In Association with KPMG

NORTH BURNETT REGIONAL COUNCIL

Flood Mitigation Study

Report

January 2014

M28000_001

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M28000_001 FLOOD MITIGATION STUDY					
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REV	**DESCRIPTION**	**AUTHOR**	**REVIEWER**	**APPROVED BY**	**DATE**
Rev 0	Draft Issue to Client	Britta Jensen	Mark Page	George Khouri	December 2013
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Signatures					

EXECUTIVE SUMMARY

Introduction

Engeny in association with KPMG has been engaged by North Burnett Regional Council to identify potential flood mitigation measures to provide protection to flood affected communities within the North Burnett region. As such, a desktop assessment of the flood risks and flood damage costs of historical and theoretical events was conducted in order to determine the potential benefits associated with potential mitigation options.

The overall objective of the study was to utilise existing flood and economic information to identify the most economically viable and effective structural mechanisms to minimise the risk of flooding to urban and rural areas in the North Burnett region.

Consistent historical data shows that the North Burnett townships and their surrounds are prone to flooding from the Burnett, Auburn and Boyne Rivers in addition to numerous other creek systems and tributaries. The impacts of the 2010, 2011 and 2013 flood events have widely affected the community and have had many direct and consequential damages.

It should be noted that this study has relied heavily upon the extent and accuracy of data provided and no data validation has been undertaken. As a result, the accuracy of the findings of the study is limited by the extent and accuracy of the input data.

Existing Flood Information

This study has utilized a significant amount of existing data and previous studies to identify flood behavior in terms of frequency, magnitude, extent and damage.

Flood Frequency Analyses (FFA) were undertaken to estimate the return interval for the recorded major historical flood events for Monto, Mundubbera and Gayndah. Based on the stream flow data obtained from Department of Natural Resources and Mines (NRM), FFA were undertaken for a number of gauging stations with between 51 and 65 years of available data.

Mapping of the design flood events was conducted using existing data obtained from previous flood mapping studies undertaken within the North Burnett region. The studies included the Gayndah Flood Study (2008) as well as the indicative (high level) flood mapping undertaken by QldRA for Mundubbera and Monto using the Level 2 Flood Investigation. The extent of inundation for the 2013 event has been mapped by NBRC using surveyed flood debris marks within each town. **Figure's 4.4** to **4.6** present the flood mapping for the historical 2013 event and various design events for Monto, Mundubbera and Gayndah. It is noted that there is no flood mapping for rural areas available for the 2013 and design events.

Based on the existing flood mapping, for the purpose of this study it has been assumed that the 2013 event in Monto was approximately a 1 in 50 AEP flood, approximately a 1 in 180 AEP event in Mundubbera and between a 1 in 100 and 1 in 200 AEP flood in Gayndah. In the absence of any other flood information, the available flood mapping has been used in this study to estimate the flood damage costs as well as the potential benefits associated with mitigation options.

It should be noted that the existing flood mapping information (with the possible exception of the Gayndah 2008 study) was based on extremely broad scale estimations with no comprehensive modelling undertaken for the study area.

Description of Flooding

The township of **Monto** is surrounded by a large defined flood plain and is generally located on a hill, resulting in relatively good flood immunity for the majority of the township. The January 2013 flood event is the largest event on record and resulted in inundation of 11 houses and 3 businesses along Mill Street, however majority of flood damage occurred to surrounding agricultural infrastructure and crops. The 2013 event has an estimated return period of between 50 and 100 years, based on the FFA. The extent of inundation is illustrated in **Figure 2.1**.

The **Mundubbera** township has flooded on a number of occasions from the Burnett River which is situated to the east of the township. The recent 2010 and 2013 flood events caused inundation to a number of properties adjacent to Red Gully. Damage to residential property was substantial during both events, with the three main accommodation facilities impacted during the 2013 event. The January 2013 flood is the largest event on record, however it is considered that the unrecorded 1942 event resulted in a greater extent of inundation in some areas. It should be noted that the construction of the bridge since 1942 is likely to influence flood levels both upstream and downstream of the bridge. The 2013 event resulted in inundation of 72 houses and 11 businesses within Mundubbera and has an estimated return period of approximately 100 years, based on the FFA. The extent of inundation is illustrated in **Figure 2.4**.

The **Gayndah** township has also experienced flooding on a number of occasions, with the largest flood events recorded in February 1942 and January 2013. In both of these events floodwater broke over the Showground and formed an inland channel behind the business centre between Oaky Creek and Sauers Gully. The January 2013 flood event resulted in inundation of 73 houses and 28 businesses within Gayndah. The extent of inundation is illustrated in **Figure 2.5**. The 2013 event has an estimated return period of approximately 100 years, based on the FFA.

Although the 2013 floodwaters caused only minor impact to the smaller towns (Eidsvold and Abercorn) due to their location, many of the smaller towns and rural areas were impacted in terms of loss of communication, electricity and access. The 2013 event resulted in inundation, isolation and loss of power (resulting in loss of water) to intensive piggeries and dairies. Floodwaters are believed to have swept away herds of cattle and caused extensive damage to citrus orchards, infrastructure and other crops.

It is understood that approximately 79 rural properties were recorded as being impacted by over floor inundation, however it is acknowledged that there may be some properties unaccounted for. Information regarding the extent of damage to farms in terms of loss of infrastructure, income, livestock and crops is also relatively unknown.

Summary of Mitigation Assessment and Estimated Costs

A preliminary assessment of the overall effectiveness associated with each considered mitigation option and the estimated construction costs were undertaken. The preliminary assessment has largely been undertaken for the townships of Monto, Mundubbera and Gayndah.

The shortlisted flood mitigation measures that were considered to have some merit and required further evaluation in this study included:

- Raising of houses and businesses;
- Flood levee;
- Relocation of Houses and businesses; and
- Combination of the above.

A summary of flood impacts and potential benefits associated with the shortlisted options for the 2013 flood event are provided in the following tables:

Monto Flood Impact Summary for 2013 Event

Monto Flood Impact and Benefit of Options			Preliminary Cost Estimate
Flood Event	Houses Impacted	Businesses Impacted	
2013 Event	11	3	-
Levee Option	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	11	1	$2.3M
Relocation Option	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	11	3	$2.14M
Raising Option	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	10	0	$0.75M

Monto Flood Impact and Benefit of Options			Preliminary Cost Estimate
Combined Levee and Relocation Option	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	11	3	$2.8M

Mundubbera Flood Impact Summary for 2013 Event

Mundubbera Flood Impact and Benefit of Options			Preliminary Cost Estimate
Flood Event	Houses Impacted	Businesses Impacted	
2013 Event	72	11	-
Levee Option 2	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	61	8	$9.2M
Relocation Option	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	72	11	$14.4M
Raising Option	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	45	2	$3.5M
Combined Levee Option 2, Raising and Relocation Option	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	72	11	$10.3M

Gayndah Flood Impact Summary for 2013 Event

Gayndah Flood Impact and Benefit of Options			Preliminary Cost Estimate
Flood Event	Houses Impacted	Businesses Impacted	
2013 Event	73	28	-
Levee Option 1	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	19	5	$2.2M
Levee Option 2	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	7	3	$0.9M
Relocation Option	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	73	28	$19.5M
Raising Option	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	22	3	$1.9M
Combined Levee Option 2, Raising and Relocation Option	Houses Potentially Protected	Businesses Potentially Protected	
2013 Event	73	28	$15.2M

Cost Benefit Analysis

A preliminary cost benefit analysis (CBA) has been prepared for differing flood mitigation initiatives in the townships of Monto, Mundubbera and Gayndah. As a component of the CBA, damages to residential properties, commercial properties and Council infrastructure was calculated as a base case in the areas of inundation for which mitigation was considered. This analysis utilised the flood lines prepared to represent inundation during the January 2013 event. Under these base cases, damages in Monto, Mundubbera and Gayndah were estimated to be approximately $1 million, $10.8 million and $9.5 million respectively.

The findings in each town highlight that the lower the capital requirement associated with the mitigation measure, the higher the BCR. This reflects the low density of commercial

and residential property development in all three (3) townships, and the limited number of properties and infrastructure assets that a structural measure (i.e. a levee) can protect. Based on the cost benefit analysis, the most viable option for each town was:

- Monto: House and business raising for the 1 in 100 year design which produced a BCR of 1.21;
- Mundubbera: House and business raising for the 1 in 50 year design which produced a BCR of 1.14; and
- Gayndah: House and business raising for the 1 in 50 year design which produced a BCR of 1.18.

Recommendations

Key recommendations from this preliminary assessment of flood mitigation measures include:

- Re-evaluation of shortlisted flood protection measures including a detailed hydraulic analysis of the preferred mitigation options for Monto, Mundubbera and Gayndah. This would allow for a more detailed flood damage estimate for a range of flood events as well as a more comprehensive evaluation of mitigation options. It is recommended that new two-dimensional models be developed for Mundubbera and Monto and the existing TUFLOW model should be updated and refined to include the bridge for Gayndah.
- Hydrological analysis for the upper Burnett River catchment using an updated URBS model from BoM or the model developed for Bundaberg Regional Council. The model outputs will provide inflow hydrography's to the hydraulic models and can also be used for flood prediction purposes.
- Hydraulic analysis of the rural reaches to gain an understanding of the flood risks and allow for improved agricultural land use planning.
- Mapping of the 2013 flood extent for the rural reaches of the Burnett River and associated tributaries. Flood marks currently exist and therefore it is recommended that Council obtain survey of the marks to provide comprehensive mapping of the 2013 event throughout the region.
- More detailed economic analysis in order to refine the analysis of reduced damages that can be achieved through any mitigation measure.
- Develop a flood management plan for the region including a flood warning and emergency management strategy given that the most beneficial form of flood mitigation for the entire North Burnett region is likely to be from non-structural measures such as flood warning and emergency management as well as agricultural land use planning.

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1. INTRODUCTION AND BACKGROUND

1.1 Summary

The North Burnett Regional Council (NBRC) is committed to improving community protection from flooding and building resilience during future flood events. The Council was successful in obtaining funding for the North Burnett Flood Mitigation Study through the 2012-2013 Local Government Grants and Subsidies Program – Local Government Flood Response Subsidy. This funding has been provided to assist NBRC to prepare a business case for funding support from the state and federal governments to further evaluate and implement flood protection measures for flood affected communities.

The major North Burnett townships of Monto, Eidsvold, Mundubbera and Gayndah, and their surrounds are well known for their strong agricultural base and the region has a consistent history of flooding from the Burnett, Auburn and Boyne Rivers and numerous creek systems. The region has experience flood damage to varying magnitudes over the past three years from the 2010, 2011 and 2013 flood events. The 1942 and 2013 events are generally considered to be the largest events on record.

Engeny Water Management (Engeny) in association with KPMG has been engaged by NBRC to undertake a desktop assessment of the flood risks and flood damage costs of historical and theoretical events for the purpose of identifying potential flood mitigation measures to provide protection to flood affected communities within the North Burnett region.

1.2 Project Scope and Objectives

The overall objective of this study was to utilise existing flood and economic information to identify the most economically viable and effective structural mitigation options to minimise the risk of flooding to urban and rural areas in the North Burnett region. The scope of works included:

- Data compilation (collection, review and gap analysis);
- Site assessment (prioritisation of flood risk areas and extent of study areas);
- Consultation with the Project Steering Committee, stakeholders, and flood recovery groups;
- Prepare flood mapping for historical and design events based on available flood information;
- Flood frequency analysis for relevant stream flow gauging stations to determine the estimated recurrence interval of various historical events;
- Identification and prioritisation of high flood risk areas including urban and rural areas;

- Identification of potential flood mitigation options;
- Evaluation of shortlisted flood mitigation options;
- Cost-benefit assessment of shortlisted mitigation options; and
- Preparation of a study report outlining the scope of works, methodology, identification and assessment of mitigation options, cost benefit analysis, conclusion and recommendations.

A preliminary cost benefit analysis has been undertaken for the shortlisted flood protection measures in order to determine the viability of the identified measures; however it should be noted that the study is based on existing flood information and economic data that was available at the time of the project.

1.3 Background

The North Burnett townships and their surrounds are well known for their consistent history of flooding from the Burnett, Auburn and Boyne rivers including numerous local creeks and tributaries. Recent events have included five separate major floods of varying magnitudes over the last three years; however recorded significant floods in the Burnett River extend back to the middle of last century.

The impacts of the recent events have affected a large number of the community and have had many direct and consequential damages including:

- Damage to public infrastructure;
- Financial cost to businesses directly impacted;
- Loss of income to the broader business community due to the inability to trade;
- Reputational damage;
- Loss of business and community confidence;
- Increased recurrent costs such as insurance premiums; and
- Overall emotional and financial impact on the community.

The Climate Commission Report has indicated that the North Burnett region can expect higher risk of heavy rainfall. This prediction along with the growing community awareness regarding national flood mitigation programs and the fact that no comprehensive economic and technical analysis has been previously undertaken within the region has led Council to seek funding to undertake a preliminary review of flood damage costs to the community and identify potential flood mitigation options and estimate the associated benefits. The aim of this study was to undertake a preliminary assessment of flood

damage costs and potential mitigation measures based on existing information to assist Council in developing a business case for funding of additional technical studies and ultimately flood mitigation measures.

2. FLOOD HISTORY

The Burnett River catchment is located in south east Queensland, with a main system incorporating the rivers of Three Moon Creek, Burnett River, Nogo Creek, Auburn River and the Boyne River, in addition to many other creek and tributaries. The total Burnett River catchment area is approximately 33,000 square kilometres. This area is bound by the catchments of the Fitzroy and Kolan Rivers to the north; the Dawson and Condamine Rivers to the east and the Brisbane and Mary Rivers to the South.

The Burnett River catchment has had a long history of flooding that has impacted both the urban centres and rural areas. **Figure 2.1** to **Figure 2.5** provides mapping of available flood events (including 2013) for each of the towns in the region.

2.1.1.1. Urban Centres

A number of urban centres within Council area are susceptible to regional flooding due to their proximity to Three Moon Creek and Burnett River. Historically, the towns of Monto, Mundubbera and Gayndah have experienced the most significant impacts. Importantly, the January 2013 event exceeded the 1942 levels in the majority of areas across the region.

Monto Township

The township of Monto is located at the confluence of Monal Creek and Three Moon Creek approximately 200 m upstream of the Three Moon Creek Bridge and Burnett Highway embankment. The catchment upstream of Monto is approximately 1038 km^2 in area and encompasses Cania Dam, approximately 50 km upstream of the township, with a catchment area of 300 m^2.

The township of Monto is surrounded by a large defined flood plain and is generally located on a hill, resulting in relatively good flood immunity for the majority of the township. The historical flood records show that the low flood immunity of the connector roads at Three Moon Creek bridge and the Burnett Highway embankment can cause the town to be isolated from the north for a period of time. During the 1942 event, floodwaters are known to have reached 3.51 m above the deck level of the Three Moon Creek bridge.

The January 2013 flood event resulted in inundation of 11 houses and 3 businesses along Mill Street. The town was isolated and without electricity for 3 to 4 days. The event has caused damage to the water treatment plant and there was complete failure of communications for a 24 hour period with only partial communication for a further 48 hours.

Impacts of other known historical flood events at the Monto township have been relatively minor, with the majority of flood damage occurring to surrounding agricultural infrastructure and crops.

Mundubbera Township

The Burnett River is situated to the east of Mundubbera township and is defined by a deep incised channel, approximately 20 m deep and 300 m wide. During flood events, the river swells from shallow flows at the base of the channel to a fast flowing watercourse that extends across the flood plain causing a backup of floodwater into Killala Creek (Red Gully).

The Mundubbera township has flooded on a number of occasions, with the recent 2010 and 2013 flood event inundating properties adjacent to Red Gully. Damage to residential property was substantial during both events, with the three main accommodation facilities impacted during the 2013 event.

The January 2013 flood, which was just below the levels recorded for the 1942 flood event, resulted in inundation of 72 houses and 11 businesses within Mundubbera. The town was isolated from other regional centres for 4 to 5 days. Mundubbera was without electricity for about 4 days, there was extensive damage to the water treatment plant and complete failure of communications for a 24 hour period with only partial communication for a further 48 hours.

The Auburn and Boyne Rivers were not subjected to major flood during the January 2013 event and therefore the impacts were generally caused by flooding from the Burnett River. A coincident flood event of all systems would have caused more significant flood damage to Mundubbera.

Gayndah Township

The Burnett River passes through the Gayndah township, with the main township (business centre) located to the south and the majority of residential and industrial properties and the airport are located to the north. The Burnett River at Gayndah is a deep incised channel, approximately 20 m deep and 250 m wide. Flood impacts to Gayndah are also experienced from backflow of floodwater from Oaky Creek and Sauers Gully to the south and Reid Creek to the north.

The Gayndah township has experienced flooding on a number of occasions, with the largest flood events recorded in February 1942 and January 2013. In both of these events floodwater broke over the Showground and formed an inland channel behind the business centre between Oaky Creek and Sauers Gully. In both events large areas of the township, both north and south of the river were inundated or isolated by floodwaters. Damage to commercial and residential property was substantial.

The January 2013 flood event resulted in inundation of 73 houses and 28 businesses within Gayndah. The town was isolated from other regional centres for 4 to 5 days. Gayndah was without electricity for 4 to 5 days, there was extensive damage to the water treatment plant and there was complete failure of communications for a 24 hour period with only partial communication for a further 48 hours.

Fortunately, the Auburn and Boyne Rivers were not in flood during the January 2013 event and therefore impacts were generally caused by flooding from the Burnett River. A coincident flood event of all systems would have caused more significant flood damage to Gayndah.

Other Towns

Although the 2013 floodwaters caused only minor impact to the smaller towns (Eidsvold and Abercorn) due to their location, many of the smaller towns and rural areas were impacted in terms of loss of communication, electricity and access. Eidsvold water supply is also known to have been damaged by the 2013 floods however it is understood that the water pumping station is being relocated as part of the flood recovery program facilitated by QldRA.

2.1.1.2. Rural Areas

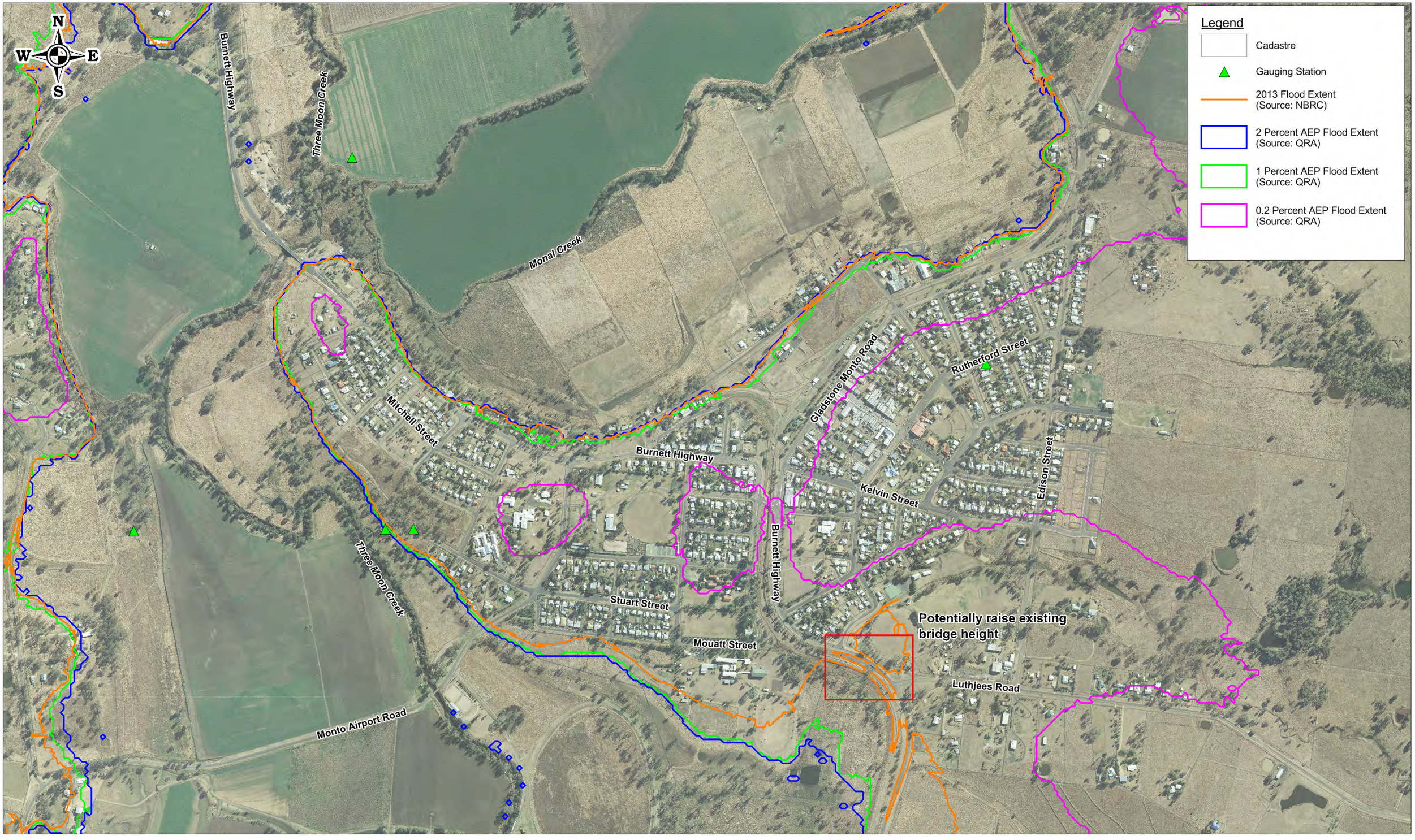
The majority of the North Burnett's high value agricultural enterprises are located within the flood plain of the river systems. Agriculture is the principal land use for the catchment with the main industries being beef and dairy cattle, sugar cane, field crops, horticultural crops and intensive livestock. It is understood that 74% of the total catchment area is involved in actual agriculture; where the predominant land use is grazing. In addition to this many farming houses are located in the flood plain, many unaware of the associated flood risks.

The 2013 event resulted in inundation, isolation and loss of power (resulting in loss of water) to intensive piggeries and dairies. Floodwaters are believed to have swept away herds of cattle and caused extensive damage to citrus orchards, infrastructure and other crops.

Regional areas suffered from isolation for up to five (5) days. Communications were lost for a period of 24 hours with only partial communication for a further 48 hours. It is understood that there are a number of communications 'black spots' throughout the region, thereby impeding communication prior to and during the event. As expected, a number of property owners have since purchased generators to manage the loss of power in preparation for another event.

Rural areas situated between Eidsvold and confluence of the Boyne River were impacted by the highest flood waters. Areas downstream of the Boyne River were impacted by lower floodwaters due to the Boyne River providing some flood storage during the 2013 event.

It is understood that 79 rural properties were recorded as being impacted by over floor inundation, however it is acknowledged that there may be some properties unaccounted for. Information regarding the extent of damage to farms in terms of loss of infrastructure, income, livestock and crops is also relatively unknown.



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ENGENY WATER MANAGEMENT

NORTH BURNETT REGIONAL COUNCIL

0 200 400
Scale in Metres (1:10,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

North Burnett Flood Mitigation Study

Figure 2.1

Monto Flood Extent Map

Job Number: M28000_001
Revision: 0
Drawn: JNA
Date: 04 Dec 2013

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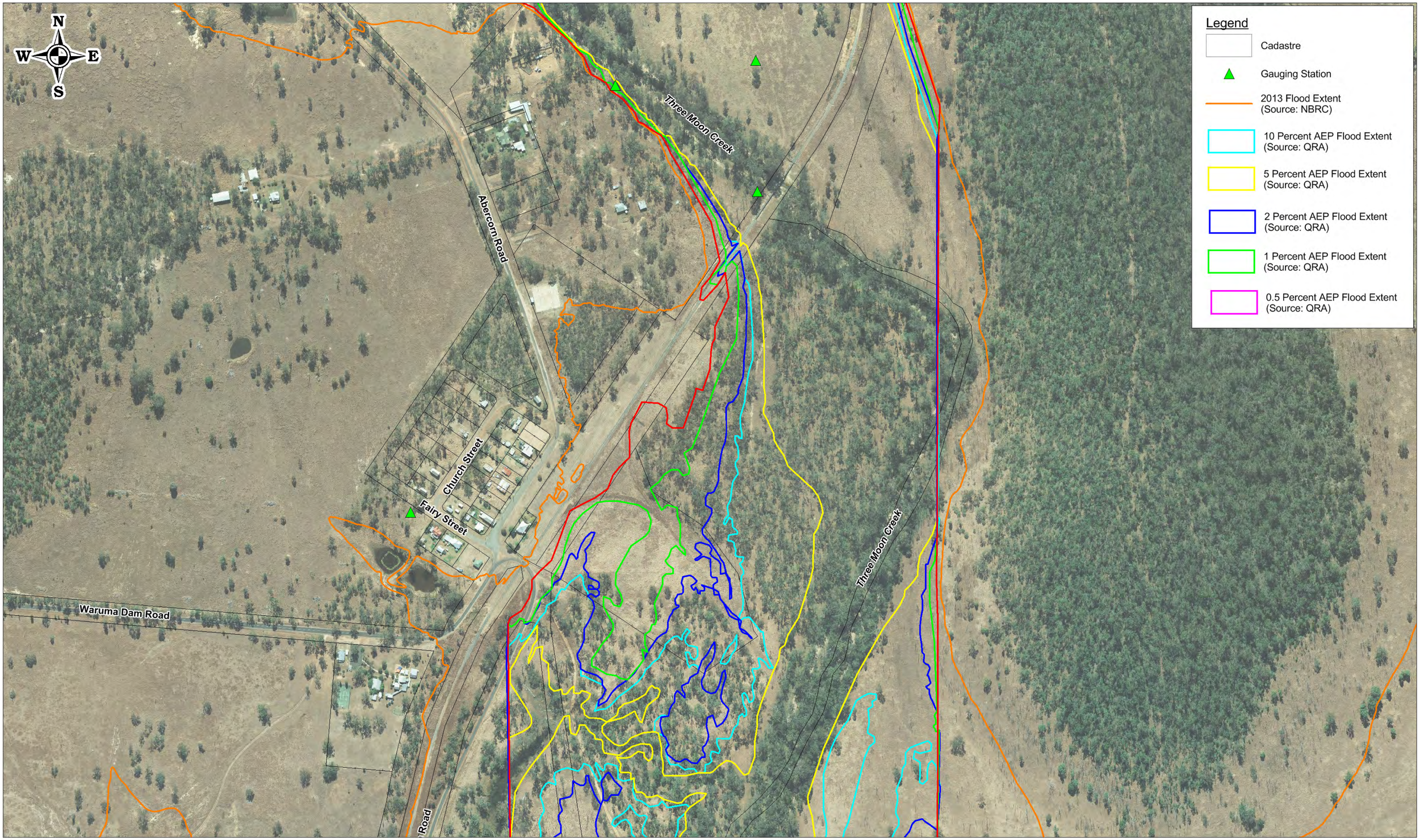

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North Burnett Flood Mitigation Study

Figure 2.2

Abercorn Flood Extent Map

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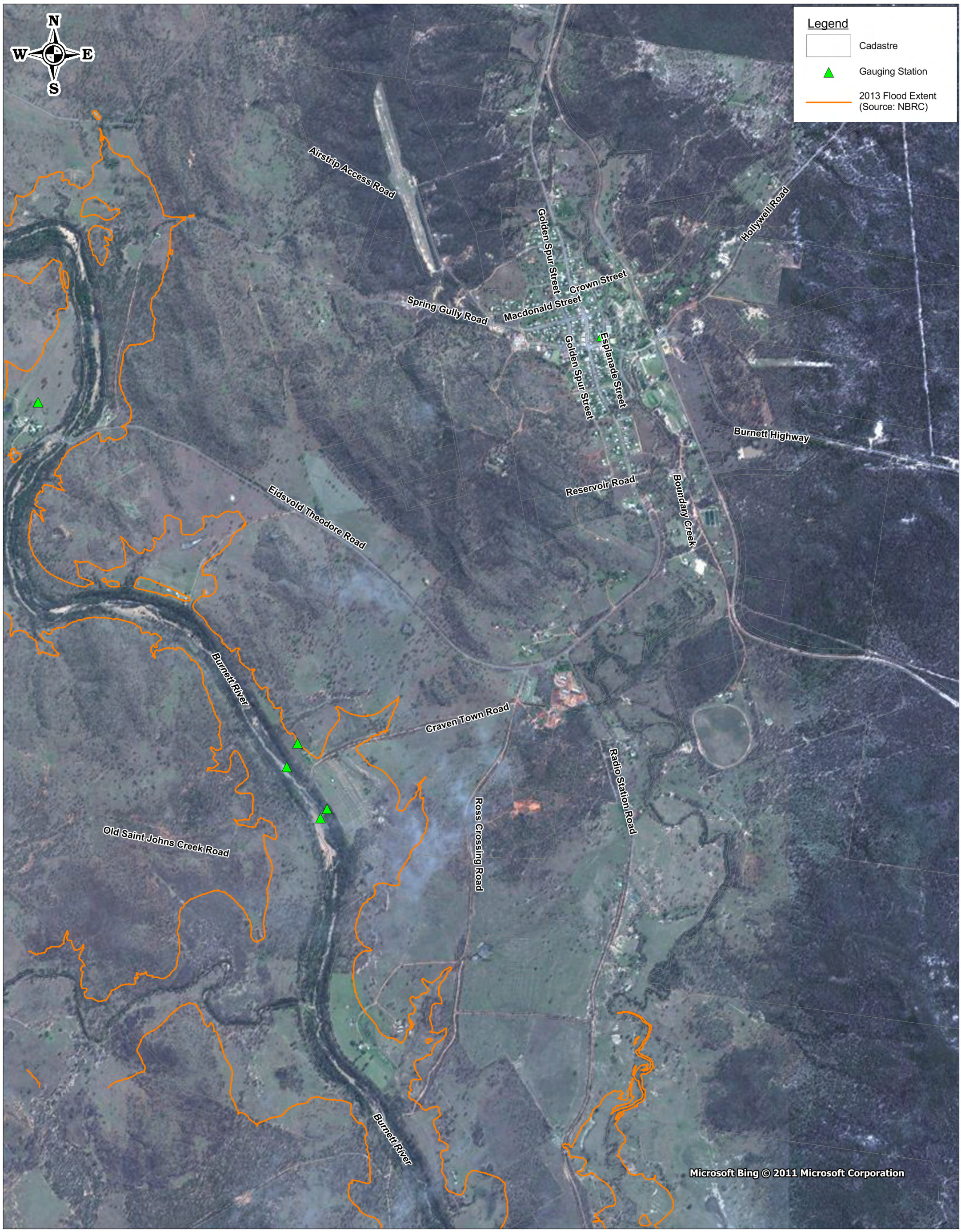

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North Burnett Flood Mitigation Study

Figure 2.3

Eidsvold Flood Extent Map

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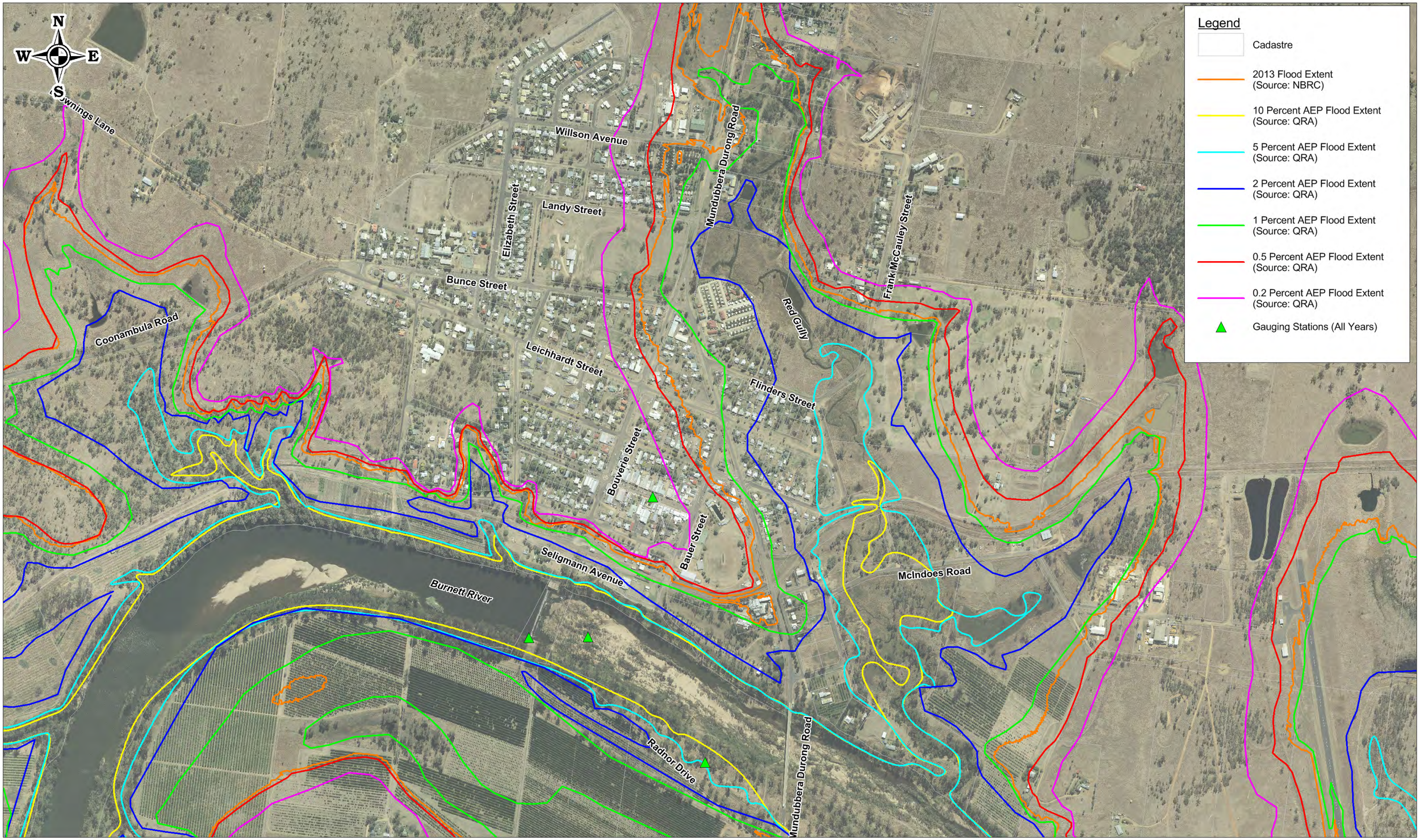

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Figure 2.4

Mundubbera Flood Extent Map

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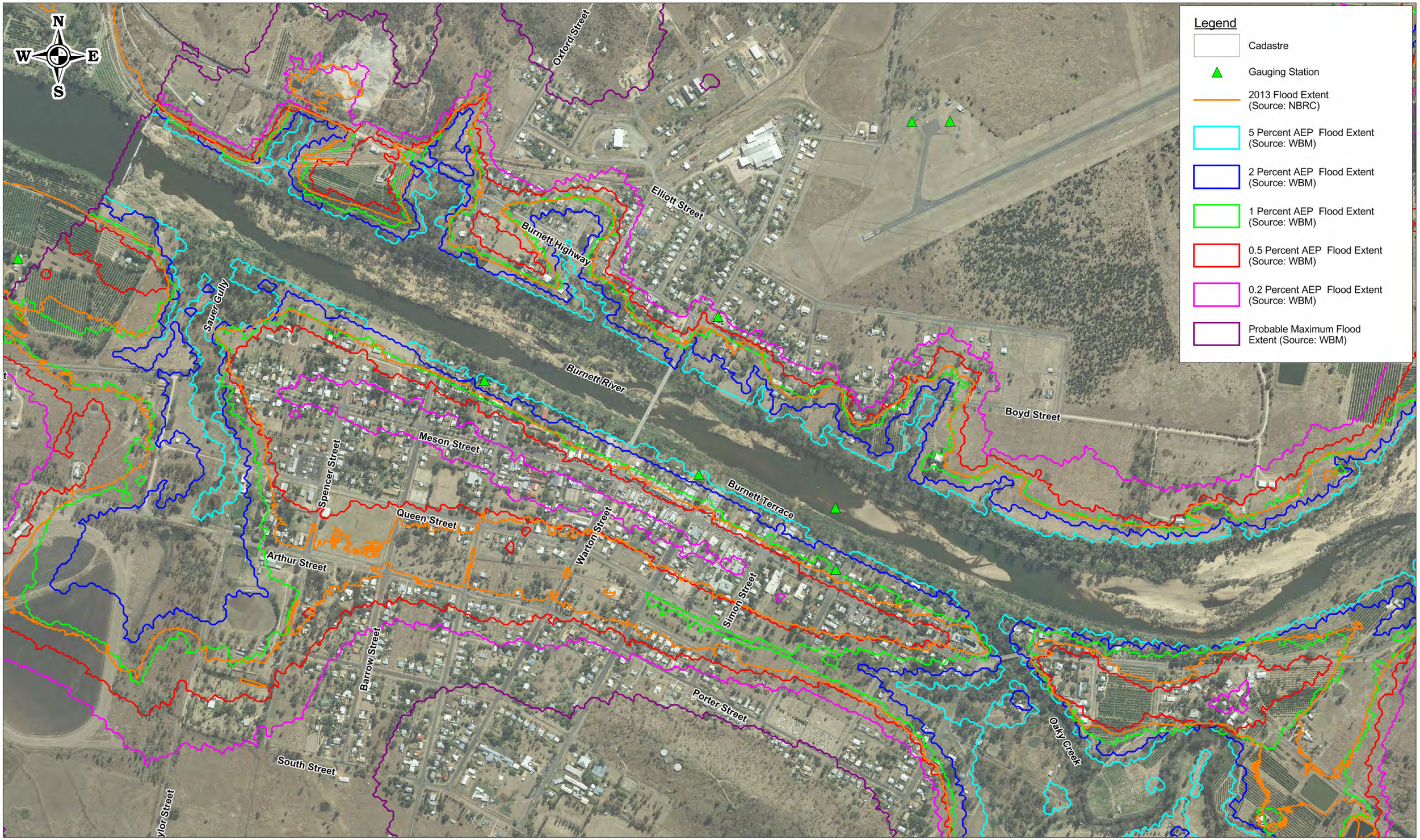

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North Burnett Flood Mitigation Study

Figure 2.5

Gayndah Flood Extent Map

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3. STUDY DATA

This study has drawn upon existing data and previous studies provided by North Burnett Regional Council, SunWater, Department of Transport and Main Roads (DTMR), Department of Natural Resources and Mines (NRM), Queensland Reconstruction Authority (QldRA), Geosciences Australia and the North Burnett Chamber of Commerce. A summary of the data and previous studies used for this project is provided in the sections below and further detailed in Appendix A.

