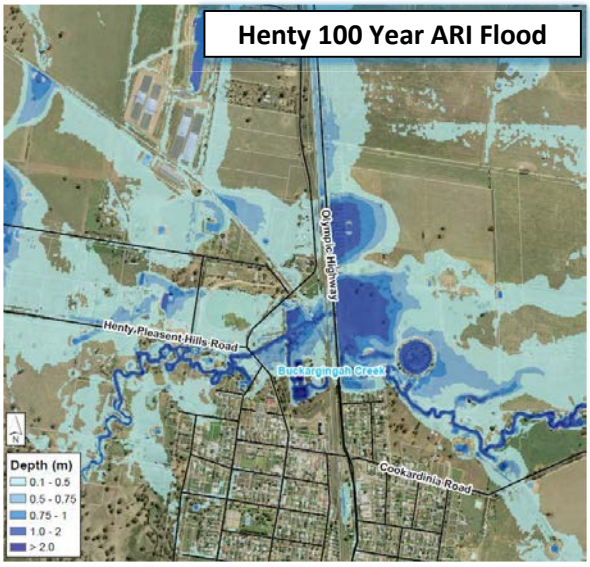
Come along to our Community Workshop

When: **Tuesday 14th October at 2:00 pm to 8:00 pm**

Where: **Henty Community Library**
Sladen Street, Henty

Flood Mitigation through Computer Modelling

The Flood Study aimed at understanding and determining the nature and extent of flood affectation in Henty. As part of this work detailed computer models were established to model flood behaviour in the Study Area. One of the benefits of these models is that various flood mitigation measures can be tested to determine what works will provide the greatest mitigating effect whilst insuring that there are no negative impacts such as increased flood levels in the surrounding areas.



What mitigation works can help reduce flood risks?

Flood Mitigation Works

Various types of flood mitigation works are used to reduce flood affectation. Not all mitigation measures are appropriate for all areas. For example, levees are often used to exclude flood water due to riverine or creek flooding from flood prone areas, however these will often increase flood levels and affectation outside of the levee as well as stopping local runoff from entering the creek, inadvertently causing flooding inside to the levee as well. Accordingly, a detailed investigation of all proposed flood mitigation works must be undertaken using the Flood Study Models.

Levees

Levees are used to exclude flood water from flood prone areas. A well known example of this is at Wagga Wagga were a levee protects the Wagga CBD from Murrumbidgee River flooding. Levees are often constructed of earthen embankments or from reinforce concrete if limited space is available.


Example earth bank levee

Culverts and Bridges

Culverts and bridges allow water to flow under roads, train tracks or similar obstructions. The use of bridges and culverts helps reduce upstream flood levels up until the capacity of the structure is exceeded. In some instances it may be beneficial to increase the conveyance capacity of existing culverts to decrease upstream water levels, however the downstream impacts of such works must also be taken into account.

Drains and Channels

Drains and channels assist in the removal of floodwaters by increasing the rate at which flow is dispersed from a flood affected area. These structures are often situated in existing flow paths and are generally either earthen or concrete lined. In Henty, there are a number of earthen channels situated downstream of the Main Southern Railway Line that assist in the transfer of flow back into Buckargingah Creek once they pass through culverts under the Olympic Highway and Railway.

Henty
Floodplain Risk Management Study & Plan

In some instances, flood mitigation works such as those mentioned on the previous page may not be suitable for mitigation of flood risk and affectation. In such situations flood risk management measures may be better suited to reduce risk to life and property.

Property Modification Measures

Voluntary Purchase

Voluntary Purchase (VP) involves the acquisition of flood affected properties situated in high hazard areas, and demolition of the residence to remove it from the floodplain. The New South Wales State Government recognises VP as an effective floodplain risk management measure for existing properties in areas where:

- There are highly hazardous flood conditions from riverine or overland flooding and the principal objective is to remove people living in these properties and reduce the risk to life of residents and potential rescuers.
- A property is located within a floodway and the removal of a building may be part of a floodway clearance program that aims to reduce significant impacts on flood behaviour elsewhere in the floodplain by enabling the floodway to more effectively perform its flow conveyance function.
- Purchase of a property enables other flood mitigation works (such as channel improvements or levee construction) to be implemented because the property will impede construction or may be adversely affected by the works with impacts not able to be offset.


High Hazard Flooding

VP is an effective strategy where it is impractical or uneconomic to mitigate high flood hazard to an existing property and it is more appropriate to cease occupation to meet the above objectives. Government funding for VP schemes can be made available through the Floodplain Management Program as long as a number of complying criteria are met.

It is important to note that all properties involved in a VP scheme are valued by Valuer General of NSW and the property is assessed as though it is flood unencumbered. As part of this Study we are interested in determining the level of community interest in such a scheme. The questionnaire attached to this newsletter provides you with an opportunity to tell us if you would be willing to be involved in the VP process. Please note that the VP process is entirely voluntary and anyone involved in the scheme can withdraw at anytime. Also worth noting, where such a scheme is implemented it is done on a priority basis and such schemes can take many years to be carried out in full.

Voluntary House Raising

Voluntary House Raising (VHR) has been widely used throughout NSW to eliminate or significantly reduce flooding of habitable floors particularly in lower hazard flood areas, albeit in limited overall numbers. VHR is recognised as an effective floodplain risk management measure for both riverine and overland flood conditions. It is generally undertaken to:


House Raising

- Reduce the frequency of exposure to flood damage of the house and its contents – reducing the frequency of household disruption, associated trauma and anxiety, and clean up after floods may also have social benefits.
- As a compensatory measure where flood mitigation works adversely affect a house which is generally considered part of the mitigation work rather than a separate VHR scheme.

VHR can be an effective strategy for existing properties in low flood hazard areas where mitigation works to reduce flood risk to properties are impractical or uneconomic. It should be part of an overall floodplain risk management strategy for an area rather than a stand-alone option as it does not deal with issues such as risk to life.

More information on the NSW Government's VP and VHR schemes can be obtained from:

http://www.environment.nsw.gov.au/resources/water/coasts/20130055fmpvolpurchase.pdf
http://www.environment.nsw.gov.au/resources/water/coasts/20130056fmpvolraising.pdf

Henty

Floodplain Risk Management Study & Plan

Community involvement in the Study is important. The Henty Floodplain Management Committee includes members from Council, Office of Environment and Heritage, the State Emergency Services and local residents who will oversee this Study. A questionnaire is included with this newsletter so that your views and ideas can be included in this Study. You are also invited to attend a community workshop where we welcome you to provide input into potential flood management options in more detail as well as to discuss the Study.

How can I have my say?

A questionnaire is enclosed with this newsletter. Please complete this and return to the FREEPOST address in the envelope provided.

Please make sure that all surveys are returned before 24th October 2014 or they may not be counted.

If you have additional information you would like to make available for the Study, or further comments, please attach to your questionnaire response or alternatively email to the contacts below.

The easiest and best way to be heard is to attend the community workshop at Henty Library on Tuesday 14th October 2014 between 2 pm and 8 pm.

Feedback from the community will be analysed and considered in this Floodplain Risk Management Study.

The hydraulic models constructed in the Flood Study will be used to assess the impacts of the potential mitigation options raised by the community in more detail and determine if these mitigation ideas are commercially viable. Modelling will also ensure that there are no negative impacts in the surrounding areas. The community workshop will be run in conjunction with this newsletter/questionnaire to provide opportunity for the community to ask questions in an open forum and to assist WMAwater engineers in determining potential mitigation works.

Contacts

If you would like to know more or have any information on flooding which would assist in this Study, please complete the relevant sections on the questionnaire and return using the provided 'postage paid' envelope. Additional information and comment can be attached to the questionnaire when you return it or provided to the contacts below.

Michael Oliver
Manager Infrastructure & Traffic
moliver@greaterhume.nsw.gov.au

Greater Hume Shire Council
40 Balfour Street, Culcairn NSW, 2660

Tel: 02 6029 8588

Zac Richards
Project Engineer
henty@wmawater.com.au

WMAwater
Level 2, 160 Clarence Street
Sydney, NSW 2000

Tel: 02 9299 2855

Henty

Floodplain Risk Management Study & Plan

Please complete this questionnaire and return to the FREEPOST address in the envelope provided. Please make sure that all surveys are returned before 24th October 2014 or they may not be counted.

1. Your Details

(Please note your contact details are optional, will be held confidential and will only be used to contact you for more information regarding this study)

Name:

Address:

Telephone:

Email:

2. Can we contact you directly for more information?

☐ Yes ☐ No

If 'Yes', what method of contact would you prefer? e.g. telephone, Email etc.

3. Do you think something should be done to reduce flood risk in Henty?

☐ Yes ☐ No ☐ Don't Know

4. Is the flood risk you are referring to due to:

☐ Buckargingah Creek ☐ Other

If 'Other', please detail the source of flooding.

5. At what frequency would you consider flooding "acceptable"?

☐ Annually ☐ 5 years ☐ 10 years ☐ 50 years ☐ 100 years ☐ Never

Henty

Floodplain Risk Management Study & Plan

6. If eligible, would you be interested in a Voluntary Purchase scheme?

☐ Yes ☐ No

7. If eligible, would you be interested in a Voluntary House Raising scheme?

☐ Yes ☐ No

Please note that Questions 6. and 7. are only to obtain an indication of the level of community interest in these schemes. Please feel free to comment on the VP and VHR schemes below.

8. Have you got any ideas to reduce flood risk at Henty?

☐ Yes ☐ No

If 'Yes' can you please describe the location of where you think flood risk could be improved (please provide nearest crossroads or known landmarks or alternatively display on the attached map on page 8).

Henty

Floodplain Risk Management Study & Plan

Please use this page to describe how flood risk may be reduced?

Please use as many details as possible to describe how flood risk may be reduced. Note that you might find the attached map over page useful to aid in your description.

Henty

Floodplain Risk Management Study & Plan

Greater Hume Shire
simply greater

Henty 100 year ARI flood depth map – Please indicate how you would reduce flood risk?

Appendix D

D. Appendix D: Hydraulic Categorisation – Floodway Definition

Introduction

The Henty hydraulic categorisation maps for the 5% and 1% AEP events and the PMF are presented in Figure 9 to Figure 11 respectively. The floodway was determined for the 1% AEP events and the same methodology then applied to the 5% AEP and PMF events.

Hydraulic categorisation is the process by which flood behaviour for a given design event is classified into areas of flood storage, flood fringe and floodway. The NSW Floodplain Development Manual 2005 (Reference 1) provides definitions for all three categories, however these are descriptive definitions and aren't suitable for directly calculating/assessing the categories. The definitions as per Reference 1 are provided below for clarity.

> *Floodway* – areas in the floodplain where significant discharge occurs. Often aligned with natural channels. Floodways are areas that even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
>
> *Flood Storage* – those parts of the floodplain important for the temporary storage of floodwaters during a flood. Extent and behaviour of flood storage areas may vary greatly for different events and so a range should be examined.
>
> *Flood Fringe* – remaining areas of land in the floodplain after flood storage and floodway have been defined. (NSW FDM, 2005)

Three further definitions that are suitable for directly calculating/assessing the floodway extent and that are widely used to describe the characteristics of the floodway are described below:

1. The extent which comprises a significant proportion of flow in a flow path (80 to 90% is often used as the portion of flow within the floodway); and
2. The extent which if partially blocked causes impacts in excess of 0.1 m to occur upstream of the partial blockage.
3. The Floodplain Risk Management Guidelines (2007) (Reference 17) advise that the minimum width of a floodway is required to be at least as wide as the main channel as determined from the top of bank.

These three definitions have been used to assist in determining the floodway extent at Henty.

Defining the floodway is a critical component of the flood risk management work carried out under the NSW Floodplain risk management program. This relates to the fact that the defined floodway extent will typically not be available for further residential development. As such it is imperative that the floodway definition is appropriate and not conservative.

Approach

Generally speaking there is no definitive method and defining a floodway is often an iterative process. In the context of 2D and 1D/2D models, the output used in the mapping tends to be in a

raster format. A raster presents flood modelling outputs for each grid cell in a gridded format for the given study area. The velocity depth (VD) product for each cell can, and has in previous studies, been used to define the floodway. For example the Howells et al (Howells) method utilises the VD product and the velocity (V) when assessing hydraulic categories.

The Howells method differentiates the floodway from other hydraulic categories by selecting a VD criteria that exceeds a specific threshold. Some subjectivity still exists within the methodology and different regions often require different V and VD criteria to produce suitable results. Testing varying V and VD criteria, to some degree, is comparable to a calibration exercise where the VD product to be used as a threshold for defining floodway is modified until such a time as a suitable floodway is obtained.

Given that the VD product can provide a base for defining the floodway extent for raster results, the next issue with floodway definition is defining what the VD product should be "calibrated" to, to achieve a reasonable floodway definition. In other words, what VD product will define a floodway extent which will satisfy the three floodway definitions mentioned above.

Methodology

In the 2012 paper by Thomas et al., the two previously mentioned floodway definitions were investigated and a remarkable correlation was observed between the 80% - 90% flow criteria and a 0.1 m afflux.

The proposed approach builds on the criteria proposed by Howells et al. in their 2004 paper using various VD and V parameters to estimate the floodway and then verifies results using encroachment analysis similar to that found in Thomas et al. (2012).

In the encroachment analysis all areas not defined as floodway via the Howells method have been totally excluded from the modelling domain and the subsequent impact on flood levels is examined. In other words the encroachment run undertaken as a check, conservatively assumes that all areas outside the floodway are blocked and should development occur outside the floodway zone defined herein the impact is likely to be less than 0.1 m

A summary of VD and V values investigated (VDV criteria) is listed below:

a. VD > 0.20 m^2/s and V>0.20 m/s; or V>1.0 m/s;
b. VD > 0.15 m^2/s and V>0.15 m/s; or V>1.0 m/s;
c. VD > 0.10 m^2/s and V>0.10 m/s; or V>1.0 m/s;

In addition to the Howells method, other methods are also utilised to define the Henty floodway and further add to the robustness of results. The top of the main channel bank has been adopted as the minimum floodway width, satisfying the guidelines discussed above. Also, the percentage of flow conveyed in the floodway is investigated to see if it fits the 80% - 90% criteria, as previously mentioned.

The remainder of the floodplain outside the defined Floodway becomes either Flood Storage or Flood Fringe.

In the past, the 20Y ARI flood extent has been used to define the 1% AEP floodway. As a

supplementary test, this approach has also been considered in this investigation by comparing the 20Y ARI flood extent (trimmed to remove depths greater than 0.1 m) to the VD and V criteria listed above.

Results

Appendix Figure D1 displays the afflux associated with the encroachment analysis testing for Henty. The Buckargingah Creek study area satisfies the VDV criteria (c), mentioned previously. The defined floodway using this VDV criteria was found on encroachment analysis testing to produce an afflux of approximately 0.1 m for the majority of the Buckargingah floodplain. Using this criteria the 2nd floodway definition is satisfied.

In some areas, particularly in the upstream, the afflux produced is below 0.1 m. The width of the floodway in these regions could not be decreased without excluding the top of the channel bank and therefore not meeting the guidelines previously outlined. By extending the defined floodway to at least as wide as the main channel (as determined from the top of bank) the 3rd floodway definition is satisfied.

The 20Y ARI flood extent slightly overestimated the floodway extent, producing an afflux lower than 0.1 m. Thus, the Howells method extent and the top of bank are more appropriate for hydraulic categorisation in Henty.

A number of cross sections that measure flow in the model are also displayed in Appendix Figure D1. For each cross section, the flow distribution (%) both within and outside of the floodway are displayed. It can be seen that the percentage of flow contained within the defined floodway is within 80% – 90% thus satisfying the 1st floodway definition. This adds further robustness to the floodway results.

Conclusions

Defining a floodway is a non-precise process. The goal is to produce floodway extents that match flow behaviour so that the areas which need to be retained for flow are identified whilst other parts of the flood extent can be developed as appropriate. While the allocation of floodway is likely to be a contentious issue that would merit a precise definition, the fact remains that a one size fits all approach still eludes the practitioner. The method presented defines a reasonable floodway extent using VD and V criteria and then confirms the suitability of the defined floodway extent by using afflux testing. The percentage of flow within the floodway was also investigated to see if the 1st floodway definition is satisfied.

The method used in defining the floodway is based on the Howells method but the VD and V thresholds are adjusted according to an encroachment analysis until the 2nd floodway definition is satisfied. When all areas outside the defined floodway are blocked and the resulting afflux is in the region of 0.1 m it can be argued that any development outside this floodway will result in an afflux less than 0.1 m which satisfies our 2nd floodway definition. Additionally, as previously mentioned, the top of bank for the main channel was set as the minimum width of the floodway extent, thus satisfying the 3rd floodway definition.

Appendix E

E. Appendix E: Flood Damages Assessment

E.1. Quantification of Damages

The quantification of flood damages is an important part of the floodplain risk management process. Flood damages can be defined as actual or potential where actual damage refers to the damage incurred during known flood events while potential damage is an estimation of the damage that could occur. Calculating potential flood damages gives a potential value of damage per property per design flood event and an overall average annual damages value which is the average cost to property owners per year owing to flood damages. By quantifying flood damage for a range of design events, appropriate cost effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including;

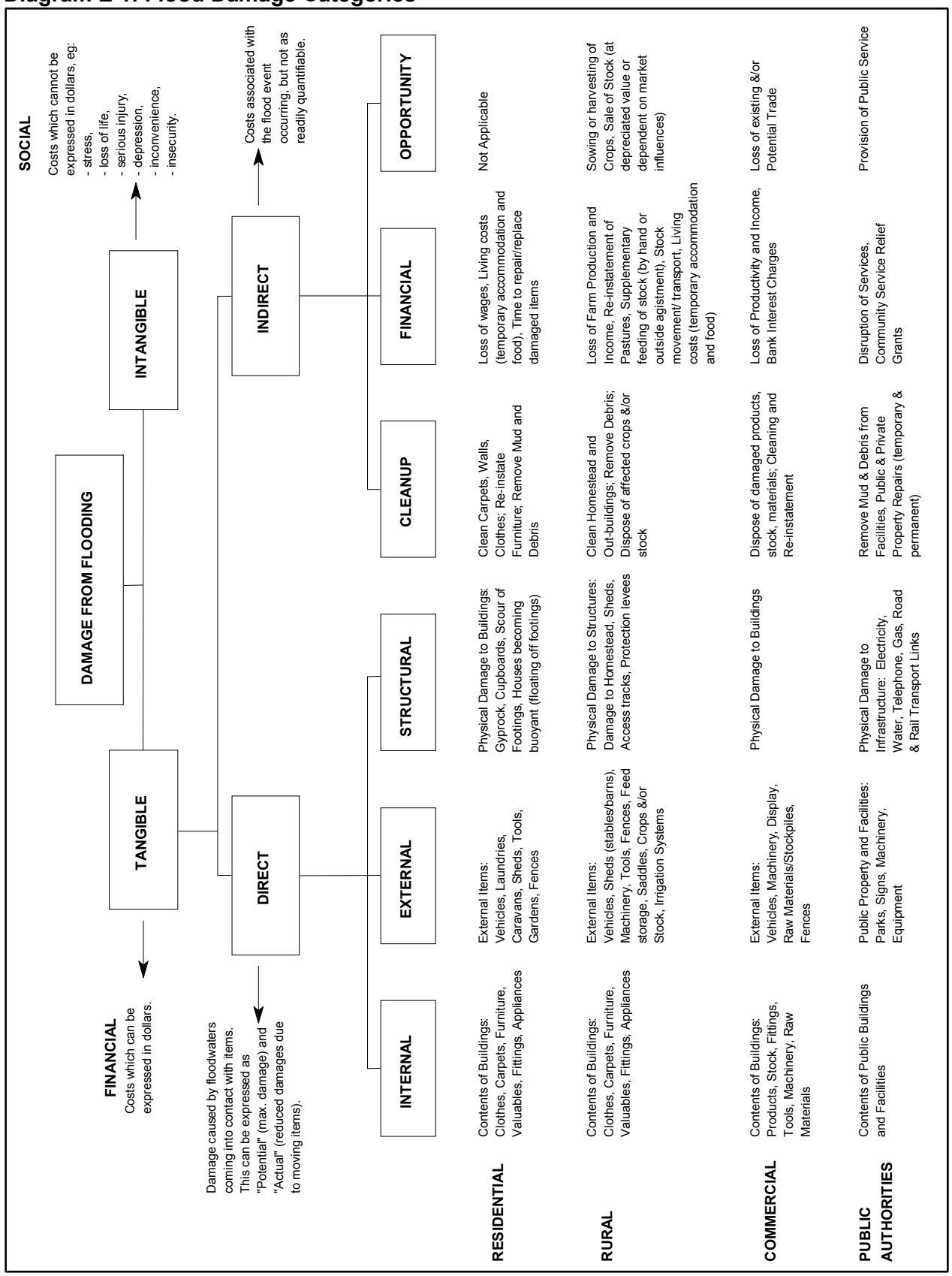
- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding;
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such failure of services (sewerage), flood borne debris; and
- The types of asset and infrastructure affected.

The estimation of flood damages tends to focus on the physical impact of damages on the human environment and can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Types of flood damages are shown on Diagram E 1 over.

To undertake the damages assessment floor level data is required. Floor level survey was performed by Hydrographic & Cadastral Survey Pty. Ltd. for nine residential properties in Henty. The floor levels of the remaining properties were estimated. Further details are presented in Section 1.5.2.

The non-residential damages are more complex than residential damages and have different damages associated with flooding. In Henty three commercial properties were surveyed. Damages for commercial properties have been assessed using separate damage curves to residential damages.

Diagram E 1: Flood Damage Categories



E.2. Identifying Flood Affected Properties

The damages assessment does not only look at potential costs due to flooding but also identifies when properties are likely to become flood affected by either flooding on the property or by over floor flooding. Figure 15 of the main report show in which design event buildings are first flooded above floor level.

Diagram E 2 and Diagram E 3 show the number of flood prone residential properties in Henty and the number of residential properties liable to above floor flooding. Diagram E 4 and Diagram E 5 show the number of flood prone non-residential properties in Henty and the number of non-residential properties liable to above floor flooding.

Diagram E 2: Number of Flood Prone Residential Properties by Street

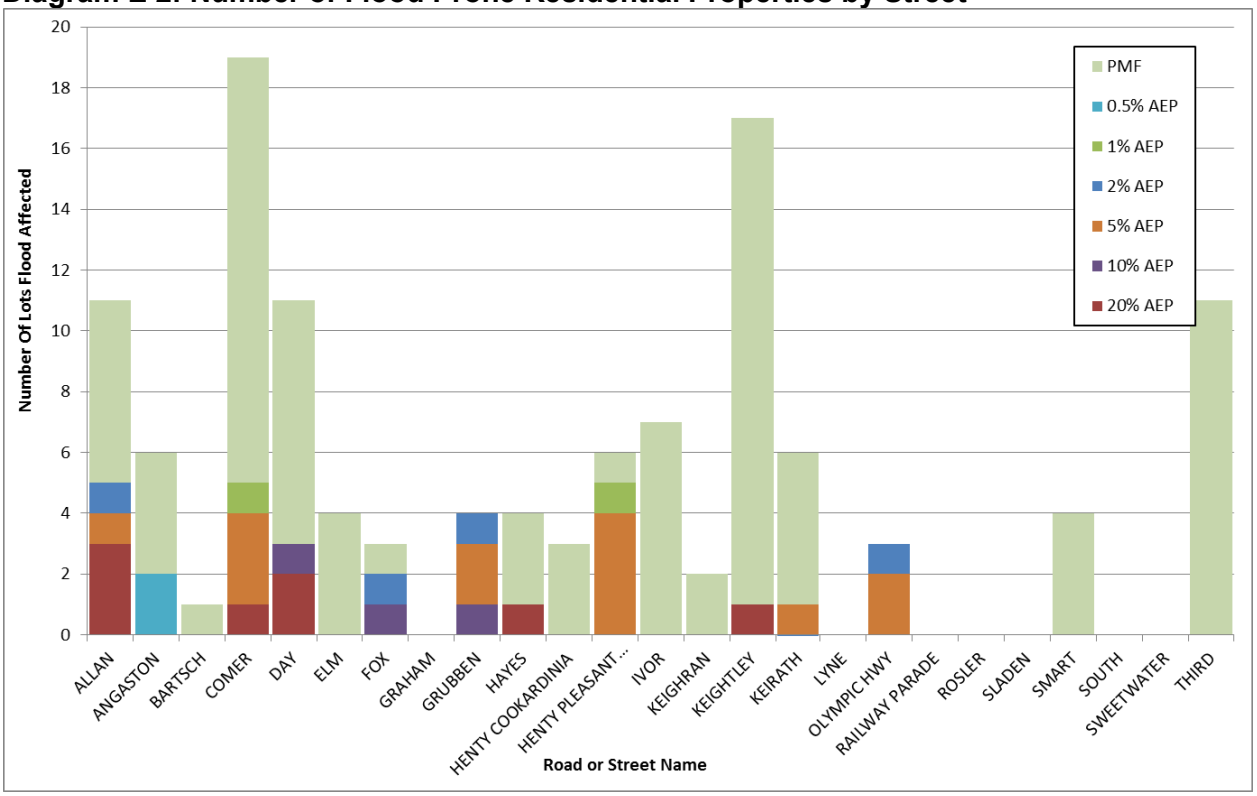


Diagram E 3: Number of Residential Properties Flooded Above Floor Level by Street