3.1 Flood Information

The available flood information included:

- Recorded streamflow data at the following gauging stations between Monto and Biggenden:
  - 136101C Three Moon Creek at Abercorn (Monto and Abercorn);
  - 136103B Burnett River at Ceratodus (Ceratodus);
  - 136106A Burnett River at Eidsvold (Eidsvold);
  - 136004A Burnett River at Jones Weir Headwater (Mundubbera); and
  - 136002D Burnett River at Mount Lawless (Gayndah).
- QldRA flood frequency analyses, flood mapping results associated with reports for:
  - Abercorn - Report on Flood Investigation for Abercorn, Flood Investigation Level 2 – Unvalidated GIS Mapping Approach (QldRA, 2012);
  - Mundubbera - Report on Flood Investigation for Mundubbera, Flood Investigation Level 2 – Unvalidated GIS Mapping Approach (QldRA, 2012); and
  - Monto – Flood Hazard Mapping – Monto, Bundle 9, Final Report 2013 (DHI Water and Environment, 2013).
- Business Flood Impact Report 2013 – North Burnett (BEIDO, 2013);
- Primary Production Flood Impact Report 2013 – North Burnett (BEIDO, 2013);
- Results and flood models for various design events associated with the Gayndah Flood Study Report - Gayndah Flood Study Final Report Report (Volume 1 and Volume 2) (BMT WBM, 2008);

- SunWater dam break information flood mapping and flows associated with:
  - Emergency Action Plan Boondoomba Dam (Sunwater, 2011, Issue 3);
  - Emergency Action Plan Cania Dam (Sunwater, 2011, Issue 3); and
  - Emergency Action Plan Wuruma Dam (Sunwater, 2011, Issue 3).
- Hydrologic and hydraulic models and report associated with the Three Moon Creek bridge upgrade at Monto - *Hydraulic Study Three Moon Creek Bridge Replacement (Transport and Main Roads, 2007);*
- Hydrologic and hydraulic models and report associated with the Killara Creek Floodway Upgrade (Red Gully) – *Killara Creek Hydrologic and Hydraulic Report (Transport and Main Roads 2010)*;
- Digitised grid sourced from peak water level survey of the 2013 flood (GIS and Asci) (North Burnett Regional Council, 2013);
- QldRA floodplain extent (GIS) (QldRA, 2011); and
- Existing gauging stations locations (GIS) (Geosciences Australia, 2013).

3.2 Topographic and Site Information

Topographic and site information were obtained from the following sources:

- Cadastre and planning scheme zones (GIS) (North Burnett Regional Council, 2013);
- Road casements (GIS) (North Burnett Regional Council, 2013);
- Aerial photography (GIS) (North Burnett Regional Council, 2013);
- Survey of impacted houses and commercial buildings (Slab or stumps) (GIS) (North Burnett Regional Council, 2013);
- LIDAR (GIS) (North Burnett Regional Council, 2013);
- Contour Data (GIS) (North Burnett Regional Council, 2013);
- Landuse Data (GIS) (Geosciences Australia, 2013);
- River basins data (GIS) (Geosciences Australia, 2013);
- Sewerage plans (PDF) (North Burnett Regional Council, 2013); and
- Stormwater Drainage Plans (PDF) (North Burnett Regional Council, 2013).

3.3 Limitations

This study has relied heavily upon the extent and accuracy of data provided and no data validation has been undertaken. As a result, the accuracy of the findings of the study is limited by the extent and accuracy of the input data. This includes the available flood information and economic assessment data for estimation of flood damage.

Further limitations of this study are due to the following gaps in information:

- Regional areas have little or no peak water level survey information for the 2013 or any other flood events;
- Due to the large magnitude of the recent historical flood events (such as 2013 and 2010 events), the stream flow and water level gauges have missing data at the peak of the events resulting in the flood frequency analysis potentially providing lower AEP estimates;
- A lack of stream flow and water level gauges have resulted in unquantifiable peak flows and flood levels for the majority of the rural reaches;
- A hydrologic model encompassing the entire catchment was not available for the study;
- Hydraulic modelling has not been undertaken for the townships of Monto and Mundubbera, or for the rural reaches of the catchment;
- Design event flood mapping prepared by the QldRA has very limited accuracy as the mapping was based on flood frequency analyses which excluded the recent 2013 event. House type survey (slab on ground or on stumps) for the rural areas was not available;
- Topographic data is limited in the rural reaches between the townships;
- Farm type survey (such as dairy or piggery) was not available; and
- Floor level survey for all impacted houses within the region was not available.

4. FLOOD ANALYSIS

4.1 Flood Frequency Analyses

Based on the stream flow data obtained from Department of Natural Resources and Mines (NRM) and in accordance with AR&R (1997), Flood Frequency Analyses (FFA) have been undertaken using the annual flood series method that comprises the peak flow in each year of historic data. Between 50 and 65 years of available data was used. The analyses have also utilized the FFA undertaken by the QldRA and associated data.

The current assessment used the water year of 1st October through to 1st September (in accordance to NRM methodology) to evaluate the peak flow. It is noted that zero and low flow outliers were removed. The gauging stations and associated towns are listed as follows:

- 136101C Three Moon Creek at Abercorn (Monto and Abercorn);
- 136103B Burnett River at Ceratodus (Ceratodus);
- 136106A Burnett River at Eidsvold (Eidsvold);
- 136004A Burnett River at Jones Weir Headwater (Mundubbera); and
- 136002D Burnett River at Mount Lawless (Gayndah).

Table 4.1 presents the stream gauge station data provided by NRM and the period used in the flood frequency analysis. **Table 4.2** presents the estimated return interval for the recent major historical floods. The flood frequency curves provided in **Figure 4.1** to **Figure 4.3** present the fitted distribution along with the 90% confidence range for the data collected at each of the stream gauging stations. These distributions account for the majority of data variations except for points identified as being less than the low flow threshold (refer to **Table 4.1**).

Table 4.1 Steam Gauge Station Details

Gauging Station	Town	Total Years of Record	Period Of Record	Low Flow Threshold (m^3/s)	Years of Data Used in FFA
136101C Three Moon Creek at Abercorn	Monto	65	1949-2013	2.34	65
136004A Burnett River at Jones Weir Headwater	Mundubbera	60	1953-2013	8.2	60
136002D Burnett River at Mount Lawless	Gayndah	76	1939-2013	115	51

Table 4.2 Estimated Peak Discharge (m^3/s) and Approximate Annual Exceedance Probability for Historical Events

Towns		1942	1971	1996	7th February 2003	23rd December 2010	28th December 2010	6th January 2011	26th January 2013
Monto	Approximate Annual Exceedance Probability (AEP)	-	1 in 15	1 in 19	1 in 15	1 in 5	1 in 25	1 in 5	1 in 50
	Estimated Peak Discharge (m^3/s)	-	500	570	500	170	640	170	840
Mundubbera	Approximate Annual Exceedance Probability (AEP)	-	1 in 30	1 in 10	1 in 10	Data Unavailable	1 in 40	Data Unavailable	1 in 100
	Estimated Peak Discharge (m^3/s)	-	7280	1900	2320	-	8950	-	11900
Gayndah Including 1942	Approximate Annual Exceedance Probability (AEP)	1 in 55	-	1 in 10	1 in 10	1 in 15	1 in 15	1 in 20	1 in 100
	Estimated Peak Discharge (m^3/s)	14980	-	2030	1950	4320	9850	6100	16480

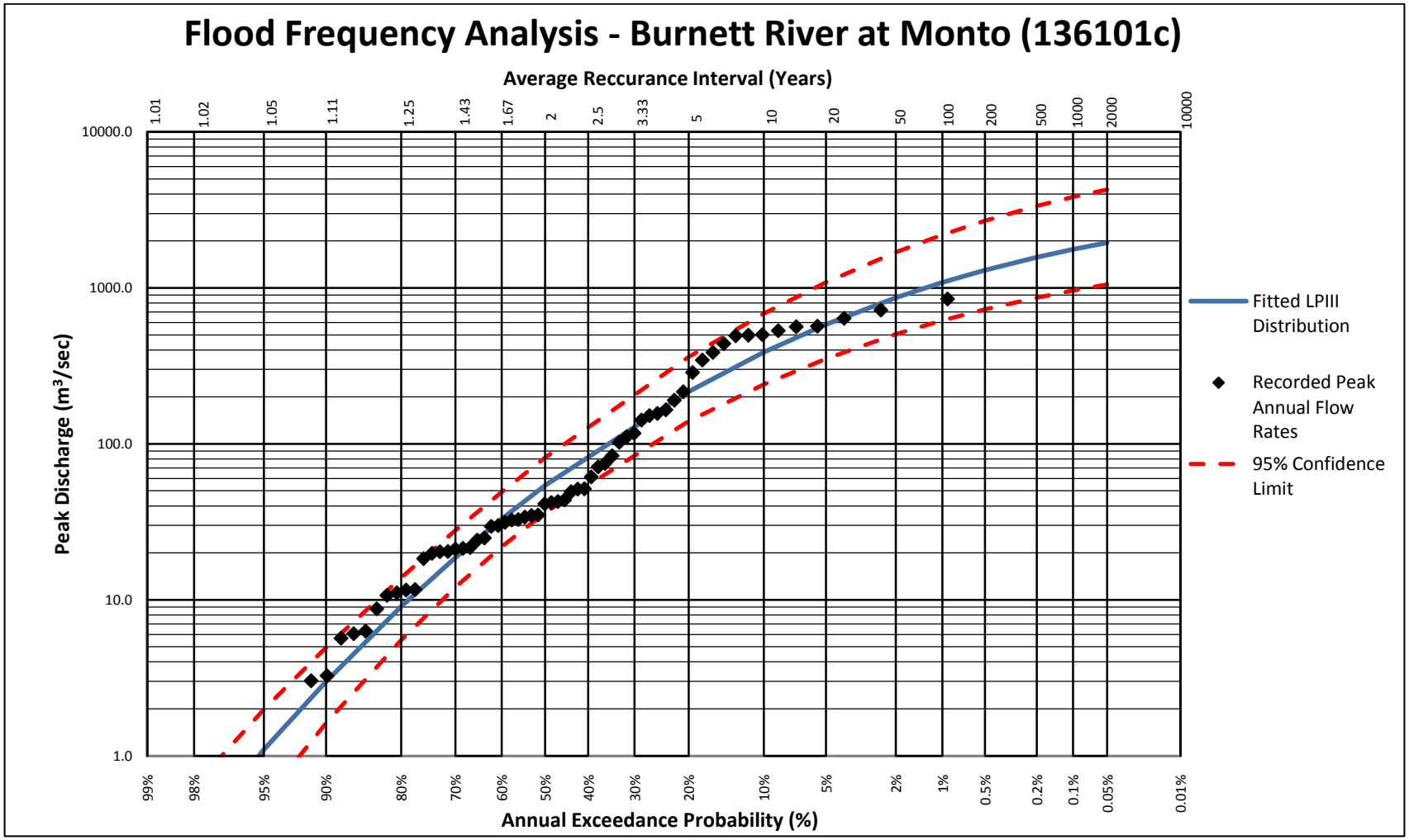


Figure 4.1 Flood Frequency Analysis – Burnett River at Monto (136101c)

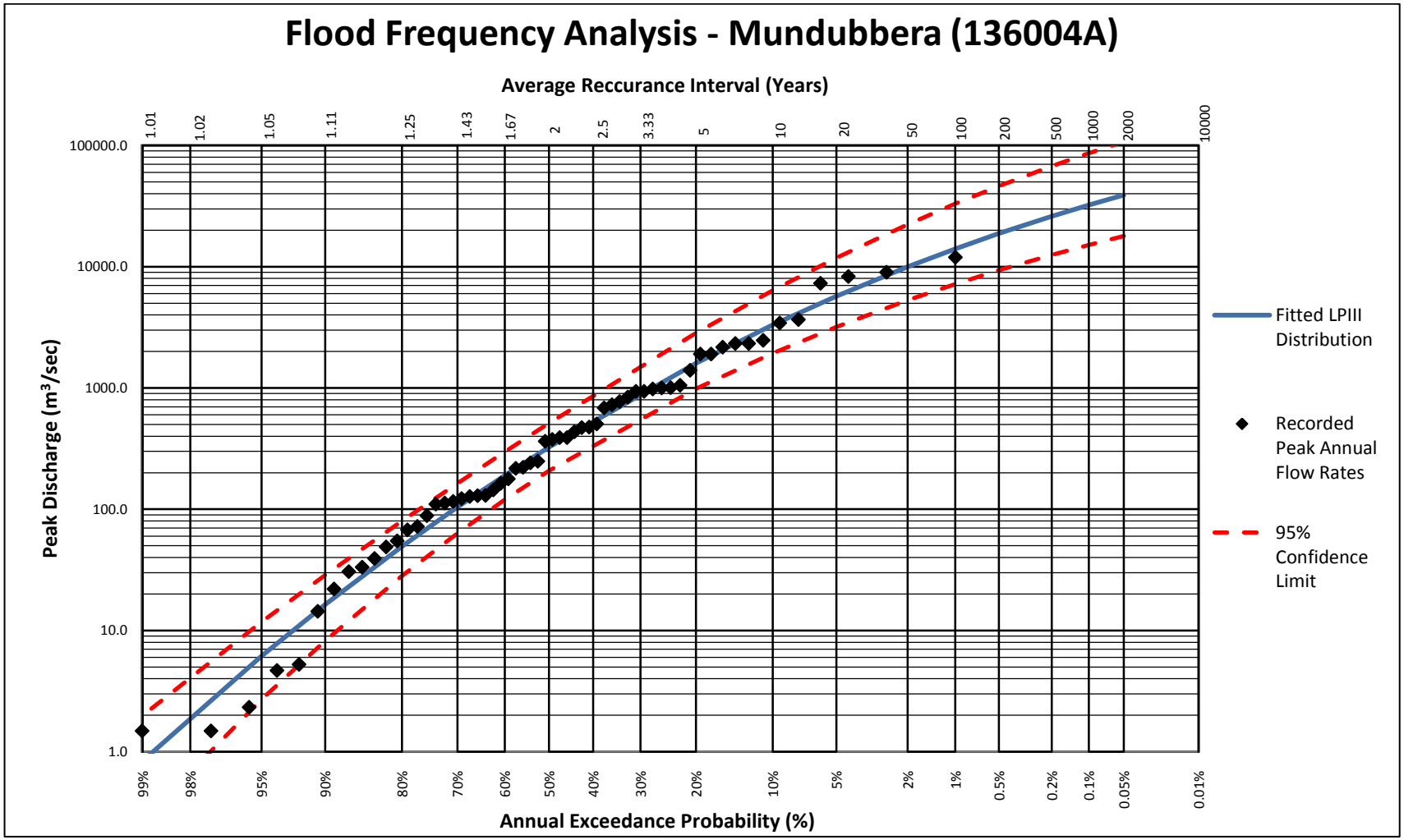


Figure 4.2 Flood Frequency Analysis – Mundubbera (136004A)

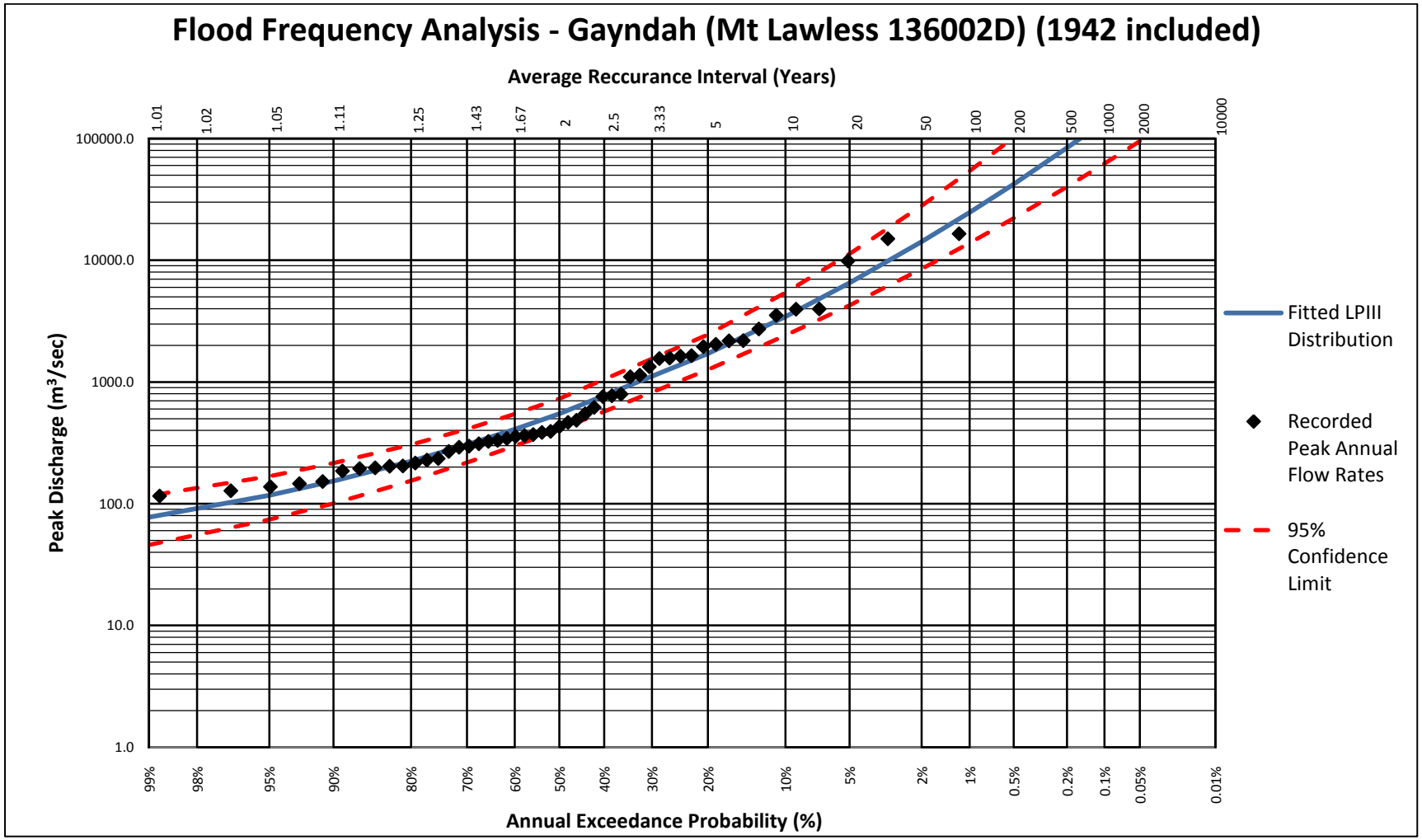


Figure 4.3 Flood Frequency Analysis – Gayndah (Mt Lawless 136002D)

4.2 Flood Mapping of Design and Historical Events

Mapping of the design events was undertaken using existing data obtained from previous flood mapping studies undertaken within the North Burnett region. The studies include the Gayndah Flood Study (2008) as well as the indicative (high level) flood mapping undertaken by QldRA for Mundubbera and Monto using the Level 2 Flood Investigation. The extent of inundation for the 2013 event has been mapped by NBRC using surveyed flood debris marks within each town.

Figure's 2.1, 2.2 and **2.5** present the flood mapping for the historical 2013 event and various design events for Monto, Mundubbera and Gayndah. It is noted that there is no flood mapping for rural areas available for the 2013 and design events. A Level 1 Flood Investigation undertaken by QldRA provided a broad outline of the flood plain for the entire catchment however this mapping was unable to be used due to the coarse nature of the mapping. Available flood mapping for the 2013 historical event was limited to urban centres only.

The flood mapping has been used in this study to estimate the flood damage costs as well as the potential benefits associated with mitigation options. It is noted that the QldRA flood mapping has not been validated and therefore there may be uncertainties in the design flood extent mapping for each of the towns. There may also be uncertainties with the FFA, particularly for the larger events where, for example, the rating curve for the Mt Lawless gauge has only been manually gauged up to a level of 7.73 m which equates to a discharge of 3,200 m^3/s and then extrapolated up to a discharge of 16,500 m^3/s.

Based on the existing flood mapping, for the purpose of this study it has been assumed that the 2013 event in Monto was approximately a 1 in 50 AEP flood, approximately a 1 in 180 AEP event in Mundubbera and between a 1 in 100 and 1 in 200 AEP flood in Gayndah. In the absence of any other flood information, the existing flood mapping has been used for this preliminary assessment of potential flood mitigation option.

5. FLOOD DAMAGES ASSESSMENT FOR 2013 EVENT

This sub-section provides **preliminary** estimates of the priced damages from the January 2013 floods. Specifically, it lists the damages sustained by agriculture, infrastructure, commercial and residential properties, as well as the response and recovery costs.

These cost estimates have been ascertained through various sources, including:

- Consultations with staff of various Government agencies, the North Burnett Regional Council, infrastructure providers, local businesses and growers; and
- Published documents of several Government agencies. The two key resources that have formed the predominant insight for the summary include the Department of State Development, Infrastructure and Planning (DSDIP) Regional Economic Impacts Assessment; and the Bundaberg Regional Council Economic Impact Assessment.

The cost estimates in this report are preliminary and should be interpreted with caution. They represent the best available information at the time of report preparation, and reflect the consolidated economic impact assessments that have been prepared to inform local and state government policy responses.

5.1 Direct Damages

5.1.1 Agricultural Damages

The initial analysis conducted by DSDIP and the Department of Agriculture, Fisheries and Forestry (DAFF) suggests that the Wide Bay Burnett region sustained significant damages to its agricultural sector in the 2013 floods. The preliminary findings estimate total losses to the sector of $256 million with extensive damage being done to the citrus, sugar cane and dairy cattle industries (DSDIP, 2013).

Most agricultural producers suffered the following damages to varying degrees:

Loss of crop/ production;

- Loss of top soil and consequently, its nutritional value;
- Loss of plantation-related infrastructure including bores, fencing, nets, pipes etc; and
- Loss of production of crops in the following season due to loss of fruiting trees.

The estimated losses were as follows:

- Crop and livestock output losses reached an estimated $104 million with citrus ($41 million), sugar cane ($26 million) and dairy cattle ($23 million) the most heavily impacted (Lawrence Consulting, 2013);

- $23 million in farming capital losses, primarily affecting the citrus ($14 million) and dairy cattle ($7.5 million) industries (Lawrence Consulting, 2013); and
- $139 million worth of estimated losses to plantation infrastructure which can be attributed to farming infrastructure ($130 million) and fisheries ($9 million) (Lawrence Consulting, 2013).

The *Primary Production Flood Impact Report 2013* Released by the Burnett Inland Economic Development Organisation (BIEDO) documents that damage to agriculture in the region was far greater from the 2013 flood than from the 2010-11 flood events. BIEDO suggest this was mainly due to:

- The increased speed of the 2013 floods (flash floods), which resulted in an increased lack of warning and lack of preparation;
- The increased volume of water experienced in the 2013 floods, which in some instances was on average 9 metres higher than 2010-11 levels (BIEDO, 2013); and
- Drought in the months prior to the 2013 floods had left topsoil vulnerable and crop fields particularly susceptible to erosion.

This high scale and velocity of the January 2013 floods resulted in extensive losses to topsoil, widespread erosion of banks and dams and completely wiped-out the region's current crops.

The Government has charged the Queensland Rural Adjustment Authority (QRAA) with administrating a flood assistance program under which various grants and loans have been made available to affected primary producers. These grants and loans include:

- Category B Loans: low interest loans up to $250,000;
- Category C Grants: grants up to $25,000; and
- Category D Packages: low interest loan and grant packages up to $650,000 for severely affected properties.

The QRAA Flood Assistance program has approved 559 primary producer applicants within the North Burnett LGA, who were paid a total of $10.02 million in loans and grants (Lawrence Consulting, 2013). The BIEDO report claims that recovery costs throughout the region start at an estimated $60,000 but can reach over $1 million on larger properties (BIEDO, 2013). As a result, Category D packages are perceived by many affected producers as an essential level of assistance. It must also be noted that these Government payouts may not meet total recovery costs of some growers.

Because of lags in recovery time, growers may not be able to sow for next season. As such, expected future income will be reduced. BIEDO suggest that this will vary across the region based on how immediately reparable a property is and also based on the

relative complexity of the damage to crops. In turn some producers may be able to generate partial income in the short term whereas others will require years to return to production.

5.1.2 Commercial Damages

The following commercial damages have been identified as having the greatest material impact on business operation during the January 2013 floods.

- Damages and loss of profit to:
  - Accommodation providers; and
  - Retail businesses.
- Longer travel distances for freight companies due to road closures.

5.1.2.1. Accommodation Providers

Two (2) accommodation providers were inundated within the Gayndah-Mundubbera district which represented a 5.7% drop in the region's total number of hotels, motels and serviced-apartments in the June Quarter of 2013. As a resulted guest rooms across the region also fell 2.7% and bed spaces were down 3.6% (Lawrence Consulting, 2013).

5.1.2.2. Retail Businesses

The business survey conducted as a part of the Regional Economic Impact Assessment suggests that retail businesses suffered costs in two key areas, direct damages to property and loss of income. These costs were calculated as follows:

- The average loss of income for completely inundated businesses in the North Burnett region was $193,167 whilst businesses that were not flooded recorded an average loss of $33,241(Lawrence Consulting, 2013); and
- In terms of direct damage the average cost to affected businesses throughout the North Burnett and Bundaberg regions was: $91,077 for buildings and fixtures, $116,880 for inventory, $72,797 for plant and equipment and $33,723 for furnishings (Lawrence Consulting, 2013).

In total the estimated damages to business across the entire North Burnett and Bundaberg region was $1.1 billion or $130,887 on a per business basis. Businesses were also adversely affected by an immediate downturn in activity combined with increased costs. This was highlighted by the business survey which estimated an increase in operating costs of 3.4%, a decrease in production levels of 15.0% and a decreased in demand of 11.1% (Lawrence Consulting, 2013).

5.1.2.3. Transport Costs

The January 2013 floods caused disruptions and closures to key sections of the North Burnett road network. These interruptions had significant impacts on both the North Burnett economy and the entire Queensland economy. The main impacts were in the areas of supply chain and logistics, interruptions to movements of the region's workforce and visitor access.

The Regional Economic Impact Assessment estimates that the loss of through traffic cost the state economy $16.1 million per day. The road network was cut off for a total of four days between 26th January 2013 and 30th January 2013 which represents a total loss to the state of $64.2 million (Lawrence Consulting, 2013).

5.1.3 Residential Damages

The DSDIP study estimates that the total damage to residential housing stock was $157 million in the Wide Bay Burnett region. The study also estimates that across flood affected areas, properties with minor damage will cost an average $5,000 to restore while properties that sustained severe damage will cost on average $150,000 (DSDIP, 2013).

The *Rapid Appraisal Method (RAM) for Floodplain Management* (NRE Victoria, 2000) suggests using a mean damage of $20,500 for all dwellings and recommends applying it to all inundated properties, including those inundated above and below floor level. The mean damage figure allows for external and internal contents as well as structural damages. Allowing for the CPI increases across Australia of 37% between 2000 and 2013 implies that the mean damage is anticipated to be in the order of $28,000 per dwelling.

5.1.4 Infrastructure Damages

All infrastructure service providers in the North Burnett were affected to varying degrees during the floods, including power, roads, water and telecommunications. The discussion that follows provides more detail.

5.1.4.1. Main Roads

Road infrastructure in the North Burnett was significantly damaged with many key segments of main road completely inundated. Total damage to roads in the Wide Bay Burnett region has been estimated at $150 million by the Department of Transport and Main Roads (DTMR, 2013).

5.1.4.2. Council Maintained Assets

After the 2013 floods, the North Burnett Council applied for an approximate $116 million in grants under the National Disaster Relief and Recovery Arrangements (NDRRA) (Lawrence Consulting, 2013). The North Burnett Regional Council (NBRC) estimates the value of damage to various asset classes as follows:

- Emergent and restoration costs for council maintained roads and streets will cost a total of $111,360,515 (NBRC, 2013);
- Total cost for council bridges is estimated at $3,027,290 (NBRC, 2013); and
- Council buildings and other structures have estimated repair costs totalling $3,549,224 (NBRC, 2013).

5.1.4.3. Water Infrastructure

The floods caused significant damage to the North Burnett region's water infrastructure. Based on the values of submissions to the Queensland Reconstruction Authority, the total cost of damage has been estimated at approximately $4.97 million. This total value can be split into emergent costs of $395,960 and restoration costs of approximately $4.58 million (NBRC, 2013).

5.2 Indirect Costs

5.2.1 Response and Recovery Costs

The costs of response and recovery are best approximated by looking at clean-up costs, government assistance costs and insurance claims. These estimates are as follows:

- The volunteer organisation, Blaze Aid acted as a first response to the floods. It was involved in the initial clean up and repairing of fences in the area. The estimated costs of fence rebuilding and labour were $2.2 million and $662,200 respectively (Lawrence Consulting, 2013);
- Government assistance through grants and low interest loans totalled an estimated $11.2 million in the North Burnett LGA (Lawrence Consulting, 2013); and
- The Insurance Council of Australia estimates insured losses from the entire flood affected region in Queensland to be in the order of $971 million (DSDIP, 2013).

5.2.2 Decline in Tourist Visitors

The 2013 floods had an overall negative effect on tourism in the North Burnett region. The Bundaberg tourism region, which includes the North Burnett LGA, saw a significant 30.3% fall in visitation throughout the March 2013 quarter. This figure actually represents a 22.9% increase on the visitation number from that period last year, providing a conflicting message. In the June 2013 quarter however, visitation dropped 20.7% when compared to a year earlier. In turn the Economic Impact Assessment suggests a net negative impact of the floods when seasonality is accounted for (Lawrence Consulting, 2013).

5.2.3 Health and Related Costs

Floods can cause severe injuries and other health related infections to residents of the affected region. These include serious body injuries and death. Flood related injuries may occur as individuals attempt to remove themselves, their family or valuables from danger. The risk of injuries at clean-up is also high due to unstable buildings and electrocution. Furthermore, the risk of vector-borne and rodent-borne infections and mental health outcomes have also been evidenced.

Costs borne out of these risks are discussed below.

5.2.3.1. Risk of Water Borne Disease

The major risk of water-borne diseases is the contamination of drinking water facilities. Flooding of sewage treatment plants, loss of power to these plants, contaminated waterways due to damaged septic tanks, leach drains and debris in the waters can cause severe infections. Furthermore, the risk of wounds and other eye and nose infections is also common through direct contact with polluted waters. Our discussions with stakeholders did not highlight any risks to residents of North Burnett arising out of these impacts.

On the other hand, increased risk of infection from both water and vector-borne diseases transmitted through flood-affected waters, including typhoid fever, cholera, malaria, dengue and the like, was highlighted at elevated levels. Stagnant water from floods and rainfall assists and hastens insect and mosquito breeding, which can consequently cause severe diseases such as dengue fever.

5.2.3.2. Risk of Wide Spread Pollution

One of the other dangers of floods is the debris that gushing waters carry, including vehicles, garbage bins and other objects which can either cause injury or can contaminate waters.

Estimates of risk to life caused by flooded waterways were not available for this study.

5.2.3.3. Risk of Life and Limb

As pointed out in the aforementioned discussions, floods can lead to loss of life. This can be while people try to rescue themselves, their families or valuables from affected areas, at the clean-up stage, or by being hit by debris carried by the water.