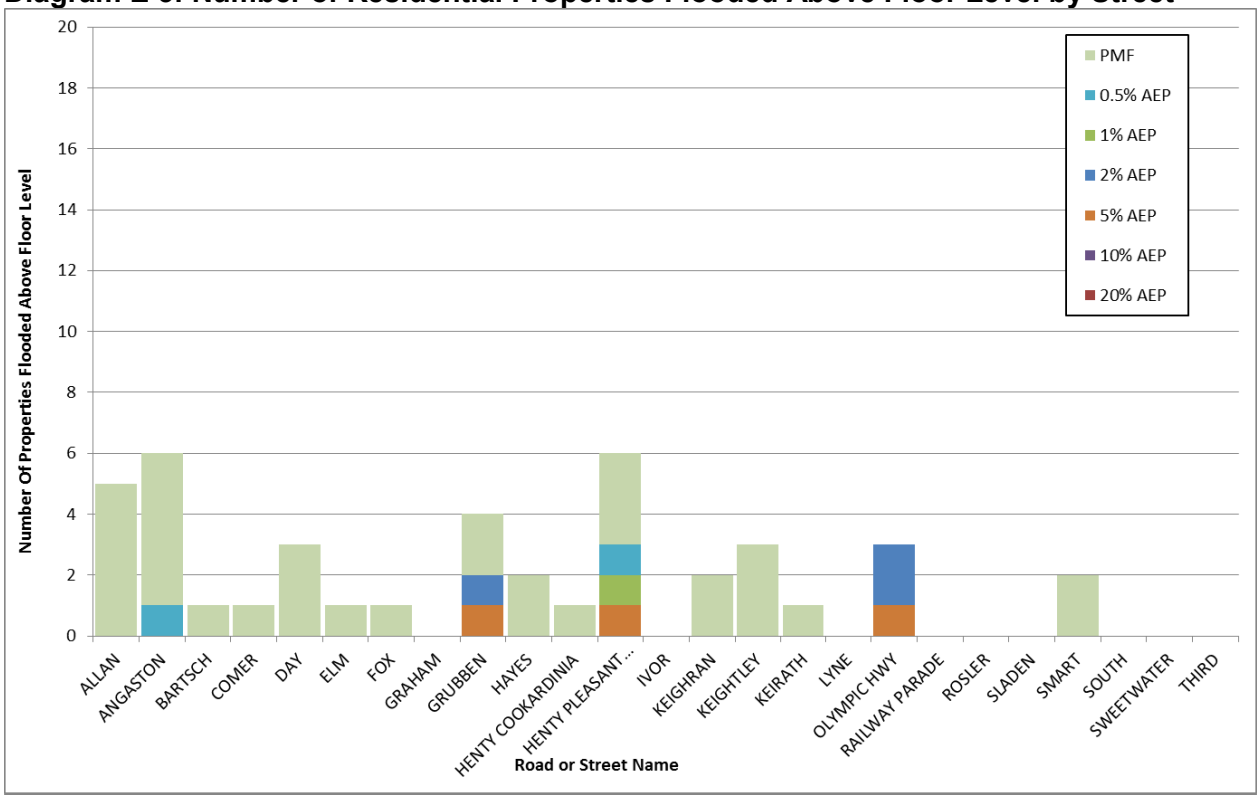


Diagram E 4: Number of Flood Prone Non-Residential Properties by Street

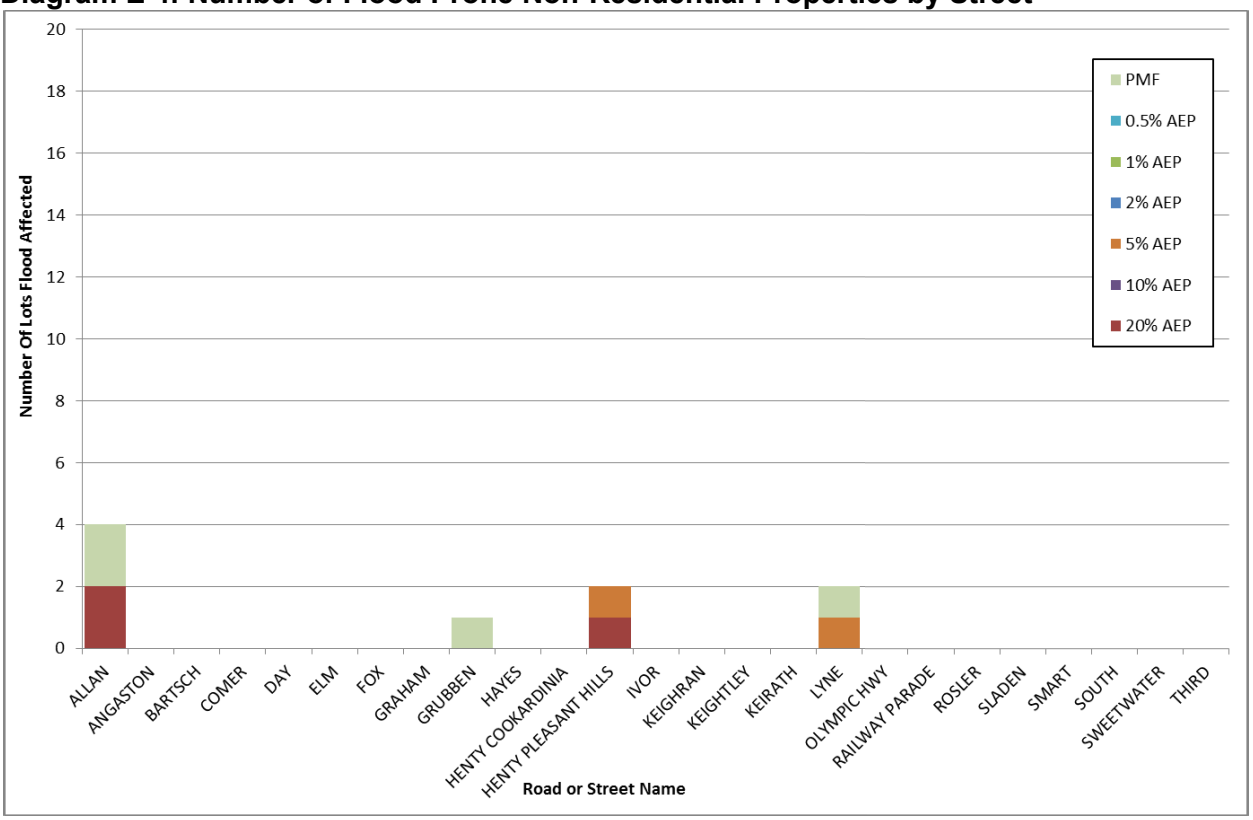
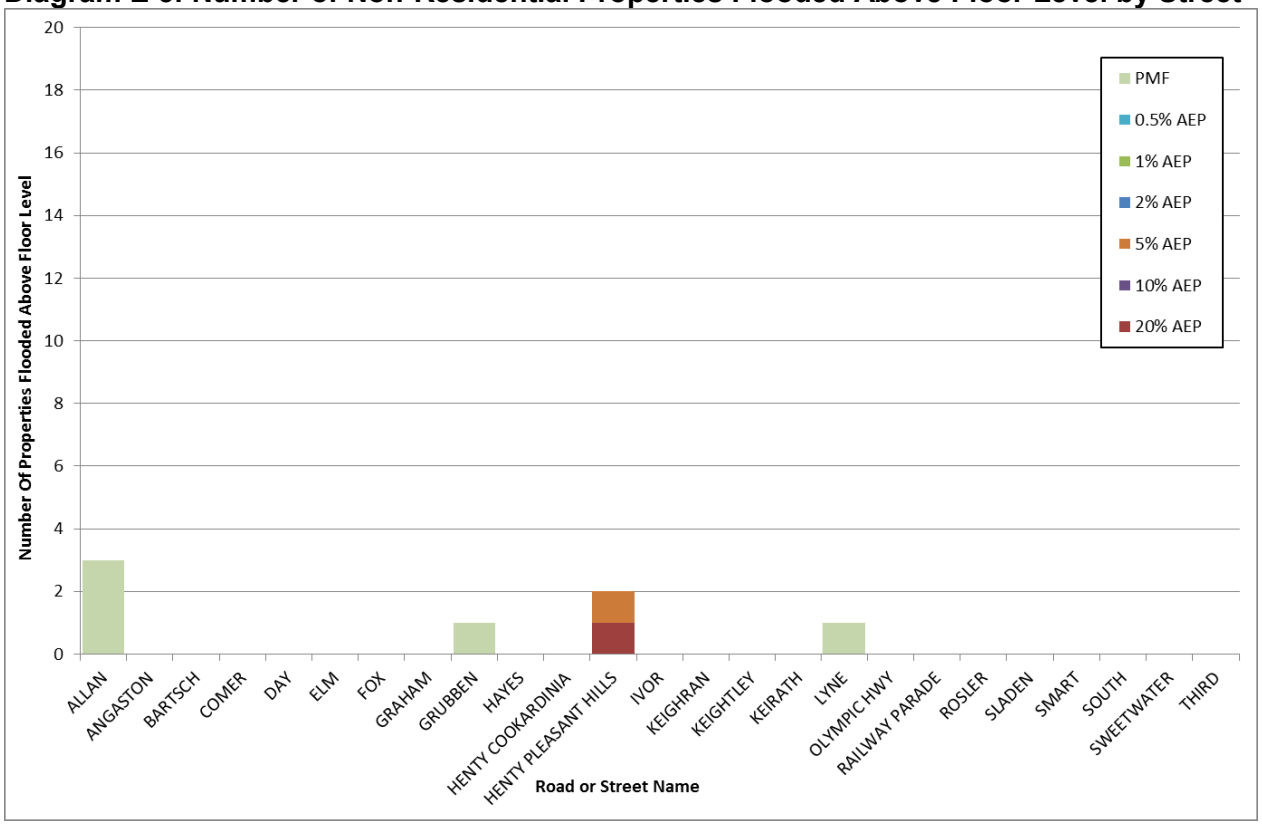


Diagram E 5: Number of Non-Residential Properties Flooded Above Floor Level by Street



E.3. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (Diagram E 1). Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees etc.

Given the variability of flooding and property and content values, the total likely damages figure in any given flood event is useful to get a feel for the magnitude of the flood problem, however it is of little value for absolute economic evaluation. However, considering damages estimates is useful when studying the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision making process.

E.4. Expressing Flood Damages

Average Annual Damages (AAD) is equal to the damage caused by all floods over a period of time divided by the number of years in that period and represents the equivalent average damages that would be experienced by the community on an annual basis. This means that the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods total potential damage refers to the total damage estimated for a given flood event. Average

damage per property is the Total damage estimated for a particular flood event divided by the number of properties flood affected in this event; either by flooding on the yard and/or above floor level of a building.

E.5. Calculating Tangible Flood Damages

The flood damages assessment was undertaken for existing development in accordance with current OEH guidelines (Reference 17) and the Floodplain Development Manual (Reference 1). Potential flood damages were calculated with the use of height-damage curves which relate the depth of water above the floor with tangible damages. The height-damage curves were established in accordance with OEH guidelines (Reference 17).

For residential damages the values used are based on the recommendations in the guidance with a post 2001 adjustment factor applied to increase damage values according to changes in Average Weekly Earnings (AWE) since 2001. Separate curves were established for non-residential damages. The resultant curves are shown in Diagram E 6 and F 7.

Structural damages vary on whether the property is slab/low set or high set. For the purpose of this study, any property with a floor level of 0.5 m or more above ground level was assumed to be high set.

In calculating AAD, it was assumed that there would be no flood damages in events smaller than the 2-year ARI event. The ARI of the PMF has been estimated to be 100,000 years.

As it is usual that commercial and industrial damages are higher than residential damages a multiplier was applied to the total damage per property for each event by adjusting the typical building size value within the curve development calculations. Other factors including the clean-up costs and external damages were adjusted to reflect the differences between commercial and residential properties.

To adjust the residential damage curve to be applicable to non-residential development, the average contents damages for a business was estimated to be $150,000 and the clean-up cost have been estimated at $4,000. This was done to take account the higher costs that businesses would incur compared to residential dwellings when flooded above floor level. The commercial damages curves were also amended to reduce the bench height based on the assumption that many commercial premises would have stock from floor level. External damage was set at $1,250 as per residential properties.

The parameters mentioned above have been kept consistent with the recently completed Lockhart and The Rock FRMS&P (Reference 18).

Diagram E 6: Flood Damages Curves – Residential Property

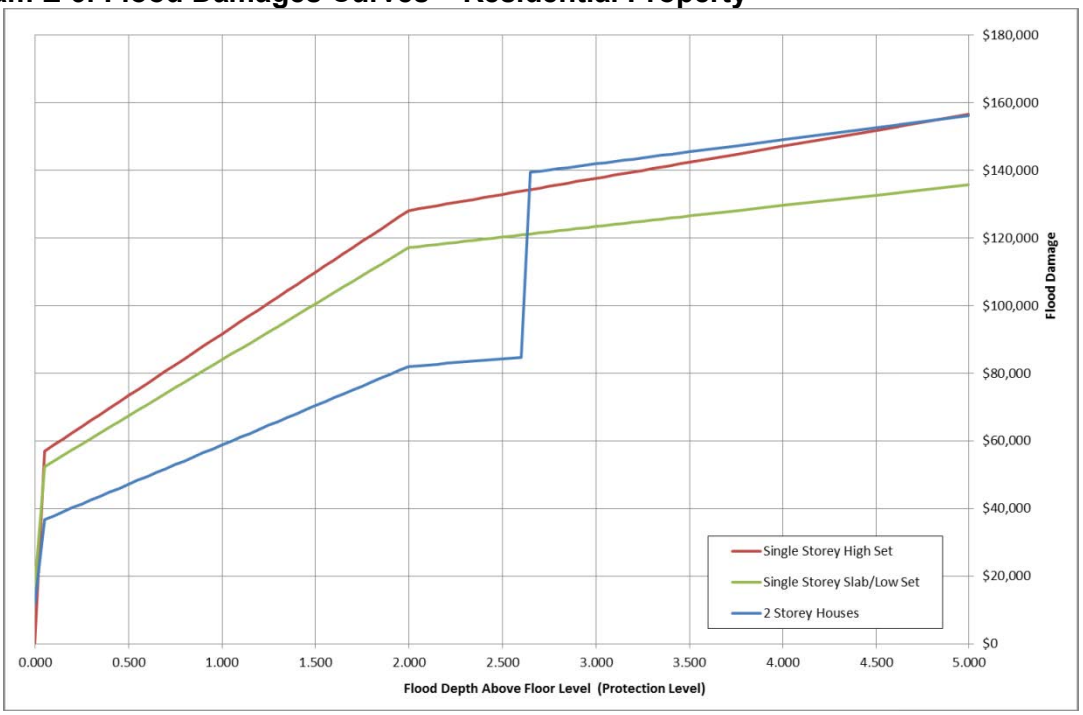
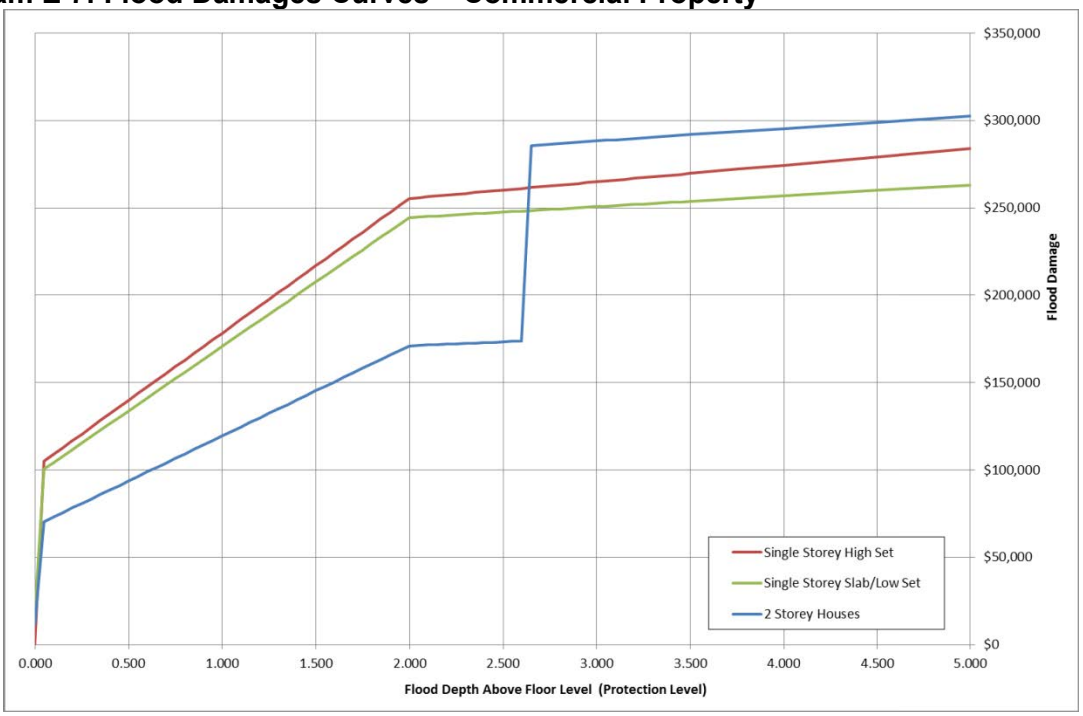


Diagram E 7: Flood Damages Curves – Commercial Property



The OEH guidelines suggest a protection level be applied when calculating damages. This effectively reduces the floor level by the given amount (usually 0.5 m). The level of protection is considered overly conservative and has not been applied in this instance. Applying a level of protection of 0.5 m at Henty would increase AAD by 1700% and the number of properties flooded above floor level in the 5-year ARI event from 3 to 133. Incorporating this would lead to Council financing flood management measures that provide little benefit.