Fortunately though, there was no loss of life in the North Burnett due to the floods in January 2013.

Nonetheless, the increased risk to life remains a genuine threat to the residents of the region. The constant threat may lead to severe mental trauma and hyper-tension, both of which can reduce the life expectancy of individuals.

5.2.3.4. Risk of Mental Health and Stress

As stated by Patrick McGorry, Australian of the Year 2010, after the Queensland floods, disasters 'produce a massive pulse of stress, trauma and loss – the three most potent environmental triggers for mental ill-health - upon a large group of people at the same point in time. Although the whole social group is affected, the burden is selectively, even randomly, visited on individual members, apparently without rhyme or reason.' Disasters, such as floods, can cause new psychiatric symptoms including anxiety, depression, irritability and sleeplessness. They can overwhelm, at least temporarily, the coping mechanisms of a whole community or even a society.

Literature points out that most people under duress recover with emotional and practical support from family, friends and the community, without needing professional help. Only a minority of people exposed to the floods are likely to develop mixtures of depression, anxiety, post-traumatic stress and substance use disorders. This may culminate in severe mental trauma and hyper-tension, both of which can reduce the life expectancy of individuals, as mentioned above.

Consultation revealed that some business owners had lost substantial assets or had sustained heavy damages to their properties. Not only do they risk losing their current income stream, but expected future income is under duress. Some of those affected repeatedly have found it tough to cope with the situation. The constant risk of floods and the increased severity has led some business owners to exit the industry. Others are wary of the situation.

Direct costs of mental ill-health and trauma were not available for this study. These do, however, need to be recognised as a qualitative cost to the community.

6. POTENTIAL FLOOD MITIGATION MEASURES

Flood risk mitigation falls into two principal categories, structural and non-structural mitigation measures. Structural mitigation measures have the ability to partially or completely eliminate existing flood risks (i.e. levee, detention basin, backflow prevention, channel improvements, house raising or relocation, etc.), whilst non-structural measures allow for the management of existing, future and residual risks (i.e. development control or land use planning, flood warning, property buy back, etc.).

6.1 Structural Mitigation Measures

In many flood prone areas, structural flood mitigation measures can offer a reduction in the number of houses and business at risk of flooding. **Table 6.1** provides a general outline of the advantages and disadvantages of the structural mitigation measures considered as part of this study.

Table 6.1 Structural Mitigation Measures

Structural Mitigation Measure	Description	Advantages/Disadvantages
Detention Basins/Dams	Dams or detention basins can provide temporary storage for floodwaters when managed and sized appropriately. Examples of where dams and detention basins have been utilised for flood storage include: Wivenhoe and Somerset dams.	Advantages • Reduce peak flooding downstream. • Land can be used for other purposes during dry periods, such as sporting fields. • Some existing water storage dams can be managed to provide some flood storage. Disadvantages • Significant cost (capital and on-going). • Requires significant amount of land. • Environmental impacts. • Governed by topography and geology.
Backflow prevention devices	Devices such as flap gates/valves that placed at the outlet of piped stormwater system to prevent water flowing back up the pipe and causing flooding in low lying areas. Examples of where backflow valves have been used include: Suburbs in Brisbane such as Milton.	Advantages • Can be cost effective. • Require minimal infrastructure. • Can protect low lying areas and trapped low points. Disadvantages • Only suitable for limited applications such as low lying areas. • There often needs to be a natural levee/constructed levee to protect area from riverine flooding. • Some backflow devices are vulnerable to trapped debris, which can impact their effectiveness.

Structural Mitigation Measure	Description	Advantages/Disadvantages
Channel Improvements	Includes deepening (dreading) or widening of the channel. Can also include vegetation clearing the creek/river channel to increase flood storage. Examples of where channel improvements have been used include: Newcastle (NSW).	Advantages • Can be very cost effective. • Dependent on flow regime and topography can have large impacts on flood storage. Disadvantages • Dependent on floodplain width, flow regime and topography can have minimal impacts on flood storage. • Environmental impacts. • Visual impacts. • Worsened flooding downstream.
Crossing Structure Upgrades	Improvement to existing bridge/culvert structures by adding more cross-sectional waterway area. This can be undertaken by construction of additional spans to bridges, raising bridge decks, and construction of larger or additional culverts. Crossing upgrades are usually targeted for structures with a large head-loss across them, usually because the existing waterway area is too small.	Advantages • Crossing Structure upgrades can achieve significant flood level reductions upstream of the structure. Disadvantages • Dependent on the width of the floodplain, crossing structure upgrades can have minimal impact on flood level reductions upstream of the structure. • Crossing structure upgrades can increase in flood levels downstream of the structure previously reduced due to the structure. • Generally expensive.

Structural Mitigation Measure	Description	Advantages/Disadvantages
Bypass Floodways	Redirection of a portion of floodwaters away from areas at risk using an alternative flow path. Often used in conjunction with levees.	Advantages • Can be effective if used with levees. • Can be effective during smaller events. Disadvantages • Constrained by topography. • Constrained by land availability. • Can cause environmental and erosion problems elsewhere. • Worsening flooding downstream. • Generally expensive.
House Raising	Stump Footings Raising houses that are built on stump footings to a height above the predetermined flood level.	Advantages • Can be cost effective. • Residents can remain on property and within their home without significant change. Disadvantages • Can disadvantage the elderly and disabled residents. • There is still a risk of over floor flooding if flood is greater that the design immunity. This can result in significant impact to infrastructure and lives. • Does not protect property and related infrastructure (sheds, carports etc.) from flooding. Access routes can become limited, making evacuation difficult.
	Slab Footing	Advantages

Structural Mitigation Measure	Description	Advantages/Disadvantages
	Raising houses that are built on slab footings to a predetermined flood level.	• Residents can remain on property and within their home without significant change. <u>Disadvantages</u> • Generally expensive. • Difficult to raise dwellings a significant height when compared with stump footing houses. • Can disadvantage the elderly and disabled. • There is still a risk of over floor flooding if flood is greater that the design immunity. This can result in significant impact to infrastructure and lives. • Does not protect property and related infrastructure (sheds, carports etc.) from flooding. • Access routes can become limited, making evacuation difficult.

Structural Mitigation Measure	Description	Advantages/Disadvantages
Levees	Permanent Levees act as a physical barrier to prevent floodwaters from entering an area. Levees are typically an elongated artificially constructed earthen embankment (usually containing a clay core) or wall. Levees are usually designed for a specified flood event and will generally include 600 mm freeboard. Unless the levee has been designed for the probable maximum flood it is expected that they can be overtopped. Flood Emergency Plans should be implemented to deal with the residual risk associated with any levee. Examples of towns where permanent levees have been used include: Goondiwindi, Bedourie and St George.	Advantages • A specified area within the levee can be protected (including dwellings, businesses, associated infrastructure and land) can be protected up to the specified design flood level. • Levees can be cost effective in appropriate situations. • Other levees in Queensland have become a tourist attraction. Disadvantages • There is a risk of levee overtopping or failing. This can result in significant impact to infrastructure and lives. • There can be the perception that an area is “flood free” resulting in a reduction in flood awareness and preparedness by the community that it protects. • The levee may impact local drainage inside levee and additional infrastructure such as backflow valves and pumps may need to be incorporated into the levee design. • Earthen Levees often require a significant footprint, resulting in additional public land requirements and purchasing of easements. • Levees may create a negative visual impact. • Levees may create a negative physical impact (such as where road crossings are required). • Earthen levees require some ongoing maintenance (such as mowing and removal of saplings). • Liability of the asset manager needs to be determined in terms of funding and maintenance obligations. • Levees can cause adverse impacts to flood levels elsewhere. • Levees can cause adverse impacts to flood velocities.

Structural Mitigation Measure	Description	Advantages/Disadvantages
	Temporary or Demountable Temporary levees are a physical barrier, erected prior to the arrival of floodwaters and designed to protect a specified area. Types of temporary levees can include sandbags earthen mounds or various proprietary demountable barriers. Unless the levee has been designed for the probable maximum flood it is expected that they can be overtopped. Flood Emergency Plans should be implemented to deal with the residual risk associated with any levee. Examples of where temporary levees have been used include: Charleville.	Advantages • Temporary levees can offer the same advantages as permanent levees. • Temporary levees can be constructed for a specified event and then removed. • Temporary levees can be minimal in footprint. • Temporary levees can be cost effective in appropriate situations. Disadvantages • A trained team of people are required to install and monitor during event. • Storage and transport is required. • There is a risk of levee overtopping or failing. Impacting infrastructure and lives perceived as “safe”. • There can be the perception that an area is “flood free” resulting in a reduction in flood awareness and preparedness by the community that it protects. • The levee may impact local drainage inside levee and additional infrastructure such as backflow valves and pumps may need to be incorporated into the levee installation. • Land requirements and easements may still be required and monitored.

6.2 Non-Structural Mitigation Measures

Non-structural flood mitigation measures can offer a reduction to the number of houses and business at risk of flooding through land use planning, flood warning and voluntary buyback. Non-structural flood mitigation works can also equip Council, emergency services, businesses and the community across all disaster management phases from prevention, preparedness and response to recovery. **Table 6.2** provide a general outline of the advantages and disadvantages of the non-structural mitigation measures considered as part of this study.

Table 6.2 Non-Structural Mitigation Measures

Non-Structural Mitigation Measure	Description	Advantages / Disadvantages
Urban Land Use Planning	Aimed at guiding inappropriate future development away from high risk areas of the floodplain. Division of flood-prone land into appropriate land uses via zoning.	Advantages • Prevents future development or redevelopment in flood prone areas. • Reduced risk to lives, livestock, cropping and structures. Disadvantages • Does not help with existing flood prone development. • Takes time to come into effect.
Agricultural Land Use Planning	Aimed at reducing the velocities, erosion and water levels during flooding. Can incorporate measures such as land levelling, strip cropping, flow spreaders, incorporation of strategic plantations, removal/relocation of fences, lowering of roads, relocation of infrastructure and sediment trapping though grass.	Advantages • Reduces damage to crops. • Reduced risk to lives, livestock, cropping and structures. Disadvantages • A flood of similar magnitude is required to determine whether changes to agricultural land use have altered the flow regime. • Generally expensive

Non-Structural Mitigation Measure	Description	Advantages / Disadvantages
Voluntary Purchase/Buyback	Voluntary Purchase/Buyback is generally results in local government purchasing land and property within high risk flood prone areas and is aimed at removing existing high hazard development from the floodplain. Can be voluntary or resumption type process.	Advantages • Removes businesses, houses and infrastructure away from known existing flood prone areas. Disadvantages • Significant cost (capital and on-going maintenance or land). • Impacts community as residents may move away. • Takes time to come into effect.
Emergency Response Planning	The plan which sets out how a flood emergency will be managed when it occurs including the responsibilities of key agencies, etc. An essential requirement to deal with flood prone areas.	Advantages • Clear responsibilities will ensure effective response. • Reduced risk to lives, livestock and structures that can be moved (such as farm machinery and pumps). Disadvantages • Structural damage can still occur.
Flood Preparedness	Forecasting is the process of predicting the severity of flooding at a particular location. Warning is the process of alerting occupants of flood-prone areas of the immediacy and severity of flood risk and persuading those at risk to take action to prevent losses.	Advantages • Advance notice of flood enables effective response. • Reduced risk to lives, livestock and structures that can be moved (such as farm machinery and pumps). Disadvantages • Structural damage can still occur.

Non-Structural Mitigation Measure	Description	Advantages / Disadvantages
Flood Response	Affected community and agency awareness of what to do and how to do it during the onset of a flood. Covers everything from training agency staff in evacuation, rescue, etc. to having local residents aware of securing property in case of evacuation. Community engagement is a critical part of this.	Advantages • Reduces the consequences of flooding. • Reduced risk to lives, livestock and structures that can be moved (such as farm machinery and pumps). Disadvantages • Structural damage can still occur.
Flood Recovery	Clean-up, welfare, restoration of services and other forms of assistance provided by volunteers and agencies in the aftermath of a flood.	Advantages • Fast recovery leading to a potential lesser economic loss Disadvantages • Structural damage can still occur.

6.3 Preliminary Assessment of Flood Mitigation Measures

A preliminary assessment of the overall effectiveness associated with each potential mitigation option was undertaken for the townships of Monto, Mundubbera and Gayndah. However some consideration for flood mitigation has also been undertaken for rural areas in the North Burnett region as detailed in the following sections. It is noted that this desktop assessment is reliant on available flood information including flood mapping and property inundation data provided by others. As such, no hydrologic or hydraulic analysis has been undertaken as part of this project.

6.3.1 Monto

6.3.1.1. Dam/Detention Basin Option

Description

Preliminary sizing of a detention basin or dam upstream of Monto was undertaken to determine the feasibility of a storage structure as a potential flood management option. For the purpose of this investigation, it was assumed that reducing upstream catchment flows to the 10% AEP storm event flows, would provide immunity to flood affected houses on Mill Street in Monto. The highest recorded flood available for Monto was the 2013 historical event and the 10% AEP flows were estimated based on the flood frequency analysis undertaken for this study (as described in **Section 4.1**). Consequently, the detention basin or dam was sized to reduce the historical 2013 flood event flows to the 10% AEP flows. It is assumed that the required flood storage is available and the dam is therefore 'dry' at the start of the flood event. Due to the location in the upper catchment area of Monal Creek and Three Moon Creek, there would be limited warning and response time to enable water releases from the flood mitigation dam/s at the start of an event. As such, the calculated storage capacity will be used entirely for flood mitigation and cannot be used for water supply purposes.

The results of the preliminary 'high level' detention basin sizing are provided in **Table 6.3**. Based on the estimated volumes, further investigation would be required to determine whether flood storage could be achieved through release of flows from Cania Dam on Three Moon Creek prior to flood event or whether the construction of a dam/s is viable in the Three Moon Creek and or Monal Creek catchments. A hydrological analysis would be required to assess the viability of this option including a more accurate estimate of dam sizing and catchment response to rainfall events.

Based on this preliminary investigation, dedicated flood storage of 28,000 ML would be required to protect 11 houses and 3 businesses in Monto for a flood with a magnitude similar to the 2013 event.

Table 6.3 Preliminary Dam Sizing for Monto

Dam Details for Monto		
Historical Flood	Approximate Flow (m^3/s)	
2013 (FFA Gauge Recording)	845	
Assumed time of concentration (hrs)	12	
Design Storm	Approximate Flow (m^3/s)	
10% AEP (FFA Gauge Recording)	300	
Resultant Volume of Storage	Volume (ML)	
Vs.(2013)	28000	
Possible Dimensions of Dam (Assumed 10m depth)	Length (km)	Width (km)
	1	2.8

The construction of detention basins or dams for flood storage is typically expensive and may require the purchase of agricultural land along Three Moon Creek and or Monal Creek. The cost of dam construction is likely to significantly exceed the benefit in terms of the number of houses and businesses protected. In addition, the dam is not considered to provide any water supply benefits due to the requirement for the flood storage volume to be available at the start of an event.

It should also be noted that potential use of the existing Cania Dam for flood storage may require up to a third of the dam to be drained prior to a flood event, potentially impacting water supply to the area.

Recommendation for Further Consideration

The detailed sizing of a flood storage dam requires intensive modelling that is beyond the scope of this project. As such, it is recommended that this option be further investigated as part of a more detailed flood assessment should Council consider this option to be potentially viable.

6.3.1.2. Backflow Prevention Device Option

Description

Backflow prevention devices are considered to provide little benefit as a standalone mitigation option for Monto. This is due to topography and the impact of regional flooding to properties on Mill Street. Backflow prevention devices are necessary to assist with flood mitigation when combined with a levee for stormwater drainage purposes and have therefore been considered along with the levee option.

Given that backflow prevention devices are considered to have little impact as a standalone mitigation option and are only proposed with the levee options, preliminary cost estimates have not been undertaken for these standalone mitigation devices.

No Recommendation for Further Consideration

Further consideration of backflow prevention devices is not warranted due to the limited benefit provided in a major regional flood event.

6.3.1.3. Channel Improvement Option

Description

Channel widening and clearing are considered to provide an insignificant reduction to peak flood levels at Monto. This is due to the shallow creek bed of both the Monal and Three Moon creeks and the extent of flood plain (over a kilometre wide) at the confluence of the two creeks at Monto.

Removal of known private levees along the Monal Creek and Three Moon Creek flood plain are also considered to provide little benefit during major events (such as the 2013 historical event) as they generally appear to have been constructed to contain the more frequent flows (minor events).

Given that channel improvements are considered to provide little protection as a mitigation measure, a preliminary cost estimate has not been undertaken for this option.

No Recommendation for Further Consideration

Further consideration of channel improvements is not warranted due to the limited benefit provided to Monto in a major regional flood event.

6.3.1.4. Burnett Highway Bridge Upgrade and/or Removal Option

Description

A preliminary assessment has been undertaken to determine the potential flood impact caused by the Burnett Highway embankment across the Three Moon Creek flood plain. The considered mitigation option included the removal of the entire Burnett Highway embankment (approximately 850 m) and replacement of the existing Three Moon Creek Bridge with a bridge spanning the width of the floodplain. Whilst this option may be excessive, it provides an indication of the impacts and potential benefits associated with upgrading the bridge. The results of this preliminary 'high level' assessment are presented in **Figure 6.1**. These results demonstrated that the peak flood level for the 2013 flood event could potentially be reduced by a maximum of 1 m at the bridge and road embankment, with an average flood level reduction of approximately 500 mm within flood affected properties on Mill Street.

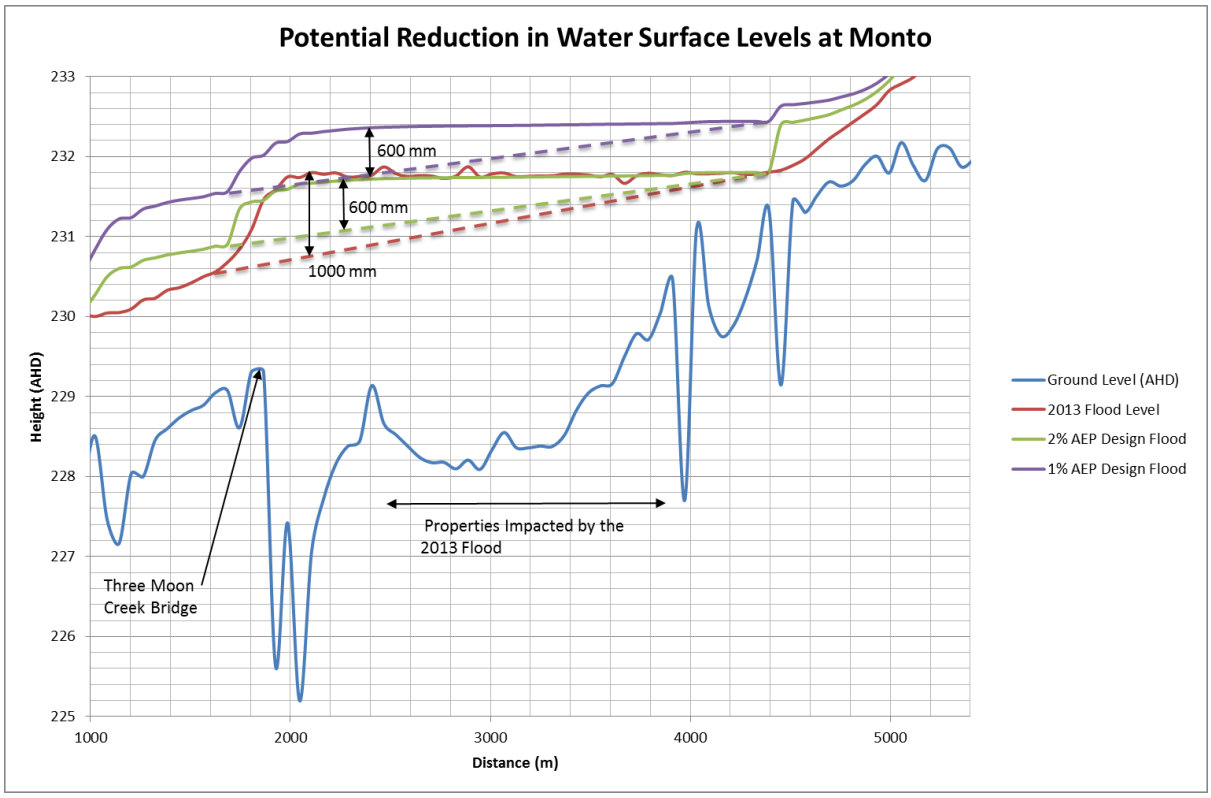


Figure 6.1 Potential Flood Impacts caused by Burnett Highway Bridge over Three Moon Creek

Given that the floor levels of the impacted properties on Mill Street are unknown, the benefit of the crossing upgrade can only be based on the anticipated flood extent. An estimate of the extent of inundation has been undertaken using contour data which has indicated that the removal of the embankment may reduce the flood extent by approximately 4 to 6 m (horizontally) at Mill Street, which is relatively steep terrain. This estimated reduction in flood level and extent is anticipated to have little to no impacts in the reduction of the number of houses inundated during the 2013 flood event or during the estimated 1% and 2% AEP design events.

The cost of removing 850 m of existing highway embankment and replacement of the existing bridge with an 850 m span bridge is considered to be economically unfeasible given the limited benefit to the number of inundated homes. It is also likely that this option could provide a negative impact on previously unaffected properties downstream of the bridge due to the removal of the obstruction and subsequent increase in flow. Given that this option is not considered to be viable, a preliminary cost estimate has not been undertaken.

No Recommendation for Further Consideration

Further consideration of a bridge upgrade is not warranted due to the excessive costs and the limited overall benefit provided to Monto in a major flood event.

6.3.1.5. Bypass Floodways

Description

The Monto township is located on a hill, upstream of the Monal Creek and Three Moon Creek confluence and as such the topography and location of the town is not conducive to a bypass floodway.

A 'high level' assessment of the topography determined that the length, depth and width required for the bypass floodway to be constructed through the hillside behind the township is considerable. In addition to this, the difference in ground levels between the creek bed upstream of the bypass and downstream of the bypass is minor, potentially resulting in little impact on flood levels due to an insignificant change in upstream and downstream slope.

This mitigation measure is considered unviable and therefore a preliminary cost estimate has not been undertaken.

No Recommendation for Further Consideration

Further consideration of a bypass floodway is not warranted for flood mitigation purposes as this option was deemed to be unviable.

6.3.1.6. Levee Option

Description

Preliminary sizing of a levee at Monto was undertaken to determine the feasibility of this structure as a flood protection measure. The levee is proposed to surround properties located on Mill Street to provide protection against Three Moon Creek and Monal Creek floodwaters. It has been estimated that the construction of a levee would potentially provide immunity to ten houses and one business for the historical 2013 and 1% and 2% AEP design events as shown in Error! Reference source not found..

The proposed levee would be a grassed earth embankment with approximately 1 in 3 slopes and a three metre top width. Further levee dimensions are provided in **Table 6.4.**

Table 6.4 Levee Configuration at Monto

Flood Event	Approximate Length (m)	Approximate Height (m) (including 300 mm freeboard)		Approximate Base Width (m)		Volume (m^3)
		Maximum	Average	Maximum	Average	
2013 Historical Event	1,150	3.7	2.8	25	20	38,500
1% AEP Design Event	1,200	4.2	3.2	28	22	51,000
2% AEP Design Event	1,150	3.5	2.6	24	19	35,500
2013 Historical Event	1,150	3.7	2.8	25	20	38,500

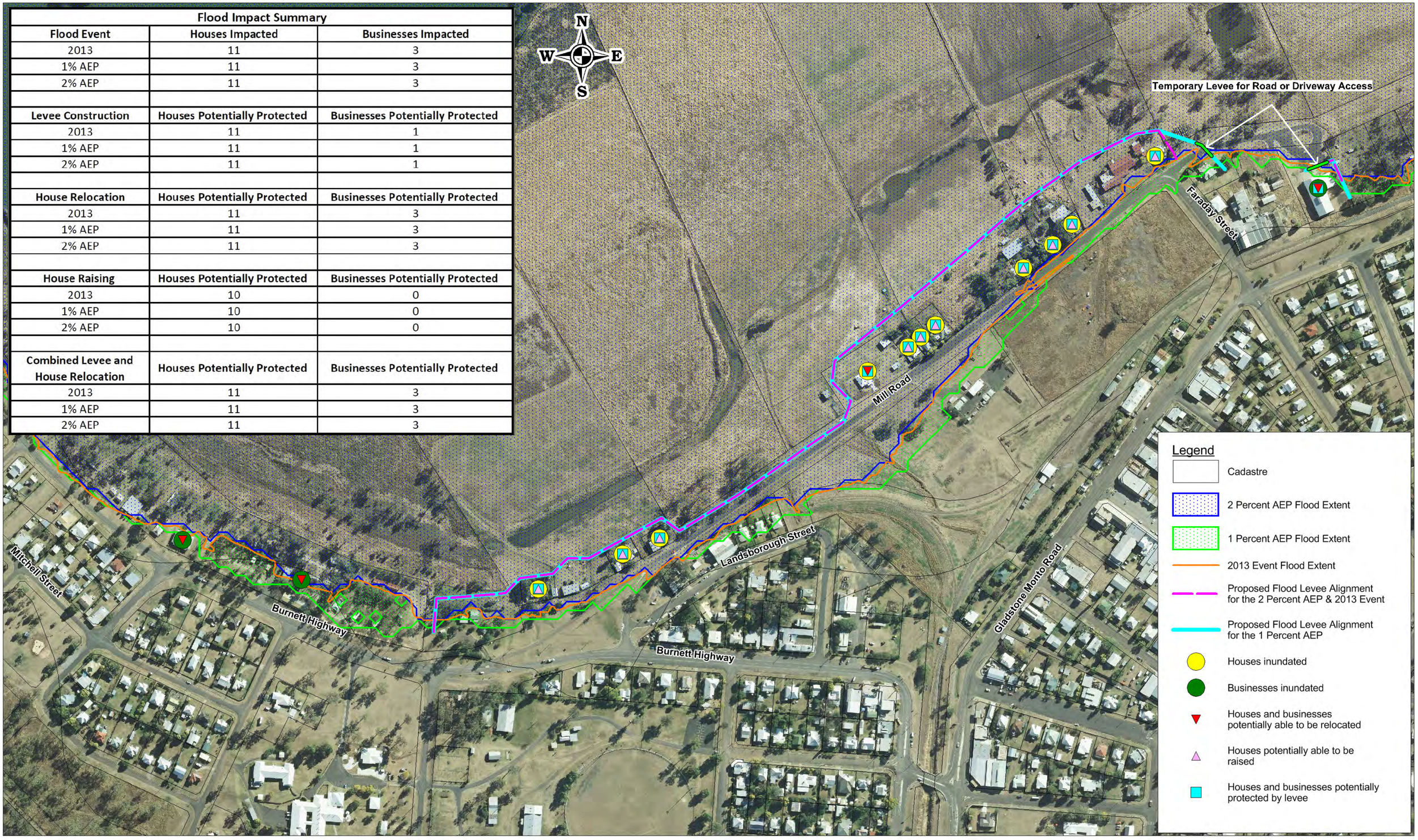
Given the height and location of the proposed levee, a standalone temporary levee (such as a removable proprietary product) is not suitable for the entire levee structure. Therefore it is recommended that temporary levees are utilised in conjunction with permanent levee where road and driveway crossings are located. Other infrastructure associated with the levee includes the use of emergency pumps and the installation of backflow valves to maintain stormwater drainage requirements during localised events whilst preventing backflow during major events.

An emergency management plan would also be required in the instance that the levee is overtopped.

Recommendation for Further Consideration

Based on the desktop assessment, the levee option is estimated to protect eleven (11) of the fourteen (14) houses and businesses recorded as being inundated during the 2013 historical event and likely to be inundated by the 1% and 2% AEP design events. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

Flood Impact Summary		
Flood Event	**Houses Impacted**	**Businesses Impacted**
2013	11	3
1% AEP	11	3
2% AEP	11	3
Levee Construction	**Houses Potentially Protected**	**Businesses Potentially Protected**
2013	11	1
1% AEP	11	1
2% AEP	11	1
House Relocation	**Houses Potentially Protected**	**Businesses Potentially Protected**
2013	11	3
1% AEP	11	3
2% AEP	11	3
House Raising	**Houses Potentially Protected**	**Businesses Potentially Protected**
2013	10	0
1% AEP	10	0
2% AEP	10	0
Combined Levee and House Relocation	**Houses Potentially Protected**	**Businesses Potentially Protected**
2013	11	3
1% AEP	11	3
2% AEP	11	3



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0 80 160

Scale in Metres (1:4,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

North Burnett Flood Mitigation Study

Monto
Potential Mitigation Options

Figure 6.2

Job Number: M28000_001
Revision: 0
Drawn: JNA
Date: 04 Dec 2013

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6.3.1.7. Raising of Houses and Businesses Option

Description

A desktop assessment has been undertaken to determine the viability of raising flood affected houses and businesses in Monto to reduce the damage associated with flooding from Monal Creek and Three Moon Creek. The assessment was based on houses and businesses located within the flood extents of the 2013 and the estimated 2% and 1% AEP design events. It is understood that the businesses vulnerable to flooding are slab on ground and are therefore unable to be raised. The houses able to be raised are illustrated in **Figure 6.2** Due to physical and economic constraints, it was not considered feasible to raise slab on ground houses and businesses and therefore these properties are not considered to be protected by this option.

Slab on ground houses and businesses were excluded from the analysis. It is noted that there are building height restrictions outlined in the Planning Scheme and therefore this provision may require review. It is also noted that some properties presented as being raiseable may not be due to unknown heights, however this has not been considered in this study due to the preliminary nature of the assessment.

Recommendation for Further Consideration

No businesses are considered to receive protection from this option however voluntary house raising is considered to protect ten of the fourteen houses recorded as being inundated by the 2013 historical event and predicted to be inundated by the 1% and 2% AEP design events. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

6.3.1.8. Voluntary House and Business Relocation (i.e. Land Swap)

A desktop assessment has been undertaken to determine the viability of relocating flood affected houses and businesses within Monto to reduce damages associated with flooding from Monal Creek and Three Moon Creek. The assessment was based on houses and businesses located within the extent of inundation of the 1% and 2% AEP design events and the 2013 historical event. Under this option, houses on stumps were considered to be eligible for relocation whilst houses with slab on ground were considered for land swap. This option is believed to be a more extreme course of action to protect houses and businesses, however it has been considered to allow for comparison against other options. **Figure 6.2** illustrates houses and businesses with relocation potential or land swap where house or business relocation is not possible due to construction type.

Recommendation for Further Consideration

The option of voluntary house and business relocation or land swap is considered to protect all fourteen houses and businesses recorded as inundated by the 1% and 2% AEP design and 2013 historical events. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

6.3.1.9. Combined Levee and Business Relocation

Description

A permanent levee structure around the properties located on Mill Street and relocation of businesses impacted by flooding but not protected by the levee has been assessed under the same conditions as described in **Sections 6.2.1.6** and **6.2.1.8**. Houses and businesses protected by the combined levee and business relocation option are provided in **Figure 6.2.**

Recommendation for Further Consideration

The combined levee and business relocation option is considered to protect all fourteen houses and businesses considered to be inundated by the 1% and 2% AEP design and 2013 historical events. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

6.3.1.10. Summary of Flood Impacts and Mitigation Results

A summary of flood impacts and potential benefits associated with the shortlisted options for the 2013 flood event are provided in **Table 6.5**.

Table 6.5 Monto Flood Impact Summary for 2013 Event

Flood Event	Houses Impacted	Businesses Impacted
2013	11	3
Levee Option	Houses Potentially Protected	Businesses Potentially Protected
2013	11	1
House Relocation Option	Houses Potentially Protected	Businesses Potentially Protected
2013	11	3
House Raising Option	Houses Potentially Protected	Businesses Potentially Protected
2013	10	0
Combined Levee and House Relocation	Houses Potentially Protected	Businesses Potentially Protected
2013	11	3

6.3.2 Mundubbera

6.3.2.1. Dam/Detention Basin Option

Description

Preliminary sizing of a detention basin or dam upstream of Mundubbera was undertaken to determine the feasibility of a storage structure as a flood management measure. It is noted that for the purpose of this preliminary investigation and in order to provide a conservative estimate of sizing, it was determined that mitigating upstream catchment flows to the 10% AEP flows would provide potential immunity to the houses. This assumption was based on the QldRA flood mapping. The largest recorded floods available for Mundubbera where the recent 2013 and 2010 historical events and the 10% AEP flows were estimated based on the flood frequency analysis undertaken for this study (refer to **Section 4.1**). Consequently, the detention basin or dam was sized to reduce the historical 2013 and 2010 flood event flows to the 10% AEP flow magnitude. It is assumed that the required flood storage is available at the start of the flood event. It would be preferable that the detention basin or dam is located on the Burnett River however the influence and interaction of the Boyne and Auburn rivers would also need to be taken into account and therefore a more detailed analysis would be required to determine the storage requirements and whether or not this option is viable.

The results of the preliminary detention basin sizing are provided in **Table 6.9**. Based on the required flood storage volume, the size of the dam/s which would be equivalent to approximately four (4) times the Boondoomba Dam storage for the 2013 event and the 2.5 times the Boondoomba Dam storage for the 2010 event.

Table 6.6 Potential Dam Sizing at Mundubbera

Potential Dam Sizing in Mundubbera			
Historical Flood	Approximate Flow (m^3/s)		
2013	12,000		
2010	9,000		
Assumed time of concentration (hrs.)	24		
Design Storm	Approximate Flow (m^3/s)		
10% AEP	4,000		
Resultant Volume of Storage	Volume (ML)		
Vs.(2013)	800,000		
Vs.(2010)	480,000		
Possible Dimensions of Dam (Assumed 10 m depth)	Length (km)	Width (km)	Depth (m)
2013	10	8	10
2010	5	8	10

The construction of a dam for flood storage is generally cost prohibitive and would more than likely require the purchase of a considerable amount of land (approximately 80 km^2) on the Burnett River. The cost of dam construction is likely to greatly outweigh the benefit in terms of the number of houses and businesses protected and the dam is not considered to provide any water supply benefits due to the requirement for the flood storage volume to be available at the start of an event.

It should also be noted that use of the existing Boondooma Dam or the Mundubbera weir for flood storage is considered to have little impact in reducing the severity of the flood event due to the small volume available for flood storage and therefore insignificant attenuation of major flows.

No Recommendation for Further Consideration

The preliminary sizing of the detention basin or dam has identified that the cost of construction and requirement for land would greatly outweigh the benefit in terms of the number of houses and business potentially saved. As such, further consideration and evaluation of this option has not been undertaken.

6.3.2.2. Backflow Prevention Device Option

Description

Backflow prevention devices are considered to provide little benefit as a standalone mitigation option for Mundubbera, due to topography and the impact of regional flooding from the Burnett River and Red Gully. Backflow prevention devices are necessary to

assist with flood mitigation when combined with a levee for stormwater drainage purposes and have therefore been considered along with the levee option.