E.6. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed above, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury, loss of sentimental items etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. However, it is still important that the consideration of intangible damages is included when considering the impacts of flooding on a community.

Post flood damages surveys have linked flooding to stress, ill-health and trauma for the residents. For example the loss of memorabilia, pets, insurance papers and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition flooding may affect personal relationships and lead to stress in domestic and work situations. In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage. The extent of the stress depends on the individual and although the majority of flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

During any flood event there is the potential for injury as well as loss of life due to causes such as drowning, floating debris or illness from polluted water. Generally, the higher the flood velocities and depths the higher the risk. Henty study area generally is classified as low hazard within the built up areas. However, there will always be local high risk (high hazard) areas where flows may be concentrated around buildings or other structures within low hazard areas.

E.7. Benefit/Cost Analyses for Management Options

To assess the full monetary benefits, including taking into account costs of construction and maintenance, Net Present Value (NPV) calculations were used and the B/C ratio established. The B/C approach is used to quantify the economic worth of each option enabling the ranking against other options. A B/C ratio is the benefits expressed in monetary terms, i.e. the reduction in AAD, compared to the actual likely cost of achieving those benefits, i.e. construction and maintenance costs.

The AAD per annum in today's monetary terms was assumed to apply for each year of the NPV damage calculation and was established for each year based on a discount rate of 7% as per the recommendation in the Residential Flood Damages FRM Guidelines (Reference 17). A construction cost was estimated and, using the NPV of the AAD assuming lifetime of 50-years, the B/C ratio was established for each of the options.

Appendix F

F. Appendix F: Draft Flood Management Development Control Plans & Policy

This draft Flood Management Policy has been prepared based on the findings of the Greater Hume Flood Study and Floodplain Risk Management Study. It is recommended that Council use this draft policy in conjunction with the relevant legislation to produce a DCP that achieve Council's aims.

GREATER HUME LGA
DRAFT DEVELOPMENT CONTROL POLICY
FOR FLOOD PRONE AREAS

Flood Management

A flood is an overflow or accumulation of an expanse of water that submerges land. Floods are a natural and inevitable event that communities must learn to live with while minimising risks to public health and safety, property and infrastructure.

This section recognises that there are some flooding risks that require development controls and guidelines in order to reduce or eliminate their impacts.

Objectives

1. To maintain the existing flood regime and flow conveyance capacity.
2. To enable the safe occupation of, and evacuation from, land to which flood management controls apply.
3. To avoid significant adverse impacts upon flood behaviour.
4. To avoid significant adverse effects on the environment that would cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of the river bank/watercourse.
5. To limit uses to those compatible with flow conveyance function and flood hazard.

Controls

General

1. For proposed development, consideration must be given to such matters as the likely depth and nature of possible floodwaters, flood classification of the area (where applicable) and the risk posed to the development by floodwaters.
2. The applicant must demonstrate:
    i) That the development will not increase the flood hazard or risk to other properties and that details have been provided of the structural adequacy of any buildings works associated with the development with regard to the effects of possible floodwaters;
    ii) That the proposed building materials are suitable;
    iii) That the development is sited in the optimum position to avoid floodwaters and allow evacuation; and
    iv) That all electrical services associated with the development are adequately flood proofed.

3. All applications for development must be accompanied by a survey plan including relevant levels to AHD (Australian Height Datum). Consideration must be given to whether structures or filling are likely to affect flood behaviour and whether consultation with other authorities is necessary.
4. Compliance with flood management controls must be balanced by the need to comply with other controls in this DCP.

Controls for land uses on flood prone land identified on the DCP Flood Map

1. A site emergency response flood plan must be prepared in case of a PMF flood.
2. Adequate flood warning systems, signage and exits must be available to allow safe and orderly evacuation without increased reliance upon the State Emergency Service (SES) or other authorised emergency services personnel.
3. Reliable access for pedestrians or vehicles must be provided from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF

SCHEDULE 1 – Flood compatible materials

Building component	Flood compatible material
Flooring and sub-floor	• Concrete slab on-ground monolith
	• Suspended reinforced concrete slab
Floor covering	• clay tiles
	• concrete, precast or in situ
	• concrete tiles
	• epoxy, formed-in-place
	• mastic flooring, formed-in-place
	• rubber sheets or tiles with chemicals-set-adhesive
	• silicone floors formed-in-place
	• vinyl sheets or tiles with chemical-set adhesive
	• ceramic tiles, fixed with mortar or chemical-set adhesive
	• asphalt tiles, fixed with water resistant adhesive
Wall structure	• solid brickwork, blockwork, reinforced, concrete or mass concrete
Roofing structure (for situations where the relevant flood level is above the ceiling)	• reinforced concrete construction • galvanised metal construction
Doors	• solid panel with water proof adhesives
	• flush door with marine ply filled with closed cell foam
	• painted metal construction
	• aluminium or galvanised steel frame
Wall and ceiling linings	• fibro-cement board
	• brick, face or glazed
	• clay tile glazed in waterproof mortar
	• concrete
	• concrete block
	• steel with waterproof applications

SCHEDUAL 1: FLOOD compatible materials (cont.)

Wall and ceiling linings (cont.)	• stone, natural solid or veneer, waterproof grout
	• glass blocks
	• glass
	• plastic sheeting or wall with waterproof adhesive
Insulation windows	• foam (closed cell types)
	• aluminium frame with stainless steel rollers or similar corrosion and water resistant material
Nails, bolts, hinges and fittings	• brass, nylon or stainless steel
	• removable pin hinges
	• hot dipped galvanised steel wire nails or similar

Electrical and mechanical equipment
For dwellings constructed on land to which this DCP applies, the electrical and mechanical materials, equipment and installation must conform to the following requirements:

Main power supply
Subject to the approval of the relevant authority the incoming main commercial power service equipment, including all metering equipment, must be located above the relevant flood level. Means must be available to easily disconnect the dwelling from the main power supply.

Wiring
All wiring, power outlets, switches, must be to the maximum extent possible, located above the maximum flood level. All electrical wiring installed below this level must be suitable for continuous underwater immersion and must contain no fibrous components. Each leakage circuit-breaker (core balance relays) must be installed. Only submersible type splices must be used below maximum flood level. All conduits located below the relevant designated flood level must be so installed that they will be self-draining if subjected to flooding.

Equipment
All equipment installed below or partially below the relevant flood level must be capable of disconnection by a single plug and socket assembly.

Reconnection
Should any electrical device and/or part of the wiring be flooded it must be thoroughly cleaned or replaced and checked by an approved electrical contractor before reconnection.

Heating and air conditioning systems
Where viable, heating and air conditioning systems should be installed in areas and spaces of the house above maximum flood level. When this is not feasible, every precaution must be taken to minimise the damage caused by submersion according to the following guidelines:

Fuel
Heating systems using gas or oil as fuel must have a manually operated valve located in the fuel supply line to enable fuel cut-off.

Installation
Heating equipment and fuel storage tanks must be mounted on and securely anchored to a foundation pad of sufficient mass to overcome buoyancy and prevent movement that could damage the fuel supply line. All storage tanks must be vented to an elevation of 600 millimetres above the relevant flood level.

Ducting
All ductwork located below the relevant flood level must be provided with openings for drainage and cleaning. Self-draining may be achieved by constructing the ductwork on a suitable grade. Where ductwork must pass through a water-tight wall or floor below the relevant flood level, a closure assemble operated from above relevant flood level must protect the ductwork

Appendix G

FIGURE G1
SUMMARY OF OPTIONS INVESTIGATED

OPTION C3
GRAIN SILOS AND
CANOLA SHEDS CHANNEL

OPTION C2
CHANNEL TO CARRY FLOW
BETWEEN GRUBBEN ROAD
AND ANGASTON ROAD

OPTION C4
CHANNEL ACROSS GRUBEN ROAD
TO MEET EXISTING DRAINAGE CHANNEL

OPTION A3
INCREASING CULVERT CONVEYANCE
700M NORTH OF BUCKARGINGAH CREEK

OPTION L4/C3
ANGASTON ROAD LEVEE

OPTION C4
LEVEES ACROSS GRUBEN ROAD
TO MEET EXISTING DRAINAGE CHANNEL

OPTION L5
EAST HENTY LEVEE

OPTION L3
GRUBBEN ROAD LEVEE

OPTION L1
WEST SHOWGROUND ROAD LEVEE

OPTION C1
CHANNEL BETWEEN OLYMPIC HIGHWAY
AND RAILWAY EMBANKMENT

OPTION A2/A4
INCREASING CULVERT CONVEYANCE 200M NORTH
OF BUCKARGINGAH CREEK

OPTION L1 L3 L5
COMBINED LEVEE SYSTEM

OPTION S1
TABLE DRAINS EITHER SIDE OF
HENTY PLEASANT HILLS RD

OPTION L2
EAST SHOWGROUNDS LEVEE

OPTION A1/A4
INCREASING BUCKARGINGAH CREEK BRIDGE
CROSSING CONVEYANCE

OPTION S2
BUCKARGINGAH CREEK
HENTRY GOVERNMENT DAM BYPASS

OPTION S4
STRAIGHTENING BUCKARGINGAH CREEK

Angaston Road
Henty Pleasant Hills Road
West Showground Road
Olympic Highway
Grubben Road
Railway Parade
Elm Street
Comer
Bartsch Avenue
Keighran Street
Smart Street
Fox Street
Graham Street
Sladen Street
Sladen Street East
Lyne Street
Comer Street
Allan Street
Keightley Street
Smith Street
First Avenue
Second Avenue

N

Levees
Drainage Channel
Creek Channel Modification
Bridges/Culvert Modifications

0 0.125 0.25 0.5 0.75 1 km

Green: Options recomended for further investigation
Red: Option not advised

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG1_Options_Summary.mxd

FIGURE G2
FLOOD IMPACT 1% AEP
OPTION L1
WEST SHOWGROUND ROAD LEVEE

Grubben Road
Olympic Highway
Angaston Road
Henty Pleasant Hills Road
West Showground Road
Bartsch Avenue
Fox Street
Smart Street
Sladen Street East
Smith Street
Comer Street
Allan Street
Ivor Street
Railway Parade
Second Avenue
Third Avenue
Rosler Parade
Yankee Crossing Road
Grubben Road
Angaston Road
West Showground Road
Grubben Road
Elm Street
Comer Street
Bartsch Avenue
Keighran Street
Smart Street
Smith Street
Sladen Street
Comer Street
Lyne Street
Allan Street

N

Levee
Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500
Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG02_Option_L1_West_Showground_Road_Levee.mxd

FIGURE G3
FLOOD IMPACT 1% AEP
OPTION L2
EAST SHOWGROUND LEVEE

N

- Roads
- Levee
- Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 100 200 400 600 800 Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG03_Option_L2_East_Showground_Levee.mxd

FIGURE G4
FLOOD IMPACT 1% AEP
OPTION L3
GRUBBEN ROAD LEVEE

Grubben Road
Orange Flat Lane
Olympic Highway
Angaston Road
West Showground Road
Henty Pleasant Hills Road
Elm Street
Smart Street
Bartsch Avenue
Railway Parade
Graham Street
Smith Street
Comer Street
Allan Street
Ivor Street
First Street

N

- Levee
- Roads
- Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500 Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG04_Option_L3_Grubben_Road_Levee.mxd

FIGURE G5
FLOOD IMPACT 1% AEP
OPTION L5
EAST HENTY LEVEE

N

Levee
Roads
Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500 2,000
Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG05_Option_L5_East_Henty_Levee.mxd

Kendalls Road
Olympic Highway
Grubben Road
Angaston Road
Henty Pleasant Hills Road
Bartsch Avenue
Railway Parade
Smart Street
Lyne Street
Smith Street
Comer Street
Allan Street
Ivor Street
Third Avenue
Orange Flat Lane
Henty Ryan Road
West Showground Road
Elm Street
Graham Street
Sladen Street East

FIGURE G5
FLOOD IMPACT 1% AEP
OPTION L1, L3 AND L5
HENTY COMBINED LEVEE SYSTEM

Kendalls Road
Olympic Highway
Grubben Road
Grubben Road
Olympic Highway
Angaston Road
Henty Pleasant Hills Road
Bartsch Avenue
Railway Parade
Smart Street
Lyne Street
Smith Street
Comer Street
Allan Street
Ivor Street
Third Avenue
Grubben Road
Olympic Highway
Olympic Highway
Grubben Road
Angaston Road
West Showground Road
Henty Pleasant Hills Road
Henty Pleasant Hills Road
Bartsch Avenue
Elm Street
Comer Street
Keighran Street
Smart Street
Smart Street
Smith Street
Comer Street
Sladen Street
Allan Street
Ivor Street
Railway Parade
Fox Street
Graham Street
Sladen Street East
Lyne Street
Smith Street
Comer Street
Allan Street
Ivor Street
Keightley Street
First Avenue
Second Avenue
Third Avenue

N

Levee
Roads
Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500
Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG06_Option_L1_L3_L5_Combined_Levee_System.mxd

FIGURE G7
FLOOD IMPACT 1% AEP
OPTION L1, L4, S1 AND C3
COMBINED LEVEE AND DRAIN SYSTEM

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG07_Option_L1_L4_S1_C3_Combined_Levee_and_Drainage_System.mxd

Kendalls Road
Olympic Highway
Grubben Road
Angaston Road
Henty Pleasant Hills Road
Bartsch Avenue
Railway Parade
Smart Street
Lyne Street
Smith Street
Comer Street
Allan Street
Ivor Street
Third Avenue
West Showground Road
Elm Street
Keighran Street

N

- Levee
- Drain
- Roads
- Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500 Meters

FIGURE G8
FLOOD IMPACT 1% AEP
OPTION L3, C2 AND C4
GRUBBEN ROAD COMBINED LEVEE AND DRAIN SYSTEM

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG08_Option_L3_C2_C4_Grubben_Road_Combined_Mitigation_Option.mxd