Given that backflow prevention devices are considered to have little impact as a standalone mitigation option and are only proposed with the levee options, preliminary cost estimates have not been undertaken for these standalone mitigation devices.

No Recommendation for Further Consideration

Further consideration and evaluation of backflow prevention devices is not warranted due to the limited benefit provided in a major regional flood event.

6.3.2.3. Channel Improvement Option

Description

A preliminary 'high level' assessment of channel improvements such as dredging and vegetation removal was undertaken for the Burnett River at Mundubbera. It was assumed that vegetation removal and dredging was able to lower the river by a maximum of 2 m as illustrated in **Figure 6.3.** The results of this preliminary assessment indicate that dredging of the creek bed would provide negligible increase of flow area or flood storage within the river. A maximum increase in volume of approximately 6% was estimated for the 2% AEP design event.

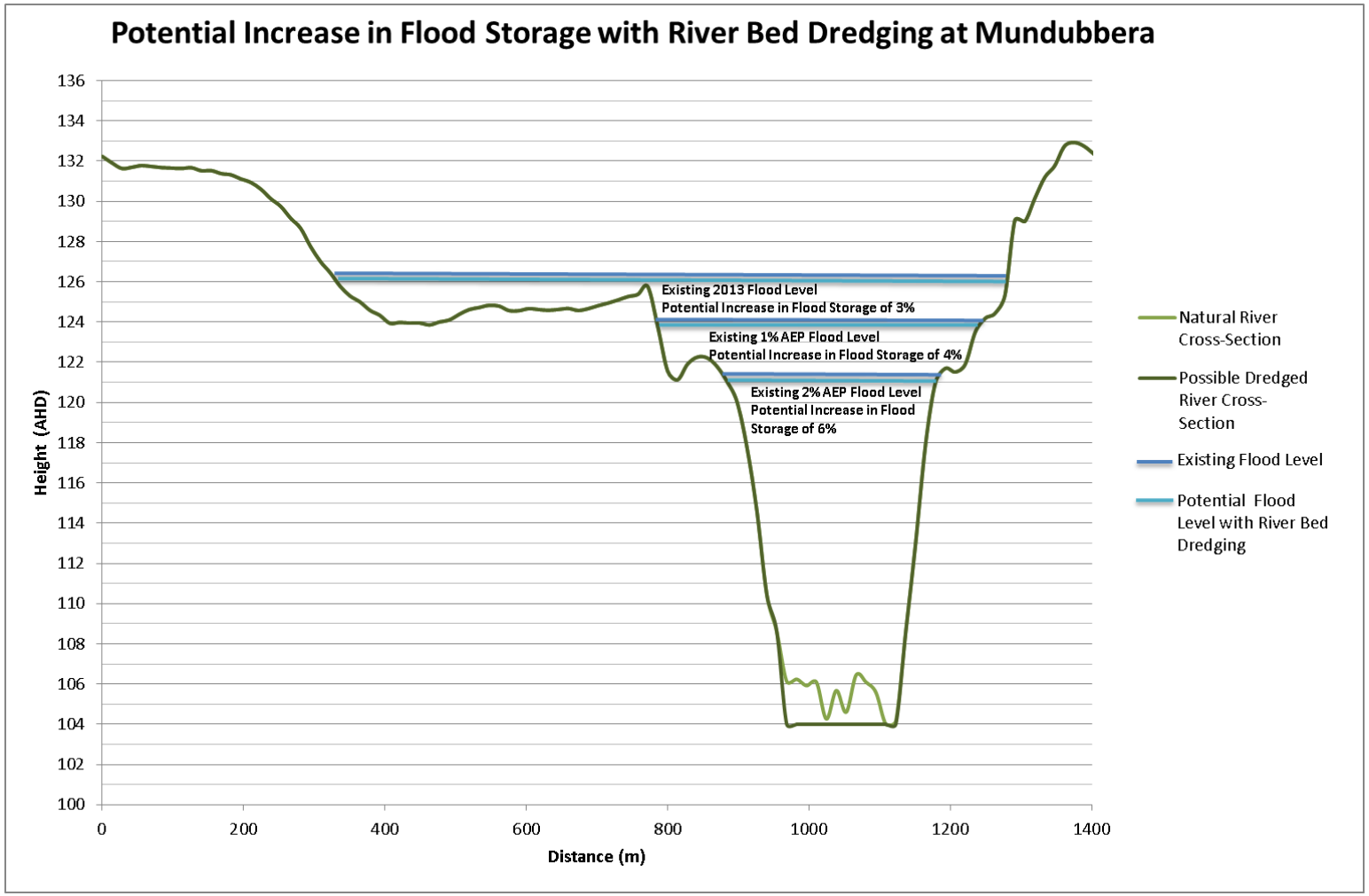


Figure 6.3 Potential Increase in Flood Storage with River Bed Dredging at Mundubbera

Depending on the profile and magnitude of the waterway, dredging and vegetation removal can be a viable and cost effective option; however in this instance the increased volume provided by dredging is insignificant for major events and therefore the benefits in terms of flood level reduction and the number of houses and businesses protected is considered to be minor. It is also noted that unfavourable impacts may occur as a result of dredging and vegetation removal including loss in biodiversity and increased flow velocities, subsequently causing erosion of the river bed and deposition of sediment elsewhere. It should also be noted that dredging and vegetation removal would be an ongoing process as it is likely that sediment would be redeposited during the following flood event.

Given that channel improvements are considered to provide little protection as a mitigation measure, a preliminary cost estimate has not been undertaken for this option.

No Recommendation for Further Consideration

Further consideration of channel improvements is not warranted due to the limited benefit provided to Mundubbera in a major flood event.

6.3.2.4. Burnett River Bridge Upgrade Option

Description

This option included raising the Dimitrios Bridge across the Burnett River flood plain. A preliminary assessment was undertaken to determine the feasibility of this option as a flood protection measure. Initial assessment of the surveyed 2013 historical flood levels indicated that there was little difference in the flood level upstream and downstream of the bridge. It should be noted that design flood levels sourced from QldRA also show no difference, however this may be due to the bridge crossing not being considered in the QldRA mapping.

The surveyed 2013 peak flood levels indicate that the bridge has little impact on flood levels during this event due to the large expanse of floodwater across the Burnett River flood plain. In order to determine the impact of the bridge during smaller events, detailed hydraulic analysis would be required. It should be noted that during the smaller events (i.e. 20% AEP), the bridge is likely to cause a greater obstruction and result in increased flood levels upstream and a reduction of flood levels downstream of the bridge.

No Recommendation for Further Consideration

For the purpose of this study, this option was not considered to be viable due to the anticipated excessive costs of upgrading the bridge and the minor benefit that the option is predicted to provide during major events.

Accurate determination of whether the existing bridge structure would cause an impact on flood levels for a range of events generally requires detailed hydraulic modelling that is beyond the data limitations and scope of this project. As such, further evaluation of this

option has not been undertaken and it is recommended that a more detailed flood assessment be undertaken should Council deem this option to warrant further evaluation.

6.3.2.5. Bypass Floodways

Description

A potential location for a bypass floodway for Mundubbera was identified at Boynewood. The bypass floodway would commence upstream of Mundubbera and discharge downstream of the cemetery. The approximate length of the bypass floodway would be approximately 3 km.

A 'high level' assessment of the topography at this location determined that the length, depth and width required for the bypass floodway was considerable. In addition to this, the difference in creek bed level upstream of the bypass and the creek bed level downstream of the bypass is minor, potentially resulting in little impact on flood levels due to an insignificant change in upstream and downstream slope.

This mitigation measure is considered unviable and therefore a preliminary cost estimate has not been undertaken.

No Recommendation for Further Consideration

Further consideration of a bypass floodway for Mundubbera is not warranted for flood mitigation purposes as this option was deemed to be unviable.

6.3.2.6. Levee Option

Description

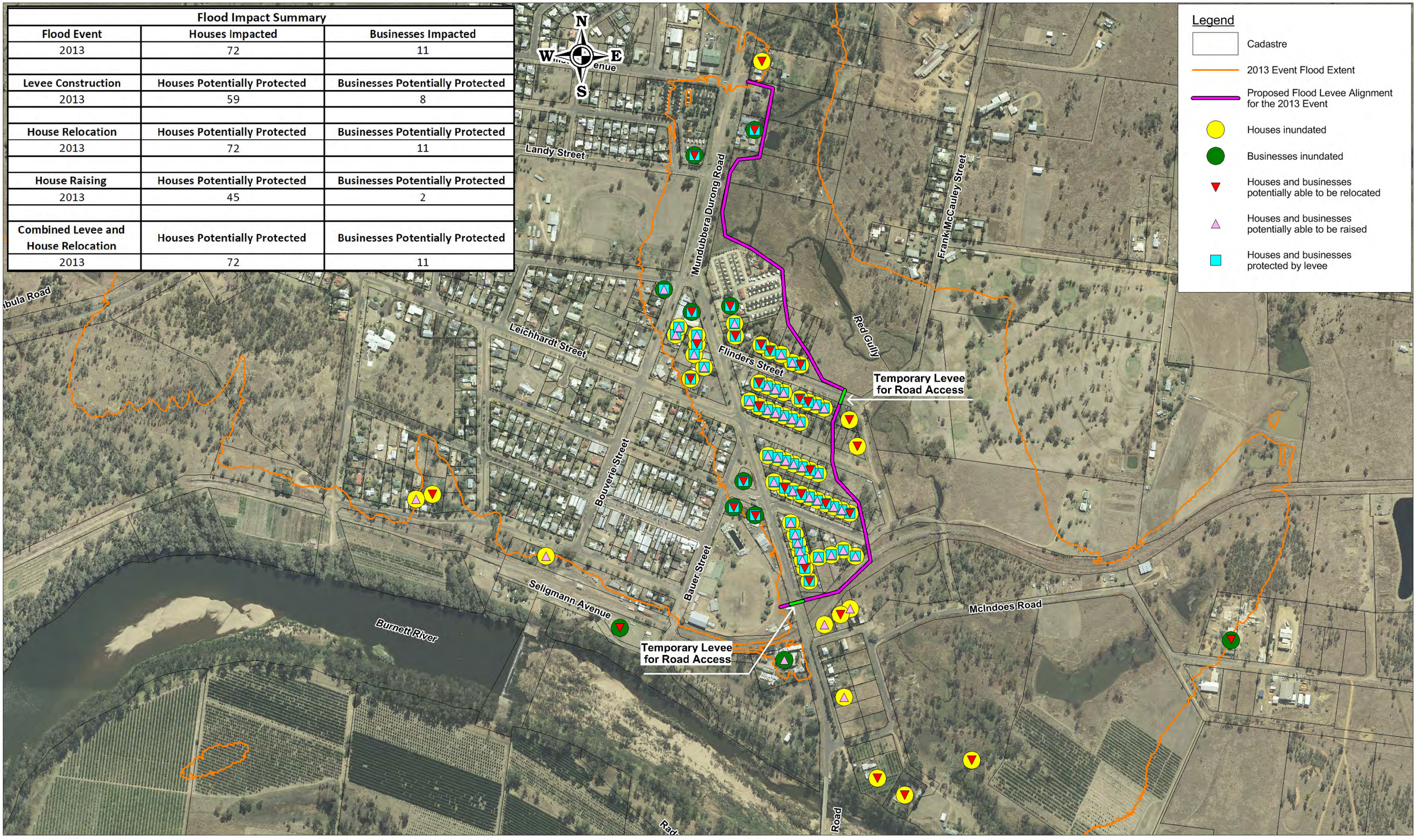
A preliminary assessment has been undertaken for two levee alignment options around properties affected by flooding from Red Gully.

As illustrated in **Figure 6.4** to **Figure 6.6**, Option 1 levee has been estimated to provide protection for up to 59 houses and 8 businesses for the 2013 historical event. The Option 2 levee alignment would provide protection to the existing sewage pumping station and up to 61 houses and 8 businesses for the 2013 historical event as presented in **Figure 6.7** to **Figure 6.9**. Both levees options are proposed to be grassed earth embankments of 1 in 3 slopes and a three (3) metre top width. Further levee dimensions for Option 1 and Option 2 are provided in **Table's 6.6** and **6.7** respectively.

Given the height and location of the proposed levee, a temporary levee structure (such as a relocatable proprietary product) is not suitable for the entire levee. It is recommended that temporary levees are utilised where road and driveway crossings are located. Other infrastructure associated with the levee includes the use of emergency pumps and the installation of backflow valves to maintain stormwater drainage requirements during localised events whilst preventing backflow during major events.

An emergency management plan would also be required in the instance that the levee is overtopped.

Flood Impact Summary		
Flood Event	**Houses Impacted**	**Businesses Impacted**
2013	72	11
Levee Construction	**Houses Potentially Protected**	**Businesses Potentially Protected**
2013	59	8
House Relocation	**Houses Potentially Protected**	**Businesses Potentially Protected**
2013	72	11
House Raising	**Houses Potentially Protected**	**Businesses Potentially Protected**
2013	45	2
Combined Levee and House Relocation	**Houses Potentially Protected**	**Businesses Potentially Protected**
2013	72	11



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Scale in Metres (1:8,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

North Burnett Flood Mitigation Study

Figure 6.4

Mundubbera Mitigation Option 1 for 2013 Event

Job Number: M28000_001
Revision: 0
Drawn: JNA
Date: 04 Dec 2013

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Flood Impact Summary		
Flood Event	**Houses Impacted**	**Businesses Impacted**
1% AEP Event	61	6
Levee Construction	**Houses Potentially Saved**	**Businesses Potentially Protected**
1% AEP Event	51	4
House Relocation	**Houses Potentially Saved**	**Businesses Potentially Protected**
1% AEP Event	61	6
House Raising	**Houses Potentially Saved**	**Businesses Potentially Protected**
1% AEP Event	36	0
Combined Levee, House Relocation and House Raising	**Houses Potentially Saved**	**Businesses Potentially Protected**
1% AEP Event	61	6

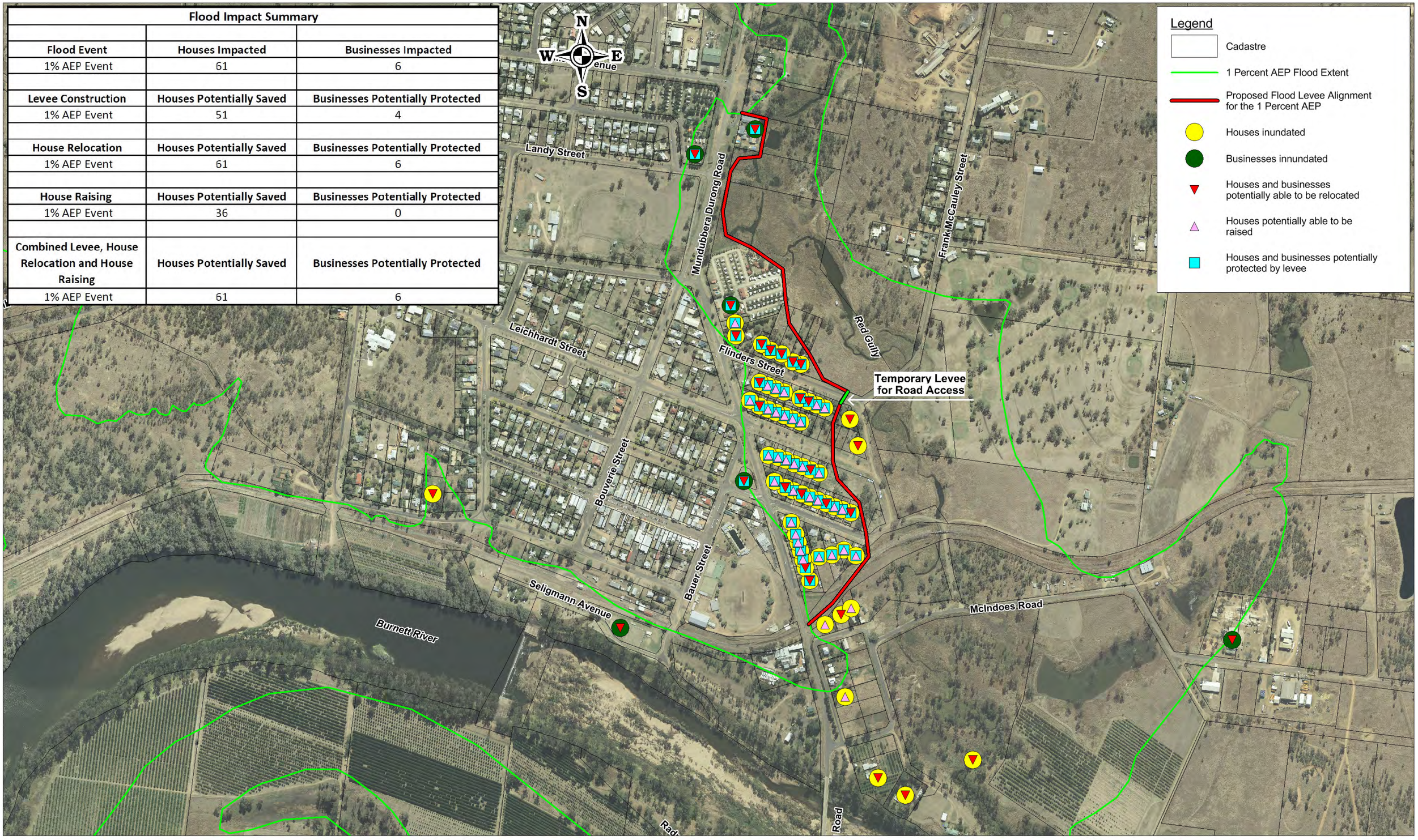

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Figure 6.5

Mundubbera Mitigation Option 1 for 1% AEP Event

Job Number: M28000_001
Revision: 0
Drawn: JNA
Date: 04 Dec 2013

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Flood Impact Summary		
Flood Event	**Houses Impacted**	**Businesses Impacted**
2% AEP Event	32	1
Levee Construction	**Houses Potentially Saved**	**Businesses Potentially Protected**
2% AEP Event	24	0
House Relocation	**Houses Potentially Saved**	**Businesses Potentially Protected**
2% AEP Event	32	1
House Raising	**Houses Potentially Saved**	**Businesses Potentially Protected**
2% AEP Event	19	0
Combined Levee, House Relocation and House Raising	**Houses Potentially Saved**	**Businesses Potentially Protected**
2% AEP Event	32	1

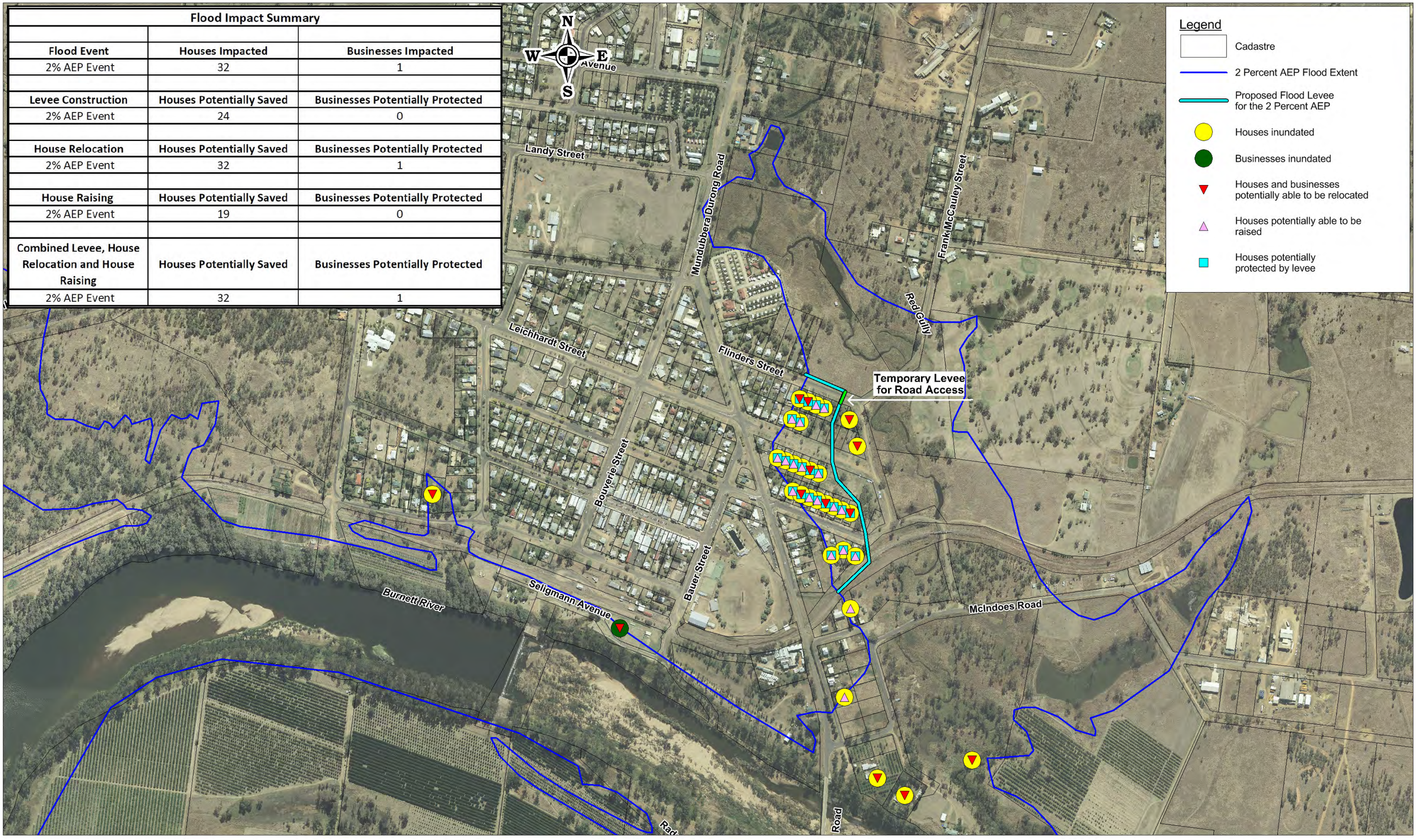

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Figure 6.6

Mundubbera Mitigation Option 1 for 2% AEP Event

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Date: 04 Dec 2013

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Flood Impact Summary		
Flood Event	Houses Impacted	Businesses Impacted
2013	72	11
Levee Construction	Houses Potentially Protected	Businesses Potentially Protected
2013	61	8
House Relocation	Houses Potentially Protected	Businesses Potentially Protected
2013	72	11
House Raising	Houses Potentially Protected	Businesses Potentially Protected
2013	45	2
Combined Levee and House Relocation	Houses Potentially Protected	Businesses Potentially Protected
2013	72	11

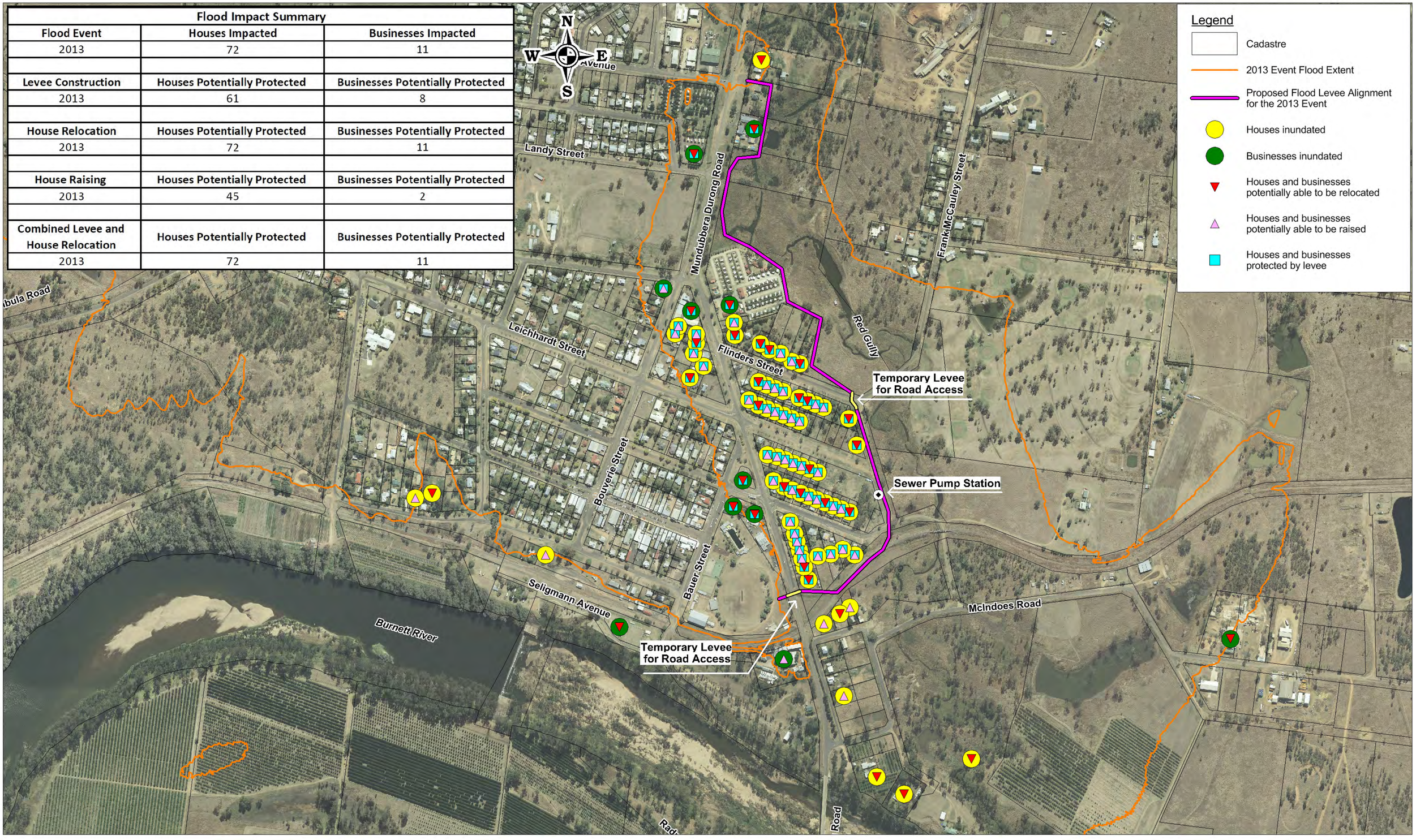

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Figure 6.7

Mundubbera Mitigation Option 2 for 2013 Event

Job Number: M28000_001
Revision: 0
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Flood Impact Summary		
Flood Event	**Houses Impacted**	**Businesses Impacted**
1% AEP Event	61	6
Levee Construction	**Houses Potentially Saved**	**Businesses Potentially Protected**
1% AEP Event	53	4
House Relocation	**Houses Potentially Saved**	**Businesses Potentially Protected**
1% AEP Event	61	6
House Raising	**Houses Potentially Saved**	**Businesses Potentially Protected**
1% AEP Event	36	0
Combined Levee, House Relocation and House Raising	**Houses Potentially Saved**	**Businesses Potentially Protected**
1% AEP Event	61	6

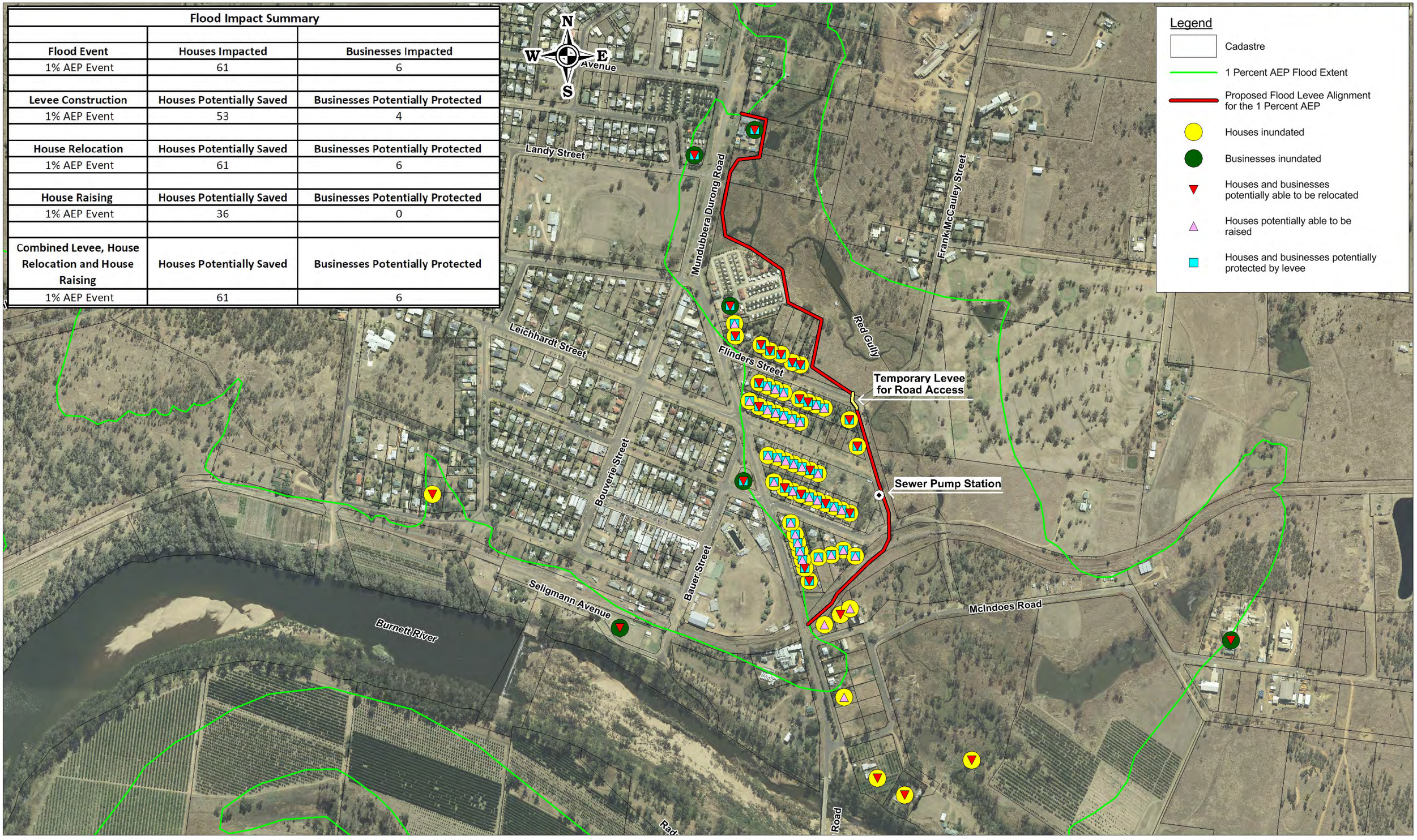

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Figure 6.8

Mundubbera Mitigation Option 2 for 1% AEP Event

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Flood Impact Summary		
Flood Event	**Houses Impacted**	**Businesses Impacted**
2% AEP Event	32	1
Levee Construction	**Houses Potentially Saved**	**Businesses Potentially Protected**
2% AEP Event	26	0
House Relocation	**Houses Potentially Saved**	**Businesses Potentially Protected**
2% AEP Event	32	1
House Raising	**Houses Potentially Saved**	**Businesses Potentially Protected**
2% AEP Event	19	0
Combined Levee, House Relocation and House Raising	**Houses Potentially Saved**	**Businesses Potentially Protected**
2% AEP Event	32	1

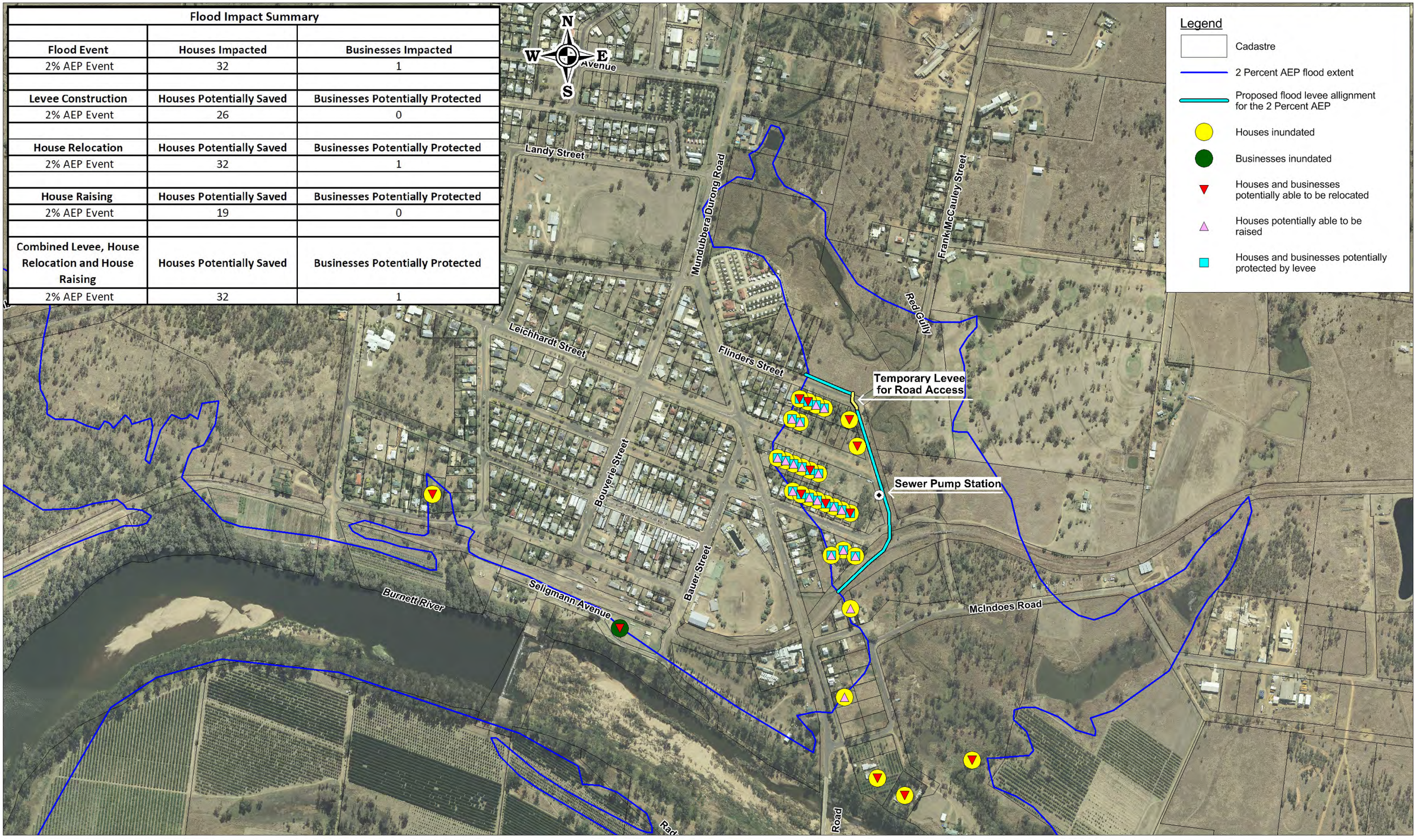

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Figure 6.9

Mundubbera Mitigation Option 2 for 2% AEP Event

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Table 6.7 Levee Option 1 Configuration at Mundubbera

Flood Event	Approximate Length (m)	Approximate Height (m) (including 600 mm freeboard)		Approximate Base Width (m)		Volume (m^3)
		Maximum	Average	Maximum	Average	
2013 Historical Event	1631	8	4.7	51	31	146,500
1% AEP Design Event	1475	6.8	3.8	44	26	92,000
2% AEP Design Event	603	3.9	2.7	27	19	20,500

Table 6.8 Levee Option 2 Configuration at Mundubbera

Flood Event	Approximate Length (m)	Approximate Height (m) (including 600 mm freeboard)		Approximate Base Width (m)		Volume (m^3)
		Maximum	Average	Maximum	Average	
2013 Historical Event	1,150	3.7	2.8	25	20	38,500
1% AEP Design Event	1,200	4.2	3.2	28	22	51,000
2% AEP Design Event	1,150	3.5	2.6	24	19	35,500

Recommendation for Further Consideration

Levee Option 1 is estimated to provide protection for up to 67 of the 83 houses and businesses recorded as experiencing inundation during the 2013 historical event whilst Option 2 alignment would provide protection to the existing sewage pumping station and up to 69 of the 83 houses and businesses recorded as experiencing inundation in the 2013 historical event. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

6.3.2.7. Raising of Houses and Businesses Option

A desktop assessment has been undertaken to determine the viability of raising flood affected houses and businesses within Mundubbera to reduce damages associated with flooding from the Burnett River and Red Gully. The assessment was based on houses and businesses located within the flood extents of the 2013 and predicted 2% and 1% AEP design events. It is understood that the businesses vulnerable to flooding are slab on ground and are therefore unable to be raised. The houses able to be raised are illustrated in **Figure 6.4** to **Figure 6.6**. Due to physical and economic constraints, it was not considered feasible to raise slab on ground houses and businesses and therefore these properties are not considered to be protected by this option.