N

Levee
Drain
Roads
Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

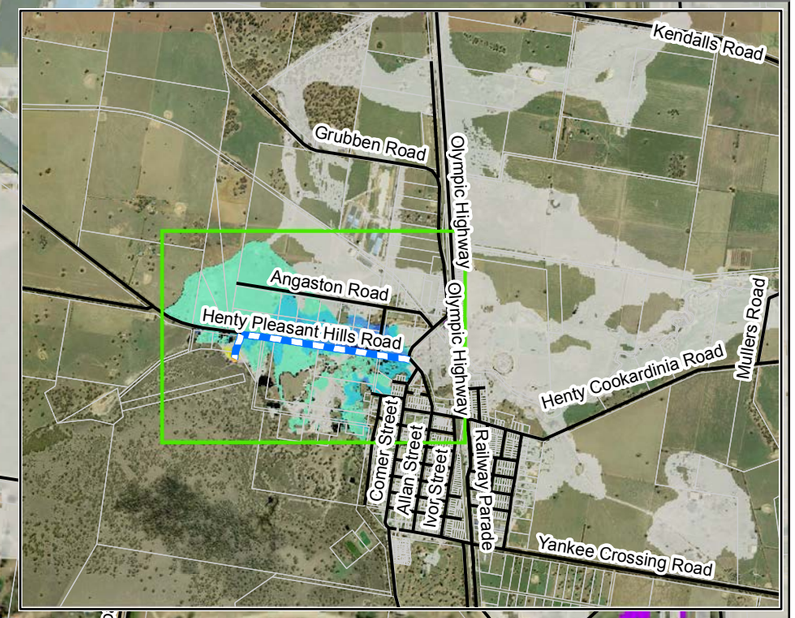
This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 100 200 400 600 800
Meters

Kendalls Road
Olympic Highway
Grubben Road
Grubben Road
Olympic Highway
Angaston Road
Henty Pleasant Hills Road
Bartsch Avenue
Railway Parade
Smart Street
Lyne Street
Smith Street
Comer Street
Allan Street
Ivor Street
Third Avenue
Angaston Road
Angaston Road
Grubben Road
Olympic Highway
West Showground Road
West Showground Road
Grubben Road
Olympic Highway
Henty Pleasant Hills Road
Henty Pleasant Hills Road
Bartsch Avenue
Comer Street

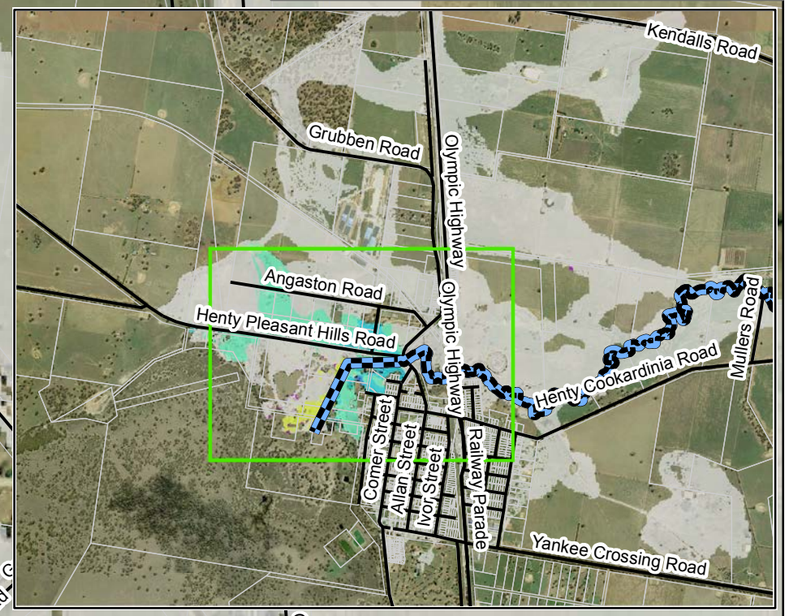
FIGURE G9

FLOOD IMPACT 1% AEP
OPTION S1
INCREASED PLEASANT HILLS ROAD DRAIN CAPACITY



J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG09_Option_S1_Increased_Pleasant_Hills_Drain_Capacity.mxd

FIGURE G10
FLOOD IMPACT 1% AEP
OPTION S4
STRAIGHTENING BUCKARGINGAH CREEK



Angaston Road
Angaston Road
Henty Pleasant Hills Road
Henty Pleasant Hills Road
West Showground Road
Grubben Road
Olympic Highway
Bartsch Avenue
Comer Street
Elm Street
Bartsch Avenue
Fox Street
Railway Parade
Keighran Street
Smart Street
Smart Street
Graham Street
Sladen Street
Comer Street
Allan Street
Ivor Street
Railway Parade
Sladen Street East
Lyne Street
Smith Street
Comer Street
Allan Street
Keightley Street
Ivor Street
First Avenue
Second Avenue
First Street
First Street

N

- Creek Alignment
- Roads
- Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500 Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Mitigation\FigureG10_Option_S4_Straightening_Buckargingah_Creek.mxd

FIGURE G11
FLOOD IMPACT 1% AEP
OPTION A1
INCREASED BUCKARGINGAH CREEK BRIDGE CAPACITY

Kendalls Road
Kendalls Road
Olympic Highway
Grubben Road
Grubben Road
Olympic Highway
Angaston Road
Henty Pleasant Hills Road
Bartsch Avenue
Henty Cookardinia Road
Smith Street
Corner Street
Allan Street
Ivor Street
Railway Parade
Third Avenue
Olympic Highway
Olympic Highway
West Showground Road
Grubben Road
Grubben Road
Henty Pleasant Hills Road
Henty Pleasant Hills Road
Bartsch Avenue
Corner Street
Elm Street
Bartsch Avenue
Smart Street
Smart Street
Corner Street
Keighran Street
Smith Street
Sladen Street
Allan Street
Railway Parade
Fox Street
Graham Street
Sladen Street East

N

- Increased Bridge Capacity
- Roads
- Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500 Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG11_Option_A1_Increased_Bridge_Capacity.mxd

FIGURE G12
FLOOD IMPACT 1% AEP
OPTION A2
INCREASED CULVERT CAPACITY 200 M NORTH OF BUCKARGINGAH CREEK

Kendalls Road
Grubben Road
Olympic Highway
Angaston Road
Henty Pleasant Hills Road
Barisch Avenue
Henty Cookardinia Road
Smith Street
Comer Street
Allan Street
Ivor Street
Railway Parade
Third Avenue
Flat Lane
West Showground Road
Keighran Street
Smart Street
Sladen Street
Fox Street
Graham Street

N

- Increased Culvert Capacity
- Roads
- Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

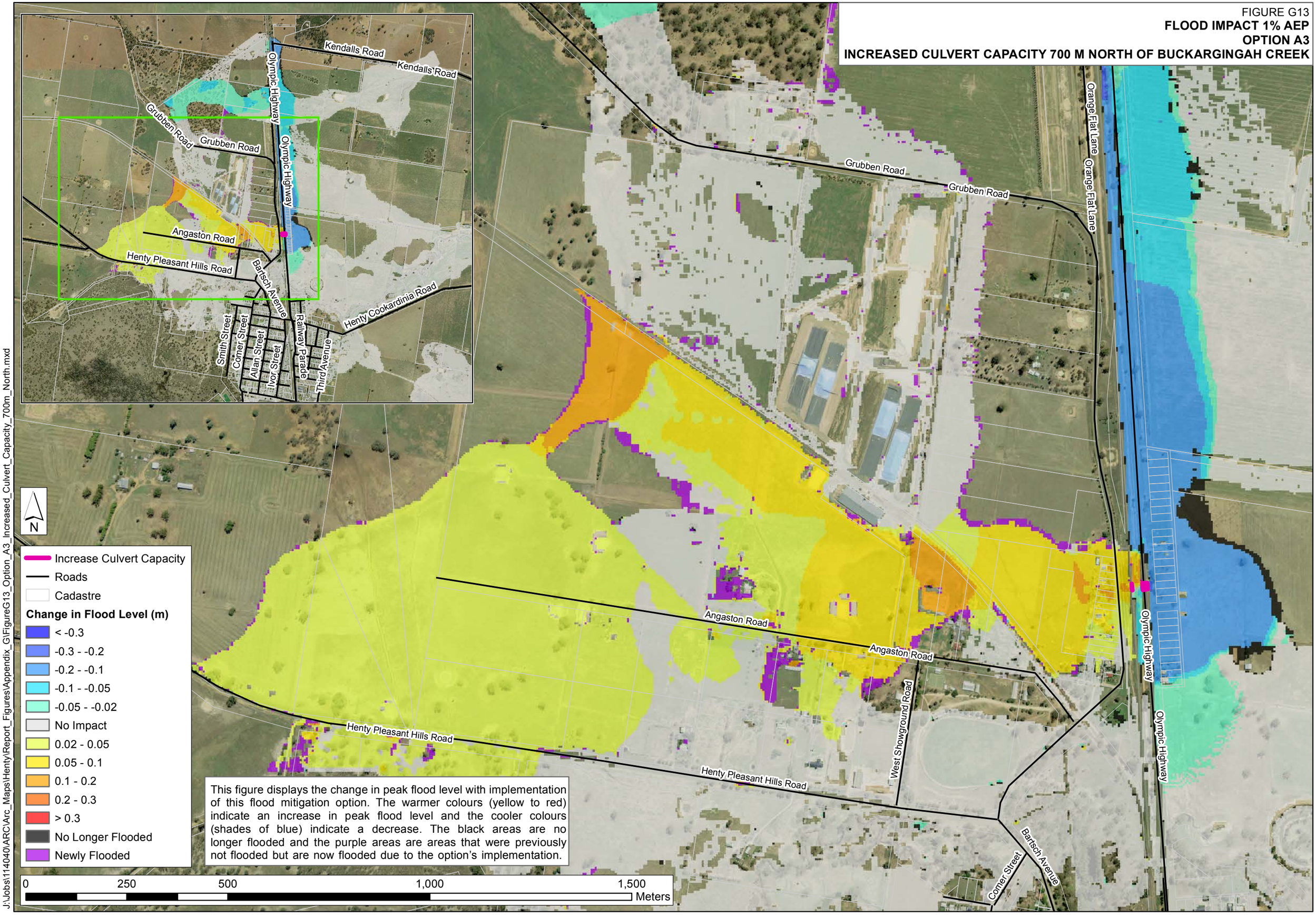
This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500
Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG12_Option_A2_Increased_Culvert_Capacity_200m_North.mxd

FIGURE G13

FLOOD IMPACT 1% AEP
OPTION A3
INCREASED CULVERT CAPACITY 700 M NORTH OF BUCKARGINGAH CREEK



This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG13_Option_A3_Increased_Culvert_Capacity_700m_North.mxd

FIGURE G14

FLOOD IMPACT 1% AEP

OPTION A4

COMBINED OPTIONS A1, A2 AND A3 - INCREASED STRUCTURE CONVEYANCE

Kendalls Road
Kendalls Road
Olympic Highway
Grubben Road
Grubben Road
Olympic Highway
Angaston Road
Henty Pleasant Hills Road
Barisch Avenue
Henty Cookardinia Road
Smith Street
Comer Street
Allan Street
Ivor Street
Railway Parade
Third Avenue
Grubben Road
Olympic Highway
Olympic Highway
Angaston Road
Angaston Road
Ryan Road
Henty Pleasant Hills Road
Henty Pleasant Hills Road
West Showground Road
Comer Street
Bartsch Avenue
Keighran Street
Smart Street
Smith Street
Comer Street
Sladen Street
Allan Street
Railway Parade
Fox Street
Graham Street
Sladen Street East

N

Increased Structure Conveyance
Roads
Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 250 500 1,000 1,500 Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_G\FigureG14_Option_A4_Combined_Option_Increased_Structure_Conveyance.mxd

FIGURE G15
FLOOD IMPACT 1% AEP
OPTION B1
PLEASANT HILLS ROAD PLAYING FIELDS BASIN

Grubben Road
Orange Flat Lane
Olympic Highway
Angaston Road
Henty Pleasant Hills Road
Bartsch Avenue
Smart Street
Railway Parade
Smith Street
Comer Street
Allan Street
Ivor Street
Second Avenue
West Showground Road
Elm Street

N

- Embankment
- Roads
- Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 50 100 200 300 400 500 Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Mitigation\FigureG15_Option_B1_Pleasant_Hills_Rd_Playing_Field_Basin.mxd

FIGURE G16
FLOOD IMPACT 1% AEP
OPTION B2
HENTY GOVERNMENT DAM BASIN

Grubben Road
Orange Flat Lane
Olympic Highway
Angaston Road
Henry Pleasant Hills Road
Bartsch Avenue
Smart Street
Railway Parade
Smith Street
Comer Street
Allan Street
Ivor Street
Second Avenue
West Showground
Elm Street
Keighran Street
Fox Street
Graham Street

N

- Embankment
- Roads
- Cadastre

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

This figure displays the change in peak flood level with implementation of this flood mitigation option. The warmer colours (yellow to red) indicate an increase in peak flood level and the cooler colours (shades of blue) indicate a decrease. The black areas are no longer flooded and the purple areas are areas that were previously not flooded but are now flooded due to the option's implementation.

0 100 200 400 600 800 Meters

J:\Jobs\114040\ARC\Arc_Maps\Henty\Mitigation\FigureG16_Option_B2_Government_Dam_Basin.mxd

Appendix H

H. Appendix H: Mitigation Option Details

This section outlines indicative costs for the investigated Henty Options and provides drawings to assist in detail design and investigation works.

These Options include:

- Option L1 – West Showground Road Levee (see Section 5.3.1.1);
- Option L1, L3 and L5 – Combined Levee System (see Section 5.3.1.6);
- Option L1, L4, S1 and C3 – Combined Levee and Drainage System (see Section 5.3.1.7); and
- Options L3, C2 and C4 – Grubben Road Combined Mitigation Option (see Section 5.3.3.5).

Note all costs are indicative and are not guaranteed. Cost will vary with contractor prices, market forces and other factors. Detailed design will enable more accurate costs to be prepared.

The combined Option L1, L3 and L5 is recommended for implementation at Henty as it provides a significant reduction in flood affected properties and has a good B/C ratio (see Section 5.3.1.5). The other above listed Options are not recommended for implementation at Henty.

Levee Freeboard Assumptions

Freeboard is incorporated into the final design height of the levee and is expressed as the incremental difference in height between the level of the flood the levee is designed to protect against, and the design crest level of the levee. Freeboard varies dependant on uncertainties in flood level estimates, wind and wave actions, storm surge, settlement, climate change etc. and therefore requirements can change significantly from levee to levee. Applying a standard freeboard allowance for a levee is considered simplistic, and in many instances, overly conservative (Reference 19).

Typical levee freeboards range from 0.5 m to 1 m in the region. For example the Main City Levee upgrade at Wagga Wagga will use a freeboard of 0.9 m (Reference 19). A full freeboard assessment is beyond the scope of the current study and will be undertaken as part of the detailed design. Accordingly, an estimated average freeboard allowance of 0.75 m has been assumed for all levees, however it is possible that the required levee allowance is significantly less than this.

For modelling of design events greater than the design height of the levee, the freeboard has been incorporated into the modelling with the assumption that the levee will not fail until the levee is overtopped.

Option L1

Preliminary concept design information for Option L1 is presented in Figure H 1. Features of this option include:

- 560 m embankment length;
- Typical embankment height of 1.45 m;
- Varying embankment level design level (see Figure H 1) with 0.75 m freeboard assumed;
- Embankment top width of 3 m;

- Embankment slopes at 1:4 ratio for both wet and dry sides; and
- Design for the 1% AEP flood level.

Easement Requirements

The levee utilises Council owned land such as road easements where possible, however acquisition of easements on private land will also be required. The total area of land that will require acquisition is estimated to be 6,300 m² assuming a 0.75 m freeboard, which allows for the foot print of the levee plus 1.5 meters from the toe of the levee. The estimated price of land in the region is $15 per/m² (source: realestate.com, March 2015).

Third Party Compensation

Increases in peak flood levels outside of the levee are less than 0.1 m in the vicinity of residential properties and are unlikely to adversely affect homes in this region. An investigation into floor level and flood affectation of properties outside of the levee indicates that increases of less than 0.1 m are expected due to construction of the Option L1 levee in both the 1% and 0.5% AEP events. Additionally, homes in this region will not be flooded over floor by either event with construction of this Option.

An estimate of $50,000 has been allowed for third party compensation for the property that is likely to experience an increase in flood levels proximate to their residence.

Option L1 Estimated Costing

A summary of the estimated costings for Option L1 is contained in Table H 1. All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers. It has been assumed that existing culverts will not be replaced, coffer dams and dewatering will not be required and that works will be undertaken during a dry period.

Table H 1: Option L1 Estimated Costing

Option L1

Levee Design – Option L1

Foundation Preparation	**UNIT**	**QUANTITY**	**2014 RATE RURAL NSW**	**COST (with factors)**
remove top soil and vegetation	m³	838	5	$ 4,190
compact foundation	m²	8,376	3	$ 25,128
excavate foundation channel (core - assumed 10% of total)	m³	568	8	$ 4,544
lime stabilisation (core - assumed 10% of total)	m³	568	15	$ 8,520
Embankment Construction				
Material	m³	5,684	8	$ 45,472
shaping of batter slopes	m²	8,376	2.5	$ 20,940
Compaction	m²	8,376	2.5	$ 20,940

Allowance to dispose of unsuitable material (10%)	m^3	568	8	$ 4,544

Finishes				
top soil placement	m^2	8,376	8	$ 67,008
seeding	m^2	8,376	7	$ 58,632

Construction Cost	**$ 259,918**

Easement and Adjoining Property Costs				
Easement Requirements (360 m x 10 m, along Pleasant Hills Rd only)	m^2	3,600	15	$ 94,500
Third party impact compensation	Total $	1		$ 20,000

TOTAL PROJECT ESTIMATE	**$ 526,000**	
TOTAL PROJECT ESTIMATE	**$ 556,210**	*a+b+c+d+e*
Construction Cost (a)	**$ 259,918**	
Contingency (b)	**$ 51,984**	*20% of a*
Design (c)	**$ 31,190**	*10% of a+b*
Construction Management (d)	**$ 37,428**	*12% of a+b*
Project Management (e)	**$ 31,190**	*10% of a+b*

**All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers.*

Combined Options L1, L3 and L5

Preliminary concept design information for the combined Option L1, L3 and L5 are presented in Figure H 2. Features of this option include:

- Option L1 has 560 m embankment length;
- Typical Option L1 embankment height of 1.2 m;
- Option L3 has 180 m embankment length;
- Typical Option L3 embankment height of 0.6 m;
- Option L5 has 600 m embankment length;
- Typical Option L5 embankment height of 1.0 m;
- Varying embankment level design level (see Figure H 2) with 0.5 m freeboard assumed;
- Embankment top width of 3 m for all levees;
- Embankment slopes at 1:4 ratio for both wet and dry sides for all levees; and
- Design for the 1% AEP flood level.

Freeboard Magnitude and Impact on Project Cost Estimates

The assigned levee freeboard will impact on the cost of construction of a levee. An increase in freeboard will not only affect the height of a levee but also the levee volume. In addition to this the levee width is also affected which impacts on easement purchase requirements. The larger the freeboard the greater the cost of the levee.

An estimate of the impact that assigned freeboard has on the cost of the Combined Option L1, L3 and L5 is presented in Table H 2. Increasing and decreasing the freeboard varies the B/C ratio significantly.

Table H 2: Estimated Cost of Construction for Option L1, L3, L5 with Various Freeboards

Scenario	Freeboard (m)	Crest Width (m)	Estimated Cost	B/C Ratio
A	0.5	3	$ 848,000	1.1
B	0.75	3	$ 1,110,000	0.9
C	1.0	3	$ 1,434,000	0.7

The cost of a levee with a freeboard of 0.5 m is estimated (see Scenario A, Table H 2) to have a B/C ratio of 1.1 which indicates that the levee would be of financial benefit. Utilising a larger freeboard decreases the freeboard, with a 0.75 m freeboard (see Scenario B, Table H 2) having a B/C ratio of 0.9 which indicates that the project does not provide financial benefit, however this does not take into account the intangible benefit of providing a significant reduction in risk to life.

Easement Requirements

The levees utilise Council owned land such as road easements where possible (Option L3), however acquisition of easements on private land will also be required. The total area of land that will require acquisition for each levee is presented below:

- Option L1 - 6,300 m²
- Option L5 - 9,600 m²

The area requirement for both easements was determined assuming a 0.75 m freeboard, which allows for the foot print of the levee plus 1.5 meters from the toe of the levee. The estimated price of land in the region is $15 per/m² (source: realestate.com, March 2015).

Third Party Compensation

Increases in peak flood levels outside of the levee are less than 0.1 m in the vicinity of residential properties and are unlikely to adversely affect homes in this region. An investigation into floor level and flood affectation of properties outside of the levee indicates that increases of less than 0.1 m are expected due to construction of the Option L1 levee in both the 1% and 0.5% AEP events. Additionally, homes in this region will not be flooded over floor by either event with construction of this Option.

An estimate of $50,000 has been allowed for third party compensation for the property that is likely to experience an increase in flood levels proximate to their residence.

Option L1, L3 and L5 Estimated Costing

A summary of the estimated costings for the combined Options L1, L3 and L5 are contained in Table H 3. All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers. It has been assumed that existing culverts will not be replaced, coffer dams and dewatering will not be required and that works will be undertaken during a dry period.

A summary of the estimated costings for the combined Options L1, L3 and L5 are contained in Table H 3.

Table H 3: Combined Options L1, L3 and L5 Estimated Costing

Options L1, L3 and L5 Combined

Levee Design L1

Foundation Preparation	UNIT	QUANTITY	2014 RATE RURAL NSW	COST (with factors)
remove top soil and vegetation	m^3	838	5	$ 4,190
compact foundation	m^2	8,376	3	$ 25,128
excavate foundation channel (core - assumed 10% of total)	m^3	568	8	$ 4,544
lime stabilisation (core - assumed 10% of total)	m^3	568	15	$ 8,520
Embankment Construction				
Material	m^3	5,684	8	$ 45,472
shaping of batter slopes	m^2	8,376	2.5	$ 20,940
Compaction	m^2	8,376	2.5	$ 20,940
Allowance to dispose of unsuitable material (10%)	m^3	568	8	$ 4,544
Finishes				
top soil placement	m^2	8,376	8	$ 67,008
seeding	m^2	8,376	7	$ 58,632

Levee Design L3

Foundation Preparation	UNIT	QUANTITY	2014 RATE RURAL NSW	COST (with factors)
remove top soil and vegetation	m^3	118	5	$ 590
compact foundation	m^2	1,176	3	$ 3,528
excavate foundation channel (core - assumed 10% of total)	m^3	65	8	$ 520
lime stabilisation (core - assumed 10% of total)	m^3	65	15	$ 975
Embankment Construction				
Material	m^3	653	8	$ 5,224
shaping of batter slopes	m^2	1,201	2.5	$ 3,003
Compaction	m^2	1,201	2.5	$ 3,003
Allowance to dispose of unsuitable material (10%)	m^3	65	8	$ 520
Finishes				
top soil placement	m^2	1,201	8	$ 9,608
seeding	m^2	1,201	7	$ 8,407

Levee Design L5

Foundation Preparation	UNIT	QUANTITY	2014 RATE RURAL NSW	COST (with factors)
remove top soil and vegetation	m^3	780	5	$ 3,900
compact foundation	m^2	780	3	$ 2,340
excavate foundation channel (core - assumed 10% of total)	m^3	600	8	$ 4,800
lime stabilisation (core - assumed 10% of total)	m^3	600	15	$ 9,000
Embankment Construction				
Material	m^3	6,000	8	$ 48,000
shaping of batter slopes	m^2	7,980	2.5	$ 19,950
Compaction	m^2	7,980	2.5	$ 19,950
Allowance to dispose of unsuitable material (10%)	m^3	600	8	$ 4,800
Finishes				
top soil placement	m^2	7,984	8	$ 63,872
seeding	m^2	7,984	7	$ 55,888

Construction Cost	**$**	**527,795**

Option L1 - Easement and Adjoining Property Costs (f)*				
Easement Requirements (360 m x 17.6 m, along Pleasant Hills Rd only)	m²	6,300	15	$94,500
Third party impact compensation	Total $	1		$20,000

Option L5 - Easement and Adjoining Property Costs (f)*				
Easement Requirements (600 m x 16 m)	m²	9,600	15	$144,000
Third party impact compensation	Total $	3		$15,000

**All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers.*

TOTAL PROJECT ESTIMATE	**$ 1,110,000**	
TOTAL PROJECT ESTIMATE	$ 1,109,527	*a+b+c+d+e+f**
Construction Cost (a)	$ 527,795	
Contingency (b)	$ 105,559	*20% of a*
Design (c)	$ 63,335	*10% of a+b*
Construction Management (d)	$ 76,002	*12% of a+b*
Project Management (e)	$ 63,335	*10% of a+b*

Combined Options L3, C2 and C4

Preliminary concept design information for the combined Option L3, C2 and C4 are presented in Figure H 3. Features of this option include:

- Option L3 has 180 m embankment length;
- Typical Option L3 embankment height of 0.6 m;
- Varying embankment level design level (see Figure H 2) with 0.5 m freeboard assumed;
- Embankment top width of 3 m;
- Embankment slopes at 1:4 ratio for both wet and dry sides;
- Option C2 is a 12 m wide and 1 m deep drain, total conveyance area of 12 m² (see Figure H 2);
- Option C4 is a 12 m wide and 1.2 m deep drain, total conveyance area of 14.4 m² (see Figure H 2);
- Combined length of the Option C2 and C4 drains is 460 m;
- Contouring of Grubben Road to allow flow over road;
- Embankment top width of 3 m for all levees; and
- Design for the 1% AEP flood event levels and flows.

Easement Requirements

The Option L3 levee utilises Council owned land, however the drains require easements through private land. The total area of land that will require acquisition for both the drains is 8,600 m².

Option C2 and C4 Drain Details

The Option C2 and C4 drains are designed to convey the 1% AEP flood flow of 11 m³/s and has a typical trapezoidal cross section as that displayed in Figure H 3. The channel should be design such that it can be easily mowed as a well-kept grass channel has been assumed in cross section calculations. The Grubben Road crossing is required to be a causeway.

Option L3, C2 and C4 Estimated Costing

A summary of the estimated costings for the combined Options L3, C2 and C4 are contained in Table H 4. All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers. It has been assumed that existing culverts will not be replaced, coffer dams and dewatering will not be required and that works will be undertaken during a dry period.

A summary of the estimated costings for the combined Options L3, C2 and C4 are contained in Table H 4.

Table H 4: Combined Options L3, C2 and C4 Estimated Costing

Option L3, C2, C4 Combined

Levee Design – Option L3

Foundation Preparation	UNIT	QUANTITY	2014 RATE RURAL NSW	COST (with factors)
remove top soil and vegetation	m^3	118	5	$ 590
compact foundation	m^2	1,176	3	$ 3,528
excavate foundation channel (core - assumed 10% of total)	m^3	65	8	$ 520
lime stabilisation (core - assumed 10% of total)	m^3	65	15	$ 975
Embankment Construction				
Material	m^3	653	8	$ 5,224
shaping of batter slopes	m^2	1,201	2.5	$ 3,003
Compaction	m^2	1,201	2.5	$ 3,003
Allowance to dispose of unsuitable material (10%)	m^3	65	8	$ 520
Finishes				
top soil placement	m^2	1,201	8	$ 9,608
seeding	m^2	1,201	7	$ 8,407

Drain Design – Option C2 and C4

Foundation Preparation				
remove top soil and vegetation	m^3	480	5	$ 2,400
Excavation (removal of soil)	m^3	5,760	10	$ 57,600
Channel Shaping	m^2	4,800	4	$ 19,200
Finishes				
top soil placement	m^2	4,800	8	$ 38,400
seeding	m^2	4,800	7	$ 33,600
Pavement/Rail Reinstatement				
Road resurfacing	m^2	240	$ 55	$ 13,200
Grubben Road Traffic Control				
Traffic Control	weeks	0.5	1,450	$ 725

Construction Cost	**$ 200,502**

Easement Acquisition Cost – Option C4 (f)*				
Easement Requirements (430 m x 20 m)	m^2	8,600	15	$129,000

TOTAL PROJECT ESTIMATE	$ 446,600	
TOTAL PROJECT ESTIMATE	$ 446,595	*a+b+c+d+e+f**
Construction Cost (a)	$ 200,502	
Contingency (b)	$ 40,000	*20% of a*
Design (c)	$ 24,000	*10% of a+b*
Construction Management (d)	$ 29,000	*12% of a+b*
Project Management (e)	$ 24,000	*10% of a+b*

**All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers.*

Combined Options L1, L4, S1 and C3

Preliminary concept design information for the combined Option L1, L4, S1 and C3 are presented in Figure H 4. Features of this option include:

- Option L1 has 560 m embankment length;
- Typical Option L1 embankment height of 1.2 m;
- Option L4 has 560 m embankment length;
- Typical Option L4 embankment height of 1.2 m;
- Varying embankment level design level (see Figure H 2) with 0.5 m freeboard assumed;
- Embankment top width of 3 m;
- Embankment slopes at 1:4 ratio for both wet and dry sides;
- Option S1 is two 12 m wide and 1 m deep drains, total conveyance area of 24 m² (see Figure H 4);
- Option S1 length is 1400 m;
- Option C3 is a 12 m wide and 1 m deep drain, total conveyance area of 12 m² (see Figure H 2);
- Option C3 length is 600 m;
- Design for the 1% AEP flood event levels and flows.