It is noted that there are building height restrictions outlined in the Planning Scheme and therefore this provision may require review. It is also noted that some properties presented as being raiseable may not be due to unpractical heights, however this has not been considered in this study due to the preliminary nature of the assessment.

Recommendation for Further Investigation

The option of voluntary house and business raising is considered to provide protection for up to 47 of the 83 houses and businesses recorded as experiencing inundated during the 2013 historical event. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

6.3.2.8. Voluntary House Relocation or Land Swap Option

A desktop assessment has been undertaken to determine the viability of the relocation of flood affected houses and businesses within Mundubbera to reduce damages associated with flooding from Burnett River and Red Gully. The assessment was based on houses and businesses located within the extent of inundation of the 1% and 2% AEP design events and the 2013 historical event. Under this option, houses on stumps were considered to be eligible for relocation whilst houses with slab on ground were considered for land swap. This option is believed to be a more extreme course of action to protect houses and businesses, however it has been considered to allow for comparison against other options. **Figure 6.4** to **Figure 6.6** illustrates houses and businesses with relocation potential or land swap where house or business relocation is not possible due to construction type.

Recommendation for Further Investigation

The option of voluntary house and business relocation or land swap is considered to protect all 83 houses and businesses recorded as being inundated by 2013 historical event. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

6.3.2.9. Combined Levee and House and Business Raising or Relocation Option

Description

A levee around flood affected properties located to the east of Mundubbera-Burong Road and the potential raising or relocation of houses and businesses impacted by flooding but not protected by the levee has been assessed under the same conditions as described in **Sections 6.3.2.6, 6.3.2.7** and **6.3.2.8**. Houses and businesses protected by the combined levee and raising or relocation option is provided in Error! Reference source not found. to **igure 6.6.**

Recommendation for Further Consideration

The combined levee and raising or relocation option is considered to provide protection for all 83 houses and businesses recorded as experiencing inundation during the 2013 historical event. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

6.3.2.10. Summary of Flood Impacts and Mitigation Results

A summary of flood impacts and potential benefits associated with the shortlisted options for the 2013 flood event are provided in **Table 6.9.**

Table 6.9 Mundubbera Flood Impact Summary for 2013 Event

Mundubbera Flood Impact Summary for 2013 Event		
Flood Event	Houses Impacted	Businesses Impacted
2013	72	11
Levee Option2	Houses Potentially Protected	Businesses Potentially Protected
2013	61	8
House Relocation Option	Houses Potentially Protected	Businesses Potentially Protected
2013	72	11
House Raising Option	Houses Potentially Protected	Businesses Potentially Protected
2013	45	2
Combined Levee and House Relocation Option	Houses Potentially Protected	Businesses Potentially Protected
2013	72	11

6.3.3 Gayndah

6.3.3.1. Dam/Detention Basin Option

Description

Preliminary sizing of a detention basin or dam upstream of Mundubbera was undertaken to determine the feasibility of a storage structure as a flood management measure. Given the proximity of Mundubbera and Gayndah within the overall catchment, it has been assumed that there would be similar storage requirements for Gayndah and it is noted that the indicative estimates represent the total storage requirements to provide protection to both towns. It is also noted that the flood storage estimates have not included inflows from the Boyne and Auburn rivers and are therefore indicative only.

For the purpose of this preliminary investigation and in order to provide a conservative estimate of sizing, it was determined that mitigating upstream catchment flows to the 10% AEP flows would provide potential immunity to the houses. This assumption was based on the QldRA flood mapping.

Whilst it is likely that a detention basin dam upstream of Mundubbera would also benefit Gayndah, a hydrological analysis of the catchment would be required to assess the viability of this option including a more accurate estimation of dam sizing and storage requirements.

provides a summary of the indicative dam sizing for the 2013 and 2010 historical events as outlined in **Section 6.3.2.1**.

Table 6.10 Indicative Dam Area at Gayndah

Indicative Dam Area at Gayndah			
Possible Dimensions of Dam (Assumed 10m depth)	Length (km)	Width (km)	Depth (m)
Reduction of 2013 historical peak flow to the 10% AEP design peak flow	10	8	10
Reduction of 2010 historical peak flow to the 10% AEP design peak flow	5	8	10

The construction of a dam for flood storage is generally cost prohibitive and would more than likely require the purchase of a considerable amount of land (approximately 80 km^2) on the Burnett River. The cost of dam construction is likely to greatly outweigh the benefit in terms of the number of houses and businesses protected and the dam is not considered to provide any water supply benefits due to the requirement for the flood storage volume to be available at the start of an event.

It should be noted that the utilisation of the existing weirs for flood storage is considered to have little impact in reducing the severity of the flood event due to the small volume available for flood storage and therefore insignificant attenuation of major flows.

No Recommendation for Further Consideration

The preliminary sizing of the detention basin or dam has identified that the cost of construction and requirement for land greatly outweigh the benefit in terms of the number of houses and business potentially saved in Gayndah. As such, further consideration and evaluation of this option has not been undertaken.

6.3.3.2. Backflow Prevention Device Option

Description

Backflow prevention devices are considered to provide little benefit as a standalone mitigation option for Gayndah, due to topography and the impact of regional flooding from the Burnett River, Oaky Creek and Sauers Gully. Backflow prevention devices are necessary to assist with flood mitigation when combined with a levee for stormwater drainage purposes and have therefore been considered along with the levee option.

Given that backflow prevention devices are considered to have little impact as a standalone mitigation option and are only proposed with the levee options, preliminary cost estimates have not been undertaken for these standalone mitigation devices.

No Recommendation for Further Consideration

Further consideration and evaluation of backflow prevention devices as a standalone measure for Gayndah is not warranted due to the limited benefit provided in a major regional flood event.

6.3.3.3. Channel Improvement Option

Description

A preliminary assessment of channel improvements such as dredging and vegetation removal within the river reaches was undertaken for the Burnett River at Gayndah. It was assumed that vegetation removal and dredging was able to lower the river bed by a maximum of 1 m as demonstrated in **Figure 6.10**. The results of this preliminary investigation indicate that dredging of the creek bed is estimated to provide an insignificant increase of flood storage (a maximum of approximately 2% during the 2% AEP design event) and is therefore unlikely to provide a significant reduction in flood level.

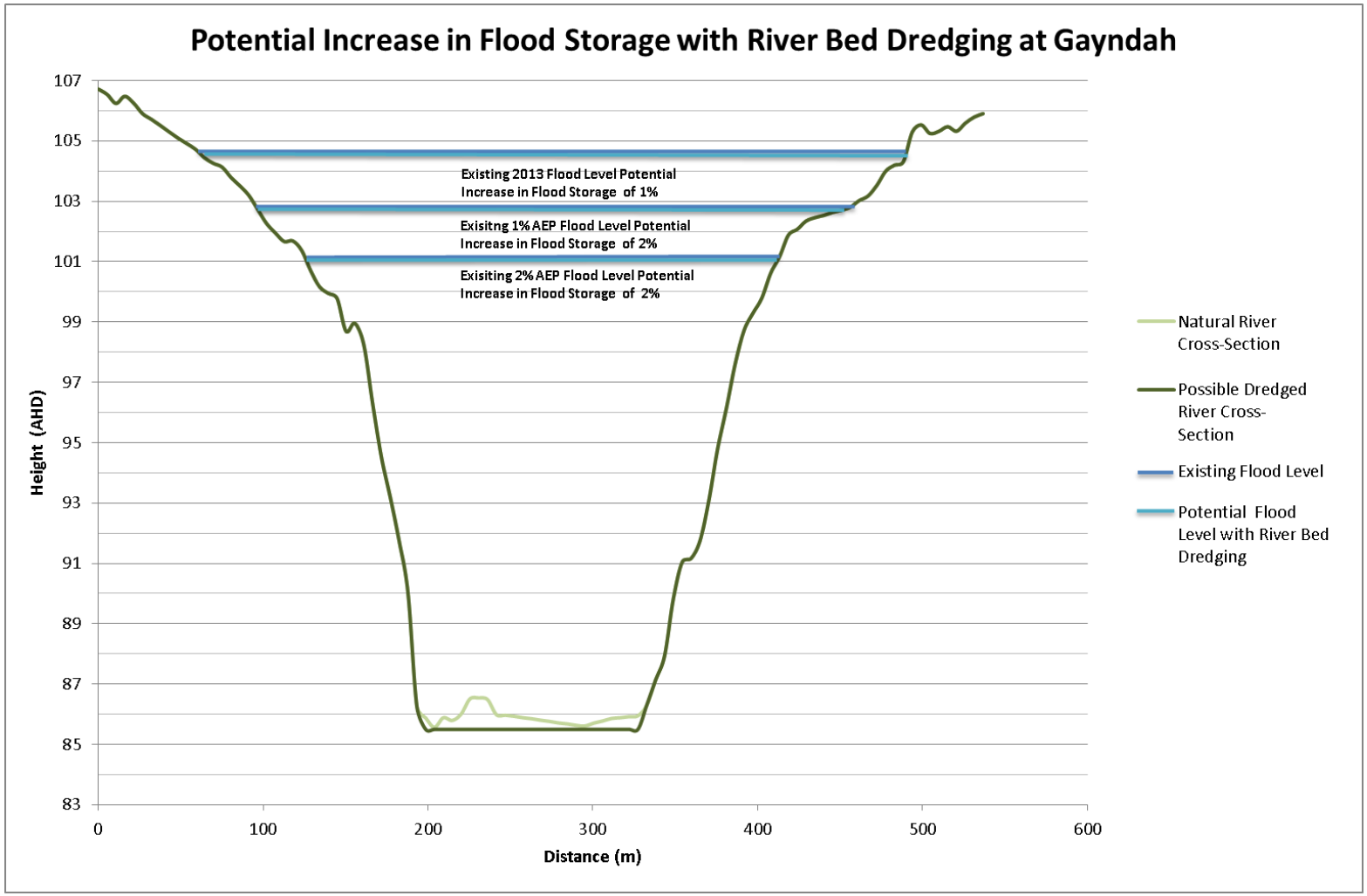


Figure 6.10 Potential Increase in Flood Storage with River Bed Dredging at Gayndah

Depending on the profile and magnitude of the waterway, dredging and vegetation removal can be a viable and cost effective option; however in this instance the increased volume provided by dredging is insignificant for major events and therefore the benefits in terms of flood level reduction and the number of houses and businesses protected is considered to be minor. It is also noted that unfavourable impacts may occur as a result of dredging and vegetation removal including loss in biodiversity and increased flow velocities, subsequently causing erosion of the river bed and deposition of sediment elsewhere. It should also be noted that dredging and vegetation removal would be an ongoing process as it is likely that sediment would be redeposited during the following flood event.

Given that channel improvements are considered to provide little protection as a mitigation measure, a preliminary cost estimate has not been undertaken for this option.

No Recommendation for Further Consideration

Further consideration of channel improvements is not warranted due to the limited benefit provided to Gayndah in a major flood event.

6.3.3.4. Burnett River Bridge Upgrade Option

This option included raising the Les Baker Bridge across the Burnett River flood plain. A preliminary assessment was undertaken to determine the feasibility of this option as a flood protection measure. Initial assessment of the surveyed 2013 historical flood levels indicated that there was little difference in the flood level upstream and downstream of the bridge. It should be noted that design flood levels sourced from flood modelling previously undertaken on behalf of NBRC also show no difference, however it is noted that the bridge crossing was not included in the 2D hydraulic modelling.

The surveyed 2013 peak flood levels indicate that the bridge has little impact on flood levels during this event due to the large expanse of floodwater across the Burnett River flood plain. In order to determine the impact of the bridge during smaller events, detailed hydraulic analysis would be required. It should be noted that during the smaller events (i.e. 20% AEP), the bridge is likely to cause a greater obstruction and result in increased flood levels upstream and a reduction of flood levels downstream of the bridge.

No Recommendation for Further Consideration

For the purpose of this study, this option was not considered to be viable due to the anticipated excessive costs of upgrading the bridge and the minor benefit that the option is predicted to provide during major events.

Accurate determination of whether the existing bridge structure would cause an impact on flood levels for a range of events generally requires detailed hydraulic modelling that is beyond the data limitations and scope of this project. As such, further evaluation of this option has not been undertaken and it is recommended that a more detailed flood assessment be undertaken should Council deem this option to warrant further evaluation.

6.3.3.5. Bypass Floodways

Description

A potential location identified for a bypass floodway for Gayndah was identified at the Gayndah Airport. The bypass floodway would begin upstream of the Gayndah township at Claude Wharton Weir Park and discharge downstream at a location opposite Beronne Road. The approximate length of the bypass floodway would be 4 km.

A 'high level' assessment of the topography at this location determined that the length, depth and width required for the bypass floodway was considerable. In addition to this, the difference in creek bed level upstream of the bypass and the creek bed level downstream of the bypass is minor, potentially resulting in little impact on flood levels due to an insignificant change in upstream and downstream slope.

This mitigation measure is considered unviable and therefore a preliminary cost estimate has not been undertaken.

No Recommendation for Further Consideration

Further consideration of a bypass floodway for Gayndah is not warranted for flood mitigation purposes as this option was deemed to be unviable.

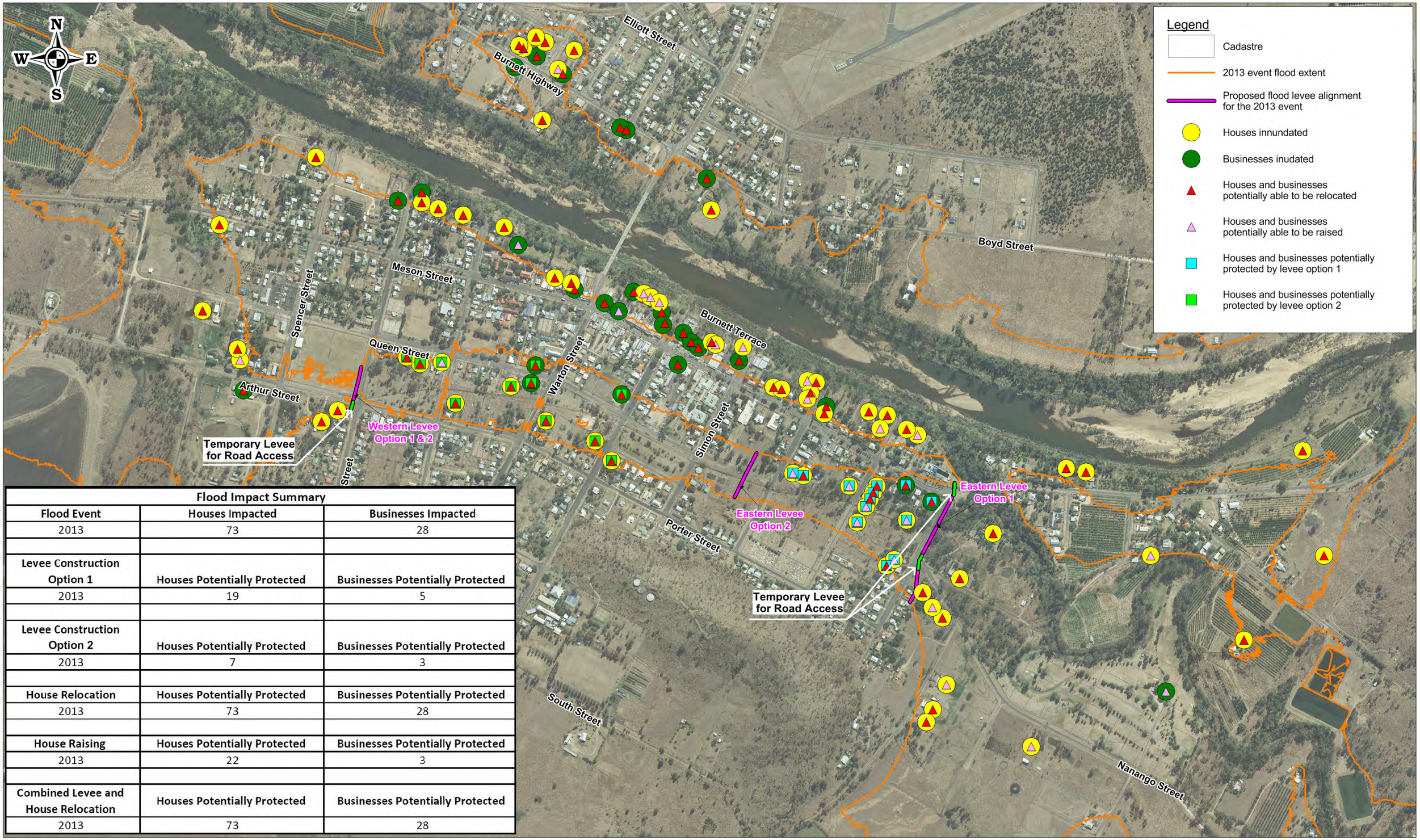
6.3.3.6. Levee Option

Description

A preliminary assessment has been undertaken for a number of levee options aimed at protecting flood affected houses and businesses in Gayndah. The levees would specifically provide protection to properties between Barrow Street and Bamboo Street from floodwaters backing up from Oaky Creek and Sauers Gully.

Two levee options have been developed to provide protection from the 2013 historical event as shown in **Figure 6.11**. Levees have also been identified to protect houses and businesses from over floor inundation during the 1% and 2% AEP design events, as shown in **Figure 6.12** and **Figure 6.13**. All proposed levees would be grassed earth embankments with 1 in 3 slopes and a 3 metre top width. Further details of the levee configuration are provided in **Table 6.9**.

Given the height and location of the proposed levees, a temporary levee (such as a relocatable proprietary product) is generally not suitable for the entire levee structure. However, a temporary levee for the western levee (Option's 1 and 2) may be suitable due to the low height and short length requirement. It is also proposed that temporary levees be utilised where road and driveway crossings are located. Other infrastructure associated with the levee includes the use of emergency pumps and the installation of backflow valves to maintain stormwater drainage requirements during localised events whilst preventing backflow during major events.



Flood Impact Summary		
Flood Event	Houses Impacted	Businesses Impacted
2013	73	28
Levee Construction Option 1	Houses Potentially Protected	Businesses Potentially Protected
2013	19	5
Levee Construction Option 2	Houses Potentially Protected	Businesses Potentially Protected
2013	7	3
House Relocation	Houses Potentially Protected	Businesses Potentially Protected
2013	73	28
House Raising	Houses Potentially Protected	Businesses Potentially Protected
2013	22	3
Combined Levee and House Relocation	Houses Potentially Protected	Businesses Potentially Protected
2013	73	28

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Flood Mitigation Study

Figure 6.11

Gayndah Mitigation Option for 2013 Event

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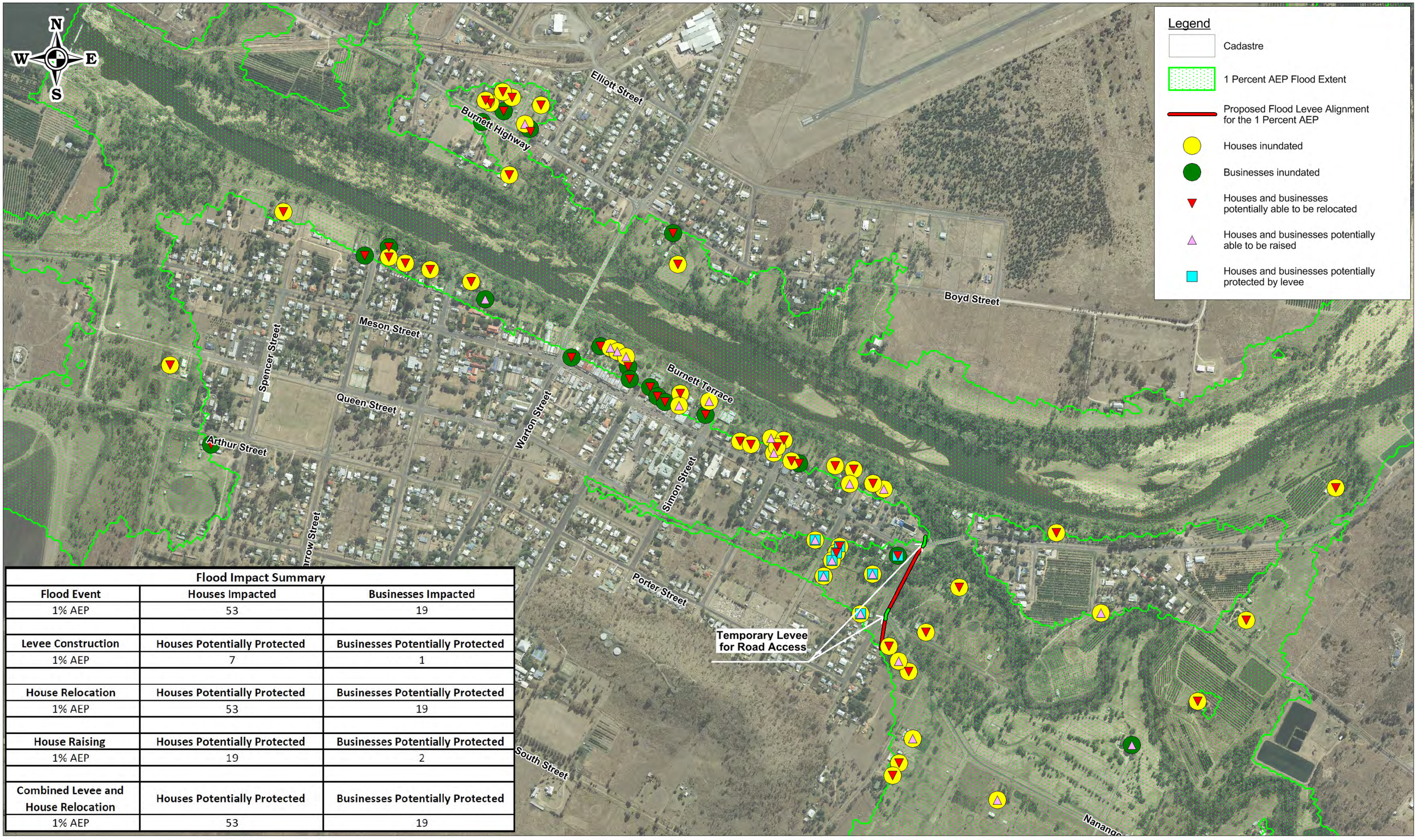

Flood Impact Summary		
Flood Event	**Houses Impacted**	**Businesses Impacted**
1% AEP	53	19
Levee Construction	**Houses Potentially Protected**	**Businesses Potentially Protected**
1% AEP	7	1
House Relocation	**Houses Potentially Protected**	**Businesses Potentially Protected**
1% AEP	53	19
House Raising	**Houses Potentially Protected**	**Businesses Potentially Protected**
1% AEP	19	2
Combined Levee and House Relocation	**Houses Potentially Protected**	**Businesses Potentially Protected**
1% AEP	53	19

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Figure 6.12

Gayndah Mitigation Option for 1% AEP Event

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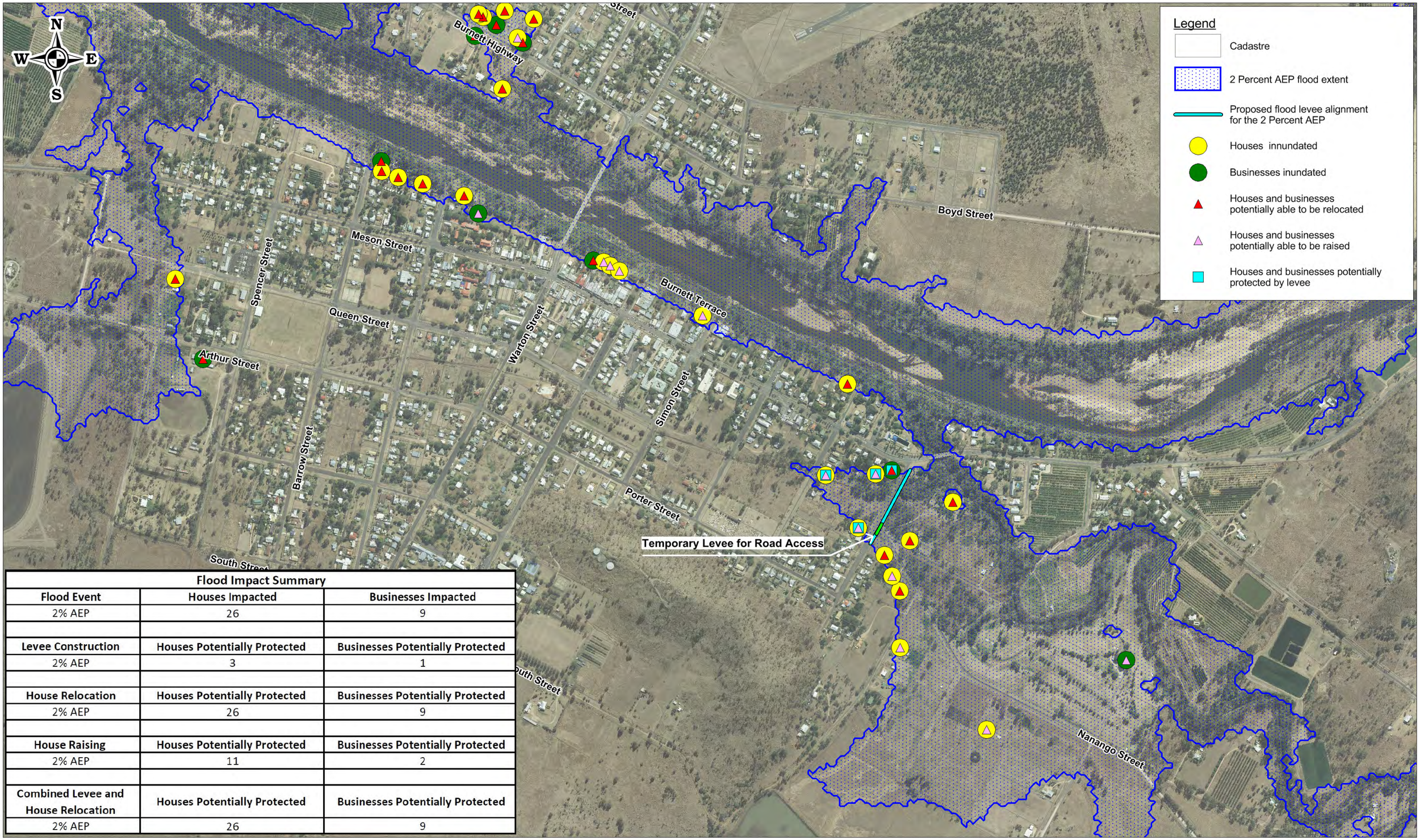

Flood Impact Summary		
Flood Event	**Houses Impacted**	**Businesses Impacted**
2% AEP	26	9
Levee Construction	**Houses Potentially Protected**	**Businesses Potentially Protected**
2% AEP	3	1
House Relocation	**Houses Potentially Protected**	**Businesses Potentially Protected**
2% AEP	26	9
House Raising	**Houses Potentially Protected**	**Businesses Potentially Protected**
2% AEP	11	2
Combined Levee and House Relocation	**Houses Potentially Protected**	**Businesses Potentially Protected**
2% AEP	26	9

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Figure 6.13

Gayndah Mitigation Option for 2% AEP Event

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Table 6.11 Potential Levee Configuration for Gayndah

Flood Event	Approximate Length (m)	Approximate Height (m) (including 600 mm freeboard)		Approximate Base Width (m)		Volume (m^3)
		Maximum	Average	Maximum	Average	
2013 Historical Event – Option 1 East	371	9.7	4.4	61.0	29.1	31,157
2013 Historical Event – Option 2 East	142	3.1	1.6	21.6	12.3	1,826
2013 Historical Event – Option 1 & 2 West	128	1.4	0.7	11.4	7.2	469
1% AEP Design Event	327	8.9	3.7	56.5	25.0	20,366
2% AEP Design Event	2439	6.9	2.7	44.5	19.4	9,261

Recommendation for Further Consideration

The levee option is considered to potentially provide protection for up to 24 of the 101 houses and businesses recorded as inundated by the 2013 historical event. Whilst this option does not provide a substantial benefit to the entire town, it may be a cost effective means of protecting some properties inundated by backwater from the Burnett River. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

6.3.3.7. Raising of Houses and Businesses Option

Description

A preliminary assessment has been undertaken to determine the viability of raising flood affected houses and businesses within Gayndah to reduce damages associated with flooding from Burnett River, Sauers Gully and Oaky Creek. The assessment was based on houses and businesses located within the 2% and 1% AEP design and 2013 flood extents that have been identified as being on stumps and are therefore able to be raised. Houses able to be raised are illustrated in **Figure 6.11** to **Figure 6.13** Slab on ground houses and businesses were excluded from the analysis. It is noted that there are building height restrictions outlined in the Planning Scheme and therefore this provision may require review. It is also noted that some properties presented as being raiseable may not be due to unpractical heights, however this has not been considered in this study due to the preliminary nature of the assessment.

Recommendation for Further Consideration

The option of house raising is considered to protect 25 of the 101 flood affected houses and businesses in the 1% and 2% AEP design and 2013 historical events. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

6.3.3.8. Voluntary House and Business Relocation or Land Swap Option

Description

A preliminary assessment has been undertaken to determine the viability of relocating flood affected houses and businesses within Gayndah to reduce the damages associated with flooding from backflow from Sauers Gully and Oaky Creek. The option for land swap would only apply to houses and business that are slab on ground constructions and are therefore not able to be raised. This option may also apply to properties that are unable to be raised due to height restrictions. The assessment was based on houses and businesses located within the 1% and 2% AEP design and the 2013 historical event, that have been identified as either being relocatable (on stumps) or require a land swap arrangement (slab on ground). Houses and businesses able to be relocated or requiring a land swap solution are illustrated in **Figure 6.11** to **Figure 6.13**.

Recommendation for Further Consideration

The option of voluntary house and business relocation or land swap is estimated to protect all 101 houses and businesses recorded as experiencing inundated during the 2013 historical event. For many properties, this option may be the only solution to protecting their properties. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

6.3.3.9. Combined Levee and House and Business Relocation or Land Swap

Description

A levee around the properties located between Barrow and Bamboo Streets, and the potential relocation of businesses impacted by flooding but not protected by the levee has been assessed under the same conditions as described in **Sections 6.3.3.6** and **6.3.3.8.** Houses and businesses protected by the combined levee and business relocation options are illustrated in **Figure 6.11** to **Figure 6.13**.

Recommendation for Further Investigation

The combined levee and business relocation or land swap option is considered to protect all 101 houses and businesses recorded as inundated during the 2013 historical event. As such, a preliminary cost estimate, cost benefit analysis and high level evaluation of this option has been undertaken as described in **Section's 7, 8** and **9** respectively.

Summary of Flood Impacts and Mitigation Option Results

A summary of flood impacts and potential benefits associated with the shortlisted options for the 2013 flood event are provided in **Table 6.12**.

Table 6.12 Gayndah Flood Impact Summary for 2013 Event

Gayndah Flood Impact Summary for 2013 Event		
Flood Event	Houses Impacted	Businesses Impacted
2013	73	28
Levee Option 1	Houses Potentially Protected	Businesses Potentially Protected
2013	19	5
Levee Option 2	Houses Potentially Protected	Businesses Potentially Protected
2013	7	3
House Relocation Option	Houses Potentially Protected	Businesses Potentially Protected
2013	73	28
House Raising Option	Houses Potentially Protected	Businesses Potentially Protected
2013	22	3
Combined Levee and House Relocation Option	Houses Potentially Protected	Businesses Potentially Protected
2013	73	28

6.3.4 Rural Areas

Due to the absence of any flood event information for the rural areas and an incomplete list of properties identified to have been affected by the 2013 flood, flood mitigation measures have been broadly considered however no assessment has been undertaken to quantify the costs and benefits associated with these measures. Given the scale of the Burnett River flood plain and associated tributaries as well as the vast extent of rural areas along the flood plain, non-structural mitigation measures such as flood warning and emergency management, agricultural land use planning and development control are generally the only flood mitigation strategies likely reduce flood damage and increase flood awareness and resilience. Although it is advised that a flood management plan be developed for the region, this is beyond the scope of this study. It is noted that North Burnett Regional Council is in the process of seeking to improve the flood warning network across the region by installing new gauging stations and upgrading existing stations. The operation of the flood warning network along with an emergency response plan and mitigation strategy should be developed and documented in a Flood Risk Management Plan as outlined in **Section 10.2.** For the purpose of this study, the following flood mitigation measures have been broadly considered to provide flood protection to rural properties:

- Channel Improvements;
- Bridge Upgrades or Removal;
- Levee;
- House Raising or Relocation; and
- Agricultural Land Use Planning.

Each of these flood mitigation measures are presented in the following sections.

6.3.4.1. Channel Improvement Option

Description

Anticipated benefits associated with channel improvements such as dredging, widening and vegetation removal were considered for the river reaches in the North Burnett region. It was predicted that vegetation removal and dredging would provide minimal benefits to flood storage as predicted at Gayndah and Mundubbera (refer to **Sections 6.2.2.3** and **6.2.3.3**). It should also be noted the length of rivers, creeks and tributaries that would require dredging and vegetation removal to provide a regional benefit would be considerable, resulting in a large upfront cost and little reduction in flood extents and levels for major events.

Channel widening, dredging and vegetation removal can also cause unfavourable impacts such as a loss in biodiversity and increased flow velocities, subsequently causing erosion of the river bed and deposition of sediment downstream. It should also be noted that

dredging and vegetation removal would be an ongoing process, required after every significant flood event where sediment is likely to be redeposited.

Given the costs, potential impacts and the fact that channel improvements are considered to provide an insignificant benefit as a mitigation measure, this option was not considered viable and therefore a preliminary cost estimate has not been undertaken for this option.

No Recommendation for Further Consideration

Further consideration of channel improvements for this study as a flood mitigation measure for rural areas for rural areas is neither possible nor warranted as this option was considered to only provide a minor benefit in a major flood event. A hydraulic analysis would be required to quantify the benefits and true viability of this option.

6.3.4.2. Bridge Upgrades or Removal Option

Description

There are several waterway crossing structures throughout the rural reaches of Three Moon Creek, Burnett River, Nogo Creek, Auburn River and the Boyne River, in addition to many other creek and tributaries. Many of these structures are in the form of low lying bridges, culvert crossings and floodway's. It is noted that there are a number of railway bridges and embankments crossing the flood plain that are likely to cause some level of impact to upstream properties. For example, the rural properties located immediately upstream of the decommissioned railway bridge at Ceratosis may experience increased inundation due to the obstruction.

As such, it is considered that there may be scope for crossing structure upgrades where rural houses and infrastructure is located directly upstream of a low lying structures known to cause a major obstruction, however identification of specific structures is beyond the scope of works and objectives for this study.

No Recommendation for Further Consideration

Determination of whether crossing structure upgrades or removal would reduce inundation of properties upstream of the structure would require hydraulic analysis which is beyond the data limitations and scope of this project. As such, further evaluation of this option is unable to be undertaken and it is recommended that a more detailed flood assessment be undertaken should Council consider this option to be viable.

6.3.4.3. Levee Option

Description

Based on discussions with members of the rural community during the community consultation period, a review of available QRA Level 1 flood mapping and site inspection, it would appear that there are no obvious flow breakout locations where a levee would serve to contain floodwaters and protect properties. Levees along a regional river system

are generally not appropriate for mitigating large rural areas due to the required height of the levee as well as the required length along rivers, creeks and tributaries. As such, a regional levee structure for the Burnett River system was not identified as a suitable option.

It is understood that a number of rural properties have constructed individual levees within their properties to protect homes, sheds and other assets; however the cumulative impact of the individual structures is likely to cause a negative impacts on the overall flood plain and adjacent properties. It is therefore advised that property owners seek approval from Council prior to construction to allow for consideration of the overall impacts. A hydraulic model representing the flood plain would allow for an assessment of proposed and existing levees.

No Recommendation for Further Consideration

The lack of available flood information as well as the scope of this study does not allow for further investigation of rural levees as a mitigation protection measure for the rural reaches.

6.3.4.4. Voluntary House Raising or Relocation

Description

A desktop assessment has been undertaken to determine the viability of raising or relocating known flood affected houses throughout the rural reaches to reduce damages associated with flooding from Three Moon Creek, Burnett River, Nogo Creek, Auburn River and the Boyne River, in addition to many other creek and tributaries. Although the number of inundated businesses in rural areas is unknown, it was assumed that these structures could not be protected through raising due to the likelihood of the buildings being dairies, piggeries, etc. As such, these buildings may need to be rebuild outside the flood plain, however there was insufficient data to determine the locations and number of such buildings. The total number and type of rural businesses known to have been inundated is unknown and therefore these businesses cannot be identified for relocation.

The availability of land within rural properties may allow for a house or building to be relocated to higher ground beyond the flood plain. It is therefore considered that the majority of flood affected houses could be either raised or relocated if considered economically viable and practical.

The survey data provided by NBRC did not identify the construction type of rural houses and therefore it is unknown whether they are on stumps and are able to be relocated or raised. It should be noted that there is also some uncertainty as to whether all rural houses and businesses within the predicted 2013 historical flood extents have been identified and documented. In addition, there is no flood event mapping for historical and design events.

For the purpose of this high level assessment, it was assumed that all 79 of the rural houses shown to have been inundated are on stumps.

Recommendation for Further Consideration

The raising or relocation of house and businesses (i.e. piggeries, dairies, etc.) is considered to potentially protect all 79 houses identified as being inundated by the 2013 event. Given the lack of available flood information as well as survey data for flood affected rural properties, further evaluation of this option was unable to be undertaken.

6.3.4.5. Agricultural Land Use Planning

Based on discussions with members of the rural community, it was apparent that property management practices could be improved to reduce the damage caused by flooding. A number of dairies, piggeries and citrus plantations are located within the flood plain and were more than likely constructed and planted without understanding the flood risks. An understanding of the flood risks including flood extents, levels, depths and velocities would enable property owners to better manage their properties and reduce the potential for flood damage. Whilst no substantiated flood mapping is available for the rural areas, it is recommended that flood modelling be undertaken to provide flood mapping that could be distributed to property owner and be incorporated into the Planning Scheme.

No Recommendation for Further Consideration

The benefits associated with improved agricultural land use planning cannot be quantified and therefore no further assessment has been undertaken in this study; however it is recommended that NBRC undertake a hydrologic and hydraulic analysis to prepare flood mapping for distribution to the community and incorporation into the Planning Scheme.

7. PRELIMINARY ESTIMATE OF COSTS

7.1 Assumptions and Exclusions

Levee Option

Due to the preliminary and 'high level' nature of this investigation, the following assumptions and exclusions were made for all levee construction costs within the towns of Monto, Mundubbera and Gayndah. It is noted that a 30% contingency factor has been applied to account for uncertainties and inaccuracies in the preliminary cost estimation.

- Assumptions;
- Earthworks included locally sourced topsoil and fill;
- Levee freeboard of 600 mm;
- Cost estimation based on an allowance of $35/m^3;
- Allowance has been made for three duty pumps, one standby pump and seven backflow valves;
- Ground is geotechnically sound;
- Pumping of 250 l/s at 7 m head is adequate to prevent localised flooding behind the levees;
- Backflow valves were based on a 750 mm diameter discharge pipe;
- Temporary levees are constructed from earth fill/sandbags for costing purposes only;
- Exclusions;
- Site establishment and site survey;
- Clearing and grubbing;
- Fence removal and reinstatement;
- Road reconstruction/ temporary flood gates associated with the 1% AEP;
- Redirection and extension of stormwater networks;
- The establishment of easements and associated legal fees;
- As-constructed survey; and
- Allocation of standby pumps.

Voluntary House Raising Option

Due to the preliminary nature of this investigation, the following assumptions and exclusions were made for all voluntary house raising in the towns of Monto, Mundubbera and Gayndah, as well as the rural areas.

- Assumptions:
  - All houses and businesses are structurally sound;
  - The ground is geotechnically stable; and
  - Cost per house or business of $75,000.
- Exclusions:
  - Plumbing and electricity costs; and
  - Fence removal and reinstatement.

House Relocation or Land Swap Option

Due to the preliminary nature of this investigation, the following assumptions and exclusions were made for all voluntary house raising in the towns of Monto, Mundubbera and Gayndah, as well as the rural areas.

- Assumptions:
  - New Land and house/business prices are based on estimated November 2013 market values;
  - Suitable land is available;
  - Water and sewerage services are available;
  - A transportation distance of 2 km was assumed for relocation of buildings on stumps;
  - Cost for relocating a building on stumps in Monto was estimated to be between $125,000 and $150,000 (depending on location) which includes the purchase of new land; and
  - Cost for providing land swap where a building is slab on ground was estimated to be $160,000 and $230,000 (depending on location) which includes the purchase of a new house and new land.
- Exclusions:
  - Connecting relocated house to services;
  - Demolition of existing slab houses and businesses; and
  - Relocation of rural businesses such as dairies and piggeries.

7.2 Monto

7.2.1 Levee Option

A preliminary estimate of costs for levee construction is provided in **Table 7.1.**

Table 7.1 Indicative Costs for Levee Construction

Flood Event	Earthworks	Duty Pumps	Backflow Valves	Total
2013 Historical Event	$ 1,570,000.00	$649,350.00	$91,000.00	$2,310,350.00
1% AEP Design Event	$ 1,970,000.00	$649,350.00	$91,000.00	$2,599,500.00
2% AEP Design Event	$ 1,290,000.00	$649,350.00	$91,000.00	$1,919,500.00

7.2.2 Voluntary House Raising Option

A preliminary estimate of costs for voluntary house raising is provided in **Table 7.2.**

Table 7.2 Indicative Costs for Voluntary House Raising

Flood Event	Estimated Houses Impacted	Estimated Businesses Impacted	Potential Houses able to be Raised	Potential Businesses able to be Raised	Preliminary Estimate of Costs
2013 Historical Event	11	3	10	0	$ 750,000
1% AEP Design Event	11	3	10	0	$ 750,000
2% AEP Design Event	11	3	10	0	$ 750,000

7.2.3 Voluntary House and Business Relocation/Land Swap Option

A preliminary estimate of costs for voluntary house and business relocation is provided in **Table 7.3.**

Table 7.3 Indicative Costs for House Relocation/Land Swap

Flood Event	Estimated Houses Impacted	Estimated Businesses Impacted	Potential Relocation of Houses on Stumps	Potential Relocation of Businesses on Stumps	Potential Relocation of Houses on Slab	Potential Relocation of Businesses on Slab	Preliminary Estimate of Costs
2013 Historical Event	11	3	10	0	1	3	$2,140,000
1% AEP Design Event	11	3	10	0	1	3	$2,140,000

Flood Event	Estimated Houses Impacted	Estimated Businesses Impacted	Potential Relocation of Houses on Stumps	Potential Relocation of Businesses on Stumps	Potential Relocation of Houses on Slab	Potential Relocation of Businesses on Slab	Preliminary Estimate of Costs
2% AEP Design Event	11	3	10	0	1	3	$ 2,140,000

7.2.4 Combined Levee and Business Relocation Option

A preliminary estimate of costs for voluntary levee and business relocation is provided in **Table 7.4.**

Table 7.4 Option 4 – Indicative Costs for Combined Levee and House Relocation

Flood Event	Estimated Houses Impacted	Estimated Businesses Impacted	Potential Houses Saved	Potential Businesses Saved	Cost
			Levee	Relocation of Businesses on Slab	
2013 Historical Event	11	3	11	3	$ 2,800,000
1% AEP Design Event	11	3	11	3	$ 3,080,000
2% AEP Design Event	11	3	11	3	$ 2,400,000

7.3 Mundubbera

7.3.1 Levee Option

A preliminary estimate of costs for levee construction is provided in **Table 7.5 and 7.6.**

Table 7.5 Indicative Costs for Levee Option 1 – Mundubbera

Flood Event	Earthworks	Duty Pumps	Backflow Valves	Total
2013 Historical Event	$6,665,750.00	$865,800	$507,000.0	$8,038,550.00
1% AEP Design Event	$4,186,000.00	$865,800	$507,000.0	$5,558,800.00
2% AEP Design Event	$932,750.00	$432,900	$338,000.0	$1,703,650.00

Table 7.6 Indicative Costs for Levee Option 2– Mundubbera

Flood Event	Earthworks	Duty Pumps	Backflow Valves	Total
2013 Historical Event	$7,794,150.00	$865,800	$507,000.0	$9,166,950.00
1% AEP Design Event	$5,378,100.00	$865,800	$507,000.0	$6,750,900.00
2% AEP Design Event	$1,446,900.00	$432,900	$338,000.0	$2,217,800.00

7.3.2 Voluntary House and Business Raising Option

A preliminary estimate of costs for voluntary house and business raising is provided in **Table 7.7.**

Table 7.7 Indicative Costs for Voluntary House and Business Raising – Mundubbera

Flood Event	Estimated Houses Impacted	Estimated Businesses Impacted	Potential Houses able to be Raised	Potential Businesses able to be Raised	Preliminary Estimate of Costs
2013 Historical Event	72	11	45	2	$3,525,000
1% AEP Design Event	61	6	36	0	$2,700,000
2% AEP Design Event	32	3	19	0	$1,425,000

7.3.3 Voluntary House and Business Relocation or Land Swap Option

A preliminary estimate of costs for voluntary house and business relocation is provided in **Table 7.8.**

Table 7.8. Indicative Costs for Voluntary House Relocation or Land Swap – Mundubbera

Flood Event	Estimated Houses Impacted	Estimated Businesses Impacted	Potential Relocation of Houses on Stumps	Potential Relocation of Businesses on Stumps	Potential Relocation of Houses on Slab	Potential Relocation of Businesses on Slab	Preliminary Cost Estimate
2013 Historical Event	72	11	45	2	27	9	$14,390,000.00
1% AEP Design Event	61	6	36	0	25	6	$11,810,000.00
2% AEP Design Event	32	3	19	0	13	3	$6,150,000.00

7.3.4 Combined Levee, House and Business Raising and Relocation or Land Swap Option

A preliminary estimate of costs for a combined levee, house and business raising and house and business relocation or land swap is provided in **Table 7.9 and 7.10.**

Table 7.9 Indicative Costs for Combined Levee Option 1, House and Business Raising and Relocation -Mundubbera

Flood Event	Estimated Houses Impacted	Estimated Businesses Impacted	Potential Houses Saved				Potential Businesses Saved				Cost
			Levee	House Raising	Relocation of House on Stumps	Relocation of House on Slab	Levee	Business Raising	Relocation of Business on Stumps	Relocation of Business on Slab	
2013 Historical Event	72	11	59	5	3	5	8	1	0	2	$ 10,488,550.00
1% AEP Design Event	61	6	51	3	3	4	4	0	0	2	$ 7,553,800.00
2% AEP Design Event	32	1	24	2	3	3	0	0	0	1	$ 3,163,650.00

Table 7.10 Indicative Costs for Combined Levee Option 2, House and Business Raising and House and House Relocation –Mundubbera

Flood Event	Estimated Houses Impacted	Estimated Businesses Impacted	Potential Houses Saved				Potential Businesses Saved				Cost
			Levee	House Raising	Relocation of House on Stumps	Relocation of House on Slab	Levee	Business Raising	Relocation of Business on Stumps	Relocation of Business on Slab	
2013 Historical Event	72	11	61	5	1	5	8	1	0	2	$ 10,228,550.00
1% AEP Design Event	61	6	53	3	1	4	4	0	0	2	$ 7,293,800.00
2% AEP Design Event	32	1	26	2	1	3	0	0	0	1	$ 2,903,650.00

7.4 Gayndah

7.4.1 Levee Option

A preliminary estimate of costs for levee construction is provided in **Table 7.11.**

Table 7.11 Indicative Costs for Levee Construction - Gayndah

Flood Event	Earthworks	Duty Pumps	Backflow Valves	Total
2013 Historical Event Levee Option 1	$ 1,438,983	$ 432,900	$ 338,000	$ 2,209,883
2013 Historical Event Levee Option 2	$ 104,422	$ 432,900	$ 338,000	$ 875,322
1% AEP Design Event	$ 926,653	$ 432,900	$ 338,000	$ 1,697,553
2% AEP Design Event	$ 421,375	$ 216,450	$ 169,000	$ 806,825

7.4.2 Voluntary House and Business Raising Option

A preliminary estimate of costs associated with voluntary house raising is provided in **Table 7.12.**

Table 7.12 Indicative Costs for Voluntary House Raising – Gayndah

Flood Event	Estimated Houses Impacted	Estimated Businesses Impacted	Potential Houses able to be Raised	Potential Businesses able to be Raised	Preliminary Estimate of Costs
2013 Historical Event	73	28	22	3	$ 1,875,000
1% AEP Design Event	53	19	19	2	$ 1,575,000
2% AEP Design Event	26	9	11	2	$ 975,000

7.4.3 Voluntary House and Business Relocation and Land Swap Option

A preliminary estimate of costs associated with voluntary house and business relocation and landswap is provided in **Table 7.13.**

Table 7.13 Indicative Costs for House Relocation or Land Swap – Gayndah

Flood Event	Estimated Houses Impacted	Estimated Businesses Impacted	Potential Relocation of Houses on Stumps	Potential Relocation of Businesses on Stumps	Potential Relocation of Houses on Slab	Potential Relocation of Businesses on Slab	Preliminary Estimate of Costs
2013 Historical Event	73	28	22	3	51	25	$ 19,465,000.00
1% AEP Design Event	53	19	19	2	34	17	$ 13,590,000.00
2% AEP Design Event	26	9	11	2	15	7	$ 6,355,000.00

7.4.4 Combined Levee, House and Business Relocation/Land Swap Option

A preliminary estimate of costs associated with combined levee and house and business relocation or land swap is provided in **Table 7.14.**

Table 7.14 Indicative Costs for Combined Levee, Raising and Relocation –Gayndah

Flood Event	Estimated Houses Impacted	Estimated Businesses Impacted	Potential Houses Saved				Potential Businesses Saved				Cost
			Levee	House Raising	Relocation of House on Stumps	Relocation of House on Slab	Levee	Business Raising	Relocation of Business on Stumps	Relocation of Business on Slab	
2013 Historical Event – Levee Option 1	73	28	19	22	0	32	5	3	0	20	$13,055,000.00
2013 Historical Event – Levee Option 2	73	28	7	28	0	38	3	3	0	22	$ 15,225,000.00
1% AEP Design Event	53	19	7	19	0	27	1	2	0	16	$ 10,820,000.00
2% AEP Design Event	26	9	3	11	0	12	1	2	0	6	$ 4,845,000.00

7.5 Rural Areas

7.5.1 Voluntary House and Business Raising Option

A preliminary estimate of costs associated with rural house raising is provided in **Table 7.15.**

Table 7.15 Indicative Costs for Rural House Raising Option

Option	Number of Houses	Cost per House Saved	Total Cost
Rural House Raising	79	$ 75,000	$5,925,000

Note: Three rural businesses have been identified as flood impacted.

7.5.2 Voluntary House and Business Relocation/Land Swap Option

A preliminary estimate of costs associated with rural house relocation is provided in **Table 7.16.**

Table 7.16 Indicative Costs for Rural House Relocation Option

Options	Number of Houses/Businesses	Cost per House Saved	Total Cost
Rural House Relocation	79	$75,000	$5,925,000

Note: Three rural businesses have been identified as flood impacted.

8. COST BENEFIT ANALYSIS

The objective of a cost benefit analysis (CBA) is to assist decision making that is consistent with 'efficiency' in the allocation of resources in areas where, for one reason or another, market forces do not guarantee an appropriate outcome.

The power of CBA as an analytical tool rests in two main features:

- Costs and benefits are each, as far as possible, expressed in monetary terms and hence are directly comparable with one another; and
- Costs and benefits are valued in terms of the claims they make on and the gains they provide to the triple bottom line as a whole, so the perspective is a 'global' one rather than that of any particular individual, organisation or group.

For the purposes of this CBA, the time-horizon has been kept at 30 years beyond the commencement of any mitigation works. This is common with standard Treasury practice of evaluating projects involving assets with a life span of 30 years and beyond.

Given that CBA takes a society wide perspective, it is important to define the geographic scope of 'society' as it applies in the analysis. Without such a limitation it is difficult to identify which impacts are 'transfer payments' as opposed to 'resource' impacts.

For the purposes of this study 'society' is defined as the whole of Queensland. This is traditional practice when preparing information for Government funded agencies and economic policy makers.

8.1 Base Case and Alternative Scenarios

For the purpose of this study, the Base Case is defined as the existing situation, i.e. without mitigation investment. The damages of flooding events under the base case are those that have historically occurred, specifically, the January 2013 floods. The relative benefit of any mitigation scenario will be the estimated reduction in average annual damage that will be enabled through investment in the mitigation measure.

A series of mitigation measures have been considered during this study. These have been refined on the basis of community consultation and feedback from the North Burnett Regional Council. Flood mitigation initiatives for which a full benefit cost analysis has been prepared are summarised below. These have been prepared for the townships of Mundubbera, Gayndah, and Monto.

8.1.1 Mundubbera

Twelve flood mitigation initiatives have been considered for Mundubbera. These are summarised in the table below.

ID	Description
M1	A *levee* along red gully constructed to the height of the January 2013 flooding event (1 in 150 year event).
M2	A *levee* along red gully constructed to the height of a 1 in 100 year flooding event.
M3	A *levee* along red gully constructed to the height of a 1 in 50 year flooding event.
M4	Voluntary *house and business raising* to a height above the level of the 2013 flooding event (1 in 150 year event).
M5	Voluntary *house and business raising* to a height above the level of a 1 in 100 year flooding event.
M6	Voluntary *house and business raising* to a height above the level of a 1 in 50 year flooding event.
M7	Voluntary *house and business relocation* or land swap for premises inundated under the 2013 flooding event (1 in 150 year event).
M8	Voluntary *house and business relocation* or land swap for premises inundated under a 1 in 100 year flooding event.
M9	Voluntary *house and business relocation* or land swap for premises inundated under a 1 in 50 year flooding event.
M10	A *combination of measures* including a levee; house and business raising; and house and business relocation to protect premises inundated to the level of the January 2013 event (1in 150 year event)
M11	A *combination of measures* including a levee; house and business raising; and house and business relocation to protect premises inundated under a 1 in 100 year flooding event.
M12	A *combination of measures* including a levee; house and business raising; and house and business relocation to protect premises inundated under a 1 in 50 year flooding event.

8.1.2 Gayndah

Fourteen flood mitigation initiatives have been considered for Gayndah. These are summarised in the table below.

ID	Description
G1	A *levee* constructed to reduce inundation under an event commensurate with the January 2013 flooding event (1 in 180 year event) (option 1)
G2	An *alternative levee* constructed to reduce inundation under an event commensurate with the January 2013 flooding event (1 in 180 year event) (option 2).
G3	A *levee* constructed to reduce inundation under an event commensurate with a 1 in 100 year flooding event.
G4	A *levee* constructed to reduce inundation under an event commensurate with a 1 in 50 year flooding event.
G5	Voluntary *house and business raising* to a height above the level of the 2013 flooding event (1 in 180 year event).

ID	Description
G6	Voluntary *house and business raising* to a height above the level of a 1 in 100 year flooding event.
G7	Voluntary *house and business raising* to a height above the level of a 1 in 50 year flooding event.
G8	*House and business relocation* away from the flooded areas of the 2013 flooding event (1 in 180 year event).
G9	*House and business relocation* away from the flooded areas of the 2013 flooding event (1 in 100 year event).
G10	*House and business relocation* away from the flooded areas of the 2013 flooding event (1 in 50 year event).
G11	A *combination of measures* including a levee (option 1); house and business raising; and house and business relocation to protect premises inundated to the level of the January 2013 event (1in 180 year event)
G12	A *combination of measures* including a levee (option 2); house and business raising; and house and business relocation to protect premises inundated to the level of the January 2013 event (1in 180 year event)
G13	A *combination of measures* including a levee; house and business raising; and house and business relocation to protect premises inundated under a 1 in 100 year flooding event.
G14	A *combination of measures* including a levee; house and business raising; and house and business relocation to protect premises inundated under a 1 in 50 year flooding event.

8.1.3 Monto

Six flood mitigation initiatives have been considered for Monto. These are summarised in the table below.

ID	Description
Mo1	A ***levee*** constructed to reduce inundation under an event commensurate with a 1 in 100 year flooding event.
Mo2	A ***levee*** constructed to reduce inundation under an event commensurate with a 1 in 50 year flooding event.
Mo3	Voluntary ***house and business raising*** to a height above a 1 in 100 flood level.
Mo4	Voluntary house and business ***relocation*** away from the inundated areas of a 1 in 100 year flooding event.
Mo5	A ***combination of measures*** including a levee; house and business raising; and house and business relocation to protect premises inundated under a 1 in 100 year flooding event.
Mo6	A ***combination of measures*** including a levee; house and business raising; and house and business relocation to protect premises inundated under a 1 in 50 year flooding event.

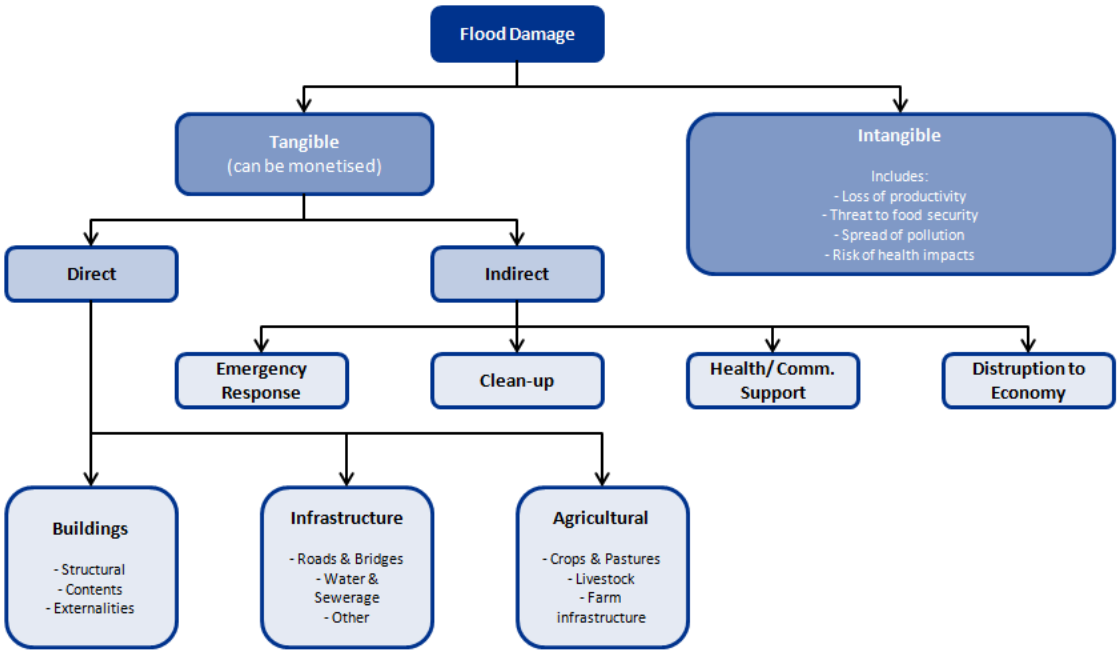
The following section discusses the marginal costs and benefits of moving from the Base Case to a scenario where mitigation measures have been implemented.

8.2 Identified Marginal Costs and Benefits

The implementation of the proposed mitigation initiatives will result in a range of resource savings, or in other words, reduce damage to the North Burnett and broader Queensland community.

Based on industry practice on flood management, damage costs can be contextualised as three broad categories, as shown in the following figure:

- Avoided direct tangible damages – these comprise the damages arising from the physical impact of the flood and largely consist of damages to buildings and structures, contents, agriculture and infrastructure;
- Avoided indirect tangible damages – these comprise losses from disruption to normal economic and social activities that arise as a consequence of the flood. Examples include response and recovery costs, health and community support costs and disruptions to employment, transport, commerce and trade, tourism etc; and
- Avoided intangible damages – these comprise broader damages for which market prices may not readily exist, but may be quantified using established 'non-market' pricing techniques, including willingness to pay and shadow pricing.



Source: KPMG analysis

Figure 8.1 Types of Flood Damage Costs

Table 8.1 lists the identified tangible and intangible economic, social and environmental costs and benefits associated with the delivery of the mitigation initiatives relative to the Base Case. The table also indicates whether the identified benefit was included in the cost benefit analysis or not, and identifies the source of that information. Each of the costs and benefits is further elaborated upon in the following pages. Valuation procedures and assumptions used in quantifying the costs and benefits are also discussed.

For the purpose of the current benefit cost analysis, savings associated with the reduction in direct damages to commercial premises, residential properties and Council infrastructure are the only benefits that have been quantified. This reflects the focus of proposed mitigation measures to prevent inundation of these premises, and the recognition that mitigation of flood damages to agricultural premises would be prohibitively expensive.

Savings associated with the reduction in profit losses from business operation have not been included as data for the individual businesses affected was not available at the time of this preliminary analysis. This approach has been confirmed with NBRC.

Finally, while data has been captured to estimate the damages of the recent January 2013 floods on residential and commercial premises, these are recognised to be relatively higher than typical guidance on damage estimates. For example, the average damage to residential premises of >$150,000 is equivalent to a complete rebuild of a residential property in North Burnett. By applying this figure to any level of inundation, there would be significant risk of over-estimating damages and the potential benefit of any mitigation measure. Accordingly, KPMG have applied the Queensland State Government guidance on Tangible Flood Damage estimation to provide a reference point for inundation damages.

Table 8.1 Identified Marginal Costs and Benefits

Economic, Social and Environmental Costs	Economic, Social and Environmental Benefits	Whether benefit Included in CBA?	Source
Capital expenditure associated with the construction of proposed mitigation initiatives. Operating expenditure associated with maintaining the proposed infrastructure assets (where applicable).	Resource savings from reduced agriculture damages.	No	-
	Resource savings from reduced commercial damages.	Yes	NRM, 2002[1]
	Resource savings from reduced residential damages.	Yes	NRM, 2002[2]
	Resource savings from reduced infrastructure damages.	Yes	NRM, 2002[3]
	Resource savings from reduced need for response and recovery.	No	-
	Reduction in productivity losses arising from flood damages.	No	-
	Reduced risk of water borne disease and consequent resource savings.	No	-
	Reduced risk of widespread pollution.	No	-
	Reduced risk of threat to life and limb.	No	-
	Reduced risk of mental health issues.	No	-

[1] Queensland Department of Natural Resources and Mines (2002) "Guidance on the Assessment of Tangible Flood Damages" *The State of Queensland*
[2] Ibid.
[3] Ibid.

8.3 Valuation of Marginal Costs

8.3.1 Capital Expenditure

Capital expenditure associated with the proposed mitigation initiatives has been summarised in the table below. It is assumed that capital works for all mitigation works will be incurred in a single year and that the benefit stream associated with these mitigation measures will commence in the year following construction.

Table 8.2 Capital Expenditure Mundubbera Mitigation Interventions

Mitigation	Description	Capital Cost
M1	*Levee* - 1 in 150 year design	$9,166,950
M2	*Levee* - 1 in 100 year design	$6,750,900
M3	*Levee* - 1 in 50 year design	$2,217,800
M4	House and business *raising* - 1 in 150 year design	$3,525,000
M5	House and business *raising* - 1 in 100 year design	$2,700,000
M6	House and business *raising* - 1 in 50 year design	$1,425,000
M7	House and business *relocation* - 1 in 150 year design	$14,390,000
M8	House and business *relocation* - 1 in 100 year design	$11,810,000
M9	House and business *relocation* - 1 in 50 year design	$6,150,000
M10	*Combination* of measures - 1in 150 year design	$10,228,550
M11	*Combination* of measures - 1 in 100 year design	$7,293,800
M12	*Combination* of measures - 1 in 50 year design	$2,903,650

Source: Engeny

Table 8.3 Capital Expenditure Gayndah Mitigation Interventions

Mitigation	Description	Capital Cost
G1	Levee - 1 in 150 year design (option 1)	$ 2,209,883
G2	Levee - 1 in 150 year design (option 2)	$ 875,322
G3	Levee - 1 in 100 year design	$ 1,697,553
G4	Levee - 1 in 50 year design	$ 806,825
G5	House and business *raising* - 1 in 150 year design	$ 1,875,000
G6	House and business *raising* - 1 in 100 year design	$ 1,575,000
G7	House and business *raising* - 1 in 50 year design	$ 975,000

Mitigation	Description	Capital Cost
G8	House and business *relocation* - 1 in 150 year design	$ 19,465,000
G9	House and business *relocation* - 1 in 100 year design	$ 13,590,000
G10	House and business *relocation* - 1 in 50 year design	$ 6,355,000
G11	*Combination* of measures - 1in 150 year design (including levee option 1)	$ 13,055,000
G12	*Combination* of measures - 1in 150 year design (including levee option 2)	$ 15,225,000
G13	*Combination* of measures - 1 in 100 year design	$ 10,820,000
G14	*Combination* of measures - 1 in 50 year design	$ 4,845,000

Source: Engeny

Table 8.4 Capital Expenditure Monto Mitigation Measures

Mitigation	Description	Capital Cost
Mo1	***Levee*** - 1 in 50 year design	$1,919,500
Mo2	***Levee*** - 1 in 100 year design	$2,599,500
Mo3	House and business ***raising*** - 1 in 80 year design	$ 750,000
Mo4	House and business ***relocation*** - 1 in 150 year design	$2,140,000
Mo5	***Combination*** of measures - 1in 50 year design	$ 2,800,000
Mo6	***Combination*** of measures - 1 in 100 year design	$ 3,080,000

Source: Engeny

8.3.2 Operational Expenditure

The proposed flood mitigation initiatives are all relatively capital intensive, with minor ongoing operational expenditure and maintenance requirements. In the case of the proposed levee investments, a fixed operational estimate of $10,000 per annum has been applied to reflect ongoing maintenance requirements.

House raising and relocation measures all represent a one-off capital investment and accordingly have no ongoing operational expenditure requirement.

8.4 Estimating Marginal Benefits

When monetising marginal benefits, it is important to bear in mind that a flood event in any given year is not certain, only probable, with the associated probability of its occurrence lying between zero and one. In turn, the potential damages brought about by any flood event also remain uncertain, too. Thus, an estimate of average annual damages for different flood event scenarios, with and without levees, is required to estimate the marginal benefit of moving from the Base Case to each of the alternative scenarios.

Secondly, the estimated potential damages and actual flood damages are not necessarily the same. This is because adequate warning times and community preparedness can help reduce the extent of actual damages.

Both of these issues are discussed below, followed by a detailed description of marginal benefits.

8.4.1 Estimating Annual Average Damages (AADs)

Depending on its size and severity, each flood will cause a different amount of flood damage. The Average Annual Damage, or AAD, measures the average damage in dollars per year that would occur in a designated area from flooding over a very long period of time.

The chance of a flood event of a given size (or larger) occurring in any one year is termed as the Annual Exceedance Probability (AEP). It is measured as a percentage value between 0 and 1. A ranking of 0 indicates that the event is highly unlikely, whereas 1 indicates that the event is certain to occur. The AEP determines the probability of a flood event, and therefore, the probability of damages associated with it. It is calculated as follows:

$$AEP = 1 - exp^{-1/ARI},$$

Where ARI is the Annual Recurrence Interval, which measures the average interval between exceedances of that event in the long term. The ARI is usually expressed in years. It should be noted that a flood event of 1 in a 100 years does not imply that the flood event will occur once in 100 years. It is feasible that the event will occur five times in five successive years and not for another 495 years.

AEP is very closely approximated by the reciprocal of the ARI for flood events with ARIs of greater than 10 years.

Given that annual average damages are only probabilistic and are dependent on the occurrence of a flood event and its associated probability, they are measured as the expected probability of damages associated with differing flood events. In other words, they are calculated as the sum of the probabilities of a flood event multiplied by the expected potential damage caused by that flood event. For example, if the probability associated with a flood event is p_i and the estimated potential damage caused by that flood event is x_i, then the AAD should be calculated as follows:

$$AAD = \sum_i p_i x_i$$

To estimate AADs with and without levees for this study, KPMG have estimated the potential damages associated with three different flood events for the base case and any given intervention scenario. These include differing combinations of the following, depending on the location and severity of the known January 2013 event.