A summary of the estimated costings for the combined Options L1, L4, S1 and C3 are contained in Table H 5.

Table H 5: Combined Options L3, C2 and C4 Estimated Costing

Option L1, L4, S1, C3 Combined

Levee Design - Option L1

Foundation Preparation	UNIT	QUANTITY	2014 RATE RURAL NSW	COST (with factors)
remove top soil and vegetation	m³	392	5	$ 1,960
compact foundation	m²	3,920	3	$ 11,760
excavate foundation channel (core - assumed 10% of total)	m³	224	8	$ 1,792
lime stabilisation (core - assumed 10% of total)	m³	224	15	$ 3,360
Embankment Construction				
Material	m³	2,240	8	$ 17,920
shaping of batter slopes	m²	3,920	2.5	$ 9,800
Compaction	m²	3,920	2.5	$ 9,800
Allowance to dispose of unsuitable material (10%)	m³	224	8	$ 1,792
Finishes				
top soil placement	m²	3,920	8	$ 31,360

seeding	m²	3,920	7	$ 27,440

Levee Design - Option L4

Foundation Preparation	**UNIT**	**QUANTITY**	**2014 RATE RURAL NSW**	**COST (with factors)**
remove top soil and vegetation	m³	253	5	$ 1,265
compact foundation	m²	2,530	3	$ 7,590
excavate foundation channel (core - assumed 10% of total)	m³	92	8	$ 736
lime stabilisation (core - assumed 10% of total)	m³	92	15	$ 1,380
Embankment Construction				
Material	m³	924	8	$ 7,392
shaping of batter slopes	m²	2,530	2.5	$ 6,325
Compaction	m²	2,530	2.5	$ 6,325
Allowance to dispose of unsuitable material (10%)	m³	92	8	$ 736
Finishes				
top soil placement	m²	2,530	8	$ 20,240
seeding	m²	2,530	7	$ 17,710

Drain Design - Option S1

Foundation Preparation				
remove top soil and vegetation	m³	1,199	5	$ 5,995
Excavation (removal of soil)	m³	8,829	10	$ 88,290
Channel Shaping	m²	11,990	4	$ 47,960
Finishes				
top soil placement	m²	11,990	8	$ 95,920
seeding	m²	11,990	7	$ 83,930

Drain Design – Option C3

Foundation Preparation				
remove top soil and vegetation	m³	1,300	5	$ 6,500
Excavation (removal of soil)	m³	10,500	10	$ 105,000
Channel Shaping	m²	13,000	4	$ 52,000
Finishes				
top soil placement	m²	13,000	8	$ 104,000
seeding	m²	13,000	7	$ 91,000

Construction Cost	$ 867,278

Option L1 - Easement and Adjoining Property Costs (f)*				
Easement Requirements (360 m x 10 m, along Pleasant Hills Rd only)	m^2	3,600	15	$ 54,000
Third party impact compensation	Total $	1		$ 50,000

TOTAL PROJECT ESTIMATE	**$ 1,374,000**	
TOTAL PROJECT ESTIMATE	$ 1,374,000	*a+b+c+d+e+f**
Construction Cost (a)	$ 867,000	
Contingency (b)	$ 173,000	*20% of a*
Design (c)	$ 104,000	*10% of a+b*
Construction Management (d)	$ 125,000	*12% of a+b*
Project Management (e)	$ 104,000	*10% of a+b*

**All costs are not guaranteed. Costs will vary with contractor's prices, market forces and competitive bids from tenderers.*

FIGURE H1
WEST SHOWGROUND ROAD LEVEE
OPTION L1
FLOOD IMPACT 1% AEP
OPTION DETAILS

Angaston Road
Henty Pleasant Hills Road
West Showground Road
Grubben Road
Olympic Highway
Corner Street
Elm Street
Bartsch Avenue
Fox Street
Smith Street
A
B
C
SECTION A

N

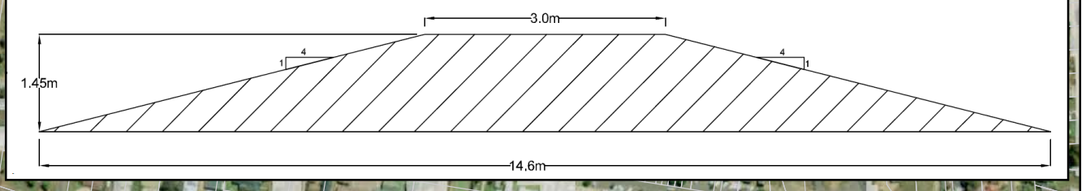
Option L1 Levee

Change in Flood Level (m)

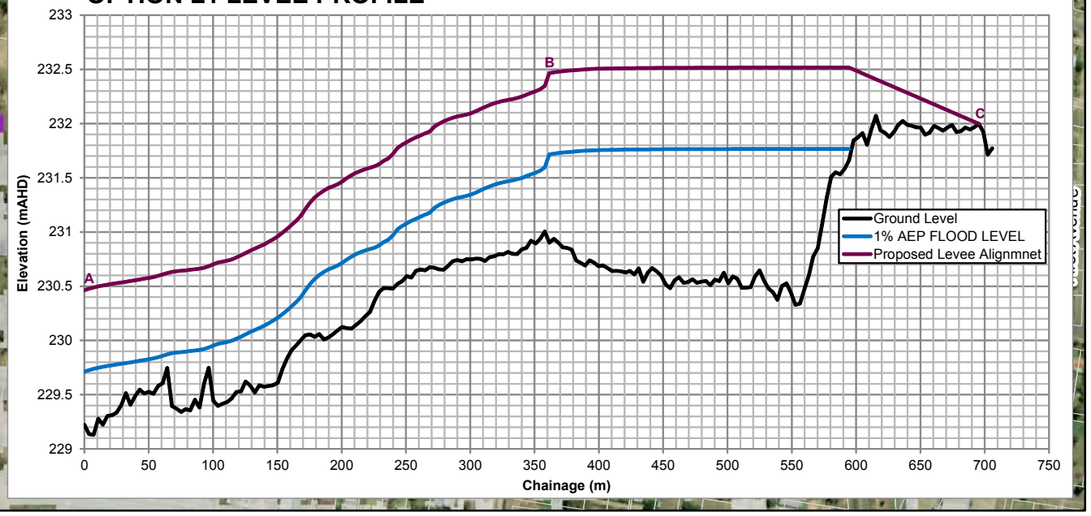
- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

0 0.125 0.25 0.5 0.75 1 km

SECTION A: TYPICAL LEVEE CROSS SECTION



OPTION L1 LEVEE PROFILE



J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_H\FigureH1_Option_L1.mxd

FIGURE H2
HENTY COMBINED LEVEE SYSTEM
COMBINED OPTIONS L1 L3 L5
FLOOD IMPACT 1% AEP
OPTION DETAILS

Angaston Road
Henty Pleasant Hills Road
West Showground Road
Grubben Road
Bartsch Avenue
Elm Street
Smart Street
Keighran Street
Sladen Street
Lyne Street
Keightley Street
Fox Street
Graham Street
Sladen Street East
First Avenue
Third Avenue
Second Street
Yan

A
B
C
D
E
F
G
SECTION A
SECTION B
SECTION C

N

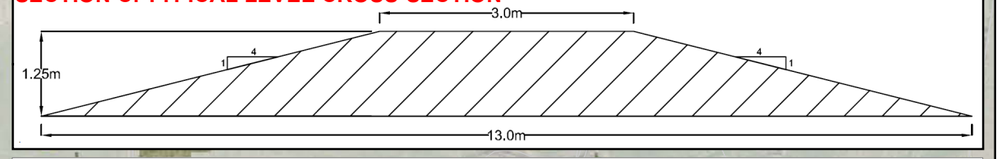
- Option L1 Levee
- Option L3 Levee
- Option L5 Levee

Change in Flood Level (m)

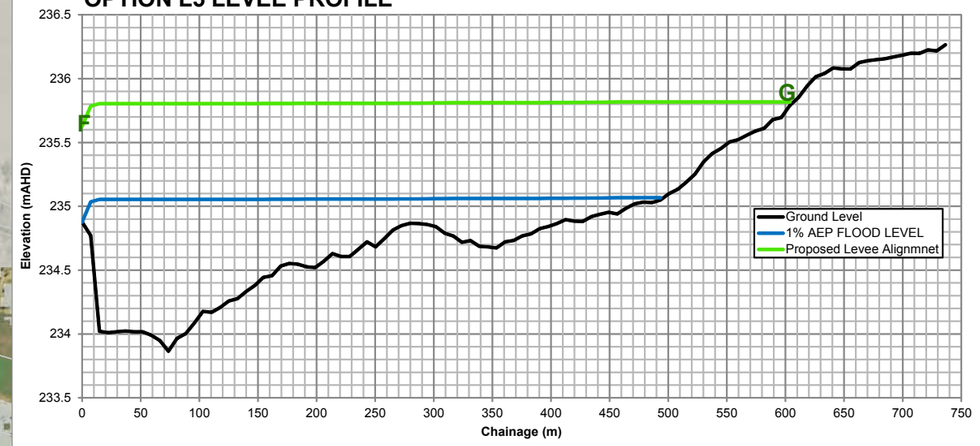
- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

0 250 500 1,000 1,500 2,000 Meters

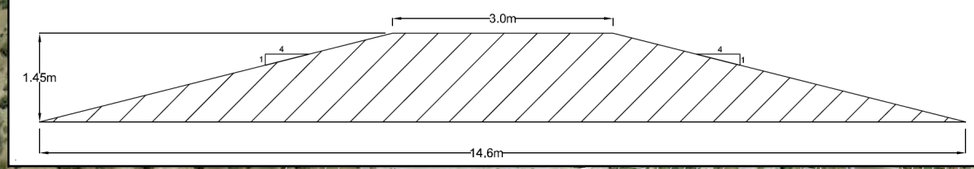
SECTION C: TYPICAL LEVEE CROSS-SECTION



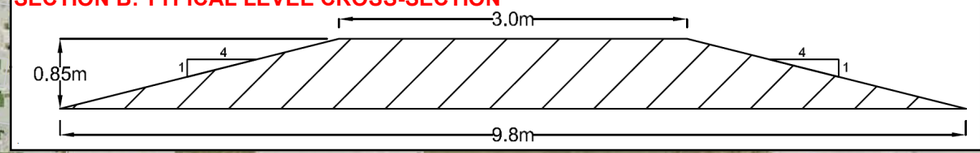
OPTION L5 LEVEE PROFILE



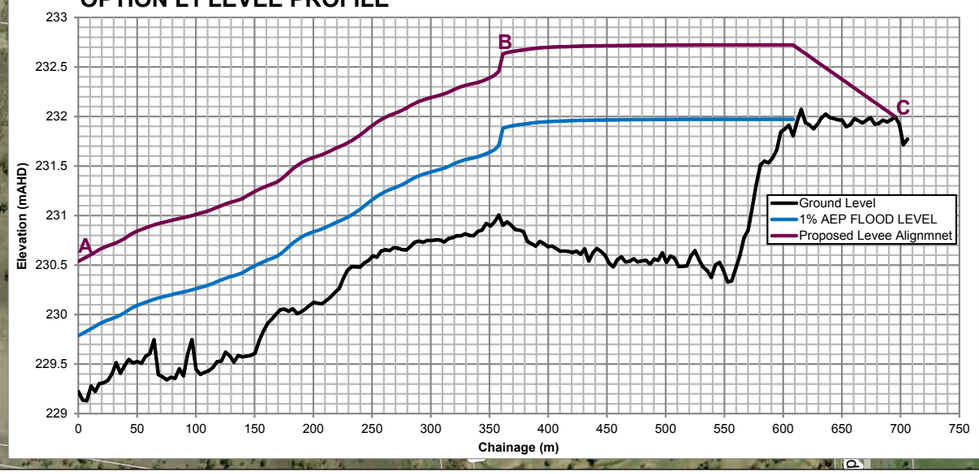
SECTION A: TYPICAL LEVEE CROSS-SECTION



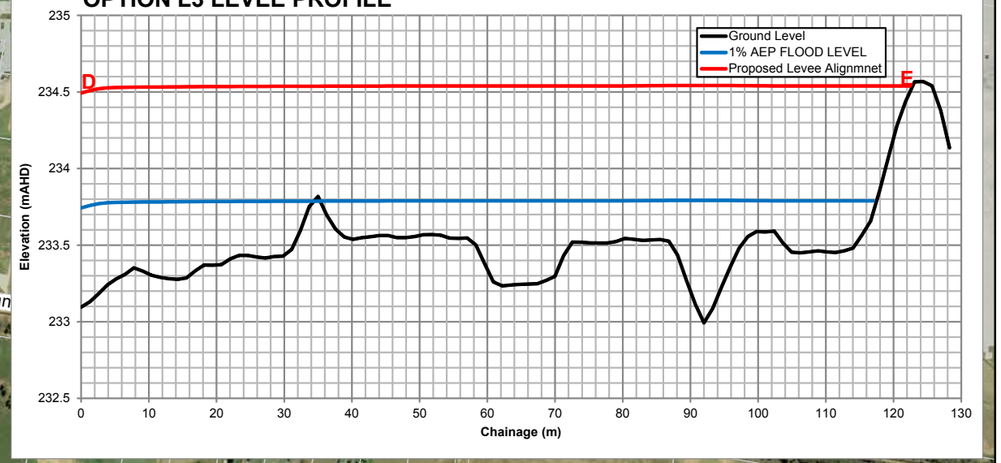
SECTION B: TYPICAL LEVEE CROSS-SECTION



OPTION L1 LEVEE PROFILE



OPTION L3 LEVEE PROFILE



J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_H\FigureH2_Combined_Option_L1_L3_L5.mxd