- a 1 in a 50-year flood, i.e. a flood with an AEP of 1.98%;
- a 1 in an 80-year flood (the January 2013 event in Monto), i.e. a flood with an AEP of 1.65%;
- a 1 in a 100-year flood, i.e. a flood with an AEP of 1%;
- a 1 in a 150-year flood (the January 2013 event in Mundubbera), i.e. a flood with an AEP of 0.66%; and
- a 1 in a 180-year flood (the January 2013 event in Gayndah) i.e. a flood with an AEP of 0.55%.

KPMG has estimated the potential damages associated with different scenarios on the basis of information provided by NBRC, this investigation and the Queensland Guidelines for the Assessment of Tangible Flood Damages. The core inputs to these tangible damage estimates are summarised below.

8.4.2 Estimating Direct Potential Damages – Residential

The assessment of potential damages to residential properties utilise stage damage curves, which describe the relationship between levels of inundation and damage incurred. Estimating the levels of inundation damage to properties consider ground heights, flood heights and floor levels in deriving estimates of damages caused. Ground heights are measured using survey techniques; flood heights are calculated using estimates from flooding models or from previous flood records and finally, floor levels are estimated from building records where over-floor inundation is the difference between the flood height and the floor height of each property.

The Department of Natural Resources and Mines recommends adopting the stage-damage curves developed using a flood model developed at the Australian National University (ANU) known as ANUFLOOD4. The stage-damage curves developed using ANUFLOOD represent a listing of the estimated damage costs for buildings based on property sizing for residential. Since these curves are based on historical data from 2002 to derive damage costs they have been adjusted using the consumer price index (CPI) to reflect damages in 2013.

[4] ANUFLOOD is designed to assess flood damages to urban dwellings

The calculation of the direct potential damages to residential properties is based on the size of the property. **Table 8.5** below highlights the stage-damage relationships for residential properties for 2013.

Table 8.5 Direct Residential Damages by Size of Premises and Level of Inundation (2013 Dollars)

Depth of inundation over Floor	Small House < 80m²	Medium House 80-140m²	Large House > 140m²
0m	$ 1,242	$ 3,509	$ 8,059
0.1m	$ 2,581	$ 7,019	$ 16,113
0.6m	$ 10,113	$ 19,181	$ 34,786
1.5m	$ 23,847	$ 25,502	$ 44,288
1.8m	$ 24,209	$ 25,890	$ 44,963

Source: Queensland Department of Natural Resources and Mines (2002) "Guidance on the Assessment of Tangible Flood Damages" The State of Queensland

In lieu of detailed flood modelling, it has been assumed that inundation for each house identified in the flooding maps has been inundated to the mid-point depth of 0.6m in the tables and that each residential property is a medium house (80 – 140 m^2).

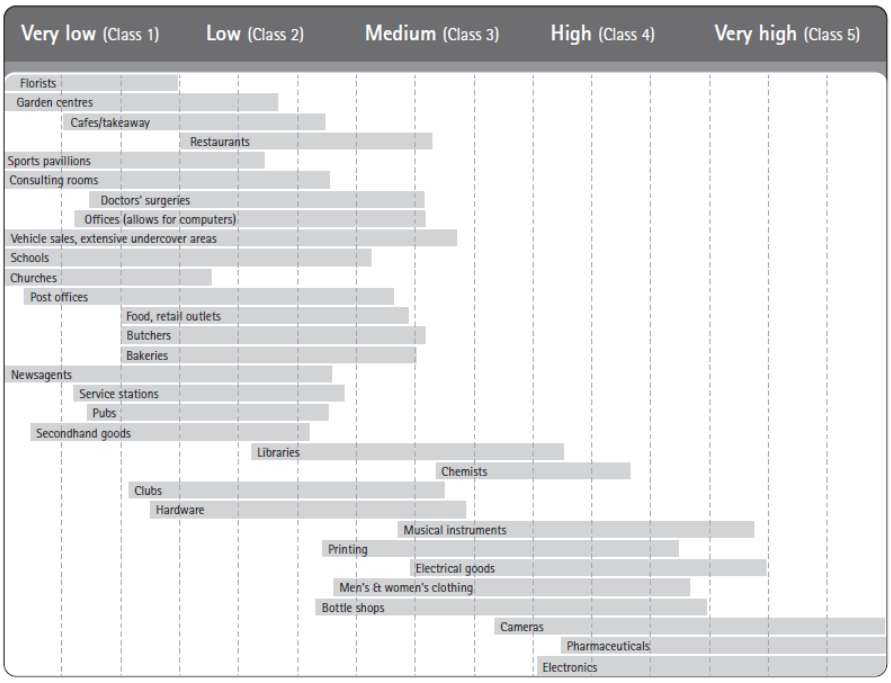
In addition to the direct damage estimates outlined above, NRM (2002) recommends the recognition of the damages to contents through the incorporation of an indirect damages estimate. As per the guidelines, this figure is estimated at 15% of direct residential damages.

8.4.3 Estimating Direct Potential Damages – Commercial

The calculation of the direct potential damages to commercial properties is based on a combination of the floor size of the property, the depth of water above floor level and the class of the property. Each property is classified based on the value of the building contents and ranges from one to five in increasing value of potential damage.

Table 8.6 overleaf displays the stage-damage relationship for commercial properties.

Table 8.6 Damage Value Class for Commercial Properties



Source: Queensland Department of Natural Resources and Mines (2002) "Guidance on the Assessment of Tangible Flood Damages" The State of Queensland

The following tables outline the relationship between the value class of properties, their relative size and the level of inundation. These tables enable the estimation of the damage caused to any given property as a result of flooding inundation.

Table 8.7 Direct Commercial Damages by Value Class of Premises and Level of Inundation, Small Properties <186 m² (2013 dollars)

Small Commercial Properties					
Depth	**1**	**2**	**3**	**4**	**5**
0 m	$ -	$ -	$ -	$ -	$ -
0.25 m	$ 3,021	$ 6,044	$ 12,087	$ 24,175	$ 48,351
0.75 m	$ 7,555	$ 15,109	$ 30,219	$ 60,438	$ 120,876
1.25 m	$ 11,331	$ 22,665	$ 45,328	$ 90,657	$ 181,312
1.75 m	$ 12,591	$ 25,182	$ 50,365	$ 100,730	$ 201,458
2 m	$ 13,346	$ 26,694	$ 53,386	$ 106,773	$ 213,546

Source: Queensland Department of Natural Resources and Mines (2002) "Guidance on the Assessment of Tangible Flood Damages" The State of Queensland

Table 8.8 Direct Commercial Damages by Value Class of Premises and Level of Inundation, Medium Properties 186 m² – 650 m² (2013 dollars)

Medium Commercial Properties					
Depth	**1**	**2**	**3**	**4**	**5**
0 m	$ -	$ -	$ -	$ -	$ -
0.25 m	$ 9,571	$ 19,139	$ 38,278	$ 76,554	$ 153,109
0.75 m	$ 23,167	$ 46,335	$ 92,671	$ 185,343	$ 370,684
1.25 m	$ 35,255	$ 70,511	$ 141,021	$ 282,079	$ 564,085
1.75 m	$ 39,031	$ 78,066	$ 156,131	$ 312,261	$ 624,523
2 m	$ 41,550	$ 83,103	$ 166,204	$ 332,407	$ 664,815

Source: Queensland Department of Natural Resources and Mines (2002)

Table 8.9 Direct Commercial Damages by Value Class of Premises and Level of Inundation, Large Properties >650 m² (2013 dollars)

Large Commercial Properties					
Depth	**1**	**2**	**3**	**4**	**5**
0 m	$ -	$ -	$ -	$ -	$ -
0.25 m	$ 10	$ 21	$ 44	$ 84	$ 167
0.75 m	$ 54	$ 107	$ 211	$ 423	$ 849
1.25 m	$ 111	$ 222	$ 447	$ 891	$ 1,780
1.75 m	$ 181	$ 366	$ 731	$ 1,461	$ 2,921
2 m	$ 218	$ 436	$ 873	$ 1,745	$ 3,492

Source: Queensland Department of Natural Resources and Mines (2002

In lieu of detailed flood modelling, it has been assumed that inundation for each commercial premises identified in the flooding maps has been inundated to the a depth of 0.25 m under the 1 in 50 year event; inundated to 0.75 m under the 1 in 100 year event; and 1.25 m under the 1 in 150/ 180 year events. The accuracy of this assumption will vary with the commercial property and will be conservative for some premises, though not for all. Detailed flood modelling would assist in estimating a more accurate estimate of the level of inundation of commercial properties.

Similarly to residential properties, NRM (2002) recommends the recognition of additional indirect damages through the incorporation of an indirect damages estimate. As per the guidelines, this figure is estimated at 55% of direct commercial damages.

8.4.4 Estimating Direct Potential Damages – Infrastructure

Infrastructural damages are calculated using annual maintenance expenditure figures and historical documented costs. The calculation includes the unit damages for roads and bridges per kilometre of road inundated. Roads are classified into three road types: major sealed, minor sealed or unsealed roads. The total cost associated with per kilometre of inundated road is the accumulative costs of initial road repair, as well as subsequent accelerated deterioration of roads. These costs are displayed in **Table 8.10** below.

Table 8.10 Direct Commercial Damages by Value Class of Premises and Level of Inundation, Large Properties >650 m^2 (2013 dollars)

	Initial Repair	Accelerated Deterioration	Total Cost/ Km
Major Sealed Roads	$ 47,833	$ 23,917	*$ 71,750*
Minor Sealed Roads	$ 14,950	$ 7,478	*$ 22,428*
Unsealed Roads	$ 6,724	$ 3,362	*$ 10,085*

Source: Queensland Department of Natural Resources and Mines (2002)

8.5 Valuation of Marginal Benefits

The benefits associated with each mitigation initiative have been accounted for on the basis of reduction in damages to residential properties, commercial premises and North Burnett Regional Council infrastructure (represented in the table below as 'Res', 'Comm' and 'Other Infr.'). The figures that have formed the basis of these benefit calculations are summarised in the tables below. Each column outlines the number of premises/ extent of the infrastructure that has been protected from inundation by the mitigation measure under different flooding events. The three flooding events used to test the efficacy of the mitigation measures include the January 2013 flooding event, a one in 100 year design event, and a one in 50 year design event.

As previously highlighted, the January 2013 event has been estimated as a one in 150 year event in Mundubbera; a one in 180 year event in Gayndah; and a one in 80 year event in Monto.

Table 8.11 Reduction in Mundubbera Premises and Infrastructure Inundated by Flooding Under Differing Mitigation Scenarios and Flooding Events

		Residential			Commercial			Council Roads (km)		
ID	Description	1 in 150	1 in 100	1 in 50	1 in 150	1 in 100	1 in 50	1 in 150	1 in 100	1 in 50
M1	*Levee* - 1 in 150 year design	61	53	26	8	4	-	2,120m[5]	1,250m	350m
M2	*Levee* - 1 in 100 year design	-	53	26	-	4	-	-	1,250m[6]	350m
M3	*Levee* - 1 in 50 year design	-	-	26	-	-	-	-	-	350m
M4	House and business *raising* - 1 in 150 year design	45	36	19	2	-	-	N/A	N/A	N/A
M5	House and business *raising* - 1 in 100 year design	-	36	19	-	-	-	N/A	N/A	N/A
M6	House and business *raising* - 1 in 50 year design	-	-	19	-	-	-	N/A	N/A	N/A
M7	House and business *relocation* - 1 in 150 year design	72	61	32	11	6	1	N/A	N/A	N/A
M8	House and business *relocation* - 1 in 100 year design	61	61	32	6	6	1	N/A	N/A	N/A
M9	House and business *relocation* - 1 in 50 year design	32	32	32	1	1	1	N/A	N/A	N/A
M10	*Combination* of measures - 1in 150 year design	72	61	32	11	6	1	2,120m	1,250m	350m
M11	*Combination* of measures - 1 in 100 year design	61	61	32	6	6	1	-	1,250m	350m
M12	*Combination* of measures - 1 in 50 year design	32	32	32	1	1	1	-	-	350m

Source: KPMG Analysis

[5] Comprising 650m of major sealed road & 600m of minor sealed road
[6] Comprising 1,125m of major sealed road & 1,000m of minor sealed road

Table 8.12 Reduction in Gayndah Premises and Infrastructure Inundated by Flooding Under Differing Mitigation Scenarios and Flooding Events

		Residential			Commercial			Council Roads (km)		
ID	Description	1 in 180	1 in 100	1 in 50	1 in 180	1 in 100	1 in 50	1 in 180	1 in 100	1 in 50
G1	*Levee* - 1 in 180 year design (option 1)	19	7	3	5	1	1	3,500m	560m	240m
G2	*Levee* - 1 in 180 year design (option 2)	7	0	0	3	0	0	2,750m	-	-
G3	*Levee* - 1 in 100 year design	-	7	3	0	1	1	-	560m	240m
G4	*Levee* - 1 in 50 year design	-	-	3	0	0	1	-	-	240m
G5	House and business *raising* - 1 in 180 year design	19	19	11	3	1	1	N/A	N/A	N/A
G6	House and business *raising* - 1 in 100 year design	-	19	11	-	1	1	N/A	N/A	N/A
G7	House and business *raising* - 1 in 50 year design	-	-	11	-	-	1	N/A	N/A	N/A
G8	House and business *relocation* - 1 in 180 year design	73	53	26	28	18	8	N/A	N/A	N/A
G9	House and business *relocation* - 1 in 100 year design	53	53	26	18	18	8	N/A	N/A	N/A
G10	House and business *relocation* - 1 in 50 year design	26	26	26	8	8	8	N/A	N/A	N/A
G11	*Combination* of measures - 1in 180 year design (incl. levee option 1)	73	53	26	28	18	8	3,500m	560m	240m
G12	*Combination* of measures - 1 in 180 year design (incl. levee option 2)	73	53	26	28	18	8	2,750m	-	-
G13	*Combination* of measures - 1 in 100 year design	53	53	26	18	18	8	-	560m	240m
G14	Combination of measures - 1 in 50 year design	26	26	26	8	8	8	-	-	240m

Source: KPMG Analysis

Table 8.13 Reduction in Monto Premises and Infrastructure Inundated by Flooding Under Differing Mitigation Scenarios and Flooding Events

		Residential		Commercial		Council Roads (km)	
ID	Description	1 in 100	1 in 50	1 in 100	1 in 50	1 in 100	1 in 50
Mo1	*Levee* - 1 in 100 year design	11	11	1	1	816	576
Mo2	*Levee* - 1 in 50 year design	-	11	-	1	-	576
Mo3	House and business *raising* - 1 in 100 year design	10	10	0	0	N/A	N/A
Mo4	House and business *relocation* - 1 in 100 year design	11	11	3	3	N/A	N/A
Mo5	*Combination* of measures - 1in 100 year design	11	11	3	3	816	576
Mo6	*Combination* of measures - 1in 50 year design	-	11	3	3	-	576

Source: KPMG Analysis

The direct damage reduction outlined in the table above has been valued through the application of the industry guidelines for tangible damage estimation as outlined in **Section 2.4**. The marginal benefit of any given mitigation intervention can be estimated by calculating the average annual damage curve for a flooding event under both the base case and the intervention scenario. These have been calculated for each of the three townships (base case) and each of the proposed mitigation interventions. As an example, the estimated damages under a base case and the 150-year levee in Mundubbera (M1) are summarised in the table below for three flooding events, a '1 in 50', '1 in 100' and '1 in 150' year event. These have been summarised in the table below.

Table 8.14 Damage Estimates, Base Case and M1 Mitigation Scenario

Flood Event	AEP	Base Case	G1
1 in 150 year event	0.66%	$ 10,824,418.50	$ 2,261,765.51
1 in 100 year event	1.00%	$ 4,336,081.50	$ 1,387,872.97
1 in 50 year event	1.98%	$ 743,160.64	$ 161,708.16

Source: KPMG Analysis

As heights and damages are only estimated for specific flood heights and return intervals, we have created intervals where, for each interval, the probability and damage of the lower and upper bound are known. This requires estimates of the maximum probable flood and associated damage (trending damages based on known probabilities to estimate the damages associated with an ~0% AEP) and the frequency of flooding that has no associated damage (one year ARI 'flood' is assumed to be damage free).[7]

The calculation used assumes that flood damage rises linearly with probability within each interval and in doing so somewhat overestimates AAD. However, given the degree of uncertainty of all parameters, this is a minor effect.

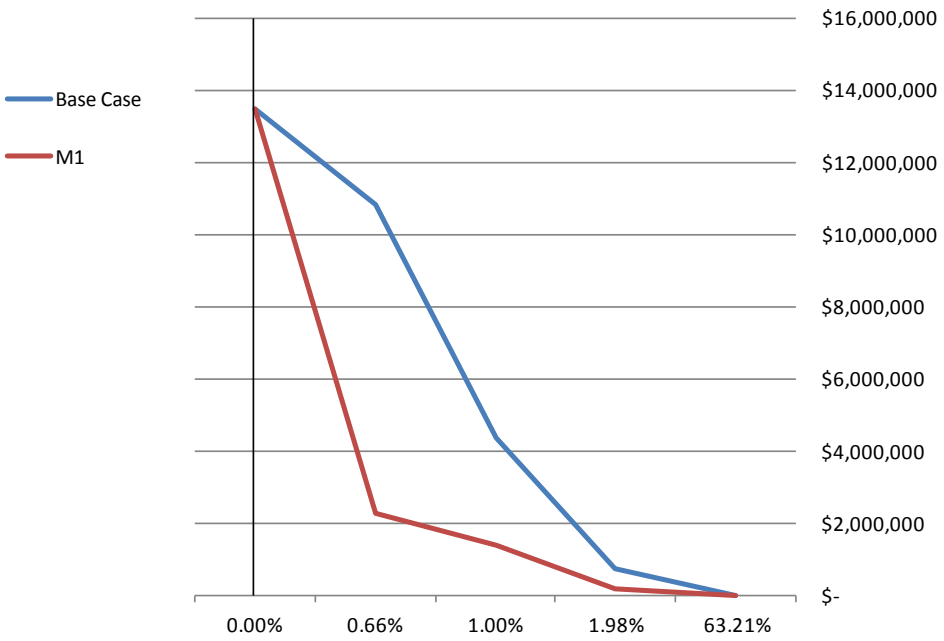
By applying a maximum 'upper-bound' damage estimate and a minimum 'lower bound' damage estimate, average annual damage curves for the base case and mitigation intervention scenario can be calculated. These are summarised in the table below and outlined graphically overleaf.

[7] The maximum probable flood was estimated to be a one in a 200 year flood based on a linear extrapolation of total potential damages from the flood modelling exercise. Results of benefits are insensitive to the choice of the maximum probable flood because of its associated probability of zero. On the other hand, the damage free flood was chosen to be a one in a one year flood. The results were found to be marginally sensitive to the selection of the zero damage flood event. Specifically, the higher the assumed ARI of the zero damage flood; the lower were the AADs and associated annual benefits, and thus, relatively less economic viability of mitigation interventions.

Table 8.15 Damage Estimates (incl. Upper & Lower Bounds), Base Case and M1 Mitigation Scenario

Flood Event	AEP	Base Case	M1
'Upper-bound' event	~0%	$ 13,495,593.01	$ 13,495,593.01
1 in 50 year event	0.66%	$ 10,824,418.50	$ 2,261,765.51
1 in 100 year event	1.00%	$ 4,336,081.50	$ 1,387,872.97
1 in 150 year event	1.98%	$ 743,160.64	$ 161,708.16
'Lower-bound' event	63.21%	$0	$0

Source: KPMG Analysis



Source: KPMG Analysis

Figure 8.2 Average Annual Damage Curves, Base Case (Mundubbera) and M1 Mitigation Initiative

The average annual damage is equivalent to the area underneath each of the curves, with the difference between the two representing the annual benefit derived from flood mitigation. The average annual damage under each curve as well as the difference between the two is summarised in the table below. The net benefit of $236,927.85 represents the annual figure inputted into the cost benefit analysis to represent the benefit stream of investment in the M1 mitigation initiative (a levee constructed to protect against inundation to the level of a 1 in 150 year flooding event).

Table 8.16 Average Annual Damage Curves, Base Case (Mundubbera) and M1 Mitigation Initiative

	AAD
Base Case	$ 358,435.80
G1	$ 121,507.95
Net Benefit	*$ 236,927.85*

Source: KPMG Analysis

By accounting for the number and type of premises and infrastructure inundated under the base case (no intervention) and each mitigation scenario, KPMG have estimated the relative benefit of each mitigation intervention.

8.6 Assessment of Quantified Net Costs & Benefits

Benefit Cost Analysis is a powerful tool used to inform investment decisions by comparing the benefits and costs associated with each investment option available to achieve a defined outcome. The tables below and overleaf provide a detailed summary of the total quantifiable costs and benefits of each of the proposed mitigation interventions.

To contrast the quantified costs and benefits over a 30 year timeframe, discounted cash-flow analysis (DCF) has been used and figures have been discounted to constant 2013/14 dollar terms using a discount rate of seven per cent (consistent with Infrastructure Australia guidance).

Three key performance measures have been applied as a component of the CBA. These include the following:

- ***Benefit Cost Ratio*** – realisation of a BCR of one or greater implies that benefits exceed costs and the progression of the project is supported.
- ***Net Present Value*** – A positive NPV indicates that the project will deliver a surplus in net present terms, and progression is supported. Conversely, a negative NPV implies a negative net cash flow in present terms.
- ***Internal Rate of Return*** – An IRR greater than the discount rate indicates support for project progression.

8.6.1 CBA Findings

The findings of the CBA for each of the proposed mitigation initiatives are summarised in the tables overleaf.

8.6.1.1. Mundubbera Mitigation Initiatives

The Cost Benefit Analysis has indicated that the significant investment required to mitigate against a 1 in 100 year event or greater is too large relative to the benefits that can be realised through reduced damages. This is reflected in the relatively lower performance of mitigation measures designed for the 1 in 100 and 1 in 150 year events in **Table 8.17**.

Conversely, the mitigation measures designed to limit the damages of smaller, more frequent, flooding events are estimated to perform better. The analysis indicates that there is a rationale for progression of targeted house raising to mitigate inundation to the level of a 1 in 50 year flood (M6). This measure achieved a positive BCR and NPV, indicating that the discounted benefits of ~$1.63 million over 30 years was greater than the upfront cost of $1.425 million. The 1 in 50 year levee (M3) similarly performs well relative to alternative mitigation measures, though the estimated benefits were insufficient to return a BCR greater than one.

Given the preliminary nature of the analysis, it is recommended that further modelling be undertaken to refine understanding of the relative damage reduction that could be achieved through the construction of a 1 in 50 year levee and 1 in 50 year house raising mitigation measures.

Table 8.17 Mundubbera Mitigation Initiative 1 – Levee: 1 in 150 Year Design

ID	Description	AAD Reduction	Total Cost (Discounted)	Total Benefit (Discounted)	NPV	BCR	IRR
M1	*Levee* - 1 in 150 year design	$243,138	$9.3m	$3.0m	($6.3m)	0.32	-
M2	*Levee* - 1 in 100 year design	$200,325	$6.9m	$2.5m	($4.4m)	0.36	-
M3	*Levee* - 1 in 50 year design	$180,867	$2.3m	$2.2m	($0.1)	0.95	6.4%
M4	House and business *raising* - 1 in 150 year design	$149,308	$3.5m	$1.8m	($1.69m)	0.52	1.4%
M5	House and business *raising* - 1 in 100 year design	$138,473	$2.7m	$1.7m	($1.0m)	0.63	2.9%
M6	House and business *raising* - 1 in 50 year design	$132,836	$1.4m	$1.6m	$0.2m	1.14	8.4%
M7	House and business *relocation* - 1 in 150 year design	$313,908	$14.4m	$3.8m	($10.5m)	0.27	-
M8	House and business *relocation* - 1 in 100 year design	$301,346	$11.8m	$3.7m	($8.1m)	0.31	-
M9	House and business *relocation* - 1 in 50 year design	$242,860	$6.2m	$3.0m	($3.2m)	0.48	0.9%
M10	*Combination* of measures - 1in 150 year design	Not Estimated.[8]					
M11	*Combination* of measures - 1 in 100 year design						
M12	*Combination* of measures - 1 in 50 year design						

[8] Key performance measures have not been estimated for these mitigation measures as they achieve the same benefits as M7-M9, however at materially greater cost.

8.6.1.2. Gayndah Mitigation Initiatives

Mitigation measures in Gayndah performed similarly to those in Mundubbera, with the low density of residential and commercial premises implying that mitigation measures for less-frequent/ higher impact inundation events did not deliver the damage reductions necessary to rationalise progression. In each case, the high level of capital investment required could not be justified through a reduction in damages.

Conversely, mitigation measures requiring a lower capital investment achieved a strong BCR measure. This is due to these measures still delivering protection from inundation under higher frequency/lower impact events. In particular, house raising to protect against inundation under a 1 in 50 year event delivered a BCR of greater than one and a positive NPV. This reflects the upfront capital investment of $975,000 delivering a present day benefit of $1,153,232 benefit over the thirty year assessment period.

Further modelling as to the height and impact of flooding events would strengthen the rigour of these estimates.

Table 8.18 CBA Findings – Gayndah Mitigation Measures

ID	Description	AAD Reduction	Total Cost (Discounted)	Total Benefit (Discounted)	NPV	BCR	IRR
G1	*Levee* - 1 in 180 year design (option 1)	$67,936	$2.3m	$0.8m	($1.5m)	0.36	-
G2	*Levee* - 1 in 180 year design (option 2)	$5,535	$1.0m	$0.1m	($0.9m)	0.07	-
G3	*Levee* - 1 in 100 year design	$62,541	$1.8m	$0.7m	($1.1m)	0.42	-
G4	*Levee* - 1 in 50 year design	$59,289	$0.9m	$0.7m	($0.2m)	0.78	4.3%
G5	House and business *raising* - 1 in 180 year design	$103,942	$1.9m	$1.3m	($0.6m)	0.68	3.5%
G6	House and business *raising* - 1 in 100 year design	$97,350	$1.6m	$1.2m	($0.4m)	0.76	4.4%
G7	House and business *raising* - 1 in 50 year design	$93,929	$1.0m	$1.2m	$0.2m	1.18	8.8%
G8	House and business *relocation* - 1 in 180 year design	$363,573	$19.5m	$4.5m	($15.0m)	0.23	-
G9	House and business *relocation* - 1 in 100 year design	$348,413	$13.6m	$4.3m	($9.3m)	0.31	-
G10	House and business *relocation* - 1 in 50 year design	$313,083	$6.4m	$3.8m	($2.5m)	0.6	-
G11	*Combination* of measures - 1in 180 year design (including levee option 1)	Not Estimated.[9]					
G12	*Combination* of measures - 1 in 180 year design (including levee option 2)						
G13	*Combination* of measures - 1 in 100 year design						
G14	*Combination* of measures - 1 in 50 year design						

Source KPMG Analysis

[9] Key performance measures have not been estimated for these mitigation measures as they achieve the same benefits as M7-M9, however at materially greater cost.

8.6.1.3. Monto Mitigation Initiatives

Mitigation measures in Monto performed similarly to those in Gayndah and Mundubbera, with the least capital intensive mitigation measure (house raising (Mo3)) the only approach to deliver a BCR of great than one. In Monto in particular, the low number of houses and commercial premises protected by levees implies that these mitigation measures are challenging to rationalise through direct damage reduction.

Table 8.19 CBA Findings – Monto Mitigation Measures

ID	Description	AAD Reduction	Total Cost (Discounted)	Total Benefit (Discounted)	NPV	BCR	IRR
Mo1	*Levee* - 1 in 50 year design	$90,957	$2.0m	$1.1m	($0.9m)	0.55	1.4%
Mo2	*Levee* - 1 in 100 year design	$95,437	$2.7m	$1.2m	($1.5m)	0.43	-
Mo3	House and business *raising* - 1 in 100 year design	$73,842	$0.7m	$0.9m	$0.2m	1.21	9.0%
Mo4	House and business *relocation* - 1 in 100 year design	$132,622	$2.1m	$1.6m	($0.5m)	0.76	4.4%
Mo5	*Combination* of measures - 1in 80 year design	Not estimated.[10]					
Mo6	*Combination* of measures - 1in 100 year design						
Mo7	*Combination* of measures - 1in 50 year design						

Source: KPMG Analysis

8.7 Key Qualifications

KPMG's experience working with areas affected by floods and climate change suggests that any results generated using potential damages estimated in this manner need to be used with caution. This is because of a number of reasons, which are outlined below:

- While data has been available to assist in the estimation of inundated premises for the January 2013 event, similar data has not been available for the 1 in 100 and 1 in 50 design events. This has implied that broad assumptions have had to be made to estimate the height and likelihood of inundation. Modelling of the height and extent of differing flooding events will be required to strengthen the rigour of the damage

[10] Key performance measures have not been estimated for these mitigation measures as they achieve the same benefits as M7-M9, however at materially greater cost.

estimates prior to the preparation of any Business Case for mitigation option progression.

- The two design events prepared to estimate the impact of a 1 in 50 and a 1 in 100 year flooding event are the product of QRA estimates and do not reflect detailed independent modelling. Accordingly, the accuracy of estimated AADs is subject to the quality of the underlying estimates of flooding extents under each scenario.

- Estimated AADs are critically dependent on the flood severity associated with different AEP values. A fair estimation of flood severity for different AEPs requires at least 75 years of reliable data to give a reasonably accurate estimate of a 100 year ARI event, with accuracy generally improving with length of record. The length of the available reliable time series is not known to KPMG, hence the accuracy of the assessment of flood severity for less frequent/more severe events.

- The North Burnett floodplain has a range of tributaries. Accordingly, the timing of peak flows through each tributary has a critical impact on the height of a flooding event in the lower reaches of the catchment, particularly around key residential and commercial centres at Gayndah and Mundubbera.

- The impact of rainfall events of the same magnitude and location could cause different levels of damage over time due to changes in land use (for e.g. more or less trees, more or less hard surfaces, more farm dams), changes to the river channel (straightening, clearing, widening or narrowing) long term trends in climate and changed rainfall patterns over time (for e.g. delivering more rainfall in more concentrated locations or shorter periods). Thus even analysis of a long period may not reflect current and future patterns of rainfall and flooding.

In summary, the results of any study using flood data should be treated with a high degree of caution.

8.8 Sensitivity Analysis

Where possible, the analysis of the costs and benefits of flood mitigation interventions has involved the selection of conservative assumptions. This approach has been taken to increase the robustness of the analysis and reduce the likelihood of an investment providing evidence supporting investment based on the approach to estimating benefits, rather than the merits of the proposed initiative. In addition to taking a conservative approach to estimating benefits, the approach taken in this report has included sensitivity analysis of the discount rate used to discount cash flows to 2014 values.

8.8.1 The Discount Rate

When comparing the costs and benefits of a potential investment such as those proposed for flood mitigation in the North Burnett, there is likely to be a mismatch between the years in which the costs and benefits are realised. In order to compare costs and benefits a DCF approach is used to value all costs and benefits in present value terms. A higher discount

rate will increase the importance of upfront costs and benefits relative to longer term costs and benefits.

In general, flood mitigation interventions include high upfront costs and ongoing benefits. In this case a higher discount rate would result in a more conservative estimate of the BCR than a lower discount rate.

As part of this analysis, a discount rate of 7% was used. This is in line with Infrastructure Australia guidelines for benefit cost analysis. In order to test the sensitivity of the BCR to this rate, two sensitivity tests were conducted at:

- 4 percent; and
- 10 percent.

The table below and overleaf summarises the results of the comparison of costs and benefits under the three scenarios (base case and two sensitivities).

Table 8.20 Sensitivity Analysis – Discount Rate

ID	Description	BCR (7%)	BCR (10%)	BCR (4%)
M1	*Levee* - 1 in 150 year design	0.32	0.25	0.44
M2	*Levee* - 1 in 100 year design	0.36	0.27	0.49
M3	*Levee* - 1 in 50 year design	0.95	0.73	1.29
M4	House and business *raising* - 1 in 150 year design	0.52	0.40	0.72
M5	House and business *raising* - 1 in 100 year design	0.63	0.48	0.87
M6	House and business *raising* - 1 in 50 year design	1.14	0.87	1.58
M7	House and business *relocation* - 1 in 150 year design	0.27	0.20	0.37
M8	House and business *relocation* - 1 in 100 year design	0.31	0.24	0.43
M9	House and business *relocation* - 1 in 50 year design	0.48	0.37	0.67
M10	*Levee* - 1 in 180 year design (option 1)	0.36	0.28	0.48
M11	*Levee* - 1 in 180 year design (option 2)	0.07	0.05	0.09
M12	*Levee* - 1 in 100 year design	0.42	0.33	0.57
M13	*Levee* - 1 in 50 year design	0.78	0.62	1.03
M14	House and business *raising* - 1 in 180 year design	0.68	0.52	0.94
M15	House and business *raising* - 1 in 100 year design	0.76	0.58	1.05
M16	House and business *raising* - 1 in 50 year design	1.18	0.90	1.64

ID	Description	BCR (7%)	BCR (10%)	BCR (4%)
M17	House and business *relocation* - 1 in 180 year design	0.23	0.18	0.32
M18	House and business *relocation* - 1 in 100 year design	0.31	0.24	0.44
M19	House and business *relocation* - 1 in 50 year design	0.60	0.46	0.84
M20	*Levee* - 1 in 50 year design	0.55	0.42	0.74
M21	*Levee* - 1 in 100 year design	0.43	0.33	0.59
M22	House and business *raising* - 1 in 100 year design	1.21	0.92	1.67
M23	House and business *relocation* - 1 in 100 year design	0.76	0.58	1.05

Source: KPMG analysis

The sensitivity analysis indicates that the model and its findings are relatively sensitive to the applied discount rate. No mitigation options returned a BCR of greater than one under the 10% sensitivity, while multiple scenarios returning a BCR of greater than one under the 4% sensitivity. Regardless of these findings, the analysis indicated that the less capital intensive mitigation measures were the most likely to return a positive BCR. Accordingly, the recommendation to undertake further modelling to investigate the rigour of damage estimates under these scenarios holds under the sensitivity analysis.

9. ASSESSMENT OF PREFFERED OPTIONS

9.1 Mitigation Option Assessment Criteria

In order to assess the overall effectiveness and impacts associated with each proposed mitigation measure, a high level assessment criterion was developed to enable for comparison between each option.

This high level assessment was undertaken to eliminate the need for detailed analysis of mitigation measures that would not effectively contribute to the overall project objective which was to minimise flood risk to the North Burnett communities through house and business protection from inundation.

The key assessment criterion of each mitigation measure was to achieve the project objective through effective hydraulic performance. However, other aspects such as environmental and social impacts and economic viability were also integrated into the assessment for consideration. The following section summarises each of the criteria used in this broad assessment.

9.1.1 Hydraulic Performance

The effectiveness of minimising flood risk to the North Burnett region through house and business protection from inundation was determined for each option using the hydraulic performance criteria. This criterion was considered as a pre-requisite for any viable option to achieve adequate flood mitigation.

An assessment of over floor inundation was carried out based on available survey data for impacted houses and businesses. This survey data was collected shortly after the 2013 flood, and as such houses that have been built or raised since this date are either not included in the dataset or are not accurately represented. However, it was considered that a significant proportion of houses affected by flooding within the study area were included in the dataset and therefore it was deemed appropriate for use as a quantitative assessment tool. Using this dataset, each mitigation measure was assessed on its ability to reduce the number of houses affected by over floor inundation. In other words, the hydraulic performance of each option was assessed based on the number of houses and businesses that were estimated to be protected from over floor flooding.

9.1.2 Environmental and Cultural Heritage Impacts

A qualitative assessment was undertaken with consideration of the possible environmental and cultural heritage impacts associated with each mitigation measure. Environmental impacts were assessed based on a number of aspects including the alignment and footprint of the mitigation measure, degree of potential disturbance, riparian vegetation removal, water quality impacts (where applicable) and possible effects on local flora and fauna.

Potential cultural heritage impacts were broadly assessed with consideration given to the alignment and footprint of the mitigation measure, as well as information provided by North Burnett Regional Council. It should be noted that this broad assessment was undertaken for comparative purposes only. A cultural heritage assessment would need to be undertaken in conjunction with the local Mandandanji people (traditional owners) to facilitate the accurate identification of sites with cultural and spiritual significance.

9.1.3 Economic Viability

As outlined in **Section 8**, a comprehensive benefit cost analysis has been undertaken which provides a benefit cost ratio (BCR) for each option. As such, consideration has been given to the economic costs and benefits associated with each option (i.e. the reduction in flood damages).

9.1.4 Social Impacts

Potential social impacts associated with each mitigation measure were qualitatively assessed based on the likely impact from each of the proposed flood mitigation measures on either community based social amenity areas (e.g. parks), resident access and business operations, visual amenity, emergency egress capacity and impacts relating to effects on business operations and income.

9.2 Monto

9.2.1 Levee Option

Table 9.1 Assessment of Levee Option for Monto

Option 1 – Levee (Refer to Figure 6.2)	
Flood Mitigation Performance	The hydraulic assessment predicts that the proposed works will result in a significant reduction in flooding for the following events: • 2013- 11 homes and 1 business. • 1% AEP- 11 homes and 1 business. • 2% AEP- 11 homes and 1 business. Local flood impacts due to the trapped low areas behind the levee will be mitigated by the extension of drainage through the levee and incorporation of emergency backflow valves. It is expected that emergency pumps will be implemented to prevent localised flooding behind the levee during large flood events.

Option 1 – Levee (Refer to Figure 6.2)	
Environmental & Cultural Heritage Issues	Some moderate environmental effects will likely occur during the construction phase of the levee. Minor stripping of the natural surface is required to ensure adequate bonding between the levee bank and ground surface. Although the approximate route has been selected to avoid as many significant vegetation areas as possible, minor tree clearing may still be required rehabilitation measures during the final construction phases may remediate these issues. Survey and consultations regarding potential historical cultural significant will need to be considered.
Economic Viability	The levee bank provides moderate reductions in the number of houses with over floor flooding. The costs associated with the construction of the levee bank are considered significant for the number of houses saved. The BCR was determined to be 0.55 and 0.43 for the 1 % and 2 % AEP events respectively.
Social Impacts	Localised day to day operational (farming) and visual amenity impacts will need to be assessed and subsequently minimised in terms of optimising a levee alignment and configuration.
Overall Assessment Outcome	Should house raising or relocation and land swap be considered unviable due to physical and financial constraints, the levee option is considered to be the most hydraulically effective option in terms of structural flood mitigation. As such, this option may warrant considered for further analysis including a hydraulic assessment for a range of flood events as well as a more detailed cost benefit assessment. Due to the relatively low number of houses and businesses estimated to be protected and the relatively high capital costs to provide flood protection, the BCR is less than one.

9.2.2 House and Business Raising Option

Table 9.2 Assessment of House and Business Raising Option for Monto

Option 2 – House Raising (Refer to Figure 6.2)	
Flood Mitigation Performance	Raising habitable floors above the 2% AEP, 1% AEP and 2013 flood levels is likely to significantly reduce the damage to houses and businesses during flood events up to the 1% AEP flood. 2013 - The available survey shows that of the total 11 houses and 3 businesses known to have experienced over floor inundation during the 2013 event in Monto, 10 houses are raiseable and 1 house and 3 businesses are slab on ground (not raiseable). As a result, it is considered that this option achieves a reduction of 10 houses with respect to over floor inundation. 2% and 1% AEP - As the 2013 event was similar in extent to the 2% AEP and below the 1% AEP, it was estimated that 11 houses and 3 businesses would be subjected to over floor inundation during the 2% and 1% AEP event in Monto. Of the total, 10 houses are raiseable and 1 house and 3 businesses are slab on ground (not raiseable).
Environmental & Cultural Heritage Issues	There are no perceived environmental or cultural heritage issues associated with the raising of houses within Monto.
Economic Viability	Given that the raising of a number of houses within Monto could be achieved and hence eliminate over floor inundation for these houses, the savings in flood damages is considered to be significant. For example, assuming that the average cost to raise each house is approximately $75,000, the total cost to raise 10 houses will be approx. $750,000, however approximately 1 house and 3 businesses would still experience above floor level inundation under this option. Due to the relatively low capital costs to provide flood protection, the BCR is greater than one and is therefore a more economically viable option.
Social Impacts	As this option does not address access and isolation issues during the flood, residents of the non-raiseable houses may be resistant to this option. Visual amenity impacts associated with the raising of a significant number of houses will need to be considered along with Planning Scheme amendments. It is noted that this option does not address damage to farm infrastructure (such as sheds and machinery) that is associated with flooding of rural properties.

Option 2 – House Raising (Refer to Figure 6.2)	
Overall Assessment Outcome	For the number of houses protected and the relatively low capital costs to provide the protection in comparison to other options, this option is favourable and has a BCR of greater than 1 for the 1 % AEP event.

9.2.3 House and Business Relocation Option

Table 9.3 Assessment of House and Business Relocation or Land Swap Option for Monto

Option 3 – House Relocation/Land Swap (Refer Figure 6.2)	
Description	A desktop assessment has been undertaken to determine the viability of relocating flood affected homes within Mundubbera to reduce damages associated with flooding from Three Moon Creek. The assessments was based on houses and businesses that have been identified as being relocatable or require a new house where existing buildings are slab on ground. The cost of land has also been taken into account.
Flood Mitigation Performance	Relocation of houses above the 2% AEP, 1% AEP and 2013 flood levels will significantly reduce the damage to houses during flood events up to the 1% AEP flood. 2013 - The available survey shows that a total of 11 houses and 3 businesses were subjected to over floor inundation during the 2013 event in Monto. House relocation or land swap would generally only apply to building unable to be raised, however this option considers relocation or land swap as the sole solution. Whilst this option can the most cost prohibitive, depending on land costs, all flood affected properties could be relocated and as such this option would prevent future flooding to 11 houses and 3 businesses. 2% and 1% AEP - As the 2013 event was similar in extent to the 2% AEP and below the 1% AEP it was estimated that 11 houses and 3 businesses would be subjected to over floor inundation during the 2% and 1% AEP events. As a result, it is considered that this option would prevent future flooding to 11 houses and 3 businesses
Environmental & Cultural Heritage Issues	There are no perceived environmental or cultural heritage issues associated with the relocation of houses and businesses (and land swap) within Monto.

Option 3 – House Relocation/Land Swap (Refer Figure 6.2)	
Economic Viability	Given that the relocation and land swap option would immunity to all previously affected properties, the savings in terms of flood damages is considered to be significant. However, the costs associated with land swap can be excessive and as such the BCR ration was determined to be less than 1 (0.76). It was assumed that the average cost to relocate each house or business would be approximately $75,000 (excluding new land) and the total cost to relocate a house to new land or provide a new house and land is estimated to be approximately $160,000.
Social Impacts	This option does not address access and isolation issues that the township would face during a significant; however the social impacts of this option are considered to be relatively minor.
Overall Assessment Outcome	This option is considered to be most effective for houses and businesses unable to be raised and depending on funding support; this option provides the greatest benefit in removing houses and business out of the flood plain. This option provided a BCR of less than 1 (0.76) for the 1 % AEP event.

9.3 Mundubbera

Table 9.4 Assessment of Levee Option for Mundubbera

Option 1 – Levee (Refer to Figure 6.4)	
Description	An assessment has been undertaken to identify the benefits of a levee at Mundubbera to protect properties against flooding from Reds Gully and the backflow from the Burnett River has been assessed. Levee Option 2 is considered to be the preferred option by Council and has therefore been assessed as the preferred levee option. The conceptual alignment of the levee is shown in Figure 6.7. The conceptual levee alignment generally extends from the railway to Flinders Street and adjacent to Mundubbera Durong Road. The availability of land and the potential to utilise the redundant railway embankment results in this option relatively practical, however the height of the levee would be significant if it were to protect properties from large events such as the 2013 flood. A total of 72 houses and 11 businesses were recorded to have experienced above floor inundation during the 2013 event.
Flood Mitigation Performance	It was estimated that the proposed levee would result in a significant reduction in flooding for the following events: 2013 - 61 houses and 8 businesses. 1% AEP - 53 houses and 4 businesses. 2% AEP - 26 houses and 0 businesses Local flood impacts due to the trapped low areas behind the levee would be mitigated by the extension of drainage through the levee and incorporation of backflow valves. It is expected that emergency pumps would be utilised to prevent localised flooding behind the levee during large flood events. A hydraulic assessment is required to determine any negative impacts caused by the levee as a result of reduced flood plain storage which may cause increased inundation on the opposite side of Red Gully.
Environmental & Cultural Heritage Issues	Some moderate environmental effects will likely occur during the construction phase of the levee. Minor stripping of the natural surface is required to ensure adequate bonding between the levee bank and ground surface. Although the approximate route has been selected to avoid as many significant vegetation areas as possible, minor tree clearing may still be required. Rehabilitation measures during the final construction phases may remediate these issues.
Economic Viability	The levee is estimated to provide a significant reduction in the number of properties experiencing over floor inundation. The costs associated with the construction of the levee are considered to be high for the number of properties protected and therefore the BCR is 0.32 for 1 in 150 year design and 0.95 in the 1 in 50 year design.
Social Impacts	Localised day to day operational and visual amenity impacts will need to be assessed and subsequently minimised in term of optimising a levee alignment and configuration. There may be social impacts associated with separation of the eastern community from the western community; however this would require further consideration.

Option 1 – Levee (Refer to Figure 6.4)	
Overall Assessment Outcome	Should house raising or relocation and land swap be considered unviable due to physical and financial constraints, the levee option is considered to be the most hydraulically effective option in terms of structural flood mitigation. As such, this option may warrant considered for further analysis including a hydraulic assessment for a range of flood events as well as a more detailed cost benefit assessment. Due to the relatively low number of houses and businesses estimated to be protected and the relatively high capital costs to provide flood protection, the BCR is less than one.

Table 9.5 Assessment of House Relocation or Land Swap Option for Mundubbera

Option 2 – House Relocation or Land Swap Option (Refer to Figure's 6.4 to 6.6)	
Description	A desktop assessment has been undertaken to determine the viability of relocating flood affected homes within Mundubbera to reduce damages associated with flooding from Reds Gully and backflow into Red Gully from the Burnett River. The assessments was based on houses and businesses that have been identified as being relocatable or require a new house where existing buildings are slab on ground. The cost of land has also been taken into account.
Flood Mitigation Performance	Relocation of houses above the 2% AEP, 1% AEP and 2013 flood levels will significantly reduce the damage to houses during flood events up to the 2013 flood. 2013 - The available survey shows that a total 72 houses and 11 businesses were subjected to over floor inundation during the 2013 event in Mundubbera. As a result, it is considered that this option would provide a solution that would remove the entire 83 identified flood affected properties from the flood plain. 1% AEP - The available survey shows that a total 61 houses and 6 businesses would be subject to over floor inundation during the 1% AEP event in Mundubbera. As a result, it is considered that this option would provide a solution that would remove all identified flood affected properties from the flood plain. 2% AEP - The available survey shows that a total 32 houses and 1 business would be subject to over floor inundation during the 1% AEP event in Mundubbera. As a result, it is considered that this option would provide a solution that would remove all identified flood affected properties from the flood plain.
Environmental & Cultural Heritage Issues	There are no perceived environmental or cultural heritage issues associated with the relocation and land swap solution.
Economic Viability	Given that the relocation and land swap option would provide flood immunity to a significant number of houses and businesses within Mundubbera, the savings in flood damages is considered to be significant. However, the total cost to provide this solution is high and therefore the BCR is less than 0.5 for all design events. It was assumed that the average cost to relocate each house or business would be approximately $130,000 (including purchase of new land) and the costs to provide a new house and land is estimated to be approximately $230,000.
Social Impacts	This option does not address access and isolation issues that the township would face during a significant; however the social impacts of this option are considered to be relatively minor.
Overall Assessment Outcome	This option is considered to be most effective for houses and businesses unable to be raised and depending on funding support; this option provides the greatest benefit in removing houses and business out of the flood plain. This option provided a BCR of less than 0.5 for all design events.

Table 9.6 Assessment of House and Business Raising Option for Mundubbera

Option 3 – House and Business Raising (Refer to Figure 6.4 to 6.6)	
Flood Mitigation Performance	Raising habitable floors above the 2% AEP, 1% AEP and 2013 flood levels is likely to significantly reduce the damage to houses and businesses during large flood events. 2013 - The available survey shows that of the total 71 houses and 11 businesses known to have experienced over floor inundation during the 2013 event in Mundubbera, 45 houses and 2 businesses are raiseable and 27 house and 9 businesses are slab on ground (not raiseable). As a result, it is considered that this option achieves a reduction of 45 houses and 2 buildings with respect to over floor inundation. 1% AEP - It was estimated that 61 houses and 6 businesses would be subject to over floor inundation during the 1% AEP event in Mundubbera. Of these buildings, 36 houses are raiseable with the remainder being slab on ground (not raiseable). 2% AEP - It was estimated that 32 houses and 1 business would be subject to over floor inundation during the 2% AEP event in Mundubbera. Of these buildings, 19 houses are raiseable with the remainder being slab on ground (not raiseable).
Environmental & Cultural	There are no perceived environmental or cultural heritage issues associated with the raising of houses within Monto.
Economic Viability	Given that the raising of a significant number of houses and businesses within Mundubbera could be achieved and hence eliminate over floor inundation for these houses and businesses, the savings in flood damages is considered to be significant. For example, assuming that the average cost to raise each house is approximately $75,000, the total cost to raise 45 houses and 2 businesses would be approximately $3.52 Million. Given the number of properties that would be protected under this option and the relatively low capital costs in comparison to other options, this option warrants further consideration. The BCR was determined to be 0.52, 0.63 and 1.14 for the 1 in 150, 1 in 100 and 1 in 50 year design scenarios respectively.
Social Impacts	As this option does not address access and isolation issues during the flood, residents of the non-raiseable houses may be resistant to this option. Visual amenity impacts associated with the raising of a significant number of houses will need to be considered along with Planning Scheme amendments. It is noted that this option does not address damage to farm infrastructure (such as sheds and machinery) that is associated with flooding of rural properties.
Overall Assessment Outcome	For the number of houses protected and the relatively low capital costs in comparison to other options, this option is considered viable and has a BCR of greater than 1 for the 2 % AEP event.

9.4 Gayndah

Table 9.7 Assessment of Levee Option for Gayndah

Option 1 – Levee (Refer to Figure 6.11 to 6.13)	
Description	A preliminary assessment has been undertaken for a number of levee options aimed at protecting flood affected houses and businesses in Gayndah. The levees would specifically provide protection to properties between Barrow Street and Bamboo Street from floodwaters backing up from Oaky Creek and Sauers Gully. A total of 73 houses and 28 businesses were recorded to have experienced above floor inundation during the 2013 event. The conceptual alignments for two levee options are provided in Figure 6.11 to 6.13. A western levee has been considered along Barrow Street to provide protection from Sauers Gully backwater and eastern levee Option 1 has been considered along Bamboo Street and Option 2 between Simon Street and Meyer Street to provide protection from Oaky Creek backwater. Two potential locations (options) are provided for the eastern levee. The practicality and viability of the levee option requires further assessment including hydraulic analysis using the previously developed TUFLOW model. Physical constraints include the maximum levee height as well as available land adjacent to or within the road reserve. Levee Option 1 (western levee and eastern levee Option 1) was considered to provide the most benefit and was estimated to provide protection to 19 houses and 5 businesses for the 2013 flood and 7 houses and 1 business for the 1 % AEP flood and 3 houses and 1 business for the 2 % AEP event. Levee Option 2 (western levee and eastern levee Option 2) is estimated to provide protection to 7 houses and 3 businesses for the 2013 flood.
Flood Mitigation Performance	It was estimated that the proposed Levee Option 1 would provide a benefit to a limited number of properties in Mundubbera. The estimated number of properties protected are as follows: 2013 - 19 houses and 5 businesses. 1% AEP - 7 houses and 1 business. 2% AEP - 3 houses and 1 business Local flood impacts due to the trapped low areas behind the levee would be mitigated by the extension of drainage through the levee and incorporation of backflow valves. It is expected that emergency pumps would be utilised to prevent localised flooding behind the levee during large flood events. A hydraulic assessment is required to determine any negative impacts caused by the levee. A levee along the banks of the Burnett River is not considered to be viable due to the levee height required to protect the town and other physical constraints. It is noted that other levee options may be identified though a detailed hydraulic investigation for Gayndah.

Option 1 – Levee (Refer to Figure 6.11 to 6.13)	
Environmental & Cultural Heritage Issues	Some moderate environmental effects will likely occur during the construction phase of the levee. Minor stripping of the natural surface is required to ensure adequate bonding between the levee bank and ground surface. Although the approximate route has been selected to avoid as many significant vegetation areas as possible, minor tree clearing may still be required. Rehabilitation measures during the final construction phases may remediate these issues.
Economic Viability	The levee is estimated to provide a minor reduction in the overall number of properties experiencing over floor inundation. The costs associated with the construction of the levee are considered to be high for the number of properties protected and therefore the BCR is 0.36 for the 1 in 180 year design, 0.42 for the 1 in 100 year design and 0.78 for the 1 in 50 year design scenario.
Social Impacts	Localised day to day operational and visual amenity impacts will need to be assessed and subsequently minimised in term of optimising a levee alignment and configuration. There may be social impacts associated with separation of the eastern community from the western community; however this would require further consideration.
Overall Assessment Outcome	Should house raising or relocation and land swap be considered unviable due to physical and financial constraints, the levee option is considered to be the most hydraulically effective option in terms of structural flood mitigation. As such, this option may warrant considered for further analysis including a hydraulic assessment for a range of flood events as well as a more detailed cost benefit assessment. Due to the relatively low number of houses and businesses estimated to be protected and the relatively high capital costs to provide flood protection, the BCR is less than one.

Table 9.8 Assessment of House and Business Relocation or Land Swap Option for Gayndah

Option 2 – House and Business Relocation or Land Swap Option (Refer to Figure's 6.4 to 6.6)	
Description	A desktop assessment has been undertaken to determine the viability of relocating flood affected homes within Gayndah to reduce damages associated with flooding from the Burnett River. The assessments was based on houses and businesses that have been identified as being relocatable or require a new house where existing buildings are slab on ground. The cost of land has also been taken into account.
Flood Mitigation Performance	Relocation of houses above the 2% AEP, 1% AEP and 2013 flood levels will significantly reduce the damage to houses during flood events up to the 2013 flood. 2013 - The available survey shows that a total 73 houses and 28 businesses were subjected to over floor inundation during the 2013 event in Gayndah. As a result, it is considered that this option would provide a solution that would remove the entire 101 identified flood affected properties from the flood plain, however this would account for the majority of the town and business centre. 1% AEP - The available survey shows that a total 53 houses and 19 businesses would be subject to over floor inundation during the 1% AEP event in Gayndah. As a result, it is considered that this option would provide a solution that would remove all identified flood affected properties from the flood plain, however this would account for a significant number of businesses in the town centre. 2% AEP - The available survey shows that a total 26 houses and 9 businesses would be subject to over floor inundation during the 1% AEP event in Gayndah. As a result, it is considered that this option would provide a solution that would remove all identified flood affected properties from the flood plain, however this would still account for a large number of businesses in the business centre.
Environmental & Cultural Heritage Issues	There are no perceived environmental or cultural heritage issues associated with the relocation and land swap solution.
Economic Viability	Given that the relocation and land swap option would provide flood immunity to a significant number of houses and businesses within Gayndah, the savings in flood damages is considered to be significant. However, the total cost to provide this solution is high and therefore the BCR is less than 0. 6 for all design events. It was assumed that the average cost to relocate each house or business would be approximately $120,000 (including purchase of new land) and the costs to provide a new house and land is estimated to be approximately $215,000. The relocation of business from the town centre may cause economic impacts in term of separating the town centre. The availability of appropriate land is also unknown and therefore this option would require further evaluation.
Social Impacts	This option does not address access and isolation issues that the township would face during a significant; however the social impacts of this option are considered to be relatively minor.

Option 2 – House and Business Relocation or Land Swap Option (Refer to Figure's 6.4 to 6.6)	
Overall Assessment Outcome	In theory, this option is considered to be most effective for houses and businesses unable to be raised and depending on funding support and it would provide the greatest benefit in terms of flood risk by removing houses and business out of the flood plain. However, there would be practical and economic constraints in terms of the number of properties impacted and land availability to essentially relocate a portion of the town.. This option is not considered to be favourable in terms of a standalone solution. This option provided a BCR of less than 0.6 for all design events.

Table 9.9 Assessment of House and Business Raising Option for Gayndah

Option 2 – House and Business Raising (Refer to Figure 6.11 to 6.13)	
Flood Mitigation Performance	Raising habitable floors above the 2% AEP, 1% AEP and 2013 flood levels is likely to significantly reduce the damage to houses and businesses during large flood events. 2013 – It has been estimated that 22 houses and 3 businesses are able to be raised and protected under this option for the 2013 event. The remainder of the properties identified to have been inundated during the 2013 event are considered to be slab on ground buildings and therefore could not be raised. 1% AEP - It has been estimated that 19 houses and 2 businesses are able to be raised and protected under this option for the 1% AEP event. The remainder of the properties predicted to experience inundation during the 1% AEP event are considered to be slab on ground buildings and therefore could not be raised. 2% AEP - It has been estimated that 11 houses and 2 businesses are able to be raised and protected under this option for the 2% AEP event. The remainder of the properties predicted to experience inundation during the 2% AEP event are considered to be slab on ground buildings and therefore could not be raised.
Environmental & Cultural Heritage Issues	There are no perceived environmental or cultural heritage issues associated with the raising of houses within Monto.
Economic Viability	Given the number of properties that would be protected under this option and the relatively low capital costs in comparison to other options, this option may warrants further consideration by Council including the survey of floor levels and hydraulic analysis to review the costs and benefits associated with this option. For this study, the BCR was determined to be 0.68, 0.76 and 1.18 for the 1 in 180, 1 in 100 and 1 in 50 year design scenarios respectively.

Option 2 – House and Business Raising (Refer to Figure 6.11 to 6.13)	
Social Impacts	As this option does not address access and isolation issues during a flood, residents of the non-raiseable houses may be resistant to this option. Visual amenity impacts associated with the raising of a significant number of houses will need to be considered along with Planning Scheme amendments. It is noted that this option does not address damage to sheds or farm infrastructure (such as sheds and machinery) that is associated with flooding of rural properties.
Overall Assessment Outcome	For the number of houses protected and the relatively low capital costs in comparison to other options, this option is considered viable and has a BCR of greater than 1 for the 2 % AEP event.

9.5 Rural Areas

9.5.1 House and Business Raising or Relocation Option

The raising or relocation of house and farm buildings such as piggeries and dairies is considered to potentially protect all 79 houses identified as being inundated by the 2013 event. Consideration should also be given to the relocation of farm buildings such as sheds, piggeries and dairies as this is likely to reduce flood damage costs to properties. Given the lack of available flood information as well as survey data for flood affected rural properties, an evaluation was unable to be undertaken. However, it is likely that the raising or relocation of houses to flood free land within individual properties is likely to provide a cost effective flood management solution for flood affected houses on rural properties. This could be further investigated should adequate flood information for specific properties become available.

10. RECOMMENDED FURTHER ASSESSMENT

This study provides a high level assessment of flooding and identifies potential mitigation measures based on flood information available at the time of the study. The available information has significant limitations in both scope and accuracy and therefore the viability and details of the mitigation measures identified in this study should be evaluated in a greater level of detail using more accurate flood information. Given the limitation of the existing information, the results of this study should be utilised for identifying the feasibility of various mitigation options and for general comparison of options to short list the viable options. However the exact locations, configurations and costing of options will need to be further investigated as necessary.

Due to the overall lack of understanding of the upper Burnett River catchment, and in the absence of previous flood studies for the region, it is recommended that a comprehensive flood assessment be undertaken for the upper Burnett River and associated tributaries. A flood study has been undertaken for Gayndah and the lower Burnett River for Bundaberg Regional Council and therefore the hydrological analysis for the upper Burnett River catchment is likely to have been completed and should be available for use. It is also understood that the Bureau of Meteorology (BoM) has an URBS hydrology model for the catchment. It is also recommended that a Flood Risk Management Plan (FRMP) be developed for the upper Burnett River catchment in order to enable strategic decisions and planning from both Council and landholders about where and how flood are managed. The FRMP would also provide more accurate quantification of the benefits associated with potential mitigation measures identified in this study.

The purpose of a **Flood Assessment (Flood Study)** is to define flood behavior in the study area whilst the purpose of a **Floodplain Risk Management Plan** is to assess and optimize strategies aimed at reducing the impact of flooding in the study area, including consideration for risks due to climate change. The FRMP would detail how flood prone land within the study area is to be managed, by adopting the preferred flood mitigation measures (structural and non-structural). This would provide the basis for Council's ongoing response to flood management issues in the region.

The recommended scope of works and indicative cost estimates for a flood assessment and flood risk management plan to be developed for the upper Burnett River catchment are outlined below.

10.1 Comprehensive Flood Study including Development of Hydrologic and Hydraulic Models

The Burnett River is a complex system which interacts with the Boyne River, Auburn River as well as a number of other major and minor tributaries. A comprehensive flood assessment is therefore fundamental to identifying and minimizing the risks of flooding and increasing community resilience to flooding.

The flood assessment would include a hydrological and hydraulic analysis using computer models developed to quantify the catchment's response to various flood events as well as

the behaviour of flood waters and the interaction between the various waterway systems. The hydraulic model could be used to quantity existing flood risks as well as determine the benefits (or otherwise) associated with potential mitigation options. Structural mitigation options such as levees generally result in changed flood behaviour which may impact areas that are not protected by the levee. The extent of the flood assessment will depend on available funding and therefore it may not be possible for a flood assessment to be undertaken for the entire north Burnett River region and the assessment may need to be focussed on township areas such as Monto, Mundubbera and Gayndah. A flood study has been undertaken previously for Gayndah and therefore the previously developed models may be used and refined to assess flood mitigation for the town. The existing URBS model developed by BoM could be updated and refined (if required) for the hydrological analysis, however new hydraulic models would need to be developed for Mundubbera and Monto or the entire river system if required.

The flood assessment provides input to the flood risk management plan and may include the following scope of works:

1. Definition of the Study Area

- Identification and prioritisation of high flood risk areas including urban and rural areas
- Identification of the flood management areas which determine the extent of hydraulic modelling
- Identification of contributing catchments which determine the extent of hydrological models

2. Data Compilation and Review

- Historical rainfall and stream flow data
- Previous relevant studies
- Topographic and survey information including a Digital Terrain Model (DTM) or Airborne Laser Survey (ALS) data
- Site Inspections
- Identification of the gaps and acquisition of additional data

3. Hydrological Analysis

- Flood frequency analysis
- Hydrological modelling using existing model developed by Bundaberg Regional Council
- Calibration and verification of the hydrological model using historical events (i.e. 2013, 2011, 2010, etc.).
- Sensitivity analysis including impact of climate change
- Simulation of design events and determine design hydrographs for all design events including the 1 in 5, 10, 20, 50, 100, 200 and 500 Annual Exceedance Probability (AEP) events and Probable Maximum Precipitation (PMP).

4. Hydraulic Assessment

- Define Flood Management Objectives
- Hydraulic Modelling
- Calibration and verification of the hydraulic model
- Sensitivity analysis including impact of climate change
- Simulation of design flood events including 5, 10, 20, 50, 100, 200 and 500 year Average Recurrence Interval (ARI) events and Probable Maximum Flood (PMF).

For funding and budgeting purposes, the indicative costs to undertake a flood study for the entire region is estimated to be anywhere between approximately $150,000 and $200,000 which may not include topographic survey costs (i.e. airborne laser survey). The indicative costs for a localised flood study for the towns may be in the order of approximately $50,000 per town, assuming that an existing hydrology model is available for use.

10.2 Flood Risk Management Planning

The outcomes from the flood assessment are used to develop a Flood Risk Management Plan which would subsequently detail how flood prone land within the study area could to be managed, by adopting the preferred flood mitigation measures. This would provide the basis for Council's ongoing response to flood management issues in the region. The scope of works is a continuation of the flood assessment and is therefore presented as Task 5; however it should be noted that the flood assessment and flood risk management plan could be undertaken in two stages or as separate projects. The scope of works generally consists of the following:

5. Flood Risk Assessment and Management Plan

- Acquisition of property and floor level data
- Flood damage assessment
- Evacuation capability assessment
- Assessment of floodplain management measures
- Flood modification - structural measures and Benefit / Cost Assessment
- Flood warning & emergency planning
- Development/ building control and land use zoning
- Assessment of future development in the floodplain
- Increasing Community Resilience Pre and Post Flood Events
- Examine impact of climate change and flood planning levels
- Formulate preferred scheme
- Preparation of the Floodplain Risk Management Plan

6. Community and Stakeholder Consultation

7. Documentation and implementation

- Interim Report and Maps
- Final Report and Mapping
- Handover including; presentation, training and incorporation of study output into Council system (i.e. flood overlays for the planning scheme, etc.)

For funding and budgeting purposes, the indicative costs to prepare a FRMP (including preliminary design) for the entire region is estimated to be anywhere between approximately $100,000 and $150,000.

11. CONCLUSION AND RECOMMENDATIONS

The study conclusion and recommendations are as follows:

11.1 Conclusion

It has been reported by the Climate Commission Report that the North Burnett region can expect higher risk of heavy rainfall. This prediction along with the growing community awareness regarding national flood mitigation programs and the fact that no comprehensive economic and technical analysis has been previously undertaken within the region has led Council to obtain funding to undertake this study.

The study has provided a preliminary review of flood damage costs to the community and identified potential flood mitigation options and associated benefits. The aim of this study was to undertake a preliminary assessment of flood damage costs and potential mitigation measures, costs and associated benefits based on existing information to assist Council in developing a business case for funding of additional technical studies and ultimately provide flood mitigation for the region.

The January 2013 flood event is the largest event on record for all towns and resulted in inundation of 11 houses and 3 businesses along Mill Street in Monto, 72 houses and 11 businesses in Mundubbera and 73 houses and 28 businesses in Gayndah however majority of flood damage occurred to surrounding agricultural infrastructure and crops. The 2013 event has an estimated return period of between 50 and 100 years, based on the FFA.

It is understood that approximately 79 rural properties were recorded as being impacted by over floor inundation, however it is acknowledged that there may be some properties unaccounted for. Information regarding the extent of damage to farms in terms of loss of infrastructure, income, livestock and crops is also relatively unknown.

The shortlisted flood mitigation measures that were considered to have some merit and required further evaluation included:

- Raising of houses and business;
- Flood levee;
- Relocation of Houses and businesses; and
- Combination of the above.

The mitigation options for the main townships have been evaluated largely based on flood mitigation performance and economic viability. Due to the absence of any flood event information for the rural areas and an incomplete list of properties identified to have been affected by the 2013 flood, flood mitigation measures have been broadly considered however only preliminary assessment has been undertaken to quantify the costs and

benefits associated with these measures. Given the scale of the Burnett River flood plain and associated tributaries as well as the vast extent of rural areas along the flood plain, non-structural mitigation measures such as flood warning and emergency management, agricultural land use planning and development control are generally the only flood mitigation strategies likely reduce flood damage and increase flood awareness and resilience.

As a component of the CBA, damages to residential properties, commercial properties and Council infrastructure was calculated as a base case in the areas of inundation for which mitigation was considered. This analysis utilised the flood lines prepared to represent inundation during the January 2013 event. Under these base cases, damages in Monto, Mundubbera and Gayndah were estimated to be approximately $1 million, $10.8 million and $9.5 million respectively.

On the basis of the reduced damages identified in this study, a preliminary cost benefit analysis was undertaken for differing flood mitigation initiatives in the townships of Monto, Mundubbera and Gayndah. This analysis is considered preliminary only as it relies on estimations of inundation rather than modelled events. As previously highlighted, detailed analysis will be required to refine the analysis of reduced damages that can be achieved through any mitigation measure.

Based on the cost benefit analysis, the most viable option for each town was:

- Monto: House and business raising for the 1 in 100 year design which produced a BCR of 1.21;
- Mundubbera: House and business raising for the 1 in 50 year design which produced a BCR of 1.14; and
- Gayndah: House and business raising for the 1 in 50 year design which produced a BCR of 1.18.

The findings in each town highlight that the lower the capital requirement associated with the mitigation measure, the higher the BCR. This reflects the low density of commercial and residential property development in all three townships, and the limited number of properties and infrastructure assets that a structural measure (i.e. a levee) can protect.

11.2 Recommendations

Key recommendations from this preliminary assessment of flood mitigation measures include:

- Re-evaluation of shortlisted flood protection measures including a detailed hydraulic analysis of the preferred mitigation options for Monto, Mundubbera and Gayndah. This would allow for a more detailed flood damage estimate for a range of flood events as well as a more comprehensive evaluation of mitigation options. It is recommended that new two-dimensional models be developed for Mundubbera and Monto and the

existing TUFLOW model should be updated and refined to include the bridge for Gayndah.

- Hydrological analysis for the upper Burnett River catchment using an updated URBS model from BoM or the model developed for Bundaberg Regional Council. The model outputs will provide inflow hydrography's to the hydraulic models and can also be used for flood prediction purposes.

- Hydraulic analysis of the rural reaches to gain an understanding of the flood risks and allow for improved agricultural land use planning.

- Mapping of the 2013 flood extent for the rural reaches of the Burnett River and associated tributaries. Flood marks currently exist and therefore it is recommended that Council obtain survey of the marks to provide comprehensive mapping of the 2013 event throughout the region.

- More detailed economic analysis in order to refine the analysis of reduced damages that can be achieved through any mitigation measure.

- Develop a flood management plan for the region including flood warning and emergency management strategy given that the most beneficial form of flood mitigation for the entire North Burnett region is likely to be from non-structural measures such as flood warning and emergency management as well as agricultural land use planning.

12. QUALIFICATIONS

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