FIGURE H3

GRUBBEN ROAD COMBINED MITIGATION OPTION
COMBINED OPTIONS L3 C2 C4
FLOOD IMPACT 1% AEP
OPTION DETAILS

SECTION B

SECTION C

SECTION A

A

B

Angaston Road

Grubben Road

West Showground Road

Olympic Highway

Comer Street

Elm Street

Barisch Avenue

Keighran Street

N

Option C2 Drain

Option C4 Drain

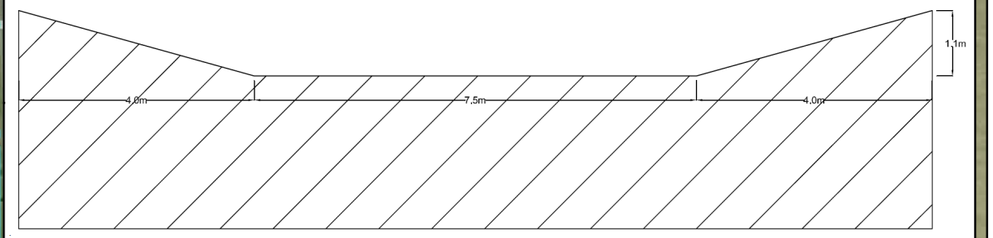
Option L3 Levee

Change in Flood Level (m)

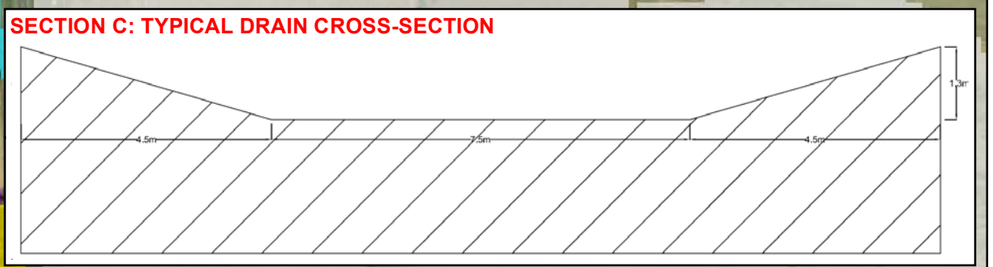
- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

0 50 100 200 300 400 m

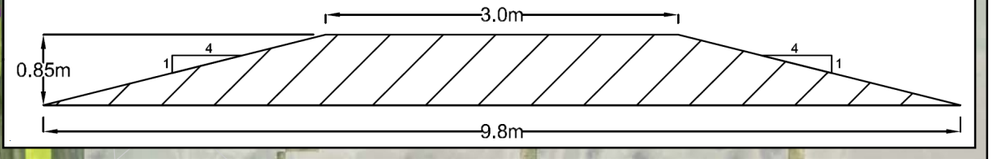
SECTION B: TYPICAL DRAIN CROSS-SECTION



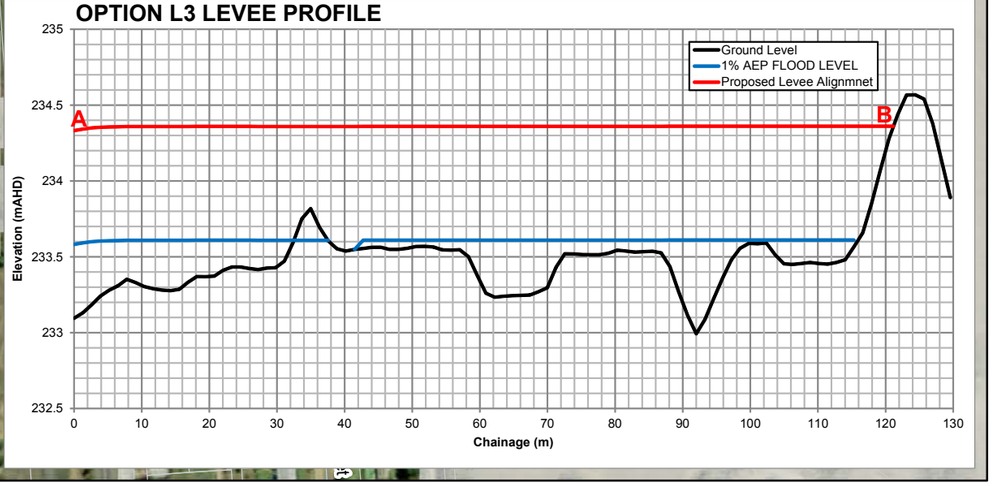
SECTION C: TYPICAL DRAIN CROSS-SECTION



SECTION A: TYPICAL LEVEE CROSS-SECTION



OPTION L3 LEVEE PROFILE

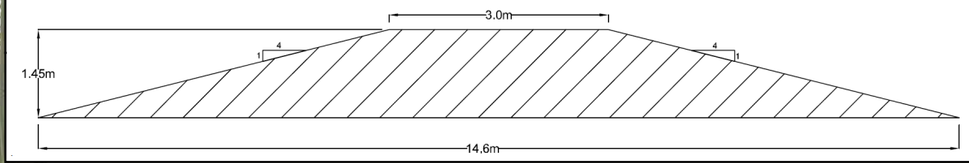


J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_H\FigureH3_Combined_Option_L3_C2_C4.mxd

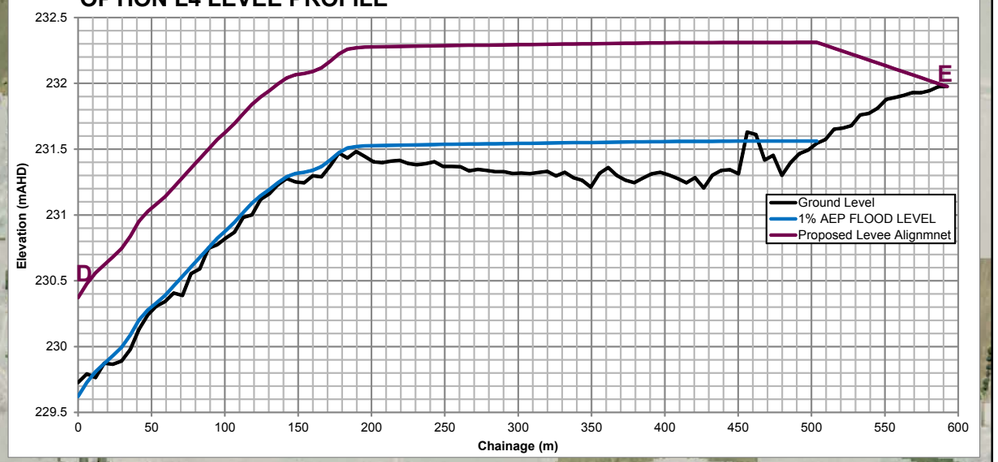
FIGURE H4

HENTY COMBINED LEVEE AND DRAINAGE SYSTEM
COMBINED OPTIONS L1 L4 S1 C3
FLOOD IMPACT 1% AEP
OPTION DETAILS

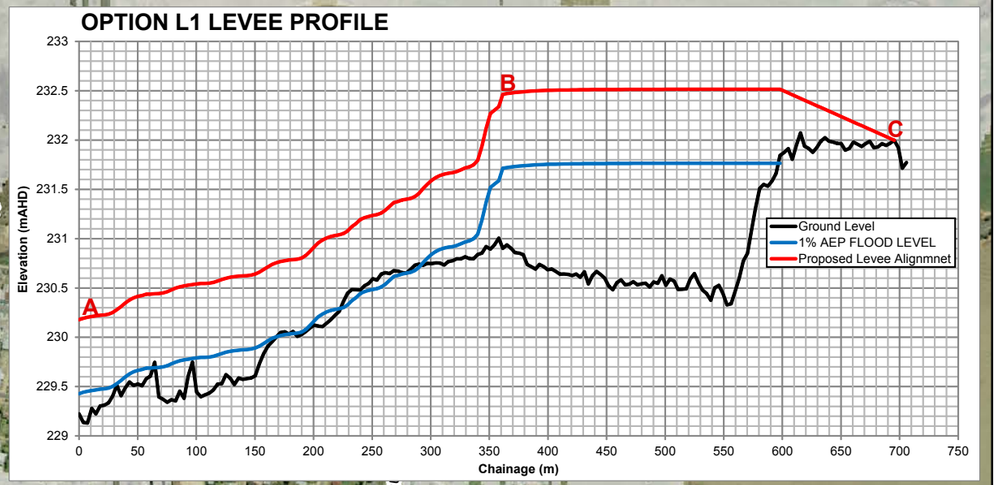
SECTION A: TYPICAL LEVEE CROSS-SECTION
SECTION B: TYPICAL LEVEE CROSS-SECTION



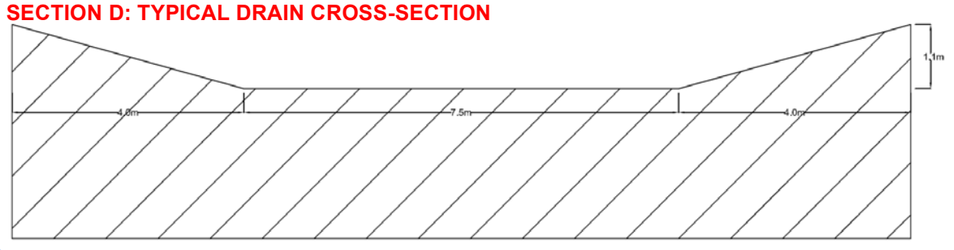
OPTION L4 LEVEE PROFILE

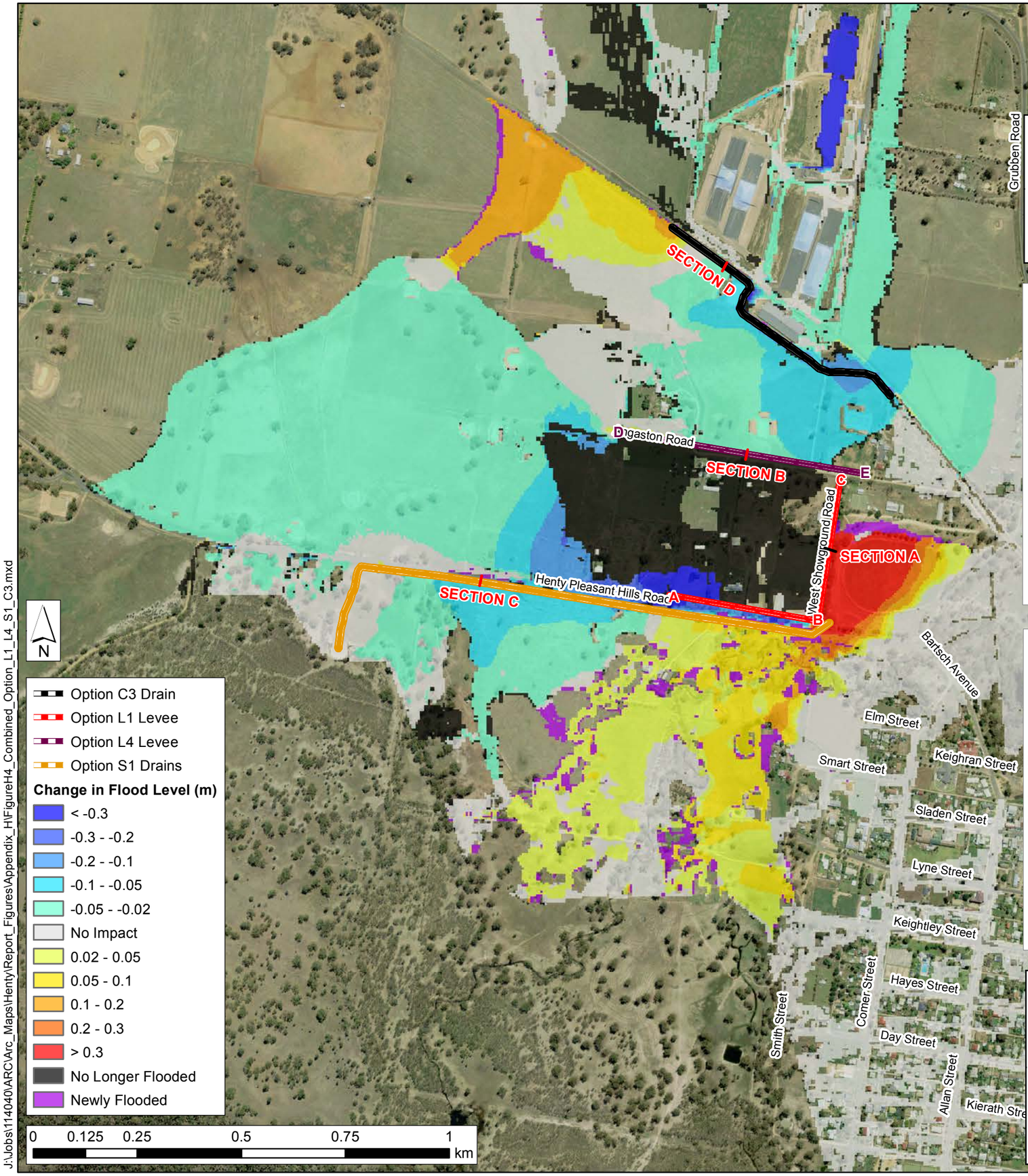


OPTION L1 LEVEE PROFILE



SECTION C: TYPICAL DRAIN CROSS-SECTION
SECTION D: TYPICAL DRAIN CROSS-SECTION





J:\Jobs\114040\ARC\Arc_Maps\Henty\Report_Figures\Appendix_H\FigureH4_Combined_Option_L1_L4_S1_C3.mxd